15427 GREEN GLASS CLODS ST. 7 115.9 g

INTRODUCTION: 15427 is a group of extremely friable greenish clods which are the smaller pieces taken from the same sample bag as 15425, 15426, and the residue fines. The green material is the common Apollo 15 volcanic (pyroclastic) glass. The largest chip is shown in Figure 1. The samples are really regolith clods with green glass concentrations varying considerably from place to place. Two types of matrix dominate, one grayish-tan, the other grayish-green; both contain green glass spheres and light colored clasts. Green glasses from this sample and 15426 have been dated as about 3.4 b.y. old, yellow volcanic glasses as about 3.6 b.y. old, and yellow impact glasses as about 3.35 b.y. old. Rare gas exposure ages are about 300 m.y.

Figure 1. Sample 15427,22. S-71-52775

The clod pieces are grayish-tan and grayish-green, and are blocky, rounded, and very friable. They were removed from the same sample bag and processed as several small pieces. 15427 was collected with clods 15425 and 15426 and fines from the north rim of Spur Crater (see cataloging of 15425 for numbering and site characteristics). Data from all of these samples are most usefully considered together. Pieces of 15427 were originally numbered as 15923 and appear as such in some publications, e.g., LSPET (1972).

PETROLOGY: Macroscopically 15427 is fine-grained and is striking in its abundance and visibility of green glass spherules. Like 15425 and 15426, there are considerable green glass concentration variations from place to place. There are too main types of matrix; one is grayish-tan, the other is grayish-green, and in at least one place, the contact between the two is sharp. Both types contain green glass spheres and light-colored clasts. One piece ,16 was described as having a pinkish gray matrix, with several irregular areas of green matrix making up less than 5%, with green glass spheres apparently composing less than 1% of the piece. Two sets of thin sections were made from two pieces, both of which were chosen to be green glass-rich pieces, hence are not representative of the bulk of the fragments. Most of the thin sections are dominated by green glass in various expressions, and heterogeneous, undevitrified yellow glasses (Fig. 2). Some plagioclase mineral grains with rare lithic and mafic mineral clasts are present. McKay et al. (1984) found an I_s/FeO of 20-30 for a tan matrix sample, indicative of an immature regolith. Gibson and Andrawes (1978) quoted a value of I_s/FeO of 0.3 from Morris (1976) but such a value does not appear in that source. Wood and Ryder (1977) provided a mode of thin section 15427,33, finding it to consist of about 90% green glass shards and spherules. Yellow heterogeneous glass is the most common (2.3%) non-green related component of the >25 micron fraction, but small amounts of lithic and mineral clasts of both highland and mare derivation are present. 15427,33 contains such a high proportion of green glass that it is likely to be an original deposit. Wood and Ryder (1977) provided average analyses of green and heterogeneous yellow glasses from this thin section and discussed the enigma of the green glass compositions. Nagle (1981) observed 15427,27 and compared it with samples of 15425 and 15426, and clods in 15007. He found that many green glass patches in 15427 are partly crystallized, as in 15425 but in contrast with 15426 (quenched) and 15007 (glassy). Agrell et al. (1973) described glasses from 15425, 15426, and 15427, and found 15427 to be like the others in containing abundant bright green glass spheres with subordinate brown spheres and glass fragments. They listed a microprobe analysis of a typical glass sphere in 15427 but in general do not specify observations from 15427. They ascribe to the green glass an impact origin, and interpreted an absence of high velocity micrometeorite impacts to indicate that the glasses, unlike many other types, were not exposed at the surface. Warner et al. (1972) analyzed glasses in 15427 and several other samples, finding many glass groups. Data from 15427 were not specified.

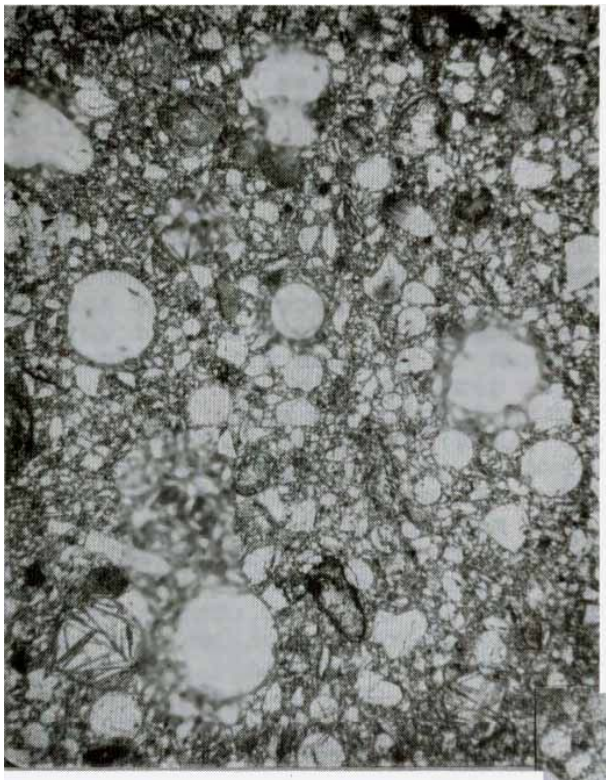

Fig. 2a

Fig. 2b

Figure 2. Photomicrographs of 15427,26. Transmitted light.
Width about 2 mm. Both show green glass spherules and shards,
including partly crystallized varieties, and heterogeneous yellow glasses.

The green glasses have received the most intensive study, following early recognition of this glass type at the Apollo 15 site as common and significant. Apart from the studies listed above, Ridley et al.(1973b) analyzed green (and other) glasses in 15427,31, and an olivine (Fo_{76}) in a green glass. They discussed mainly green glass, and suggested that the Apennine Front might contain such an ultramafic rock or its glassy equivalent. They suggested green glass might be from a pyroxenitic layer at depth in the Moon, a source for mare basalts, although the Mg/Fe is too low. Delano (1979) included 15427 glasses in his precise microprobe analyses of green glasses for major elements and Ni. These analyses defined two main groups and five individual groups. Data for 15427 were not specified. Basu et al. (1979) studied green glass vitrophyres in 15427 and 15426 (and other regoliths), and provided an analysis of an olivine in one vitrophyre in 15427. Delano et al. (1984) hand-picked glasses from 15427 to find vesicular examples, identifying 24 vesicle-bearing green glass specimens, characterized with the microprobe. Arndt et al.(1984) studied green glass in a thin section of 15427, and compared the sizes and textures with those produced in cooling and heating of synthetic green glass melts. They found that ,27 contained 28% glassy spheres and 72% vitrophyres. Olivines are of three types: 1) lattice; 2) fibre; and 3) polyhedral, of which the latter are rare. 36% have only lattice, 48% have only fibre, 16% have both (with fibre interstitial to lattice). Those spheres with only lattice olivine have a 0.36mm avg. dia.; with only fibre have 0.18 mm average diameter; with both,0.32 average. On average vitrophyres have twice the diameter of glasses (.22 vs. .094 mm) (Fig. 3). In actual fact, 49% of glasses and 38% of vitrophyres have elliptical, not circular cross sections. From experiments, the critical cooling rate for glass is 1°C/sec, and at 0.7 to 0.8°C/sec lattice olivines develop (Fig. 4). In free flight, all the spheres should be glassy (Fig. 5) hence Arndt et al. (1984) invoked suspension in a hot gas (for 10 minutes) to allow crystallization. The textures are not those of reheating or annealing, as shown by the experiments. Greagor and Lytle (1983) studied the Ti-site geometry in green glass in ,63, using x-ray absorption spectroscopy, by examination of the x-ray absorption near edge structure (XANES).

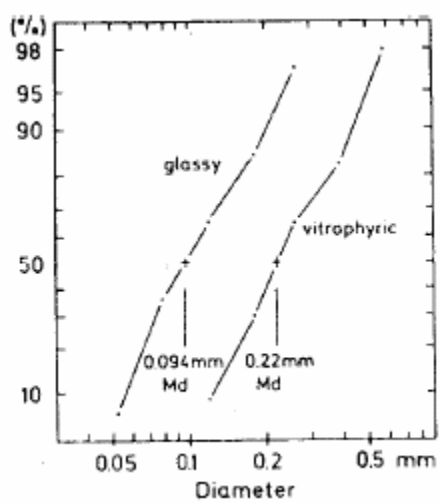

Figure 3. Size-frequency distribution of glassy and vitrophyric green glass beads in 15427,29 (average diameter of cross sections). (Arndt et al., 1984)

TABLE 15427-1. Chemical analyses of bulk materials

		,41	,2(a)	,71
Wt %	SiO2		45.18	
	TiO2		1.14	
	Al2O3		15.06	
	FeO		13.72	14.4
	MgO		12.14	
	CaO		11.11	9.9
	Na2O		0.36	0.37
	K2O		0.11	
	P2O5	0.036	0.09	
(ppm)	Sc			27.7
	V			
	Cr		2740	2580
	Mn		1400	
	Co			50.2
	Ni			191
	Rb		2.7	
	Sr		111	100
	Y		39	
	Zr		152	170
	Nb		10	
	Hf			3.9
	Ba			103
	Th		<2	1.7
	U	0.08		0.42
	Pb			
	La			10.2
	Ce			27
	Pr			
	Nd			16
	Sm			5.05
	Eu			0.919
	Gd			
	Tb			1.03
	Dy			
	Ho			
	Er			
	Tm			
	Yb			3.83
	Lu			0.540
	Li	4.5		
	Be			
	B			
	C			
	N			
	S		600	
	F	46		
	Cl	6.1		
	Br	0.196		
	Cu			
	Zn			
(ppb)	I	4.3		
	At			
	Ga			
	Ge			
	As			
	Se			
	Mo			
	Tc			
	Ru			
	Rh			
	Pd			
	Ag			
	Cd			
	In			
	Sn			
	Sb			
	Te			
	Cs			110
	Ta			550
	W			
	Re			
	Os			
	Ir			3.2
	Pt			
	Au			2.5
	Hg			
	Tl			
	Bi			
		(1)	(2)	(3)

References and methods:

(1) Jovanovic and Reed (1976); neutron and photon activation analysis
(2) LSPET (1972); XRF
(3) Korotev (1984, unpublished); INAA

Notes:

(a) Listed by its original designation of 15923.

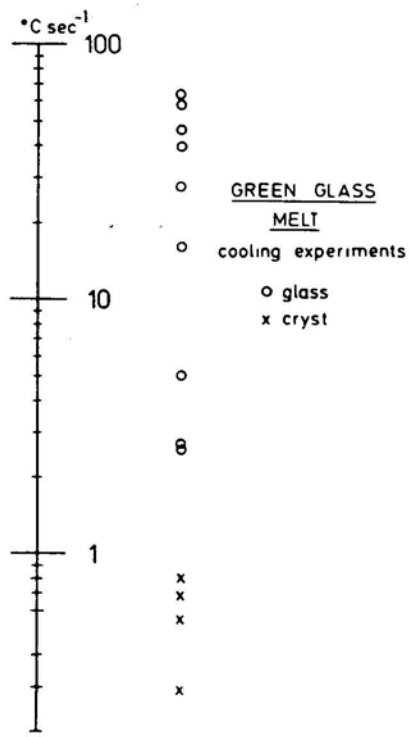

Figure 4. Cooling of synthetic green glass melt at predetermined linear rates from 1550°C to 660°C. (Arndt et al., 1984).

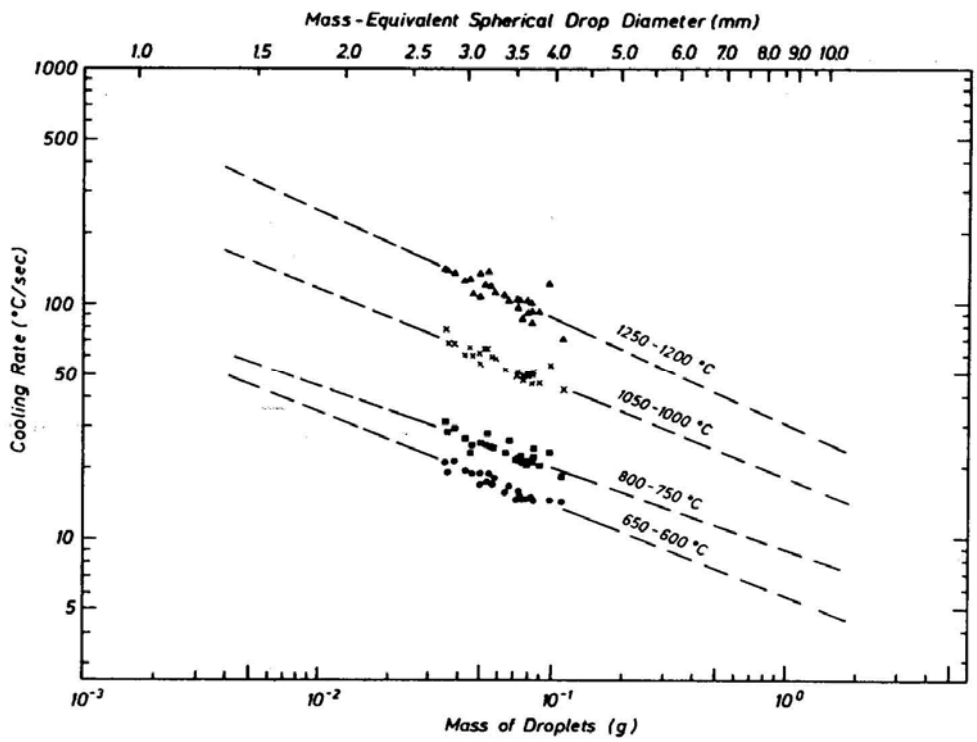

Figure 5. Free flight cooling rates of synthetic green glass melt droplets in different temperature ranges (Arndt et al., 1984).

Delano (1980b) analyzed red volcanic glasses (TiO_2 approximately 13.8 wt %) in 15427,26, as well as in samples from 15318, 15425, and 15426, for major elements and Ni using the microprobe. Data for 15427 was not specified. Ni was always less than the detection limit of 50 ppm. Three subgroups were identified, related to each other by a prominent chemical trend. Experiments on this composition indicates that trend to originate from shallow (less than 5 Kb) fractionation, and the most primitive glass to have originated at about 480 km depth.

Delano (1980a), Delano et al. (1981), and Spangler and Delano (1984) analyzed yellow impact glasses (TiO_2 about 4.8%) in 15427 as well as 15425, 15426, and 15378; chemical data for 15426 were not distinguished (see 15426 for a summary). This group is the same as the heterogeneous yellow glass of Wood and Ryder (1977), and that further investigated by Delano et al. (1982a,b).

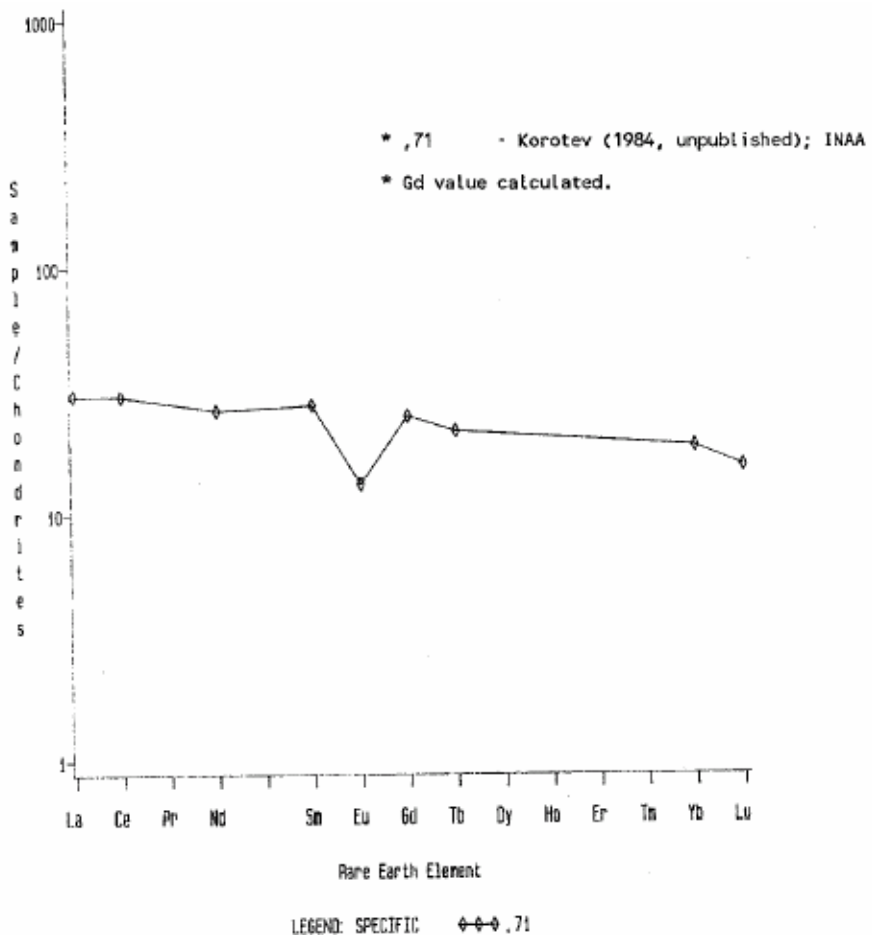

Figure 6. Rare earths in 15427 clod.

A search for vesicular volcanic glasses found three of the yellow volcanic glasses to be vesicular (Delano et al., 1984).

Glass cooling rates were calculated by Fang et al. (1982), and for 15427 the calculated rate is 12°C sec^{-1}, compared to a measured rate of >5°C sec^{-1}. However, the composition listed for 15427 is much less magnesian than green glass, and is of unknown derivation, and the application of the results to 15427 is questionable--their essential conclusion was that the glasses formed in small bodies (i.e., spherules themselves) which were later assembled into the clod at temperatures which did not reach the liquidus.

CHEMISTRY: Chemical analyses of bulk clods are listed in Table 1. Rare earths are shown in Figure 6. That of LSPET was published under the former designation, 15923. This analysis and that of Korotev (1984, unpublished) are not of pure green glass clods, and have higher aluminum and incompatible elements, and lower magnesium and iron abundances than green glass. They are more similar to other Spur Crater regoliths but lower in incompatible element abundances. They agree fairly well but that of LSPET (1972) is a little less mafic. The analysis by Jovanovic and Reed (1976) has lower incompatibles (P and U), and suggests that a different kind of subsample, perhaps green glass-rich, was analyzed. Jovanovic and Reed et al. (1976) also listed data for F, Cl, and Br for leached and residue fractions separately. Gibson and Andrawes (1978) found that the amount of N released on crushing a sample is extremely small (less than 1 ngN/gm sample). Goldberg et al. (1975, 1976) studied F in green glasses, measuring the

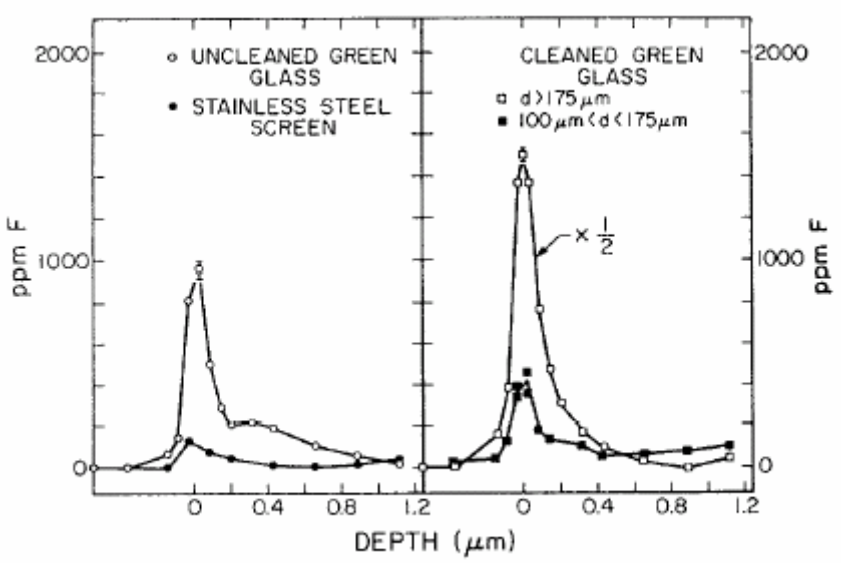

Figure 7. F-depth profiles for handpicked green glass separates from a 15427 clod and stainless steel screen behind which the green glasses were mounted. (Goldberg et al., 1976)

concentration changes with depth for handpicked green glass spheres. They found large surface enrichments of F, up to 3000 ppm in a layer less than or equal to 0.1 microns thick which cannot be terrestrial (Fig. 7). F was more enriched on particles larger than 175 microns than it was in the 100 to 175 micron fraction. F was highly localized and varied from grain to grain, with no preferential concentrations on devitrified grains as compared with clear spheres. Goldberg et al. (1976) found that F was more varied but higher on green glass than on Apollo 17 orange glass, and that other fragments (brown glass) do not have a high surface F. The bulk F determined for green glasses is about 50 ppm.

RADIOGENIC ISOTOPES AND GEOCHRONOLOGY: Spangler et al. (1984) used the laser microprobe for argon releases and dated six glasses from green glass group A (Delano, 1979) as an average 3.41 ± 0.12 b.y. old, and three from group D as an average 3.35 ± 0.018 b.y. old. The samples include examples from both 15426 and 15427. They also determined ages of yellow volcanic glass from 15426 and 15427 as an average of 3.62 ± 0.7 b.y. Spangler and Delano (1984) used the same technique to determine ages for five fragments of yellow impact glasses in 15426 and 15427, finding an average of 3.35 ± 0.05 b.y. corresponding to the age of the impact which produced them.

RARE GASES AND EXPOSURE: Spangler et al. (1984) determined Ar exposure ages of 275 to 300 m.y. for both green and yellow volcanic glasses in 15426 and 15427, and Spangler and Delano (1984) determined Ar exposure ages of 274 ± 74 m.y. for yellow impact glasses from the same samples. Spangler and Delano (1984) noted two possibilities: either the clods formed more than 300 m.y. ago so have the same exposure, or 300 m.y. is an average for soils from St. 7.

Bogard and Nyquist (1972) and LSPET (1972) provided noble gas data for 15427,2, listed as the number 15923,3. The sample has low abundances of noble gases, with the glass itself having the lowest abundances of ^{3}He, ^{4}He, ^{22}Ne, ^{36}Ar, ^{84}Kr, and ^{132}Xe of any of the Apollo 15 fines and glasses analyzed. The glass has lower ^{4}He/^{3}He than the other samples, and the ratios of ^{20}Ne/^{22}Ne, ^{22}Ne/^{21}Ne, ^{36}Ar/^{38}Ar, and ^{36}Ar/^{40}Ar are higher than other samples. The isotopic ratios of Bogard and Nyquist (1972) show ^{22}Ne/^{36}Ar to be much higher than other A14 or A15 materials (2.45 cf. about 0.2 to 0.7) and also show the presence of either a trapped neon component with lower ^{20}Ne/^{22}Ne or a spallation neon with lower ^{21}Ne/^{22}Ne. This component is not unique.

PROCESSING AND SUBDIVISIONS: 15427 originally consisted of many small pieces with masses up to 22 g. Several pieces numbered 15923 were renumbered as 15427. Most pieces have not been subdivided; the largest ,22 (22.0 g) and ,16 (17.7 g), are at Brooks. ,3, greenish matrix, was used to produce thin sections ,26; ,27; ,29-,34; ,54; ,56 via potted butt ,23 (now 4.8 g). ,7, also greenish matrix, had a daughter ,43 which was entirely used to make thin sections ,46-,52.