Table 4. Electron microprobe analyses of maroon-brown glasses from Apollo 12 (wt. %).

	35	36	37	38	39	40	41	42	43	44
SiO_2	48.14	48.43	47.56	48.00	50.22	50.13	48.44	51.55	49.74	50.68
TiO_2	2.00	2.03	2.77	2.26	2.28	2.03	1.94	1.92	2.41	1.95
Al_2O_3	15.71	14.55	13.85	14.55	16.10	16.27	15.82	16.61	15.62	17.30
FeO	10.23	11.87	11.64	11.60	11.32	10.73	10.17	10.63	11.49	10.25
MnO	0.11	0.12	0.12	0.09	0.12	0.09	0.09	0.06	0.12	0.11
MgO	7.37	7.57	8.84	7.35	7.84	7.08	6.35	6.50	6.91	6.08
CaO	12.16	11.38	11.62	10.70	10.72	10.88	10.80	10.71	10.66	10.89
Na_2O	1.14	0.87	0.63	0.88	0.74	0.99	1.21	0.53	0.95	1.17
K_2O	0.44	0.67	0.82	0.65	0.99	0.50	0.31	1.54	0.35	0.55
ZrO_2	—	—	—	—	0.28	0.17	0.20	0.24	0.17	0.16
Cr_2O_3	—	—	—	—	0.20	0.17	0.18	0.14	0.18	0.16
BaO	—	—	—	—	0.14	0.11	0.14	0.13	0.13	0.12
TOTAL	97.29	97.50	97.85	96.07	100.75	99.15	95.65	100.56	98.73	99.42
Sample No.	12034, 11 177K1	12034, 11 177K2	12034, 11 177K3	12034, 11 177K6	12033, 74 188.1	12033, 74 188.2	12033, 74 188.3	12033, 74 195.1	12033, 74 195.3	12033, 74 195.4

Table 4. (continued)

	45	46	47	48	49	50	51	52	53	54
SiO_2	49.17	49.02	49.40	49.24	49.38	50.08	48.91	50.70	49.77	50.42
TiO_2	2.33	2.33	2.06	2.76	1.87	2.16	2.32	2.25	2.08	2.07
Al_2O_3	16.26	15.59	16.23	15.26	15.64	16.50	16.11	15.51	17.47	15.75
FeO	10.70	11.54	10.67	11.29	11.57	10.80	11.95	10.52	10.13	10.53
MnO	0.08	0.06	0.07	0.11	0.12	0.06	0.12	0.10	0.10	0.09
MgO	7.80	8.01	7.27	6.82	8.36	7.05	7.15	5.73	6.65	6.85
CaO	10.87	10.68	10.72	10.80	10.89	11.33	11.11	11.23	11.00	10.99
Na_2O	1.03	0.47	0.50	1.07	0.86	0.97	0.99	1.05	1.03	0.95
K_2O	0.38	0.99	1.32	0.33	0.29	0.73	0.49	0.78	0.79	0.96
ZrO_2	0.12	0.23	0.29	0.15	0.16	0.14	0.16	0.14	0.14	0.14
Cr_2O_3	0.21	0.19	0.16	0.16	0.19	0.20	0.17	0.17	0.15	0.14
BaO	0.09	0.11	0.15	0.10	0.12	0.14	0.13	0.14	0.15	0.17
TOTAL	99.04	99.11	98.84	98.11	99.43	100.16	99.61	98.32	99.46	99.16
Sample No.	12033, 74 195.5B	12033, 74 195.5G	12033, 74 195.6	12033, 74 195.7	12033, 74 193.1	12033, 74 193.2	12033, 74 193.3	12033, 74 193.4	12033, 74 193.5	12033, 74 193.6

Table 4. (continued)

	55	56	57	58	59	60	61	62*	63†	σ†	64††
SiO_2	49.55	49.07	49.19	47.32	49.80	47.49	48.91	46.42	49.17	1.24	48.4
TiO_2	2.04	2.46	0.24	3.32	2.52	3.81	2.29	3.41	2.27	0.64	1.60
Al_2O_3	16.66	15.47	15.63	19.66	15.74	15.53	16.54	16.67	16.02	1.05	16.9
FeO	10.60	11.45	11.94	9.51	11.66	12.60	10.88	10.32	11.02	0.71	11.6
MnO	0.12	0.11	0.10	0.09	0.10	0.12	0.07	0.09	0.10	0.02	0.15
MgO	7.78	6.69	8.45	7.25	6.81	7.26	7.84	8.43	7.28	0.81	9.8
CaO	11.04	10.55	10.93	11.91	11.01	11.21	10.45	12.89	11.07	0.63	10.4
Na_2O	1.12	1.00	0.44	0.90	1.00	0.97	0.38	0.41	0.87	0.24	0.90
K_2O	0.53	0.44	1.18	0.53	0.51	0.59	1.23	0.11	0.68	0.34	0.50
ZrO_2	0.13	0.16	0.17	0.11	0.17	0.13	—	—	0.17	0.05	0.09
Cr_2O_3	0.18	0.16	0.21	0.16	0.19	0.22	—	—	0.18	0.02	0.18
BaO	0.14	0.11	0.11	0.12	0.16	0.08	—	—	0.12	0.02	—
TOTAL	99.89	97.67	98.59	100.88	99.67	100.01	98.59	98.75	98.95		100.52
Sample No.	12033, 74 193.7	12033, 74 193.10	12033, 74 193.11	12033, 74 193.16	12033, 74 193.19	12033, 74 193.20	12001, 84 162K1	12034, 11 177K4			

* Regular form of revolution; † Average of analyses 35–62 and corresponding standard deviation; †† Analysis of norite from Apollo 12 by KEIL *et al.* (1971).

Although some overlap occurs, these groups are principal compositional types characterized by differences in the abundances of major and minor elements (Figs. 5 to 8), CIPW-norms (Fig. 9), and colors. The glasses of "anorthositic" composition have high Al and low Ti, Fe, and Mn contents. The basaltic glasses are lower in Al and higher in Ti, Fe, and Mn. "Basaltic" glasses from Apollo 12 are generally lower in Ti and generally higher in Si, in comparison with those from Apollo 11. The maroon-brown glasses described above, which we found only in Apollo 12 soils and breccias, are distinguished from the average of "basaltic" glasses by lower Mg contents (Fig. 6) and higher abundances of K, Ba, and Zr (Figs. 7 and 8). As reported by other investigators these glasses ("KREEP"-glasses) are additionally characterized by high contents in rare earths, P, and U (HUBBARD *et al.*, 1971). Red-brown to dark, mostly homogeneous glasses of "pyroxenitic" composition, characterized by extremely low contents in Al and the highest abundances of Ti, Mg, and Fe were found only in Apollo 11 soils and breccias (Figs. 5 and 6).

Origin of glasses

Main criteria for the shock origin of lunar glasses are the following: (1) shocked fragmental inclusions, (2) incorporation of minute Fe-Ni-spherules which may be an evidence for the material of the impacting body, (3) lack of euhedral phenocryst inclusions, (4) rareness of fragmental inclusions which show chemical reaction with the melt, (5) strong chemical heterogeneities within a small scale, (6) existence of shock zones beneath glassy crusts of rocks, indicating hypervelocity impact of splashed melts, and (7) direct evidence of localized shock fusion within crystalline rocks.

Most of the lunar glasses show one or more of these criteria of shock origin. The origin of some homogeneous glass particles is ambiguous because they do not contain

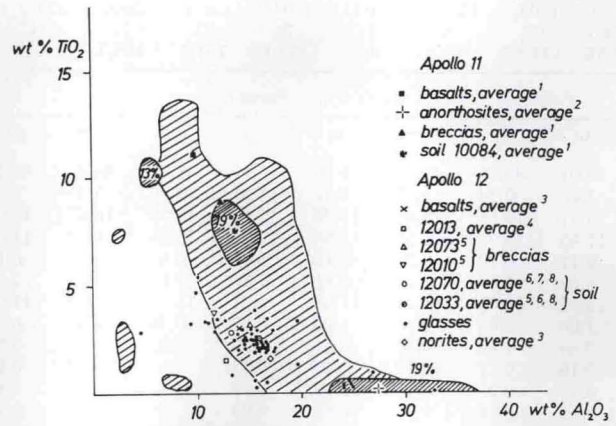

Fig. 5. TiO_2 versus Al_2O_3 contents of glasses, igneous rocks, breccias and soil from Apollo 11 and Apollo 12. Glass analyses of this work (Apollo 12) are represented by dots. All hatched areas comprise 222 data points of Apollo 11 glass analyses taken from LEVINSON, Vols. 1 and 2 (1970). The narrow-hatched areas comprise the indicated percentages of all data points. References for all other data are designated by superior numerals and listed in caption of Fig. 8.