EXPERIMENTALLY REPRODUCED TEXTURES AND MINERAL CHEMISTRY OF A-15 QUARTZ BASALTS: Gary E. Lofgren, NASA-JSC, Houston, TX 77058, C. H. Donaldson, Lunar Science Institute, R. J. Williams, NASA-JSC, and O. Mullins, Lockheed Elect. Co.

The quartz normative (QN) basalts from the Apollo 15 site display a range of textures from vitrophyric to ophitic but only minor variations in bulk chemistry suggesting sampling from various positions in a single cooling unit. If these textures can be reproduced experimentally, it would be possible to determine the chemical fractionation and the emplacement history of this group of mare basalts. Accordingly we have crystallized a synthetic QN basalt composition (Table 1) at different cooling rates in an attempt to reproduce the textures and mineralogical trends observed in QN basalts.

The experiments were performed in a one atmosphere vertical furnace with oxygen fugacity (fO2) controlled by C-O gas mixtures and monitored with an oxygen electrode. Pellets of synthetic QN basalt glass were suspended on a Pt wire loop and melted for three hours at 1255°C with a -log fO2 = 11.9 (25°C above the liquidus). The charges were cooled 200-230°C (4°/hr run cooled 120°C) at monotonic cooling rates between 2.5 and 1260°C/hr and quenched. The fO2 changed continuously, in some runs increasing to .5 log units above iron-wüstite (IW), in others remaining .5 log units below IW. Two charges were initially melted at 1255°C and then crystallized isothermally for 24 hrs, one at 1188° and the other at 1160°C, both about 0.4 log units below IW.

The minerals crystallized in the sequence chromite and metallic iron, olivine and pigeonite, augite, plagioclase, and ilmenite. Textures and grain size vary systematically with cooling rate (Table 2, Fig. 1). With decreasing cooling rate crystal morphologies change from dendritic→skeletal→equant and average grain size coarsens. At the slower cooling rates the pyroxene grain size becomes increasingly bimodal and the texture porphyritic (Figs. 1b, c, and d). In the 2.5°/hr run the pyroxene phenocrysts are set in a subophitic groundmass that has random fan spherulites of plagioclase and pyroxene (Fig. 1d).

Mineral chemistry has been determined on a few of the runs.

Olivine. Skeletal olivines in the 1160°C run are unzoned and range from Fo_{63} to Fo_{65}. Those in the 30°/hr run are zoned from Fo_{65} to Fo_{54}. Ca contents range from 0.42 to 0.25 wt% and Cr, from 0.14 to 0.22 wt%.

Plagioclase. The plagioclase in the 4°/hr and 2.5°/hr runs is zoned, An_{97} to An_{94}, with less than 0.3 mole % Or. FeO contents range from 0.8 to 1.1 wt% and MgO, from 0.3 to 0.6 wt%. The synthetic plagioclases like the plagioclases from mare basalts are nonstoichiometric, but to a greater degree (up to 10% excess Si, Table 1).

Pyroxenes. The pyroxenes in the isothermal runs are homogeneous and unzoned pigeonites. Comparison of their compositions indicates that the larger the degree of supercooling (the lower the crystallization temperature) the more CaFeAlTi rich and Mg poor they become (Fig. 2a and c). In cooling rate runs the phenocrysts have pigeonite cores and augite rims. The pigeonite cores are continuously zoned to more CaFeTiAl-rich and Mg-poor compositions. In the 4° and 2.5°/hr runs the phenocrysts usually have sharp augite rims which initially zone to a more Ca-rich and MgFe-poor composition and then change to Fe

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enrichment and CaMg depletion (Fig. 2a). A few crystals in the 2.5°/hr have zones transitional between augite and pigeonite. The groundmass pyroxenes of the 2.5°/hr run are strongly zoned to more CaMg poor and Fe-rich rims and form a band across the middle of the pyroxene quadrilateral (Fig. 2a). For a given Wo content, pyroxenes in the 30°/hr run are more Fe rich than those in the 2.5°/hr and 4°/hr runs. Comparison with the isothermal runs suggests that the pigeonite cores in the 30°/hr run nucleated at ~1165° while those in the 4 and 2.5°/hr runs nucleated above 1190°. The more magnesian (higher temperature) pigeonite cores in the 4°/hr run compared to the 2.5°/hr run are attributed to more oxidizing conditions (0.75 log units) during the 4°/hr run. Al and Ti increase uniformly from the pigeonite cores to the augite rims and groundmass augite. The trend is similar to that of 15499 (1) lying below the 1:4 Ti:Al line. In the 2.5°/hr run a few augite rims plot close to the 1:2 Ti:Al line (Fig. 2b). Minor element trends on an Al(VI) CrTi plot (Fig. 2c) are dependent on cooling rate.

The close similarity between the porphyritic textures and mineral-chemical trends of the monotonic cooling rate runs and the QN basalts (1) suggest that a two stage cooling history (2) is unnecessary. From this study it is possible to quantify, in part, the cooling history of 15499. The pyroxene cores plot close to pyroxenes from the 1188° isothermal run (Fig. 2a) suggesting that the magma cooled more slowly than 30°/hr, but faster than 4°/hr. The morphology of the pyroxene in 15499 compares favorably with the 10°/hr run (Fig. 1c). The experiments show that the textural differences among QN basalts are a response primarily to monotonic cooling rate and that the differences in mineral chemistry are responses to differences in both cooling rate and f02.

References:

(1) Bence, A. E. and J. J. Papike (1972). Proc. 3rd Lunar Sci. Conf., 2, 431-469.

(2) Bence, A. E., J. J. Papike and D. H. Lindsley (1971). Proc. 2nd Lunar Sci. Conf., 1, 559-574.

TABLE 1: Microprobe Analyses of Starting Composition and Minerals in Selected Experiments

	A	B	C	D_1	D_2	D_3	D_4	D_5
SiO_2	48.04	36.94	49.12	53.00	52.69	49.03	48.57	47.95
TiO_2	1.76	n.d.	n.d.	0.36	0.53	1.35	1.56	2.00
Al_2O_3	11.19	n.d.	32.14	1.71	2.42	5.35	5.91	2.79
Cr_2O_3	0.44	0.23	n.d.	0.94	1.08	1.48	1.26	0.49
FeO	18.03	31.51	1.01	14.14	14.72	11.60	12.78	24.53
MnO	0.28	0.32	n.d.	0.31	0.36	0.32	0.34	0.45
MgO	9.18	31.29	0.28	26.52	24.83	16.97	15.79	9.55
CaO	10.26	0.44	18.05	2.55	3.67	12.97	14.82	12.96
Na_2O	0.08	n.d.	0.36	0.00	0.00	0.03	0.03	0.03
K_2O	0.07	n.d.	0.09	n.d.	n.d.	n.d.	n.d.	n.d.
TOTAL	99.33	100.73	101.05	99.53	100.30	100.10	101.06	100.75

A. Starting composition; B. Olivine (1160°C); C. Plagioclase (2.5°C/hr); D_{1-5}. Pyroxene phenocryst core+rim (2.5°C/hr).

TABLE 2: Variation of Crystal Morphology with Cooling Rate

Cooling rate °C/hr	Olivine	Plagioclase	Pyroxene
1260			none
	dendrites	none	dendrites
220	acicular skeletons	acicular, radiate	spherulitic and acicular skeletons
30	equant skeletons		acicular skeletal phenocrysts in fan spherulitic groundmass
2.5	none	acicular, random	equant skeletal phenocrysts in fan spherulitic and sub-ophitic groundmass

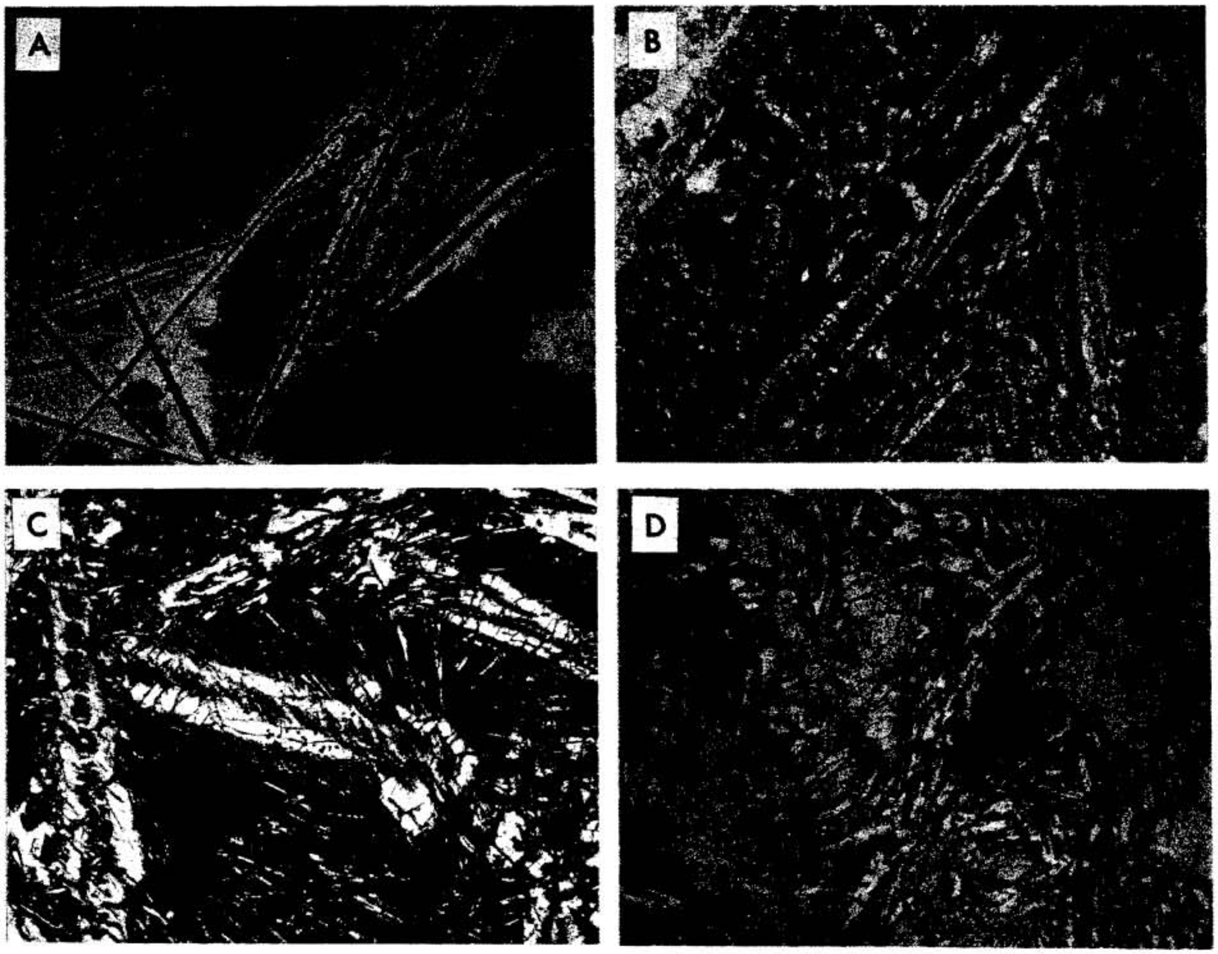

Figure 1: Photomicrographs of run products, all 2 mm across: a. 433°C/hr, b. 30°C/hr, c. 10°C/hr, d. 2.5°C/hr.

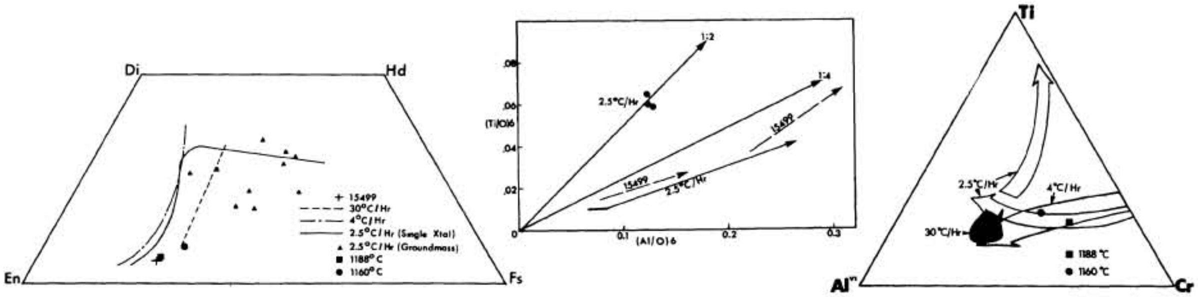

Figure 2: Chemical data on pyroxenes in cooling and isothermal runs: a. Wo-En-Fs zoning trends, b. Ti-Al behaviour, c. Ti-Cr-Al(VI) trends.