NUCLEATION AND GROWTH OF PLAGIOCLASE AND THE DEVELOPMENT OF TEXTURES IN THE 14310 ROCK SYSTEM. Peter I. Nabelek[$¢], Lawrance A. Taylor[$], and Gary E. Lofgren[*]: $ Dept. of Geol. Sci., Univ. of Tenn., Knoxville, TN 37916; ¢ The Lunar Science Institute, 3303 NASA Road 1, Houston, TX 77058; * NASA Johnson Space Center, Houston, TX 77058.

The textures and mineral chemistries of igneous rocks are generally understood to be a function of the cooling rate of the melt. In addition to cooling rate, however, there should be a marked dependence of textures on the precooling, melt history of the magma (1,2,3). In order to gain insight into the effects of melt history, a dynamic crystallization study has been conducted in the 14310 rock system, wherein a systematic investigation was performed of nucleation rates and morphology of crystals grown at various temperatures. This is a logical extension of Lofgren's (1) exploratory study.

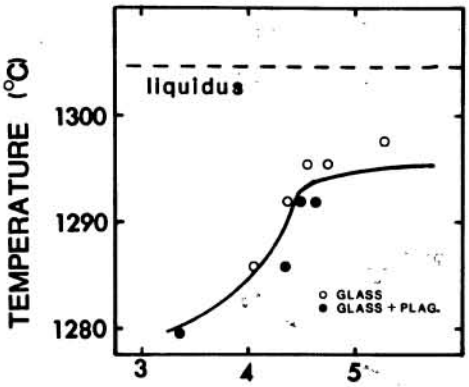

Fig. 1

In the 14310 system, plagioclase is the liquidus (1304 ±5°C) and most abundant phase (66 modal %; 4) and is the mineral of importance to this study. Lofgren's (1) starting material was used, as well as the same experimental technique. Both isothermal/quench and isothermal/cooling-rate experiments were conducted.

NUCLEATION - The incubation period (time for critical nucleii development; 5) for plagioclase is correlative with undercooling (fig. 1). With large undercooling, the incubation time is short. At 1280°C and 1250°C, it is less than ½ hour. Conversly, W-64, held at 1292°C, did not nucleate any crystals in up to 6 hours. At 1298°C, W-80 was all melt even after 60 hours. These results are consistent with those of Gibb (6) who studied plagioclase nucleation in a high alumina basalt.

The density of crystals during isothermal crystallization varies with time (fig. 2). At 1292°C, the crystal density in the charge increases to a maximum of about 2900 crystallites per 0.01 mm^3. Thereafter, some crystallites are resorbed while others grow larger, and the density levels off at values below 500. The same general pattern is observed at 1280°C; however, at this temperature, the incubation period is shorter, and the maximum crystal density is higher than at 1292°C. At 1250°C, due to large driving force for nucleation, the maximum in density is reached almost instantly. A density of 12,000 crystallites per 0.01 mm^3 in the shortest run appears to be on the resorption part of the density curve. Unfused glass particles acting as seeds for heterogeneous nucleation are significant, especially at 1250°C.

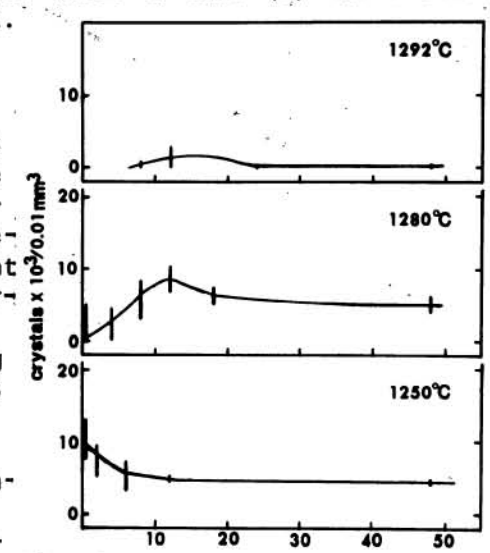

Fig. 2

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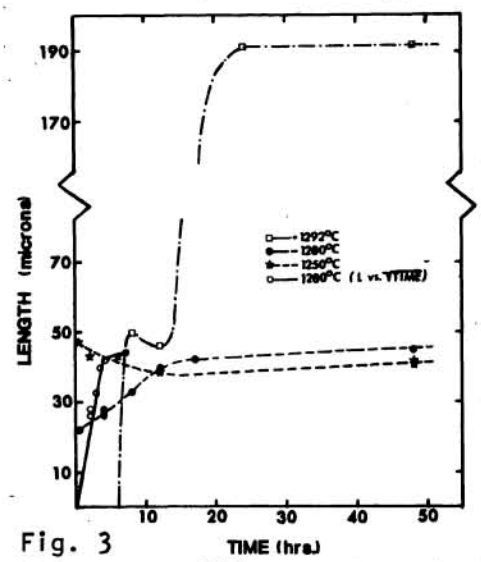

Fig. 3

CRYSTAL GROWTH - The size and shape of crystallites before the initiation of cooling were analysed in order to determine their role in the development of textures. Two types of morphology are distinguished: 1) faceted crystals where continued planar growth leads to the formation of large, tabular plagioclase laths, and 2) microlites with swallow-tail morphology, which are not conducive to growth of laths (7). Following the incubation period at 1292°C (ΔT= 12°C), crystallites grow rapidly and display spherulitic morphology (fig. 4-A), thereby indicating diffusion-controlled growth (7). With longer annealing, some of the crystals become tabular and grow slowly at a linear rate, probably by an interface-controlled mechanism (fig. 3). In W-88, (1292°C for 24 hours) even though the largest crystals have faceted morphology, there are still many that show spherulitic growth (fig. 4-E). At 1280°C (ΔT= 24°C), the initial growth is also spherulitic. A plot of length vs. $\sqrt{time}$ is a straight line (fig. 3) indicating diffusion-controlled growth (7). After 20 hours, the largest crystals have assumed a faceted morphology and slowly increase in size by interface-controlled growth. Larger undercooling (1250°C, ΔT=54°C), causes initial growth with the largest crystallites attaining lengths of ≈50 μm. Thereafter, the length decreases with time, as the system attempts reequilibration. When the crystals reach ≈40 μm size, the system has become relatively "stable"; growth becomes interface-controlled (fig. 3). 40 μm length seems to be the optimum for the development of large laths, since at all temperatures the crystal growth becomes interface-controlled when the crystals reach that size (fig. 3).

TEXTURES - The understanding of crystal sizes and shapes before cooling helps us to predict the development of rock textures. Three types of textures were observed in the cooling experiments - poikilitic, intersertal, and porphyritic. These textures can be produced in charges cooled at the same rate, but starting with differing conditions of the melt.

Runs cooled from above and slightly below the liquidus (e.g. fig. 4-B) started with crystal-free melts, and all developed porphyritic texture. W-99 (1292°C., 12 hrs. + 10°C/hr, fig. 4-C) initially contained many faceted crystals in the melt prior to cooling. This charge therefore developed intersertal texture with large,unoriented plagioclase laths, more abundant than in W-104. The larger amount of crystal laths in W-99 is the consequence of the initial presence of faceted crystallites. Their less-skeletal shape can be attributed to interface-controlled growth on crystallites with planar interfaces.

Two runs cooled at 2°C/hr from 1280°C (W-45, W-32; fig. 4-G,H) have intersertal texture. The large plagioclase laths in these charges can be attributed to growth on planar, 40 μm crystal surfaces present before cooling. The larger amount of crystal laths in W-32 (1280°C, 88 hrs.) as opposed to W-45 (1280°C, 24 hrs.) is due to the higher relative abundance of faceted crystallites in the former charge at the initiation of cooling. From the poikilitic texture deve-

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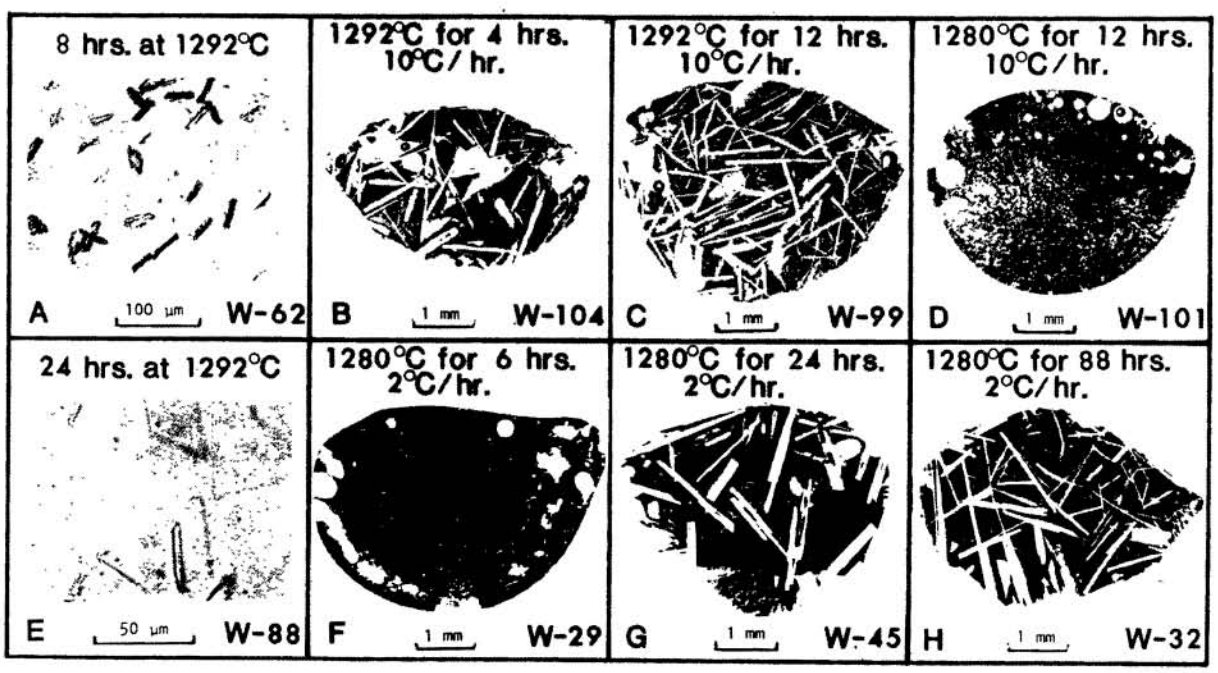
loped by W-29 (fig. 4-F) upon cooling, it would appear that the melt, derectly preceeding the initiation of cooling, contained many small spherulitic bundles of crystals and possibly a portion of unfused glass "seeds".

W-100 and W-101 (1280°C, 2 and 12 hrs., resp., 10°C/hr; fig. 4-D) possess poikilitic texture. This texture is attributed to lack of faceted crystallites in the melt prior to cooling, as well as to the fast cooling rate. The texture in these charges differs markedly from that of W-99 and W-104, even though all four were cooled at the same rate.

CONCLUSIONS - The results of this study help explain the origin of textures in impact produced melts, such as formed in 14310 (8) or in the matrix enclosing the clasts such as in poikilitic matrix breccias (9). A poikilitic texture is produced most readily by cooling a melt with a high nucleation density comprising spherulitic crystallites and/or unfused particles which act as seeds for heterogeneous nucleation. Poikilitic texture can grade to interser, tal, if there are faceted, 40 μm crystals in the melt at the initiation of cooling. Plagioclase laths become particularly abundant if most crystallites are faceted and the overall crystal density in the initial melt is low. Porphyritic texture is most readily formed by cooling a crystal-free melt. In general, these concepts agree with those of Lofgren (1), except that he did not evaluate the significance of the shape and size of the plagioclase crystals at the initiation of cooling. The fact that 14310 does not contain any phenocrysts, but has textures ranging from intersertal to poikilitic, suggests that it formed from a crystal laiden melt, such as that generated by an impact process. However, such a magma derived by igneous process cannot be totally excluded. Chances of eliminating all nucleii in a large body of impact melt are small; therefore, no porphyritic texture can form in such an impact-produced melt.

REFERENCES: (1) Lofgren, 1977, PLSC 9; (2) Ryder & Bower, 1976, PLSC 7; (3) Swanson, 1977, Amer. Min. 39; (4) Nelson et al., 1972, Lunar Sci. III; (5) Turnbull, 1948, Trans. AIME. 175; (6) Gibb, 1974, Min. Mag. 39; (7) Kirkpatrick, 1975, Amer. Min. 60; (8) James, 1973, U.S.G.S. PP 841; (9) Simonds, 1973, PLSC 4.



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