DYNAMIC MELTING AND CRYSTALLIZATION STUDIES ON A LUNAR SOIL. Gary Lofgren, NASA Johnson Space Center, Houston, TX 77058 and Dennis Smith, Lockheed Electronics Company, Inc., Houston, TX 77058.

In a study of the dynamic crystallization properties of a synthetically prepared material similar in composition to 14310, Lofgren (1) showed that the density and distribution of nucleation sites have important implications for the resulting textures. Most noteworthy was the effect of the distribution of nuclei on the close spatial association of widely divergent textures. In areas with a high density of nuclei, poikilitic textures were common; gradations to medium or low densities of nuclei could within a few millimeters result in close spatial association of intersertal or subophitic textures. Such different textures are usually associated with differences in cooling rate which are not readily obtained over such short distances except perhaps at the quench margins of a cooling body.

Because synthetic starting material was used in Lofgren's study, several important questions such as the effect of grain size in the lunar soil and the presence of clasts of various sizes and compositions, whether they be minerals or glasses, could not be treated. Only a lunar soil would have the necessary properties and 15101 was chosen because it came the closest to being within the composition range of the poikilitic rocks as defined by Simonds (2).

Pellets of otherwise unaltered, <1 mm 15101 were tacked onto Pt-wire loops and suspended in a vertical, gas-mixing furnace (3). The oxygen fugacity was controlled at approximately 0.5 log units below the Iron-Wüstite buffer. The samples were melted at temperatures between 1230 and 1280°C for as little as 10 minutes or as long as 4 days. Runs were cooled at linear rates of approximately 2°C/hr from the melting temperature to 900 ± 25°C. The resulting charges were diced and thin sections prepared from appropriate slices.

The dynamic melting experiments consisted of placing the material in the furnace at a given temperature for a known time and then quenching. The sample is placed in the hot zone of the furnace within a few seconds and extracted in a similar time. These data only generally approximate the phase relations because there is some progressive iron loss and the starting material is not of uniform grain size. Plagioclase is present in all the experiments. At 1280°C there are only three crystals and whether they are present because they are stable or because they were initially too large to melt in 3 hours is uncertain. Clearly the liquidus cannot be very much removed from 1280 ± 10°C. There are also very few plagioclase crystals at 1270°C after 3 hrs. Olivine is present in all runs at 1230°C and some pyroxene is still evident after only 1 hour melting at 1230°C, but is not present in runs melted for a longer time. Olivine behaves in a similar fashion at 1250°C.

There is a distinct variation in the shape of the melting plagioclase with both the time at a given temperature and the temperature itself. At 1270°C and 1280°C the plagioclase is rounded (Figure 1a); at 1250°C it is generally rounded after 16 hrs but after one hour many angular to subangular grains remain. At 1230°C the plagioclase generally shows more angular shape (Figure 1b). With one exception, the plagioclase and olivine melt with a planar or arcuate surface. At 1270°C there is evidence of fretwork melting. All the charges contain skeletal, swallow-tail plagioclase generally less than 10 microns long. It is problematical whether these are quench crystals.
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or whether they nucleated and grew at the melting temperature. Since the soil does not necessarily consist of an equilibrium assemblage of phases, nucleation of phases appropriate for the temperature would not be surprising. At 1280° and 1270°C, however, these crystals occur only as overgrowths on existing plagioclase and may, in fact, be growth on the quench. At 1250° and 1230°C they occur throughout the charge and nucleate independent of existing crystals and more likely are a stable phase.

In general, the partially melted charges do not show the same marked variation in the distribution and density of crystals as did the first crystallized, then partially melted 14310 material described by Lofgren (1). This difference most likely results from differences between the phases present and their sizes at the start of melting. The 14310 material was crystallized at the solidus and would have a near equilibrium assemblage of evenly-distributed, fine-grained crystals. The lunar soil most assuredly does not have an equilibrium assemblage of phases nor an even size distribution. The lunar soil, which has a large component of fine-grained material and glass, melts rapidly with little convection within the experimental charge. Once melted, it may be out of equilibrium and if so plagioclase nucleates with a relatively even distribution throughout the charge.

The textures in the cooling experiments reflect these melting properties of the soil. The textures range from intersertal to poikilitic depending on the density of crystals in the melt, but the closely-spaced, textural variations observed in the 14310 study (1) are seen in these experiments. The crystallization textures also reveal the more cotectic nature of 15101 bulk composition compared with 14310. When cooled from a complete liquid the texture is not porphyritic, but displays fine-grained intergrowth of plagioclase, olivine, and pyroxene (Figure 1c) with only a few plagioclase phenocrysts. The rapid increase in the fraction of crystals in this composition liquid and its effect on texture is readily seen by comparing the cooling run from 1250°C (Figure 1d) to the cooling run from 1230°C (Figure 1e and d). In just 20°C there is a marked increase in the fraction of crystals (nuclei) in the liquid and thus the 1230°C cooling experiment is much finer grained than the 1250°C cooling run.

In addition there is a distinct segregation of unmelted material to upper portion of charge during the melting episode (the vertical up direction during the experiment is indicated by the arrow). The clasts are not necessarily floating, but may be carried up by effervescing gas that is trapped in the charge. This gas is trapped because the outer part of the pellet melts first when it is placed in the furnace and gas trapped inside must either diffuse out through the melt or the bubbles must migrate to the surface through this layer of liquid.

It is apparent from these experiments that the textures that crystallize from melted or partially melted lunar soil are strongly dependent on the temperature attained during melting, the time at that temperature, the pre-melting, heating history, and the subsequent cooling rate. In addition to these obvious factors any processes that could result in an irregular distribution of nuclei such as convection or flow are equally important.

Figure 1. Dynamic melting and crystallization experiments on lunar soil 15101. A. Rounded plagioclase, 3 hr melt, 1280°. B. Angular plagioclase, 16 hr melt, 1230°. C. Cooling run, 2°/hr, 3 hr melt, 1280°. D. Cooling run, 1.8°/hr, 1 hr melt, 1250°. E. Crystal distribution in charge, 16 hr melt, 1230°. F. Effect of crystal distribution on texture, 2°/hr, 16 hr melt, 1230°.