

FELDSPATHIC BASALT 14310, A LUNAR MANTLE DERIVED MAGMA. M.L. Crawford, Department of Geology, Bryn Mawr College, Penna. 19010, and L.S. Hollister, Department of Geological and Geophysical Sciences, Princeton University, Princeton, N.J. 08540.

Despite the increase in the number of lunar samples with the composition of KREEP, its origin has not been established. We have continued our efforts in understanding the crystallization history of feldspathic basalt 14310, A KREEP basalt, in the hopes that we might arrive at an interpretation of its origin and hence the origin of other lunar samples with the composition of KREEP. In addition to our detailed studies of the pyroxenes and feldspars in 14310,21, the interpretation given below is based on the papers on 14310 in the Proceedings of the Third Lunar Science Conference and on the work of James (1973).

In this, as in other lunar rocks, the minor element variations in the pyroxene and feldspar are critical to obtain a complete crystallization history. In 14310, we have recognized two generations of orthopyroxene based on the Al_2O_3 zoning trends. The first, or core, bronzite ($En_{76}Fs_{20}Wo_4$) has a low (less than 2%) but variable Al_2O_3 content while the second, which surrounds the first, is slightly but uniformly more magnesian ($En_{79}Fs_{18}Wo_3$) and has higher Al_2O_3 (up to 3.6%) adjacent to the boundary of the core grains. Outward from the boundary, the Al_2O_3 content drops smoothly to a level comparable to that of the core bronzite. Minor elements in plagioclase are used to determine the crystallization sequence by assuming that the later plagioclase will have a higher $Fe/(Mg+Fe)$ and K/Na ratio due to concentration of Fe and K in the melt as crystallization proceeds. The correlation of $Fe/(Mg+Fe)$ in plagioclase in 14310 to the progressive decrease in grain size from mm long blocky grains to large, medium and then fine tabular crystals supports the reliance on minor element variation as a guide to the order of crystallization.

We propose the following interpretation for the history of sample 14310:

1. Crystallization of sodic augite together with the first generation bronzite. The sodic augite occurs as blebs enclosed within the core bronzite as described by Hollister, et al. (1972). The experimental evidence (Walker, et al., 1973) suggests this clinopyroxene may have crystallized at pressures as high as 15 kb. The minute amount of clinopyroxene observed and the absence of spinel, which crystallizes with the clinopyroxene in the

Sample 14310

Crawford, M.L., and L.S. Hollister

experimental charges, suggests the crystallization at high pressure was possibly followed by resorption of early crystals. The earliest plagioclase may accompany the crystallization of the core bronzite, but this cannot be demonstrated; it forms the cores of the large blocky grains, has the lowest Fe/(Mg+Fe) ratio (.17-.25) and the highest anorthite content (An_{96}) of any in the rock. The core bronzite and the core of the blocky plagioclase grains are free of inclusions (with the exception of the sodic augite) in contrast to later pyroxene and plagioclase.

2. Crystallization of orthopyroxene ceased but growth of blocky plagioclase continued. The Fe/(Mg+Fe) ratio of the plagioclase changes from .25 to .38 and it becomes slightly more sodic (An_{92}). This is interpreted to correspond to continued crystallization of plagioclase during the rise of the magma, outside the field of crystallization of pyroxene + plagioclase (10 to 0 kilobars; Walker, *et al.*, 1973).

3. Near the outer margins of the blocky plagioclase grains there is a sharp decrease in anorthite content (to An_{86}), with no accompanying change in Fe/(Mg+Fe) ratio. This is interpreted as reflecting the initial exsolution of volatiles from the melt and probably occurs when the magma is very close to or at the surface.

4. The second generation of orthopyroxene, slightly more magnesian than the first, starts to crystallize at or shortly after the abrupt change in plagioclase content, accompanied by nucleation and growth of the coarsest of the tabular plagioclase grains. Small bronzite needles about 20 μ long and a few μ in width are enclosed within the cores of plagioclase of An_{86} on the rims of the blocky grains. The first generation bronzite also served as a nucleation site for this second bronzite and in a number of places tabular plagioclases have nucleated on that boundary and are enclosed in the second bronzite. The initially high Al_2O_3 content of the second bronzite is probably due to rapid growth in a highly aluminous melt. Many of the bronzite grains trapped melt which later crystallized to plagioclase with a distinctive high K content. As plagioclase continues to nucleate and grow, in large part as radial aggregates of tabular grains, the Al_2O_3 in the bronzite decreases and reaches a level equal to or slightly below that of the core bronzite ($T \sim 1200^\circ$, Walker, *et al.* 1973). Individual grains of second generation orthopyroxene, some with cores of first generation orthopyroxene, occur in intergrowths which can best be interpreted as a group

Sample 14310

Crawford, M.L. and L.S. Hollister

of grains growing outward from a common nucleation area. When these clusters are intersected by the plane of a thin section the intergranular relations can be quite complex.

5. Due to the rapid initial growth of plagioclase and pyroxene and consequent release of heat of fusion, the rate of temperature decrease is slowed and possibly even reversed locally.

This is interpreted to result in complex crystallization trends in the outer zones of the second bronzite. Some continue to crystallize as orthopyroxene, reaching compositions of $\text{En}_{60}\text{Fs}_{36}\text{Wo}_4$. James (1973) reports even more iron rich hypersthene.

Others zone continuously outward to pigeonite ($\text{En}_{59}\text{Fs}_{31}\text{Wo}_{10}$) followed by augite ($\text{En}_{41}\text{Fs}_{28}\text{Wo}_{31}$). A number of grains which follow the latter trend show evidence of inversion of the earliest pigeonite back to orthopyroxene with accompanying exsolution of augite lamellae parallel to (100), as discussed by James (1973).

6. The plagioclase crystallization trend splits into two parts as a result of the onset of liquid immiscibility in the remaining melt (Trzcinski and Kulick, 1972; Roedder and Weiblen, 1972). One of the liquids is enriched in K, Ba and Na and precipitates plagioclase to $\text{An}_{73}\text{Ab}_{22}\text{Or}_5$ followed by a Ba-K phase. The other liquid, depleted in the above elements, precipitates anorthite ($\text{An}_{93}\text{Ab}_6\text{Or}_1$), high iron pigeonite, and fine grained plagioclase-pyroxene clots. The immiscible liquids reported by Roedder and Weiblen (1972) from sample 14310 may represent only the final stages of this immiscibility.

Our data are consistent with a model of the 14310 melt being generated at depth (> 300 km) in the moon, partially crystallizing during ascent, and finally quenched at the surface. Based on the systematic, multiple history reflected in the plagioclase and orthopyroxene zoning, the 14310 melt is unlikely to have resulted from a simple quench of an impact produced melt.

References

Walker, et al. (1972): Proc. 3rd Lunar Sci. Conf. (Supp. 3, Geochim. et Cosmochim. Acta), V. 1, 115-129; Roedder and Weiblen (1972), ibid, 251-279; Trzcinski and Kulick (1972), ibid, 591-602; James (1973) U.S. Geological Survey Prof. Paper, in press; Hollister, et al. (1972) Lunar Science III, L.S.I, ed. Watkins, 386-388.