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PETROLOGY OF LUNAR HIGH-ALUMINA BASALT, Ikuo Kushiro, Geophysical Laboratory, Carnegie Institution of Washington, Washington, D. C. 20008

Melting experiments on the Apollo 14 high-alumina basalt 14310 (new chemical analysis given in Table 1) have been made in a pressure range 5 to 30 kilobars(kb) and in a temperature range 1100° to 1470°C with graphite capsules. Synthetic glass of this rock composition was also used as a starting material. Below about 10 kb, calcic plagioclase is the liquidus phase and is followed by chromian spinel (~ 20 wt.% Cr_2O_3), aluminian orthopyroxene and clinopyroxene with lowering temperature. Between 10 and 20 kb, spinel is the liquidus phase and above 20 kb garnet (~ $Ca_{20}Mg_{58}Fe_{22}$) is the liquidus phase. Aluminian clinopyroxene is the second phase to crystallize above 15 kb. The melting interval is 120 - 180° between 5 and 25 kb. In the 1 atm quenching runs made on the synthetic glass, olivine crystallizes at least near 1220°C. The liquid of the 14310 rock composition shows cotectic nature at about 10 and 20 kb; however, the coexisting phases are plagioclase+spinel and spinel+garnet, respectively, at these pressures. In the system anorthite-olivine-silica, the composition of rock 14310 (and 14310 - 10 % plagioclase) as well as feldspathic basalt (or gabbroic anorthosite) which Reid et al. (1971) have suggested to be a lunar highland material lies on the plagioclase side of the olivine-plagioclase or pyroxene-plagioclase cotectic boundary at least up to 10 kb (~300 km). On the other hand, the possible lunar 'mantle' material (peridotite or pyroxenite with or without a small amount of plagioclase) lies on the olivine or pyroxene side of the cotectic boundary. If rock 14310 is not a plagioclase cumulate rock or a plagioclase cumulate rock with addition of plagioclase less than 10 %, the rock cannot be a product of direct partial melting of the possible materials of the lunar interior under anhydrous conditions. It is also not a product of fractional crystallization of the magma which was formed by direct partial melting of the lunar interior. Therefore, a double-stage model must be considered for the origin of the rock 14310. One possibility is that the magma was generated by bulk melting or partial melting of a plagioclase cumulate rock which had been formed by a large-scale differentiation of magma in the shallow part of the lunar interior. It is mentioned that the magma of the 14310 rock composition **may** be produced by partial melting of gabbroic anorthosite.

Table 1

SiO_2 46.88, TiO_2 1.19, Al_2O_3 21.68, FeO 8.22, MgO 7.42, CaO 12.55, Na_2O 0.72, K_2O 0.50, Cr_2O_3 0.25, MnO 0.13, P_2O_5 0.17, Total 99.71 (wt.%)

(Analyzed by H. Haramura with conventional wet chemical analysis method.)

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The above discussion is based on the assumption that there was no loss or gain of alkalies and other elements during the magmatic stage. Recently, however, Brown and Peckett (1971) have suggested a significant (~ 70 wt.% or more) alkali loss for rock 14310. If this is true, the above discussion may be subject to change. To examine this, melting experiments have been made on the synthetic glass of the 14310 rock composition with 3.2 wt.% Na_2O and about 1 % K_2O. The plagioclase liquidus drops drastically and olivine crystallizes to higher pressures, and in consequence, olivine, plagioclase, spinel and orthopyroxene appear within 20° at about 3 kb (~ 100 km). This evidence suggests that the liquid of this composition could be formed by direct partial melting of plagioclase and spinel bearing peridotite at depths of about 100 km. Therefore, if significant alkali loss occurred, as suggested by Brown and Peckett, the origin of rock 14310 could be explained by a single-stage model.

Orthopyroxene in rock 14310, which occurs as the core of pigeonite and subcalcic augite, contains 1.5 - 3.1 wt.% Al_2O_3, whereas that crystallized at 10 kb at 1250°C and at 5 kb at 1200°C contains 5.7 - 7.7 % Al_2O_3 and 4.3 %, respectively, presumably as a Tschermak's component, supporting the low-pressure crystallization of the 14310 orthopyroxene. Upon cooling of the magma, small-scale fractional crystallization took place and the following compositional variations in pyroxenes and plagioclase are observed: orthopyroxene $Ca_4Mg_{79}Fe_{17}$-$Ca_5Mg_{62}Fe_{33}$, pigeonite $Ca_{10}Mg_{58}Fe_{32}$-$Ca_{11}Mg_{15}Fe_{74}$, Ca-rich clinopyroxene $Ca_{34}Mg_{46}Fe_{20}$-$Ca_{17}Mg_{17}Fe_{66}$, plagioclase $An_{94}Ab_6$-$An_{73}Ab_{27}$. In the late stage of crystallization, minor minerals such as Ba-bearing K-feldspar, phosphate minerals, Zr-rich and rare earth-bearing minerals crystallized and the residual liquids that were concentrated in the interstices of early crystallized plagioclase and pyroxene became potassic rhyolite in composition. In some interstices, liquid immiscibility occurred, having produced rhyolitic and Ti-rich, pyroxenitic liquids.

Another crystalline rock 14053, which has been also analyzed with the microprobe, contains plagioclase (An_{92}-An_{74}), pigeonite ($Ca_{12}Mg_{60}Fe_{28}$-$Ca_{13}Mg_{44}Fe_{43}$), subcalcic augite and ferroaugite (e.g., $Ca_{25}Mg_{45}Fe_{30}$-$Ca_{23}Mg_6Fe_{71}$), hedenbergitic clinopyroxene ($Ca_{42}Mg_2Fe_{56}$), ilmenite, spinel (both Ti-bearing chromite and Cr-bearing ulvospinel), olivine (Fa_{37} and Fa_{88}), cristobalite, K-feldspar with mesostasis of high K, rhyolitic composition. The bulk composition of rock 14053 is significantly different from that of rock 14310 and rather similar to those of the Apollo 12 crystalline rocks with intermediate FeO/(FeO+MgO) ratio, which is higher than that of rock 14310.

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