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Subject: Final Report for NGR 38-003-009, "Plagioclase  
Thermometry of Igneous Rocks."

Work completed as of the termination date of this grant, 31 October 1970, has been aimed primarily at systematizing the composition and temperature dependence of some of the important properties of natural magmatic systems. Much of the current knowledge regarding these systems is strictly valid only for the specific compositions which have been investigated experimentally. The problem of plagioclase crystallization is a good example of the restricted applications possible from such studies. Many experimental investigations have been made in the past attempting to specify the crystallization history of plagioclase feldspars from silicate melts. Unfortunately, only a few of these investigations have succeeded in quantitatively relating the chemical composition of the crystallizing plagioclase (a solid solution phase,  $(\text{NaSi}, \text{CaAl}) \text{AlSi}_2\text{O}_8$ ) to the chemical composition of the melt and to the temperature of crystallization. It is precisely this type of information which is of use in interpreting igneous processes, e.g., in evaluating the role of plagioclase in igneous differentiation via fractional crystallization or in using plagioclase for geothermometry. Notable exceptions to this lack of quantitative data are the investigations of N. L. Bowen and his co-workers in the synthetic systems  $\text{NaAlSi}_3\text{O}_8\text{-CaAl}_2\text{Si}_2\text{O}_8$ ,  $\text{CaMgSi}_2\text{O}_6\text{-NaAlSi}_3\text{O}_8\text{-CaAl}_2\text{Si}_2\text{O}_8$ , and  $\text{CaTiSiO}_5\text{-NaAlSi}_3\text{O}_8\text{-CaAl}_2\text{Si}_2\text{O}_8$ . These systems, which crystallize plagioclase feldspars, have been investigated in a manner which allows a quantitative analysis of plagioclase composition as a function of temperature and co-existing liquid composition. Even here, however, no attempt has been made to extrapolate these relations to the more complicated chemistry of natural magmatic systems.

As part of the final report for NGR 38-003-009, please find enclosed five copies of a paper entitled: "An Igneous Plagioclase Thermometer," which successfully correlates plagioclase composition, temperature of crystallization, and magmatic liquid composition for a wide range of natural magma types and temperature.

In attempting to quantitatively discuss igneous differentiation by means of crystal-liquid preparation processes, it is necessary to know the density of silicate liquids. Again, this property is a sensitive function of chemical composition as well as temperature. Consequently, the few direct measurements of density which have been made for molten

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rock systems have limited applicability. The very wide range of chemistry displayed by natural magmas points to the desirability of a systematic approach to the composition dependence of liquid density. The second part of the final report for NGR 38-003-009 is a paper entitled: "Densities of Liquid Silicate Systems Calculated from Partial Molar Volumes of Oxide Components." The results presented in this paper make it possible to accurately calculate the density of magmatic liquids over the complete range of naturally encountered compositions and temperatures.

The studies carried out under grant NGR 38-003-009 have made it possible to treat quantitatively two of the important properties of silicate melts, density and plagioclase crystallization. These properties have been systematically investigated with respect to their dependence on composition and temperature, and the resulting models are valid for a wide range of geologic situations.

Respectfully submitted,

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Principal Investigator

31 November 1970