

MELTING RELATIONS IN THE SYSTEM JADEITE-DIOPSIDE AT 30 AND 40 KILOBARS

PETER M. BELL and BRIAN T. C. DAVIS*

Geophysical Laboratory, Carnegie Institution of Washington,
Washington, D. C. 20008

ABSTRACT. At 30 kb and 40 kb jadeite-diopside is a binary system. A melting interval extends for the full compositional range and is analogous to that observed in plagioclase feldspars. This system leads to petrogeny's residua system, and the fractionation behavior follows Bowen's trend except that an extremely narrow melting interval may produce only limited concentrations of jadeite constituents in high-pressure magmas.

Relationships in the subsolidus region can be deduced in a qualitative way from volumetric data measured on solid solutions along the binary join. Calculations of a regular solution model suggest that the addition of diopside to jadeite will not have a great effect on the breakdown of jadeite to albite + nepheline.

INTRODUCTION

The pyroxene omphacite is mainly a solid solution of jadeite ($\text{NaAlSi}_2\text{O}_6$)-diopside ($\text{CaMgSi}_2\text{O}_6$). The occurrences of omphacite are intriguing because of its most common association with high-pressure minerals such as pyrope garnet, kyanite, and diamond. The natural environment of many omphacites, therefore, is in the high-pressure zone of the Earth's crust and mantle.

Laboratory observations of systems containing the omphacite composition have heretofore been limited to plagioclase, nepheline, and diopside, phases stable under the low-pressure conditions of the upper crust. It has been the purpose of the present study to continue some of these investigations at high pressures which are more consistent with the geologic setting of the mineral phases involved.

Bowen's (1913) classic experiments on melting phenomena proved the exact relationship of the melting interval in the $\text{Ab}(\text{NaAlSi}_3\text{O}_8)$ - $\text{An}(\text{CaAl}_2\text{Si}_2\text{O}_8)$ system which previously had been investigated at the U. S. Geological Survey and the Geophysical Laboratory (Day and Allen, 1905). His analysis of the actual two-phase melting region revealed the process of fractional crystallization by which natural melting produces zoned and reversed zoned plagioclase crystals. This process accounts for the existence of a nearly continuous variation of the compositional phase region in many igneous plagioclases. After this study on plagioclase, Bowen in collaboration with Schairer continued studying melting phenomena and, in particular, investigated systems containing FeO , K_2O , and MgO in addition to the plagioclase components (for example, Bowen, 1915). Bowen (1937) assembled much of his and Schairer's phase equilibrium results and with great insight proposed petrogeny's residua system. This system, including mainly NaAlSiO_4 - KAlSiO_4 - SiO_2 , was the goal of the crystal fractionation process containing the components SiO_2 - Al_2O_3 - FeO - CaO - MgO - Na_2O - K_2O , which includes about 97 percent of the average igneous rocks (Bowen, 1937). Phases containing much of the CaO

* deceased

and MgO are precipitated in the course of the fractionation trend, and the liquid is therefore enriched in alkalis, alumina, and silica. Further experimentation and field observation have frequently borne out Bowen's contention.

Attempts to define the exact nature of the liquid residue within the alkali–alumina–silicate ternary have been rewarding. In following many of the same chemical systems as Bowen, Schairer and Yoder obtained additional information on petrogeny's residua system. Experimentally following the trends within the 7-component system (a summary of relevant diagrams is given in Yoder and Tilley, 1962, p. 399), Schairer and Yoder (1960) showed that residual liquids fall within the zone suggested by Bowen but separated into two groups within the zone. This separation is caused by the development of a thermal divide, for example, along the albite–diopside join. On one side of the divide the system is undersaturated in SiO_2 , and a nepheline normative trend is produced. On the other side of the divide the system is supersaturated with SiO_2 , and a quartz normative trend is produced. Evidently igneous liquids can follow either trend depending on slight differences in original composition and the fractionation process. The residua system is the final goal of most igneous processes and therefore is of utmost importance in interpreting the geology of rocks exposed at the Earth's surface.

The fractionation process originates at great depths and therefore at high pressures within the Earth's crust and mantle. The basic question is how does high-pressure behavior modify the trends at depth that lead to the various portions (oversaturated, saturated, undersaturated) of petrogeny's residua system at low pressure? Jadeite–diopside lies in the system nepheline–diopside–quartz, and a study of its melting relations at high pressure should provide a partial answer to the nature of the trend determining processes.

OMPHACITE COMPONENTS

The usual significance of albite as excluding nepheline ($\text{NaAlSi}_3\text{O}_8$) and quartz (SiO_2) compatibility ceases to be meaningful at high pressures. Jadeite, silica-poor compared to albite, becomes more stable and constitutes a member of a new thermal divide. Jadeite–diopside at high pressure may be thought, therefore, to play a corresponding role as albite–diopside at low pressure. In another analogy, the jadeite–diopside join might be considered to act as a thermal divide at high pressure as the plagioclase join does at low pressure because jadeite, not albite, is stable.

Liquidus relationships were first investigated at 30 kb because past experience with jadeite melting (Bell, 1964; Bell and Roseboom, 1965) demonstrates this to be the lower pressure limit of congruent behavior. Relationships at 40 kb were investigated next in order to examine pressure effects and at the same time to support the phase equilibria analysis of the 30 kb section. Temperatures required at 40 kb are considerably higher, and therefore sluggish melting, which is characteristic of sodium-bearing silicates, is nearly eliminated. Subsolvus relationships were not