HIGH-PRESSURE STABILITY OF ACMITE

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ABSTRACT. Acmite, $NaFe^{3+}Si_2O_6$, continues to melt incongruently to hematite + liquid up to at least 45 kb. The equation $T\,(°C) = 988 + 20.87P\,(kb) — 0.155P^2\,(kb)$ reproduces the fusion curve for acmite = hematite + magnetite + liquid over the pressure range 0 to 45 kb. The initial slope of this curve is about $20°C/kb$, which is steep for silicates. An acmitic pyroxene may be stable in equilibrium with metallic iron. Under conditions of low relative oxygen fugacity, acmite melts incongruently to fayalite + liquid. Acmite and some other silicates do not exhibit a linear relation between melting temperature and compressibility and therefore do not obey the recently proposed "new law of melting".

INTRODUCTION

The pyroxene end member acmite, $NaFe^{3+}Si_2O_6$, is important because it occurs as the principal constituent in pyroxenes of the late alkaline igneous rocks and because it is the second most important component of the jadeitic pyroxenes found in blue-schist facies terranes (for example, Coleman, 1965, table 2). Bowen and Schairer (1929) originally demonstrated that this compound melts incongruently at 1 atm pressure to hematite + liquid. Thus, separation of iron oxides from a magma would drive the liquid to more silica and soda-rich compositions, providing a possible fractionation mechanism for the development of the alkaline rocks. The remaining question was whether or not this incongruent melting would persist to the pressures characteristic of the lower crust and upper mantle where magmas are believed to be generated.

In the Franciscan metagraywackes of California, jadeitic pyroxenes are formed principally by the breakdown of sodic plagioclase to jadeite-rich pyroxene + quartz and have regional distribution (McKee, 1962; Ernst, 1965). In addition, pyroxenes of the eclogites occurring with the glaucophane schists of California, the Group C eclogites of Coleman and others (1965, table 5), are about equally rich in jadeite and diopside constituents, with acmite third in importance. Further reflection also indicates that a clinopyroxene phase is the most likely silicate to house ferric iron under the bulk composition-temperature-pressure conditions realized in the upper mantle. If the environment at depth had more Fe^{3+} than could be balanced by Na, then Ca-Fe^{3+} phases such as garnet would be important. Ferridiopside is not likely to be significant, as it probably has no great stability at high pressure (Huckenholz, Schairer, and Yoder, 1968). Calcic amphiboles, including those Na-bearing, are not stable above 800° to 900°C at 30 kb and so may also be ruled out at depths greater than 70 to 100 km (Gilbert, 1968).

The question now raised is the effect of the acmite component on clinopyroxene stability. In order to answer these questions, acmite itself must first be studied at high pressure, and this paper reports the results of such an investigation.

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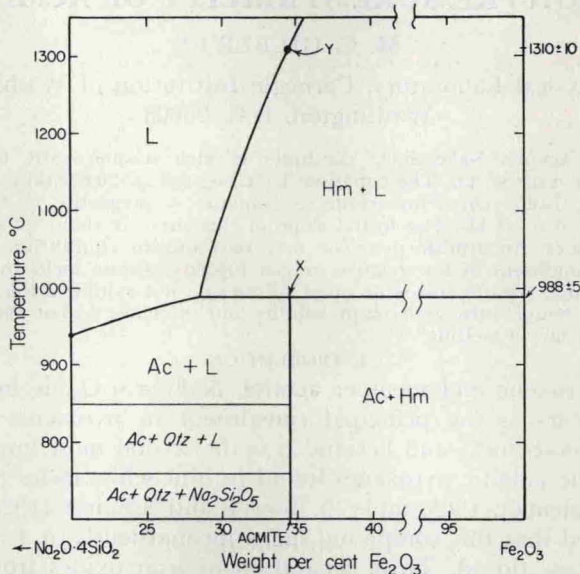
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Fig. 1. One atmosphere T-X diagram featuring acmite composition. Abbreviations: Ac, acmite; L, liquid; Hm, hematite; Qtz, quartz. The form of the phase relationships was first worked out by Bowen and Schairer (1929). The temperatures of acmite melting (X) and of the liquidus for acmite compositions (Y) are from Bailey and Schairer (1966). Only the right side of the diagram, from acmite to hematite, can be considered binary. Light lines and italicized assemblages represent ternary equilibria.

PREVIOUS EXPERIMENTAL WORK ON ACMITE

At 1 atm and in equilibrium with air, acmite melts incongruently to hematite + liquid, as shown in figure 1 (Bowen and Schairer, 1929). Where a liquid phase is formed the system becomes nonbinary because of small amounts of ferrous iron in the liquid, the amount increasing with temperature (Bowen, Schairer, and Willems, 1930). Although ferrous iron can be neglected in a gross way, departure from a truly binary system at 1 atm is evident in the more recent experimental results on pure acmite composition in which acmite melted over a 13°C interval (Bailey and Schairer, 1966, p. 124). This melting interval implies acmite-ferrosilite solid solution during the melting.

A preliminary report on the system Na_2O-FeO-SiO_2 at 1 atm, which includes "reduced" acmite composition, was made available several years ago (Schairer, Yoder, and Keene, 1954). Although pyroxene was not positively identified at that time, one of the phases retrieved on quenching appeared to be acmite pyroxene (H. S. Yoder, Jr., personal commun.).

Bailey (1969) has investigated the melting relations of acmite in the presence of water under conditions of controlled oxygen fugacity, at fluid (= total) pressures of 2 and 5 kb. He also made unbuffered runs up to 10 kb and was able to show that incongruent melting persists to at least