analyses agree well with those determined by the *x*-ray method using Yoder and Sahama's formula.

The olivines were separated from additional material collected on the 1953 East Greenland Geological Expedition. Sample 5181 was separated from a rock of the same locality as the original sample, 1907, at a structural height[1] of 1800 m in the layered series. Sample 5112 was separated from a rock at a height of 600 m, somewhat higher than the original sample, 4077, collected at about 300 m. The new analyses were made of pure material on a semi-micro scale. Measurements of the d_{130} spacing (by M.G.B.) using a Philips high angle diffractometer followed essentially the procedure of Yoder and Sahama. The d_{130} spacing for the sample 5181 is 2.8128 Å, in excellent agreement with that determined on sample 1907 by Yoder and Sahama (1957, Table 3), namely 2.8126 Å. Sample 5112 has d_{130} of 2.7944 Å, close to the d_{130} value of 2.7951 Å determined by Yoder for the sample 4077. The newly determined $2V_x$ values (by J.A.V.D.) are within 1° of the values given by Deer and Wager (1939). The accompanying table summarizes these results.

This work, done some time ago, was undertaken because a series of further determinations on olivine of the Skaergaard intrusion was being made, and it was necessary to determine whether the Skaergaard olivines conformed to the *x*-ray and optics of the usual olivine of basic rocks.

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[1] The structural heights quoted are revised values.

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GROWTH OF FORSTERITE CRYSTALS IN A REACTIVE CRUCIBLE[1]

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A recent note by Shankland and Hemmenway (1963) on the growth of forsterite crystals in a Verneuil furnace prompts us to report on our experiences with the production of similar monocrystals using a different method which may have more general applicability. The technique used may be described as a modification of the Bridgman method in that compacted pellets of appropriate composition were melted in a crucible with a pointed bottom which was cooled slowly by power adjustment or by

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[1] Contribution No. 57, Hawaii Institute of Geophysics.

change in heating zone position. Preliminary attempts to grow this type of crystals were carried out using prefused short rods of the constituent oxides attached to an alumina rod by flame fusion. These were suspended, oxides downward, without contact inside a graphite crucible which was to function as a high frequency susceptor. The arrangement was heated by induction in a vacuum system. It was found that a bell-jar unit exhausted by a rotary oil pump with a dry ice-acetone trap was adequate for good results. With a fast pump and high conductance connections a pressure of approximately 1 torr could be maintained in this equipment when the furnace was at its maximum temperature (approximately 2000° C.). In the course of these experiments portions of the molten silicate dropped from the suspension rod onto the bottom of the graphite crucible, but, surprisingly, on examination these were found to show evidence of good crystallization. In subsequent work the pellets were placed in direct contact with the graphite crucibles.

The charge was prepared from C.P.-analyzed magnesium oxide powder and crushed vitreous silica both of -200 mesh. Portions of these oxides conforming to the stoichiometric composition for forsterite were mixed by tumbling for 4 hours, and 3% stearic acid dissolved in carbon tetrachloride was added. The carbon tetrachloride was evaporated from the slurry and pellets were formed by compression to about 12,000 psi. The stearic acid was then sublimed and burned off by heating to redness in air. The most successful growth of large crystals was achieved by placing several such pellets in a graphite crucible with a pointed bottom. This crucible was surrounded by a bed of graphite granules, and the whole was contained inside another crucible of alumina. After heating for only a few minutes at maximum temperature (about 2000° C.) the charge was cooled slowly by lowering the crucible, or by decreasing the power over a 15-minute period. A great deal of gas was evolved during a run, and samples were found to be reduced in weight by as much as 60% from the initial charge. The resulting boules were cloudy, with some striations, and many showed indications of crystal faceting. The largest obtained thus far were about 1 centimeter in diameter.

Thin sections show the best boules to be single crystals with polycrystallinity in evidence near the edges in some cases. Gas bubbles were present in the form of long striae extending in the direction of crystallization. The *x*-ray powder determination showed only the forsterite pattern (Yoder and Sahama, 1957). Chemical analyses also agreed with the expected composition within the limits of experimental error.

The unusual feature about these experiments is that any crystals should be obtainable from a fully oxidized sample under these conditions in a graphite crucible. Calculation by the usual method (Margrave, 1959) of the thermodynamic stability of forsterite in contact with graphite at approximately the melting point (1890° C.) indicates non-stability with a large pressure of gaseous magnesium and carbon monoxide resulting at equilibrium. One can postulate a "spittle-on-the-hot-iron effect" as a likely phenomenon which might explain the intact boules. Since the forsterite-graphite reaction would yield quantities of gas, it could be conceived that the liquid boule drop might be in contact with the graphite only intermittently, being in general cushioned on a gaseous layer of its own reaction products. This would assume no reaction with the gaseous products and a high surface tension. Indeed, calculation of the thermodynamic stability of forsterite in contact with carbon monoxide shows it to be stable at temperatures around the melting point, and the surface tension estimated from the additivity of that of the oxides (Kingery, 1959) is approximately 500 ergs/cm^2, a relatively high value.

Attempts to grow iron-containing orthosilicate (olivine) crystals by this technique have not been successful, with polycrystallinity and evidence of metallic iron present in the resulting masses. Although we have not as yet tried the technique extensively, we believe that other silicate systems with the right combination of high surface tension and thermodynamic stability may be amenable to sizeable crystal production by this method.

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ON MERTIE'S ANALYTIC CLASSIFICATION AND QUADRIPLANAR CHARTING OF ANALYSES WITH NINE OR MORE COMPONENTS

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Introduction

According to Mertie (1961) the nine components of a chemical analysis can be reduced to three *unique* numerical indices which are the eigenvalues of the matrix which has the chemical components as its elements (Mertie, p. 617).