"PYROXENE" - ILMENITE XENOLITHS FROM THE STOCKDALE PIPE; KANSAS: CHEMISTRY, CHRYSTALLOGRAPHY, AND ORIGIN

Robert H. McCallister: Department of Geosciences
Henry O. A. Meyer : Purdue University, West Lafayette, Indiana, 47907, U.S.A.

Douglas G. Brookins : Department of Geology, University of New Mexico, Albuquerque New Mexico, 87106, U.S.A.

Originally Harger (1906), Williams (1932) and MacGregor, Ferguson and Amm (1937) described the occurrence of xenoliths of enstatite-ilmenite and diopside-ilmenite intergrowths in kimberlite. In recent years a number of pyroxene-ilmenite intergrowths have been studied and reported on by several authors including: MacGregor and Wittkopp (1970); Ringwood and Lovering (1970); Dawson and Reid (1970); Brookins (1971); Boyd (1971); Boyd and Dawson (1972); Boyd and Nixon (1973) and Mitchell et al. (1973). In this paper we present and discuss results of a study on the chemistry of an ilmenite-"serpentinized" pyroxene xenolith from the Stockdale kimberlite pipe of Riley County, Kansas. Also, we will discuss the crystallographic relationships between intergrowth phases of the types previously mentioned as well as possible mechanisms of formation.

Texturally the Stockdale and other pyroxene-ilmenite xenoliths, mentioned above, are alike in that both are composed of alternating lamellae of two phases. In the Stockdale intergrowth the lamellae consist of ilmenite and serpentine with an average interlamellar width of 0.8 mm, and a serpentine lamellae thickness of approximately 0.6 mm. The ilmenite/serpentine ratio was determined to be 27%: 73% ± 2%. In thin-section calcite stringers were observed cutting across serpentine lamellae. This was confirmed by electron-microprobe analysis. We did not observe the varying habits of ilmenite or the 120° intersection of lamellae which were described by Dawson and Reid (1970).

Representative analyses of the ilmenite and serpentine are presented in Table 1. The ilmenite has been recast to give the relative proportions of $FeTiO_3$ (ilmenite) to $MgTiO_3$ (geikielite). The high geikielite content of the ilmenite is consistent with compositions of ilmenites from other kimberlites. The excess Fe after Mg, Fe, and Mn atomic proportions were subtracted from Ti corresponds to approximately 6.0 wt % Fe_2O_3 although we only give iron as FeO. The serpentine is relatively homogeneous throughout the section and corresponds chemically to antigorite. The results of x-ray diffraction and scanning electron microscope studies confirmed antigorite as the polymorph.

Table 1.
Representative analyses of Stockdale intergrowth

	Ilmenite	Antigorite
SiO_2	0.20	43.1
TiO_2	54.9	0.45
Al_2O_3	0.90	1.97
FeO	30.8	3.87
MgO	12.8	39.5
CaO	0.04	0.06
MnO	0.25	0.03
	99.9	89.0 less H_2O 11.0

Ilmenite	55
Geikielite	45

In an attempt to understand the structural relations between intergrowth phases of ilmenite and silicates precession photographs were taken of an ilmenite plate from Stockdale, a clinopyroxene-ilmenite couple from Monastery Mine (supplied by Dr. Ian MacGregor) and an orthopyroxene-ilmenite couple from Monastery Mine (supplied by Dr. F.R. Boyd). Unfiltered MoK radiation was used in all diffraction experiments.

The ilmenite in each sample was found to be oriented such that the plane of the lamella was equivalent to the basal plane of ilmenite (i.e. [0001] was perpendicular to the plane of the ilmenite plate).

For the case of the clinopyroxene-ilmenite couple however, it was found that b* of the clinopyroxene is parallel to $h0\bar{h}0^*$ of the ilmenite. Also, the plane of the clinopyroxene which is parallel to basal plane of the ilmenite is (201).

In the orthopyroxene-ilmenite intergrowth b* of orthopyroxene is also parallel to $h0\bar{h}0^*$ of the ilmenite; however, the common plane between the two structures is parallel to (100) of the orthopyroxene and (001) of the ilmenite.

On the assumption that the configuration of oxygen atoms in the two phases is nearly coincident for some layer parallel to (100) in the orthopyroxene and (0001) in the ilmenite, successive plots of oxygen positions were made for both members in planes at varying distances along their respective [100] and [0001]. Allowing for certain approximations a rather good fit was obtained between the two structures at 3.51Å along c of ilmenite and the composite oxygen positions at 17.05, 17.12 and 17.30Å along a of the orthopyroxene. The common layers closely correspond to a close-packed layer of oxygens, and the nearness of fit suggests a low strain energy configuration.

A number of suggestions with regard to the mechanism of formation of these intergrowths have been made by several authors and reviewed by Boyd (1971). These include:

a. Eutectic crystallization which was originally proposed by Williams (1932) on the basis of the graphic texture, and later confirmed as a possibility by MacGregor and Wittkopp (1970) through their experimental work on the diopside-geikielite system.
b. Discontinuous precipitation suggested by Dawson and Reid (1970). In this instance ilmenite is exsolved from a supersaturated Ti-rich clinopyroxene phase.
c. Eutectoid transformation proposed by Ringwood and Lovering (1970). This is also a solid state reaction however, all three phases taking part in the reaction are structurally distinct. The reaction, proven experimentally, is a single garnet phase transforming at pressures less than 105 kb at 1000^{0}C to ilmenite + clinopyroxene.

In terms of theoretical considerations, the equations for predicting interlammelar spacing as a function of undercooling are virtually identical for all three processes. Textures produced by the three mechanisms all look similar. Thus, a textural study alone will not aid in definitively answering the question of mechanism. Furthermore, the crystallographic relations observed between the pyroxene and ilmenite lamellae could be produced by any of the three processes mentioned above.

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