American Mineralogist, Volume 62, pages 1038–1041, 1977

Anorthoclase–calcite rodding within a kaersutite xenocryst from the Kakanui Mineral Breccia, New Zealand

R. CLELAND WALLACE[1]

Geology Department, Otago University
Dunedin, New Zealand

Abstract

Unusual white rods of anorthoclase and calcite are described from a kaersutite xenocryst from the Kakanui mineral breccia, New Zealand. The calcite and anorthoclase are interpreted as secondary infillings of parallel tubicles in the kaersuitite. These tubicles are thought to be large elongate fluid inclusions that resulted from the growth of gaseous "bubbles" on the crystal contemporaneously with crystal growth.

Introduction

The constituents of the Kakanui Mineral Breccia have been investigated by many authors (Mason, 1966, 1968; Dickey, 1968a, 1968b; White *et al.*, 1972), who described xenoliths (lherzolite, eclogite hornblendite, pyroxenite, granulite, and schist) and xenocrysts (pyrope, augite, anorthoclase, hornblende, and ilmenite) set in a tuffaceous matrix rich in carbonates, montmorillonite, anorthoclase, and phillipsite. Melanephelinite, which mantles many of the inclusions, is thought to be the magma that brought the xenoliths to the surface. During a recent visit to the Kakanui Mineral Breccia I found a large hornblende xenocryst with coarse white rods passing through it (Fig. 1).

Mineralogy

The xenocryst is a rounded, relatively well-polished kaersutite crystal measuring 15 × 15 × 10 cm, and is conspicuous in having white rods passing through it. The rods are up to 3 mm in diameter, with a maximum length of 5 cm, and often have blind bulbous tips. They commonly pinch and swell and occasionally flatten into broad spoon-shaped regions. No example of a rod bifurcating was observed.

The rods are not uniformly distributed throughout the grain, but form zones of parallel rods lying on the $(1\bar{1}0)$ cleavage plane at an angle of 49° to the cleavage intersection (Fig. 2). Although this direction is the dominant one, others do occur (Fig. 1), and individual rods occasionally change direction. The rods remain parallel after changing direction, and in the region of bending they narrow significantly. The nature of the specimen does not allow observations as to whether all the rods are continuous at the bend; however, at least three are continuous. The rods change direction through an angle of 28° to the Z vibration direction, the new direction being at 13° to the $(1\bar{1}0)$ plane (Fig. 2).

The rods usually have a rounded cross section, but in some instances the morphology of the rod is controlled by the cleavage, producing a rhombic cross section. The rods are composed of fibrous anorthoclase, often radiating from the kaersutite host (Fig. 3), with magnesian calcite infilling the interstices between the anorthoclase. Optical zoning in the kaersutite adjacent to the rods can occasionally be discerned.

Analyses of the kaersutite (table 1) show that it is of similar composition to the other amphibole xenocrysts described from the breccia (Mason, 1966, 1968; Dickey, 1968a; White *et al.*, 1972). The optically-zoned kaersutite adjacent to the rods is richer in magnesium and titanium and depleted in iron compared to the rest of the crystal.

Discussion

The nature of the anorthoclase and calcite forming the rods, and the occurrence of anorthoclase and calcite in the tuffs associated with the mineral breccia, suggest that these minerals are of secondary origin. The areas now filled by the calcite and anorthoclase may have been produced by: (1) exsolution of a sec-

---

[1] Present address: Geological Survey, Pretoria, South Africa.

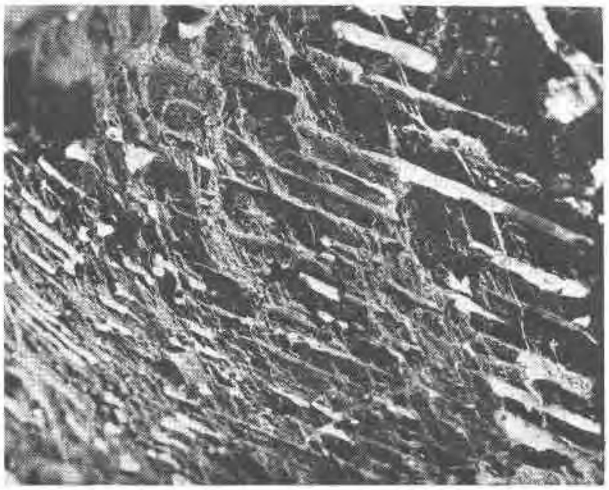

Fig. 1. White rodding in the kaersutite xenocryst; note the slight change in direction of the rodding and the smooth furrows where the rods have been removed. Photograph is 7 cm wide.

ond phase out of the kaersutite and the later removal of this phase; (2) eutectic crystallization or subsolidus reequilibration and removal of one of the phases; (3) the formation of tubular fluid inclusions in the kaersutite.

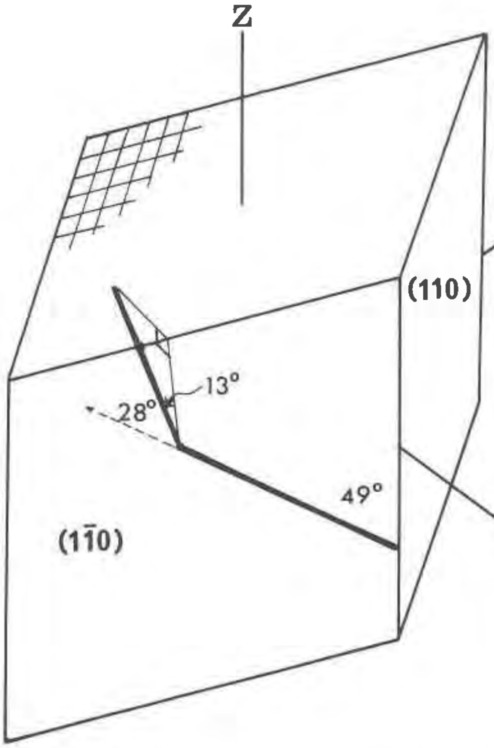

Fig. 2. Diagrammatic representation of the rodding in the kaersutite xenocryst. The major part of the rods is in the (1$\bar{1}$0) plane, at 49° to the intersection of the cleavages. After bending through 28° the rods are at 13° to the (1$\bar{1}$0) face.

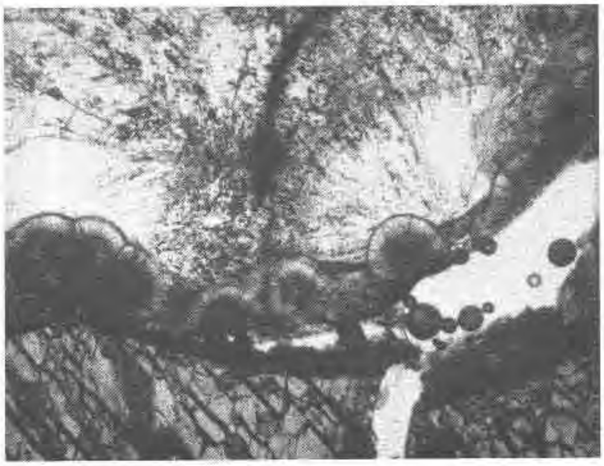

Fig. 3. Cross-section of a rod in the kaersutite, showing the radially-orientated anorthoclase around the perimeter of the rod and calcite, also fibrous-radiating, toward the core. The ratio calcite:anorthoclase is quite variable. The photomicrograph is 0.6 mm wide.

The regular nature of the rodding presents a strong case for formation by exsolution. Descriptions of phases exsolving from actinolite and common hornblende are common (see Ross *et al.*, 1969; Cooper and Lovering, 1970, and references therein), and poorly developed examples of ilmenite apparently

Table 1. Microprobe analyses of kaersutite containing anorthoclase-calcite rodding

	1	1*	2	2*
SiO_2	40.39	5.959	39.79	5.779
Al_2O_3	13.91	2.418	14.41	2.464
TiO_2	4.98	0.553	5.87	0.641
FeO**	12.41	1.530	8.76	1.063
MnO	0.10	0.012	0.03	0.003
MgO	11.88	2.614	14.55	3.148
CaO	10.11	1.597	11.22	1.746
Na_2O	2.91	0.831	2.41	0.679
K_2O	1.94	0.365	1.74	0.323
	98.63		98.78	

1: Kaersutite megacryst
2: Leached zone in kaersutite adjacent to rodding
* Total iron as FeO
** Structural formulae based on 23 oxygens

Analyzed using 15 kV accelerating voltage, 2 micron beam diameter, 0.03 μm amps specimen current and following data reduction methods of Bence and Albee (1968).

exsolving from kaersutite have been reported by Wallace (1973, unpublished M.Sc. thesis, University of Otago, New Zeland) and observed by the author in xenoliths in a mafic phonolite in Otago, New Zealand (Price and Wallace, 1976). However, in these occurrences of exsolution from an amphibole, the exsolution has been planar and the lamellae less than a micron wide. Although coarse exsolution has not been reported in an amphibole, Ringwood and Lovering (1970) have described coarse ilmenite exsolution in a pyroxene host. If, however, the rods represent replacement of an exsolved phase it is difficult to explain how that phase could have been so completely removed. Williams (1932) has reported a silicate/ilmenite intergrowth from the Monastery (South Africa) Mine where the original silicate has been completely altered but the ilmenite was not. Also, where a chromite/orthopyroxene symplectite from the Moeraki River diatreme (Wallace, 1975) has come in contact with the CO_2–H_2O fluids associated with this intrusion, the silicate has been altered, leaving skeletal chromite. Therefore, environments do exist where one phase of an intimately associated set of phases has been completely altered without apparently the other phase being affected. However, in these environments the silicate has been altered.

Eutectic crystallization or subsolidus reequilibration would not readily explain the textures described, as this usually produces irregular symplectic intergrowths (Boyd, 1971; Griffin, 1971; McBirney and Aoki, 1973; Whitney and McLelland, 1973; Dawson and Smith, 1975; Wallace, 1975). There is also the problem of replacing one of the phases without altering the other.

If the calcite–anorthoclase rods are secondary, then the texture in the kaersutite resembles the blind subparallel tubular voids with bulbous ends in labradorite phenocrysts described by Gutmann (1974). Gutmann suggested that these voids resulted from nucleation of a gas phase on the crystals. The gas "bubble" prevented crystal growth, and both bubble and crystal grew at a similar rate, producing a tubular void within the crystal. This may explain the texture in the Kakanui kaersutite. The Kakanui mineral breccia is the result of a gas-rich explosive eruption, and gases may have been exsolving while the kaersutite crystallized. The apparent influence of the cleavage over the location of the tubicles may be due to some form of variation in surface energy effects along the cleavage allowing preferential nucleation of fluid "bubbles" at these points. The uniform change in direction of "bubble" growth (reflected in the bend of the rods) is difficult to explain, but if the "bubbles" developed at right angles to a face of the grain, then any alteration in the orientation of this face (due to variations in the rate of crystal growth) would produce a change in direction in the growth of the "bubble." The zoning of the megacryst about the tubicles is probably the result of secondary leaching prior to or during eruption, but it may be primary and be the result of the bubble restricting the access of material to the growing crystal surface. Blackerly (1968) suggested a similar mechanism of a viscous globule retarding the movement of material toward a crystal surface to explain "convolute zoning" in plagioclase.

Conclusion

Rodding in a kaersutite megacryst from the Kakanui mineral breccia is thought to be a secondary infilling of tubicles produced by the masking effect on the megacryst by a gaseous phase nucleating on it. The gas tubicle has grown at a similar rate to the growth of the megacryst, thereby developing hollow pipes in the grain. During eruption the kaersutite was broken up and polished and the pipes were filled by fluids from which anorthoclase and carbonates crystallized.

Acknowledgments

I wish to thank A. Reay, B. R. Watters, and C. Frick for discussions concerning the unusual texture. R. P. Stapleton assisted with the photography.

References

Bence, A. E. and A. L. Albee (1968) Empirical correction factors for the electron micro-analysis of silicates and oxides. *J. Geol., 76,* 382–403.

Blackerly, B. A. (1968) Convolute zoning of plagioclase phenocrysts in Miocene volcanics from the western Santa Monica Mountains, California. *Am. Mineral., 53,* 954–962.

Boyd, F. R. (1971) Pargasite-spinel peridotite xenolith from the Wesselton Mine. *Carnegie Inst. Wash. Year Book., 70,* 138–142.

Cooper, A. F. and J. F. Lovering (1970) Greenschist amphiboles from Haast River, New Zealand. *Contrib. Mineral. Petrol., 27,* 11–24.

Dawson, J. B. and J. V. Smith (1975) Chromite-silicate intergrowths in upper-mantle peridotites. *Phys. Chem. Earth., 9,* 339–350.

Dickey, J. S. (1968a) Eclogite and other inclusions in the mineral breccia member of the Deborah Volcanic Formation at Kakanui, New Zealand. *Am. Mineral., 53,* 1304–1319.

—— (1968b) Observations on the Deborah Volcanic Formation near Kakanui, New Zealand. *N.Z. J. Geol. Geophys., 11,* 1159–1162.

Griffin, W. L. (1971) Genesis of coronas in anorthosites of the Upper Jotun Nappe, Indre Sogn, Norway. *J. Petrol., 12,* 219–243.

Gutmann, J. T. (1974) Tubular voids within labradorite phenocrysts from Sonora, Mexico. *Am. Mineral., 59,* 666–672.

Mason, B. (1966) Pyrope, augite, and hornblende from Kakanui, New Zealand., *N.Z. J. Geol. Geophys., 9,* 474–480.

——— (1968) Eclogite xenoliths from volcanic breccia at Kakanui, New Zealand. *Contrib. Mineral. Petrol., 19,* 316–327.

McBirney, A. R. and K. Aoki (1973) Factors governing the stability of plagioclase at high pressures as shown by spinel-gabbro xenoliths from the Kerguelen Archipelago., *Am. Mineral., 58,* 271–276.

Price, R. C. and R. C. Wallace (1976) The significance of corona textured inclusions from a high pressure fractionated alkalic lava, North Otago, New Zealand. *Lithos, 9,* 319–329.

Ringwood, A. E. and J. F. Lovering (1970) Significance of pyroxene-ilmenite intergrowths among kimberlite xenoliths. *Earth Planet. Sci. Lett., 7,* 371–375.

Ross, M., J. J. Papike and K. W. Shaw (1969) Exsolution textures in amphiboles as indicators of subsolidus thermal histories. *Mineral. Soc. Am. Spec. Pap., 2,* 275–299.

Wallace, R. C. (1975) Mineralogy and petrology of xenoliths in a diatreme from South Westland, New Zealand. *Contrib. Mineral. Petrol., 49,* 191–199.

White, A. J. R., B. W. Chappel and P. Jakes (1972) Coexisting clinopyroxene, garnet, and amphibole from an "eclogite", Kakanui, New Zealand. *Contrib. Mineral. Petrol., 34,* 185–191.

Whitney, P. R. and J. M. McLelland (1973) Origin of coronas in metagabbros of the Adirondack Mountains, N.Y. *Contrib. Mineral Petrol., 39,* 81–98.

Williams, A. F. (1932) *The Genesis of the Diamond.* Ernest Benn, London.

Manuscript received, October 20, 1976; accepted for publication, March 24, 1977.