# CORONITIC TROCTOLITE OF PROBABLE JURASSIC AGE, NORTH CAROLINA PIEDMONT


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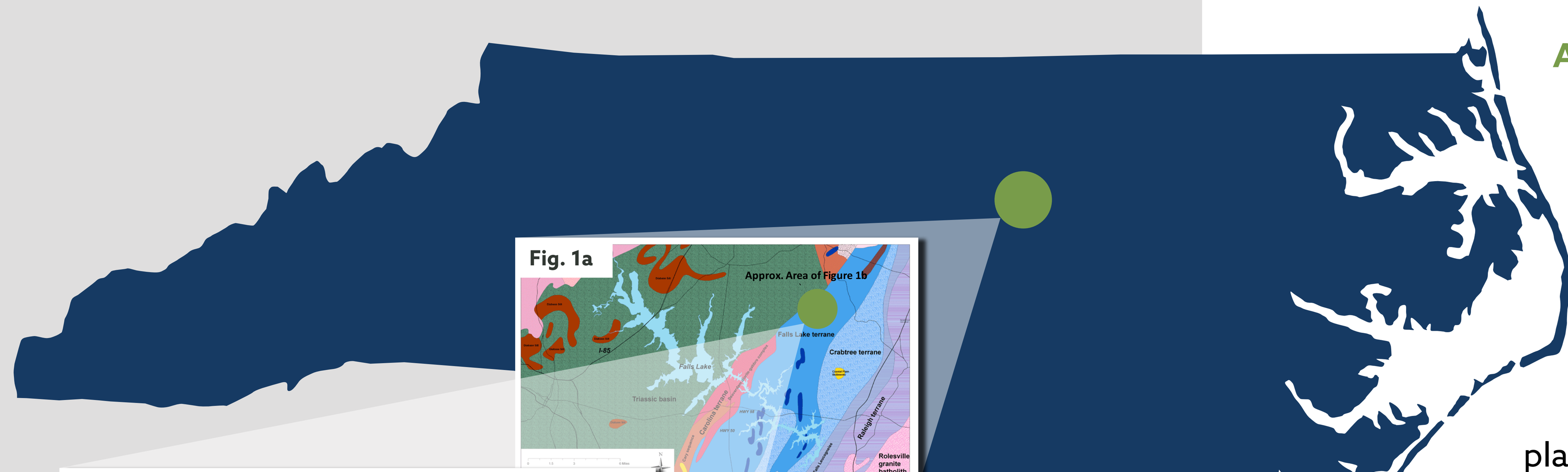


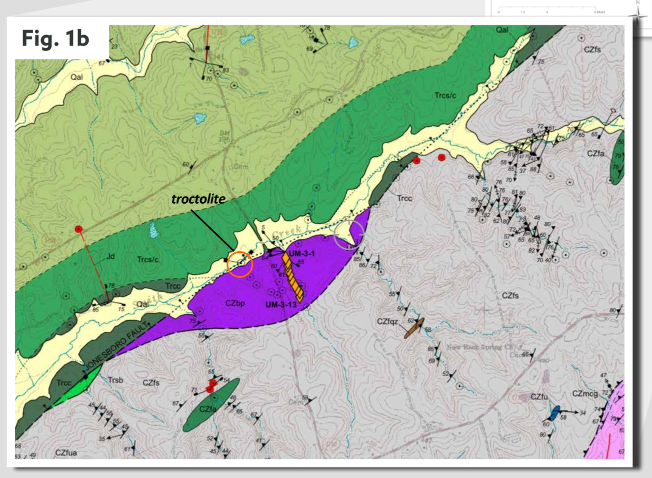




**Figure 1.** Location of troctolite exposure. (a) Regional geologic map of north-central North Carolina (modified from NCGS, 1985). Circle shows approximate location of Figure 1b; (b) Portion of geologic map of the Grissom Quadrangle (Blake and others, 2003), showing location of outcrop along the Jonesboro fault. The author first encountered the outcrop in the late 1970s or early 1980s, in the course of reconnaissance field mapping, while at North Carolina State University.


**Figure 2a.** Troctolite outcrop in Smith Creek.


**Figure 2b.** Close-up view of freshly broken troctolite. End of hammer handle for scale.

## Table 1. Selected Mineral Analyses

| Mineral | Olivine | Olivine | Olivine | Olivine | Spinel | Orthopyroxene | Orthopyroxene | Amphibole |
|---|---|---|---|---|---|---|---|---|
| | B | B | B | A | C1 | A | C2 | C |
| $SiO_2$ | 37.00 | 35.46 | 37.27 | 38.59 | 0.01 | 55.11 | 56.75 | 48.75 |
| $Al_2O_3$ | | | | | 62.37 | 2.89 | 2.01 | 12.40 |
| $TiO_2$ | | | | | | 0.18 | 0.14 | 1.57 |
| FeO | 24.40 | 24.68 | 25.20 | 24.26 | 24.75 | 14.46 | 14.40 | 9.52 |
| MnO | 0.26 | | | | | | | 0.00 |
| MgO | 38.55 | 39.58 | 39.56 | 38.57 | 13.63 | 26.70 | 26.64 | 15.57 |
| CaO | | | | | | 1.51 | 0.87 | 11.14 |
| $Na_2O$ | | | | | | 0.22 | 0.88 | 2.12 |
| $K_2O$ | | | | | | | | 0.30 |
| total | 100.21 | 99.72 | 102.03 | 101.42 | 100.76 | 101.07 | 101.69 | 101.07 |
| # oxy | 4 | 4 | 4 | 4 | 4 | 6 | 6 | 23 |
| Si | 0.973 | 0.942 | 0.964 | 0.995 | 0.000 | 1.953 | 1.994 | 6.707 |
| $Al^{iv}$ | | | | | | 0.047 | 0.006 | 1.293 |
| $Al^{vi}$ | | | | | | 0.074 | 0.077 | 0.718 |
| Ti | | | | | | | 0.004 | 0.162 |
| Fe | 0.537 | 0.548 | 0.545 | 0.523 | 0.547 | 0.429 | 0.423 | 1.095 |
| Mn | 0.006 | | | | | | | |
| Mg | 1.511 | 1.567 | 1.526 | 1.482 | 0.537 | 1.410 | 1.395 | 3.192 |
| Ca | | | | | | 0.057 | 0.033 | 1.642 |
| Na | | | | | | 0.015 | 0.060 | 0.565 |
| K | | | | | | | | 0.053 |
| total | 3.027 | 3.058 | 3.036 | 3.000 | 1.084 | 3.985 | 3.992 | 15.427 |
| Mg/(Mg+Fe) | 0.738 | 0.741 | 0.737 | 0.739 | 0.495 | 0.767 | 0.767 | 0.745 |
| Ca/(Ca+Na) | | | | | | | | 0.744 |


## Abstract

An unusual spinel-bearing troctolite occurs in a single outcrop located along Smith Creek in southern Granville County, North Carolina. It lies on the trace of the Jonesboro fault, a major west-dipping normal fault that constitutes the eastern border of the Durham sub-basin of the Deep River Triassic basin in this area.

Petrographic examination shows that phenocrysts of olivine to 0.5 cm in diameter are surrounded by calcic plagioclase in a likely cumulate texture. Mineral analyses and imaging (done at the SENC-MIC, located at Fayetteville State University) reveal discontinuous corona reaction zones between the olivine and plagioclase. These zones consist of varying proportions of orthopyroxene, pargasitic amphibole, and possible sparse clinopyroxene, as well as green Al-spinel, which occurs in symplectic intergrowth.

Although the rock has not been dated, it may represent a cumulate fraction related to the Jurassic-age olivine diabase dikes common in the area. The mineral content and chemistry, the implied bulk composition, and the lack of greenschist to amphibolite facies metamorphic overprint all provide evidence for this conclusion. The reactions likely occurred at near-solidus conditions.


### Southern Appalachian diabase

Jurassic diabase (CAMP) dikes in the southern Appalachians have been the subjects of geological investigations for years. Many of these studies have focused on whole-rock geochemistry (see Ragland, 1991, for summary and references). However, mineralogy and mineral chemistry have been investigated in detail in some studies (e.g. Warner and others, 1985, 1986, 1992; Clark and others, 2014).

Studies of diabase petrography in North Carolina's Deep River basin have described some occurrences of olivine-rich varieties of diabase (e.g. Justus, 1966; Chalcraft, 1972). These varieties are sometimes referred to as picritic (Hermes, 1964); some examples are reported to contain more than 45% olivine. There are also reports of cumulate (or "cumulate-like") textures, with olivine being the typical cumulus phase (Justus, 1966; Froelich and Gottfried, 1985).

Perhaps significantly, the Freetown layered igneous complex, of Sierra Leone, is a tholeiitic Mesozoic pluton containing troctolite zones and cumulate textures (Barrie and others, 2010); these authors believe it is related to the CAMP association.

### Reaction textures in gabbroic and metagabbroic rocks

Corona reaction structures between olivine and plagioclase have been reported worldwide from a variety of geological settings and have been interpreted variously as the products of late-stage igneous or high-grade metamorphic processes (e.g. Mason, 1967; Joesten, 1986a, b; Ashworth, 1986; Turner and Stuwe, 1992; Whitney and McLelland, 1973; Gallien and others, 2012; see also Deer and others, 1982, p. 267-277). Olivine – plagioclase reactions commonly have reaction products that are some combination of garnet, clinopyroxene, orthopyroxene, amphibole, and spinel.

Metatroctolites having spinel-bearing symplectites have also been described from the Buck Creek ultramafic body in the North Carolina Blue Ridge (Tenthorey and others (1996); Lang and others (2004)). Gabbroic rocks from the Lake Chatuge metaigneous complex possess reaction textures that include coronas and locally carry spinel (Meen, 1988). Gabbros (ca. 400-Ma) of the North Carolina Piedmont exhibit cumulate textures and local symplectite textures adjacent to olivine (McSween and others, 1984; Olsen and others, 1983). Green spinel (though not from a symplectite) is reported from the Concord gabbro (Olsen and others, 1983).

### Mineralogy and mineral chemistry (Table 1)

Olivine analyzed in the Smith Creek troctolite is Fo74; plagioclase was not analyzed but, based on optical properties, appears to be in the range An70-75. These compositions are within the ranges reported by Warner and others (1985, 1986, 1992) and by Clark and others (2014).

Amphibole appears to be a magmatic late-crystallizing intercumulus phase in some cases (e.g. Figure 5, Figure 8) and a product of a corona-forming reaction in others (e.g. Figure 6, Figure 7b). The single analysis, of the grain in Figure 5, is a pargasite (Leake and others, 1997). Such a composition may be found in a wide range of igneous and metamorphic rock types (see, for example, Veblen and Ribbe, 1982), but apparently has not been reported from Jurassic diabase or related rocks. At relatively high pressure amphibole may be produced by liquidus reaction between olivine and plagioclase, as noted by Morse (1980, p. 389).

Orthopyroxene analyzed from the reaction coronas is a slightly Al-enriched bronzite. Its composition is similar to some of those reported by Deer and others (1978) from several mafic to intermediate igneous rocks. Low-Ca pyroxenes from southern Appalachian diabase is typically pigeonite (e.g. Warner and others, 1985, 1986; Reising and Stoddard, 2006; Stoddard, unpublished data). However, Warner and others (1992) makes reference to two South Carolina dikes they studied that contain bronzitic orthopyroxene.

Spinel analyzed from the reaction coronas is a translucent green Al-spinel with a composition close to $Fe_{0.5}Mg_{0.5}Al_2O_4$. It has more chemical similarity to some reported high-grade metamorphic spinels (e.g. Meen, 1988; Tenthorey and others, 1996; Lang and others, 2004; Graybeal and others, 2012) than to those reported from mafic igneous rocks. Spinel-group minerals reported from Mesozoic diabase and related rocks are dominated by magnetite and/or chromite endmembers. Olsen and others (1983) report an analysis of Al-spinel ("pleonaste") from the Concord gabbro.

Examples of symplectic intergrowths of green (Al-) spinel with orthopyroxene or amphibole from Argentina were reported by Gallien and others (2012), and inferred to be products of olivine – plagioclase reaction at high metamorphic grade ("gabbro-granulite transition"). These rocks may bear the greatest similarity to the Smith Creek troctolite, except for the fact that clinopyroxene is a major phase in the Argentine rocks.

### Possible origin and significance

The Smith Creek troctolite lies along a major west-dipping normal fault that forms the eastern border of the northern part of the Durham sub-basin of the Deep River Triassic basin. Adjacent footwall rocks are Neoproterozoic rocks of the Carolina and Falls Lake terranes that have been metamorphosed to upper greenschist and lower amphibolite facies. Original olivine and pyroxene in these rocks have been completely replaced by metamorphic talc, serpentine, and green actinolite and hornblende. Because of the lack of an obvious regional metamorphic overprint on the minerals of the troctolite, and the preservation of the original igneous cumulate texture, the age of the troctolite must be younger than the metamorphic country rocks. Furthermore, because of the similarity of the olivine and plagioclase to those reported from Jurassic olivine diabase, it is probable that the Smith Creek troctolite is also Jurassic in age and closely related to the diabase.

The troctolite may represent a pod of cumulate material crystallized from tholeiitic magma, and from which residual magma intruded to form nearby diabase dikes and sills. At least some of the mineral reactions must have occurred at liquidus conditions (e.g. formation of intercumulus amphibole).

The corona-forming reactions may have occurred at depth, or perhaps as a result of ascent (intrusive and/or tectonic) at least part of which was along the Jonesboro fault.

This very general hypothesis is broadly consistent with the model presented by Froelich and Gottfried (1985; their Figure 15.3). Their model also explains the observation that, in this portion of the Deep River basin, steeply dipping dikes dominate in the eastern portion of the basin, while sill-like bodies dominate in the west (Koch, 1967).

## Photomicrographs and X-ray Maps

*Note that for Figures 3 - 8a, the left-hand image was taken under plane-polarized light, and the corresponding right-hand image under cross-polarized light.*

**Figure 3.** Photomicrograph of olivine diabase from nearby exposure. Note the abundant augite, which is not present in the troctolite. The olivine in this rock is unusually abundant and the crystals unusually euhedral compared to typical diabase in the area. Sample 15-SC-12.

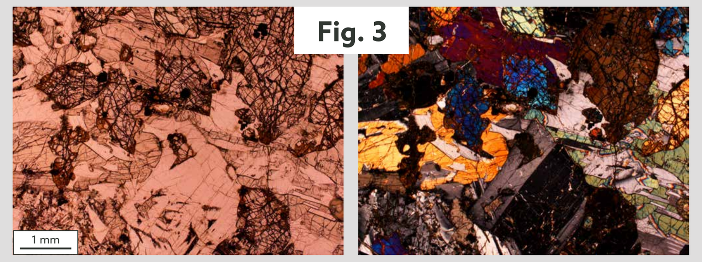



**Figure 4.** Photomicrographs showing examples of cumulate textures in Smith Creek troctolite. Note that some of the sections are thick. (a) Cumulus olivine with intercumulus plagioclase, 82-GR-2; (b) Another view of cumulus olivine with intercumulus plagioclase, GR-2 (probe); (c) Cumulus olivine with intercumulus amphibole, 15-SC-9.

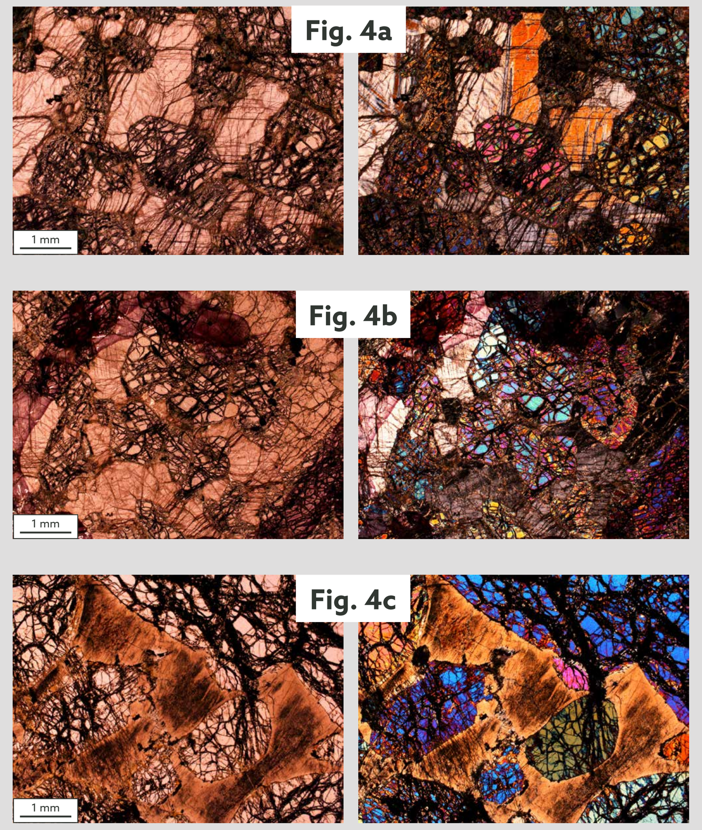



**Figure 5.** Cumulus olivine, with altered intercumulus plagioclase and intercumulus amphibole. Partial reaction coronas between olivine and plagioclase are dominated by orthopyroxene. Sample 15-SC-1.


**Figure 6.** Several views of microprobe section GR-1 showing reaction zones between olivine and plagioclase. View 1: (a) Low-power objective; (b) Detail of (a) showing symplectic Al-spinel. View 2: (a) Low-power objective; (b) Detail of portion of (a); (c) Detail of different portion of (a).

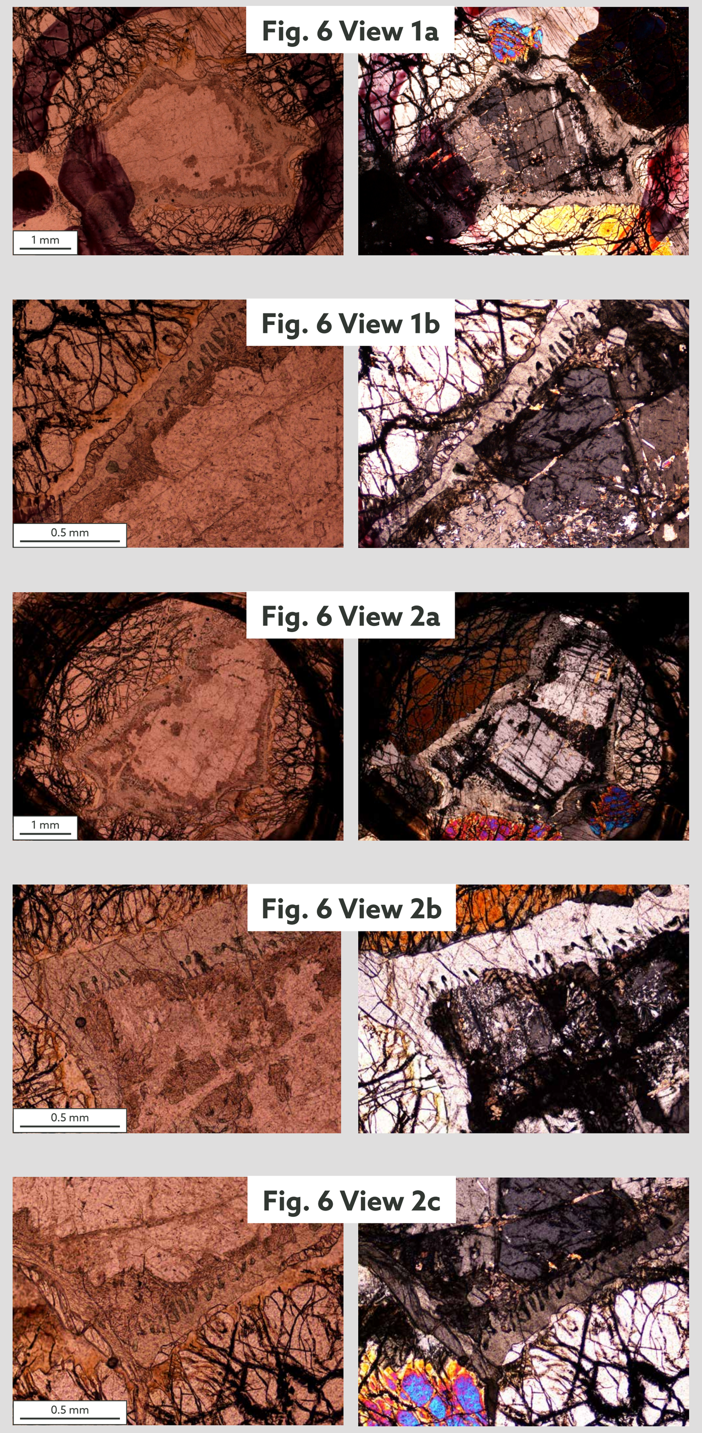



**Figure 7.** Corona reaction zones between cumulus olivine and (partially altered) intercumulus plagioclase, sample 82-GR-1. (a) Low-power objective; (b) Detail of (a).

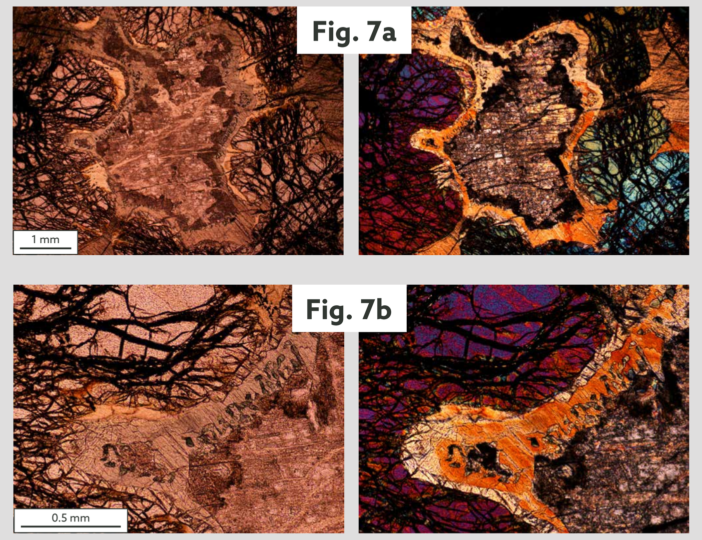



**Figure 8.** Intercumulus amphibole in microprobe section GR-1. (a) photomicrograph; (b) Backscattered electron image and selected elemental X-ray maps for area of (a).

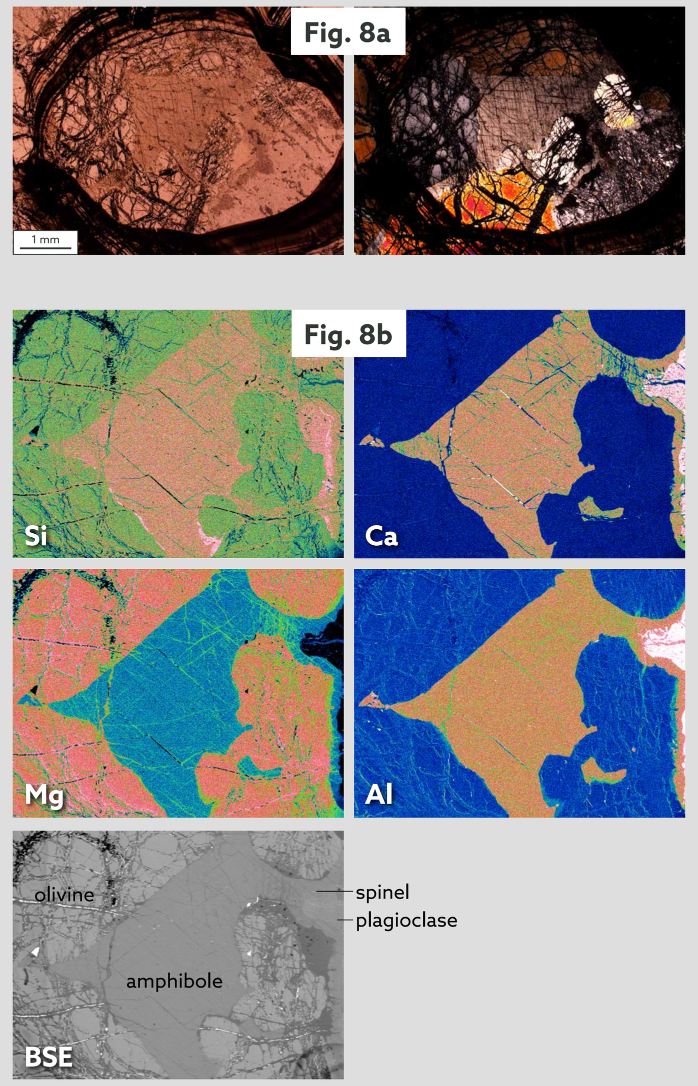
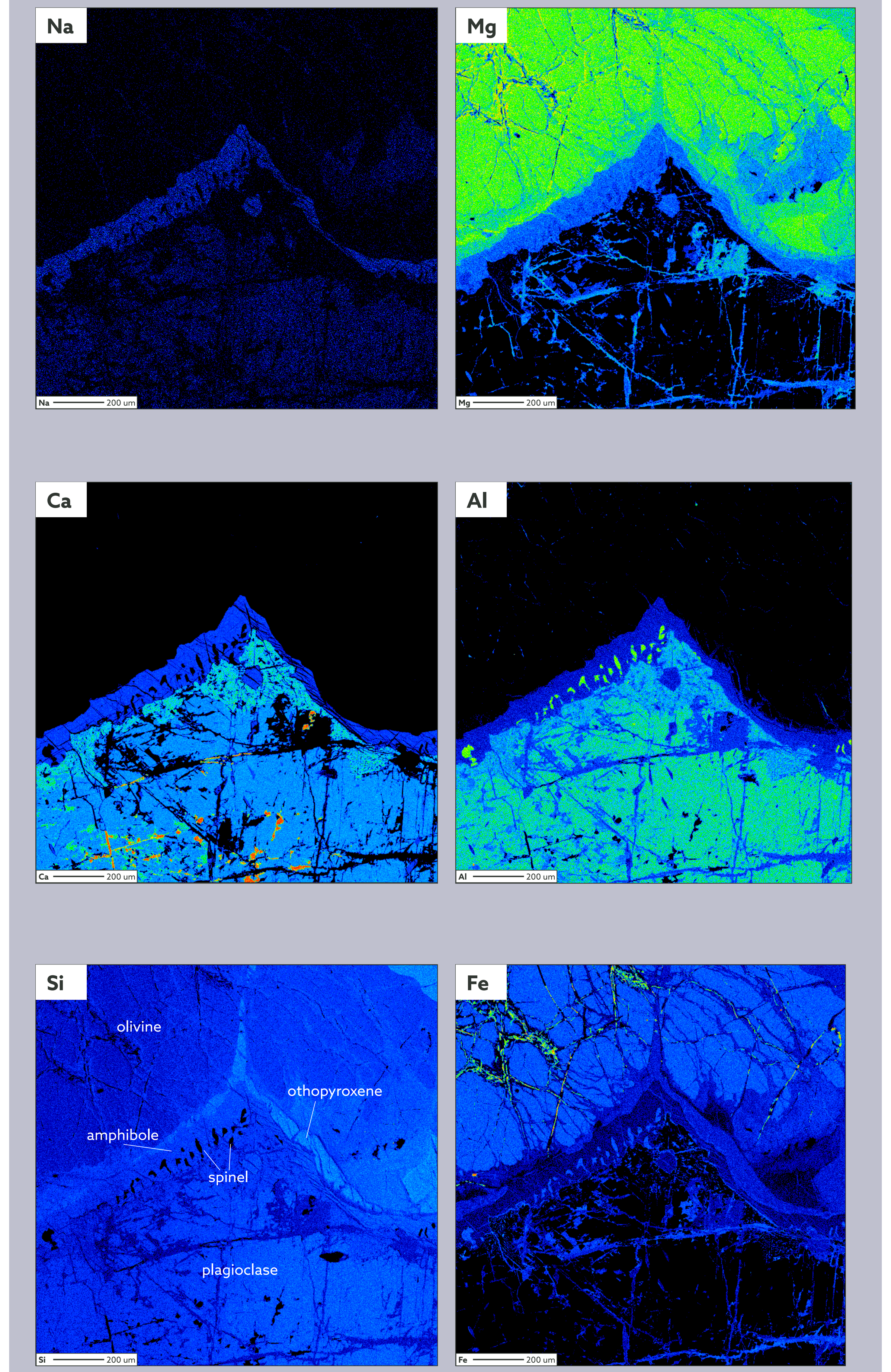



**Figure 9.** Selected elemental X-ray maps for coronitic reaction zone between olivine and plagioclase in section GR-1. Area is approximately the same as in photomicrograph of Figure 6, View 2b.





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