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CORONAS IN OLIVINE GABBROS FROM THE NIQUELÂNDIA MAFIC-ULTRAMAFIC COMPLEX, GOIÁS, BRAZIL

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Introduction

Corona textures are commonly described in mafic and ultramafic rocks of amphibolitic and granulitic terrains. The corona represents the sub-solidus reequilibrium between unstable igneous phases and may comprise essentially anhydrous phases or involve hydrous phases (Griffin & Heier, 1969; Griffin, 1971; Whitney & McLelland, 1973). The present paper describes the different types of coronas occurring in olivine gabbros from the Niquelândia complex, where anhydrous and hydrous coronas are found, and analyses the possible corona-forming reaction sequences.

Geological setting and petrography - The Niquelândia complex is a mafic-ultramafic body of presumably Archaean or Proterozoic age, occurring within metamorphic terrains in central Goiás, Brazil. According to Girardi et al. (1986), the layered complex is composed of a Lower Sequence, subdivided into a Basal Gabbro zone, a Basal Peridotite zone, a Layered Ultramafic zone and a Layered Gabbro zone, and by an Upper Sequence that includes an Upper Gabbro zone and an Upper Amphibolite zone.

The coronas treated in this study developed in olivine gabbros of the Upper Sequence of the complex. These rocks display relict cumulitic textures; cumulus minerals are olivine, plagioclase, clinopyroxene and ilmenite.

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Coronas

The olivine-plagioclase sub-solidus reequilibria resulted in three main types of corona assemblages:

Type (1): ol (opx + $(cpx + sp)_{sympl}$) - plag

Type (2): ol (opx + $(parg + sp)_{sympl}$) - plag

Type (3): ol (opx + hbl + gar) - plag

Abbreviations are as follows: ol=olivine; opx=orthopyroxene; cpx=clinopyroxene; parg=pargasite; hbl=hornblende; sp=spinel; gar=garnet; plag=plagioclase; qz=quartz.

The first corona type is the least frequent and is made up of two shells: the inner one, in contact with olivine, is formed by radially arranged prismatic aggregates of orthopyroxene, and the outer shell, by a symplectite of clinopyroxene and numerous fine vermicules of green spinel, which are arranged radially outwards towards plagioclase in subconcentric sets. This corona is similar to those described by Griffin & Heier (1969, 1973) and Whitney & McLelland (1973).

The second corona type shows an inner shell, around olivine, formed by orthopyroxene, and an outer shell of symplectitic pale green pargasite and green spinel. Small grains of clinopyroxene sporadically occur in symplectite. A stringer of small green spinel grains may be observed between the orthopyroxene shell and the symplectite. When olivine is exhausted, the inner part of the corona is composed of a granular aggregate of orthopyroxenes rimmed by the prismatic orthopyroxenes of the first shell. Similar coronas are reported by Lamoen (1979) and Mongkoltip & Asworth (1983).

The third corona type, comparable with those described by Griffin (1971), shows an inner shell of prismatic orthopyroxene, an intermediate shell of dark-green hornblende and an outer shell of garnet. Some coronas show a stringer of garnet between prismatic orthopyroxene and hornblende, occupying the position which corresponds to the spinel stringer of the second corona type. Intermediate stages between the first and second types, as well as between the second and

third types, may be observed. The latter transition is most frequently observed where, along with hornblende and garnet, the pargasite-spinel symplectite locally occurs.

In all these corona types, plagioclase is generally clouded by minute inclusions of green spinel and minor clinopyroxene grains; a narrow zone of granoblastic clear plagioclase occurs near the corona boundary.

Mineral chemistry

Analysis of mineral phases of the various types of coronas were carried out with an ARL electron microprobe (Modena University, Italy). Analytical data is available from the authors on request.

Olivine - The olivine composition varies from Fo 67 to Fo 75. No zoning has been found. Pyroxenes - The pyroxenes formed in the three coronas have a Mg/Fe ratio that is always dependent on the associated olivine composition (Fig. 1). In orthopyroxenes, this ratio varies from 0.73 to 0.78, whereas in clinopyroxenes from 0.80 to 0.87. The Al_2O_3 content of the orthopyroxenes varies in the three corona types: the highest values being those of the first corona type (up to 4.9 wt%) and the lowest, those of the third one (up to 2.2 wt%). Spinel - Only a few microprobe analysis were obtained due to the very small grain size of the vermicular spinel. They are essentially aluminous, Cr-free, and show lower Mg/Fe ratio with respect to olivine (Fig. 1). Amphibole - In type II coronas the amphiboles are pargasites (nomenclature according to Leake, 1978), with $(Na + K)_A$ about 1 and Al^{IV} about 2. In the third corona type, amphiboles tend to Mg-horblende with concomitant decrease in $(Na + K)_A$ and Al^{IV}. Pargasites, coexisting with spinel, show a lower Mg/Fe ratio than the hornblendes coexisting with garnet (Fig. 1). Primary amphiboles eventually present in some gabbros are ferroan pargasites with high Ti content. Garnet - Garnets show the lowest Mg/Fe ratio of the femic phases (Fig. 1); this value depends on the Mg/Fe ratio of the femic reacting minerals. Garnet compositions vary between 33-38% pyrope, 38-41% almandine, 22-28% grossular (in mol %). In the coronas, where two shells of garnets occur, the one near plagioclase is relatively enriched in Ca with respect

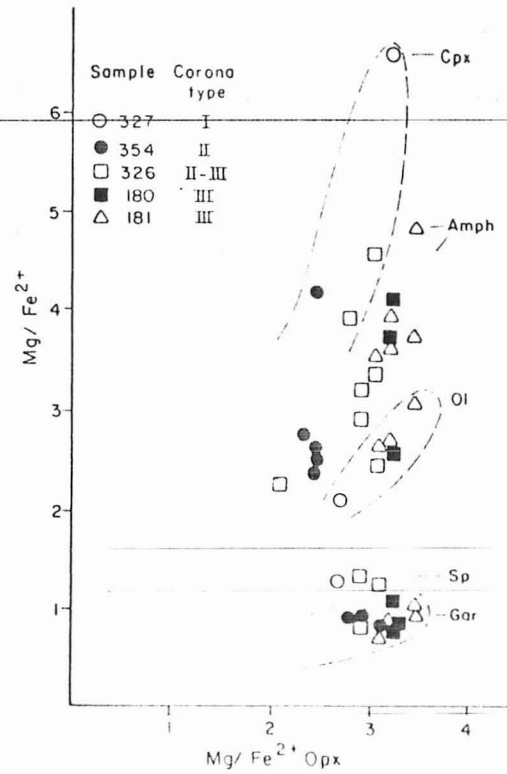

Figure 1 -- Mg/Fe ratio plot of various femic phases vs. orthopyroxene.

to the inner shell (see also Griffin, 1971). Plagioclase - Primary plagioclase is strongly zoned. The An content of crystal cores varies commonly between An_{65} to An_{71}. The original zoning, preserved in some crystals, shows a decrease in An content towards the rim. The An content of recrystallized plagioclase generally varies from An_{52} to An_{66}.

Corona forming reactions

The discussion concerning the possible corona forming reactions is made in a qualitative way, assuming a closed system, except for the fluid phase. A more extensive analysis of the system, and a quantitative treatment of the reactions is described in Candia et al. (in press).

The development of type I coronas can be represented by the reaction:

(1) 2 ol + 1 an = 1 opx + 1 cpx + (1-x) sp

This reaction is similar to that of Kushiro & Yoder (1966) and Green & Ringwood (1967). In reaction (1) only anorthite is considered; the Ab molecule present in the reacting feldspar (assumed about An_{60}) can enter in the clinopyroxene as Jadeite molecule (Na_2O in cpx about 0.87 wt%). The enrichment

in Tschermakitic molecule in pyroxene (Al_2O_3 up to 4.9 wt%) justifies the (1-x) coefficient in spinel, according to Kushiro & Yoder (1966).

The occurrence of relict grains of Al-rich clinopyroxene (comparable with that of type I coronas) and the formation of pargasite-spinel phases, suggest that type II coronas are formed from the first ones by supply of H_2O into the system. The lower Al content in orthopyroxene of type II coronas with respect to the first one is related to the formation of pargasite and additional spinel, the last occurring as stringers between the orthopyroxene shell and the symplectite. The pargasite development requires Ab- component as a reagent, therefore it is reasonable to assume that the plagioclase does not change notably its composition during the development of this corona (Na:Ca ratio in pargasite is about 1:2, similar to the ratio in plagioclase - An_{60}, see also Candia, 1983). The following coupled reactions could explain the type II corona formation:

(1) 2 ol + 1 an = 1 opx + 1 cpx + 1 sp

(2) 1.5 opx + 1 cpx + 1 an + 1 ab + 1 H_2O = 1 parg + 4 qz

(3) 4 ol + 4 qz = 4 opx

The sum of these reactions gives:

(4) 6 ol + 2 an + 1 ab + 1 H_2O = 3.5 opx + 1 parg + 1 sp

Reaction (4) could explain the formation of type II coronas directly from olivine-plagioclase reaction, or through type I coronas.

The development of type III coronas led to the disappearance of spinel whilst forming garnet, and the amphibole tending to a Mg-hornblende, that corresponds to an increase in the tremolitic molecule of the pargasite. The partial symplified reactions that could explain this corona type area:

(5) 1 an + 1 sp + 2 opx = 2 gar

(6) 4 an + 7.5 opx + 1 H_2O = 1 tremolite + 4 gar + 3 qz

Reaction (5) forms garnet in the stringers, and reaction (6) is responsible for the garnet-amphibole formation in the outer shell. The tremolite formed in reaction (6) displaces the composition of amphibole from pargasite to Mg-hornblende. In reactions (5) and (6) anorthitic plagioclase is consumed,

therefore, the recrystallized plagioclase must be more sodic than the reagent. Silica liberated from reaction (6) reacts with olivine giving orthopyroxene according to reaction (3). Adding reactions (5), (6) and (3), follows that:

(7) 5 an + 3 ol + 6.5 opx + 1 sp + 1 H_2O = 6 gar + 1 tremolite

The reaction sequence reproduces satisfactorily the mineralogical and textural changes observed from type I anhydrous coronas to type III, with anhydrous and hydrous phase coronas. The transformation from the first to the third type could be produced by an increase of P_{H_2O} in the fluid phase.

P-T conditions - An estimate of T was obtained through the Graham & Powell (1984) geothermometer in hbl-gar associations present in amphibolitic rocks which occur interlayered with the olivine gabbros in the Upper Sequence of the complex. The temperatures obtained in the most recrystallized, granoblastic amphibolite rocks varied between 557 ℃ and 629 ℃. Pressure estimate, of about 5-6 Kbar, was obtained applying Newton & Perkins (1982) geobarometer in cpx-plag-gar-qz assemblage, present in gabbroic recrystallized rocks from the Upper Sequence of the complex.

Conclusions

The occurrence of the three corona types practically associated implies that diffusion between original domains was incomplete during the re-equilibria reactions, at the moment they were submitted to the same P-T conditions. In this case, each corona develops in presence of a fluid phase with different P_{H_2O} content: the pyroxene-spinel assemblage forms under pratically anhydrous conditions, whereas the orthopyroxene-Mg-hornblende-garnet develops under higher P_{H_2O} in the fluid phase. Assuming that P-T values obtained in granoblastic amphibolite represent the H_2O saturated equilibrium conditions, all the coronitic assemblages could be related to the same sub-solidus event. The possibility of a deuteric origin for the coronas cannot be proven or disproven (Danni et al., 1982; Girardi et al., 1986), however there is a clear evidence of extensive growth of garnet-hornblende in the coronas, in amphibolite rocks and also in gabbroic rocks, certainly of sub-solidus origin and more compatible with a high

grade (amphibolite) metamorphism.

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HYDROTHERMAL ALTERATION OF VOLCANIC ROCKS ASSOCIATED WITH THE FORMATION OF AMETHYSTS-SOUTHERN PARANÁ BASIN, BRAZIL

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