CHEMICAL CHARACTERISTICS OF METAMORPHIC MINERALS IN LOWER CRETACEOUS BASIC FLOWS FROM THE COAST RANGE, CENTRAL CHILE.

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INTRODUCTION

The Lower Cretaceous Ocoite Group (Aguirre *et al.* 1989) with a thickness of 3-13 km constitutes a *c.* 1000 km long belt of volcanic rocks in the Coast Range of central Chile. Predominant rock types are basic lava flows characterized by high K content which classify as high-K calcalkaline basalts and basaltic andesites with shoshonitic affinity (Levi *et al.*, 1982, 1988; Vergara *et al.*, 1995). They present porphyritic textures with abundant phenocrysts of plagioclase and minor clinopyroxene. Very low to low-grade burial metamorphism affects them with development of quartz,albite,K-feldspar, prehnite, pumpellyite, epidote, actinolite, white mica, chlorite, calcite and zeolites present as pseudomorphs of primary minerals, as groundmass replacement and filling amygdales. Metamorphism increases in grade with stratigraphic depth in the rock pile from zeolite facies at the top to greenschist facies at the base (Levi, 1969;Levi *et al.* 1982).

Here we study the chemical composition of some of the secondary minerals present in the basic lavas of the Ocoite Group from the Bustamante Hill area located *c.* 35 km west of Santiago. In this area the Cretaceous lavas are well exposed with the presence of unaltered levels in which the primary mineralogy and the chemistry are preserved. The aim of this work is to show the chemical variations of some of the secondary minerals, both at a macro and microdomains.

MINERAL CHEMISTRY

In order to avoid the influence of microdomain chemistry in the composition of the metamorphic phases, the study was largely restricted to minerals filling amygdales among which K-feldspar, chlorite, epidote and pumpellyite are the most representative phases. Minor prehnite, albite and quartz appear in some lavas. Most commonly,primary plagioclase phenocrysts are partially or totally replaced by albite, epidote and white mica, with some relict primary patches of composition between $An_{56}Ab_{40}Or_4$ to $An_{70}Ab_{28}Or_2$ (figure 1a).

Chemical analyses were performed in a CAMECA-CAMEBAX microprobe (20kV, 10nA, 10μ) at the University of Granada, Spain.

K-feldspar

K feldspar (Or_{67} to Or_{98} with An ≤ 4) appears as patches replacing primary plagioclase phenocrysts as well as filling amygdales (figures 1a and 1b). K-feldspar replacing primary plagioclase phenocrysts are characterized by a BaO content ranging from 0.30 to 0.56% (figure 1b). On the other hand secondary feldspar in amygdales is mainly adularia ($Or_{97}Ab_3$) with BaO contents up to more than 2.5% (figure 1b) and varying in composition from core to rim in a same crystal.

Pumpellyite

Pumpellyite in amygdales presents strong chemical variations in terms of Fe_2O_3 and Al_2O_3 (figure 2) with XFe^{3+} values (= $100Fe^{3+}/(Fe^{3+} + Al_t)$) ranging from 12 to 33% and increasing from the top levels to the bottom, a tendency already pointed out by Levi *et al.*(1982). We have studied pumpellyite chemical variations at the scale of a single crystal in different amygdales finding that a similar variation, characterized by increasing Fe_2O_3 and decreasing Al_2O_3 from core to rim, exists in these crystals. This chemical variation is strong and accounts for high point spreading in the Al-Fe-Mg diagram where compositions in a same crystal plot in different reference fields (which could be interpretated as generated at different metamorphic facies!).

Chlorite

Chlorite also presents remarkable compositional variations from top to bottom of the Ocoite Group. The general trend is characterized by an increase in chlorite molecular component (%*Xc*) from top to bottom (figure 3) accompanied by the increase of the temperature value obtained from the Cathelineau geothermometer (Cathelineau & Nieva, 1985). At the level of one amygdale, an increase in chlorite component, and consequently of the temperature of formation, exists from rim to core

Epidote

Epidote compositional variations in amygdales are very similar from top to bottom in the pile, with no particular trends being observed. Largest variations of the XFe^{3+} observed cover the interval 22 to 37%.

DISCUSSION

The presence of secondary minerals rich in K and Ba (adularia and white mica) replacing primary plagioclase phenocrysts and filling amygdales can be interpreted as being conditioned by a primary high K whole rock composition or as produced by K and Ba being introduced to the system during burial metamorphism. In this respect, it is worth noting that in the Mesozoic magmatism of central Chile, only those rocks with a shoshonitic affinity include adularia in the secondary assemblages. The K_2O contents in whole rock analyses of unaltered aphanitic samples from the studied region range from 1.18% (in basalts) to 3.90%(in andesites) (Vergara *et al.*, 1995). Considering the maximum K_2O content found in primary Ca-rich plagioclase (*c.* 0.6%) and taking 30% as the modal percentage of plagioclase phenocrysts in the rocks, the K_2O content of the groundmass can be calculated applying simple mass balance. Thus, the K_2O contents could vary from *c.* 1.0% in basalts to *c.* 3.7% in andesites. These contents of primary K could account for the presence of secondary adularia in patches of primary plagioclase phenocrysts due to internal remobilization of K. More chemical work is needed to determine if the K available in the system suffices to explain the presence of abundant adularia in amygdales. Concerning Ba, calculations are more complex due to the fact that only some phenocrysts are partially replaced by adularia and, in these cases, the BaO content of this adularia is very minor.

The compositional variations from top to bottom found in pumpellyites, with an increase of the XFe^{3+} contents, could be related to the metamorphic gradients (Levi *et al.*, 1982). Moreover, the strong compositional variations observed in a same amygdale, with increase in Fe_2O_3 from core to rim, must be interpreted as due to local variations in fO_2 in thermodynamic conditions of disequilibrium. These dramatic variations in the pumpellyite chemistry are a major limitation in using the composition of this mineral for qualitative estimations of the metamorphic grade. Variations in the XFe^{3+} in single crystals of epidote and pumpellyite from a particular amygdale are also taken as a consequence of disequilibrium conditions, at least at the amygdale scale.

Chemical variations observed in chlorites agree with the general metamorphic pattern determined by Levi *et al.* (1982), with an increase in the chlorite component from top to bottom. Variations into a single amygdale also agree with the general trend characterized by a rising chlorite component from rim to core. For the lower levels of the volcanic pile studied, the calculated temperatures coincide with the temperatures usually assigned to the prehnite-pumpellyite to greenschist facies.

CONCLUSIONS

Two main conclusions can be drawn based on the chemical variations described. These variations largely fit in the regional metamorphic pattern already established by Levi *et al.* (1982). However, the compositional trends found for some index minerals, *i.e.* chlorite and notably pumpellyite, reflect highly heterogeneous conditions during this burial metamorphism, at least at the scale of a same lava flow. This heterogeneity can result from severe variations in fO_2 from top to bottom in a same lava flow during the formation of the pumpellyites and the mafic phyllosilicates. Thus, conclusions concerning metamorphic grade based on the compositional reference fields of the Fe-Al-Mg diagram should be critically assesed.

Concerning the presence of abundant Ba-rich adularia in amygdales, further detailed work must be carried out to clarify its origin, either primary or metasomatic.

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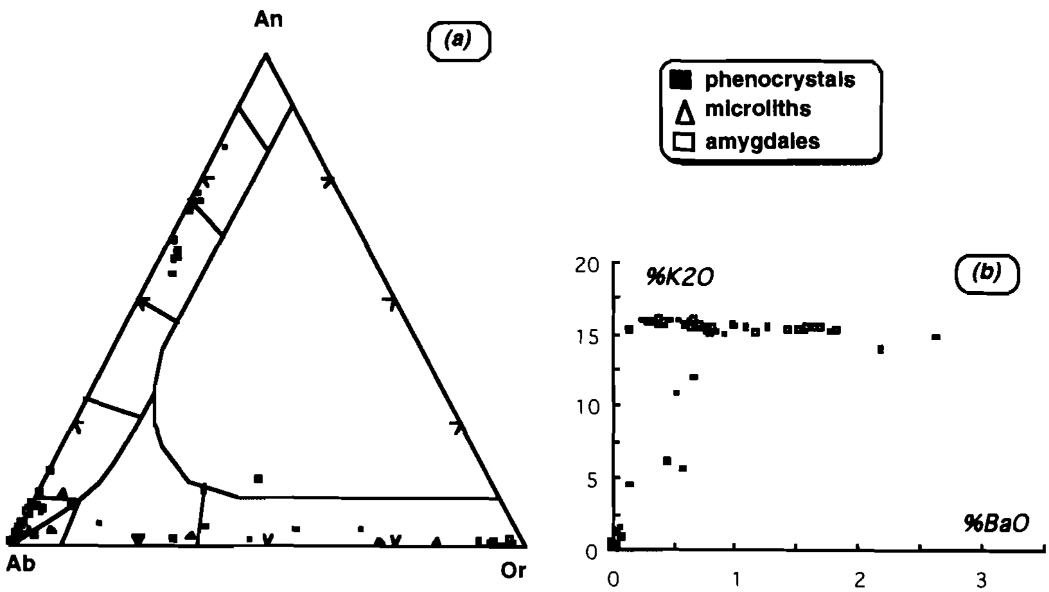

Figure 1.- Feldspar compostional variations in Cretaceous lavas from the Coast Range, Central Chile.

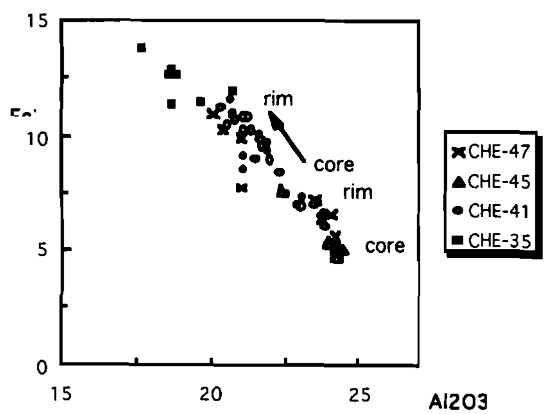

Figure 2.- Al_2O_3 vs Fe_2O_3 in pumpellyites from amygdales. Samples in legend are stratigraphically ordered from top (sample CHE-47) to bottom (CHE-35).

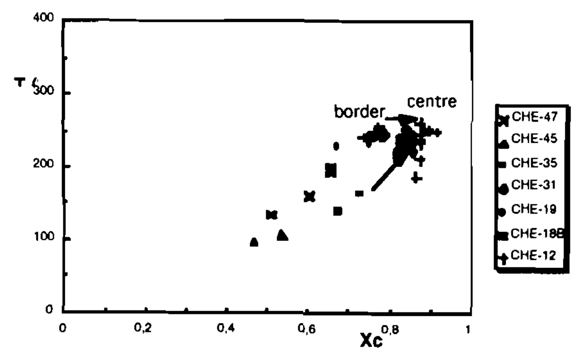

Figure 3.- %Xc vs T (° C) in chlorites from amygdales. Samples in legend are stratigraphically ordered from top (sample CHE-47) to bottom (CHE-12).