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# LOW-GRADE METAMORPHISM IN MESOZOIC-CENOZOIC VOLCANIC ROCKS FROM PATAGONIA BETWEEN LATITUDES 43° AND 46°S.

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## INTRODUCTION

Preliminary results from a petrological reconnaissance survey in the Chilean Patagonia between approximate latitudes 43° and 46° S (Futaleufu to Lago Elizalde) are reported. The survey, centered on volcano-sedimentary units with assigned ages in the interval Jurassic - Neogene, aimed at establishing the presence of very low to low-grade metamorphic phenomena affecting these rocks.

The samples studied (*c*.60) were divided in four age groups: **Group (1)** = volcanic rocks of Jurassic age ($J_2$)[1] comprising the Futaleufú Group and the Ibáñez Formation; **Group (2)** = Cretaceous volcanic rocks ( $K_{i1}$ and K)[1] mainly representing the Divisadero Formation; **Group (3)** Estratos de La Junta of supposed Paleogene age[2] which crop out near the village of La Junta and; **Group (4)** = Neogene lava flows exposed immediately south of Puyuhuapi, near the village of Coyhaique Alto (Morro Negro) and at roadcuts 12 km north of Balmaceda.

## LITHOLOGY

Rocks from Group (1) correspond to: (a) fine to medium-grained amygdaloidal basalts with relict quenching textures; (b) amygdaloidal, porphyritic, andesite flows; (c) porphyritic dacite flows with albitized plagioclase and altered amphibole phenocrysts in a felsitic(quartz,plagioclase,iron oxide) groundmass and: (d) dacitic ignimbrites with chloritized «*fiamme*».

Group (2) comprises: (a) amygdaloidal olivine basalts with partially albitized phenocrysts of plagioclase and olivine ghosts in a fine-grained groundmass of plagioclase microliths, clinopyroxene (augite) and iron oxides, and (b) porphyritic, partly amygdaloidal, andesite flows and flow-breccias with plagioclase phenocrysts in an intersertal groundmass of plagioclase and iron oxides.

Rocks analysed from Group (3) are : (a) poorly amygdaloidal basaltic andesites with plagioclase and clinopyroxene phenocrysts; (b) porphyritic andesite flows with plagioclase phenocrysts, and (c) lapilli tuffs containing numerous diabasic-clasts.

Group (4) is represented by porphyritic,highly amygdaloidal, olivine basalts with plagioclase and fresh olivine phenocrysts in a hyalopilitic groundmass.

## METAMORPHIC ASSOCIATIONS, MINERALS AND FACIES.

All the samples studied have been affected by very low-grade to low-grade metamorphism as shown by the presence of secondary mineral assemblages representative of the zeolite, prehnite-pumpellyite and greenschist facies.

Zeolite facies assemblages characterize the metamorphism of the lavas of Group 4 (Fig.1). They are found filling amygdales and consist of various types of zeolites and minor amounts of chalcedony and calcite. Smectite is abundant in the groundmass as a product of glass alteration. The zeolites correspond to the Ca-Na and Ca-K-Na varieties; in this last type either Ca or K can be the predominant cation.

Prehnite-pumpellyite facies associations are well represented in rocks of Group 2 (Fig.1) with prehnite, pumpellyite and epidote as amygdale infilling or as replacement of primary plagioclase phenocrysts. The composition of pumpellyites, with $Fe_2O_3t > 10\%$ and $XFe^{3+}$ in the interval 18.3 - 33.4, is typical of Fe-pumpellyites of sub-greenschist facies and plots in the prehnite-pumpellyite reference field of Jonestown[3,4] (Fig.2). $Fe^{3+}$ partitioning between pumpellyite, prehnite and epidote takes place with $XFe^{3+}_{epi} > XFe^{3+}_{pmp} > XFe^{3+}_{prh}$ In these associations, chlorite is present in composite amygdales coexisting with celadonite in a concentric ring arrangement, and as pseudomorphs after olivine. The interlayered cations (Na+K+Ca) and Si contents of these chlorites (Fig.3a)

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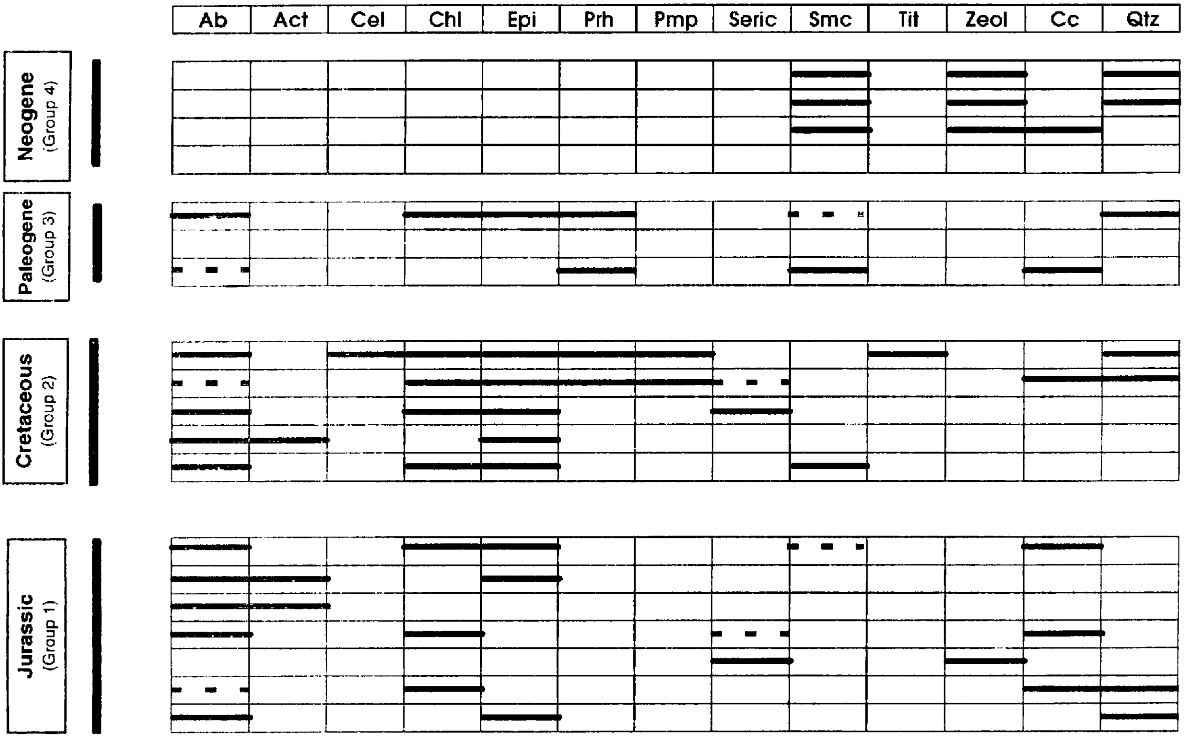


FIG.1 Metamorphic mineral assemblages in Mesozoic-Cenozoic volcanic rocks of the Chilean Patagonian region between latitudes 43° and 46°S. Ab = albite; Ac = actinolite; Cel = celadonite; Chl = chlorite; Epi = epidote;Prh = prehnite; Pmp = pumpellyite; Seric = sericite; Smc = smectite; Tit = titanite; Zeol = zeolites; Cc = calcite; Qtz = quartz.

are largely comprised in the range defined for discrete chlorites (0.1 and 6.0 respectively)[5]. This composition is confirmed by the plot of non-interlayered cations (Si+Al+Fe+Mg) *vs.* $Al_t$ (Fig.3c) which shows a concentration of points close to the chlorite end member of the tri-octahedral phyllosilicate saponite-chlorite series.

Metamorphic assemblages composed of albite, chlorite,epidote and prehnite with minor smectite and quartz characterize the samples from Group 3 (Estratos de La Junta). Although these associations are not diagnostic, they might be assigned to the prehnite-pumpellyite facies since the presence of pumpellyite in the matrix of conglomerates belonging to this unit has been previously recognized (O. Urbina, personal communication).

Actinolite-bearing assemblages including albite and epidote have been identified in some lavas from Groups 1 (Jurassic) and 2 (Cretaceous) where the actinolite either replaces primary phenocrysts (Ca-plagioclase and

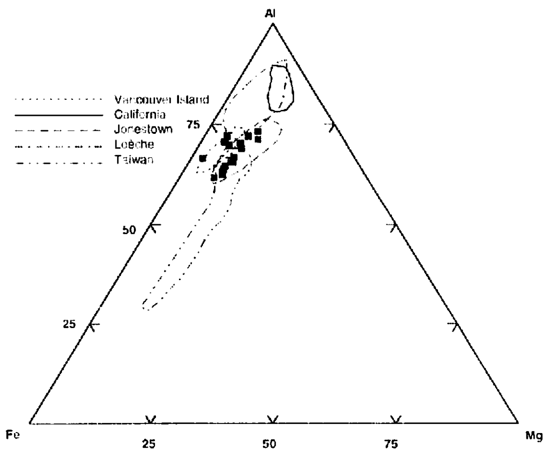


FIG.2 Composition of pumpellyite in basic lava flows from Group 2 (Cretaceous).

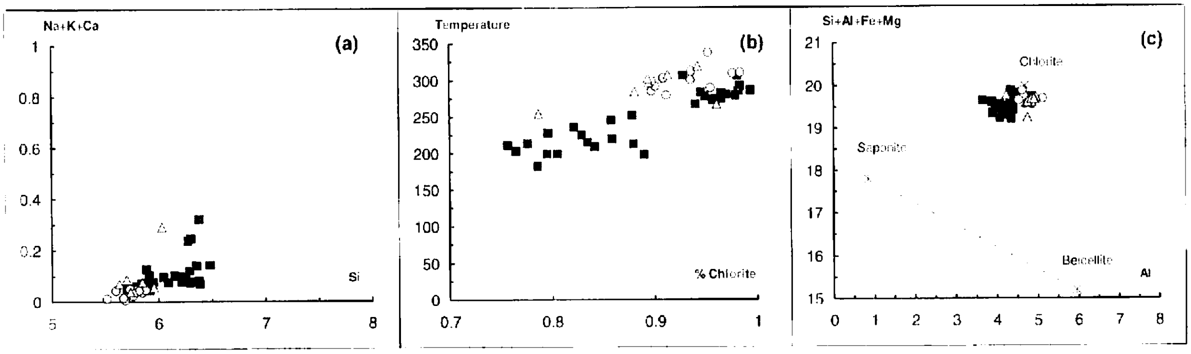


FIG.3 (a): Sum of interlayered cations (Na+K+Ca) versus Si content for chlorites in rocks of Groups 1 (Jurassic), 2 (Cretaceous) and 3 (probably Paleogene); open circles = Group 1; black squares = Group 2; open triangles = Group 3. (b): Binary plot of temperature (calculated using the Cathelineau geothermometer) versus % chlorite (=proportion of chlorite to swelling component); same samples and symbols as in (a). (c): Sum of the major, non-interlayered cations (Si+Al+Fe+Mg) versus total Al for chlorites; same samples and symbols as in (a) and (b).

hornblende) or occupies the margin of veinlets. In these rocks epidote is a major phase. These assemblages could be tentatively assigned to the greenschists facies.

## CHARACTERISTICS OF THE METAMORPHISM. CONCLUSIONS

A non-deformational metamorphism of very low to low-grade is typically present in all the rocks studied and its characteristics are similar to those found in the extensional (diastathermal) type of metamorphism in other segments of the Andes[6,7].

Pressures being low (<3kb) for the extensional geodynamic settings envisaged for most of the Andean evolution, the main controlling parameters for this metamorphism are the temperature and the thermal gradient whose effects can be modified in various ways by the action of oxygen fugacity, element activity, water/rock ratio, reaction kinetics and other factors.

For the Patagonian rocks, a chlorite geothermometer based on the correlation between $Al^{IV}$ and T [8,9] provides a mean to evaluate the range of temperatures reached by the metamorphism. The values obtained for chlorites in rocks from Groups 1, 2 and 3 cover the interval 183° - 338° C (Fig.3b). Within this interval, the lowest temperatures correspond to chlorites from rocks of Group 2 ( 183° - 307°C) whereas the highest are for chlorites from a rock of Group 1 (280° - 338°C). Values for chlorites in rocks of Group 3 (255° - 319°C) are close to those of Group 1. A good correlation is observed in Figure 3b between the temperature and the percentage of chlorite to swelling component calculated using the method of Wise (see reference 5).

The temperatures indicated by the chlorite geothermometer closely coincide with the P-T field for the prehnite-pumpellyite facies as given by various authors[10,11,12]. Temperatures over 300°C obtained for some of our chlorites are already inside the P-T field of the greenschist facies in Frey's *et al.* petrogenetic grid[12]. This would explain the appearance of actinolite in some of the associations as previously mentioned. This rise in temperature reflected in some of the secondary parageneses is to be mainly related to the genesis and emplacement of the numerous plutons of the Patagonian Batholith.

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