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ANCIENT ARC/BACK-ARC AND N-MORB VOLCANICS INCORPORATED IN THE LATE PALAEOZOIC/EARLY MESOZOIC METAMORPHIC COMPLEX OF THE COASTAL CORDILLERA OF CHILOE, SOUTHERN CENTRAL CHILE

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INTRODUCTION

The coastal cordillera of Chiloé is part of a low grade metamorphic complex exposed in the coastal ranges of central to southern Chile from 32°S down to 45°S. This complex is characterized by pelitic to psammitic schists and minor intercalations of mafic schists and serpentinite bodies with dominating greenschist facies metamorphism. Due to the rare occurrence of blue amphiboles, the coastal metamorphic complex was interpreted to be an accretionary wedge [1]. Abundant phengites with high Si content in both pelitic and basic lithologies have implied high-pressure, low-temperature conditions for an early metamorphic stage [2]. The dated age of the greenschist facies metamorphism is Late Palaeozoic [1].

The study focused on the geochemical characteristics of the mafic schists of the coastal cordillera of Chiloé.

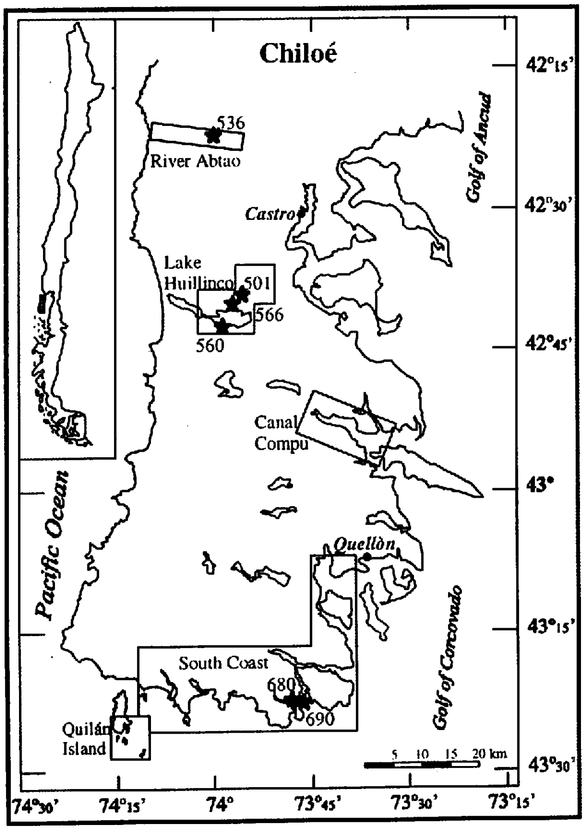

Fig. 1: Map showing the study areas (in frames) on Chiloé and sample locations of metabasites (stars) discussed in the text.

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GEOLOGICAL SETTING AND PETROGRAPHY

Although significant parts of Chiloé are covered by glacial deposits, the low grade metamorphic complex is well exposed north of Lake Huillinco in the Cordillera Piuchén and along the southern and southeastern coast of Chiloé (Fig. 1). Within the study areas the metamorphic complex is clearly dominated by metasediments. U-Pb isotope data from detrital zircons [3] indicate, an age of less than 388 Ma for the deposition of the sediments. Metamorphic K-Ar and Ar-Ar ages are Triassic [3].

In the eastern part of the southcoast study area a sequence of alternating mafic and pelitic schists occurs. The thicknesses of the metabasite layers range between 20 cm to several meters. Layers of metabasites also occur at Canal Compu, Lake Huillinco, and Rio Abtao (Fig. 1). In the western part of southern Chiloé the metamorphic complex is covered by unmetamorphosed sediments and andesitic volcanics. The latter occurs on southern Quilán Island and on the Esmeralda island group.

The schists suffered from an intensive penetrative deformation. Along the southern coast of Chiloé a variation in deformation is discernible as a result of accretionary wedge formation [2]. In the westernmost outcrops only a crenulation can be observed in addition to the main foliation, whereas to the east a third deformation event can be noted. This event is characterized by tight isoclinal folds that are omnipresent in the northern study areas of Chiloé.

The mineral paragenesis of the pelitic schists is white mica + chlorite + quartz + albite + sphene ± apatite ± epidote ± tourmaline ± graphite. Analyzed phengites in the pelitic schists occasionally show high Si contents as seen in other parts of the coastal range of Chile [2]. Based upon this Si content the estimated pressure for the high pressure event is 6 to 8 kbar at 300 to 400°C.

The observed paragenesis of the mafic schists is chlorite + epidote + albite + amphibole + sphene ± quartz. Amphibole is actinolite but relics of blue amphibole are also detected.

GEOCHEMISTRY

Thirty mafic schists from the study areas on Chiloé were analyzed with a XRF spectrometer at the University of Heidelberg, Germany. Rare Earth Elements (REE), Hf, Pb, Th and U were determined using ICP-MS at CNRS Strasbourg, France.

Because the mafic schists were intensively deformed and metamorphosed under greenschist facies conditions, the primary geochemical characteristics are best described using immobile elements, e.g. Ti, REE, Nb, Cr and Ni. Alkali (Na, K, Rb) and alkaline-earth elements (Sr, Ba) have to be dealt with carefully because of their susceptibility to mobilization during metamorphism.

After plotting the data in REE-diagrams and multi-element diagrams, as well as comparing element ratios, the matabasites can be subdivided into two groups. One group shows arc/back-arc characteristics (Fig. 3a and 4). The other group have evidence for a characteristic MORB signature (Fig. 3b and 5). All the samples are subalkaline basalts (Fig. 2a). The majority are tholeiitic, five are calc-alkaline basalts (Fig. 2b) and three are andesites.

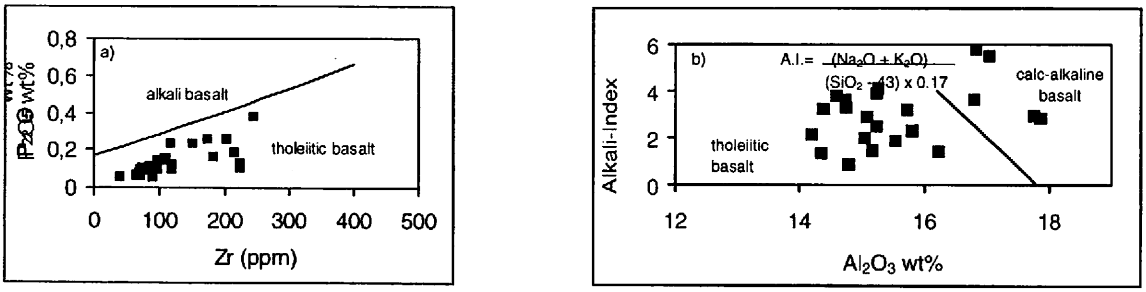

Fig. 2: Classification of magma series of the analyzed metabasites a) based upon Winchester& Floyd [4]. b) based upon Middelmost [5]

Two of the samples with arc/back-arc characteristics are calc-akaline metabasalts (samples 501 and 560). A further is a tholeiitic metabasalt (sample 536). In the chondrite normalized REE plot (Fig. 3a) both of calc-alkaline metabasalts show a more intensive REE fractionation than the tholeiitic. The tholeiitic metabasalt has a pattern that is generally characteristic for MORB origin, but also possible for basalts extruded at back-arc spreading centers [7]. The pattern of metabasalts 501 and 560 is diagnostic for calc-alkaline oceanic island arc basalts.

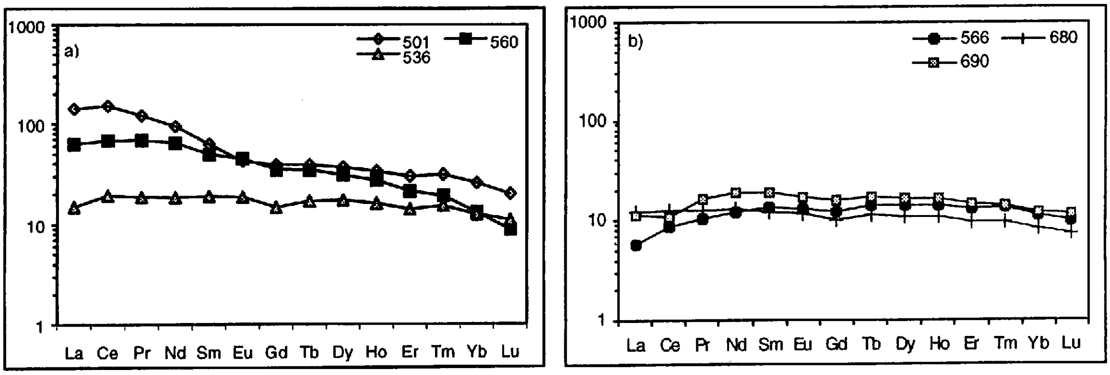

Fig. 3: Chondrite-normalized rare earth element (REE) patterns of mafic schists. a) calc-alkaline metabasalts 501 and 560 from Lake Huillinco and tholeiitic metabasalt 536 from river Abtao. b) tholeiitic matabasalt 566 from Lake Huillinco and 680 and 690 from the southcoast. Normalization is according to Sun and McDonough [6].

Taking into account other element concentrations and element ratios, the interpretation of the REE pattern is not quite clear. Island arc basalts for example, usually have TiO_2 content below 1.0 wt %. The discussed metabasalts however, show significantly higher contents, between 1.5 and 1.7 wt % TiO_2. The Zr and Y content are also relatively high. On the other hand, the Th/La, Nb/U, as well as the Th/Nb ratios fit with volcanics from island arcs. The N-MORB normalized multi-element pattern (Fig. 4) shows the typical Nb-trough characteristic for island arc magmas. For typical island arc basalts, however, this trough should be below the normalization ratio. Such less prominent Nb-anomalies are common for basalts from back-arc spreading centers, e.g. back-arc basalts form the East Scotia Sea [7]. Therefore, we suggest that the protolith of the tholeiitic mafic schist originally extruded at a back-arc spreading center. The protolith of the calc-alkaline mafic schists could have formed at an island arc or a back-arc spreading center, however, all arguments point to an arc/back-arc origin.

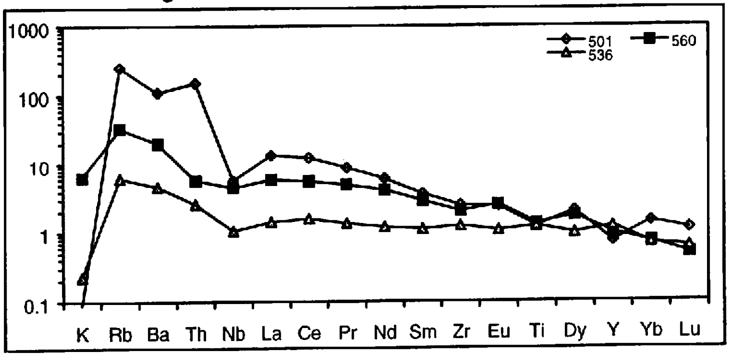

Fig. 4: N-MORB normalized extended multi-element pattern for calc-alkaline metabasalts (samples 501 and 560) from Lake Huillinco and tholeiitic metabasalt (sample 536) from river Abtao. Element incompatibility increases from left to right. K is added on the left side. Normalization is to N-MORB composition, according to Sun & McDonough [6].

The chondrite normalized REE patterns in Fig. 3b show almost entirely unfractionated heavy REE abundances with several samples depleted in light REE. Primitive basalts have REE concentrations ten times or fewer than those of chondrites. Such REE patterns are characteristic for basalts with N-MORB origin. This interpretation also agrees with several element ratios as well as with the N-MORB normalized multi-element patterns shown in Fig. 5. Except for the relatively mobile elements, the tholeiitic basalts have normalized ratios around 1, characteristic for N-MORB basalts. Thus, it is assumed that these tholeiitic metabasalts originated at a mid-ocean ridge spreading center, where N-type MORB occurs.

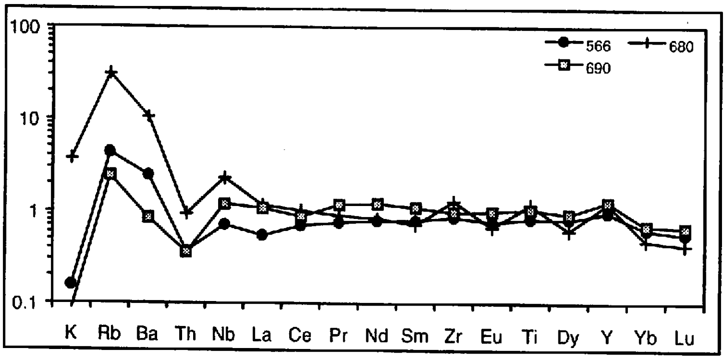

Fig. 5: N-MORB normalized extended multi-element pattern for tholeiitic metabasalts. Sample 566 from Lake Huillinco, samples 680 and 690 from southcoast. Element incompatibility increases from left to right. K is added on the left side. Normalization is to N-MORB composition, according to Sun & McDonough [6].

CONCLUSIONS

Due to its tectonic position within the accretionary wedge at least a part of the subducted oceanic crust can be characterized and reconstructed. The arc/back-arc signature of several metabasites support the hypothesis that a part of the subducted crust was an island-arc back-arc complex. Nevertheless, the majority of the accretionated oceanic crust is composed of metabasites with a N-MORB signature. Without geochronological data, however, it is not possible to determine the relationship between individual oceanic crust fragments and their source areas.

ACKNOWLEDGEMENT

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