EROSION TRACING OF THE CHILEAN-BOLIVIAN OROCLINE BY HEAVY MINERAL AND MAJOR AND TRACE ELEMENTS DISCRIMINATION IN SEDIMENTS OF NEOGENE BASINS

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INTRODUCTION

In northern Chile and northwestern of Bolivia, the main mountain ranges i.e., Precordillera, Western Cordillera and Eastern Cordillera (Fig. 1) are parallel to the Andean basins: Central Depression, the Mauri, Corque and Oriental basins in the Altiplano, and the piggyback basins in the Subandean Zone (Fig. 1). The basins are aligned throughout the mountainous fronts, and the deposits reach up to 10.000 m thickness (Fig. 1). In general, they are characterised by detrital deposits, with coarse sands and gravels in the Central Depression and Altiplano, and sandy to silty sediments in the Subandean Zone. Several stratigraphic units have been defined because of the strong facies variations existent in these basins (Fig. 2). Masek *et al.* (1994) indicates that the northern segment of the orocline in the Subandean Zone would have undergone a greater erosion with respect to the southern segment during Andean uplift. Nevertheless, the recent estimations of shortening indicate that the greater shortening has taken place in the southern segment (*e.g.* Rochat *et al.*, 1999). In addition, it is not known with certainty when the Eastern Cordillera and the Western Cordillera were constituted as mountain ranges. In the frame of this geological setting, it would turn out interesting to determine the nature of the rocks exposed to erosion during the Neogene in order to give light on the evolution of the relief in this region at that time. The analysis of the stratigraphic register in the Neogene basins is essential for solving this tectonic and sedimentary problem. In this work we present the preliminary results on the heavy mineral content, and major and trace element analyses of sedimentary deposits from the Cenozoic basins in this region as a tool for the determination of rocks that were subjected to erosion during the Neogene, discuss and its significance in the Andean paleogeographic evolution in the North segment of the orocline. The heavy minerals were identified by X-Ray (Debye Scherrer method) and determined by SX50-CAMEBAX electron-microprobe (UPS-CNRS, Toulouse); the major elements were analysed by ICP-AES at the Service d'Analyse des Roches et des Minéraux, CRPG, Nancy, and the trace elements by ICP-MS at the Laboratoire de Mécanismes de Transfert in Géologie, UPS-CNRS, Toulouse.

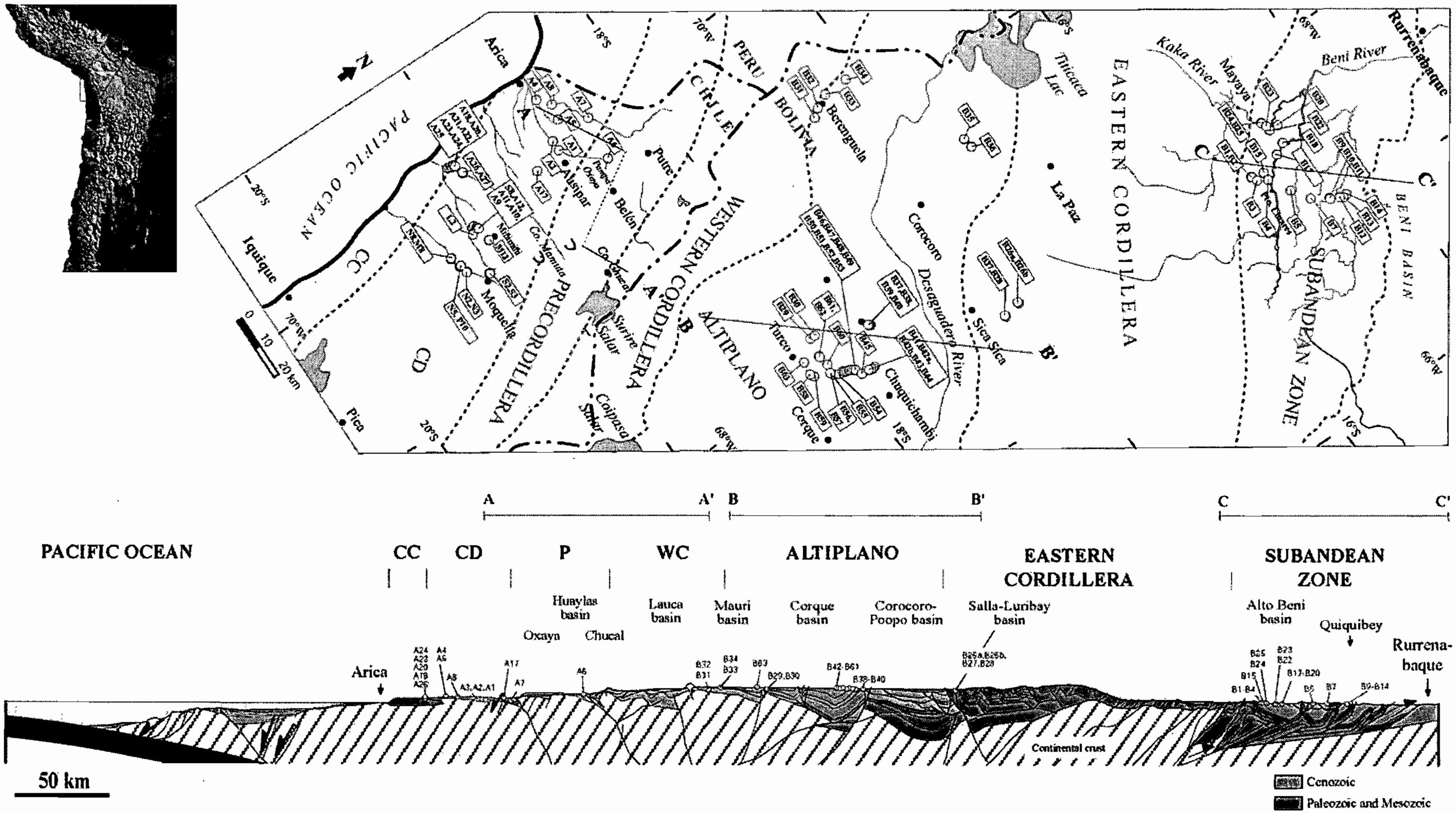

Figure 1. Distribution of Cenozoic basins and location of samples along a SW-NE profile un the Central Andes. CC: Coastal Cordillera, CD: Central Depression; P: Precordillera; WC: Western Cordillera.

RESULTS AND DISCUSSION

The mineral components in the the heavy mineral fraction and the element content in the Neogene sediments (Fig. 3) suggest the continuous erosion of volcanic arcs and the discontinuous erosion of a crystalline and metamorphic basement. (a) The sediments in the Central Depression indicate a intermediate to basic volcanic character of the sediment sources reflected in the low concentrations of SiO_2 and Ta and high concentration in Al_2O_3 with respect to the other basins. This is confirmed by the presence of Diopside and Actinolite in the Oligocene to Early Miocene sediments, and Enstatite, Augite and Forsterite in the Middle Miocene deposits. While the intermediate volcanic components decrease consistently with time in the Central Depression, the basic component increase progressively. While the granitic and metamorphic components are well represented by heavy minerals in the Oligocene to Early Miocene sediments, these are completely absent in the Middle Miocene units. The metamorphic components in the oldest series proceed very possibly from the chilean Belén and the bolivian Cerro Uyarani Metamorphic Complexes. The intermediate volcanic source can correspond either to the Mesozoic Coastal Cordillera or the Precordillera substratum, whereas the basic volcanic source evidently corresponds to the Middle Miocene volcanoes of the Western Cordillera. (b) The presence of granitic material (garnet of the Almandine-Pyrope-Spessartine series) and the greater concentration of SiO_2 in the sediments of the Altiplano basins demonstrate the erosion of mature sedimentary deposits and intrusive bodies – quartzites, granites and/or gneiss – with a continuous supply of volcanic material. The absence of Enstatite and Forsterite and a greater percentage of Magnesiohastingsite, Phlogopite (Fig. 3), Fluorapatite and Titanite, and the greater concentration of SiO_2 indicates that the volcanic supply to the Altiplano basins was more acid than the sedimentary supply to the Central Depression. The volcanic supply to these basins would correspond to the igneous rocks from the Western Cordillera and Eastern Cordillera. (c) An opposite signal is obtained from the analysis of the Subandean Zone sediments, which display a clear predominance of quartz during all its evolution. In this region, the greater concentration of Al_2O_3, Rb and REE, indicates the predominance of the clay fraction in the deposits. In addition, the low Na, Sr and high SiO_2 concentrations (Fig. 3) would be associated to a great alteration or maturity of the sediment (Bathia and Crook, 1986). Nevertheless, the good roundness of tourmalines, zircons, and garnets supports the hypothesis of a long transport or recycling of the material more than an alteration. Thus, these results would indicate that the metamorphic basement and basic volcanic buildings of the Western Cordillera supplied material mainly to the Central Depression. The crystalline basement and acid volcanic deposits of the Western Cordillera and igneous and sedimentary rocks of the Eastern Cordillera supplied material to the Altiplano basins. Whereas the basins of the Subandean Zone only received material from sedimentary rocks eroded along the eastern edge of the Eastern Cordillera being isolated from the volcanic source during all their evolution.

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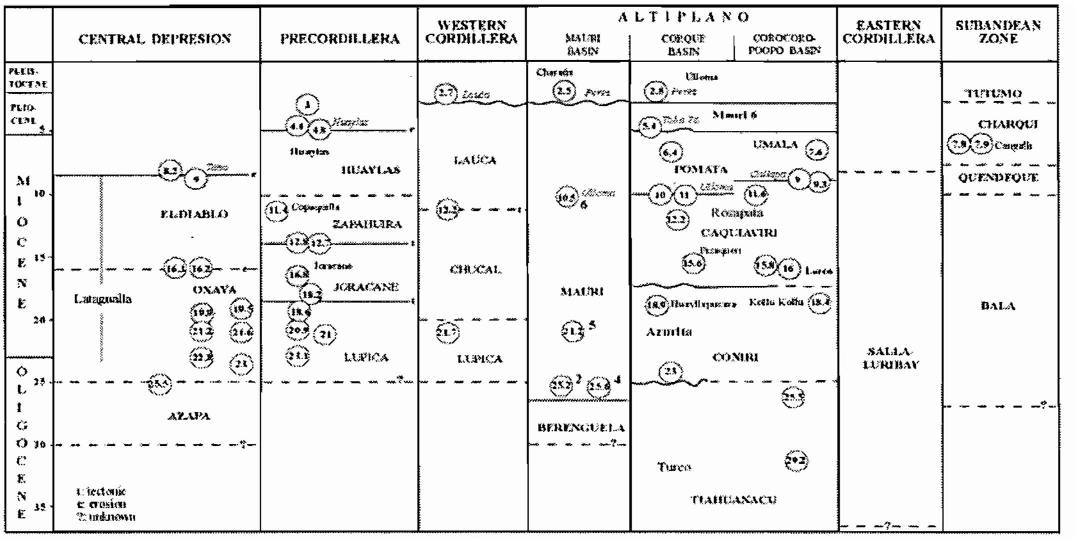

Figure 2. Stratigraphic correlations between the Cenozoic formations, northern Chile and northwest Bolivia. The names in capital letters represent regional formation and the names in italic to local formations or facies. The radiometric ages are in circles and million years. The waved lines represent tectonic pulse and the segmented lines represent not well-known relations between formations.

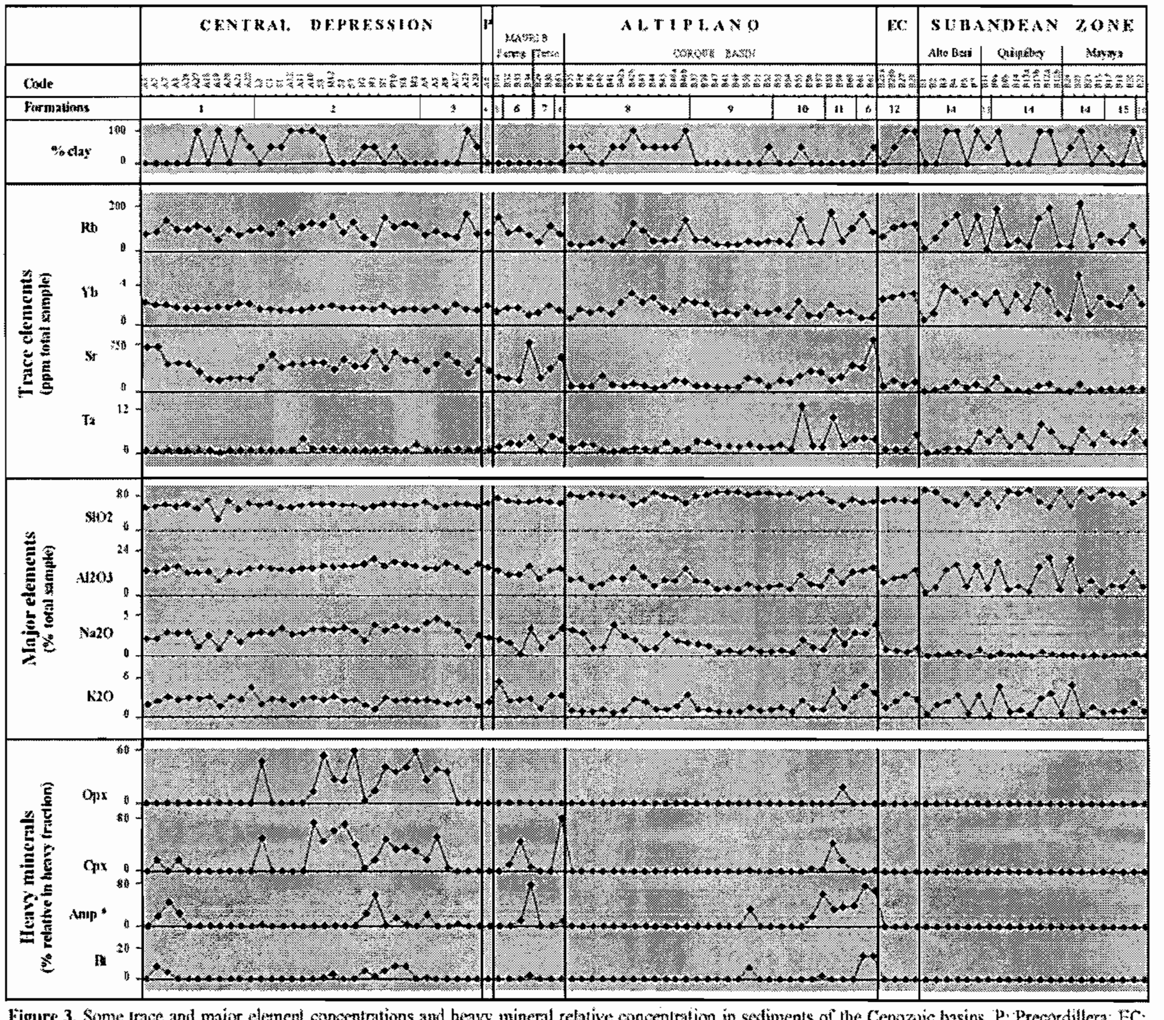

Figure 3. Some trace and major element concentrations and heavy mineral relative concentration in sediments of the Cenozoic basins. P: Precordillera; EC: Eastern Cordillera; Opx: orthopyroxene (Enstatite); Cpx: clinopyroxene (Diopside, Augite); Amp: calcic amphiboles (Magnesiohornblende, Pargasite, Magnesiohastingsite); (*) The A7 sample of the Azapa Fm. contains 24% of Actinolite and 20% of others amphiboles; Bt: biotites. Formations: (1) Azapa-Oxaya Fm., (2) Lataguaila Fm., (3) El Diablo Fm., (4) Huaylas Fm., (5) Berenguela Fm., (6) Mauri Fm., (7) Azurita Fm., (8) Tiahuanacu Fm., (9) Coniri Fm., (10) Caquiaviri Fm., (11) Pomata Fm., (12) Salla-Luribay Fm., (13) Bala Fm., (14) Quendeque Fm., (15) Charqui Fm., (16) Tutumo Fm.

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