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CARACTERISTICAS GEOQUIMICAS DE LA ZONA VOLCANICA MERIDIONAL (SVZ) DE LOS ANDES ENTRE LOS 41°30' Y 46°00' S.

GEOCHEMICAL CHARACTERISTICS OF ROCKS FROM THE ANDEAN SVZ BETWEEN 41°30'S AND 46°00'S

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Between 41°30'S and 46°00'S the oceanic Nazca plate underthrusts the continental South American plate giving as a result an intense volcanism represented by thirteen major centers (Fig. 1). In this region, the Nazca plate has many fracture zones, and we think that the zig-zag alignment of the volcanic front reflects their control over the volcanism of the region. This volcanic area, whilst is part of the Andean SVZ, ends at Hudson volcano, located on the northern side of the triple junction South America - Nazca - Antarctic plates. The geochemical characteristics of the volcanism of this area is not well known mainly because of serious logistic problems (lack of roads, bad climatic conditions, dense vegetation, massive glaciers). By using an helicopter financed by the Japenese Ministry of Education, Science and Culture, we were able to sample those thirteen major volcanic centers. For economical and climatic reasons, this sampling was just a survey one. Anyway, we think that it is valuable because probably many years will pass before a detailed study is carried out in this region. In this report we briefly discuss the petrography, major and trace element geochemistry, some isotopic data obtained and the SB systematic applied to the volcanism of this area.

PETROGRAPHY

The volcanoes located in the northern part of this area (41°30' - 44°00'S) belong either to the pigeonite or to the hypersthene series. Actually, rocks from Apagado (or Hualaihue), Corcovado and Melimoyu volcanoes include pigeonite as microphenocrysts and/or in the ground mass. Southward, pigeonite is absent and the volcanic rocks can be considered belonging to the hypersthene or to the alkalic series. Whilst the Cpx + Opx + Ore mineral assemblage is common in rocks from the northern volcanoes of this area, the Ol + Cpx assemblage is common in rocks from the southern volcanoes.

MAJOR AND TRACE ELEMENTS

Thirty two volcanic samples were collected in this survey study. According to the

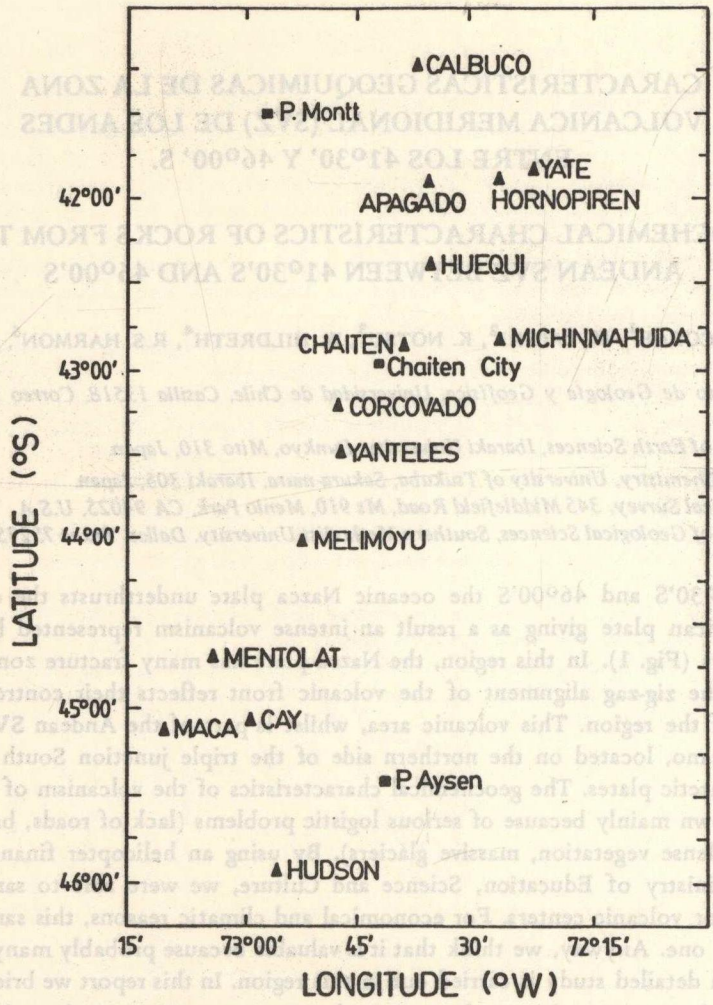

Fig.1. Volcano distribution in the Andean SVZ between 41°30'S and 46°00'S.

Fig.1. Distribución de los volcanes de la SVZ (Zona Volcánica Meridional) de los Andes entre 41°30'S y 46°oo'S.

classification criteria of Irvine and Baragar (1971), they are calcalkaline, in spite that some of them contain pigeonite, and in the classifcation scheme of Peccerillo and Taylor (1976), eleven samples are basalts (SiO_2< 52 wt%), nine are basaltic andesites (SiO_2 = 52 – 56 wt%), ten are andesites (SiO_2 = 56-63 wt%), one is a dacite (SiO_2 = 63.02 wt%) and one is a rhyolite (SiO_2 = 74.44 wt%). Basalts can be divided into two groups. Respect to group 1 (Apagado, Corcovado, Cay and Maca volcanoes) basalts, group 2 (Michinmahuida and Hudson) basalts are enriched in FeO* (>9 wt% vs< 9 wt%) and have higher FeO*/MgO (>2.2 vs<1.6), K_2O/Na_2O (>0.25 vs <0.25) and Na_2O/SiO_2 (>0.07 vs <0.07) ratios but have similar Al_2O_3/CaO ratios (1.9 – 2.1) and lower (Mg/ (Mg + Fe*) ratios (<0.50 vs >0.50). Both groups also differ in trace element abundances. Thus, respect to group 1, group 2 basalts are enriched in V (225–250 ppm vs 170–215 ppm),

Rb (23–30 ppm vs 8–14 ppm), Cs (0.6 – 1.4 ppm vs 0.4 – 0.6 ppm), Ba (295 - 380 ppm vs 140 - 220 ppm), REE (see Fig. 2), Hf (3.7 - 4.7 ppm vs 1.9 - 3.8 ppm), Th (2.8 - 3.7 ppm vs 1.2 - 2.2 ppm), U (0.7 - 0.9 ppm vs 0.3 - 0.7 ppm) and Y (31 - 41 ppm vs 19 - 22 ppm). Group 2 also has lower Sr/Nd ratios (13 - 19 vs 30 - 46 but similar La/Sm (2.2 - 3.5), Rb/Cs (1.8 - 3.5), Ba/La (14 - 24), K/Ba (24 - 34) and Ba/Th (78 - 129) than group 1 basalts. Also, K/Rb (303 - 364) and Ba/Rb (10 - 15) ratios in group 2 basalts tend to be slightly lower than in group 1 (K/Rb = 345 - 594; Ba/Rb = 14 - 18).

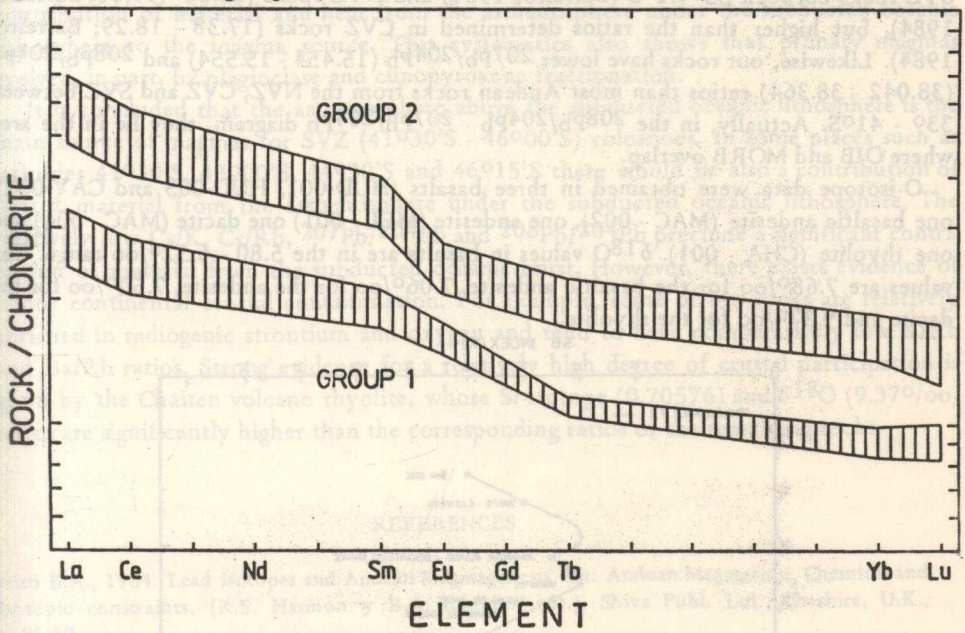

Fig.2. REE-normalized patterns range of group 1 and 2 basalts from the Andean SVZ between 41°30'S and 46°00'S.

Fig.2. Rango en los padrones normalizados de tierras raras de basaltos de los grupos 1 y 2 de la SVZ entre 41°30'S y 46°00'S.

ISOTOPIC COMPOSITION

All analyzed basalts have Sr isotopic ratios in the 0.70401 - 0.70446 range. None of our rocks with SiO_2 less than 64 wt% have ratios outside the 0.70400 - 0.70450 range and most of them have ratios in the 0.70420 - 0.70450 range The latter group includes from basalts to dacites. The highest value (0.70576) is exhibited by the small Chaitén volcano (42°50'S) rhyolite. This volcano is neighbour of the huge Michinmahuida volcano (42°48'S), whose rocks, of basalt to andesite composition, have Sr-isotope ratios in the 0.70440 - 0.70450 range. This situation contrasts with that observed at Laguna del Maule region (36°S; Frey et al., 1984) or at Villarrica volcano,39°50'S, Deruelle et al., (1983) where rocks ranging in composition from basalt to rhyolite have similar Sr-isotope ratios. However, a similar case is observed at Maipo volcano area (34°15'S, Stern et al., 1984); here, the rhyolites have Sr-isotope ratios significantly higher than the more basic volcanic rocks. Sr-isotope data are discussed in more detail by Notsu et al. (This volume).

Three basalts (APA-001; COR-003 and CAY-001), one basaltic andesite (MEN-003) and one dacite (MEN-004) have Nd-isotope determinations. The range for basalt is 0.512712 - 0.512826. The value for the basaltic andesite is 0.512871 and that for the

Mentolat volcano dacite is 0.512896. In the Nd-Sr-isotope diagram, basalts lie within the mantle array, but the basaltic andesite as well as the dacite from the Mentolat volcano are enriched in radiogenic Sr.

Pb-isotope determinations have been made in four basalts (COR-003, MIC-001, CAY-001 and HUD-003), one andesite (MEN-005) and one dacite (MEN-004). Their $^{206}Pb/^{204}Pb$ ratios (18.386 - 18.549) are lower than the average ratio (18.58) of the SVZ rocks between 33°-41°S (Barreiro, 1984) and NVZ rocks (18.60 - 19.00; Barreiro, 1984), but higher than the ratios determined in CVZ rocks (17.38 - 18.29; Barreiro, 1984). Likewise, our rocks have lower $^{207}Pb/^{204}Pb$ (15.454 - 15.554) and $^{208}Pb/^{204}Pb$ (38.042 - 38.364) ratios than most Andean rocks from the NVZ, CVZ and SVZ between 33° - 41°S. Actually, in the $^{208}Pb/^{204}Pb$ - $^{207}Pb/^{204}Pb$ diagram, they lie in the area where OIB and MORB overlap.

O-isotope data were obtained in three basalts (HUD-001, HUD-003 and CAY-002), one basaltic andesite (MAC - 002), one andesite (MEL - 001) one dacite (MAC - 004) and one rhyolite (CHA - 001). $\delta^{18}O$ values in basalts are in the 5.80 - 6.32°/oo range. The values are 7.68°/oo for the basaltic andesite, 7.06°/oo for the andesite, 7.50°/oo for the dacite and 9.37°/oo for the rhyolite.

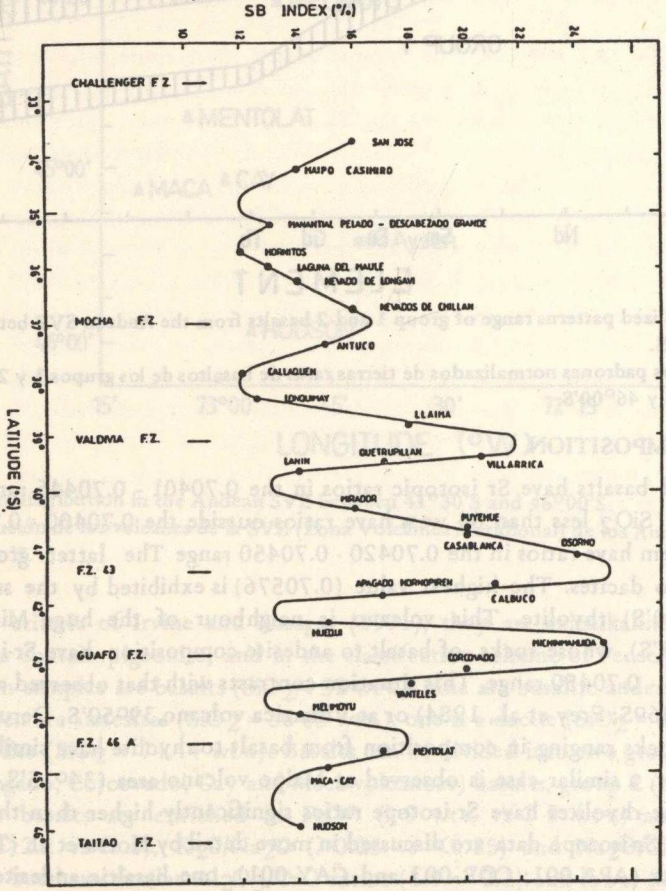

Fig.3. SB index versus Latitude diagram for the Andean SVZ between 33° and 46°S. This index represents the estimated degree of melting of a given souce required to generate a primary magma.

Fig.3. Diagrama Indice SB vessus Latitud para la SVZ de los Andes entre los 33° y 46°S. Este indice representa el grado estimado de fusión de una fuente determinada, que se requiere para generar un magma primario.

SB - SYSTEMATICS

The SB-index vs latitud diagram (Fig. 3; López et al., in prep.) shows four maxima in the area of our study. The SB index is considered as a measure of the degree of partial melting required to generate a given primary magma. The maxima are found where the projections of the 43 (41° 30' S), Guafo (43° 00' S), 46 A (44° 30' S) and Taitao Fracture Zones intersect the continent. These maxima would reflect the local contribution of material and heat from the asthenosphere under the subducted oceanic lithosphere to the magma source. This systematics also shows that primary magmas evolved, in part, by plagioclase and clinopyroxene fractionation.

It is concluded that the asthenosphere above the subducted oceanic lithosphere is the main source of magmas for SVZ (41°30'S - 46°00'S) volcanoes. In some places such as latitudes 41°30'S, 43°00'S, 44°30'S and 46°15'S there would be also a contribution of heat ± material from the asthenosphere under the subducted oceanic lithosphere. The relatively low Cs/K, Cs/Rb, $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ preclude a significant contribution of material from the subducted oceanic crust. However, there exists evidence of minor continental crustal contamination. For example, some of our rocks are relatively enriched in radiogenic strontium and oxygen and tend to have comparatively low K/Rb and Ba/Rb ratios. Strong evidence for a relatively high degree of crustal participation is given by the Chaiten volcano rhyolite, whose Sr-isotope (0.70576) and $\delta^{18}O$ (9.37°/oo) ratios are significantly higher than the corresponding ratios of the remaining rocks.

REFERENCES

Barreiro B.A., 1984. Lead isotopes and Andean Magmagenesis. En: Andean Magmatism, Chemical and Isotopic constraints. (R.S. Harmon y B.A. Barreiro, eds.). Shiva Publ. Ltd., Cheshire, U.K., p. 21-30.

Deruelle B., Harmon R.S., Moorbath S., 1983. Combined Sr - O isotope relationships and petrogenesis of Andean volcanics of South America. Nature 302: 814-816.

Frey F.A., Gerlach D.C., Hickey R.L., López L., Munizaga F., 1984. Petrogenesis of the Laguna del Maule volcanic complex, Chile (36°S). Contr. Mineral. Petrol., v. 88, p. 133-149.

Irvine T.N., Baragar W.R.A., 1971. A guide to the chemical classification of the common volcanic rocks. Can Jour. Earth Sci., 8, p. 523-548.

López-Escobar L., Onuma N., Takaku Y., (in prep.). Possible contribution of the asthenosphere, below the subducted oceanic lithosphere, to the genesis of arc magmas: geochemical evidence from the Andean SVZ (33°S-46°S).

Notsu, K.; López-Escobar, L., and Onuma, N.(This volume)) Behaviour of the strontium Isotope ratios along the strike of the Andean SVZ with emphasis in the 41°30'S - 46° 00' S region.

Pecerrillo A., Taylor S.R., 1976. Geochemistry of Eocene calc-alkaline volcanic rocks from Kastamonu area, northern Turkey. Contr. Mineral Petrol., v. 58, p. 63 - 81.

Stern C.R., Futa K., Muehlenbachs K., Dobbs F.M., Muñoz J., Godoy E., Charrier R., 1984. Sr, Nd, Pb and O isotope composition of Late Cenozoic volcanics, northernmost SVZ (33 - 34°S). En: Andean Magmatism, Chemical and Isotopic constrainsts. (R.S. Harmon and B.A. Barreiro eds.). Shiva Publ. Ltd., Cheshire, U.K., p. 96 - 105.