COMUNICACIONES Nº 50 (1999): 81-86

# BASE AND PRECIOUS METALS DISTRIBUTION IN THE MAINLAND CHILEAN PATAGONIA : EXPLORATION POTENTIAL

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*KEY WORDS: Geochemistry, anomalies, Patagonia, Southern Andes, Chile.*

## INTRODUCTION

The distribution and geochemical contents of base and precious metals in rock units of the mainland Chilean Patagonia (44°00'-47°30' S; Fig. 1) were investigated through a regional survey that included over 1000 rock samples. Geochemical anomalies based on threshold value estimation are indicated, with a brief description of alteration, mineralization, and characteristics of the detected geochemical anomalies.

## GEOLOGICAL AND TECTONIC BACKGROUND

The surveyed area (Fig. 1) is a segment of the Southern Andes where during the Late Jurassic and Cretaceous a suprasubduction magmatic arc developed on the active western margin of the South American continent and an ensialic back-arc marine basin was formed inland. The arc and back-arc basement is composed of Paleozoic metamorphic rocks that are interpreted as sedimentary wedges accreted to the Gondwana paleocontinent. By the end of the Mesozoic the back-arc basin was filled, and was discordantly overlain by Tertiary volcanic and terrestrial sedimentary rocks that represent local basins and within plate volcanism.

## GEOCHEMISTRY

1068 samples were collected and assayed at commercial laboratories for 30 elements by inductively coupled plasma atomic emission spectrometry (ICP-AES), and Au was determined by atomic absorption spectrometry (AAS). For ICP-AES, a 0.5-g subsample was digested with a 3 ml 3-2-1 $HCl-HNO_3-H_2O$ leach at 95°C for one hour, then diluted to 10 ml with water. For Au-AAS, a 10-g subsample was digested with aqua regia at 95°C for one hour, then diluted to 100 ml with water. An MIBK extraction was used. Altered rock samples in which strong silicification was identified (over 70% silicified) were leached with hot HF + $HClO_4$-$HNO_3$-HCl, instead of aqua regia.

To assess precision and accuracy duplicated rock samples and analysis of laboratory internal standard samples were done. Statistical tests and scatter diagrams indicate precision within the 90% confidence level and accuracy within the 95% confidence level for all the studied elements (Mo, Cu, Pb, Zn, Ag, As and Au; Townley et al., 1999).

Early work presented by Townley et al. (1999) classified geochemical results into two broad groups : i) unaltered unmineralized rocks and ii) altered and mineralized rocks. Statistical treatment of results was further done for data interpretation.

Unaltered unmineralized rock geochemistry was classified with respect to the main regional rock units. Mean and standard deviation of the mean values were compared to global normal contents for similar rock types (Table1) indicating that except for As, all other studied elements are within global ranges. Arsenic shows a conspicuous positive anomaly in all rock types, specially in the volcanic type. These values define a regional background (Table 1). Geochemical correlations indicated element associations normal to rock forming minerals such as that observed in amphiboles, pyroxenes and feldspars (Townley et al., 1999).

Altered and mineralized rock geochemistry was also classified according to regional rock units. Mean and standard deviation of mean values were compared to the previously defined regional background and global values, and rock units that show anomalies well above background, were subject to a statistical population analysis. Statistical results, regional background and/or global values were considered for the determination of geochemical anomaly threshold values for the different regional rock units (Table 1). A correlation analysis for logarithmically transformed data and a factor analysis indicate element associations typical of polymetallic sulphide mineralization with or without precious metals mineralization. Mo and As and to a lesser degree, Cu, show little association with other elements, not being recommendable as pathfinder elements.

Table 1. Regional, global and recommeneded exploration threshold values for the Aysén region (data from Townley et al., 1999).

| Rock Unit | Elem-ent | Unit | Regional upper limit values* | Global Mean Values** | Recommended exploration threshold values | % of samples above threshold |
|---|---|---|---|---|---|---|
| Metamorphic basement | Mo | ppm | 3.2 | 1 - 3 | 3 | 19.84 |
| | Cu | ppm | 63.1 | 42 - 50 | 79 | 16.67 |
| | Pb | ppm | 30.8 | 10 - 25 | 31 | 14.28 |
| | Zn | ppm | 91.6 | 20 - 100 | 100 | 19.84 |
| | Ag | ppm | 0.18 | 0.05 - 0.19 | 0.26 | 29.36 |
| | As | ppm | 24.9 | 2.5 - 15 | 65 | 17.46 |
| | Au | ppb | 1.9 | 4 - 5 | 15 | 14.28 |
| Andesites Ibañez Fm. | Mo | ppm | 6.7 | 1.0 - 1.5 | 7 | 6.47 |
| | Cu | ppm | 22.2 | 30 - 72 | 72 | 27.36 |
| | Pb | ppm | 17.7 | 4 - 15 | 29 | 19.40 |
| | Zn | ppm | 57.4 | 60 - 94 | 165 | 12.93 |
| | Ag | ppm | 0.11 | 0.07 - 0.10 | 0.46 | 24.87 |
| | As | ppm | 13.4 | 1.5 - 2.0 | 30 | 25.87 |
| | Au | ppb | 1.4 | 3.2 - 4 | 24 | 7.96 |
| Felsic volcanic rocks, Ibañes Fm. | Mo | ppm | 2.3 | 1.0 - 1.5 | 4 | 21.74 |
| | Cu | ppm | 11.9 | 30 - 72 | 56 | 17.39 |
| | Pb | ppm | 27.9 | 4 - 15 | 38 | 23.91 |
| | Zn | ppm | 117 | 60 - 94 | 153 | 14.67 |
| | Ag | ppm | 0.37 | 0.07 - 0.10 | 1.6 | 7.61 |
| | As | ppm | 19.1 | 1.5 - 2.0 | 28 | 36.95 |
| | Au | ppb | 2.5 | 3.2 - 4 | 33 | 9.24 |
| Coihaique Group | Mo | ppm | 2.2 | 1 - 3 | 5 | 20 |
| | Cu | ppm | 20.2 | 42 - 50 | 50 | 3.33 |
| | Pb | ppm | 17.6 | 10 - 25 | 25 | 10 |
| | Zn | ppm | 83.7 | 20 - 100 | 100 | 26.67 |
| | Ag | ppm | 0.24 | 0.05 - 0.19 | 0.24 | 26.67 |
| | As | ppm | 10.9 | 2.5 - 15 | 16 | 23.33 |
| | Au | ppb | 1.2 | 4 - 5 | 5 | 3.33 |
| Divisadero Formation | Mo | ppm | 2.8 | 1.5 - 2.0 | 4 | 16.85 |
| | Cu | ppm | 20 | 10 - 12 | 29 | 10.87 |
| | Pb | ppm | 15.1 | 18 - 20 | 56 | 24.46 |
| | Zn | ppm | 45 | 40 - 51 | 89 | 19.02 |
| | Ag | ppm | 0.09 | 0.03 - 0.04 | 2.3 | 13.04 |
| | As | ppm | 13.6 | 1.5 - 2.1 | 55 | 25.54 |
| | Au | ppb | 2.2 | 2.3 - 4.0 | 10 | 22.83 |
| Plateau basalts | Mo | ppm | 6.3 | 1 - 1.5 | 7 | 21.43 |
| | Cu | ppm | 17.4 | 72 - 100 | 100 | 0 |
| | Pb | ppm | 9.4 | 4 - 5 | 9 | 0 |
| | Zn | ppm | 40.6 | 94 - 100 | 100 | 0 |
| | Ag | ppm | 0.19 | 0.1 | 0.19 | 14.28 |
| | As | ppm | 26.2 | 1.5 - 2.0 | 2.6 | 7.14 |
| | Au | ppb | 5.2 | 3.2 - 4.0 | 5 | 14.28 |
| Patagonian Batholith | Mo | ppm | 2.4 | 1.0 - 1.5 | 11 | 13.99 |
| | Cu | ppm | 31.3 | 30 - 72 | 78 | 17.10 |
| | Pb | ppm | 18.3 | 4 - 15 | 42 | 4.14 |
| | Zn | ppm | 52.6 | 60 - 94 | 130 | 9.84 |
| | Ag | ppm | 0.08 | 0.07 - 0.10 | 0.3 | 13.99 |
| | As | ppm | 23.2 | 1.5 - 2.0 | 75 | 3.11 |
| | Au | ppb | 4.1 | 3.2 - 4 | 12 | 4.66 |

** mean values were estimated including values below detection limit, considering those as half the detection limit, and regional upper limit values were calculated as the standard deviation of the mean.*

*** global mean value ranges where compiled from the following references : Turekian and Wedepohl, 1961; Wedepohl, 1969; Wedepohl, 1969 - 1978; Levinson, 1974; Turekian, 1977; Saager et al., 1982. Values for the metamorphic basement rocks are obtained with respect to most probable protolith, shale and limestone. Ibañez Formation volcanic rocks are obtained with respect to granodioritic and mafic rock values. Divisadero Formation rocks are obtained with respect to granitic rock values.*

## MINERALIZATION

The main ore deposits known in the region are coeval with Late Jurassic - Cretaceous magmatism and this is consistent with the geochemical data. Younger rocks show low geochemical values suggesting that the change of tectonic regime by the end of the Mesozoic resulted in limited mineralization processes during the Tertiary in Aysén.

Altered and mineralized rock geochemistry and statistical treatment of data suggest potential for further polymetallic deposits in the region, the most prospective rock units being the Mesozoic volcanic rocks.

## GEOCHEMICAL DISTRIBUTION

Based on the previously suggested geochemical anomaly threshold values, various geochemically anomalous areas of different potential were determined. These are plotted in Fig.1 and listed geographically from north to south in Table 2. A brief description of each is given, including mineralization deposit type interpretations.

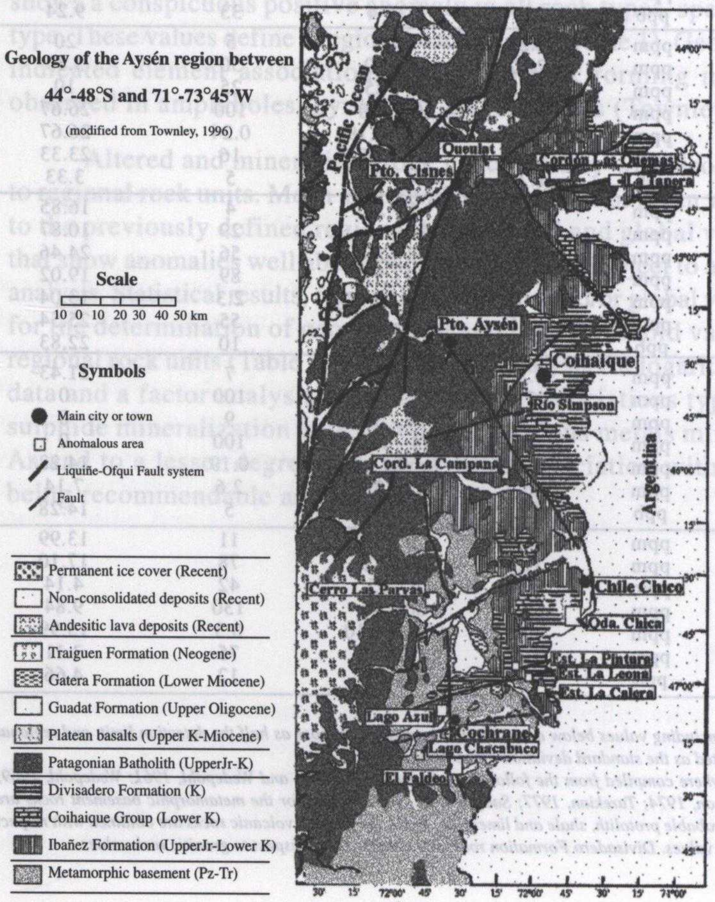


*Figure 1. Simplified geological map of the Aysén region, including geochemically anomalous areas. The Halcones-Leones area, mentioned in Table 2 is represented by Estero La Pintura, Estero La Leona and Estero La Calera areas.*

## CONCLUSIONS

Known ore deposits in the Aysén region are largely restricted to arc-related Jurassic and lower Cretaceous volcanic and intrusive rocks, and some are locally hosted by Paleozoic metamorphic rocks of the basement. Mineral and geochemical associations indicate main potential for polymetallic deposits, mostly of the epithermal vein-type, and minor skarns. There is inconclusive evidence for Au-rich porphyry copper mineralization potential. The overall mineral potential of the Aysén region is not comparable to the rich mineralization of northern Chile, and major metallic deposits appear to be lacking in the studied section of the southern Andes. The extensive areas composed of Paleozoic basement south of Cochrane are not explored, so that the mineral potential of these metamorphic rocks is still unknown.

Table 2.

Summary list of geochemically anomalous areas in the Aysén region, Chile.

| Prospect name and type of mineralization | Mineralization | Alteration | Host rock | Geochemical anomalies |
|---|---|---|---|---|
| 1) La Tapera, pegmatit e related veinlets | Mo-Qz veinlets | Qz-ser and Prop. | Granodioritic stock and andesites | Mo-As |
| 2) Cordón Las Quemas, epithermal | Qz-Py stockwork and vein | Silic. and arg. | Andesitic and dacitic tuffs | Ag-Pb-As |
| 3) Queulat, epithermal | Qz-Py-Aspy-Cpy-Sph vein and stockwork | Silic. and Prop. | Phyllites and dioritic porphyry | Au-Ag-Cu-As |
| 4) Río Simpson, epithermal | Qz-Py-Sph-Ga vein | Qz-ser and arg. | Andesites and shales | Ag-Pb-Zn-As |
| 5) Co. La Campana, mesothermal vein | Qz-Py-Sph-Ga-Cpy vein | Silic. and qz-ser | Dacitic tuffs and porphyry | Ag-Pb-Cu-As |
| 6) Co. La Parva, epithermal | Qz-Py-Aspy veinlets | Qz-ser and arg. | Phyllites, conglomerates and andesites | Ag-As |
| 7) Qda. Chica, epithermal | Qz-Py-Sph-Ga veinlets, stockwork and fracture fill | Adv. arg., arg. and lesser qz-ser | Dacitic and rhyodacitic tuffs | Au-Ag-Pb-Zn-As |
| 8) Halcones - Leones, epi- to meso- thermal vein | Qz-Py-Sph-Ga vein and veinlet | Silic., qz-ser and arg. | Andesitic and dacitic tuffs, granodioritic stock | Au-Ag-Pb-Zn-As |
| 9) Lago Azul, epithermal and porphyry at depth (?) | Qz-Py-stockwork, bre-ccia and disseminations | Qz-ser and silic. | Granodioritic porphy-ry, andesitic and dacitic tuffs, schist and phyllites | Au-Ag-As-Cu |
| 10) El Faldeo, mesothermal replacement and epithermal, porphyry at depth (?) | Qz-Py-Aspy- Sph-Ga veinlet, stockwork and disseminations | Qz-ser, silic., arg. and prop. | Dacitic and rhyodaci-tic tuffs, conglomerate and schist | Zn-Pb-Au-Ag-As |
| Lago Chacabuco, mesothermal vein | Qz-Py-Po-Sph-Ga-Cpy-Aspy vein | Silic., arg. and lesser qz-ser | Schist and phyllites | Zn-Pb-Au-Ag-As |


## ACKNOWLEDGEMENTS

The research was supported by Grant FONDEF MI-15 from CONICYT, Chile, and was developed by the Department of Geology, University of Chile, in collaboration with Arauco Resources.

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