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COMPOSICION ISOTOPICA DE AGUAS METEORICAS DE SUDAMERICA Y SU SIGNIFICADO GEOLOGICO EN YACIMIENTOS MINERALES CENOZOICOS

ISOTOPIC COMPOSITION OF SOUTH AMERICAN METEORIC WATERS AND THEIR SIGNIFICANCE IN YOUNG MINERAL DEPOSITS

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INTRODUCTION

Quantitative isotopic tracing of meteoric water in hydrothermal ore deposits has provided much information on water/rock interaction related to wallrock alteration, metal transport and deposition (e.g., H. P. Taylor, 1974). The identification of isotopically unaltered or only slightly altered surface waters in hydrothermal deposits can also potentially provide constraints on the heat and material balance that characterizes mixing processes which lead to alteration and mineral precipitation. Further, isotopic recognition of paleo-surface waters can assist in paleo-hydrologic reconstruction and provide information on climatic and tectonic evolution (e.g., Alpers and Whittimore, 1990).

This paper summarizes new isotopic data on various types of groundwater and precipitation in Chile, plus isotopic data from the literature (largely from IAEA-supported studies) in the form of a preliminary $\delta^{18}O$ and δD contour maps of South America. The topology of these maps differs markedly from that published by Yurtsever (1975; Figure 1). The purpose of constructing these maps is to provide a graphical reference point for the recognition of meteoric waters in young hydrothermal ore deposits. Similar isotopic

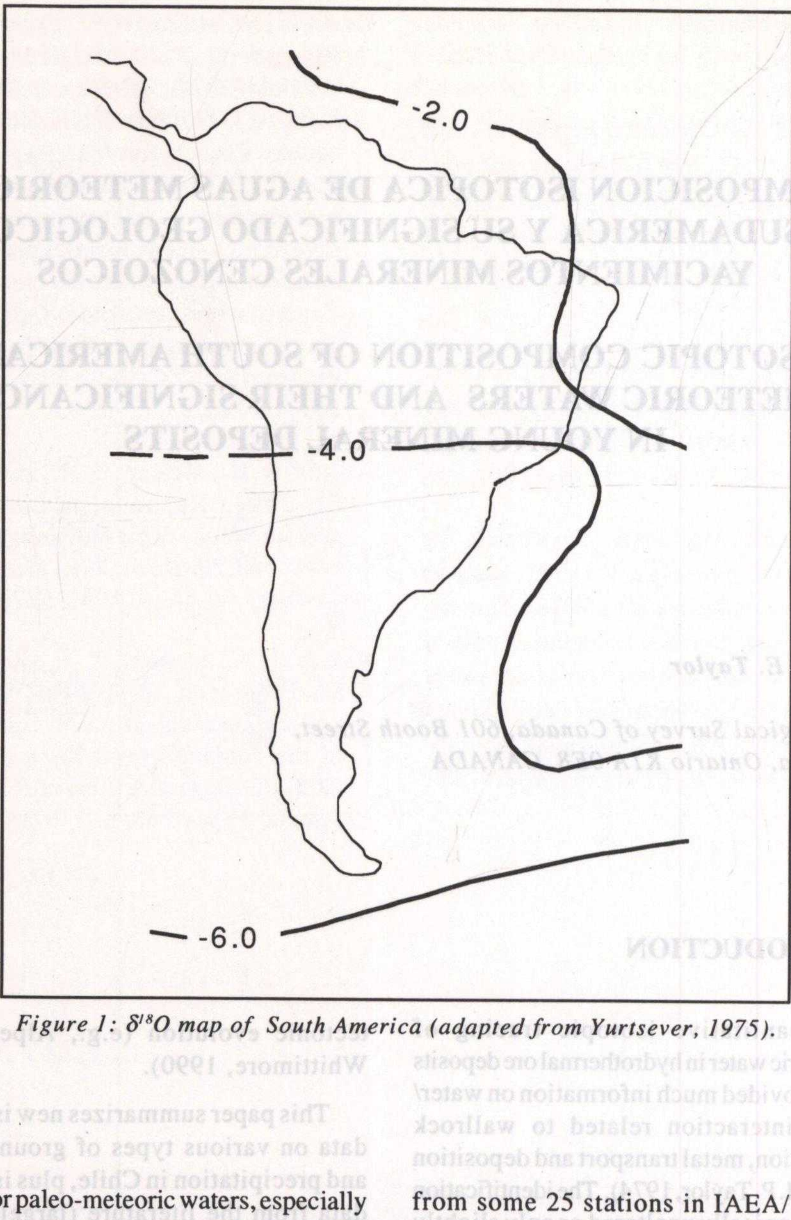

Figure 1: $\delta^{18}O$ map of South America (adapted from Yurtsever, 1975).

maps for paleo-meteoric waters, especially for Tertiary waters, are a matter of current research. These maps will be useful for the study of Tertiary ore deposits, and have particular bearing on the uplift history of the Andes.

A large data base of stable isotopic analyses of surface waters in South America has been gathered over the last three decades (e.g., IAEA, 1992) from some 25 stations in IAEA/WMO a station network. Unfortunately, fewer such data exist for western South America, where most of the isotopic variability occurs. As part of the present study, 36 samples of precipitation and/or shallow ground waters were collected along four different traverses in Chile at approximate latitudes of 44º25'; 42º20', 33º15'; 22º20'. Descriptions and exact locations of the samples will be reported elsewhere.

ISOTOPIC COMPOSITION OF WATERS ANALYZED IN THIS STUDY

The isotopic compositions of 34 newly-collected waters are plotted on a δD-$\delta^{18}O$ diagram in Figure 2. The ranges of $\delta^{18}O$ and δD are -15.28 to 3.33, and -115 to -29, respectively. The majority of these samples plot on or sub parallel to the global meteoric water line ($\delta D = 8\,\delta^{18}O + 10$). The samples plotted in Figure 2 comprise principally springs, but include several samples from rivers and shallow wells. The data are defined by $\delta D = 7.56\,\delta^{18}O - 0.21$, which contrasts with δD-$\delta^{18}O$ relationship for waters from IAEA stations east of the Andes, where $\delta D = 8.27\,\delta^{18}O - 10.13$ (IAEA, 1992). The lower "δ-excess" value ($= \delta D - 8\delta^{18}O$) of -0.21 for the Chilean waters of this study suggests that evaporation has played a relatively more important role in their history than is apparent east of the Andes, where evapotranspiration is pronounced (Salati et al., 1979). In addition, compositionally different atmospheric sources may be involved.

Samples of cold water from the underground workings of the R-T mine, Pampa Norte (elevation, 2900 m), and thermal waters (hot spring, geyser, and stream) from El Tatio geothermal field (which are isotopically similar to the average of Giggenbach, 1978) clearly plot off the global meteoric water line in Figure 2. The shift in composition for the El Tatio samples reflects both evaporation as well as oxygen isotope exchange with hot rocks in the geothermal field. The R-T Mine waters are less easily explained. They may represent older waters that have undergone ^{18}O enrichment in a paleo-hydrothermal system, or were derived from precipitation by evaporation during and/or before infiltration.

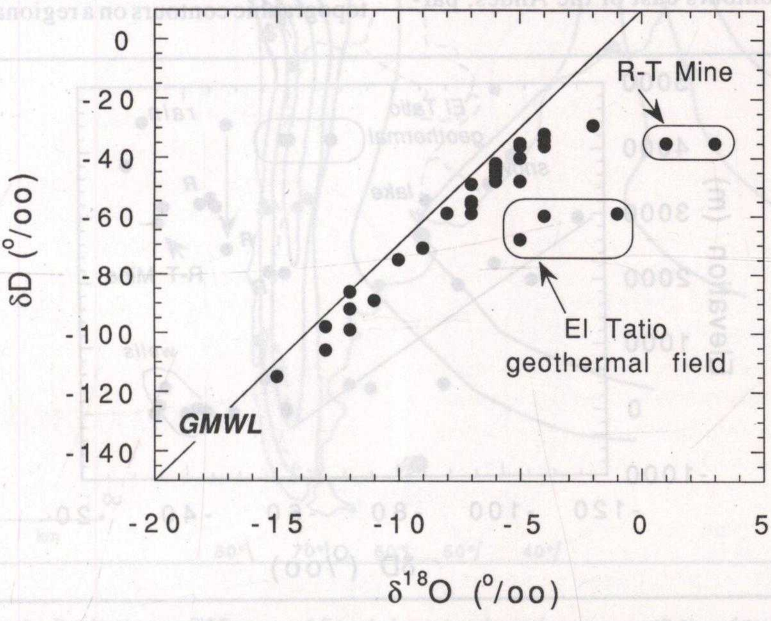

Figure 2. Plot of δD and $\delta^{18}O$ of springs and other types of waters collected in Chile; GMWL = global meteoric water line (after Craig, 1961).

Where springs represent an average of local precipitation, they decrease in δD on the order of 20‰/1000m (Figure 3). The isotopic composition of samples of precipitation (e.g., snow and rain, Figure 3) do not appear to vary systematically with respect to elevation. Whereas springs and shallow ground waters can provide an averaged sample of precipitation, direct samples of precipitation reflect large variations in δD and $\delta^{18}O$ due to evaporation and to "reservoir" effects during precipitation.

δD AND $\delta^{18}O$ MAPS OF SOUTH AMERICAN METEORIC WATERS

Figures 4 and 5 illustrate, respectively, preliminary $\delta^{18}O$ and δD maps for present-day South American meteoric waters. The topology of each map is essentially identical owing to the linear relationship between $\delta^{18}O$ and δD. The wide spacing of the contours east of the Andes, particularly across the Amazon basin, is due in large part to the isotopic effect of recycling of meteoric water by evapotranspiration (Salati et al., 1979). Rain-out (or, amount-effect) may also constitute an important factor as storms move westward, towards the Andes in eastern and central Argentina. The Andes provide an effective hydrologic barrier for the western coast. West of the Andes, the Pacific Ocean provides relatively little moisture (by evaporation) to easterly winds, owing to the cold, north-flowing Humboldt current.

The most obvious feature of the isotopic maps (Figures 4 and 5) is the marked orographic effect of the Andes, which causes a progressive isotopic depletion of precipitation at higher elevations. Some Atlantic moisture is thought to occasionally precipitate on the western slopes of the Andes in northern Chile (Aravena et al., 1989), but this does not disturb the fundamental and general correspondence between isotopic and topographic contours on a regional scale.

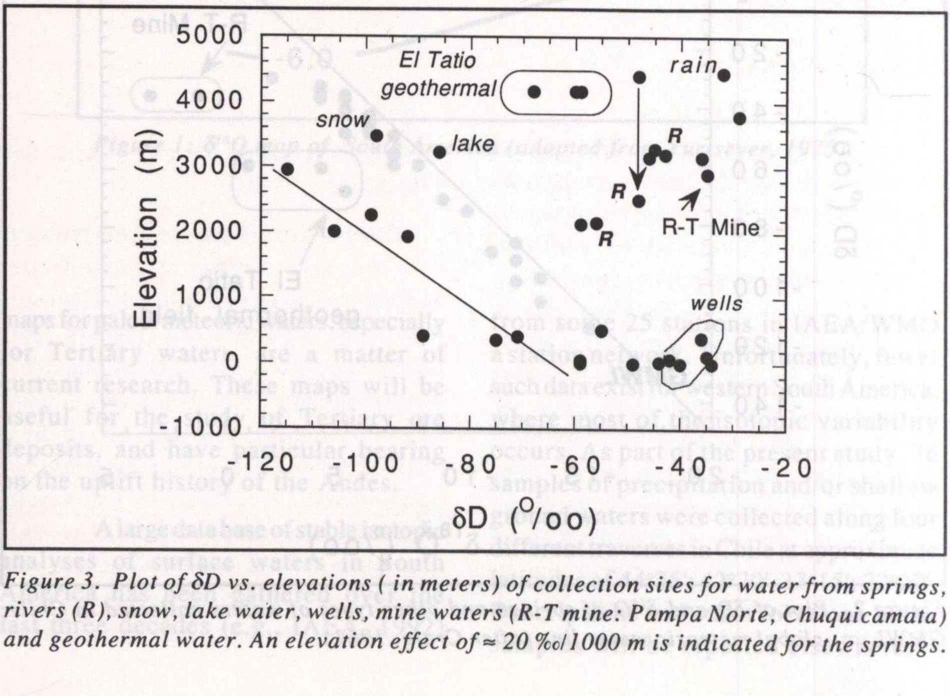

Figure 3. Plot of δD vs. elevations (in meters) of collection sites for water from springs, rivers (R), snow, lake water, wells, mine waters (R-T mine: Pampa Norte, Chuquicamata) and geothermal water. An elevation effect of ≈ 20 ‰/1000 m is indicated for the springs.

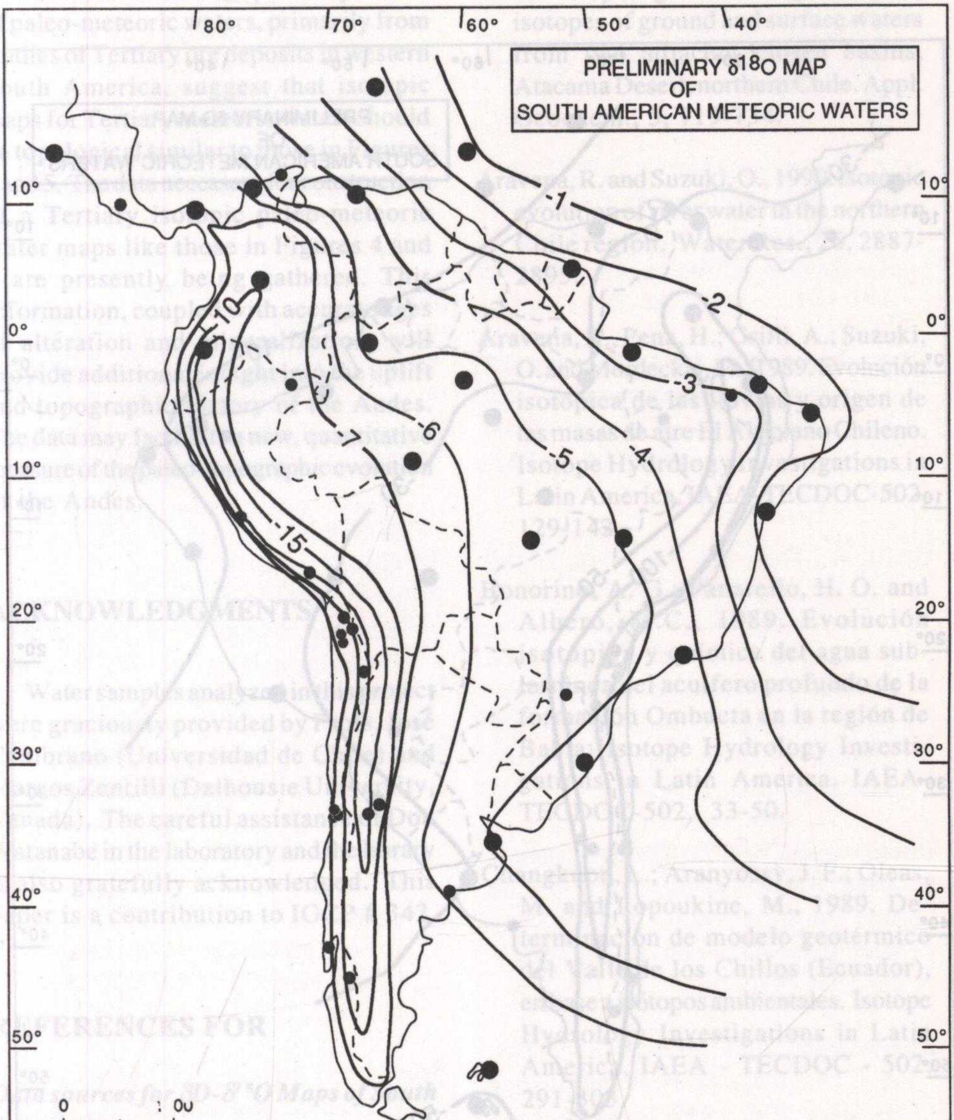

Figure 4. Preliminary $\delta^{18}O$ map of South America based on cummulative data for IAEA stations (large dots; IAEA Tech. Rept. Series, No. 331), and additional data from the present and other studies (small dots; see list of references).

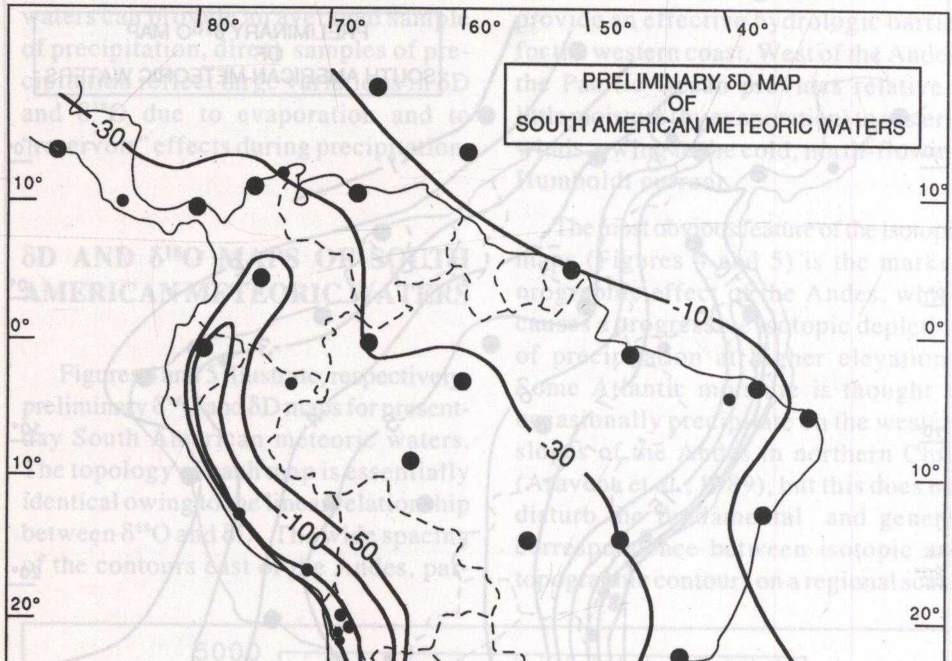

Figure 5. Preliminary δD map for South America. Data sources and symbols as listed in Figure 4.

δD AND $\delta^{18}O$ OF PALEO-METEORIC WATERS AND THEIR TECTONIC IMPLICATIONS

Estimates of the isotopic composition of paleo-meteoric waters, primarily from studies of Tertiary ore deposits in western South America, suggest that isotopic maps for Tertiary meteoric waters should be topological similar to those in Figures 4 and 5. The data necessary for construction of a Tertiary isotopic paleo-meteoric water maps like those in Figures 4 and 5 are presently being gathered. This information, coupled with accurate ages of alteration and mineralization, will provide additional insight into the uplift and topographic history of the Andes. The data may facilitate a new, quantitative measure of the paleo-topographic evolution of the Andes.

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