ENVIRONMENTAL ISOTOPES OF PAMPA DE GAN GAN, NORTH PATAGONIAN MASSIF, CHUBUT

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INTRODUCTION

The area is located in the centre north of the Patagonian Massif. The studies presented in this paper are part of the University of Buenos Aires projects UBACYT X 164 and X 628. The aim of these investigations is to gain a better comprehension of the hydrological system in the area of the Pampa de Gan Gan and the surrounding ranges using environmental stable isotopes (^{2}H and ^{18}O), and to make a first approach to the origin of natural Chubut province, Argentina (42°00'-42°30' S; 69°00'-67°15' W) (Fig. 1).

The region is formed by several elevated ranges and displays a typically broken morphology, dissected by ephemeral streams and creeks ("arroyos"). The surface waters formed temporary and permanent lakes. The highest points are Sierra de Chacays (1400 m), Sierra de Talagapa (1600 m) and Sierra Pire Mahuida (close to 2000 m) (Fig. 1). Gan Gan town is located over an old depressed plain surrounding by those highest ranges. The water circulation from the higher to lower altitudes flows through the fractures in hard rocks and alluvial fans close to the border of the ranges. Spring waters generally flow along the surface or subsurface before they infiltrate through the detrital sediments or basalt flows. Small alluvial deposits cover depressed areas.

Gan Gan town has a phreatic well drilled in alluvial sediments, which provides drinkable water.

The equilibrium of the system is very fragile; the hydrologic balance is usually negative so the evaporation predominates over the inputs (precipitation, stream flow, infiltration and surface runoff). Occasionally, some recuperation of the water lake level is observed during higher rainy years. Infiltration is high due to volcanic rocks fissures and soil characteristics. The insufficient number of water wells reduces the groundwater interpretation of the global area.

The region has a cold arid climate with a dry cold season. Although the region cannot be considered to be homogeneous , the lack of available information allow us to use the few meteorological data which are assumed to be representative for the whole area. However, it is known that a snow cover is common during the winter season. The mean annual precipitation (rain and snow) is frequent below 200 mm, but the distribution is heterogeneous. Precipitation is higher in winter and snow remains until November. Summer is warm and very dry. The mean annual temperature is 13ºC, January being the warmest month (20ºC) and July the coldest (< 5ºC). The region is very windy, predominantly from the West.

The precipitation-evaporation balance is usually negative in summer promoting an increase in the water content of dissolved solids and enrichment in the isotope stable composition.

Precipitation (snow and rain) is the variable contribution to the whole system and local infiltration the only recharge process.

GEOLOGICAL REGIONAL SETTING

The area is emplaced in the Somuncura Massif (Ramos, 1999), Extra Andean Chubut (Fig. 1). On regional scale, the basement consists of metamorphic and igneous rocks of Paleozoic age, and a Mesozoic sequence integrated by volcanic and sedimentary rocks. The marine deposits of the Upper Cretaceous - Lower Tertiary are represented by the Chubut Group and Colonia Formation. The Tertiary magmatic sequence includes in the lower level the basic intrusive bodies of the El Buitre Formation (Ardolino and Franchi, 1993; Ardolino et al., 1995) of Paleocene-Eocene age and olivine basaltic flows with a possible link in age with the intrusive bodies (Bechis, 2003).

The Quiñelaf Super Unit (Oligocene-Miocene) represents the main structure of the range (Franchi et al., 2001). This unit is integrated by basic and mesosilicic lava flows and hipabisal rocks.

The lava flow of the Plan Luan volcano outcrops overlying the deposits of the Colhue Huapense (Sarmiento Group, Simpson, 1941). The volcanic rocks of Plan Luan are Miocene according to Corbella and Barbieri (1989).

Sandstones and conglomerates deposits of Miocene-Pliocene? age (Ardolino, 1987) compose the Pampa Sastre Formation (out of the map).

Alluvial, colluvial, lake deposits and gravity slumps represents the Quaternary stratigraphy.

MATERIALS AND METHODS

During April, 2000, seven water samples were collected from springs, surficial water and groundwater.

Temperature, electric conductivity (CEE) and pH were determined in field by means of a portable conductivimeter, pH meter and the positioning of samples with GPS technology (datum WGS84).

Isotopic analyses were done at INGEIS Laboratories. ^{2}H in water samples was measured by Coleman et al. (1982) procedure and for the measurement of ^{18}O was used the methodology described in Panarello and Parica (1984). Isotope ratios were measured with a multicollector McKinney type mass spectrometer, Finnigan MAT Delta S.

The results are expressed like δ‰ defined as:

$$\delta = 1000 \frac{R_S - R_P}{R_P} ‰$$

δ: isotopic deviation in ‰
S: sample P: international standard
R: isotopic ratio ($^{2}H/^{1}H$; $^{18o}/^{16o}$).

The standard is Vienna Standard Mean Ocean Water (V-SMOW) (Gonfiantini, 1978). The analytical errors were ±0.1‰ and ±1.0‰ for $\delta^{18}O$ and $\delta^{2}H$ respectively.

RESULTS AND DISCUSSION

The spring waters (M4, M7), small streams ("arroyos") M2 and M5, phreatic water from Gan Gan well, Verde (M3) and Gan Gan (M1) lakes were sampled to perform isotope analyses (^{18}O, ^{2}H) (Fig. 1).

The pH shows slightly variations, from 7 to 7.5, only M3 is strongly alkaline, probably related to presence of carbonates. Conductivity ranges from 700 to 1700µS/cm, indicative of low to medium salinity. The water temperature is very cold (Table 1) showing good correlation with the ambient temperature.

Table 1 shows the isotopic values for $\delta^{18}O$, $\delta^{2}H$, conductivity and water temperature of the analyzed samples. In addition, Figure 2 exhibits a scatter plot $\delta^{18}O$ *vs* $\delta^{2}H$ of samples, global meteoric water line (MWL), $\delta^{2}H = 8*\delta^{18}O + 10‰$ (Craig, 1961) and some individual precipitation from Comodoro Rivadavia city. During 1985 some rain samples were collected at this city (Levin et al., 1988). Southwards, the precipitation collector station Los Altares has a very short isotope record, with some $\delta^{18}O$ values (-13.6 to -1.8‰). It belongs to the National Network of Isotopes in Precipitation (RNC) of Argentina and the Global Network for Isotopes in Precipitation (GNIP) (Dapeña and Panarello, 1999; IAEA/WMO, 2002). Today, it is out of service.

Springs, streams and phreatic water show very depleted isotopic values (Table 1; Fig. 2).

The depletion of the heavy isotope content of precipitation as a function of altitude and latitude, designate "Altitude effect" and "Latitude Effect" were defined by Dansgaard (1964) and has been most usefully applied in hydrologic research (Gat and Reitti-Shati, 1999) .

The spring M4 shows the most depleted values ($\delta^{18}O$= -12,9‰, $\delta^{2}H$= -109‰) indicating probably higher altitude. M5 and M2 have values also depleted ($\delta^{18}O$= -11,1‰, -10,5‰) but lower than M4 probably showing different altitude recharge or a selective precipitation. The Gan Gan well has $\delta^{18}O$= -12,4‰ and reflects the mixing from waters coming from the surrounding ranges.

The lake waters have the most enriched isotope values indicating high evaporation. They fit on an evaporation line: $\delta^{2}H$=5,4; $\delta^{18}O$= -31,5.

These evidences support the idea that meteoric waters are the main source of recharge for surficial waters and groundwater. Local meteoric rainwater could play a minor role by direct infiltration through fractured volcanic rocks. In addition, the snow cover represents an important water source.

CONCLUSIONS

We propose that the main sources of recharge are related of the phreatic level in Gan Gan are related to meteoric waters, which isotopic composition represents the mixing of snowfall or rainfall in the higher levels of the surrounding ranges. The different values obtained for different points of the hydrological system are closely related to "Altitude Effect" and "Latitude Effect". Evaporation is mainly represented in lakes by large isotopic enrichment.

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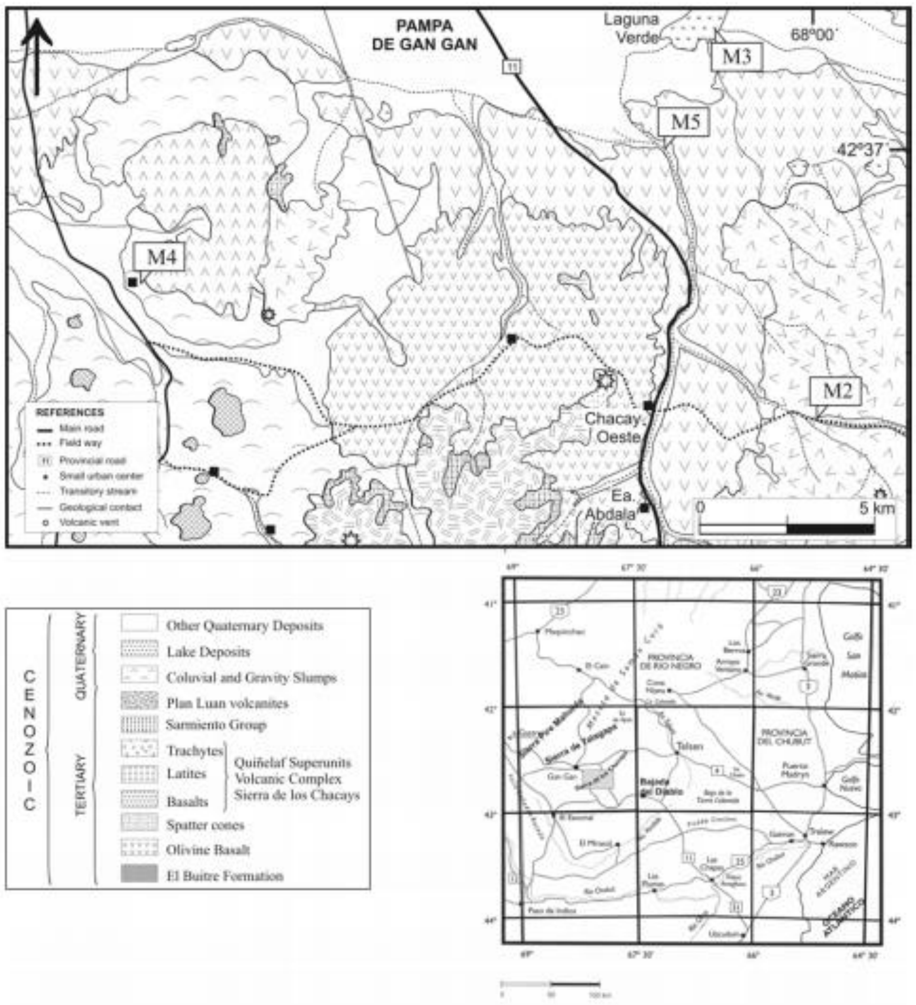

Figure 1. Location area (dashed) and geological map (adapted from Bechis, 2003).

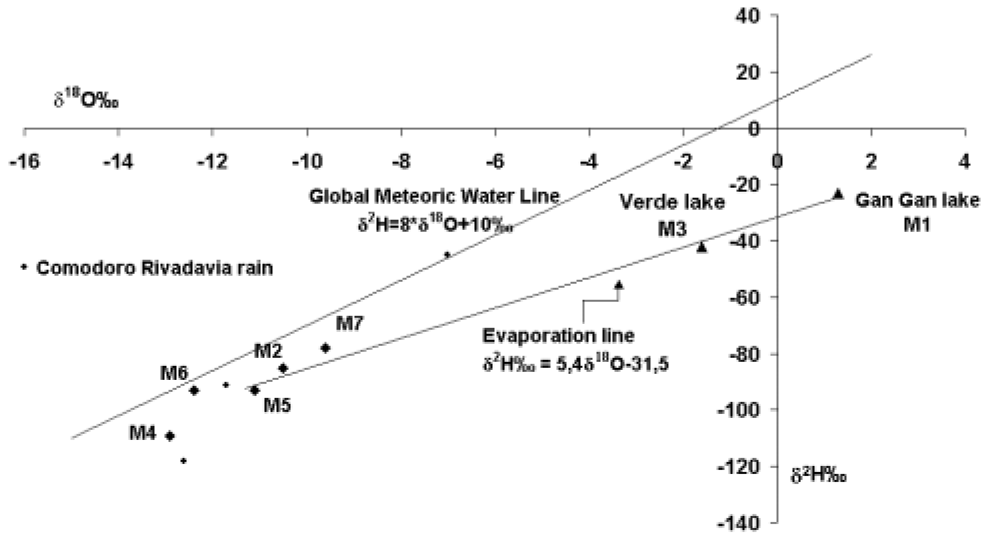

Figure 2. Scatter plot $\delta^{18}O$ *vs* $\delta^{2}H$.

Table 1. Location, water temperature, conductivity, isotope values.

# Lab	Sample	Latitude	Longitude	$\delta^{18}O \pm 0.1‰$	$\delta^{2}H \pm 1‰$	T °C	CEE µS/cm
11531	M1	42°31'15"	68°16'45"	1.3	-23	7.0	700
11532	M2	42°40'44"	68°00'30"	-10.5	-85	9.1	700
11533	M3	42°30'35"	67°58'22"	-1.6	-42	5.9	1700
11534	M4	42°39'05"	68°14'08"	-12.9	-109	8.7	600
11535	M5	42°37'21"	68°03'20"	-11.1	-93	7.6	1300
11536	M6	42°21'52"	68°17'18"	-12.4	-93	9.6	700
11537	M7	42°53'16"	67°29'17"	-9.6	-78	7.2	1200