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Geochemical mechanisms controlling the chemical composition of groundwater and surface water in the southwest of the Pampean plain (Argentina)

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ABSTRACT

The Pampean plain is one of the most extended regions of the world. In this plain there are numerous shallow lakes that have different origins associated with climate changes at the end of the Quaternary period. Chasicó Lake is the main waterbody in the southwest of the Chaco-Pampean plain. It shows some differences from the typical Pampean shallow lakes. The aim of this paper is to explain the geochemical process that determines the chemical composition of the water of Chasico Lake. The results show that the groundwater is sodium bicarbonate type. Chebotarev's diagram indicates that the catión-exchange takes place in groundwater. The surface water of Chasicó Lake is sodium chloride type. Gibbs's diagram shows that the geochemical processes that affects the Chasicó Lake are evaporation and crystallization, being the water of the lake similar to seawater. The BEI (Base Exchange Index) shows that the process of cation-exchange in the water is not relevant. As, F and V concentrations were studied in surface and groundwater showing significant correlations in groundwater between As vs. F ($r = 0.99$, $p < 0.05$), As vs. V ($r = 0.99$, $p < 0.05$) and V vs. F ($r = 0.99$, $p < 0.05$), while in surface water it was only found for As vs. F ($r = 0.91$, $p < 0.05$). The As, F and V concentration values were higher and more widely dispersed in surface water than in groundwater, as a consequence of evaporation. The fact that these elements do not correlate in surface water may also indicate a different origin.

1. Introduction

The Chaco-Pampean plain is one of the most extended regions of the world. The development of wetland systems and very shallow lakes (Iriondo and Drago, 2004) have a straight relationship with the climate and geomorphology of the region, which play a significant role in the overall hydrological cycle of the Buenos Aires province (Argentinean Southern Pampa).

Pampean shallow lakes have various origins associated with climate changes at the end of the Quaternary period, but without lakes as predecessors, including deflation by eolian action and tectonic action, or abandoned fluvial beds, isolated lagoons, and old estuaries (Iriondo et al., 2009). These shallow lakes show typical profile of "*pfanne*" or "*wanne*" (Miretzky et al., 2001). These shallow lakes are alkaline ecosystems, with circulation patterns characteristic of polymictic lakes (average depth of 1.5 m). This implies nearly continuous vertical mixing promoting high concentration of suspended particulate matter and low transparency. The water column is almost always thermally homogeneous and saturated with dissolved oxygen, and is characterized by a high content of dissolved organic matter, mainly humic substances (Conzonno and Fernandez Cirelli, 1987, 1988). The Pampean sediment, known as Pampean loess, has volcanic pyroclastic origin. Based on the description of Teruggi (1957), the sand fraction of the Pampean loess is formed by plagioclases, alkaline feldspar, intermediate feldspar (andesine), as well as by volcanic litoclasts, quartz, and volcanic glass. The composition of the silt fraction is similar to the sand fraction, but contains a great amount of fresh and altered volcanic glass shards. Montmorillonite is the clay mineral in this region. Calcium carbonate is also found in the Pampean loess as calcite (8%). Cation exchange capacity of loessic sediments plays an important role in determining the chemical evolution of groundwater (Miretzky et al., 2000), which is strongly associated with Pampean shallow lakes, as reported by Fernández Cirelli and Miretzky (2004).

The Chasicó Lake is the main water body in the southwest of the Chaco-Pampean plain. It shows some differences from the typical Pampean shallow lakes, namely, its tectonic and eolic origin, greater depth, and high salinity (Volpedo and Fernández Cirelli, 2013).

The elevated concentrations of As and F in surface waterbodies (Puntoriero et al., 2014; Rosso et al., 2011a, 2011b) and in groundwater (Alarcón-Herrera et al., 2013; Nicolli et al., 2012) that were reported in the region, suggest that there may be a relationship between surface water and groundwater. However, in these regions the geochemical

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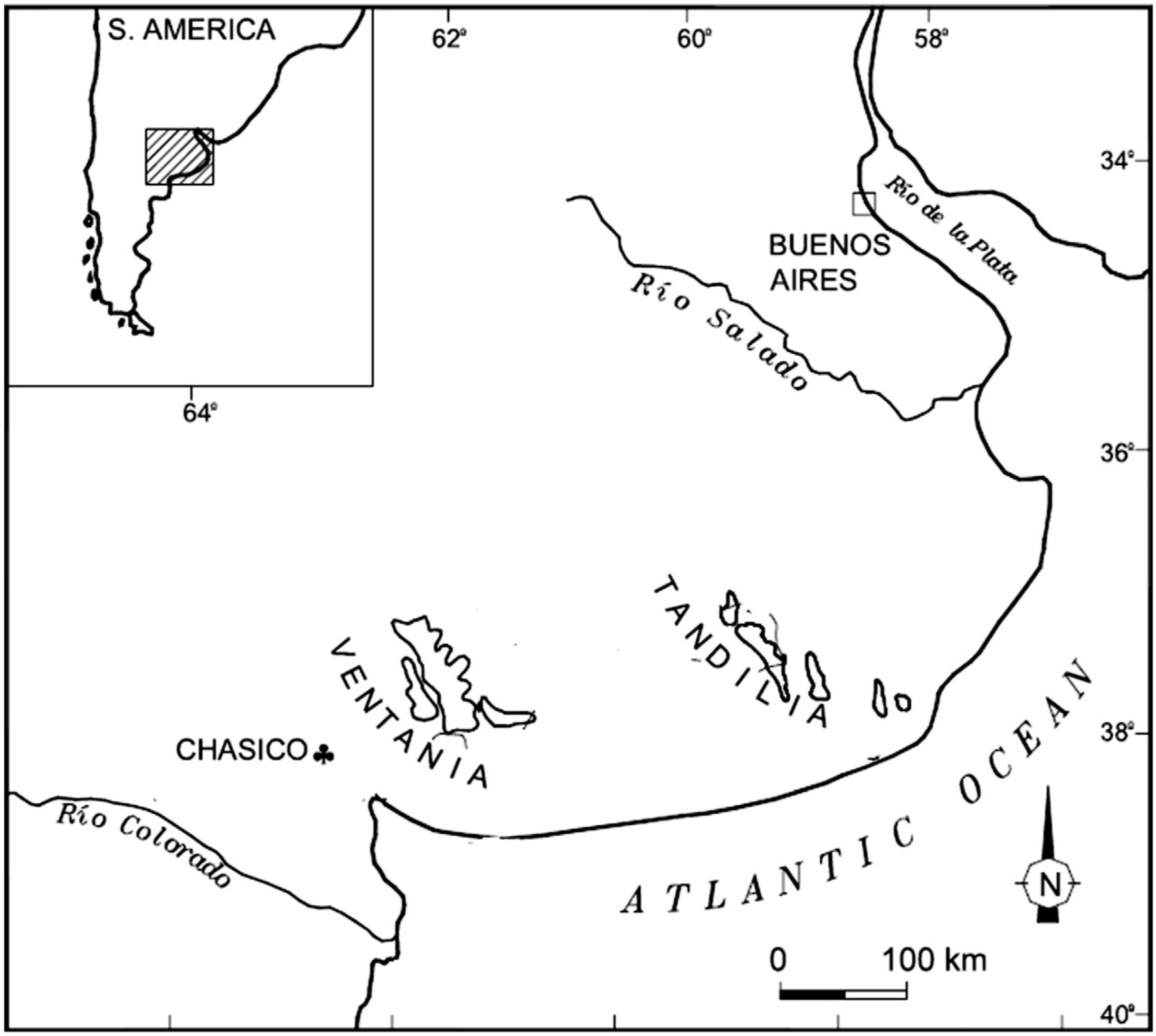

Fig. 1. Chasicó Lake location.

processes that explain the chemical composition of Chasico Lake were not studied.

The geochemical processes that may explain the composition of surface water in Chasicó Lake are analyzed and discussed in this paper and compared with those occurring in the typical pampasic shallow lakes (pampasic ponds).

2. Study area

The Chasicó Lake is an endorheic system that receives the waters of the Chasicó Stream and drains into the Ventania system (Fig. 1). It is placed on a tectonic belt located more than 20 m below sea level, on southwest slopes of the orographic Ventania system. This strip extends in a northwest to southeast direction, parallel to the tectonic pit inside which is located the Colorado River. The late Tertiary succession of the southern Pampean region comprises an extensive plateau capped by a thick calcrete crust, which in turn is covered by a thin apron of late Pleistocene–Holocene eolian deposits (Zárate et al., 2007). Geologically, in the Quaternary period, the sea ingression and regression left ancient salts.

The lake recharge occurs from direct precipitation, groundwater system and surface runoff from a reception basin of 3764 km^2 (Bonorino et al., 1989).

The area of the Chasicó Lake was of 31 km^2 in 1963, increased to 85 km^2 in 2003–2004, and decreased to 50.3 km^2 at present (Remes and Colautti, 2003). This may be the result of natural periods of flooding and drought, which were reflected in salinity and aquatic biota changes. The average maximum depth of this water body is 16 m.

3. Sampling and analytical methods

3.1. Sampling

Water was sampled in March (wet period) and August (dry period) during 2010 and 2011 (Fig. 2). The values of precipitations and temperature in both periods were: wet period 2010: precipitations: 120.8 mm, temperature: 26.6 °C and 2011: precipitations: 109.3 mm, temperature: 27.3 °C; dry period 2010: precipitations: 3.9 mm, temperature: 16.3 °C and 2011: precipitations: 3.7 mm; temperature: 15.9 °C (Servicio Meteorológico Nacional, 1992). The samples were taken from the surface of the pelagic zone of the Chasicó Lake and from the Chasicó Stream ($N = 10$). Groundwater samples ($N = 10$) were collected from wells (average depth of 7-15 m, depending on the specific construction characteristics) used for human consumption in the Chasicó locality, and from the forest center "Alexander Humbold" (depth of 650 m) (S 38°38.826 W 63°01.114) (Fig. 2). Groundwater of the latter is of geothermal origin. Samples were taken in triplicate, filtered through a