Preliminary results on hydrogeochemical processes at Pica thermal groundwater (North of Chile)

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Abstract. Pica Oasis is located in the Atacama Desert at 1400m.a.s.l., in the most arid place in the world. A rate of 10 mm/year average rainfall and a higher rates of evaporation (150-250mm/month) cause a deficit between precipitation and evaporation.

The main aquifer is related to fractured Oligocene units which low-moderate permeability, and the presence of the thermal springs is due to fracture systems presents (Scheihing *et al.*, 2017).

Pica economy is dependent from groundwater due to surface water lack and it is used for human consumption, agriculture and mining purposes. In addition thermal groundwater has a balneological use.

In the last 15 years, piezometric levels decreased up to 2m. Salinity increase indicates a water stress, probably due to precipitation-evaporation deficit, overexploitation and pollution processes related to the agriculture activity. The high NO_3^{2-} values measured, up to 714 ppm, show a clear anthropic influence in the Pica area hydrogeochemistry.

During winter 2016, 30 samples were collected at Pica and Salar de Huasco area. Sampled points are wells, springs and surficial waters. Pica's thermal spring show the lowest values of EC that range between 324 and 8780µS/cm. Temperatures are between 12.7ºC (Salar del Huasco) and 31.7ºC (Pica Thermal water) and pH interval is 6.8-8.8. The water types are SO4-Na, Cl-Na and some HCO3-Na. The hierarchical cluster analysis indicates 3 groups. G1 group includes thermal springs, the samples are the most diluted and mainly Na-SO4 water type and show a Na-HCO3 trend from to Na-SO4 water type, wich could be related atmospheric precipitation. G2 is formed by waters with the higher average values of TDS with Na-SO4 water type, and the evaporation process is predominant together with the agriculture pollution. G3 is formed by waters with concentrations between G1 and G2. Hydrogeochemistry of G3 show water-rock processes as source of the ionic composition.

Keywords: Pica Oasis, Salar del Huasco, thermal springs, hydrogeochemical processes.

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Preliminary results about hydro-geochemical processes in the Pica thermal springs (North of Chile)

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Keywords: Pica, Salar del Huasco, spring system, hydrogeochemical.

1. Introduction

Nowadays hot springs have several uses: aquaculture, agriculture, bottled water, industrial processing and extraction of rares elements. Due to the boom of natural medicine, uses like balneotherapy has granted significance to hot springs. This way and having under consideration the propper use of springs like a sustainable natural resource, the hydrotherapy can contribute to the development of the local and regional economy.

Located at the Atacama Desert, The Pica oasis is one of the most arid desert of the world, with an average precipitation of 10 mm/year under de 2000 masl. Since prehispanic ages Pica has been a human settlement that holds his development using underground waters due the absent of the surface waters courses. The main uses of underground water are human consumption, agriculture and mining, meanwhile the hotsprings are used recreationally.

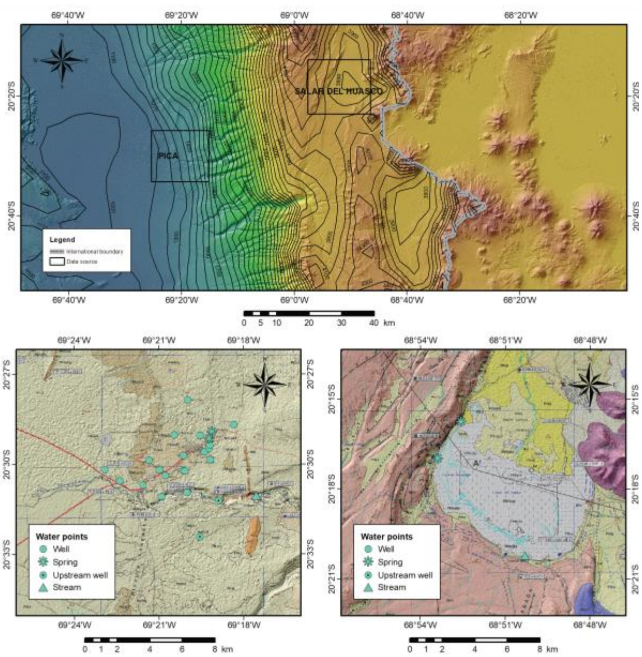

Figure 1: Geology map

The regional morphologic setting can be subdivided in to 3 main geological units. These are the Pampa del Tamarugal, followed east by the Precordillera and the Antiplano Plateau. The area is dominated by alternating Jurassic to Quaternary strata of thick continental sedimentary rocks such as conglomerates and sandstone, and minor horizons of felsic volcanic rock. Cretaceus to Eocene plutonic rock intrude section of de Mesozoic basement (Blanco and Landino, 2012).

The goal of this work is to analyze the hydrogeothermal system and identify the physiochemical processes and peculiarities of the waters, in this manner promoting the value of the oasis and generating useful tools to improve the development of the special tourism.

2. Methodology or Chapter 1

During the end of winter of 2016, 27 samples were collected, 5 springs, 2 surface waters and 20 underground waters, from which 2 are upstream in the Pica oasis and Salar del Huasco, located at 1400 and 3800 masl, respectively.

We measured in situ physical properties as temperature, pH, electrical conductivity and redox potential. Geochemical analisys of major, minor and trace elements, were performed in the laboratories Andean Geotermal Centre of Excellence (CEGA). ions were determinated by Ion Chromatography (IC, Dionex ICS 2011), cations by Atomic Absorption Spectrophotometry (AAS, Perkin-Elmer Pinaacle 900F), B and Li by Inductively Coupled Plasma Mass Spectrometry (ICP-MS, Thermo iCAP Q), Silica by Portable Photometer (Hanna HI96705), Bicarbonate by Volumetric Titration using Giggenbach and Goguel (1989) finally $\delta^{18}O$ and $\delta^{2}H$ by Finnigan Delta Plus XL mass spectrometer. Isotopes were measured in the Estación Experimental de Zaidín, Spain.

The geostatistical method used in this investigation is factorial hierarchical cluster (HCA). And the data obtained from HCA is visualized as a dendogram.

3. Results

3.1. Hydrogeochemical

At the field works near of 30 spots of water were sampled at the sites of Pica and Salar de Huasco. The sampling spots are springs, river and most of all wells. The electro-conductivity (EC) fluctuates among 324 and 8780 µS/cm, the samples of Pica's thermal spring show the lowest values of EC. The temperatures are between 12.7 and 31.7 Celsius degrees, respectively to springs of Salar de Huasco and Pica. The pH ranged between 6.8 to 8.8. The most abundant hydrochemical types are Na-SO4 and Na-Cl, also appearing some Na-HCO3 ones.

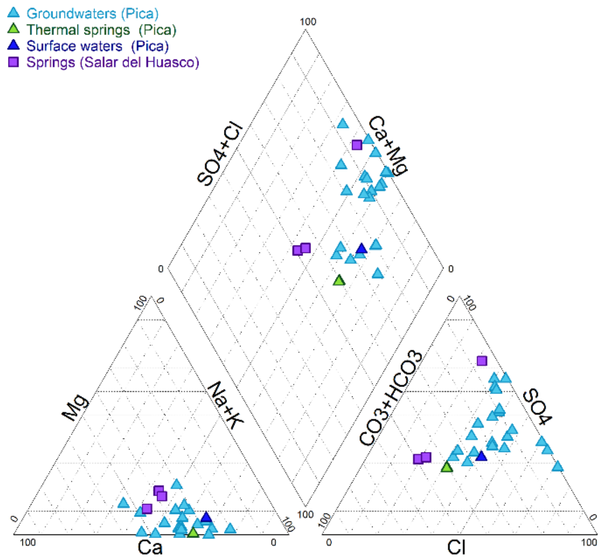

Figure 2: Piper diagram.

In the HCA (Fig. 3) we recognized 3 principal groups (G1, G2 and G3). The cluster G3 includes the thermal springs and the samples are the most diluted, having the lowest concentration of Cl, SO4, Br, NO3, HCO3, Na, K, Ca, Mg, B and Li. Meanwhile, the cluster G2 includes samples with the higher values of these ions, except for HCO3. The cluster G1 includes the springs of Salar del Huasco and two samples of a surrounding creek to South of Pica, the water types are from Na-HCO3 to Na-Cl and showing intermediate concentration of major elements.

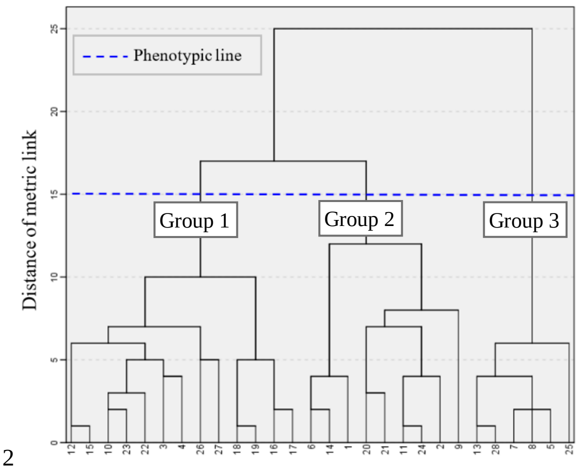

Figure 3: Dendogram using Ward's link.

In Fig. 4, total molar cation/Cl ratios vs. TDS in groundwater, shows the importance of evapotranspiration in high salinity groundwater. This plot shows that groundwater with TDS concentration >1,200 mg/L, the molar cation/Cl ratios are relatively low (~3.0-5.0), showing the dominant role of evapotranspiration in control the chemistry of Group 2's waters.

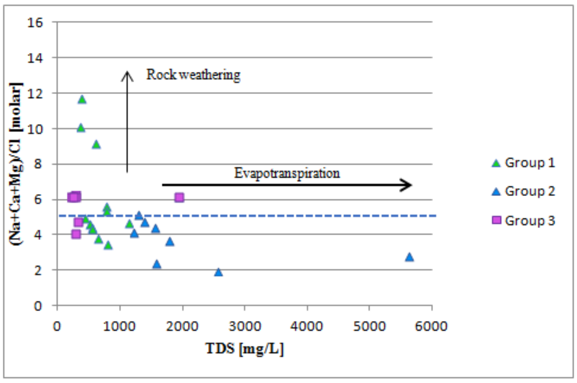

Figure 4: Molar cation/Cl ratios.

The Gibbs plot (Fig. 5) showing TDS vs ratio (Cl+HCO3)/Cl. In the diagram, medium TDS and lower ratio points the control of rock weathering (Group 1), and high TDS and higher ratio (close to 1) indicates the influence of evaporation and crystallization (Chen, 1987).

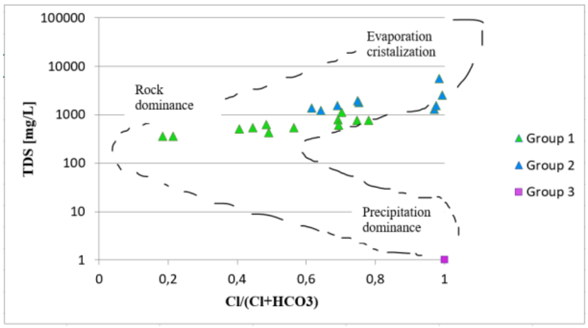

Figure 5: Gibbs plot.

3.2. Isotope composition

We can distinguish three groups, the first one has values of $\delta^{18}O$ between -13.6 to -12.0‰ and of -105 to -95‰ for δD. The second group has values of $\delta^{18}O$ between -12.0 to -10.0‰ and of -100 to -85‰ for δD. The last group values ranged from -11.2 to -7.0 for $\delta^{18}O$ and from -75 to -65‰ for δD.

Plot of $\delta^{2}H$-$\delta^{18}O$ showing the conceptual model of evaporative isotope enrichment for a nonseasonal climate with constant monthly evaporation rate (Craig, H. and L. Gordon, 1965).

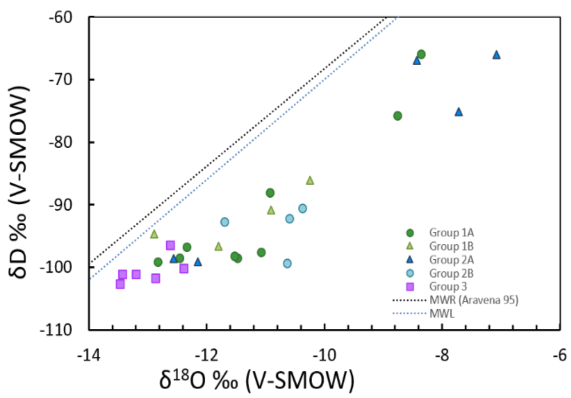

Figure 5: Plot of stable isotopes.

Conclusions

The thermal springs are located near the traces of the Chintaguay and Longacho flexures, in the Tarapacá Region.

The physical and chemical characteristics of the Pica waters define three main domains. The G3 group, the diluted waters, where the main process could be precipitation. Group 2 would correspond to the waters with the highest dissolved solids, in which the evaporation process would be one of the main ones. And group 1 is made up of waters with concentrations of solids between G2 and G3, and the weathering of the rock would influence mainly the waters.

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