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Geothermal water in the San Juan Bautista Londó aquifer, BCS, Mexico

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Abstract

The San Juan Bautista Londó aquifer, with an extent of 593 km^2, is the major source of potable water for the City of Loreto. The San Juan Bautista Londó Basin was an important agricultural area in the seventies but despite over-exploitation, a significant reduction of agriculture activity took place. Previous studies indicated that the composition of thermal water in Concepcion Bay, Guaymas Basin vents, and deep circulation water from Las Tres Virgenes near Santa Rosalia show little variation. Their composition and typical ocean water were compared to water samples from different wells, located in the San Juan B Londó watershed. Based on cluster analyses, five different groups of groundwater were separated which represent seawater, the geothermal end-member, groundwater with a stronger geothermal component, groundwater with a certain geothermal influence, and groundwater without a geothermal influence.

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Keywords: The San Juan Bautista Londó aquifer, shallow geothermal water, cluster analyses.

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1. INTRODUCTION

Over exploitation is a phenomenon that occurs in many watersheds in the State of Baja California Sur and in case of the San Juan Bautista Londó aquifer, the problem is known since the seventies. All studies agree that there is an annual deficit in groundwater balance, estimated between 0.8 Mm^3 and 2.9 Mm^3, which caused a decline in aquifer pressure of 0.6 meters per year [1]. The main problem of over pumping a coastal aquifer is sea water intrusion but recent studies postulate that the San Juan Londó aquifer is not

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affected by direct salt water intrusion [1] but lowering the groundwater table under sea level provoked an up-flow of deeper groundwater, which had a negative impact on groundwater quality. Prol-Ledesma, and Ortega [2] suggested the existence of a thermal component in the groundwater of the San Juan Londó Valley.

In order to verify the hypothesis that there is no marine intrusion into the SJL aquifer but an increase of the thermal component in the aquifer, we analyzed the groundwater quality and compared the actual hydro-chemical conditions with the situation documented by UNAM in 1986 [3] and by Lesser in 2006 [1]. The main objective was to understand the salinity increase in the groundwater of the San Juan Bautista Londó watershed and to identify the processes and chemical reactions involved.

2 GEOGRAPHICAL AND GEOLOGICAL SETTINGS

2.1 Description of the San Juan Bautista Londó watershed and economy of the area

The San Juan Bautista Londó watershed with an extension of 593 km^2 is the major source of potable water for the City of Loreto. It is located approximately 30 kilometers to the northwest of Loreto and distributes groundwater throughout the communities Loreto and Nopolo [4]. Loreto is a town of about 10000 inhabitants and the seat of the municipality of Loreto in the Mexican state of Baja California Sur. The town and surrounding area depend heavily on tourism, focused mainly on sport fishing; more than 60,000 tourists visit Loreto each year [4]. The economy of Loreto is expected to experience strong growth in the coming years, based on tourism and real estate development. The San Juan Bautista Londó Basin was an important agricultural area in the seventies but a significant reduction of agriculture activity took place and recently many water rights were transferred to provide the water, needed for tourist projects in the Loreto area.

2.2 Occurrence of thermal water in and near the study area

Prol-Ledesma and Ortega [2] observed elevated temperatures of more than 40°C in some groundwater wells, located in the San Juan Londó Valley and concluded that there is a thermal component in the groundwater that is related to high concentrations of chloride and low concentrations of magnesium. There are several sites near the study area, where hydrothermal activity can be observed. Hydrothermal activity occurs along faults, which are probably related to the Tertiary extensional tectonics of the Gulf of California. Deep submarine hydrothermal activity can be found at a distance of about 100 km to de SJL aquifer, in the center of the Gulf of California; in the Guaymas Basin the vents of an active spreading center are connected to the East Pacific Rise, the location has been extensively studied [5, 6]) (Fig. 1). In Concepción Bay, at a distance of 50 km to the north from the SJL Valley, shallow submarine hydrothermal activity has been described [7, 8, 9]. Here diffuse and focused hydrothermal venting of water and gas occurs in intertidal and shallow submarine areas at 15 meters below sea level along a NW-SE trending fault. The temperature varies from 50°C at the sea bottom up to 87°C at a depth of 10 cm in the sediments. The thermal water is enriched in Ca, As, Hg, Mn, Ba, HCO_3, Li, Sr, B, I, Cs, Fe and Si with respect to seawater [9]. Prol-Ledesma et al. [7] define the thermal end-member composition using a mixing model between the two components: local seawater and thermal water.

3 METHODOLOGY

The Na–K–Mg diagram after Giggenbach [10], which indicates the suitability of thermal waters for the application of ionic solute geothermometers, was used to classify samples into fully equilibrated, partially equilibrated and immature waters. The diagram also allows estimating temperatures at which water-rock equilibrium of the geothermal water took place, during the rise towards the surface [11]. The composition of the geothermal end-member and the composition of ocean water were compared to water samples from different wells, located in the San Juan B Londó watershed. Multivariate data analysis was useful to define the chemical and hydrologic contributions from the end-member sources in the composition of the groundwater. The data set included samples from 15 wells, taken in 2006 and 2007. Cluster analysis was used to classify the samples into distinct groups. Parameters which are highly correlated (>99.9%) to at least one other parameter in the data base and variables with insufficient number of measurements above the limit of calibration were excluded. From the 41 hydrochemical variables in the data-base the variables Ca, Mg, Na, K, Cl, SO_4, HCO_3, SiO_2, F, B, Ba, As and Sr were finally used in this analysis.

4 RESULTS AND CONCLUSIONS

The state of equilibrium and temperatures of water-rock interaction can be visualized in the Na-K-$\sqrt{Mg}$ diagram after Giggenbach [10]; the thermal end-member is located in the region of full equilibrium at a temperature of 225°C, whereas the three samples from San Juan Bautista Londó Aquifer, recognized as groundwater with a strong geothermal component, lay in the field of partial equilibrium; the theoretical line of equilibrium state points to a temperature of approximately 160°C (see Fig. 2). This is higher than the equilibrium temperature of about 120°C in Concepcion Bay, calculated with chemical geothermometers by Villanueva-Estrada et al. [9]. Based on the cluster analysis (Fig. 3), five different groups of groundwater were identified: 1) Sea water, 2) the geothermal end-member, 3) groundwater with a strong geothermal component, 4) groundwater with a reduced geothermal influence and 5) geothermal unaffected groundwater. Another important observation is the elevated contents of arsenic, fluoride and boron in thermal water, but only boron in seawater.

The observed composition of the geothermal component in the study area coincides with the typical geothermal reservoirs in Concepcion Bay, Guaymas Basin vents, and deep circulation water from Las Tres Virgenes near Santa Rosalia. Seawater intrusion occurs not only at the coast but also in the central part of the watershed; up to 5 per cent seawater was found in one well. The major risk in this aquifer is therefore the contamination by up-flow of thermal water due to over-exploitation and in minor degree seawater intrusion. In order to reduce groundwater contamination, the extraction rates must be reduced and additional drinking water sources have to be found.

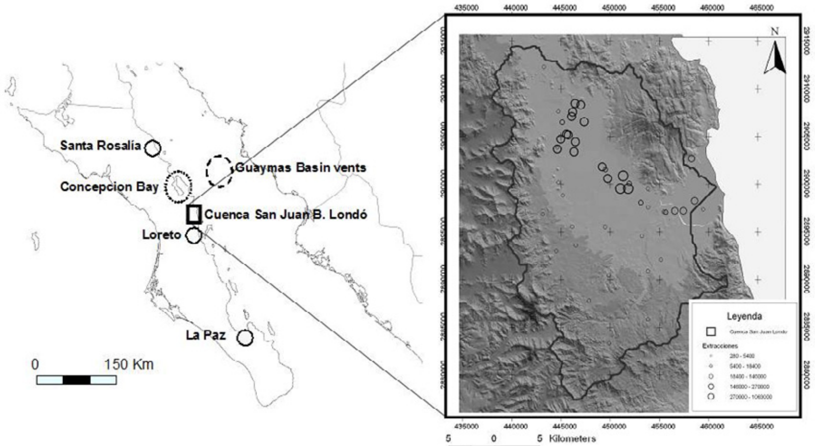

Fig. 1 (a). Sketch map of the Mexican State of Baja California Sur and the main locations mentioned in the text; (b) sketch map of the San Juan Bautista Londó aquifer and the main wells and extraction rates (cubic meter per year).

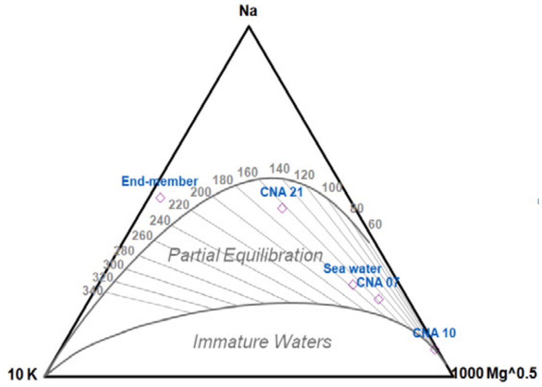

Fig. 2. Na–K–√Mg triangular diagram (Giggenbach, 1988) with three groundwater samples in the field of partial equilibrium.

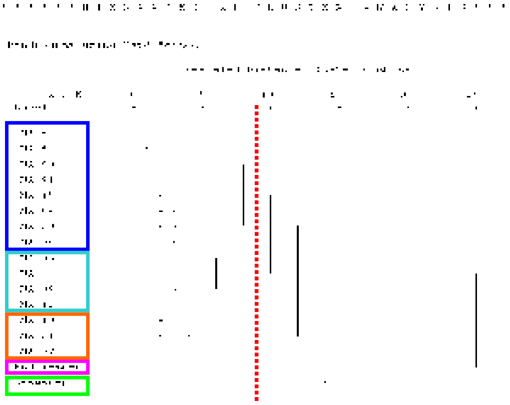

Fig. 3. Dendrogram in q-mode of groundwater analyses separated in five clusters.

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