GEOCHEMICAL AND ISOTOPIC EVALUATION OF
SAN MARCOS GEOTHERMAL **AREA.** GUATEMALA.

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ABSTRACT

San Marcos Geothermal Area lie in San Marcos Caldera (Pleistocene age), an elliptic depression with axis about 13 and 9 km, in the western part of the country.

Chemical and isotopic analyses were made to 60 **spring** samples with surface temperature range from 15 "C to 95 "C (boiling point in the area) and two river samples were chemically analyzed.

Results show that there are two different reservoirs; a deeper one with subsurface temperature around 250 "C (chloride content = 600 mg/l) and a shallower one with subsurface temperature close to 200 "C (chloride content = 500 mg/l). Chemically the waters are of three types; sodium chloride, calcium bicarbonate and a mixture between them. Isotopically the sodium chloride water seems to be a mixture of 76 % meteoric water and 24 % andesitic water.

Previous gas analyses confirm underground temperature and magmatic origin of the water.

1.0 INTRODUCTION

San Marcos Geothermal area is about 250 km to the northwest from Guatemala City by road, close to the Mexican border (Figure 1), around the San Marcos Town. It's elevation ranges from 4,200 masl in Tajumulco Volcano to 1900 masl in La Cimarrona, were some hot springs are located. The annual mean temperature is 1.3.8 "C, and the rainfall is between 2,000 and 4,000 mm per year. Hydrologically the area is in Rio El Naranjo basin.

In 1981 OLADE (1982) madearegional study to define geothermal potential areas in Guatemala, **As** result of this study there were identified 13 areas of interest; San Marcos **was** classified in **A** group or priority one. After that Giggenbach (1986) made a preliminary geochemical **study** in the area, concluding that there is a geothermal reservoir of **high** enthalpy.

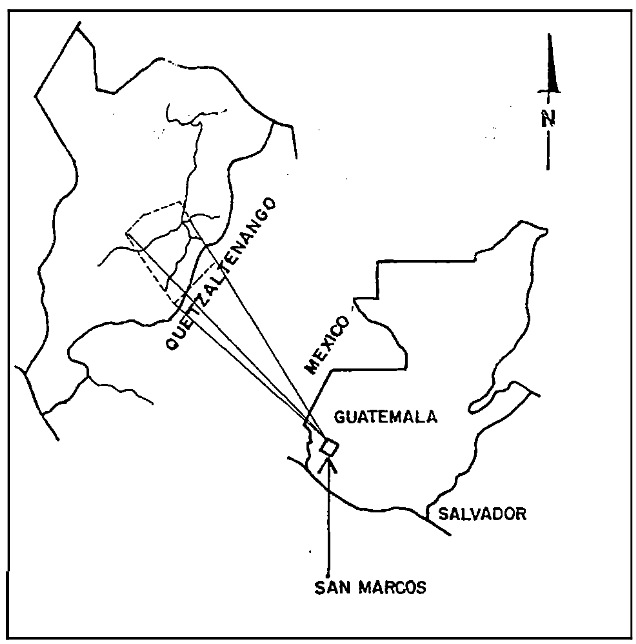


Figure 1. Location map of San Marcos Geothermal area.

2.0 GEOLOGY

Geomorphologically, the area is in the San Marcos Caldera, originated in the late tertiary, lower Pleistocene, wich is an elliptical depression with axis 13 and 9 km long, located close to the pacific border of the Caribbean Plate. It's last eruption of pyroclastic flows is dated < 100000 years, all the products have evolved from dacite to rhyolite since they are the result of fractionated crystallization process that took place inside superficial magmatic chambers.

The basement is a regional intrusive made up of diorite and is cover with volcanic products. Tertiary volcanites are lava layers with subordinate pyroclastites and lahares. The overlying quaternary products are mainly ignimbrites, lahares and breccias.

In addition to the **main** ring faults associated with the **San** Marcos Caldera, there are three systems of directional faults, trending east-west, north west-southeast and northeast-southwest, on the other hand, the caldera is located between two of the litospheric segments that cut through the pacific ridge of the Caribbean Plate.

3.0 WATER CHEMISTRY

Based on Piper diagram (Figure **2),** waters from **San** Marcos geothernial area are classified in three different types:

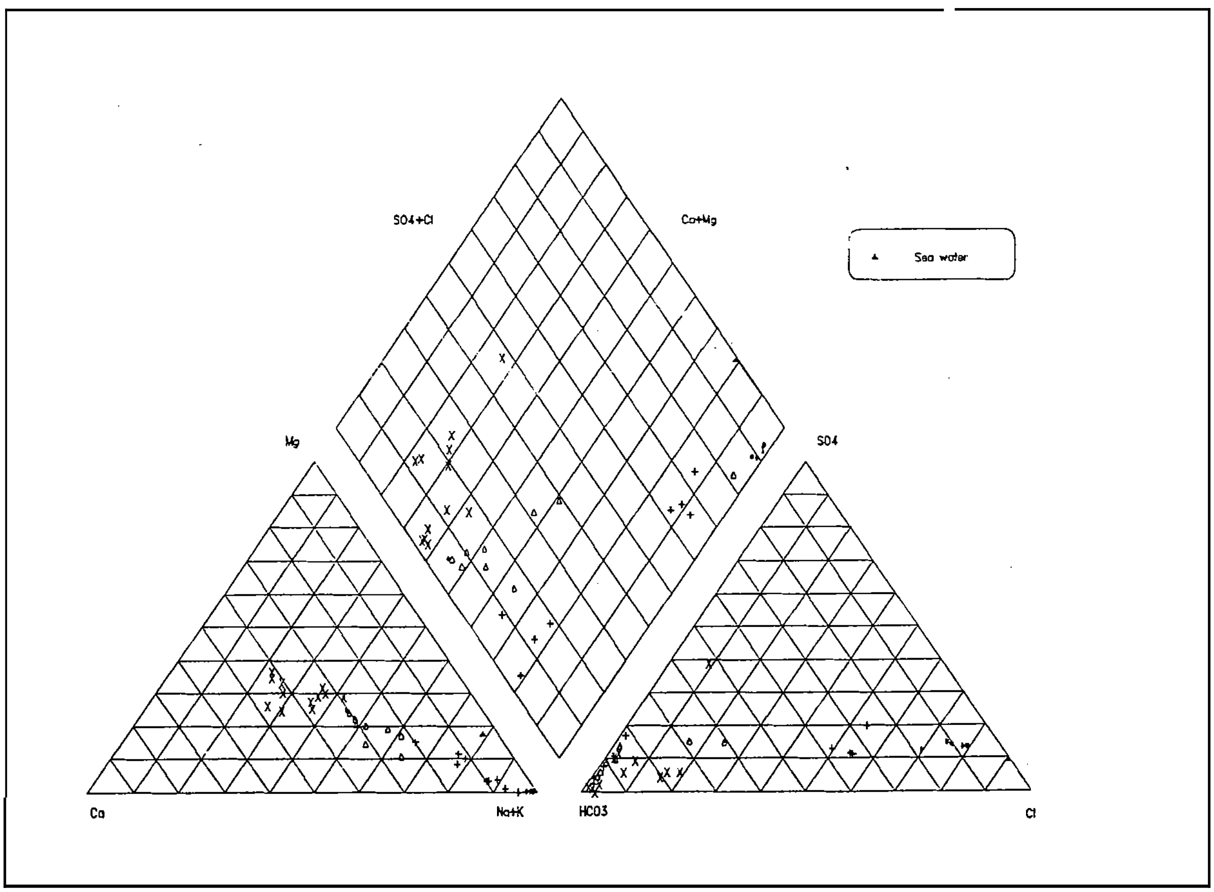


Figure 2. Piper **Diagram** for waters from San **Marcos.**

- The first one of sodium chloride waters, that includes waters with high saline content (42 to 54 meq/l) **and** high surface temperature, close or equal to the boiling point in the area. This waters (marked with asterised with X in the figure) and warm waters with high bicarbonate and Na + K greater ***than*** 21 % (marked with + in the figure).

- The third group type includes the rest of samples (marked with triangles in the figure) that are a mixture between sodium chloride and bicarbonate waters.

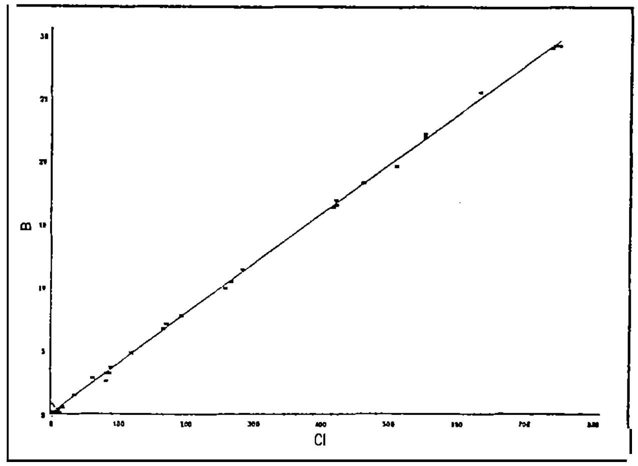


Figure 3. Cl-B diagram for waters from *San* Marcos

All the waters in the area have the same Cl/B ratio, then, the same origin. The Chloride-Boron diagram (Figure **3)** shows a good correlation and implies that the waters of the third type are formed by mixture between a deeper sodium chloride water and shallow bicarbonate waters andor by other process, that keep constant the Cl/B relation, like steam loss . Similar correlation, with a little bit dispersion, is obtained plotting chloride vrs lithium (Figure 4).

The typical sodium chloride thermal waters have low contents of Mg, Ca, and bicarbonate, while the waters of the 'third type have relatively high contents of Ca, Mg and bicarbonates, this phenomena can be explained by lixiviation of the rocks, due to the transformation of the CO, in HCO, during the process. The chloride content of this waters is relatively low (550 - 600 ppm), suggesting that waters are coming from the dioritic basement.

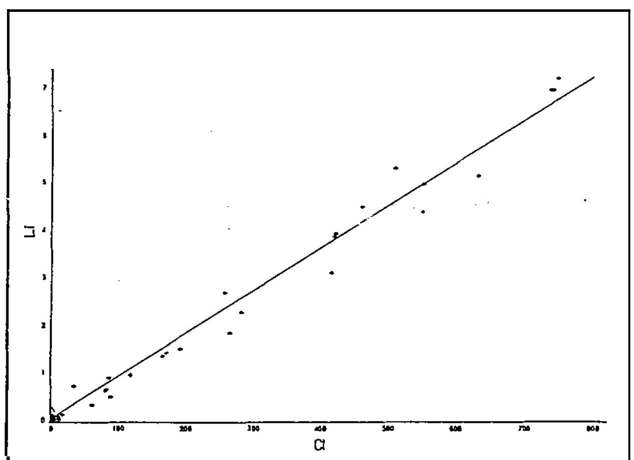


Figure 4. Cl-Li diagram for waters from San Marco

4.0 GEOTHERMOMETRY

The use of geothennometers is based on deep equilibrium conditions for specific element concentrations, however, the elements concentrationis supposed not affected during rise by mixture phenomena, reequilibration at different temperatureor elements loss (Janik et **al** 1990, Giggenbach 1992). Silicageothermometers are most affected by dilution or reequilibration during rise (Janik et **al, 1990)** while the cation geothermometers must be limited when the waters are considered inmatures (Fournier, 1990, Truesdell, 1992) preferring the use of silica geothennometers which must be compared with Na-K-Ca geothennometer. The mature and inmature waters classification is based on total or partial equilibrium conditions and is **obtained** from the Na-K-Mg triangular diagram. The use of this diagram is also considered appropriate to calculate deep temperatures instead of geothermometers when the waters are not full reaction equilibrated or have had mixture process **as** happen with San Marcos waters.

Silica geothemometers applied to sodium chloride waters from San Marcos yield values between 170 "**C** and 260 °C, while for bicarbonate waters show appreciable difference between quartz and chalcedony, the values for quartz geothennometerare between 107" and 170 "C (excepting one sample), while for chalcedony the values are from 53 "C to 147 "C implying that the waters are not reequilibrated with chalcedony. In the case of sodium chloride waters, there are a good correlation between silica and Na-K-Ca geothermometers.

The Na-K-Mg **triangular** diagram applied to the San Marcos waters, (Figure 5) indicate that three sodium chloride waters (**La** Castalia area) are in equilibrium at about 250 "C while two of them (La Cimarrona **area**) are partially matures and have a mixture tendency of magnesium reequilibration around 180 "C and 215 "*C*. Inmature waters, include bicarbonate and mixed waters, are located in the magnesium comer, this fact confirm the hypothesis that are shallow or mixture of them with deep origin waters.

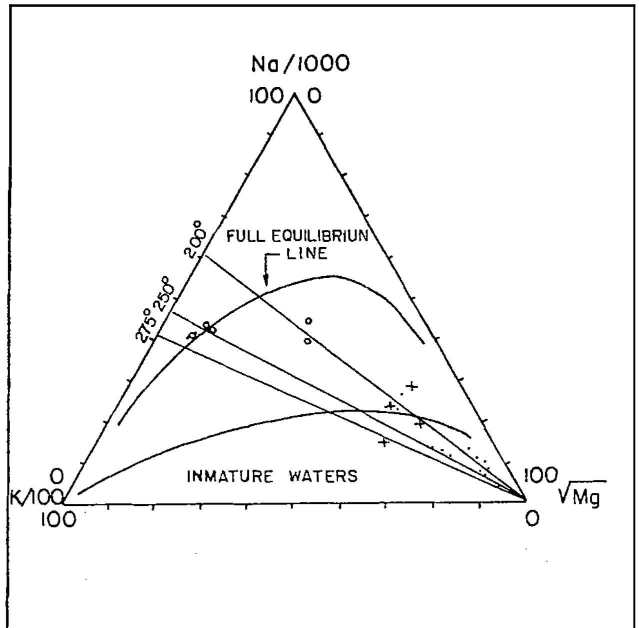


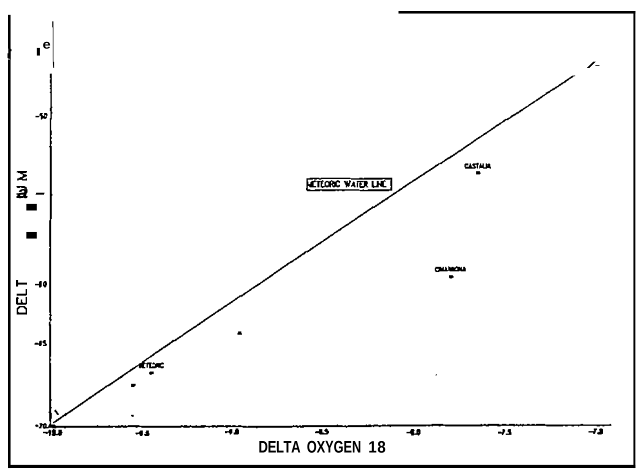
Figure 5. Na-K-Mg diagram for San Marcos waters.

Based on geothermometers, we can conclude that there are two different reservoir in San Marcos, one beneath La Cimarrona area, with temperature of 180 to 215 °C and the otlier one, probably deeper, beneath La Castalia, with temperature a depth of 250 °C.

Gas geothermometersare more reliable to calculate deep temperatures when the springs are affected by reequilibration or dilution phenomena (**Janik** et al, 1990); in the case of San Marcos, Giggenbach **(1986)** has calculated deep temperatures based on gas analyses obtaining values between 230" and 250 °C.

5.0 STABLE ISOTOPES

Stable isotope analyses have been madc to some springs of San Marcos geothermal area. The results show tha: the low chloride content waters are close to the meteoric water line defined by Craig.



The sodium chloride waters, present **an** ^{18}O shift of approximately 1.8 o/oo (Fig. 6) which implies water rock interaction at temperature greaterthan 300°C (Giggenbach, 1986) or that the water coming from the reservoir is a mixture of local meteoric water with the so called andesitic water (Giggenbach, 1992). The graphic **also** shows that the recharge water comes from low altitude

In the case of ^{18}O enrichment due to **a** mixing process with magmatic water, also called andesitic water, which contents $6^{18}O = 10 \pm 2$ o/oo and 6 D= -20 ± 10 o/oo that also implicate a deuterium shift; the andesitic water fraction (Xa) **is** calculated with the following equation (Giggenbach et al 1992)

$$X_a = (\delta_d - \delta_m) / (\delta_a - \delta_m)$$

where: δ_d= geothermal water isotopic composition.
δ_a= andesitic water isotopic composition.
δ_m= meteoric water isotopic composition.

Applying this formula to the waters from San Marcos, the value obtained is approximately 24% of andesitic water in the San Marcos geothermal area reservoir waters.

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