Proc. 10th New Zealand Geothermal Workshop 1988

GEOCHEMICAL CHARACTERIZATION OF THERMAL WATERS IN MEXICO

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ABSTRACT

Chemical analyses of most hot and warm springs have been carried out by the Federal Electricity Commission, as a first step for the assessment of the geothermal potential of Mexico. These analyses include data from a large part of the country and characterize most tectonic provinces. The temperature of the thermal waters range from slightly above 30°C up to the boiling point. The chemistry of the waters is also variable, and it reflects the existence of mixing processes with cold groundwater for most springs. Here, chemical analyses data for 19 of the 24 states with important hydrothermal activity manifestations are presented. The results of contouring the concentration values indicate a well defined trend in the data, showing major maxima anomalies for chloride and silica associated with the most active areas: Transmexican Volcanic Belt (TMVB), Chiapas, and the continuation of the Rio Grande Rift in the northern part of Mexico. Deep temperatures calculated with geothermometers indicate that the heat sources are related to recent volcanic and tectonic processes.

INTRODUCTION

Several studies on the classification of the waters have been fulfilled for the evaluation of the geothermal potential of prospective geothermal zones (Medina, 1986; Tello, 1986a, b; Quijano, 1986). In a regional scale, there are published works on the silica concentration of thermal waters (Prol and Juárez, 1985; Prol-Ledesma and Juárez, 1986), and also on the dissolved gases composition (Polak et al., 1982; Polak et al., 1985; Kononov et al., 1988). These works attempt an analysis of the chemical variations of the fluid discharged by surface thermal manifestations and their relation with the geologic structures and the tectonic activity. The results obtained show that the concentrations of silica, carbon dioxide, sulphuric acid, methane, nitrogen, hydrogen and the helium isotopic ratio follow a pattern related to the major geologic structures.

TECTONICS AND GEOLOGICAL SETTING

The geological and tectonic setting of Mexico is rather complex. In a large scale it can be described by 13 geologic provinces (Fig.l) related to the geodynamic processes that have taken place in this region, including the superposition of different tectonic regimes in the observed geologic structures.

Since the Tertiary, most structural features in Mexico have been closely related to the evolution of the plate

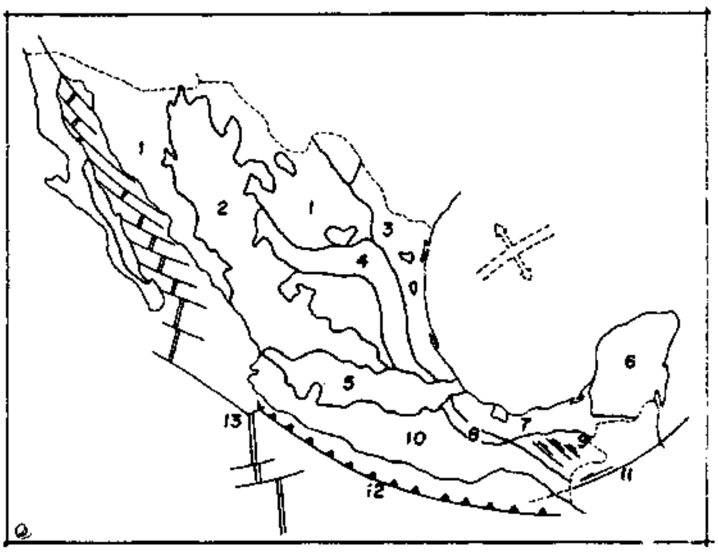

Fig. 1. Main tectonic structures in Mexico: 1-Basin and Range Province continuation to the South; 2-Sierra Madre Occidental; 3-Sierras and Valleys in Coahuila St.; 4-Sierra Madre Oriental; 5-Mexican Volcanic Belt; 6 - Yucatan Platform; 7-Gulf of Mexico Coastal Province; 8-Sierra de Juárez; 9-Sierra de Chiapas; 10-Sierra Madre del Sur; 11-Polochic-Motagua Fault System; 12 - Acapulco Trench; 13-East Pacific Rise. (After Moran - Zenteno, 1986).

boundaries in the Pacific Coast. In particular, many hydrothermal manifestations may be associated to processes related to the subduction in the Eastern Pacific. The subduction process along the western coast of Mexico started about 100 m.y.b.p. and the formation of the Sierra Madre Occidental, as well as the activity in the Mexican Volcanic Belt (TMVB) have generally been related to this process (Molnar and Sykes, 1969; Mooser, 1973; Demant and Robin, 1975; Demant, 1978). However, lately there have been some other hypothesis about the formation and development of the TMVB in relation with stress and transformed faulting processes (Shurbet and Cebull, 1984).

The main consequences of the changes in the ocean plate tectonics have been the diversity in the types of volcanic activity that have taken place in Mexico since the Tertiary up to the present. This volcanic activity has formed the extensive ignimbrite fields in the western part of Mexico (Sierra Madre Occidental) (Fig. 1), the alkaline volcanics of the Sierra Madre Oriental, the igneous rocks in the Baja California Peninsula, and the TMVB. The recent volcanic activity in Chiapas, the Southermost state of Mexico, represented by the activity of El Chichón and El Tacaná is more related to the Central America Volcanic Chain than to the TMVB (Thorpe, 1977).

Recently, it has been proposed that the tectonic and volcanic activity in the eastern section of the central part of Mexico may be linked to the existence of a rifting triple point within the continent, which includes three graben structures: Chapala, Colima and Nayarit (Luhr and Carmichel, 1981).

WATER CHEMISTRY DATA

535 analyses of water samples were used in this study. The samples were collected from hot and warm springs with temperatures that range from slightly above 30°C up to the boiling point. The pH measurements were made in the laboratory, most values correspond to neutral-type waters, though some waters with sightly acid pH were sampled in the southeastern part of Mexico, in the vicinity of El Chichón and Tacaná volcanoes, where sulphate-type waters predominate (Fig. 2). High sulphate concentrations of more than 500 mg/1 can be observed also in the southern and northeastern borders of the TMVB, and in the central area of the north of Mexico (Chihuahua State).

Chloride concentration values (Fig. 3) present maxima in the TMVB zone as well as in the coastal areas of the Gulf of Mexico and the Gulf of California. Thus, it is related to high temperature hydrothermal activity and to sea-water mixing. Smaller maxima are also observed in the Chihuahua state.

Mixing processes are very likely to have taken place for most samples; this results in relatively high concentrations of bicarbonate (Fig. 4). On the other hand, the largest anomalies in the bicarbonate concentration are closely related with the sulphate (Fig. 2) and calcium (Fig. 5) anomalies within the TMVB, and they seem to be due to the anhydrite and calcite solubility which would be high for the low. temperatures observed in the areas of evaporites and limestones.

The silica content of the thermal waters has been correlated to the heat flow (Marvin, 1984; Prol and Juárez, 1985; Prol-Ledesma and Juárez, 1986). Here we added more data to the isolines map (Fig. 6), however, the pattern is similar to the one obtained previously. Three zones of maximum values for the silica concentration are related to the most active areas: TMVB, southeastern Mexico and the Chihuahua State.

Fig. 2. Isolines map for sulphate concentration in the waters sampled. Contours in mg/1.

Fig. 3. Chloride concentrations isolines. Contours as in Fig. 2.

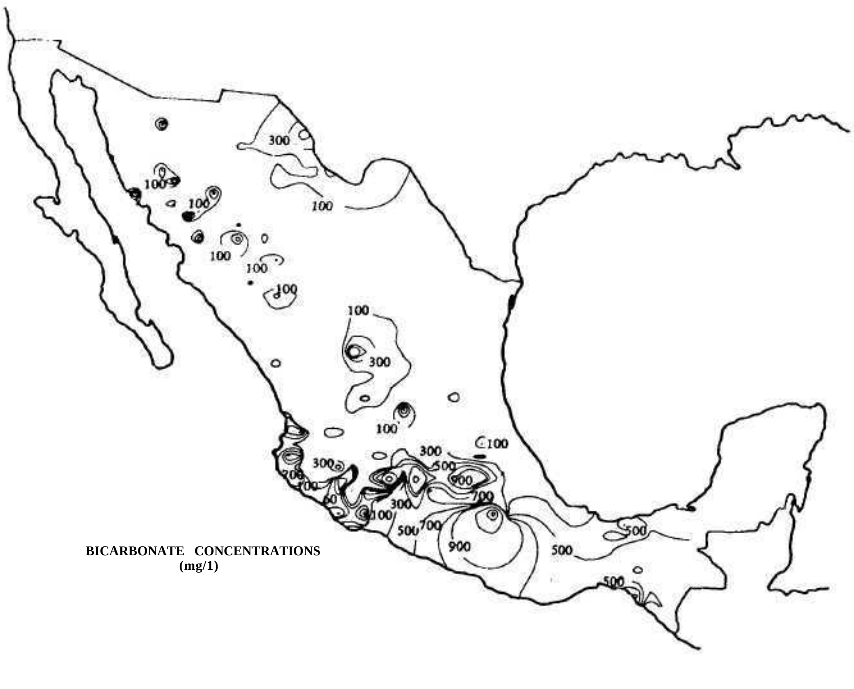

Fig. 4. Bicarbonate concentration isolines. Contours as in Fig. 2.

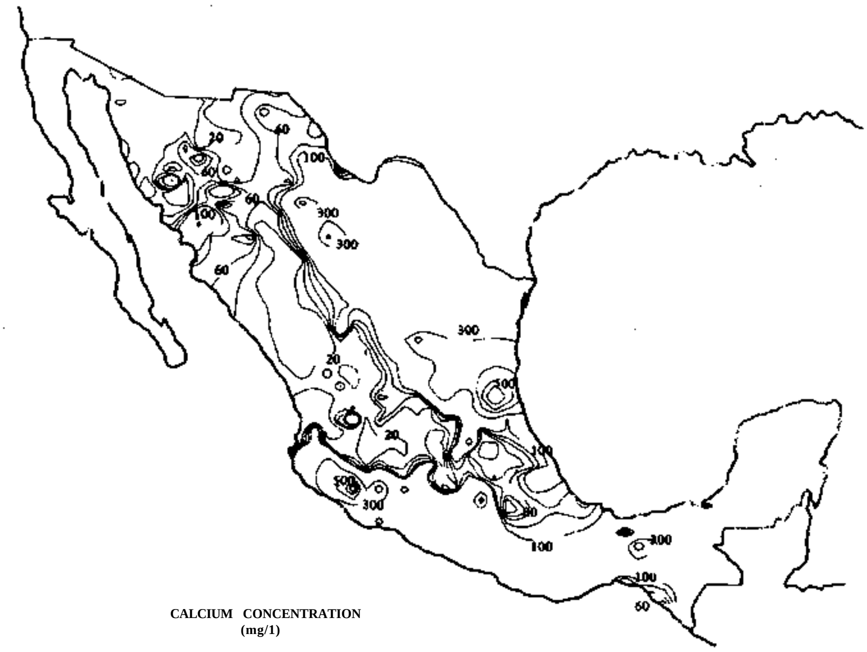

Fig. 5. Calcium concentration isolines. Contours as in Fig. 2.

Fig. 6. Silica concentration isolines. Contours as in Fig. 2.

DISCUSSION

According to the chemical data presented, it can be observed that in all the concentration isolines maps, the TMVB area is the area with the largest anomalies related to hydrothermal activity. The northern and southeastern zones show secondary anomalies, however they represent also areas with intense hydrothermal activity related to recent tectonic and volcanic activity The TMVB contains most of the active volcanoes in Mexico, though in the southeastern State of Chiapas are located two volcanoes: El Chichón and El Tacaná. that presented intense activity in the last years. On the other hand, the northern part of Mexico has been linked to the anomalies that define the Rio Grande Rift, and that have been observed in the United States. As it would be expected, all those areas are characterized by higher concentrations of silica in the thermal waters. This results in higher temperatures calculated with the silica geothermometer, that in the anomalous zones are always higher than 120SC (Prol-Ledesma and Juárez, 1986).

Isolines of the concentrations of bicarbonate, sulphate and calcium present a good correlation especially for the areas where evaporitic layers are reported, as in the central part of the TMVB. This zone is also characterized by low surface and silica temperatures (Prol and Juárez, 1985). This fact correlates well with a higher solubility of the anhydrite and the calcite. Therefore, higher concentrations of bicarbonate, sulphate and calcium should be expected.

Further processing of the data is needed in order to make a classification of the waters and the mixing patterns in each area.

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