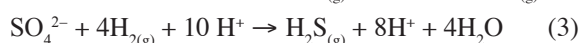
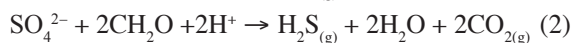


Erratum -- corrected equation (2)

sulfur and carbon across the region are provided to verify the hydrogen sulfide source to the spring water.

Processes generating H₂S

H₂S gas occurs in nature associated with high-temperature environments such as hydrothermal vents, geothermal sources, and volcanoes (Meyer 1977). It is also found in low-temperature environments, including petroleum and gas deposits, salt domes, swamps, anoxic sediments, sewage, and some groundwater (Meyer 1977, Drever 1982, Toth 1999, Stoessel 1992). In the environments mentioned, H₂S may be formed by bacterial action on sulfur compounds present in organic material (see Reaction 1 below), by sulfate reduction during oxidation of organic matter (Reaction 2, Morel & Hering 1993), or reduction of hydrogen (Reaction 3, Meyer 1977, Stumm & Morgan 1996). In these schematic reactions, CH₂O represents any organic compound and R-S is an organic compound containing sulfur.



The presence of sulfate and organic carbon is thermodynamically unstable in diagenetic environments below 200°C (Machel 2001). High burial temperatures and pressures can promote abiotic sulfate reduction (thermochemical sulfate reduction, TSR), or alternatively at lower temperatures and pressures microbial interaction can catalyze biological sulfate reduction (BSR). From the hydrogeologic perspective, sulfate reduction can be favored in one of two settings: when organic matter that is dispersed through the aquifer supports microbial sulfate reduction or when organic material contained in fine-grained layers diffuses into more permeable layers and comes in contact with sulfate-rich groundwater (Appelo & Postma 1993).

Table 1. Subsurface environments and their main characteristics listed in order of increasing Total Dissolved Ions (TDI). Values are expressed in mg/L and water temperature in °C.

Geochemical groups or Subsurface environments	Local	Northern		Southern
		Only on the NW	Only on the N	
Distribution	Widely distributed	Only on the NW	Only on the N	Only on the S
Water type	Ca ²⁺ -HCO ₃ ⁻	Ca ²⁺ -SO ₄ ²⁻	Na ⁺ -Cl ⁻	Na ⁺ -Cl ⁻
SiO ₂	2.5-7	9-16	14-20	11-16
K ⁺	<1.5	5-14	10-26	5-22
B	<0.04	0.2-0.5	0.3-0.9	0.2-1.0
Li ⁺	<0.02	0.1-0.2	0.2-0.5	0.1-0.4
End member	Arroyo Azul (L15)	La Gloria E (N5)	B. El Azufre W (N1)	Puyacatengo House (S13)
Spring type *	Fresh cold	Brackish cold, warm and thermal		
Water Temp.	≤ 27	28-31	24-32	26-35
TDI	<600	1100-2200	1100-2900	1700-600

* From Chapter II

Study Region Physiographic and Geologic Framework

The study region is in the tropical area of Mexico. It comprises an area approximately 30 by 50 km at the northern edge of Sierra de Chiapas in southeastern Mexico, in the states of Tabasco and Chiapas (Figure 1). At the north end of this range, the terrain drops abruptly from ~1,500 m above sea level (a.s.l.) at the Sierra de Chiapas to 20 m a.s.l. at the Tabasco fluvial plain (INEGI 1983, 1985). The Sierra de Chiapas rises to an altitude of ~2,800 m a.s.l. farther south.

Cretaceous carbonates and Paleogene clastic rocks crop out in the topographic highs, while Cenozoic clastic and volcanic rocks fill the topographic lows. The main regional lithologies are described by Alcántara-García et al. (2004), Aquino-López (2004), García-Palomo et al. (2004), Meneses-Rocha (2001), and PEMEX (unpublished data). These units, shown in Figure 2, consist of 1) probable plutonic basement similar to the Chiapas Massif, 2) Paleozoic schists and quartzites, 3) Middle to Upper Jurassic halite and clastic deposits with minor carbonates and anhydrite, 4) Cretaceous dolostones interbedded with anhydrite, transitioning upward to limestones with chert, and to limestones with marl, 5) Paleogene to Neogene marls, shales, and other clastic rocks and scarce carbonates, 6) Pliocene to recent andesitic to basaltic lava flows and pyroclastic rocks, 7) Pliocene granodiorite, and 8) Quaternary fluvial and tufa deposits.

The geologic units exposed form part of the Chiapas Fold Belt (Meneses-Rocha 2001). This fold belt developed from Miocene NE-directed compression and transpression accommodated in sinistral strike-slip faults and en-echelon folds and thrusts formed over shallow detachments in the Jurassic evaporite rocks and broad basement uplifts. Plio-Pleistocene to recent magmatism is localized along NE-trending extensional faults; the best example is the active El Chichón Volcano (Figure 1B).

Sulfur and organic carbon in the subsurface

Organic matter available for sulfate reduction can vary from hydrocarbons located at various depths to recent organic compounds derived from the surface. Based on their location at Sierra de Chiapas, the hydrocarbons belong to Oil Families 2b and 3 (Guzmán-Vega & Mello 1999). The δ¹³C of the organic carbon in these oils is included in Table 2. They are characterized by the presence of aromatic and NSO (Nitrogen, Sulfur and, Oxygen) components, by 0.7 to 3% S, and by an API (American Petroleum Institute) gravity of 18 to 36° API. This API gravity corresponds to components from the Heavy, Medium, and Light crude oil classes (< 22.3° API, 22.3 to 31.1° API, and > 31.1° API, respectively). The source rock for these oils has been interpreted as organic-rich Early Cretaceous limestones deposited in a hypersaline environment (Figure 2). These source rocks are also reservoirs and are located at ~4,000 m