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Chapter 12

Region 9, Sierra Madre Oriental

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INTRODUCTION

The infiltration, circulation, and occurrence of ground water in the Sierra Madre Oriental is directly influenced by the lithology and structure of the rocks. This region (Fig. 3, Table 2; Heath, this volume) is composed primarily of a series of folded calcareous rocks of Mesozoic age that have a general northwest to southeast orientation. The region is characterized by arid and semiarid zones, except in its eastern portion; there it joins with the Gulf Coastal Plain, and the climate is transitional to humid tropical. The region is divided into three subregions (Fig. 1), the north, central, and south, respectively, which are designated: Sierra del Burro, Cuenca de Ojinaga-Monclova-La Paila Basin, and Sierra Torreon-Monterrey-Tamazunchale.

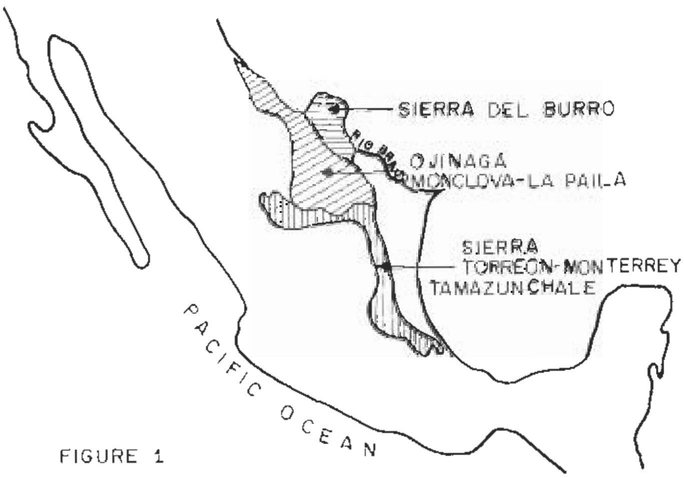

Figure 1. Map showing three subdivisions of the region.

SIERRA DEL BURRO

General setting

This subregion is south of the Big Bend of the Rio Bravo (Rio Grande) and has elevations about 600 m above sea level. It is an extensive uplift of limestones of Cretaceous age that form an anticline striking northwest; flank dips are very gentle, normally 3° to 5°. Although the rocks of this region are chiefly carbonates, in places they are shaley. The rocks were deposited in a shallow marine environment known as the Laguna de Maverick (Maverick Basin) that was surrounded by the Stuart City Reef of Cretaceous age (Fig. 2). The lithology of the rocks and the gentle folding to which they have been subjected have given them different hydrogeologic characteristics than those of the rocks underlying the surrounding areas.

The rocks of the Lower and Middle Cretaceous are essentially highly soluble, medium-bedded limestones with a small amount of shale. These rocks grade laterally into the Stuart City Reef, which has a high primary porosity and many fractures that increase the permeability. The rocks of the Upper Cretaceous contain more shale and have lower permeability.

The eastern flank of the Sierra del Burro is underlain by alluvial fill and conglomerates of Tertiary and Quaternary age—products of the weathering and erosion of the topographically higher regions. These deposits are only about 50 m thick. However, they are highly permeable and contain important volumes of ground water.

Geochemistry

Two zones can be identified according to the chemical composition of the water. One occurs in the western two-thirds of the Sierra del Burro and is characterized by the presence of potable water. The second zone occurs in the eastern part of the Sierra and contains nonpotable water. The boundary between the two types of water is designated the "bad-water line" (Fig. 3). This "bad-water line" continues in an easterly direction into the

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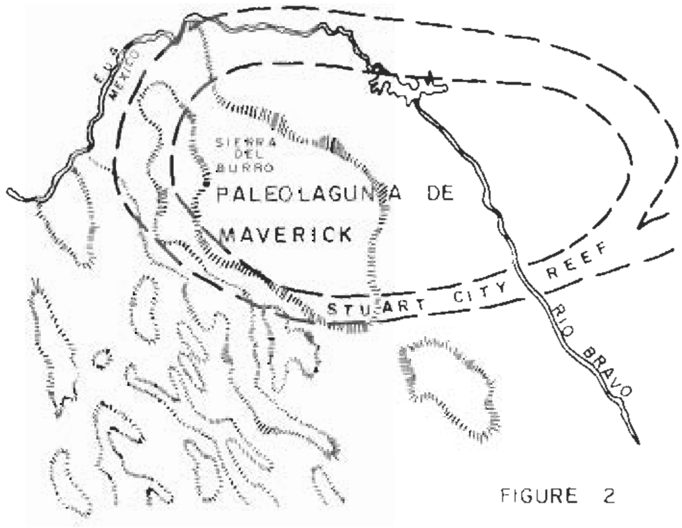

Figure 2. Map showing location of the Maverick Basin.

Five different hydrologic zones can be differentiated as follows:

Zone 1. At the foot of the Sierra, the water is a calcium carbonate type of good quality, and contains less than 1,000 mg/L dissolved solids. The aquifer is composed of Cretaceous-age limestone that was deposited in the Laguna de Maverick (Fig. 3).

Zone 2. To the southeast, where the water is of bad quality, it contains more than 1,000 mg/L dissolved solids and is chiefly a calcium sulfate type. This zone occurs within the Maverick paleolagoon where the rocks characteristically contain evaporites, disseminated pyrite, and carbonaceous material.

Zone 3. In the extreme southeast, where little ground water occurs at depth or where the water is of bad quality.

Zone 4. The zone in which ground water exists only in isolated locations.

Zone 5. Areas in which the water has more than 1,000 mg/L dissolved solids and a high sulfate content related to the amount of gypsum in the valley-fill deposits. Isolated outcrops of limestone also occur and, where present, the limestone aquifers have water of good quality.

aquifer composed of the Edwards and associated limestones of south Texas (Jorgensen and others, this volume).

The nonpotable water is characterized by a high concentration of dissolved solids and is a sodium bicarbonate, calcium sulfate, and sodium chloride type that contains hydrogen sulfide, H_2S. The occurrence of this water is thought to be restricted to the paleolagoon of the Maverick Basin, and its origin is a consequence of the dissolution of evaporitic and calcareous material from the McKnight Formation, and dissolution of pyrite from the Eagle Ford and Buda Formations. The water temperature also is higher than normal ground water, and in this region the aquifer has low permeability. This delineation between poor-quality and good-quality water has been mapped to the vicinity of Monterrey, but the area of most accurate delineation is in the Sierra del Burro and south Texas (Back and others, 1977).

The aquifer with potable water is in the Aurora and Edwards Formations and their equivalents. At greater depths the water is highly saline and is a calcium-bicarbonate type.

The position of the "bad-water line" is influenced significantly by ground-water flow, which is controlled by the distribution of fractures associated with the uplift of the Sierra del Burro. The position of the Stuart City Reef marks the limit of the bad-water line. This line is continuous to the south, where its existence is associated with the presence of gypsum. Marked hydrogeologic differences occur within the zones of water of good and bad quality. The porosity and permeability of the aquifer are secondary; for example, in the fresh-water zone the fabric of the carbonate rock is altered, and the water is strongly oxygenated and has low dissolved solids. In the zone of nonpotable water, the aquifer has primary porosity and permeability; the fabric of the carbonate rock is only slightly altered, the water has high dissolved solids and is in a reducing environment.

Hydrology

The various rock units underlying the subregion contain confined aquifers. Some of the tight confining beds are breached by tractive systems that improve the degree of hydraulic interconnection between aquifers. The partial hydraulic connection among the near-horizontal aquifers causes significant local and areal variations in water levels, well depths, ground-water flow, and well yields. These aquifers are recharged by rainwater that infiltrates in the higher parts of the Sierra del Burro and flows generally to the north and east.

The southeastern prolongation of Sierra del Burro, known as the Peyotes Anticline, is an anticline with gently dipping flanks. Here the Austin Formation, a calcareous rock with a little shale, crops out. A shallow aquifer of small potential occurs in the fractured part of the formatiou. The plain east of the Sierra del Burro is underlain by permeable granular alluvium 30 to 50 m thick. The alluvium is recharged by the limestone aquifer in the Austin Formation. Springs with average flows of 600 L/s issue from the highly permeable alluvium.

CUENCA (BASIN) OJINAGA–LA PAILA

General Setting

This subregion is underlain by calcareous rocks of Cretaceous age that have been folded into a series of anticlines that form sierras oriented N20°W. The sierras emerge as isolated forms within the extensive plains formed by alluvial material. These sediments of Cretaceous age were deposited in the open sea on a platform environment and generally are dense micrites with little or no primary permeability. These sediments do not form aquifers except in folded zones that have been fractured where

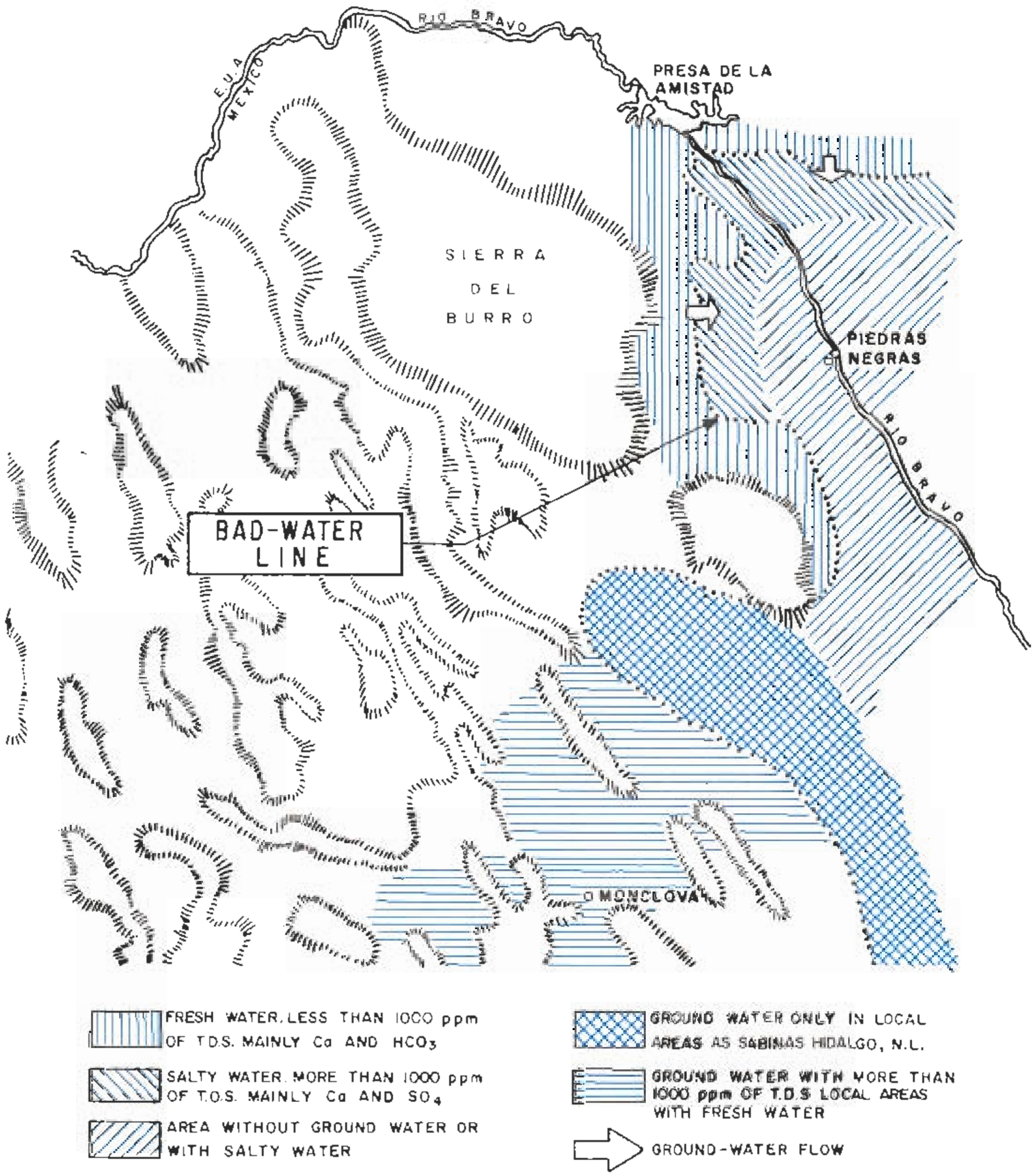

Figure 3. Map showing location of the "bad-water line" and chemical character of ground water.

dissolution along fracturing resulted in development of good permeability. Conditions for this process to take place are not favorable.

The subregion is underlain by two types of aquifers: (1) those that occur in the granular sedimentary fill, and (2) those that occur in the limestones. The aquifers in the granular sediments of the valleys and basins consist of low-permeability sand and shale. These aquifers contain saline water derived from dissolution of gypsum of Jurassic age that crops out in the high parts of the sierras. The aquifers occur in the Lower and Middle Cretaceous limestone.

The aquifers of the second type occur in the lower and middle parts of the limestones of Cretaceous age. Where these limestones outcrop in the sierras, the aquifers are recharged directly from rainfall. This recharge moves downdip toward the valleys. Wells drilled on the flanks of the sierras penetrate the aquifers between depths of 1,000 and 2,000 m and generally flow during the rainy season because of the high potentiometric surface. However, during the dry season, water levels decline as much as 100 m due to pumping, and wells cease to flow.

In some places near the valley floors, fractures that penetrate the aquifers give rise to large springs; among these are the springs at Muzquiz, Monclova, and Cuatro Cienegas, with flows of 1,000 L/sec.

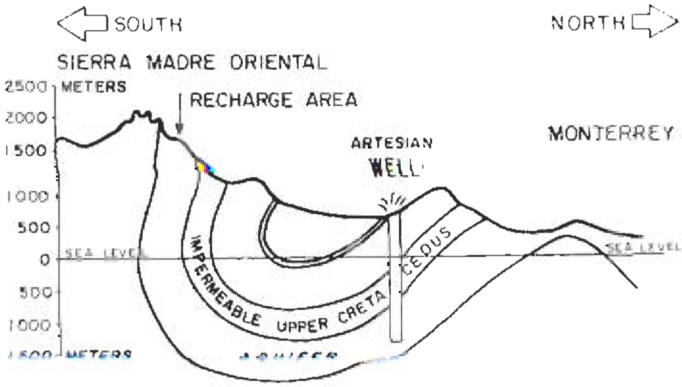

Figure 4. Cross section showing effects of folding on recharge and occurrence of ground water.

Geochemistry

The potable water that occurs in the limestone aquifer has low dissolved solids and is a calcium-bicarbonate type. The nonpotable water has a high salinity content composed of calcium and sulfate, temperatures higher than ambient, and a high content of H_2S. Generally the nonpotable water is present in the deeper zones that are a considerable distance downdip from the recharge areas. Occasionally water from the deeper zones moves upward through fractures and faults and contaminates the shallow aquifers.

SIERRA TORREON–MONTERREY–TAMAZUNCHALE

General Setting

A series of continuous folds in carbonate rocks of Cretaceous age have formed the Sierra Madre Oriental chain. Its northern end is in the Mapimi area where the folding strikes N40°W, and continues southeast toward Torreon, where the folding trends east–west to the latitude of Monterrey and then changes to N20°W. The Sierra has altitudes greater than 4,000 m, a length of about 1,200 km, and a width of 200 km. In the Sierra are spectacular canyons with vertical walls exposing outcrops of rocks ranging in age from Precambrian to Quaternary; the principal exposures are limestone of Cretaceous age.

The climate is humid tropical in the eastern part of the Sierra where the mountains receive precipitation and humid winds from the Gulf of Mexico. A few kilometers to the west the Sierra has altitudes of 2,000 m with a variable climate. Rainfall diminishes westward where the Sierra becomes semiarid to arid.

Torreon

Within the Sierra are intermontane valleys and basins composed of alluvial materials that form aquifers. The Laguna region of Torreon is an area of arid climate, and is one of the major agricultural regions of Mexico. About 3,000 wells for irrigation in this region have overexploited the alluvial aquifers. To the west and south are carbonate aquifers greater than 1,000 m thick. These limestones contain little or no shale, are not dolomitized, and have been subjected to dissolution. This aquifer helps recharge the overexploited alluvial aquifers of the Laguna region, as confirmed by isotopic studies (Latorre and others, 1981).

Monterrey

In the greater part of the Sierra there are reef complexes whose primary permeability, augmented by fracturing, forms highly permeable zones; at higher elevations these are recharge zones and at lower elevations they are aquifers. The anticlines that form the sierras of this region have steeply dipping flanks that are vertical to overturned in places. The steep bedding enhances the infiltration of rainfall and, combined with the primary porosity (reefal) and secondary porosity (fracturing and dissolution), permits the development of aquifers of great potential. On the flanks and plunging noses of these anticlinal structures, water is at depths of about 1,000 m and is under artesian conditions (Fig. 4). This type of aquifer is primarily exploited in the Monterrey-Saltillo area where the abundant yields satisfy the needs of Monterrey, the third largest metropolitan area of Mexico.

Tamazunchale

In the southern part of the Sierra Madre Oriental, water infiltrates the higher elevations of the Sierra and is discharged through great springs at the base of the Sierras adjacent to the coastal plain. Patterns of carbonate sedimentation play a major role in aquifer development. The extensive El Abra–Doctor reef complex, which formed on the margin of the Valles–San Luis Potosi Platform in Albian-Santonian time, contains carbonates with high permeability. In the high Sierra are numerous dolines and sink holes where water infiltrates, flows laterally, and discharges as springs at the base of the Sierras (Fish, 1977). These springs, such as Coy and Frio, are among the largest in the world and have discharges of 25 m^3/sec.

Within the Sierra are local and regional flow patterns. Water of local flows is recently infiltrated and of a calcium-bicarbonate type, whereas water of regional flows contains additional quantities of magnesium and sulfates.

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