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HYDROGEOLOGY OF THE SOCORRO AND LA JENCIA BASINS, SOCORRO COUNTY NEW MEXICO

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INTRODUCTION

The Socorro and La Jencia Basins in central New Mexico were studied to get a better understanding of the hydrogeology of two adjacent alluvial basins along the Rio Grande rift. These two basins each have some unique characteristics. The Socorro Basin has flow-through drainage and is hydraulically connected to other basins in the rift area by both the Rio Grande and ground-water flow through alluvial sediments. The La Jencia Basin has no perennial stream drainage and is separated from the Socorro Basin by the Socorro Peak—Lemitar Mountains intergraben horst. The horst acts as a hydraulic barrier that restricts ground-water flow between basins.

The purpose of this report is to describe the hydrogeology of the Socorro and La Jencia Basins. Existing hydrologic data, especially ground-water-quality data, are used to interpret the flow systems of the area. This study conceptualizes the connection between the Socorro, Peak Known Geothermal Resource Area and the flow systems of the Socorro and La Jencia Basins.

LOCATION

The Socorro and La Jencia Basins are located in central Socorro County, New Mexico (fig. 1). The Socorro Basin is one of many basins in the Rio Grande rift that has flow-through drainage; it is linked by the Rio Grande to the Albuquerque-Belen Basin on the north and the San Marcial Basin on the south.

The Socorro Basin is bounded on the east by the southern end of the Joyita Hills, the Lomas de las Cafias (a low set of hills predominantly composed of Paleozoic rocks), Cerro Colorado, and the Little San Pasqual Mountains (fig. 1). On the west, the Socorro Basin is separated from the La Jencia Basin by the Lemitar Mountains and Socorro Peak.

The La Jencia Basin is bounded on the west by the Bear Mountains and on the south and west by the Magdalena Mountains. The basin is bounded on the north by the Colorado Plateau and the Ladron Mountains (fig. 1).

CLIMATE

The climate of the two-basin area is semiarid. Data from the weather station in Socorro shows that June, July, and August are the warmest months with mean temperatures in the mid 20's Celsius. December and January are the coldest months with mean temperatures of about 2.0 degrees Celsius. The mean annual precipitation at Socorro is 23.9 cm and is 29.8 cm at Magdalena (Gabin and Lesperance, 1977). Most of the precipitation occurs from July through September as intense thunderstorms.

GEOLOGY AND WATER-BEARING CHARACTERISTICS

Many of the interpretations of ground-water movement and water quality are based on the geology of the area; thus, a short discussion of major geologic structures and rock units is presented. The structural features with the potential to affect the ground-water flow system and water quality are: (1) rift boundary faults on the east side of the Socorro Basin; (2) boundary faults between the Magdalena Mountains and the La Jencia Basin; (3) the Socorro Peak—Lemitar Mountains intergraben horst; (4) faults east of the Socorro Basin in the Lomas de las Cafias area; (5) the Morenci lineament that trends northeast through the area; and (6) the Capitan lineament that trends northwest through the area (fig. 2).

Many of the rock units in the area have been combined into hydrogeologic units on Figure 2 and Table 1. The hydrogeologic units consist of the Mesozoic-Paleozoic aquifer system, Tertiary sedimentary aquifer system, Tertiary volcanic aquifer system, and the principal aquifer system. The Precambrian rocks of the area have not been considered as water-bearing units in this report, and thus will not be discussed, although they have been included in the Mesozoic-Paleozoic aquifer system in Figure 2.

The Mesozoic-Paleozoic aquifer system is an important water-bearing unit east of the Socorro Basin and in the Magdalena Mountains. The aquifer system consists of rocks of Mississippian to Cretaceous age. Mississippian and Pennsylvanian rocks are primarily limestones and dolomites with some interbedded shales and sandstones. The Permian rocks consist of shales and sandstones with some interbedded conglomerates, limestones, and gypsum. The Triassic rocks consist of sandstone, siltstone, and shale. The Cretaceous rocks are shales, sandstones, and siltstones.

The sandstones, conglomerates, and limestones (where fractured) act as aquifers, whereas the shales and siltstones act as confining beds. Limestone, dolomite, and gypsum have a significant influence on the water quality of the area.

The Tertiary sedimentary aquifer system is a major water-bearing

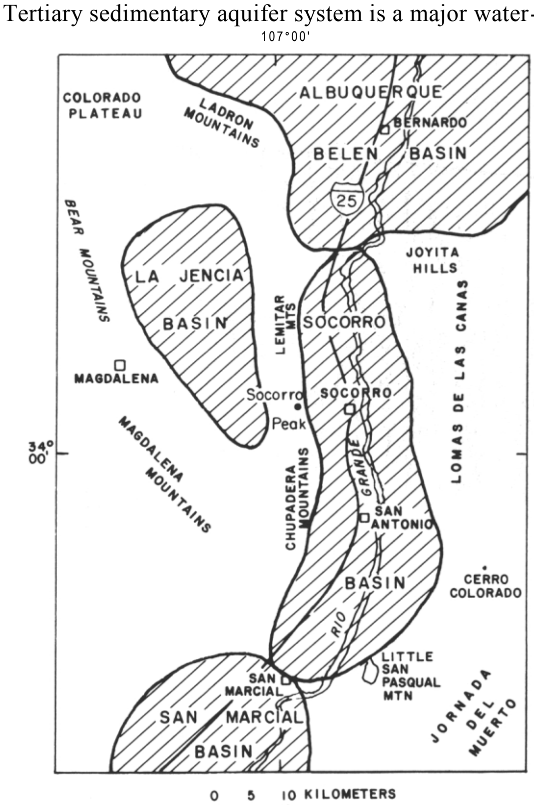

Figure 1. Location of the Socorro and La Jencia Basins.

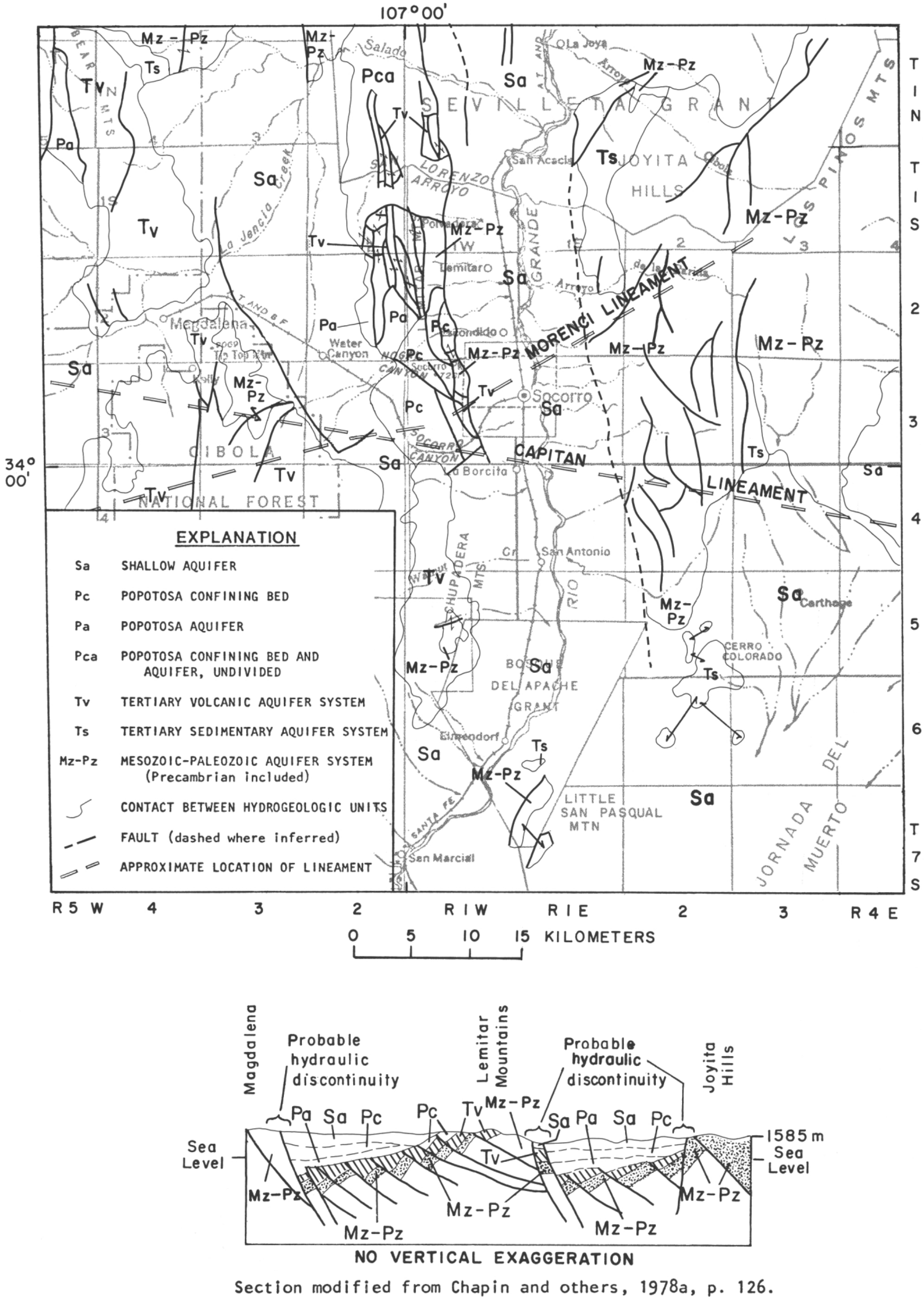

Figure 2. Hydrogeologic map and diagrammatic section of the Socorro and La Jencia Basins and adjacent areas.

Table 1. Correlation chart between geologic units and hydrogeologic units.

Geologic Units		Hydrogeologic Units	
	Quaternary deposits	Shallow aquifer	Principal aquifer system
Santa Fe Group	Sierra Ladrones Formation		
	Upper part of Popotosa Formation	Popotosa confining bed	
	Lower part of Popotosa Formation	Popotosa aquifer	
	Tertiary volcanic rocks		Tertiary volcanic aquifer system
	Datil Group (Osburn and Chapin, 1983)		Tertiary sedimentary aquifer system
	Baca Formation		
	Mesozoic rocks		Mesozoic-Paleozoic aquifer system
	Paleozoic rocks		
	Precambrian rocks		

unit southeast of San Antonio. The aquifer system is composed of the Baca and Datil Formations. The Baca Formation consists of alluvial basin deposits containing conglomerates, sandstones, and shales. The Datil Formation is composed of rhyolitic to andesitic ash-flow tuffs and conglomerates and sandstones derived from volcanic rocks. Sandstones and conglomerates in this aquifer system are water-bearing units and have been reported to yield as much as 3.1 L/sec, whereas the ash-flow tuffs generally yield much less water (Weir, 1965).

The Tertiary volcanic aquifer system consists of ash-flow tuffs with minor amounts of andesitic to basaltic lavas, landslide deposits, rhyolitic lavas, and rhyolitic domes. The vertical and areal distribution of this aquifer system is variable due to the complex depositional history of these rocks.

Chapin and others (1978b, p. 121-125; D'Andrea-Dinkelman and others, this guidebook) found that the volcanic rocks (Tertiary volcanic aquifer system) near Socorro have been enriched in potassium and depleted in sodium. This type of alteration is common in geothermal settings where hot ground water has altered the reservoir rocks. Chapin and others (1978b) have proposed that the Socorro potassium anomaly represents the effects of an ancient geothermal system in which the volcanic rocks acted as the principal reservoir.

Because of the continued tectonic activity in the Socorro area, the fracture permeability of the volcanic rocks is probably greater now than when the postulated ancient geothermal system was present. The largest fracture permeability is probably in the Socorro Peak area and along fault zones. Several springs in the Madgalena Mountains discharge from fractured zones in the Tertiary volcanic aquifer system.

The Santa Fe Group and Quaternary deposits form the major water-bearing unit in the Socorro and La Jencia Basins and will hereafter be referred to as the principal aquifer system. This aquifer system can be divided into: (1) the Popotosa aquifer; (2) the Popotosa confining bed; and (3) the shallow aquifer. The Popotosa aquifer and the Popotosa confining bed are considered together in some areas of the hydrogeologic map (fig. 2) because of the complex geologic nature of the area and common usage on previously published maps.

The Popotosa aquifer constitutes the lower part of the principal aquifer system and corresponds with the lower fanglomerate facies of the Popotosa Formation. The Popotosa aquifer consists of mudflow deposits and fanglomerates. In many areas near Socorro, the Popotosa aquifer is unusually well indurated and brick-red in color, indicating alteration possibly due to the postulated ancient geothermal system (Chapin and others, 1978b, p. 123). The Popotosa aquifer, because it is well-indurated, is densely fractured near fault zones. Several springs near Socorro Peak and San Lorenzo Arroyo issue from fractures in the Popotosa aquifer, indicating that the Popotosa aquifer may also be a significant water-bearing unit in the Socorro area.

The Popotosa confining bed corresponds with the upper part of the Popotosa Formation, which has been interpreted to have been deposited in a playa environment (Chapin and others, 1978b, p. 117). The Popotosa confining bed consists of claystones, mudstones, siltstones, sandstones, and conglomerates. Many of the mudstones and claystones contain considerable amounts of disseminated gypsum.

The shallow aquifer is the upper aquifer in the principal aquifer system and is composed of the Sierra Ladrones Formation and Quaternary deposits. The Sierra Ladrones Formation is composed of flood-plain and axial-river deposits that interfinger with piedmont-slope deposits, alluvial-fan deposits, and basalts. The axial-river deposits consist of fine- to coarse-grained sandstones and pebble conglomerates. The flood-plain deposits interfinger with the axial-river deposits and consist of beds of mud, silt, and sand. The alluvial-fan and piedmont-slope deposits consist of poorly sorted conglomerates and sandstones. The Quaternary deposits consist of alluvial-fan, piedmont-slope, landslide, and fluvial deposits. The lithology of the Quaternary deposits is very similar to the Sierra Ladrones Formation. The contact between the units cannot be distinguished in drillers' and geophysical logs.

The thickness and extent of the shallow aquifer is not well known. Chamberlin (1980, p. 352) estimated that there may be as much as 300 m of fluvial deposits north of Socorro Canyon and east of the Socorro Peak range-bounding fault. No wells in the Socorro and La Jencia Basins are known to have been drilled to zones deeper than the shallow aquifer.

Hantush (1961, p. 188-193) analyzed two sets of aquifer-test data for wells completed in the shallow aquifer near Lemitar. Reported hydraulic conductivities are 12.5 and 18.2 m/day. A calculated storage coefficient of 0.23 was reported for one of the tests. These hydraulic conductivities are in the same range as calculated hydraulic conductivities for similar deposits in the Albuquerque area to the north (William Scott, 1982, written commun.).

HYDROGEOLOGY

The Socorro and La Jencia Basin area may be divided into three parts based on major faults or structural features that influence ground-water flow (fig. 3): (1) Lomas de las Callas; (2) La Jencia Basin and Socorro Peak—Lemitar Mountains; and (3) Socorro Basin. A discussion of ground-water flow followed by a discussion of ground-water quality will be given for each area.

The hydrogeologic map and generalized hydrogeologic cross section shows that the principal aquifer system is very thick in the Socorro and La Jencia Basins (fig. 2). The major rift boundary faults in the area juxtapose the Mesozoic-Paleozoic aquifer system and the Teritary volcanic aquifer system with the principal aquifer system (fig. 2).

Ground-water-quality data used in conjunction with water-level data can be helpful in analyzing flow systems. Inflow from adjacent areas and the presence of vertical flow are many times indicated by water-quality data. Piper diagrams (Piper, 1953) are used in discussion of the water-quality data. References to percent are to the percent of total milliequivalents per liter of the major cations or anions in a sample.

Lomas de las Callas Area

The Mesozoic-Paleozoic aquifer system is the major water-bearing unit north of Cerro Colorado. Near Cerro Colorado and to the south, the Tertiary sedimentary aquifer system and the shallow aquifer are the main water-bearing units (fig. 2). The Popotosa confining bed and the Popotosa aquifer are probably not present in this area.

The geologic structure and the relationship between aquifers and confining beds in the Mesozoic-Paleozoic aquifer system are the major controls on the ground-water flow system north of Cerro Colorado. There are several springs along bottoms of arroyos in this area where aquifers are in fault contact with confining beds. Springs also occur where dipping aquifers are underlain by confining beds and the contact is exposed in the arroyo bed.

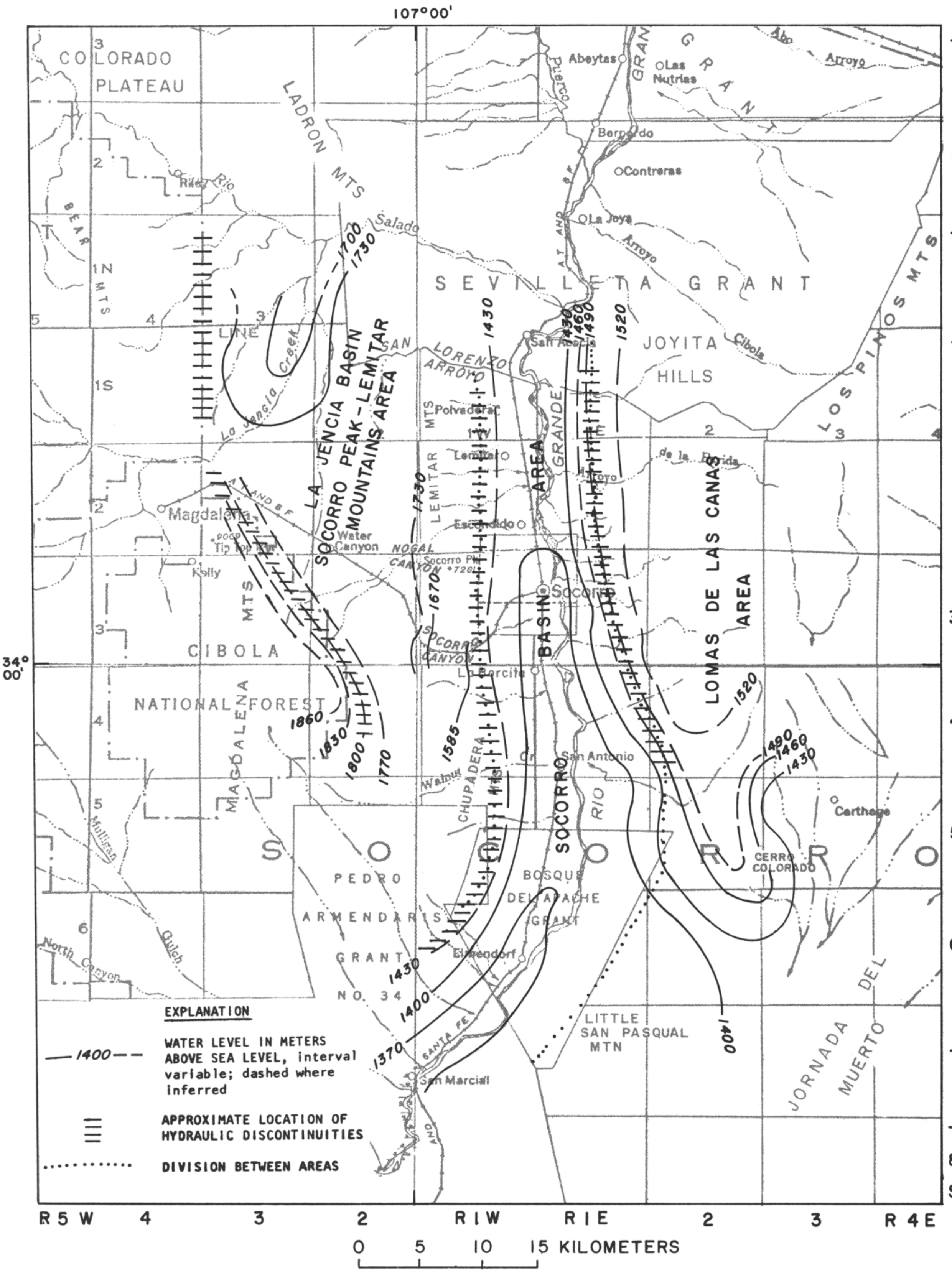

Figure 3. Water levels, divisions between areas, and location of hydraulic discontinuities.

The recharge in the Lomas de las Carias area occurs along arroyo channels where runoff from precipitation infiltrates through the stream bed. The annual recharge to this area is estimated to be 2.0 cubic hectometers (Jack Dewey, 1983, written commun.). The available data indicate that ground water flows westward in the Mesozoic-Paleozoic aquifer system toward the Socorro Basin (fig. 3). There is a significant difference in water levels on opposite sides of the fault that separates the Lomas de las Callas and the Socorro Basin areas (fig. 3). This hydraulic discontinuity is caused by the relatively impermeable Precambrian rocks near the surface east of the rift fault, which cause high water levels, and the thick section of very permeable alluvial-basin deposits (principal aquifer system), which are drained by the Rio Grande west of the fault (fig. 2).

The water-level map indicates a ground-water mound that is probably caused by recharge in the Cerro Colorado area (fig. 3). The hydraulic gradients are relatively steep in this area and flatten out in the shallow aquifer (fig. 3). This indicates that the relative permeability is larger in the shallow aquifer than in the Tertiary sedimentary aquifer system. The water-level map also shows that ground water flows from the northern end of the Jornada del Muerto into the southern Socorro Basin (fig. 3).

The specific conductance of 19 ground-water samples in the Lomas de las Cafias area ranges from 561 to 6,500 micromhos. The variation in specific conductance is produced by reactions between the ground water and the different rock types through which the ground water has flowed and the respective residence time.

A piper diagram shows three groupings on the basis of cation percentages (fig. 4). One group has less than 20 percent sodium plus potassium, one group has approximately 25 percent sodium plus potassium, and one group has greater than 30 percent sodium plus potassium (fig. 4). In general, water with sodium plus potassium greater than 30 percent has a larger percentage of bicarbonate (fig. 4) and a smaller specific conductance than water in the other two groups. The smaller specific conductance and relatively larger percentage of bicarbonate often indicate the water is closer to the recharge area; the relatively larger percentage of sodium may indicate cation exchange. One sample with a specific conductance of 561 micromhos has 10 percent sulfate and almost 90 percent bicarbonate (fig. 4). This sample probably represents recharge water with short residence time and which has not contacted gypsiferous rocks.

The generally large percentage of sulfate in most ground water on the piper diagram probably indicates contact with gypsum-bearing rocks (fig. 4). The similarity in the specific-conductance range and the distribution of cations and anions of ground water derived from the Mesozoic-Paleozoic aquifer system and the Tertiary sedimentary aquifer system suggests reaction with like mineral assemblages.

Chemical equilibrium calculations on these same samples using WATEQF (Plummer and others, 1978) indicate that ground water in the Mesozoic-Paleozoic aquifer system is generally supersaturated with respect to calcite and dolomite. Ground water with a specific conductance greater than 2,000 micromhos was found to be supersaturated with respect to gypsum.

The distribution of cations and anions on the piper diagram, the results of chemical equilibrium calculations, and the larger percentage of bicarbonate in ground water with a smaller specific conductance suggests that the chemical evolution of ground water is controlled by the following geochemical processes: (1) dissolution of calcite (limestone); (2) dissolution of dolomite or magnesian limestones; (3) dissolution of gypsum; (4) precipitation of calcite and magnesian limestones, and possibly (5) cation exchange of calcium and magnesium for sodium. A possible scenario might be that recharge water contacts and dissolves calcite and dolomite. Subsequently the water moves through gypsum-bearing rocks, picking up calcium and sulfate through rock dissolution

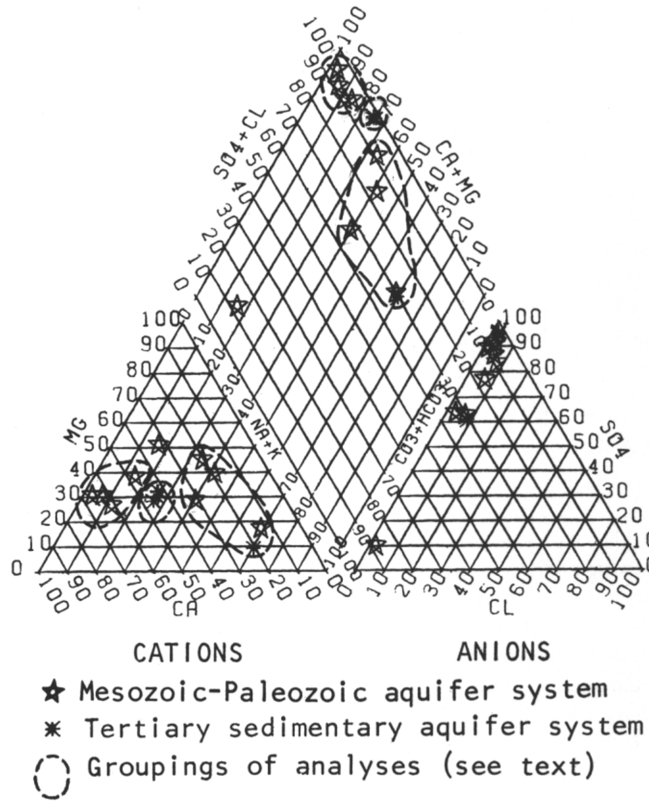

Figure 4. Piper diagram of selected ground-water analyses in the Lomas de las Cañas area.

and precipitating calcite. This precipitation of calcite is due to the increased calcium concentration caused by the common ion effect. The precipitation of calcite reduces the concentration of bicarbonate and calcium. Cation exchange of calcium or magnesium for sodium probably occurs continuously but is more prevalent where the ground water travels through elastic sediments.

La Jencia Basin and Socorro Peak—Lemitar Mountains Area

The La Jencia Basin is separated from the Socorro Basin by the Socorro Peak—Lemitar Mountains intergraben horst. The Tertiary volcanic aquifer system, the Popotosa aquifer, and the Popotosa confining bed are the major units exposed in the Socorro Peak—Lemitar Mountains that affect the ground-water flow between the Socorro and La Jencia Basins. The Popotosa confining bed is exposed in Socorro Canyon and along much of the west side of the Socorro Peak—Lemitar Mountain horst (fig. 2).

Recharge to the principal aquifer system in the La Jencia Basin occurs as inflow from adjacent aquifer systems and infiltration of runoff from the Magdalena Mountains, Bear Mountains, and the Socorro Peak—Lemitar Mountain horst. The annual recharge from infiltration of runoff from the Magdalena Mountains is about 4.0 cubic hectometers (Jack Dewey, 1983, written commun.).

Along the margins of the La Jencia Basin, especially along the Magdalena Mountains, water levels are about 100 m higher than water levels near the basin center. The areas of high water levels are probably underlain by benches of relatively impermeable rock (Precambrian) that are covered by a thin veneer of alluvial deposits (shallow aquifer). There are probably hydraulic discontinuities located near the faults separating these benches and the principal aquifer system. The suspected locations of these hydraulic discontinuities are shown in Figure 3.

The water-level map indicates that ground water flows from the Magdalena Mountains toward the center of the basin, where the hydraulic gradients become very low (fig. 3). Ground water flows northward from the center of the basin toward La Jencia Creek (fig. 3). On the east side of the basin near Nogal Arroyo and Socorro Canyon, ground water flows from the La Jencia Basin into the Socorro Basin. There are no water-level data north of Nogal Arroyo, but the presence of springs in the San Lorenzo Arroyo area indicates that some ground water flows eastward into the Socorro Basin from the northern part of the La Jencia Basin. The amount of ground-water flow between basins is limited by the permeability of the rock units of the Socorro Peak—Lemitar Mountains horst. The Tertiary volcanic aquifer system and the Popotosa aquifer are probably well fractured in the horst area and transmit water. The Popotosa confining bed is the major control on the amount of ground water flowing between basins.

Waldron (1956, p. 130) suggested a ground-water divide in the Socorro Canyon area. This ground-water divide suggests that very little ground water enters the Socorro Basin from the La Jencia Basin in this area. The ground-water divide may be caused by the Popotosa confining bed, which underlies the area. Most wells in Socorro Canyon are near arroyos, and may tap water in the shallow aquifer that is perched by the Popotosa confining bed. There may be ground-water flow entering the Socorro Basin from the La Jencia Basin through the Tertiary volcanic aquifer system near Socorro Canyon. It is not known if there is a continuous ground-water flow system between the Socorro and La Jencia Basins or if ground-water flow between basins occurs only in areas where arroyos breach the Socorro Peak—Lemitar Mountains horst.

Near the mouth of Socorro Canyon, there is a difference of 150 m in water levels in two wells 2.5 km apart. This hydraulic discontinuity occurs where ground water perched in the shallow aquifer by the Popotosa confining bed enters the principal aquifer system in the Socorro Basin. A hydraulic discontinuity probably exists along the boundary fault that separates the Socorro Basin from the Socorro Peak—Lemitar Mountain horst and the Chupadera Mountains (fig. 3).

The specific conductance of ground water in the Magdalena Mountains (the major recharge area for the La Jencia Basin) and the La Jencia Basin ranges between 291 and 570 micromhos. A piper diagram shows that ground water in the Magdalena Mountains has a slightly larger percentage of calcium and magnesium than ground water in the La Jencia Basin (fig. 5). Bicarbonate is the dominant anion in samples from both the Magdalena Mountains and the La Jencia Basin. The percentage of sulfate is generally less than 40 and the percentage of chloride less than 20 in ground water in the Magdalena Mountains and the La Jencia Basin (fig. 5). The variability in the distribution of cations in the Magdalena Mountains and the La Jencia Basin may be due to exchange of calcium and magnesium ions for sodium ions. Water in the principal aquifer system in the La Jencia Basin has a longer contact time with more clay minerals, which act as ion exchangers, than water in the Mesozoic-Paleozoic aquifer system and the Tertiary volcanic aquifer system in the Magdalena Mountains.

The specific conductance and percentage of sulfate is generally larger in ground water in the Socorro Peak—Lemitar Mountains area than ground water in the La Jencia Basin. The characteristics of ground water discharging through the Socorro Peak—Lemitar Mountains area from the La Jencia Basin differ because of the different rock types of the area (fig. 2).

The percentage of sodium plus potassium in ground water in the San Lorenzo Arroyo is 98 and 60 for two analyses of springs that discharge from the Popotosa aquifer. The percentage of bicarbonate is greater than 80 (fig. 5). The high percentage of sodium in the ground water suggests that ion exchange may be a dominant process in the chemical evolution of this water.

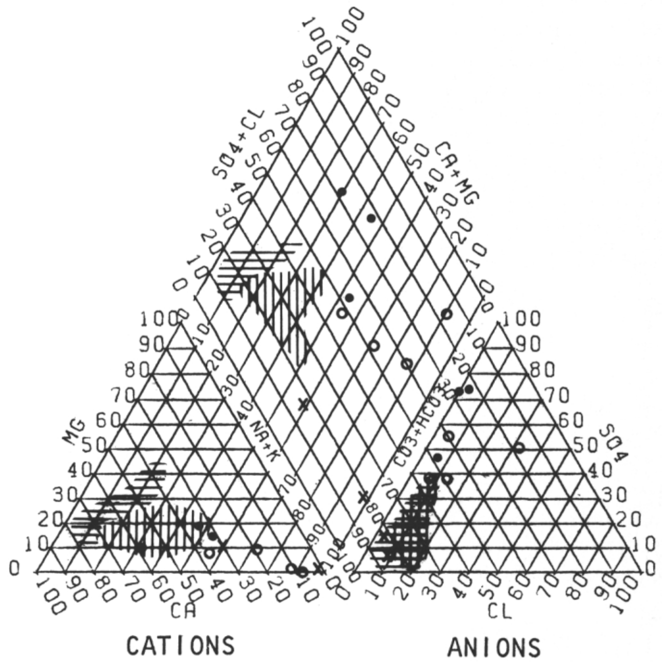

Figure 5. Piper diagram of selected ground-water analyses in the La Jencia Basin and Socorro Peak–Lemitar Mountains area.

The distribution of anions and cations on the piper diagram (fig. 5) is variable in ground water from the Nogal Canyon area, but in general the specific conductance and percentage of sulfate is larger here than in ground water in the La Jencia Basin. In much of the Nogal Canyon area the Popotosa confining bed is exposed at the surface. The larger percentage of sulfate in ground water in the Nogal Canyon area may indicate ground water has dissolved gypsum from the Popotosa confining bed.

The percentage of sodium plus potassium in the Socorro Canyon area is greater than 70 and the percentage of sulfate is greater than 35 (fig. 5). The Popotosa confining bed crops out along most of Socorro Canyon. Cation exchange and the dissolution of gypsum are probably dominant processes that affect ground water flowing from the La Jencia Basin to the Socorro Basin in the Socorro Canyon area. Hall (1963) indicated that cation exchange occurred in ground water associated with the thermal springs in the Socorro area.

In contrast, one ground-water sample from the Socorro Canyon area has a specific conductance of 1880 micromhos and contains 34 percent chloride (fig. 5). A large specific conductance and percent chloride is not seen in other wells in the Socorro Canyon or La Jencia Basin area.

Socorro Basin Area

On a regional scale, ground-water flow in the Socorro Basin is dominated by ground water inflow from adjacent areas. On a local scale in the irrigated part of the river valley, ground-water flow is dominated by the river, conveyance channels, laterals, and drains. These two flow systems interact extensively and thus cannot be separated except in a general sense. A generalized hydrologic cross section through the irrigated part of the river valley shows the general mechanics of the local flow system (fig. 6). In general the fields are sloped so that applied water will flow across the fields and into the drains. The drains also act as sinks to the ground-water system. Water that is not lost to evapotranspiration infiltrates and recharges the shallow aquifer as irrigation return flow (fig. 6). The drains were constructed so that this water will not cause a large rise in water levels under a field, but will flow toward and into the drain (fig. 6), which also helps keep the soils flushed of salts that are concentrated by evapotranspiration. Ground water inflow from adjacent areas is also intercepted by the drains (fig. 6).

Except during times of high discharge, the water in the river is diverted into conveyance channels at San Acacia in the northern part of the study area (fig. 1) to reduce the amount of evapotranspiration that occurs in the river between San Acacia and San Marcial. The riverside drains are constructed to intercept flow resulting from the infiltration of surface water from the river and conveyance channels (fig. 6).

The regional trends in the water-level map show that ground water flows toward the river valley along the margins of the basin. The flow in the river valley is parallel to the river at a gradient of approximately 1 meter per kilometer. This gradient is similar to the gradient of the river which further indicates that the river, conveyance channels, and drains are dominant controls on the flow system in the Socorro Basin.

Water quality in the Socorro Basin is very complex. The mixing of inflow water from adjacent areas (regional ground water) and water that infiltrates from excess applied irrigation water (irrigation return flow) is the major factor affecting the water quality in the area.

Large chloride concentrations (greater than 1,000 mg/L) are found in ground water in the southern Albuquerque-Belen Basin, which is adjacent to the northern part of the Socorro Basin. A constriction (reduction in cross-sectional area of the principal reservoir) to ground-water flow exists at the southern end of the Albuquerque-Belen Basin (F. Birch, 1980, unpublished report for U.S. Geological Survey). Thus, this chloride-enriched water may represent deep-basin ground water that is moving upward at the southern end of the Albuquerque-Belen Basin and flowing into the northern Socorro Basin.

Chloride concentrations in the northern part of the Socorro Basin are as large as 1,000 mg/L, which is up to 50 times larger than chloride concentrations in the basin near Socorro. One sample has a specific conductance of 4,700 micromhos, contains 80 percent sodium, and 60 percent chloride. This sample is probably representative of the ground water from the Albuquerque-Belen Basin. In contrast, the irrigation return flow is characterized by a specific conductance of approximately 1,550 micromhos and approximately 40 percent sodium and 20 percent chloride (Simonett, 1981) (fig. 7). The largest chloride concentrations are present near San Acacia and decrease to the south, indicating that the upward movement does not extend very far south of San Acacia. The large range in percentage of chloride and sodium present in the northern part of the Socorro Basin is caused by mixing of irrigtion return flow and the upward moving ground water.

Nearer to the southern part of the basin, from Lemitar to La Borcita, the ground-water quality is characterized by specific conductances that range from 200 to 2,000 micromhos, but generally are less than 1,000 micromhos. Sulfate and bicarbonate are the dominant anions, and calcium and sodium are the dominant cations (fig. 7). Differences in ground-water quality are caused by mixing of regional ground water and irrigation return flow. The average specific conductance of irrigation water near Socorro is approximately 750 micromhos (Simonett, 1981, p. 14). If irrigation efficiency is 50 percent, the specific conductance of the irrigation return flow would be approximately 1,500 micromhos. In the Socorro area, the regional ground water has a specific conductance as small as 200 micromhos. Mixed water would therefore be expected to have a larger specific conductance than the regional ground water.

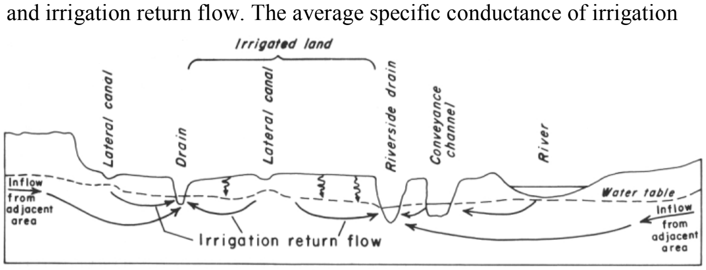

Figure 6. Schematic hydrologic section through the irrigated part of the Rio Grande valley.

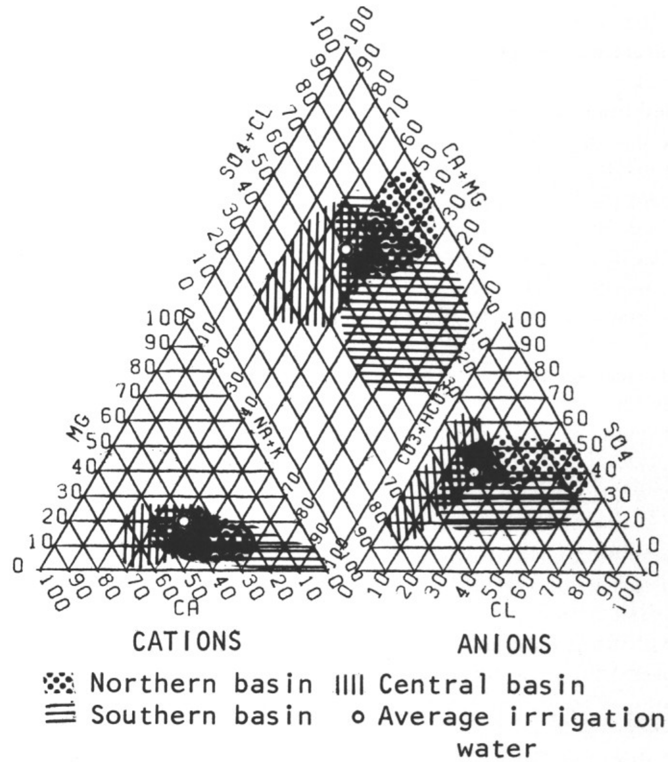

Figure 7. Piper diagram of selected ground-water analyses in the Socorro Basin area.

Ground water with chloride concentrations as large as 1,100 mg/L is found in the southern part of the basin, from approximately La Borcita to San Marcial. The specific conductance of ground water in this area ranges from 500 to 6,750 micromhos. The percentage of sulfate is generally less than 35 but ranges from 25 to 45 percent (fig. 7). The percentage of sodium ranges from 35 to 95 with most greater than 60 percent (fig. 7). The wide range of specific conductance and percentage of sulfate, chloride, and bicarbonate suggests mixing of regional ground water with irrigation return flow.

Although the ground water in the southern basin has large concentrations of chloride like the extreme northern part, the percentages of individual constituents are different. For example, the ground water in the southern part of the basin generally has a larger percentage of sodium, and a smaller percentage of sulfate than the ground water in the northern part of the basin (fig. 7).

The source of the large concentrations of chloride in ground water in the southern part of the basin has not been identified. Chloride concentrations are smaller in the ground water in the Lomas de las Cafias area, so the large chloride concentrations are not due to ground-water inflow from that area. Concentration of irrigation water by evapotranspiration is not the cause of the large chloride concentrations in the ground water because large chloride concentrations in the ground water are found up the potentiometric gradient from irrigation areas.

One possible explanation may be that geothermal fluids associated with the Socorro Peak Known Geothermal Resource Area may be moving upward in the southern part of the basin. The northern boundary of the area of large chloride concentrations in ground water coincides

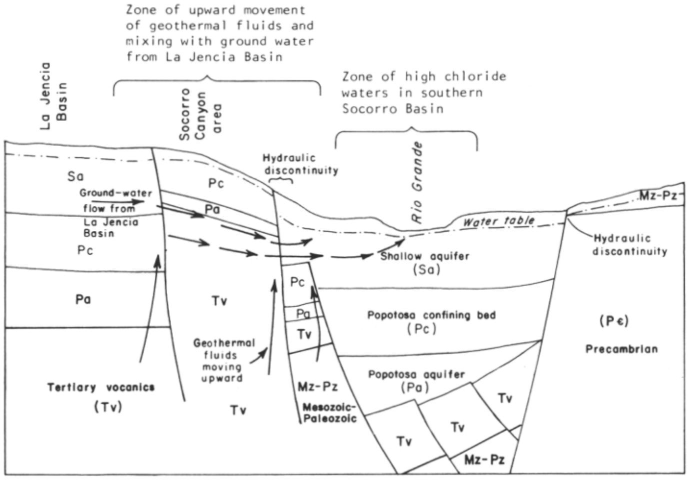

Figure 8. Schematic hydrogeologic section (looking north) through the Socorro Canyon area.

with the Capitan lineament (fig. 2). Upward movement of geothermal water may occur along the lineament from Socorro Canyon to the east side of the Socorro Basin or be localized in areas along the lineament. The extent of the area of geothermal fluid movement cannot be delineated with the available data. Water from a well in Socorro Canyon with a chloride concentration of 230 mg/L suggests that there may be movement upward through the Popotosa confining bed in the Socorro Canyon area. The presence of only one well that samples ground water with a large chloride concentration suggests that there may not be significant upward flow in Socorro Canyon or that the Popotosa confining bed restricts the upward flow of water with large chloride content.

Hall (1963) found that ground water from thermal springs in the Socorro Peak area had approximately 60 percent sodium. This Hall attributed to cation exchange as the ground water flowed through the Tertiary volcanic aquifer system. Ground water with large chloride concentrations in Socorro Canyon contains 90 percent sodium while that in the southern part of the Socorro Basin has as much a 95 percent sodium. Ion exchange processes may be occurring in this water which may travel through the Tertiary volcanic aquifer system. Because the Tertiary volcanic aquifer system is near the surface and highly fractured in the Socorro Canyon area, most upward flow of geothermal water probably would occur in this area (fig. 8). The hydraulic head difference of 275 m between the Socorro Basin and the La Jencia Basin may be forcing the geothermal water in the Tertiary volcanic aquifer system eastward from Socorro Canyon into the principal aquifer system in the southern part of the basin (fig. 8). The geothermal water then mixes with irrigation return flow and regional ground water flowing south in the basin. The geothermal water may then cool and mix with other waters as it moves through the principal aquifer system thus explaining the lack of high temperature ground water in the southern part of the basin. In general, ground water with the largest chloride concentrations has temperatures as much as 15°C higher than the majority of groundwater samples collected elsewhere in the Socorro and La Jencia Basin area.

Another possible explanation for the ground water with large chloride concentrations in the southern part of the basin may be due to upward movement of deep basin water, similar to what may be happening near San Acacia. The floor of the Rio Grande rift may have significant relief near the Capitan lineament. Chapin and others (1978b) state that transverse horsts are often associated with lineaments along the Rio Grande rift, and go on to say that hot springs are often associated with these horsts. It is possible that the Popotosa confining bed is faulted up along a transverse horst in the southern part of the basin, causing deep-basin ground water to be forced upward due to the change in hydraulic conductivity. The ground water with large chloride concentrations in the southern part of the basin may also be a combination of upward movement of deep-basin water and upward movement of geothermal fluids (fig. 8).

CONCLUSIONS

The principal aquifer system in the Socorro and La Jencia Basins consists of the shallow aquifer, Popotosa confining bed, and Popotosa aquifer. The Mesozoic-Paleozoic aquifer system, Tertiary sedimentary aquifer system, and the Tertiary volcanic aquifer system are important along the basin margins. Ground water flows into the principal reservoir in the Socorro Basin from the eastern basin margin and from the La Jencia Basin through the Socorro Peak—Lemitar Mountains on the west. Ground water in the La Jencia Basin also flows north toward La Jencia Creek.

Water with chloride concentrations greater than 1,000 mg/L is found in the northern and southern Socorro Basin. The large chloride content of ground water in the northern Socorro Basin is probably caused by upward movement of deep-basin ground water from the southern Albuquerque-Belen Basin. The large chloride content of ground water in the southern Socorro Basin is probably caused by upward movement of geothermal fluids along the Capitan lineament, upward movement of deep-basin ground water, or a combintion of both.

Further study of the Socorro Canyon area and the area between Socorro Canyon and the southern part of the Socorro Basin is needed. This should include test drilling, measurements of the vertical potentiometric gradient in the Tertiary volcanic aquifer system, and water-quality sampling (including stable and unstable isotopes). This would be useful in developing a better understanding of the large chloride content in ground water in the southern part of the basin and in defining the hydraulic connection between the Socorro and La Jencia Basins.

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