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GEOLOGY AND WATER RESOURCES OF THE SANTA FE AREA, NEW MEXICO

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ABSTRACT

The Santa Fe area, a 15-minute quadrangle of 243 square miles in north-central Santa Fe County, N. Mex., was investigated to determine the general geologic and hydrologic conditions. Santa Fe, capital and second largest city in New Mexico, is at the west base of the Sangre de Cristo Mountains, in the northeastern part of the area. The population of the area is about 30,000. The principal natural resources of the region are rangelands, timber, water, base metals, turquoise, and construction materials. Intangible resources include the varied scenery, the salubrious climate, and the numerous points of archeological and historical interest.

The map area is divided into four principal subareas: (a) the timbered foothills in the eastern part, at altitudes of 7,000 to 9,000 feet, underlain principally by Precambrian rocks that extend upward to nearby alpine peaks more than 12,500 feet high; (b) an extensive semiarid grassland piedmont slope at altitudes of 6,000 to 7,000 feet, developed on downfaulted blocks of sediments of the Santa Fe group, of late Cenozoic age; (c) the Cerrillos, a faulted igneous complex intruded into Mesozoic—early Tertiary sediments and middle Tertiary volcanos, forming low hills in the southwest corner; and (d) a lava mesa on the west side, underlain by Quaternary(?) basalt flows, in part uplifted by normal faults.

The Precambrian rocks consist of a sequence of schist and gneiss intruded successively by gray granite, amphibolite, and red granite. Pre-Carboniferous brecciated zones are abundant. Limestone, shale, and sandstone, mostly of Pennsylvanian age (Magdalena group) crop out in small areas in the foothills near Santa Fe. Sedimentary rocks of Cretaceous age are the oldest rocks exposed in the southwestern corner, where they represent the upper part of a sequence of upper Paleozoic to middle Tertiary rocks more than 2 miles thick. The overlying rocks are the Galisteo formation, a conglomeratic to silty sandstone of Eocene and Oligocene(?) age, about 1,300 feet thick in the map area, and flows and intrusive centers of intermediate composition and of Oligocene and Miocene(?) age. A few scattered exposures of the igneous rocks occur along the mountain front south of Santa Fe.

The Santa Fe group consists of alluvial fans, river channel deposits, and interbedded volcanic rocks of middle(?) Miocene to Pleistocene(?) age, preserved in a complex of depressed fault blocks within the Rio Grande depression. The group contains the Tesuque formation (newly named), which is equivalent to the Santa Fe Formation of some reports; the Ancha formation (newly named), which includes several remnant graded surfaces locally buried by gravel deposits, hitherto designated as "the Ortiz surface," and basalt flows.

The Tesuque formation, best exposed north of the Santa Fe River, consists principally of several thousand feet of stream-deposited pinkish-tan soft arkosic sandstone and minor siltstone and conglomerate. It is correlative with sediments to the north that bear the classic Santa Fe fauna of late Miocene and early Pliocene age. Interbedded near the base of the Tesuque formation are the Bishops Lodge member (newly named), consisting of 50–530 feet of locally tuffaceous volcanic-derived sediments, and thin flows of olivine basalt. The Bishops Lodge member was formed largely of debris from the Oligocene and Miocene(?) volcanic rocks but in part from the products of contemporaneous volcanism; it is tentatively correlated northward with the Abiquiu tuff of Smith. The arkosic sediments of the Tesuque formation were derived from the Precambrian rocks to the east. Faulting and westward tilting of the Tesuque formation accompanied the last stage of uplift. Subsequent erosion removed the Tesuque formation from the southern part of the area.

The Ancha formation, consisting of silt, sand, and gravel, forms a blanket 100–300 feet thick over two-thirds of the area. The Ancha formation is inferred to be of late Pliocene or early Pleistocene age. It rests on a westward-sloping erosion surface that bevels beds of the Tesuque formation. A second westward-sloping graded surface was buried by a layer of basalt lapilli tuff which blankets the Ancha-Tesuque contact in the northwestern part of the area. The tuff is overlain by Quaternary(?) flows of basalt, which intertongue with gravel of the Ancha formation. The ancestral Santa Fe River was diverted southward by the basalt flows to Cienega at the junction of basalt flows from the northwest and south. During the existence of a local base level on the basalt, the Santa Fe River cut and partly refilled a wide valley in the piedmont slope. Lenses of pumice, which correlate with the pumice of the early stages of volcanism in the Valles Mountains 35 miles to the west, are interbedded in the upper 50 feet of the Ancha formation in the central and eastern parts of the Santa Fe area.

Downfaulting during the Pleistocene epoch southwest of the area permitted active erosion and eventual lowering of the local base level at Cienega, whereupon the present erosion of the Santa Fe area began. The channel of the Santa Fe River, flanked by terraces, now is north of and 60 feet below its former gravel-filled course.

A structural basin in the basement (Precambrian(?)) rocks is from 7,000 to 14,000 feet deep and trends north-northwest, according to geophysical studies. The basin and the rocks preserved in it are divided into two east-west structural blocks by the Santa Fe river fault, which trends west-southwest through Santa Fe. South of the Santa Fe River, subparallel faults bounding the east side of the basin trend north-northwest and have vertical displacement totaling 3,000–6,000 feet along a zone 1½ miles wide. North of the Santa Fe River, the faults east of the basin trend north. The west side of the basin is formed by faults trending north-northwest. Pre-Santa Fe rocks are exposed west of the fault zone in the southwest part of the area. The wedge of Tesuque formation preserved in the basin thickens northward. The faulting was post-Tesuque in part, but it may have occurred during the deposition of the Tesuque formation. The Ancha formation has apparently not been faulted significantly in the map area, although elsewhere equivalent beds were faulted appreciably.

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domestic and stock supplies after 1716. The Santa Fe River drains most of the map area and the mountains to the east. Water from the upper canyon of the main river is stored for municipal use by Santa Fe. Increased use of water and concurrent droughts after World War II necessitated development of ground water to supplement surface supplies. At the same time, ground water for irrigation was developed in the area of the city well field, and water levels declined locally as a result of heavy pumping during the 1950–51 drought.

A linear relation was formed in graphing the logarithm of the precipitation against altitudes ranging from 5,000 to 10,000 feet in north-central New Mexico. The average annual total water yield of the Santa Fe area ranges from about 0.5 inch (4 percent of the precipitation) on the piedmont slope to 6.0 inches (27 percent of the precipitation) in the upper canyon of the Santa Fe River. The annual water yield averages about 10,000 acre-feet in the piedmont area and about 12,000 acre-feet in the mountains.

Water yield from the mountain area consists of snowmelt, storm runoff, and ground water from glacial sediments, alluvium, and fractured Precambrian rocks. Streamflow and precipitation recharge the aquifers of the Santa Fe group. Water in these extensive aquifers moves generally westward and is discharged naturally in tributaries of Galisteo Creek, tributaries of the Santa Fe River in the vicinity of Cienega, the Rio Tesuque, and the Rio Grande.

The pre-Santa Fe rocks may be considered the "bedrock floor" of the water-bearing formations in the area. Small supplies of ground water are obtained from the Precambrian rocks in the larger valleys and at depths of less than 100 feet. However, dry holes or wells affording insufficient yields for domestic supply are common even in these areas. Discontinuous limestone beds of the Magdalena group in the larger areas of outcrop locally yield small water supplies. Cretaceous rocks in the vicinity of the Cerrillos are generally fine grained, have low permeability, and generally contain water high in sulfate. The Galisteo formation also has a low permeability but may yield small supplies in the southern part of the area. Extrusive and intrusive Tertiary rocks generally yield very small supplies.

The Tesuque formation is generally favorable as a source of domestic or larger supplies of water, except locally near the base of the formation and near the mountains. Moderate to large yields are obtained from the Tesuque formation within the corporate limits of Santa Fe, and similar yields are probably available southwest, west, and northwest of Santa Fe, and locally in Tesuque.

In the southern part of the area the Ancha formation is generally underlain by pre-Santa Fe rocks at depths of about 200 feet; in the remainder of its extent the Ancha formation overlies the Tesuque formation. Except in a few places the Ancha is not saturated.

Terrace sediments along the Santa Fe River received recharge by irrigation until the water from the river was diverted for public use. Alluvium, which is underlain by nearly impermeable rocks in mountain valleys and near Cienega, yields small quantities of ground water of good quality. West of the mountains, alluvium in the arroyos absorbs runoff readily and transmits the water downward to underlying aquifers. Slope wash and colluvial sediments probably are not saturated anywhere in the area, but they aid recharge by absorbing precipitation readily and transmitting it downward.

Ground water south of the Santa Fe River and north of the drainage of Gallina Arroyo discharges in the Cienega area and is represented by the

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base flow of the Santa Fe River below Cienega. The annual natural discharge of the Cienega area is about 4,700 acre-feet, 2,500 of which is now used consumptively above the temporary gaging point. The average unit water yield for the 131 square miles tributary to the Cienega discharge area is about 0.7 inch. Of this, a mountain drainage area of 23.8 square miles contributes about 1,600 acre-feet. The piedmont slope contributes the remaining 3,100 acre-feet, mostly as ground water, corresponding to an average annual ground-water discharge of 0.5 inch.

The median discharge of the Santa Fe River near Santa Fe for the 38-year period of record through 1951 is about 3,800 acre-feet. The average annual supply capturable by storage and use from above Santa Fe, under 1951 conditions, is about 4,800 acre-feet. As the runoff in some wet years is more than the sum of current use and existing surface storage, there should be occasional periods of spill. The water supply from the Santa Fe river must be supplemented by ground water in many dry years, and if the demand increases as much as 15 percent, supplemental supplies of ground water will be required in most years. Water-level and pumpage data for the city well field suggest interference among wells, amplified by boundaries. Excessive declines of water level in the easternmost wells are due to boundary effects and to overpumping of individual wells. Therefore, the surplus surface flow in wet years might advantageously be used to replenish the ground-water supplies withdrawn in dry years. The capacity of existing wells in and near Santa Fe already exceeds the annual average recharge and ground-water inflow, but the actual average withdrawal may be less than the average annual inflow and recharge for many years to come.

The water in all aquifers in the Santa Fe area is of good to fair chemical quality for most uses. The hardness generally ranges from 80 to 220 ppm (parts per million); the hardness of the ground water used for auxiliary municipal supply at Santa Fe averages 150 ppm. The hardness of surface water in the Sangre de Cristo Mountains varies with the discharge but is generally less than 30 ppm.

Gravimetric, magnetic, electrical-resistivity, and refraction seismic methods were used to confirm subsurface features inferred from the geologic and hydrologic data. Although the hydrologic study was found to furnish the best data, several features were delineated more precisely by applying one or more of the standard geophysical methods. The Precambrian rocks have an average bulk density of 2.7 grams per cubic centimeter, resistivity of about 1,000 ohm-feet, and seismic velocities between 13,700 and 16,000 feet per second. The rocks of Mesozoic age have an average bulk density of 2.55 grams per cubic centimeter and resistivities of 50 to 1,000 ohm-feet. The lower and middle Tertiary rocks have bulk densities ranging from 2.18 to 3.08 (average 2.54), resistivities ranging from 400 to 1,000 ohm-feet, and seismic velocities of 8,000–12,000 feet per second. The Tesuque formation has an estimated average bulk density of 2.1 grams per cubic centimeter, resistivities of 30–600 ohm-feet dry and 10–300 ohm-feet wet, and seismic velocities of 7,000–8,500 feet per second. The Ancha formation and alluvium have averaged bulk densities of 1.7 grams per cubic centimeter, resistivities of 100–2,000 ohm-feet dry and 30–500 ohm-feet wet, and seismic velocities of 600–3,600 feet per second dry and about 6,000 feet per second wet. Volume susceptibilities and magnetization are essentially zero for alluvium, the Ancha and Tesuque formations, and the rocks of Mesozoic age, but they vary considerably for the Tertiary volcanic and intrusive rocks.