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BASE FLOW SOURCES IN THE UPPER REACHES
OF RITO DE LOS FRIJOLES
BANDELIER NATIONAL MONUMENT

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BASE FLOW SOURCES IN THE UPPER REACHES OF RITO DE LOS FRIJOLES

BANDELIER NATIONAL MONUMENT

by

Paul K. Christensen

ABSTRACT

The Rito de los Frijoles is a small perennial stream located in the northern portion of Bandelier National Monument. The stream originates in the Sierra de los Valles of the Jemez Mountains in north-central New Mexico and dissects the east flank of the Valles Caldera. The Sierra de los Valles separates the Valle Grande, a wide valley in the Jemez Mountains, and the drainage of the Rito de los Frijoles physiographically. The Valle Grande is underlain by a thick artesian aquifer of pumiceous sand and gravel. The rocks of the Sierra de los Valles and the east flank of the Valles Caldera are Pliocene to Pleistocene volcanic flows, domes, and tuffs. Springs which supply base flow for the upper reaches at Frijoles Creek are derived from small perched water tables in fractured and jointed zones or basal pumice units of the volcanics. The Valle Grande aquifer does not appear to supply water to these springs. Water chemistry yield no significant clues.

INTRODUCTION

The Rito de los Frijoles is a small perennial stream located in the northern portion of Bandelier National Monument. See figure 1 for locations. The stream originates on the southeast flank of the Valles Caldera and flows southwestward through Canon de los Frijoles into the Rio Grande. This paper is the result of an investigation to determine the hydrogeological origin and nature of the base flow in the upper reaches of the Rito de los Frijoles (Frijoles Creek), and to determine whether a hydraulic connection exists between the base flow of the upper reaches of the creek and the caldera fill aquifer in the Valle Grande which is located northeast of the caldera rim. The methodology behind the investigation includes both hydrological and geological reports of neighboring areas and field work carried out in August 1979 in the upper reaches of the creek and the Valle Grande.

PHYSIOGRAPHIC AND GEOLOGIC SETTING

Bandelier National Monument lies on the southeast flank of the Valles Caldera, a central structure feature of the Jemez Mountains of north-central New Mexico. The flank geomorphologically is a plateau (Pajarito Plateau) dissected by steep canyons. The Sierra de los Valles forms the Caldera rim and is a part of the Jemez Mountains.

The Jemez Mountains comprise a complex volcanic pile at the locus of intersection of two regional geologic features: the eastern rim of the Colorado Plateau to the west and the Rio Grande rift to the east. The rift, which is Miocene to Holocene age, includes a central graben as well as flanking faults and uplifts.

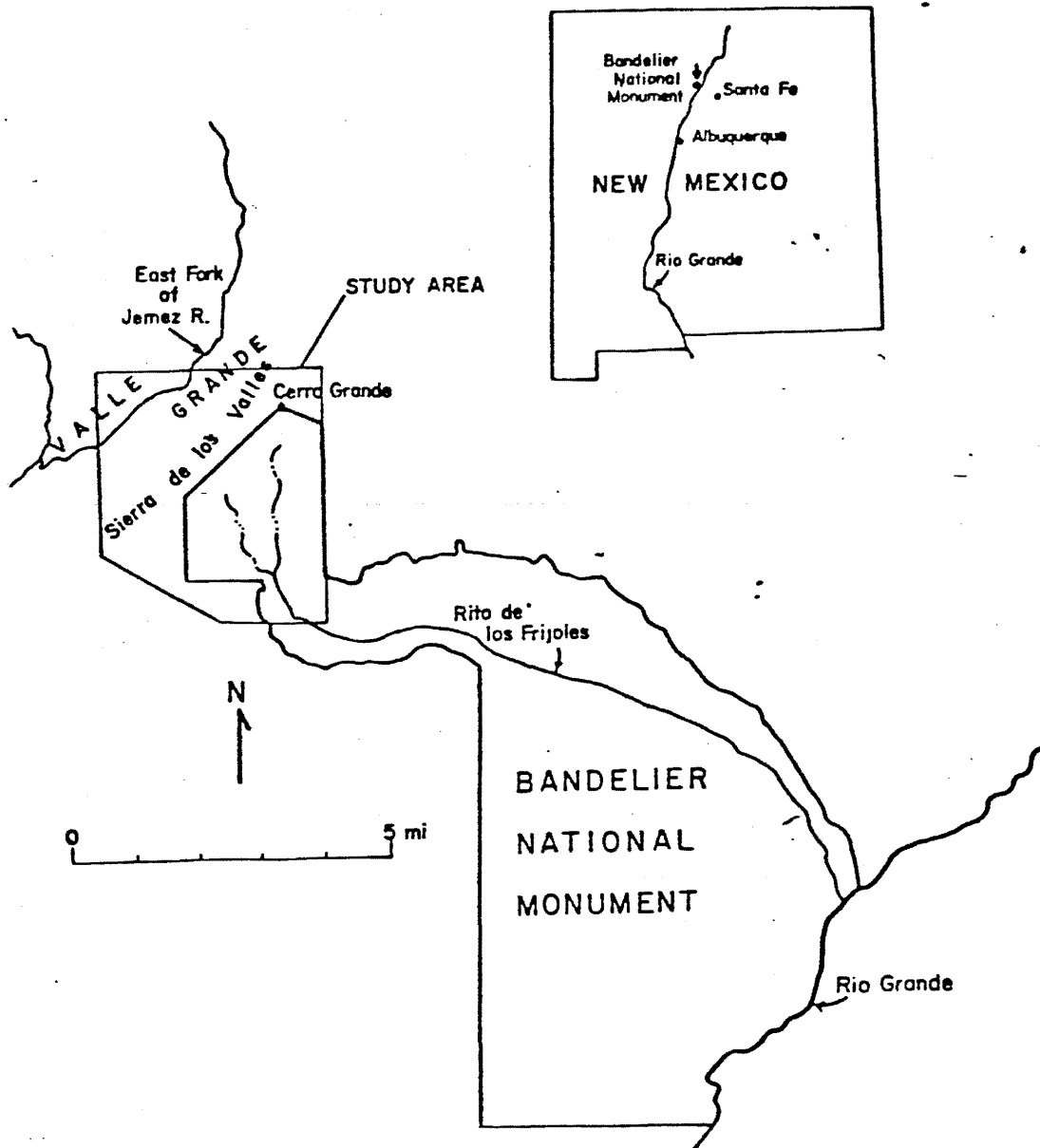


FIGURE 1. Location of the study area in Bandelier National Monument and the Valle Grande.

Volcanic activity began in the Jemez Mountains area in later Miocene to earliest Pliocene with the deposition of the volcanic Paliza Canyon and Tschicoma formations, which formed the earliest volcanoes. The Paliza Canyon formation is a series of andesite and dacite flows and tuffs. The Tschicoma formation which is comprised of latite, quartz latite and pyroxene andesite flows and domes rests on the Paliza Canyon formation.

Following a period of quiescence and erosion, two violent pyroclastic events followed two collapses of the ancient volcano(es) in the mid-Pleistocene. They first formed the Toledo Caldera and deposited the Otowi member of the Bandelier Tuff. The second created the Valles Caldera and laid down the Tschirege member of the Bandelier Tuff. The Bandelier Tuff consists of unconsolidated pumice deposits, pumiceous tuff breccia, and welded rhyolite tuff.

A period of uplift, doming, and faulting followed within the calderas along ring fractures. Rhyolitic domes are common in the caldera. The caldera later was filled with lake deposits, landslide debris, alluvium, and alluvial fans. The flanks of the volcanic pile were dissected by streams and steep canyons formed.

The study area of this report lies in the upper reaches of Frijoles Creek and the neighboring Valle Grande. The Sierra de los Valles separates physiographically the Valle Grande and the drainage of the Rito de los Frijoles. The Valle Grande is a wide valley in the Jemez Mountains. The elevation of the valley floor is about 8500 feet. The East Fork of the Jemez River drains the Valle Grande towards the southwest out of the mountains. The Sierra de los Valles here is

predominately comprised of the Tchicoma formation. On the southeast flanks of these mountains, the Bandelier Tuff was laid down. Very steep relief characterizes the area of the drainage of Frijoles Creek. Elevations range from 10,199 feet (MSL) at Cerro Grande to about 7,700 feet at the canyon floor of Frijoles Creek at the southeastern boundary of the study area. The steep and heavily vegetated terrain in the drainage area is covered with debris. Except in cliff areas, the formations are generally poorly exposed. See figure 2 for geologic map.

STRATIGRAPHY

The Tchicoma formation forms part of the complex cone of the original volcanoes. It is composed of coarsely porphyritic dacite, rhyodacite, and quartz latite flows and domes. The phenocrysts are pyroxene, hornblende, biotite, and plagioclase, with minor quartz. Cooling joints and fractures are common in some zones.

The Bandelier Tuff contains two members. Each member consists of a basal pumice bed overlain by a non-welded to densely welded ash flow tuff containing bipyramidal quartz and chatoyant sanidine phenocrysts. Cliffs often dominate canyons where the Bandelier is exposed.

The older member (Otowi) is unwelded to poorly-welded in the Pajarito Plateau area. It is soft, friable and greyish-white in color. Cavities are common. Accidental lithic inclusions are abundant. Cooling or settling joints are found occasionally in the Otowi. The Otowi is absent or unexposed in most of the study area. Exposures appear on the southwest wall of the Canon de los Frijoles near the southwestern limit of the field area, where thickness approaches 500 feet.

FIGURE 2. Geologic map of study area showing spring locations and distribution of surface flow for the Rito de los Frijoles, August 22 through 25, 1979.

EXPLANATION

Quaternary	Qal	Alluvial and lake terrace deposits
	Qf	Fan deposits
	Qv	Non-differentiated volcanic units
	Qbt	Tschirege member of the Bandelier Tuff
	Qbo	Otowi member of the Bandelier Tuff
Tertiary	Tt	Tchicoma formation
	—	contact
	— — —	monument boundary
	— • —	extant surface flow in the Rito de los Frijoles, August 22 through 25, 1979
	Q	springs in the upper reaches of the Rito de los Frijoles
		extensive baseflow contribution sources to the upper reaches of the Rito de los Frijoles
	—	other flowing streams
	— · —	intermittent streams
	A—A'	cross-section found in figure 3

The younger Tschirege member in the study area is non-welded to densely-welded. Accidental lithic inclusions are sparse. Color varies from white to orange to grey to pink. Unwelded zones often have cooling joints like the Otowi. Moderately-welded zones usually have distinctive columnar jointing. Densely-welded zones are lithoidal, and exhibit numerous subhorizontal joints that impart a platy appearance to the outcrop. Cavities are characteristic of the unwelded to lightly-welded tuffs. The Tschirege member pinches out towards the Sierra de los Valles and is not found exposed in the Valle Grande which is located in the study area. Maximum thickness is about 600 feet in the southernmost part of the study area. The Tschirege member is eroded away in the canyons, exposing the Tchicoma formation.

Some valley fill deposits are found on the canyon floor of Frijoles Creek where the valley floor widens. The valley fill consists predominately of colluvium (a very poorly sorted material composed of boulders, cobbles, sand, silt, and clay) and some alluvium. Below cliffs, substantial debris occurs. Talus slopes are common in the canyons.

The lowlands in the caldera were covered, for at time, by a lake. The lake was filled with debris largely from the rhyolite domes inside the caldera and from rocks of the caldera rim. The sedimentary units are Pleistocene lacustrine, terrace, alluvial, fan and channel deposits.

In the Valle Grande, the caldera fill is pumiceous sand and gravel overlain by a thick clay layer. The maximum thickness of the upper clay and underlying sand and gravel are 295 and 880 feet, respectively (Conover and others, 1963). Maximum thickness of the caldera fill is

not known. A test hole in Valle Grande penetrated 1,185 feet of fill without reaching bedrock. The lowermost cuttings are very pumiceous, suggestive of a pumice bed. The clayey unit is thickest in the central part of the valley and it interfingers with clastic rocks toward the edges of the valley. The terraces, alluvium and alluvial fans lie upon this thick clay layer.

A fault probably exists along the flanks of the Sierra de los Valles in the Valle Grande. The valley fill accumulated on the relatively downthrown block.

GROUND WATER HYDROLOGY

Both the Tchicoma formation and the Bandelier Tuff are poor aquifers, yielding small quantities of water to springs and seeps. Both lie well above the main water table. Porosities and permeability is very low except in fractures, joints, pumice beds, and flow boundaries. Impermeable zones which impede the loss of water can cause perched water zones.

Porosity varies in volcanic rocks from less than 1 percent in dense volcanics to more than 85 per cent in pumice (Davis and DeWiest, 1966). Dense massive flow rocks such as the Tchicoma or densely-welded units of the Tschirege member of the Bandelier Tuff will have from 1 to 10 percent porosity. Although porosity may be high, the permeability is largely a function of other primary and secondary structures in the rock. Horizontal permeability is largely owing to interflow spaces and the vertical permeability is mostly owing to fracturing of partially solidified lava in the last stages of movement together with shrinkage

fracturing. Most commonly, vertical permeability is very small in comparison with horizontal permeability (Davis and DeWiest, 1966). Welded tuffs have medium to low porosities and very low permeabilities. Nonwelded to poorly welded tuffs have high porosities but very low permeabilities.

Porosity may be increased locally by weathering. Depths of weathering of 5 to 50 feet are normally encountered (Davis and DeWiest, 1966). Permeabilities and porosities thus increase near the surface of a volcanic unit.

Groundwater in the Tchicoma formation moves along fractures and joints or in broken zones at the boundaries of individual flows (Griggs, 1964). Small quantities of groundwater emitted naturally on the slopes of the Sierra de los Valles indicate that the Tchicoma does not contain large bodies of perched water at altitudes above the floors of the deep canyons that cut the formation. In spite of the deep canyons in the outcrop area, the base flow of streams fed by groundwater on the eastern slopes of the Sierra de los Valles is small (Griggs, 1965).

The Bandelier Tuff in places contains bodies of perched water. Springs emerge in perched zones in the Tschirege member at high altitudes on the eastern slopes of the Sierra de los Valles. Springs are also emitted from pumice beds at the base of the Tschirege where permeabilities and porosities are higher and also from the fractured zones of welded units.

The principal aquifer in the Valle Grande is the pumiceous sand and gravel in which water is confined under pressure by an overlying clay

and silt zone. The static water level is 10 or more feet above the surface of the valley floor near the East Fork of the Jemez River in the study area. The water of the caldera is high in silica and low in total dissolved solids. Residence of the water is therefore short. The coefficient of transmissibility of the aquifer is at least 25,000 gpd/ft. The specific capacity of wells in this aquifer can be expected to be about 25 gpm/ft drawdown (Conover and others, 1963).

The alluvial fans and terraces bear water which surfaces as springs in the Valle Grande at the exposed contacts with the clayey aquitard and each other. The ground water in the Valle Grande aquifer is naturally discharged through springs in the valley of the East Fork of the Jemez Mountain downstream from the area.

A cross-section (figure 3), was constructed using data from Conover and others (1963), Griggs (1964), and Smith and others (1970), to illustrate the hydrogeological relationships of the rocks of cross-section A-A'. Precipitation that falls on the rubble upon the Tschicoma and on the rocks of the Tschicoma moves downward only a short distance before it reaches the relatively impermeable interior of the Tschicoma.

A perched water zone lies at the contact between the Tschirege member and the Tschicoma formation, and is not continuous throughout the area of the contact. The relatively impermeable rocks of the interior of the Tschicoma rocks block any significant leakage from the caldera fill aquifer and helps thereby to maintain the artesian conditions of the caldera fill aquifer.

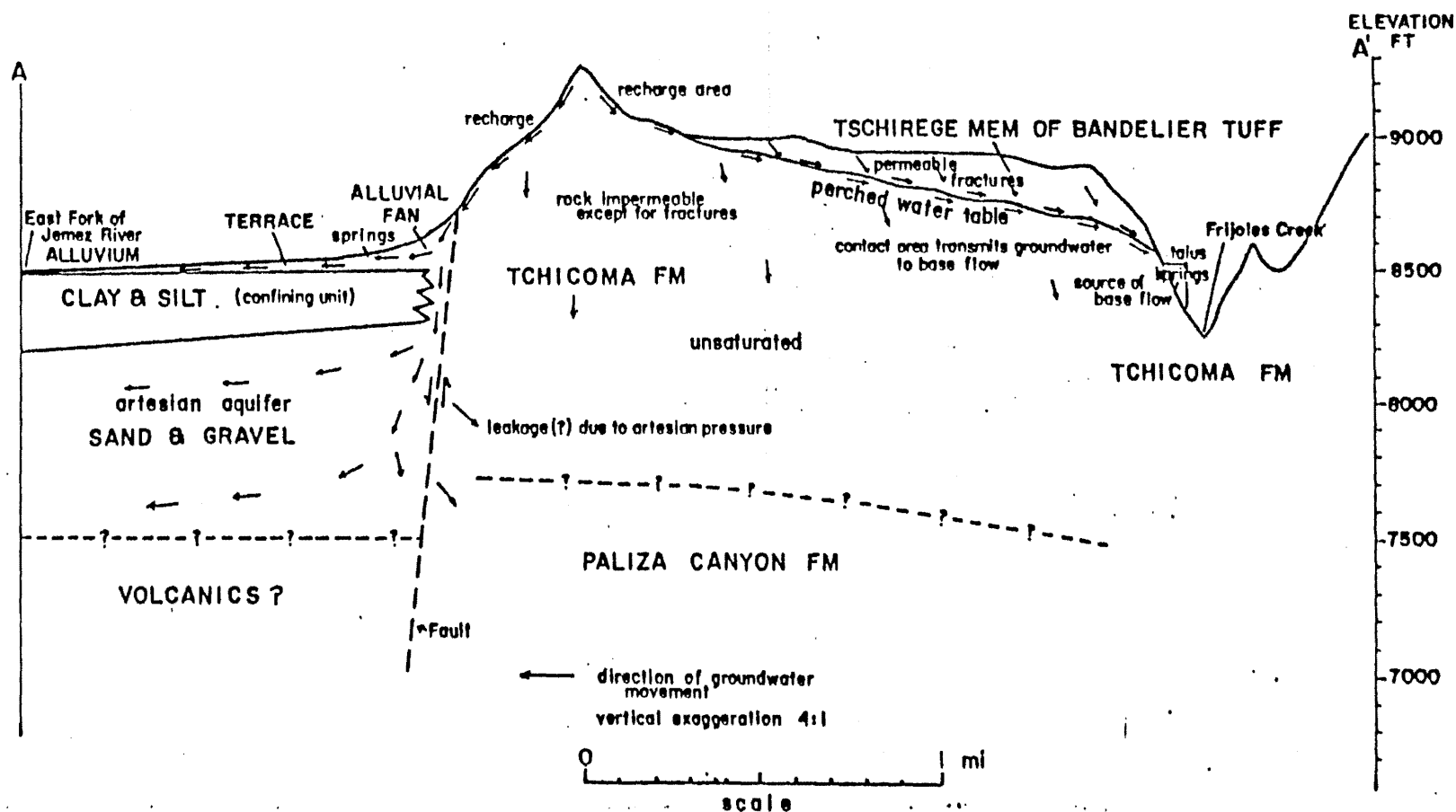


FIGURE 3. Cross-section showing relationships between geology and hydrology of the Valle Grande aquifer and the Rito de los Frijoles

ORIGIN OF BASE FLOW OF UPPER FRIJOLES CREEK

Frijoles Creek in its upper reaches divides into two forks which in this paper are termed the left and right forks. Observed surface flow in channels and sites of base flow origin were mapped August 22-25, 1979 (see figure 2).

The principal sources for base flow are springs and seeps. The major contributing sources are mapped in figure 2. The most significant base flow source of the creek is also the predominant base flow source for the right fork. The zone is characterized by many springs and seeps emitting from a talus slope located above and below the contact of the Tschirege member of the Bandelier Tuff and the Tchicoma formation.

The left fork flows continuously from a spring to the confluence. The water issues from fractures in the Tchicoma. At the confluence of the two forks, water issued from talus and alluvium probably has Tchicoma rocks as the transmitting unit. A small tributary enters Frijoles Creek south of the confluence, whose base flow is emitted from the Tschirege member of the Bandelier Tuff, probably a densely-welded unit within the member. Several other springs and seeps discharge into the creek along its course (see figure 2 for locations).

Further upstream in both forks a few springs discharge into the stream-beds, but the water flows only for a short distance in the channel before disappearing into fractures and joints or into valley fill. These springs have their sources in the Tschirege member of the Bandelier Tuff (the welded tuff units) or the Tchicoma formation. The left fork begins to flow where the valley bottom narrows to the width of the channel. No

surface flow was observed in either fork where the valley floor widens and relatively thick valley fill occurs. Water flows in the stream channels when the infiltration rate of water into the stream bed does not exceed the amount of water supplied by springs and seeps. An aquitard or water-saturated units beneath the stream channels must exist in order to accommodate surface flow.

Canyons north of Frijoles Creek in the Los Alamos area, that drain surface water eastward to the Rio Grande from the Sierra de los Valles, have base flows that originate from perched water zones in the rocks of the Tschicoma volcanics and the Bandelier Tuff (Griggs, 1964). Springs in these canyons issue from the pumice beds at the base of the Tschirege member of the Bandelier Tuff, from talus slopes and alluvium and fractures in the Tschirege member and the underlying Tschicoma volcanics (Griggs, 1964). The occurrences of springs which supply base flow to upper Frijoles Creek are similar to these canyons to the north.

WATER CHEMISTRY

The chemistry of the rocks through which and in which ground water travels and resides is similar in both the Valle Grande fill and the Sierra de los Valles rocks. Length of residence is a major factor in water chemistry.

T-test run on the Valley Grande wells water chemistry as one sample group and that of Frijoles Creek as the other sample group show that the waters are similar enough to be classified as belonging to the same population in regards to bicarbonate content, specific conductance, and total dissolved solid levels with a significant level of 0.005. In

regards to silica levels, the samples from the two groups are not from the same population with a significance level of 0.005 (see table below).

	<u>Degrees of Freedom</u>	<u>Calculated t</u>	<u>Table t</u>	<u>Significance Level</u>
SiO ₂	8	5.65	3.36	0.005
HCO ₃	8	1.22	3.36	0.005
TDS	8	2.83	3.36	0.005
Specific Conductance	8	1.49	3.36	0.005

A significance level of 0.005 expresses a 99.5 per cent probability. The calculated t must be lower than the table t for a positive possibility, and higher for a negative possibility. Chemical analyses do not show, though, that the water of the base flow of the upper Rito de los Frijoles is derived from the Valle Grande aquifer, but rather show the length of residence of ground water and chemical similarities of water-bearing rocks.

The silica content in parts per million averages $56^{+4.8}$ in the water of Frijoles Creek and $71.2^{+3.6}$ in the Valle Grande aquifer. This is probably due to the fact that the samples of Frijoles Creek were collected when substantial snowmelt could have occurred or due to a shorter residence time.

CONCLUSIONS

Geological and hydrological data presented in this paper suggest that there is no significant leakage from the Valle Grande aquifer to the springs that supply base flow for upper Frijoles Creek. The springs

which supply base flow for upper Frijoles Creek are derived from small perched water tables in Tschirege member of the Bandelier Tuff and the Tschicoma formation. These water tables are found in fractured and jointed rocks or a pumice bed at the base of the Tschirege. Recharge to the springs occurs through infiltration and percolation into and through rocks on the southeast flank of the Sierra de los Valles.

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