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Hydrochemistry of the Valle Toledo, Valles Caldera, New Mexico

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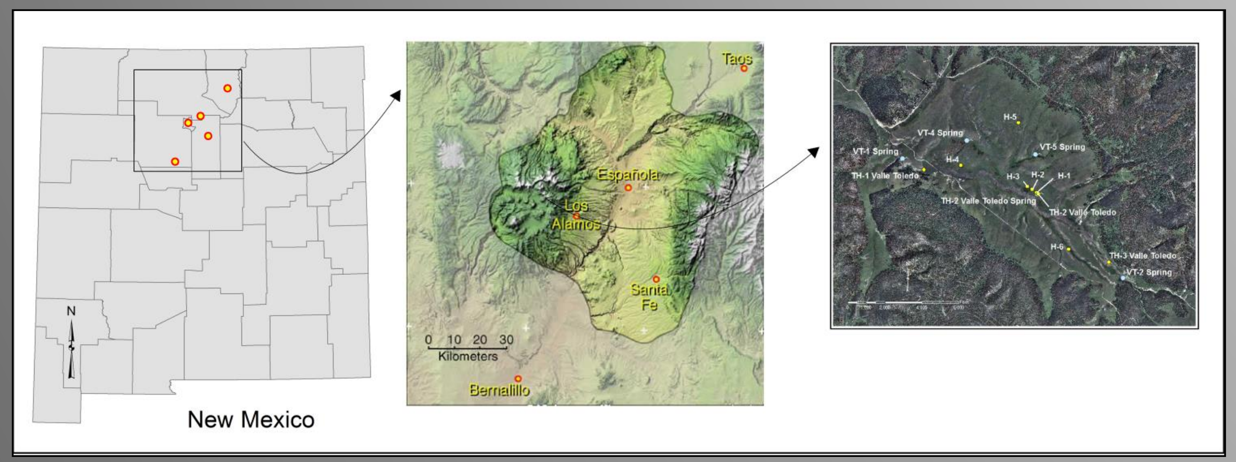
Abstract

Initial groundwater resource investigations were conducted in the Valle Toledo and other areas near Los Alamos, New Mexico during the late 1940's and early 1950's. The investigations included drilling of numerous test holes and installation of several observation and pumping wells. Test holes within the Valle Toledo penetrated an artesian sand and gravel aquifer 122 m thick. Results of the water resource investigations determined that pumping and development of the aquifer would deplete flow to the San Antonio River and potentially obstruct surface-water rights; hence, groundwater resources in the Valle Toledo were not developed. This investigation was conducted to evaluate hydrochemical characteristics and groundwater residence times. Groundwater samples were collected and analyzed for major ions, trace elements, low-level tritium, radiocarbon in dissolved inorganic carbon (DIC), and stable isotopes of hydrogen, oxygen, and carbon in DIC. Groundwater is characterized by a sodium-calcium-bicarbonate composition with total dissolved solids (TDS) ranging from 100 to 130 mg/L. Concentrations of nitrate as nitrogen range from 0.02 to 0.04 mM (0.3 to 0.5 mg/L) and sulfate range from 0.01 to 0.03 mM (1.4 to 2.8 mg/L). Water-rock interactions are not extensive based on the TDS content and chemical composition of the groundwater samples. Compositions of δ^2H and $\delta^{18}O$ range from -92.6 to -88.1 ‰ and from -12.9 to -12.2 ‰, respectively, suggesting that snowmelt and rain provide local recharge to the aquifer system. Activities of tritium were less than detection (0.2 tritium units, 0.6 pCi/L), with no modern component of water present. This suggests that recharge to the artesian aquifer is greater than 60 years. Unadjusted radiocarbon activities as fraction modern carbon in dissolved inorganic carbon range from 0.82 to 0.74, corresponding to estimated ages ranging from 1,521 to 2,400 years. The San Antonio River is the principal drainage from the Valle Toledo and is designated as a High Quality Coldwater Aquatic Life water source. Discharge of groundwater from the Valle Toledo supports headwater baseflow to the San Antonio River. Groundwater discharging to the San Antonio River is not susceptible to present-day contamination, as reflected by the average age exceeding 1,500 years.

Purpose and Objectives

The purpose of this investigation is to (1) determine if anthropogenic contamination is present in the Valle Toledo artesian aquifer and (2) assess average groundwater age and residence time within the aquifer system. Specific objectives include (1) evaluating site-specific hydrogeological conditions, (2) characterizing major ion chemistry and radiogenic and stable isotopes of carbon, hydrogen, and oxygen, (3) identifying potential contaminants, and (4) quantifying water-rock interactions within the aquifer system.



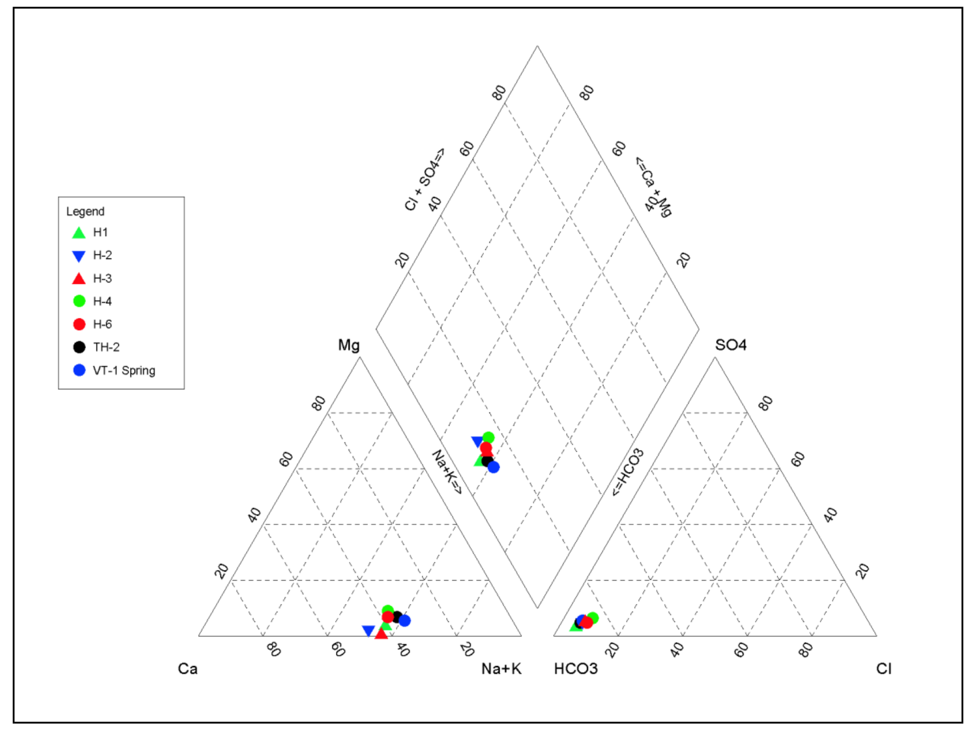
Geology and Hydrogeology

Based on recent field mapping and subsequent publication of a preliminary geologic map for the Valle Toledo (hereafter, valley) by Gardner et al. (2006) and earlier investigations conducted by the US Geological Survey (Griggs, 1964 and Smith, 1938), the surficial geology of the valley floor is comprised mainly of Quaternary age alluvial fans and terrace gravels. Minor exposures of more recently deposited alluvium and alluvial fans occur along the drainage of the valley, which extend from the southeast to the northwest. Colluvial deposits are located along the flanks of the valley (see geologic map). At depth, Quaternary age lacustrine deposits (sands, gravels, and clay) interfinger with fan and terrace deposits. The maximum thickness of these deposits is approximately 170 meters (m) (see Figure 1). Thick (≈27 m) lacustrine clay deposits occur in the subsurface near the western edge of the valley. Surrounding the valley floor to the northeast is the Sierra de Toledo, a highland mountain-block feature of the Toledo Embayment. This area is composed of porphyritic rhyolite. Southeast and southwest portions of the valley are bounded by massive (≈350 m of relief) ring-fracture features also composed of porphyritic rhyolite. An extensive zone of faulting and deformation features is present along the northwest portion of the valley where a variety of volcanic and sedimentary rocks crop out. The volcanic highlands surrounding the valley are likely deep seated and presumably represent the basement beneath the Valle Toledo basin-fill sediments.

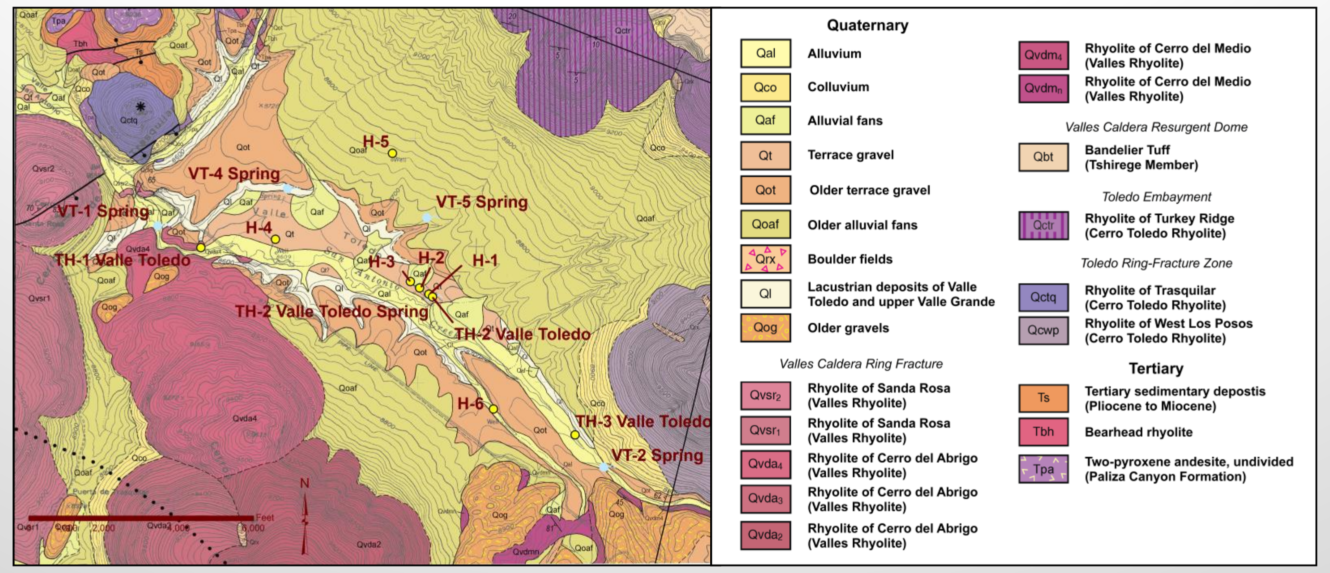
Well drilling, aquifer pumping tests, and surface-water flow measurements were conducted in the late 1940's (Stearns, 1948; Conover, et al., 1963; and Griggs, 1964). The purpose of these investigations was to determine if the artesian aquifer could be developed for water-supply purposes. Clay deposits probably act as upper confining units for the artesian aquifer. Head-pressure measurements from drill holes and wells indicate that the potentiometric surface of the artesian aquifer slopes towards the northwest where a set of large flowing springs (VT-1 Spring) are present, which likely represent the discharge zone for the artesian aquifer. The thick clay-rich deposit located along the western portion valley focuses groundwater flow to the surface represented by VT-1 Spring. Recharge to the artesian aquifer probably occurs along the perimeter of the valley floor and surrounding highland areas. Snowmelt infiltrates downward through and within the edges of the highland structures, moving laterally into the valley-fill material (see Figure 1). Aquifer pumping-test data and water-level and surface-water flow measurements show that the artesian aquifer discharges at a rate of 2.23 cubic feet per second (cfs), with the bulk of the flow supporting the headwater for the San Antonio River. As part of the earlier investigations, one of the 11 boreholes drilled in the Valle Toledo was completed to a total depth of about 150 m and screened from 117 to 130 m below ground surface. In response to the well's (H-1) artesian condition, a high-pressure valve had to be installed at the surface. In the past, the valve cracked producing a significant leak (see photo of H-1). Flow from the well head is estimated at a rate of 1 cfs. Flow from H-1 extends about 50 m where it joins with the present-day channel of the San Antonio River. Perennial flow in the channel supports an ecosystem where fish and other aquatic life thrive. Prior to the valve cracking, flow in the channel at this position was likely ephemeral. Surface-water flow in the San Antonio River, at the confluence of water released from well H-1 and VT-1 Spring, is estimated (visually) at a rate of 2 cfs. The rate of surface-water flow increases downstream of this confluence where it eventually joins the Jemez River near La Cueva, New Mexico.

Analytical Methods

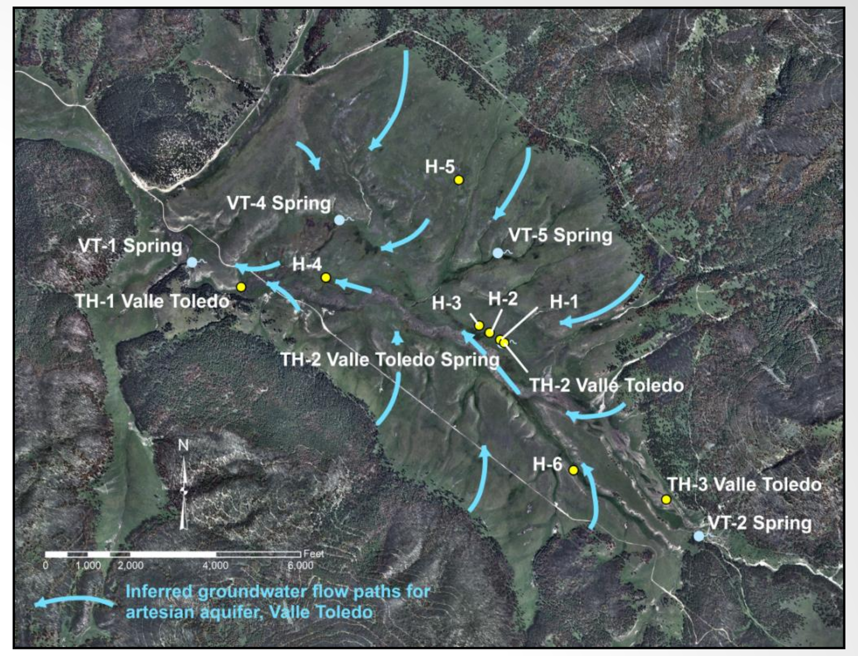
- **Carbon-14**, accelerator mass spectrometry (U of Arizona)
- **Tritium**, electrolytic enrichment (U of Miami)
- **Stable isotopes**, isotope ratio mass spectrometry (EES)
- **Anions**, ion chromatography (EES)
- **Metals**, inductively couple (argon) plasma-optical emission spectroscopy (ICP-OES) and inductively couple (argon) plasma-mass spectrometry (ICP-MS) (EES)
- **Total carbonate alkalinity**, titration (EES)
- **Perchlorate**, liquid chromatography-mass spectrometry (ALS)



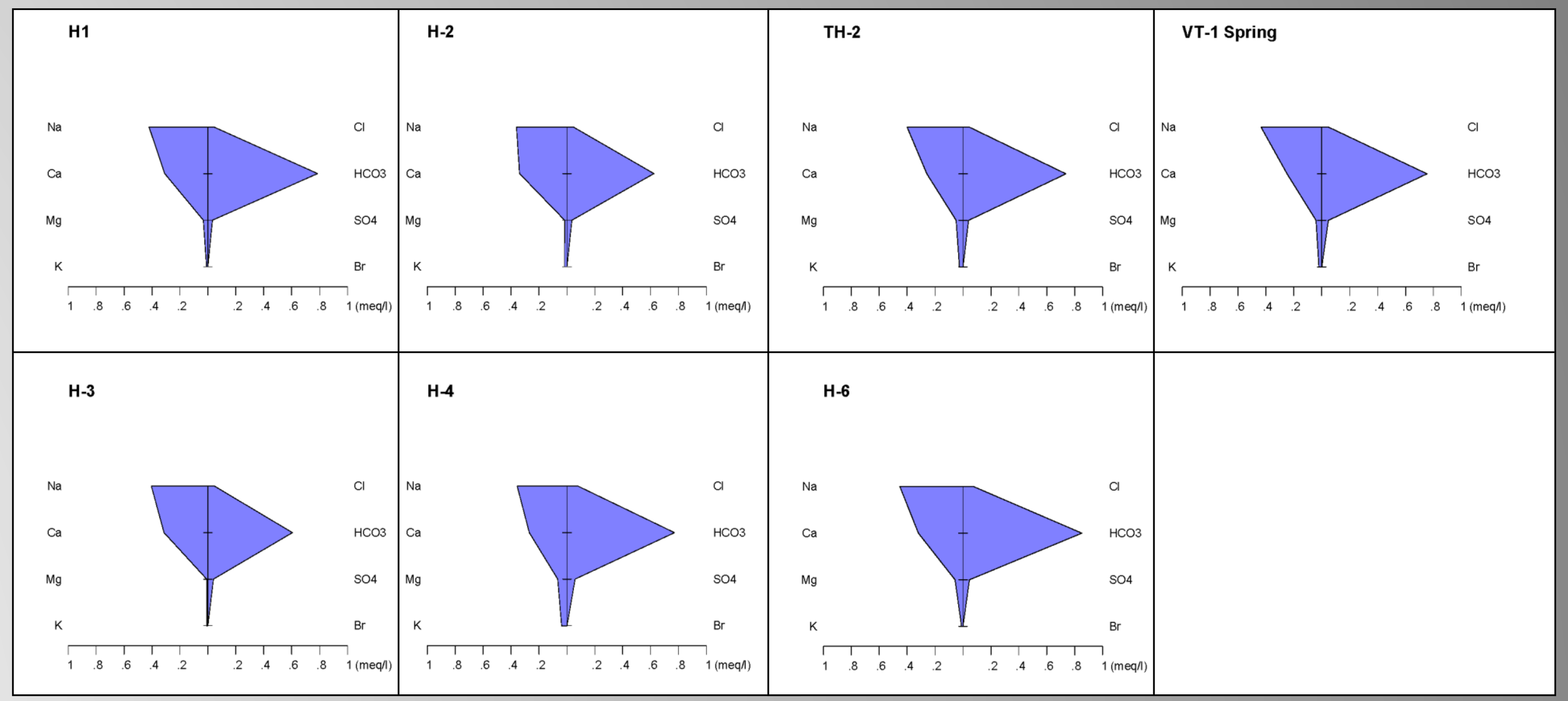
Trilinear diagram for Valle Toledo groundwater, Jemez Mountains



Geology of the Valle Toledo from "Preliminary geologic map of the Valle Toledo quadrangle, Los Alamos and Sandoval Counties, New Mexico, May 2006, Gardner J., Goff, F., Reneau, S, Sandoval, M., Drakos, P., Katzman, D., and Goff, C. NMBGMR Open-file Geologic Map 133



Generalized conceptual model of groundwater flow within Valle Toledo



Stiff diagrams for Valle Toledo groundwater, Jemez Mountains

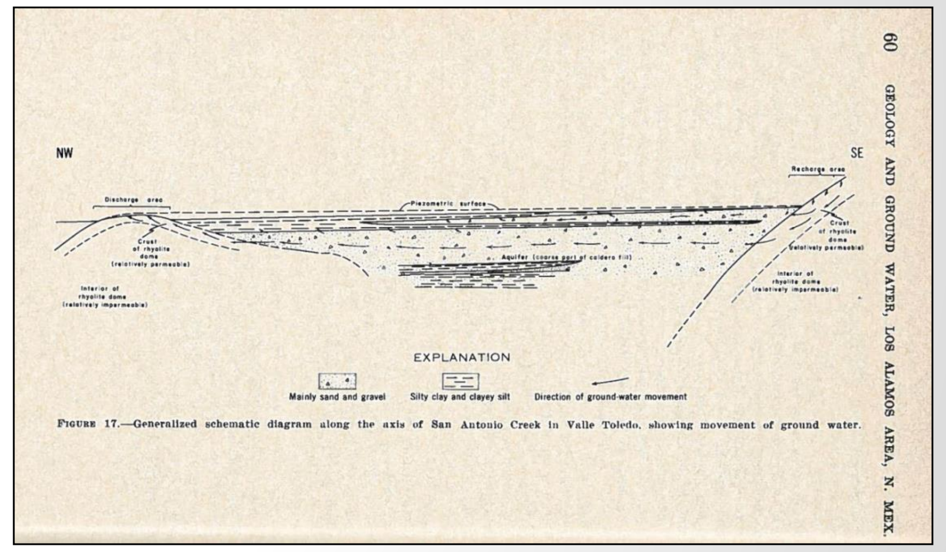
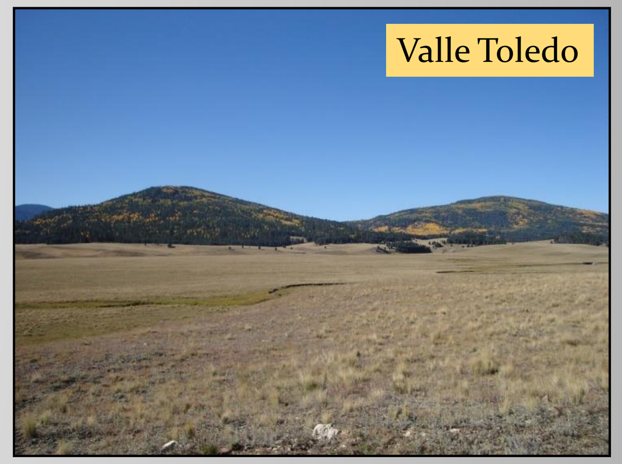
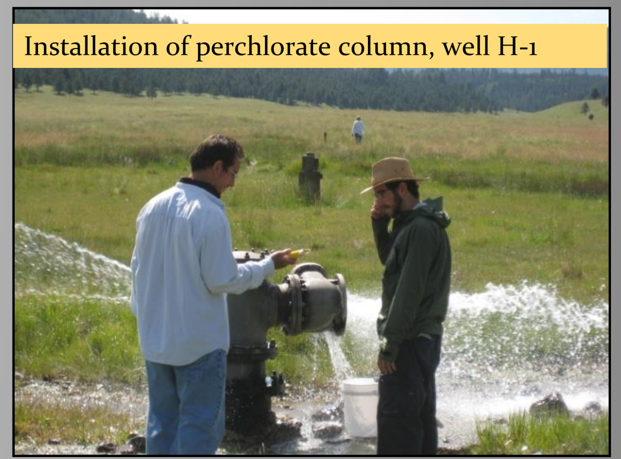
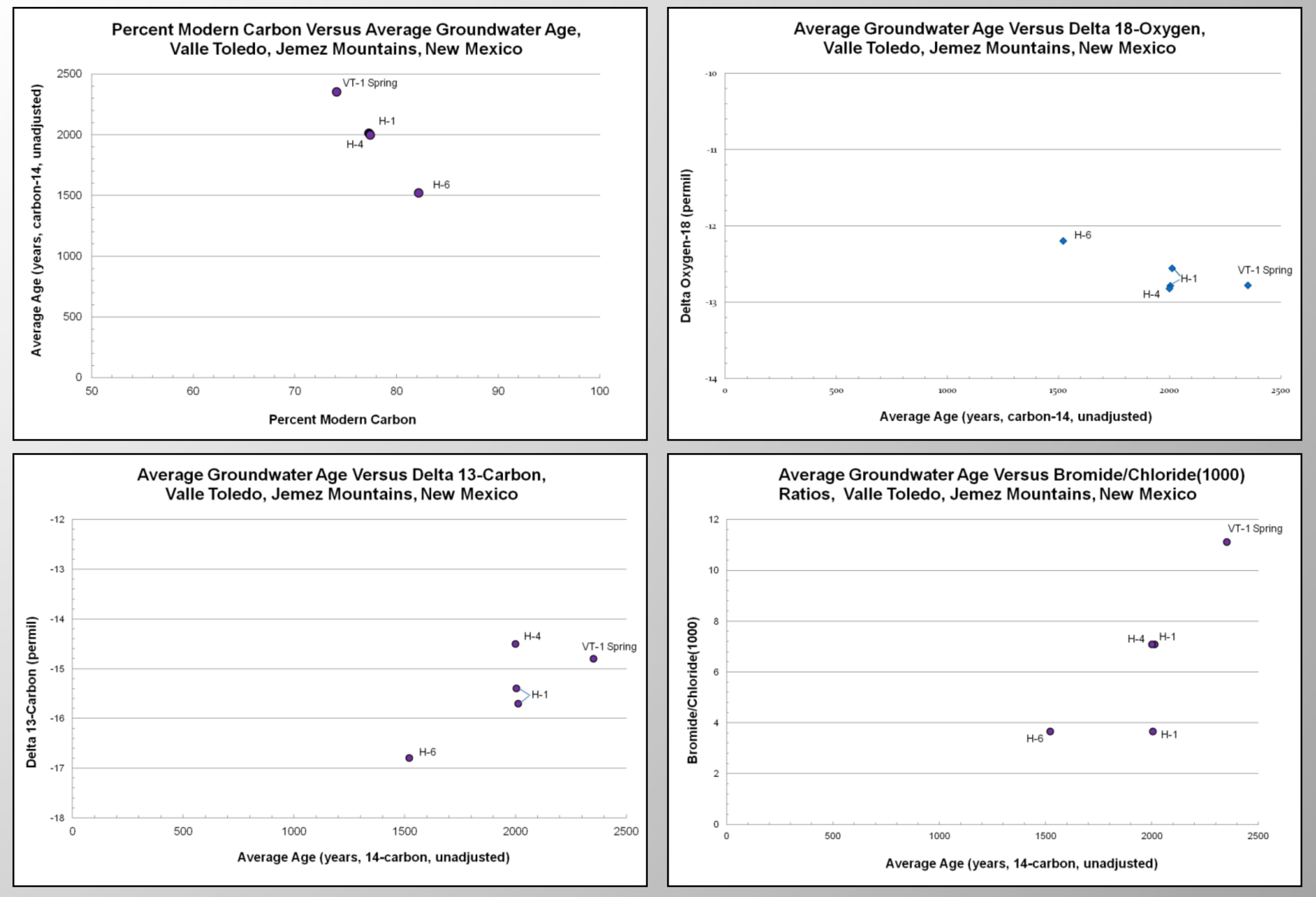


Figure 1 – Generalized cross-section of the Valle Toledo (Griggs, 1964)



View to the southeast





Average groundwater age and aquifer chemistry

Conclusions

The average age of the artesian aquifer, based on unadjusted carbon-14 measurements, ranges from 1521 to 2427 years before present.

The artesian aquifer has not experienced recent recharge since the early 1950's based on the non-detection of tritium (<0.28 pCi/L, 0.09 TU).

Groundwater within the artesian aquifer system is characterized by a sodium-calcium-bicarbonate composition with concentrations of TDS less than 100 mg/L.

Water-rock interactions (mineral precipitation-dissolution) have not taken place to a significant extent within the artesian aquifer. Dissolution of soluble volcanic-derived glass has released conservative solutes (boron and fluoride) to groundwater.

For additional information please contact Michael Dale at mdale@lanl.gov or (505) 661-2673

DATA SOURCES and REFERENCES:

(1) Conover, C. S. et al., 1963, Geology and Hydrology of the Valle Grande and Valle Toledo, Sandoval County, New Mexico
(2) EBTAG website: http://geoinfo.nmt.edu/ebtag
(3) Gardner, J. N. et al., 2006, Preliminary Geologic Map of the Valle Toledo Quadrangle, Los Alamos and Sandoval Counties, New Mexico
(4) Griggs, R. L., 1964, Geology and Groundwater Resources of the Los Alamos Area New Mexico
(5) LANL Earth and Environmental Sciences Geology and Geochemistry Research Lab (EES-14 GGR Laboratory)
(6) New Mexico Environment Department
(7) Smith, H. T., U., 1938, Tertiary geology of the Abiquiu quadrangle, New Mexico, *Journal of Geology*, v. 46, no. 7, p. 933-965.
(8) Stearns, H. T., 1948, Ground-water supplies for Los Alamos, New Mexico