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Hydrogeologic Framework of Antelope Valley and Bedell Flat, Washoe County, West-Central Nevada

Water-Resources Investigations Report 01-4220

Prepared in cooperation with the
WASHOE COUNTY DEPARTMENT OF WATER RESOURCES

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By David L. Berger, David A. Ponce, *and* Wyn C. Ross

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Carson City, Nevada
2001

U.S. DEPARTMENT OF THE INTERIOR
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U.S. GEOLOGICAL SURVEY
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PLATE

[Plate is in pocket at back of report]

FIGURES

TABLES

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
acre-foot (acre-ft)	1,233	cubic meter
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year
foot (ft)	0.3048	meter
foot per second (ft/s)	0.3048	meter per second
foot squared per day (ft^2/d)	0.09290	meter squared per day
gram per cubic centimeter (g/cm^3)	62.4220	pound per cubic foot
inch (in.)	2.54	centimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Temperature: Degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by using the formula °F = [1.8(°C)]+32. Degrees Fahrenheit can be converted to degrees Celsius by using the formula °C = 0.556(°F-32).

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929, formerly called "Sea-Level Datum of 1929"), which is derived from a general adjustment of the first-order leveling networks of the United States and Canada.

Altitude, as used in this report, refers to distance above or below sea level.

Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness $[(ft^3/d)/ft^2]ft$. In this report, the mathematically reduced form, square foot per day (ft^2/d), is used for convenience.

Note: English units are used throughout this report, except in instances where a measurement has no common English-unit equivalent.

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ABSTRACT

Description of the hydrogeologic framework of Antelope Valley and Bedell Flat in west-central Nevada adds to the general knowledge of regional ground-water flow north of the Reno–Sparks metropolitan area. The hydrogeologic framework is defined by the rocks and deposits that transmit ground water or impede its movement and by the combined thickness of Cenozoic deposits. When data are lacking about the subsurface geology of an area, geophysical methods can be used to provide additional information. In this study, gravimetric and seismic-refraction methods were used to infer the form of structural features and to estimate the thickness of Cenozoic deposits in each of the two valleys. In Antelope Valley, the thickness of these deposits probably does not exceed about 300 feet, suggesting that ground-water storage in the basin-fill aquifer is limited. Beneath Bedell Flat is an elongated, northeast-trending structural depression in the pre-Cenozoic basement; the maximum thickness of Cenozoic deposits is about 2,500 feet beneath the south-central part of the valley. Shallow ground water in the northwest corner of Bedell Flat may be a result of decreasing depth to the pre-Cenozoic basement.

INTRODUCTION

Recent population growth in west-central Nevada has led to the expansion of urban development to rural valleys north of the Reno–Sparks metropolitan area (fig. 1). Currently, the Truckee River provides more than 75 percent of the water supply for the Reno–Sparks area (Wyn C. Ross, Washoe County Department of Water Resources, oral commun., 2000). For most of the outlying valleys to the north, however, ground water is the only source of water, particularly where Truckee River water may be impractical to deliver. The Washoe County Department of Water Resources (WCDWR) has initiated several hydrologic investigations in these valleys, focusing primarily on describing the ground-water flow systems in basin-fill aquifers that underlie the valleys and on determining the potential effects on these systems of regional ground-water development.

The first step toward evaluating regional ground-water flow is to develop an understanding of the regional hydrogeologic framework and its control on ground-water movement. A hydrogeologic framework often can be inferred from information about the geometry and thickness of basin-fill deposits. In most valleys, however, the thickness of these deposits frequently is unknown. Geophysical methods can provide a practical and economical means to estimate the thickness of basin fill and to describe a valley's general hydrogeologic framework.

In 2000, the U.S. Geological Survey (USGS), in cooperation with the WCDWR, began a 2-year water-resources investigation to add to knowledge of regional ground-water flow systems in west-central Nevada and to provide background information for future hydrologic studies. This investigation uses surface geophysical methods to assist in describing the hydrogeologic framework of the Antelope Valley and Bedell Flat Hydrographic Areas[1] (fig. 1).

[1]Formal hydrographic areas in Nevada were delineated systematically in the late 1960's by the U.S. Geological Survey and Nevada Division of Water Resources for scientific and administrative purposes (Cardinalli and others, 1968; Rush, 1968). The official hydrographic-area names, numbers, and geographic boundaries continue to be used in Geological Survey scientific reports and Division of Water Resources administrative activities.

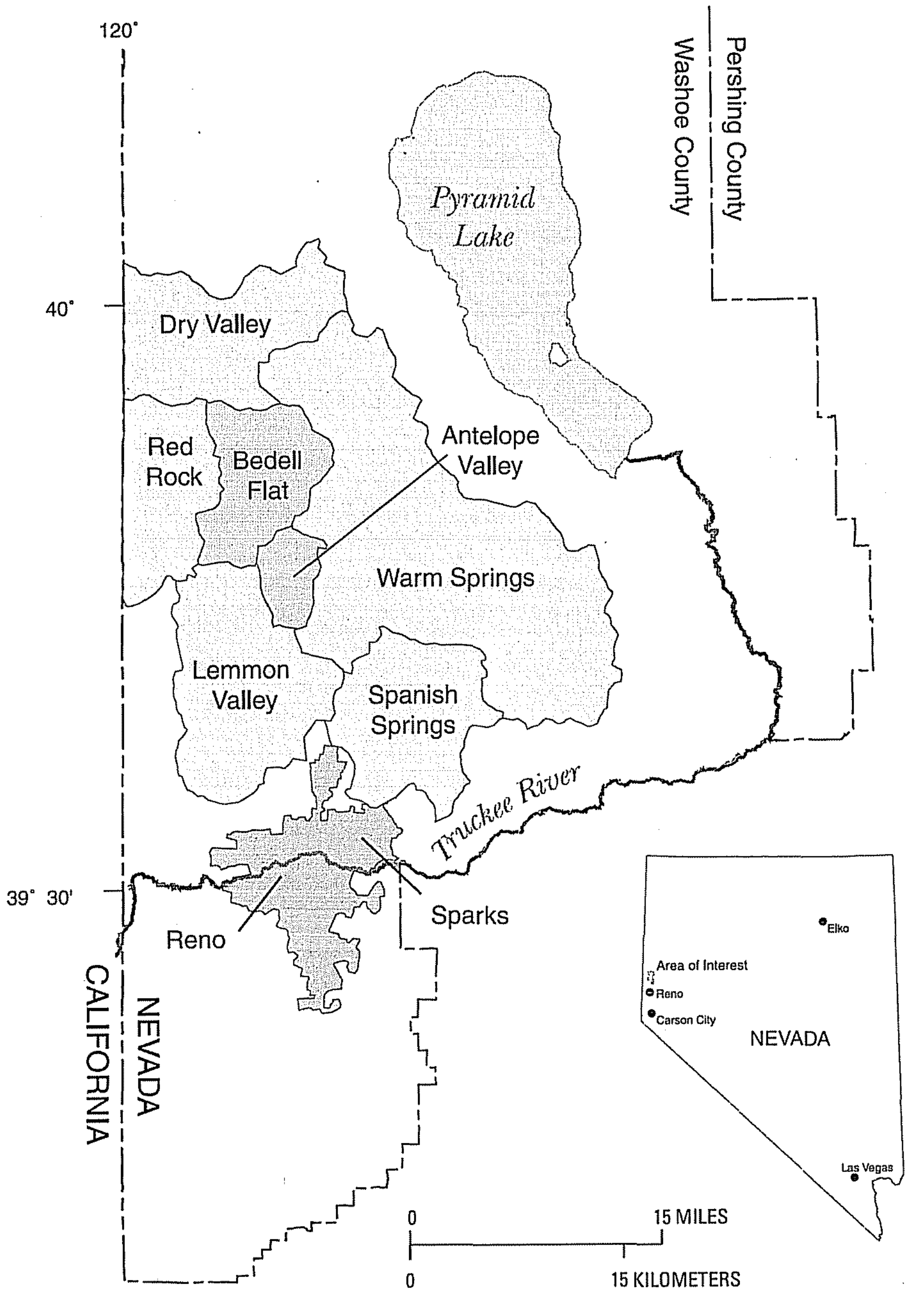

Figure 1. Location of Antelope Valley and Bedell Flat Hydrographic Areas, west-central Nevada.

Located in southern Washoe County about 15 mi north of Reno, the Antelope Valley and Bedell Flat Hydrographic Areas have a combined area of 68 mi^2. Antelope Valley, the smaller (17 mi^2) of the two areas, is topographically closed. There is limited use of ground water in Antelope Valley, mainly from domestic wells associated with large-parcel development. The 51 mi^2 Bedell Flat is mostly undeveloped, but urbanization is expected to increase ground-water use in the next 5 to 10 years.

Antelope Valley is bounded on the east by Hungry Mountain and Warm Springs Mountain (which are nearly 6,000 ft in altitude) and on the west by Freds Mountain (nearly 7,200 ft in altitude) and by the northern extension of an unnamed mountain (pl. 1). Forming the southern boundary are the northern extensions of two unnamed mountains that separate Antelope Valley from Lemmon Valley. A series of low hills forms the northern boundary, which coincides with part of the southern boundary of Bedell Flat. The floor of Antelope Valley is about 2 mi wide and 5 mi long and covers about 55 percent of the total drainage area. In the lowest part of the valley is a playa at an altitude of about 5,100 ft.

Dogskin Mountain, the highest mountain in the study area at nearly 7,500 ft in altitude, makes up most of the northern and eastern boundaries of Bedell Flat. A series of low hills and a narrow alluvial divide complete the eastern boundary. Bedell Flat is bounded on the west by the Sand Hills, which have altitudes approaching 6,200 ft. A low, broad alluvial divide between the southern extension of the Sand Hills and the east flank of Freds Mountain makes up most of the southern boundary. The valley floor, which decreases in altitude from about 5,200 ft in the southwest to about 4,800 ft in the northeast, covers about 58 percent of the drainage area. The drainage line on the valley floor in Bedell Flat trends to the northwest and is estimated to discharge about 70 acre-ft of streamflow annually through a narrow draw to Red Rock Valley (Rush and Glancy, 1967, p. 30).

The principal source of precipitation to the region is the Pacific Ocean, which typically provides moisture from October to June. During the summer months, tropical air from the Gulf of California produces scattered but intense convective showers (Houghton, 1969, p. 5; Brenner, 1974). In the study area, annual precipitation on the valley floors is about 8 in/yr; the surrounding mountains receive about 15 in/yr (Berger and others, 1997, p. 31). Estimated annual precipitation is 9,000 acre-ft/yr in Antelope Valley and 28,000 acre-ft/yr in Bedell Flat (Rush and Glancy, 1967, p. 21). Ground-water levels, reported by well drillers, generally are between 80 to 100 ft beneath the floor of Antelope Valley. According to a limited number of well drillers' logs in Bedell Flat, ground-water levels are about 100 to 200 ft beneath the valley floor in the southern part of the valley and less than 5 ft beneath the northwestern part.

Purpose and Scope

The purpose of this report is to describe the hydrogeologic framework of the Antelope Valley and Bedell Flat Hydrographic Areas. This framework is defined by (1) the rocks and deposits that transmit ground water or impede its movement, and (2) the combined thickness of basin-fill deposits and volcanic rocks. For purposes of this study, Quaternary and Tertiary basin-fill deposits and Tertiary volcanic rocks are collectively defined as Cenozoic deposits. Plutonic and metamorphic rocks are defined as pre-Cenozoic basement.

Geophysical methods were used to infer the form of structural features and to estimate the thickness of Cenozoic deposits in Antelope Valley and Bedell Flat. Gravimetric data were compiled from 351 gravity stations. Data from 14 of these stations are publicly available on a CD-ROM (Ponce, 1997); data from 126 stations were collected by Thomas C. Carpenter (Thomas C. Carpenter, Consulting Geophysicist, written commun., 1998), and data from 211 stations were collected in April 2000 as part of this study (Jewel and others, 2000). Seismic-refraction data were collected along five profiles during several weeks from August to December 2000. The seismic-refraction data were used as additional control points for gravity interpretation in areas of limited borehole data.

GEOPHYSICAL METHODS

Geophysical methods can be used to determine indirectly the hydrogeologic framework of an area based on the physical properties of the subsurface. The combination of gravimetry and seismic refraction is well-suited for use in west-central Nevada. Among the different hydrogeologic units in this area, differences in rock densities and seismic velocities can be very pronounced. The gravimetric method allows for a large area to be surveyed rapidly to produce a general description of the hydrogeologic framework. When more detail about the subsurface is required, the seismic-refraction method can be used. Brief descriptions of the gravimetric and seismic-refraction methods follow; for additional information see Grant and West (1965), Telford and others (1976), and Dobrin (1976).

Gravity

The objective in gravity exploration is to associate variations in measured gravity with differences in the distribution of densities in the subsurface, which correspond to different rock types. Differences in rock densities produce small changes in the Earth's gravitational field that can be detected by a gravimeter. In the study area, the contrast in density between Cenozoic deposits and pre-Cenozoic basement produces distinctive gravity anomalies. These anomalies can be used both to determine the thickness of Cenozoic deposits and to infer the structure and geometry of the basement.

Density information from hydrogeologic units within the study area (table 1) is essential to understanding the relationship between gravitational anomalies and their causative sources. From 25 rock samples collected in the study area, the saturated bulk density of pre-Cenozoic basement (plutonic and metamorphic rocks) was found to range from 2.28 to 3.03 g/cm^3, with an average of about 2.71 g/cm^3. Samples of Cenozoic volcanic rocks ranged in density from 2.11 to 2.36 g/cm^3, with an average of 2.24 g/cm^3. The density of basin-fill deposits beneath valleys in Nevada has been determined to range from about 1.60 to 2.20 g/cm^3 (Jewel and others, 2000, p. 6; Berger and others, 1997, p. 21). The density of Cenozoic deposits, particularly basin fill, generally increases with depth as a result of compaction. In this study, a layered-density model (Jachens and Moring, 1990, p. 14) was used to describe the relation between density and depth of Cenozoic deposits (table 2). Additional physical property data, locations of samples, description of gravity reduction procedures used, and an isostatic anomaly map of the study area are presented by Jewel and others (2000).

Table 1. Density of rock samples collected in Antelope Valley and Bedell Flat, west-central Nevada (modified from Jewel and others, 2000)

[Abbreviation: g/cm^3, grams per cubic centimeter]

Map unit	Number of samples	Saturated bulk (g/cm^3)	
		Range	Average
Volcanic rocks	4	2.11–2.36	2.24
Plutonic rocks	21	2.28–3.03	2.67
Metamorphic rocks	4	2.69–2.78	2.74

Table 2. Density-depth function (Jachens and Moring, 1990) for Cenozoic deposits in Antelope Valley and Bedell Flat, west-central Nevada

[Abbreviation: g/cm^3, grams per cubic centimeter. Symbol: >, greater than]

Depth range (feet)	Density of basin-fill deposits (g/cm^3)	Density of volcanic rocks (g/cm^3)
0–660	2.02	2.22
661–1,970	2.12	2.27
1,971–3,940	2.32	2.32
>3,940	2.42	2.42

The thickness of Cenozoic deposits beneath Antelope Valley and Bedell Flat was determined by an iterative gravity inversion method that uses isostatic gravity anomalies (Jachens and Moring, 1990). Isostatic gravity was used in this analysis because these anomalies reflect density variations in the shallow (depth of less than about 4,000 ft) mid-crust of the Earth from which the structure of the subsurface can be inferred (Simpson and others, 1986). The inversion method separates the isostatic gravity field into two components: the gravity field generated by pre-Cenozoic basement and the gravity field generated by less-dense overlying Cenozoic deposits. Gravity data were interpolated with a minimum curvature method (Briggs, 1974) from the 351 point values (pl. 1) to a regular 656-foot grid (Webring, 1981).

The inversion process is started by using an initial basement gravity field determined from gravity data collected on outcrops of pre-Cenozoic rock exposed in the mountains. This initial field is a first approximation because gravity measured on basement outcrops is influenced by the gravity effect of low-density deposits in adjacent basins, especially for those measurements nearest the edge of a basin. The difference between the isostatic and basement gravity fields represents an initial basin gravity field. The effects of this gravity

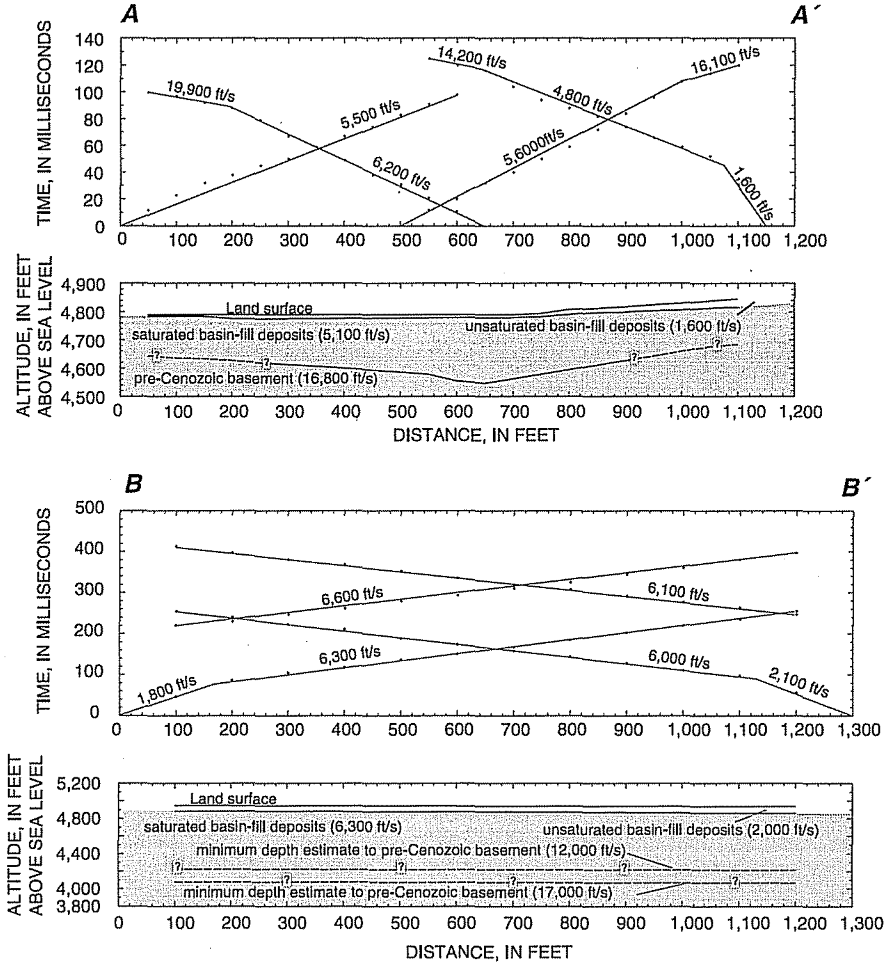

Figure 2. Time-distance curves and velocity-depth cross-sections for seismic profiles A through E.

field are removed from gravity measurements made on the basement rock, essentially removing gravitational effects caused by low-density basin material, and thus creating an improved measure of the basement gravity field. This process is repeated until successive iterations produce small changes in the basement gravity field. Inversion of the final basin gravity field yields the final estimate of depth to pre-Cenozoic basement.

The inversion process is based on the density contrast between Cenozoic deposits and pre-Cenozoic basement. Density assignments of basement rocks are constrained by the lateral (horizontal) extent of mapped units, contact between basin fill (Cenezoic units) and consolidated bedrock (pre-Cenezoic) units (Lydon and others, 1960; Bonham, 1969; and Stewart and Carlson, 1978). The density of Cenozoic deposits were allowed to vary according to the density-depth function of Jachens and Moring (1990; table 2). Reported depths to consolidated rock from drillers' logs in Antelope Valley and Bedell Flat and data from five seismic-refraction profiles were used as independent constraints during the inversion process.

The inversion process used to determine the thickness of Cenozoic deposits is subject to a number of limitations, including: (1) the coverage of gravity data, especially for stations on basement outcrops; (2) the ability of the density-depth function to represent the relationship of increasing density and depth in the Cenozoic deposits; (3) the accuracy or scale of geologic mapping; and (4) the simplifying assumptions regarding concealed geology. A more detailed discussion of the limitations and accuracy of the inversion method

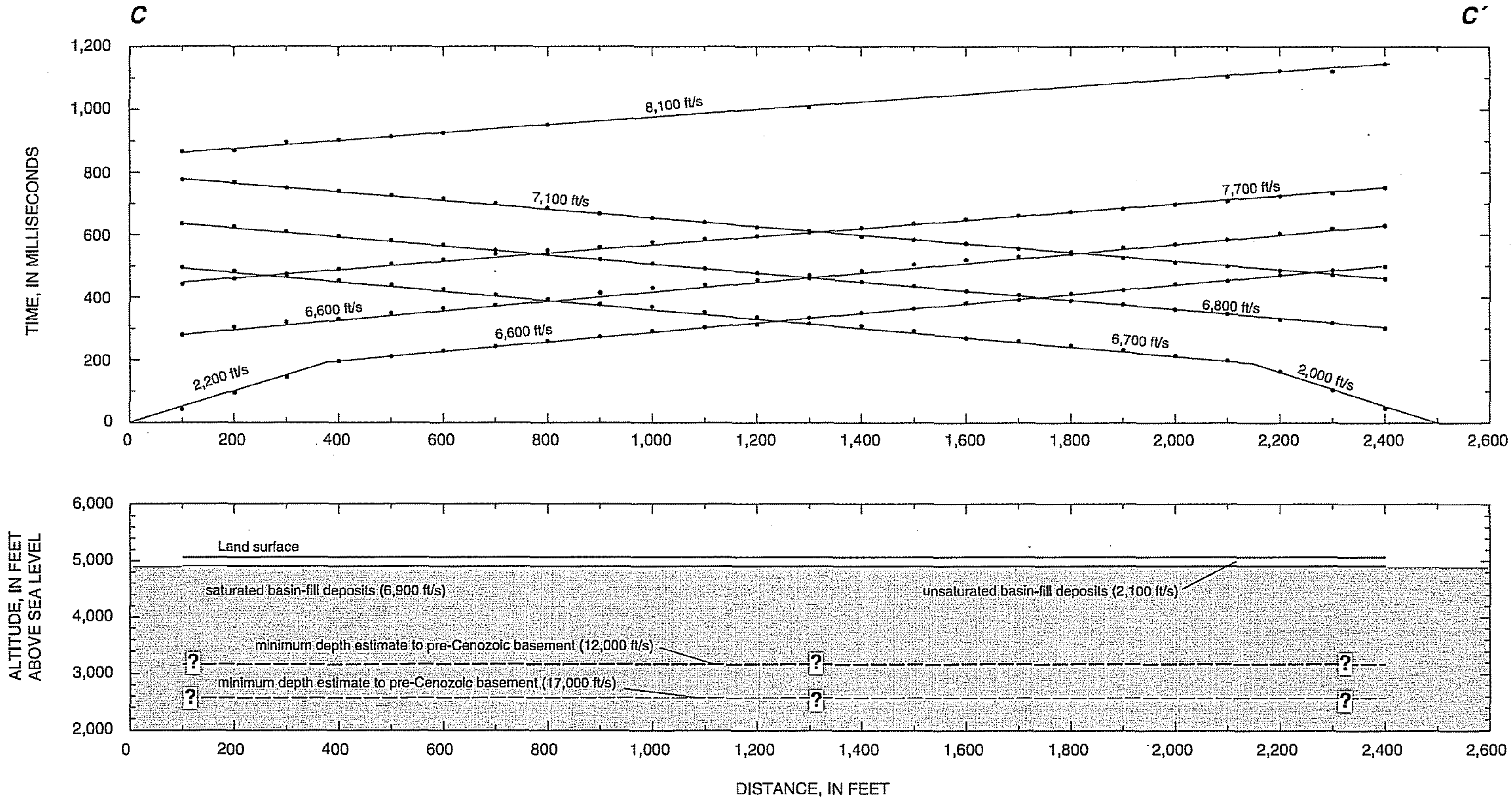

Figure 2. Continued.

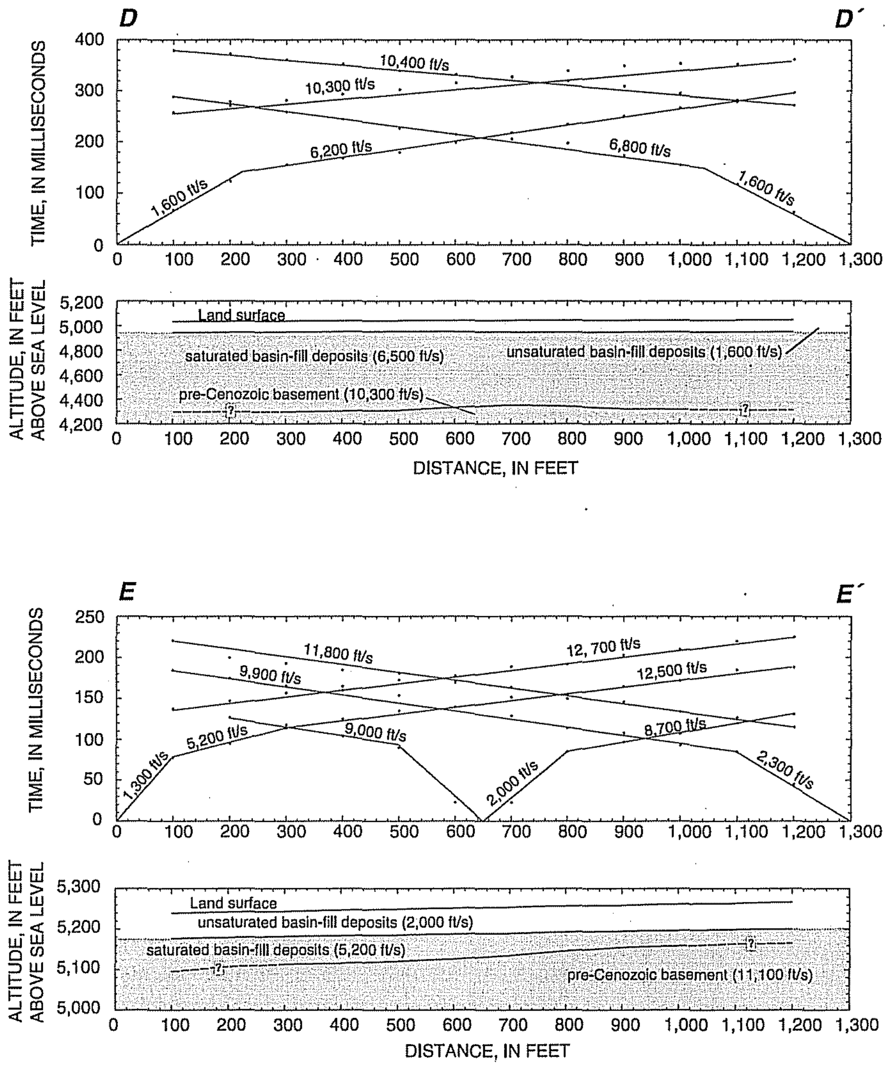

Figure 2. Continued.

is provided by Jachens and Moring (1990). The lines of equal thickness shown on plate 1 are contoured at an interval of 250 ft. Because of the limitations mentioned above and the inherent ambiguity in the gravity method, caution should be exercised when thickness values are interpolated beyond this interval.

Seismic Refraction

The seismic-refraction method is based on measured traveltimes of artificially generated waves of elastic energy as they propagate through the subsurface. When seismic waves encounter a velocity contrast in the subsurface, such as the water table or Cenozoic basement, they refract according to Snell's Law (Telford and others, 1976, p. 245). The refracting interface represents an increase in seismic velocity; the depth to this interface can be determined using wave-path geometry and recorded traveltimes. The objective of a seismic-refraction survey is to profile the velocity contrasts within the subsurface on the basis of depth and dip of each refractor encountered. For the seismic-refraction method to be successful, each successively deeper refractor must have a higher seismic velocity along with a considerable velocity contrast.

To determine seismic velocity, traveltimes of refracted waves are measured by an array of geophones and plotted against distance from the shot point along the profile (fig. 2). The inverse slope of the time-distance curve is equal to the apparent seismic velocity of the corresponding refracting interface. Traveltime data are collected from shot points at either end of the seismic profile (reverse profiling) to correct for dipping interfaces and to compute a true seismic velocity. Shot points are moved outward from the geophone array at successively greater distances to increase the depth of investigation beneath the profile. At greater depths only the central portion of the refracting interface is sampled by the seismic waves.

Seismic velocity depends on a large number of factors, including mineralogical composition, grain size, cementation, pressure, and direction with respect to bedding. Generally, the type of most hydrogeologic units can be inferred from seismic velocities, although ambiguities exist. Weathered near-surface sediments typically exhibit velocities between 400 ft/s and 700 ft/s (Haeni, 1988, p. 41). In basin-fill deposits beneath many valleys in Nevada, seismic velocity increases with depth mainly because of compaction, but also from partial cementation by mineral precipitation. Unsaturated basin-fill deposits exhibit seismic velocities that typically range from 1,200 ft/s to about 3,000 ft/s.

When it reaches the water table, the velocity of the seismic wave may increase by as much as 150 percent. This increase, which creates a considerable contrast in velocity at the interface between unsaturated and saturated basin fill, is represented as the first change in slope on the time-distance curve (fig. 2, profiles B–E). Seismic velocities in saturated basin fill range from about 5,000 ft/s to 8,000 ft/s depending on the depth and induration of the basin-fill deposits (fig. 2). The velocity increase resulting from saturation allows the refraction method to be generally successful in determining the depth to the water table. Volcanic rocks of Tertiary age in west-central Nevada typically exhibit seismic velocities between 7,000 ft/s and 10,000 ft/s. Because older basin-fill deposits may be semi-consolidated, a characteristic that increases seismic velocity, differentiating between older basin fill and Tertiary volcanic rocks based solely on seismic velocity generally is not possible. Consolidated rocks, such as granodiorite or metamorphic rocks, exhibit seismic velocities that range from about 10,000 ft/s to 23,000 ft/s, depending on the degree of weathering and extent of fracturing of the rock encountered (Haeni, 1988, p. 41). In this study, measured velocities assumed to represent pre-Cenozoic basement ranged from 10,300 ft/s to 19,900 ft/s. Pre-Cenozoic basement was not detected beneath seismic profiles B–B′ and C–C′ (fig. 2). Minimum depths to the basement were computed assuming that the latest recorded traveltime was refracted from an interface with a velocity of 12,000 ft/s and 17,000 ft/s.

For this study, seismic-refraction data were collected along four profiles in Bedell Flat and one profile north of Antelope Valley to help corroborate depth estimates obtained from the gravity data. Time-distance curves and the corresponding velocity-depth cross-sections for the five seismic profiles are in figure 2. No seismic-refraction data were collected in Antelope Valley because an adequate distribution of depths to consolidated rock was available from drillers' logs. The seismic-refraction data initially were interpreted in the field from time-distance curves using the intercept-time formula (Dobrin, 1976, p. 297). Subsequent interpretations were guided by an inversion algorithm that uses the delay-time method (Barthelmes, 1946; Pakiser and Black, 1957) to obtain a first-approximation depth model, then enhanced by a series of ray-tracing iterations (Scott, 1993).

HYDROGEOLOGIC FRAMEWORK

The study area lies in a transitional zone between major tectonic structures of the Sierra Frontal Fault Zone and the Walker Lane System (Bell, 1981, p. 35). Structural features associated with these provinces, in part, define the hydrogeologic framework and control the regional movement of ground water in the study area. The Sierra Frontal Fault Zone, which separates the Sierra Nevada from the Basin and Range physiographic province, consists of a series of north-trending faults extending from Reno south to Owens Valley, California. Fault displacement in the study area is dominantly normal (Bell, 1981, p. 17) with some component of strike-slip movement (VanWormer and Ryall, 1980). The Walker Lane System is a right-lateral shear zone trending northwest-southeast and extending to southern Nevada (Bell 1981, p. 17). At oblique angles to the main zone of right-lateral movement is a series of conjugate fault sets.

Bonham (1969, p. 42) suggests that southern Washoe County has undergone two main periods of structural deformation. Because of the absence of pre-Mesozoic rocks, the earliest deformation identified took place in the late Mesozoic Era, resulting in pre-Tertiary sedimentary and volcanic rocks being folded, faulted, and regionally metamorphosed prior to the intrusion of granitic plutons during the Cretaceous period. The second period of deformation began in the middle to late Tertiary and has continued to the present. Structural features associated with this deformation include normal faulting that has formed the structural depression beneath Bedell Flat and the existing topographic features in the study area.

Rock types and deposits in the study area were grouped into five hydrogeologic units (modified from Bonham, 1969). The five units are (1) metamorphic rocks of Triassic and Jurassic age; (2) plutonic rocks, mostly granodiorite in composition, of Jurassic to early Tertiary (?) age; (3) volcanic rocks of Tertiary age; (4) older basin-fill deposits of Quaternary and Tertiary age; and (5) younger basin-fill deposits of Quaternary age. Pre-Cenozoic basement consists of units 1 and 2, and the Cenozoic deposits consist of units 3, 4, and 5.

The oldest rocks exposed in the study area are metamorphic rocks, probably of the Peavine sequence (Bonham, 1969, p. 7). These rocks occur as an isolated roof pendant in the plutonic rocks that make up Freds Mountain (Gimlett, 1967, p. 13). The most widespread and abundant consolidated rock type in the study area is plutonic rock that is thought to be indistinguishable from the most common Sierran types (Gimlett, 1967, p. 6). This rock covers about 35 percent of the study area, makes up most of the bounding mountains, and is assumed to underlie the valleys. The lines of combined thickness of the Cenozoic deposits shown in plate 1 define the depth to the top of this hydrogeologic unit. Although this unit has little if any primary permeability, ground water may occur in openings developed through fracturing, faulting, and associated weathered zones. Reported transmissivities of granitic-type rocks range from 30 to 1,000 ft^2/d (Harrill, 1973, p. 30). Because of the abundance of plutonic rocks in the study area, their effect on local ground-water movement probably is significant, particularly in terms of inter-basin flow where they generally impede ground-water movement except along faults and fractures (Harrill, 1973, p. 44).

Exposures of Tertiary volcanic rocks make up a small percentage (about 6 percent) of the total area of Bedell Flat and are not exposed in Antelope Valley. In Bedell Flat, the volcanic rocks are part of the Hartford Assemblage and occur as erosional remnants that unconformably overlie Mesozoic granitic rocks (Bonham, 1969, p. 22, 52). The assemblage consists predominantly of volcanic rocks and lesser amounts of intercalated sedimentary rocks. Transmissivities of fractured rhyolite thought to be part of the Hartford Assemblage in adjacent Lemmon Valley range from about 150 to nearly 400 ft^2/d (Harrill, 1973, p. 20).

Basin-fill deposits make up the principal aquifers in the study area, although ground water probably is present in all five hydrogeologic units. Exposures of older basin-fill deposits cover about 30 percent of the drainage area in Bedell Flat and are not exposed in Antelope Valley (pl. 1). Where they are saturated, the older basin-fill deposits may form important aquifers for low- and possibly medium-yielding wells that would be suitable for domestic uses, livestock, and small public supply requirements. Younger basin-fill deposits cover about half of the valley floor in Bedell Flat and the entire floor of Antelope Valley. The younger basin-fill deposits form the most important water-bearing formations in the study area and are capable of yielding large supplies of water to wells where the hydrogeologic unit is thick and saturated.

Cenozoic deposits beneath Antelope Valley are relatively thin and probably do not exceed more than about 300 ft in depth (pl. 1). The shallow depth to basement suggests a limited volume of ground water in storage in the basin-fill aquifer. Several structural depressions exist in the pre-Cenozoic basement in Antelope Valley, including the largest beneath the area occupied by the playa.

Bedell Flat is underlain by an elongated structural depression in the pre-Cenozoic basement that generally trends to the northeast. The maximum thickness of Cenozoic deposits is about 2,500 ft beneath the south-central part of the valley. Minimum depth estimates to pre-Cenozoic basement beneath seismic-profile C–C′, computed using 12,000 ft/s and 17,000 ft/s as representing basement velocities, range from 1,900 to 2,500 ft. The maximum thickness of deposits in Bedell Flat is similar to that estimated by Schaefer and Maurer (1981, p. 8) in adjacent Lemmon Valley. Other isolated basement depressions are indicated beneath the north-central and southern parts of the valley. The abrupt decreases in the thickness of Cenozoic deposits along both the northwest and southeast sides of the largest structural depression suggest that the depression is fault-controlled. The geometry of the basement also suggests that the range-bounding faults of the Sand Hills are about 2 mi southeast of the mountain front. These faults generally have no surface expression except for one mapped fault near the northwest part of the depression. A structural high in the extreme southern part of Bedell Flat nearly coincides with the hydrographic-area boundary and probably acts as a ground-water divide. The thickness of Cenozoic deposits decreases toward the northwest corner of Bedell Flat; this decrease may help explain the presence of shallow ground water beneath the northwest part of the valley. Ground water appears to exit Bedell Flat beneath the narrow draw to Red Rock Valley (Rush and Glancy, 1967, p. 43). As Cenozoic deposits thin toward the northwest, ground-water flow becomes constricted and is forced toward land surface.

SUMMARY

This report describes the hydrogeologic framework of Antelope Valley and Bedell Flat, adding to general knowledge of geologic controls on regional ground-water flow in west-central Nevada. The hydrogeologic framework is defined by (1) the rocks and deposits that transmit ground water or impede its movement, and (2) the combined thickness of basin-fill deposits and volcanic rocks. For purposes of this study Quaternary and Tertiary basin-fill deposits and low-density Tertiary volcanic rocks are defined as Cenozoic deposits. Plutonic and metamorphic rocks are defined as pre-Cenozoic basement. Land-based geophysical methods were used to infer the form of structural features and to estimate the thickness of Cenozoic deposits in Antelope Valley and Bedell Flat.

Antelope Valley and Bedell Flat cover a combined area of 68 mi^2 in southern Washoe County about 15 miles north of Reno, Nevada. Gravimetric data were compiled from 351 gravity stations throughout the study area. An iterative gravity inversion method was used to determine the thickness of Cenozoic deposits. Seismic-refraction data collected along five profiles were used as additional control points for gravity interpretation in areas of limited borehole data.

The study area lies in a transitional zone between the Sierra Frontal Fault Zone and the Walker Lane System. Structural features associated with these provinces, in part, define the hydrogeologic framework and control regional ground-water movement. Rock types and deposits in the study area were grouped into five hydrogeologic units: (1) Triassic and Jurassic metamorphic rocks, (2) Jurassic to early Tertiary (?) plutonic rocks, (3) Tertiary volcanic rocks, (4) Quaternary and Tertiary basin-fill deposits, and (5) Quaternary basin-fill deposits. The basin-fill deposits make up the principal aquifers in the study area, although ground water probably is present in all five hydrogeologic units.

The thickness of Cenozoic deposits beneath Antelope Valley probably is not greater than about 300 ft, which suggests that the volume of ground water in storage is limited. Bedell Flat is underlain by an elongated structural depression in the pre-Cenozoic basement. The maximum thickness of Cenozoic deposits in Bedell Flat is about 2,500 ft, similar to the thickness estimate obtained in an adjacent valley. The geometry of the structural depression suggests that the range-bounding faults of the Sand Hills are about 2 mi southeast of the mountain front. Shallow ground water in the northwest corner of Bedell Flat may be a result of the decreasing depth to the pre-Cenozoic basement, causing ground-water flow to become constricted and forced to land surface.

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