Geologic Framework and Ground-Water Conditions in Basin-Fill Aquifers of the Dayton Valley and Churchill Valley Hydrographic Areas, Western Nevada

A product of the National Water-Quality Assessment Program-- Carson River basin, Nevada

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 91-4072

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MANUEL LUJAN, JR., *Secretary*

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, *Director*

For additional information write to:

U.S. Geological Survey
333 West Nye Lane
Carson City, NV 89706

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Multiply	*By*	*To obtain*
acre-foot (acre-ft)	0.001233	cubic hectometer
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

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 both the United States and Canada.

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ABSTRACT

The Dayton Valley and Churchill Valley hydrographic areas are typical of many alluvial-filled structural basins in the Great Basin Physiographic Province. Thickness of basin-fill deposits in these valleys ranges from 0 to almost 3,000 feet, on the basis of analysis of gravity and aeromagnetic data. Basin-fill deposits are the primary aquifers in both hydrographic areas. Within the Dayton Valley hydrographic area, the Carson Plains was estimated to have 2,900 feet of basin fill. Churchill Valley was estimated to have a maximum thickness of basin-fill deposits between 2,100 and 2,900 feet.

Recharge to the aquifers in these two hydrographic areas is primarily by infiltration of precipitation on the surrounding mountains. Discharge is by pumpage and evapotranspiration. Depth to water averages about 60 feet in the Carson Plains and Stagecoach Valley areas of Dayton Valley and 40 feet in Churchill Valley within much of the alluvial deposits. Maximum depths to water are greater than 200 feet in alluvial-fan areas near the mountain fronts. Ground-water flow is generally from west to east, following the course of the Carson River, and ground water probably discharges to the Carson River and Lahonton Reservoir during some parts of the year. Little or no ground water appears to leave the two hydrographic areas other than by evapotranspiration, pumpage, and discharge to surface-water bodies. Fluctuations in the water table have been relatively small during the last several years. A water-level decline of about 11 feet during the 13 years of record was observed in one well.

INTRODUCTION

In 1986, Congress appropriated funds for the U.S. Geological Survey to test and refine a program of study for a National Water-Quality Assessment (NAWQA). The long-term goals of the program, Nationwide, include defining and describing (1) water-quality conditions, (2) long-term trends in water quality, and (3) factors that affect or may affect current water-quality conditions (Hirsch and others, 1988). The Carson River basin is one of seven areas in the Nation that were chosen as sites of pilot projects during the first phase of the full-scale program (Welch and others, 1989, p. 9).

The Carson River basin encompasses an area of 3,980 mi^2 in parts of eastern California and western Nevada; the larger part is in Nevada. For the purposes of the NAWQA study, the basin has been subdivided into six hydrographic areas (fig. 1). The one feature that all six areas have in common is the connection to the Carson River; otherwise, the physiography varies. The Headwaters area is alpine in nature in contrast to the Carson Desert, a salt-flat sink. The Dayton Valley and Churchill Valley hydrographic areas have common physiography; the valleys are surrounded by alluvial fans, wide pediments, and low mountains. The Dayton Valley hydrographic area consists of two subareas, Carson Plains and Stagecoach Valley (fig. 1). The Churchill Valley hydrographic area contains a large flat area surrounding Lahontan Reservoir (fig. 1).

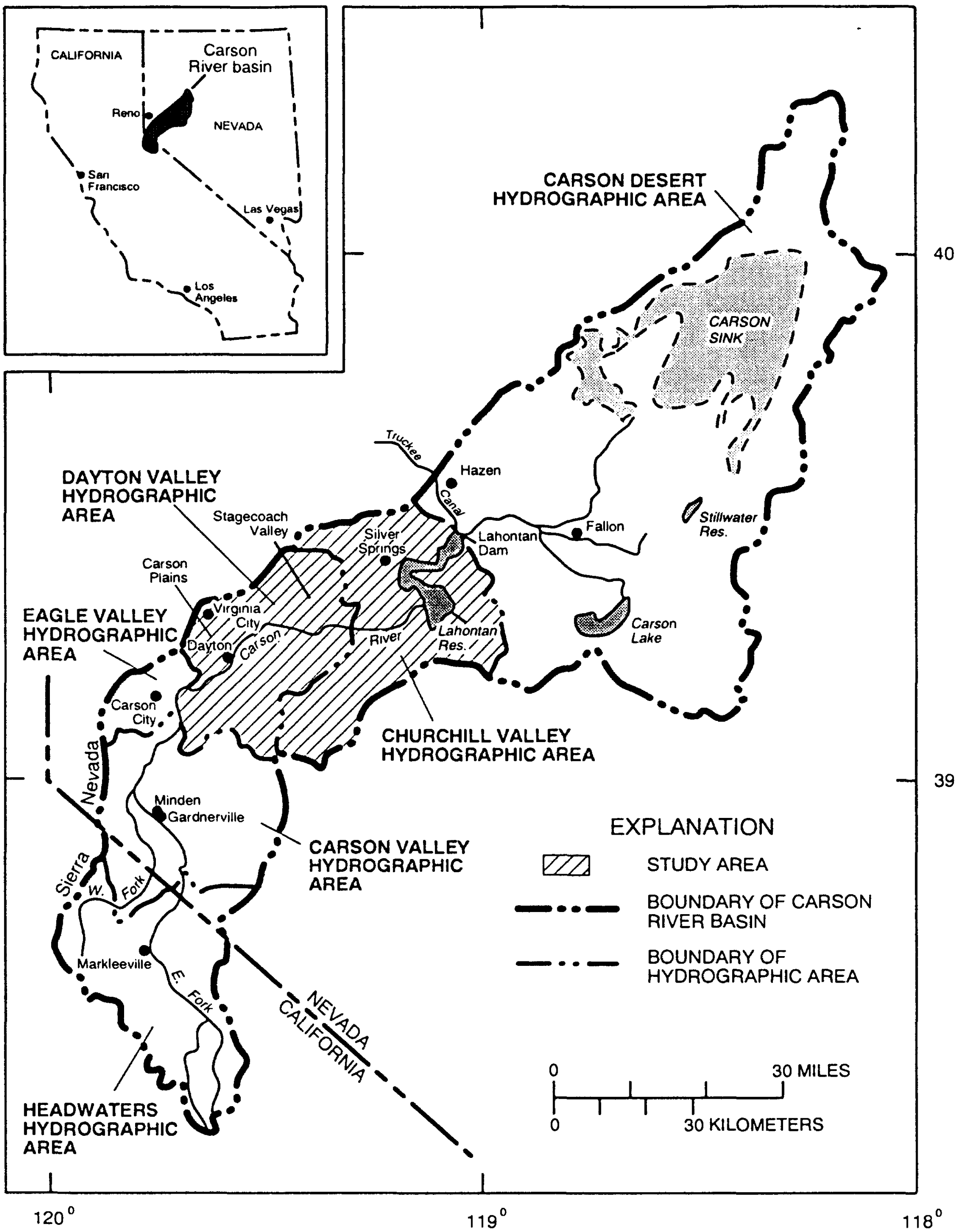

FIGURE 1.--Location of study area in Carson River basin.

The geologic framework and ground-water conditions in the Dayton Valley and Churchill Valley hydrographic areas are the least documented in the Carson River basin (Welch and others, 1989, p. 15). The purpose of this report is to provide a geologic background for description of ground-water quality in these areas to be addressed in other NAWQA studies. Included are descriptions of geologic units and delineation of ground-water altitudes in the two valleys. In addition, an estimate was made of the thickness of basin-fill deposits that serve as the principal aquifers in both hydrographic areas.

This report describes the results of compiling existing geologic and geophysical information on the basins and generalizing the information to adequately describe the hydrogeology. The geologic framework of the area provides a basis for understanding the relation between geology and ground-water quality. Lithology of the rocks that ground water flows through can have a profound influence on water quality.

Water-level maps were constructed for this report using available data and reports. Existing gravity and magnetic data for the study area and additional gravity measurements made during the study were used for geophysical modeling to estimate thickness of basin-fill deposits.

GEOLOGIC FRAMEWORK

Each of the alluvial valleys in the Carson River basin consists of a structural basin that formed as a result of extensional faulting. These basins are bounded laterally by consolidated rocks that comprise the mountain blocks; the basin-fill deposits are underlain by consolidated rocks of the down-faulted valley block. These structural basins can contain several thousand feet of unconsolidated basin-fill deposits. These deposits are the only important aquifers in most of the basins.

Lithology

Consolidated Rocks

On the basis of differences in lithology and rock chemistry, the consolidated rocks in the Dayton Valley and Churchill Valley hydrographic areas are grouped into five geologic units. The units used in this report follow closely the geologic units described by Welch and others (1989) but differ in that the older sedimentary rocks of Tertiary age are included with the consolidated rocks. Tertiary sedimentary rocks crop out at the surface along the margins of the alluvial valleys above the water table or deeply underlie the more recent basin-fill sediments that are the primary aquifers. Harrill and Preissler (in press, table 1) included the Tertiary sedimentary rocks of low permeability in Stagecoach Valley as part of the consolidated rocks.

A generalized geologic map (pl. 1) shows areal distribution of the five consolidated-rock units. The consolidated-rock geologic units, based on geology from Moore (1969), Willden and Speed (1974), and Greene and others (1991) for the Dayton Valley and Churchill Valley hydrographic areas, include: (1) silicic volcanic rocks of Tertiary and Quaternary age that consist of rhyolite, latite, and dacite; (2) basic volcanic rocks of Tertiary and Quaternary age that consist of basalt, andesite, and trachyte; (3) tuffaceous sandstone, siltstone, rhyolitic tuffs, and clays, silts, sand, and gravels of Tertiary age; (4) granodiorite and quartz monzonite of Jurassic to Tertiary age; and (5) metasedimentary and metavolcanic rocks of Triassic and Jurassic age. A summary of the hydrologic properties of the consolidated rock units is given in table 1.

TABLE 1.--Lithologic units and their hydrologic properties

Lithologic unit (plate 1)	Thickness (feet)	Occurrence and general lithologic and hydrologic properties
Basin-fill deposits	0 - 3,000	Present throughout area on valley floors and alluvial fans. Also includes flood-plain and playa deposits. Composed of unconsolidated and sorted to unsorted clay, silt, sand, gravel, and boulders. This unit is the primary aquifer in Dayton Valley and Churchill Valley hydrographic areas. Can have low permeability in areas with large percentage of clay. Yields water freely in areas of poorly sorted, coarse-grained material.
Silicic volcanic rocks	0 - 2,000	Some occurrence in northeast part of basin. Minor outcrops near Stagecoach Valley. Composed of devitrified crystal-rich ash-flow tuffs. Slightly to strongly welded. Rocks consist of rhyolite, latite, and dacite. Generally not water bearing because in most places above water table. Might contain small amounts of water in joints and fractures, but can have high permeability where highly fractured.
Basic volcanic rocks	0 - 2,000	Widespread occurrence throughout area. Composed of flow breccias and lava flows. Rocks consist of basalt, andesite, and trachyte. Generally not water bearing because in most places above water table. Might contain small amounts of water in joints and fractures, but can have high permeability where highly fractured.
Sedimentary rocks	0 - 8,000	Present primarily in northeast part of Pine Nut Mountains and northwest part of Desert Mountains. Present north and south of Churchill Butte. Composed of tuffaceous sandstone, siltstone, diatomaceous shale, and rhyolitic tuff, as well as clays silts, sands, and gravels. Can contain water in joints and fractures but generally low permeability.
Granitic rocks	0 - unknown	Minor surface outcrops in southern part, other outcrops near Stagecoach and Dayton Valleys. Composed of undifferentiated granodiorite and quartz monzonite. Might contain small amounts of water in joints and fractures, but generally low permeability.
Metavolcanic-metasedimentary rocks	0 - 10,000	Present in southwest part of basin, near Stagecoach Valley, and forms part of Churchill Butte. Composed of shale, slate, tuffaceous siltstone, sandstone, and graywacke largely derived from volcanic rocks. Interbeds of conglomerate, limey shale, limestone, dolomite, and gypsum. Might contain water where fractured, but generally low permeability.

Unconsolidated Deposits

The basin-fill deposits as described by Welch and others (1989, p. 11) consist of three units; one is the Tertiary sedimentary rocks, which herein are included with the consolidated rocks. The other two units include deposits associated with (1) alluvial fans, pediments, and valley lowlands, and (2) Pleistocene Lake Lahontan, ancient Carson River deltas, and river flood plains. For the purposes of this report, these two units have been combined into a single geologic unit referred to as basin-fill deposits of Tertiary and Quaternary age. The unit consists of unconsolidated, sorted to unsorted clay, silt, sand, and gravel. The basin-fill deposits constitute the primary aquifer in both Dayton Valley and Churchill Valley hydrographic areas. Plate 1 shows the areal distribution of the basin-fill deposits in the study area. A summary of the hydrologic properties of the basin-fill deposits is given in table 1.

Basin Structure

The thickness of basin-fill deposits is an important geologic factor because these deposits are the primary aquifer material. Few water wells penetrate the total thickness of the basin fill except at basin edges where depths to consolidated rocks are shallow. Therefore, to estimate depth to consolidated rocks, and to determine the thickness of basin-fill deposits, a combination of gravity and aeromagnetic profile modeling was analyzed.

Gravity Data

The gravity data, including latitude, longitude, altitude, and Bouguer gravity values for approximately 450 stations in the Carson River basin, were obtained from Saltus (1988a, b). The locations of these stations are shown in plate 1. The Bouguer gravity anomaly values were reduced using the standard density of 2.67 gm/cc. Additional information regarding the reduction of these data is described by Saltus (1988a, b).

In addition to the existing data, 31 gravity measurements were made in areas where data were lacking. These data were reduced in a manner similar to the original data set, and are shown in plate 1. Additional data from Schaefer and others (1986) for Stagecoach Valley were used. All data sets were mathematically gridded at a 1.24-mi interval and contoured. The resulting map (pl. 1) shows variations in gravity intensity that are a function of both the types of underlying geologic material and the structure (geometry). Bouguer gravity anomaly values range from a high of about -150 mGals in the mountainous areas in the northeast part of the valley to low of -185 mGals in the middle of Carson Plains (pl. 1). The structural depressions filled with basin-fill deposits are generally well defined by the gravity data. An exception is the pronounced gravity low south of Carson Plains and east of the Pine Nut Mountains. This gravity low is probably due to an extensive layer of lower density sedimentary rocks of Tertiary age (pl. 1) that underlies the basaltic rocks rather than a thick layer of basin-fill deposits.

Aeromagnetic Data

Aeromagnetic data were also used in the geophysical modeling. These data were from various small aeromagnetic surveys flown during the last several years and are described in more detail by Hildenbrand and others (1983). The data have been corrected to a constant flight altitude of 12,500 ft above sea level, and the International Geomagnetic Reference Field (IGRF) has been removed. The data were acquired in a 1.24-mi gridded format and were contoured (pl. 2). The aeromagnetic values range from a high of almost 500 nanoTeslas to a low of almost -600 nanoTeslas. In general, the aeromagnetic contour map does not resemble the gravity contour map because different physical properties are detected. Similarities exist, however, in how the techniques respond to large accumulations of basin-fill deposits. This can be seen in both plates 1 and 2 in the vicinity of Dayton Valley. The aeromagnetic response to this area is a series of closed contours and relatively steep gradients, implying the presence of a thick layer of non-magnetic material. The gravity response is a similar series of closed contours and steep gradients that also result from a thick layer of less-dense material.

Geophysical Modeling and Analysis

The geophysical modeling used three profiles across Dayton Valley and Churchill Valley hydrographic areas to determine thickness of the basin-fill deposits. The locations of these profiles are shown in plates 1 and 2. Profile A-A' crosses the approximate center of Carson Plains and profiles B-B' and C-C' cross Churchill Valley. No profiles were constructed across Stagecoach Valley (part of the Dayton Valley hydrographic area) as this area is described by Harrill and Preissler (in press).

The geophysical modeling procedure used in this study is illustrated by the geologic sections and corresponding geophysical profiles A-A', B-B', and C-C' (fig. 2). The procedure consists of first constructing a generalized geologic section along the geophysical profile based on available data and judgment of the modeler. A mathematical representation of the model, including locations of the various lithologies (shown as "blocks" on fig. 2) as well as physical properties (densities and magnetic susceptibilities), is entered in a geophysical modeling program called SAKI (Webring, 1985). The computer program then calculates the theoretical gravity and magnetic profiles for the cross section compared to the observed data. Where differences are large, the assumptions in the geologic model (materials, structural geometry, and physical properties) can be changed and the process repeated until a subjective "best fit" of estimated values to observed data is obtained. Figure 2 reflects some intervention in that the geologic models shown were changed after initial attempts at modeling. This facilitates the modeling effort, but still constrains the model within available geologic knowledge.

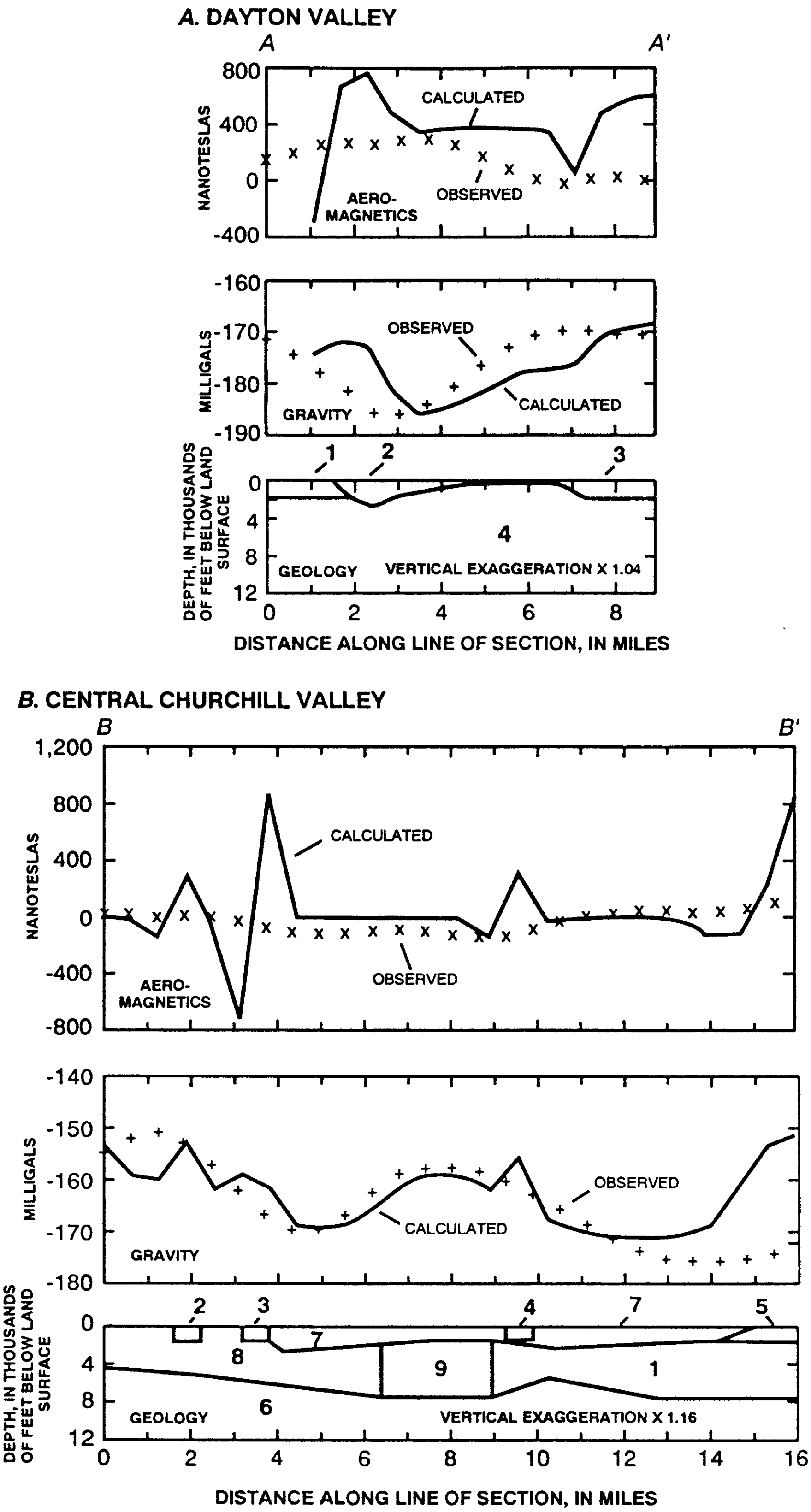

FIGURE 2.--Generalized geologic sections and corresponding profiles of Bouguer gravity anomaly and aeromagnetic intensity.

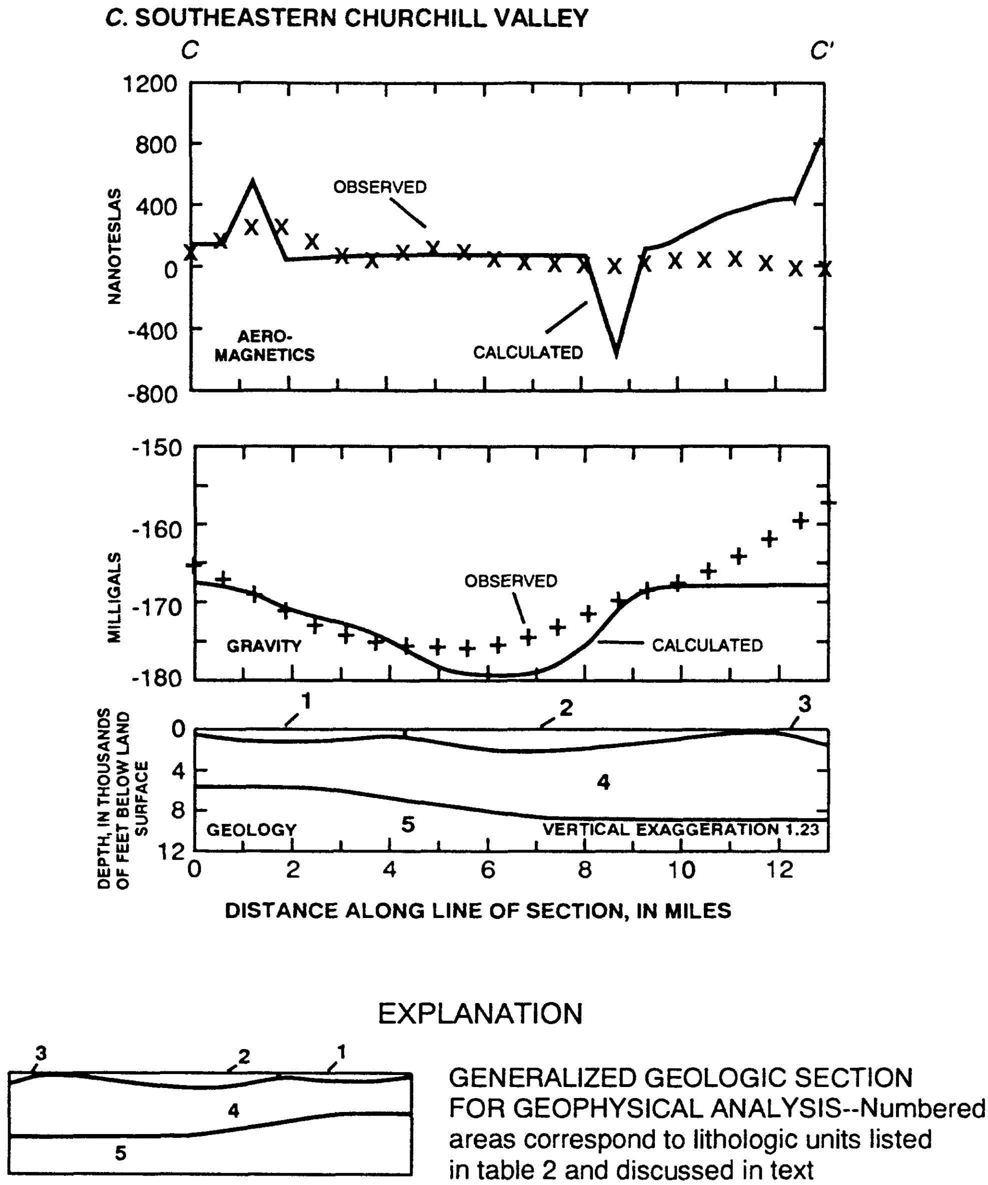

FIGURE 2.--Continued.

Geophysical modeling such as this results in non-unique solutions to the observed gravity and magnetic profiles as well as estimates of the physical properties of the geologic model. One must rely on the reasonableness of the geologic model to obtain a "best fit." The goal in the modeling effort is to achieve a good fit between observed and calculated fields based on geologic knowledge of the basin.

Dayton Valley Area

The Carson Plains part of the Dayton Valley hydrographic area is approximately 40 mi^2 and is bounded on the north by the Virginia Range and Flowery Range, and on the south by the Pine Nut Mountains. These mountainous areas are composed primarily of basic volcanic rocks of Tertiary and Quaternary age. However, bedrock underlying the Quaternary basin-fill deposits is probably composed of quartz monzonite and granodiorite of Jurassic to Tertiary age.

Modeling along profile A-A' indicates a maximum basin-fill thickness (body No. 2) of about 2,900 ft (fig. 2A). This maximum thickness occurs near the northwestern edge of the valley close to the mountain front. This suggests some range-front faulting in the formation of the structural basin, with the basin-fill wedge thinning to the southeast. A discrepancy between observed and calculated values for both the gravity and aeromagnetic fields on the northwest part of the profile is probably due to a prism of basin-fill deposits underlying the basic volcanic rocks. Figure 2A also shows the observed and calculated gravity and aeromagnetic fields. A summary of the physical properties for the various bodies in the geologic model is given in table 2.

The Stagecoach Valley part of the Dayton Valley hydrographic area is bounded on the north by the Flowery Range, on the south by the Pine Nut Mountains, and on the east by Churchill Butte. Thickness of basin-fill deposits in Stagecoach Valley area of the Dayton Valley hydrographic area was determined during previous studies (Harrill and Preissler, in press). Thick basin-fill deposits exist along a zone that extends from the north-central part of the valley beneath Misfits Flat to the area east of Table Mountain (pl. 1). The thickest fill is slightly southwest of Misfits Flat where it reaches a maximum thickness of 3,000 ft (Harrill and Preissler, in press). Most of the fill throughout the rest of the valley ranges from 500 to 2,000 ft in thickness.

TABLE 2.--Physical properties for bodies in geologic sections along geophysical profiles

Body No.	Lithologic unit	Density (grams per cubic centimeter)	Magnetic susceptibility (centimeter-gram-second units)
	Profile *A-A'*		
1	Basic volcanic rocks	2.87	0.003
2	Basin-fill deposits	2.22	.000001
3	Basic volcanic rocks	2.97	.003
4	Granitic rocks	2.67	.000001
	Profile *B-B'*		
1	Sedimentary rocks	2.37	0.000001
2	Silicic volcanic rocks	3.07	.003
3	do.	3.07	.003
4	Basic volcanic rocks	3.07	.003
5	do.	3.07	.003
6	Granitic rocks	2.67	.000001
7	Basin-fill deposits	2.22	.000001
8	Sedimentary rocks	2.37	.000001
9	Metavolcanic rocks	2.67	.000001
	Profile *C-C'*		
1	Basic volcanic rocks	2.67	0.003
2	Basin-fill deposits	2.17	.000001
3	Basic volcanic rocks	2.71	.003
4	Sedimentary rocks	2.37	.000001
5	Granitic rocks	2.67	.000001

Churchill Valley Area

Churchill Valley hydrographic area is approximately 130 mi^2 and is bounded on the north by the Virginia Range, on the south by Desert Mountains, and on the northeast by Dead Camel Mountains. These mountainous areas are composed primarily of basic and silicic volcanic rocks of Tertiary and Quaternary age. Tertiary sedimentary rocks probably are hydrologic boundaries in much of the area and crop out in the southwestern part of the valley. The Tertiary sediments probably are underlain by granitic rocks of Triassic to Jurassic age.

Profiles B-B' and C-C' cross Churchill Valley and trend southeast and southwest, respectively (pls. 1 and 2). The two profiles were oriented to determine if a connection to Churchill Butte exists (profile B-B') and to determine thickness of the basin-fill deposits in what may be the deepest part of the structural basin (profile C-C').

Profile B-B' (fig. 2B) crosses Churchill Valley near Silver Springs. The basal unit of the profile is probably granitic rocks (body No. 6), with Tertiary sedimentary rocks (bodies No. 8 and No. 1) overlying that unit and forming the consolidated-rock boundary of the aquifer. Near the center of the profile, a plug of metavolcanic rocks and sedimentary rocks (body No. 9) is postulated to extend from Churchill Butte. Minor units of silicic and basaltic volcanic rocks crop out along the profile (bodies No. 2, No. 3, and No. 5) and basaltic volcanic rocks (body No. 4) might cap the metavolcanic unit. Modeling of this profile indicates a maximum thickness of basin-fill deposits of about 2,900 ft. Modeling also indicates that the basaltic rocks might connect to Churchill Butte. Figure 2B shows the resultant calculated gravity and aeromagnetic values based on the geologic model. Comparison of the curves indicates that the model fits reasonably well. Major departures between the calculated and observed gravity values develop at the southeast end of the profile. These departures probably are due to combination of effects, such as modeling with data from near the edge of the area (edge effects) and underestimating the thickness of the basalt layer. A summary of the results of the geologic model and the physical parameters is given in table 2.

Profile C-C' crosses Churchill Valley from the Dead Camel Mountains on the northeast to the Desert Mountains on the southwest. This profile was assumed to cross the part of the valley where the basin-fill deposits are thickest. The profile consists of granitic rocks (body No. 5) at depth overlain by Tertiary sedimentary rocks (body No. 4). The basin-fill deposits (body No. 2) overlie the Tertiary sedimentary rocks and are flanked by basaltic rocks (bodies No. 1 and No. 3; fig. 2C).

Modeling of profile C-C' showed that the bottom of the basin-fill in this area is not quite as deep as in the northern part, indicated by profile B-B'. Maximum thickness of basin-fill deposits in this profile is about 2,100 ft. The calculated gravity departs from the observed gravity near the southwestern end (C') where the calculated anomaly is less negative, possibly due to a wedge of basin-fill deposits underlying the basaltic rocks in this area (fig. 2C). No data exist to confirm this possibility, but a wedge of basin-fill deposits would explain this departure. A summary of the results of the geologic model and the physical parameters is given in table 2.

GROUND-WATER CONDITIONS

Ground water tapped by wells in the Dayton Valley and Churchill Valley hydrographic areas is present primarily in unconfined (water-table) aquifers of basin-fill deposits. Locally, where clay or other fine-grained materials occur, the aquifers may be confined.

Recharge to the aquifers is by percolation of precipitation from the surrounding mountains, by leakage from the Carson River, and by subsurface inflow from adjacent hydrographic areas. Potential recharge from precipitation was calculated by Glancy and Katzer (1976, table 17) to be about 7,900 acre-ft/yr for Dayton Valley and about 1,300 acre-ft/yr for Churchill Valley. Recharge from the Carson River is difficult to quantify. Average annual streamflow into the Dayton Valley hydrographic area from Carson Valley and Eagle Valley was estimated to be 276,000 acre-ft/yr, whereas streamflow into Churchill Valley from Dayton Valley was estimated to be 268,000 acre-ft/yr (Glancy and Katzer, 1976, table 12). The net loss, about 8,000 acre-ft/yr, includes recharge to aquifers near the river in Dayton Valley, along with use of surface water by irrigation, public supply, and evapotranspiration. A similar estimate of net loss for the Churchill Valley hydrographic area would be overwhelmingly dominated by evaporation from Lahontan Reservoir and evapotranspiration from vegetation.

Ground-water discharge from the two hydrographic areas includes pumpage for domestic, irrigation, and industrial uses. Water-use figures for 1988 show about 8,000 acre-ft for Dayton Valley and 1,700 acre-ft for Churchill Valley (James Crompton, U.S. Geological Survey, written commun., 1990). Discharge from the basin also includes evapotranspiration by plants and evaporation from lakes and reservoirs. No direct evidence of subsurface outflow from Churchill Valley exists, but fractures in the surrounding consolidated rock may allow some ground-water movement from the valley.

Ground-water flow within the two basins is generally from west to east, following the course of the Carson River. Plate 3 shows the altitude of the water-level surface and arrows indicate general direction of ground-water movement based on water-level measurements in wells in the early 1980's. The use of data representing different seasons was deemed acceptable in construction of contours based on analysis of a few long-term observation wells in the two ground-water basins. Figure 3 shows hydrographs from four long-term observation wells. The observed water levels responded to both seasonal and yearly precipitation variations and two of the four wells showed water-level declines as population and irrigation resulted in increased ground-water use in these two basins. However, the total observed variation in water levels in each of the four wells was less than 11 ft.

Depths to ground water vary in the two hydrographic areas, from a maximum of more than 200 ft in the alluvial fan areas close to the mountain fronts, to near land surface close to the Carson River and Lahontan Reservoir (pl. 4). Average depth to water in Carson Plains and Stagecoach Valley appears to be approximately 60 ft. Depth to water in Churchill Valley averages about 40 ft.

Ground water in the study area is used primarily for domestic and agricultural purposes. Water-use figures for 1988 (James Crompton, U.S. Geological Survey, written commun., 1990) estimate domestic use in Dayton Valley to have been about 1,100 acre-ft/yr. Domestic use in Churchill Valley is estimated to have been about 640 acre-ft/yr in 1988. Irrigation is the major use of ground water in the two basins (8,200 acre-ft in 1988), although much of the farming is concentrated along the Carson River where surface water is used.

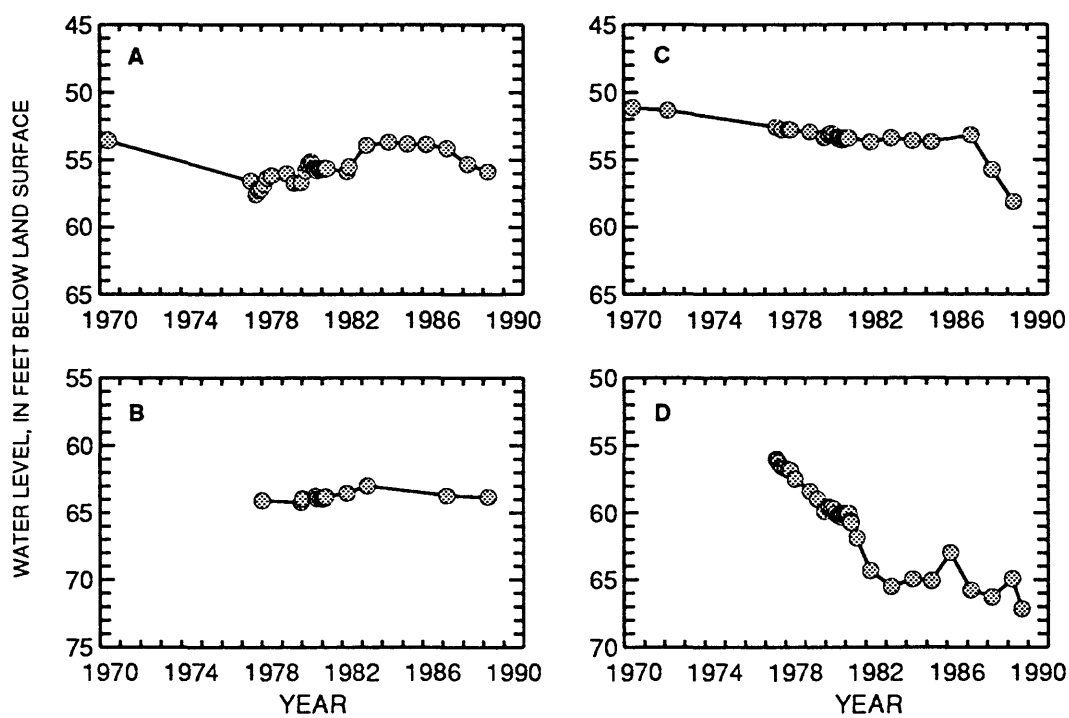

FIGURE 3.--Water levels in selected wells (plates 3 and 4).

SUMMARY

The geologic setting of the Dayton Valley and Churchill Valley hydrographic areas is typical of the Great Basin Province--alluvial valleys surrounded by mountains. In both Dayton and Churchill Valleys, most of the recharge to basin-fill deposits is derived from precipitation in the mountains.

Thickness of basin-fill deposits ranges from 0 to almost 3,000 ft, on the basis of the analysis of gravity and aeromagnetic anomaly profiles. Carson Plains was estimated to have 2,900 ft of basin fill and Churchill Valley was determined to have a maximum between 2,100 and 2,900 ft. Stagecoach Valley was estimated to have a maximum of 3,000 ft, on the basis of previous work.

Discharge from the aquifers is by pumpage for domestic or agricultural uses and by evapotranspiration. Little or no ground water appears to leave the hydrographic areas as outflow to adjacent hydrographic areas. Depth to water is about 60 ft in the Carson Plains and Stagecoach Valley areas and 40 ft in Churchill Valley. Movement of ground water within the aquifers is primarily from west to east. A maximum decline of about 11 ft was measured in one observation well over a period of 13 years in Stagecoach Valley.

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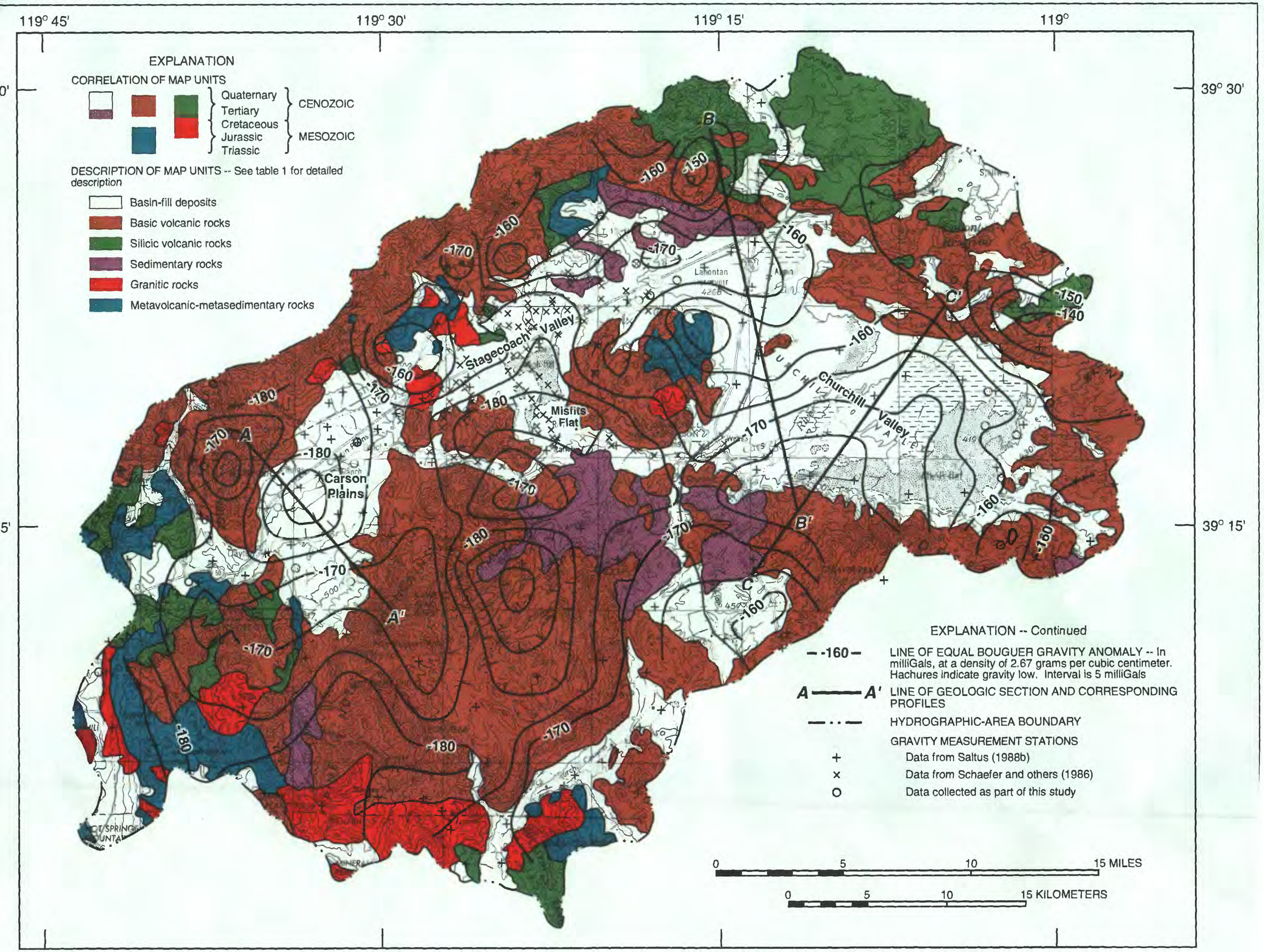
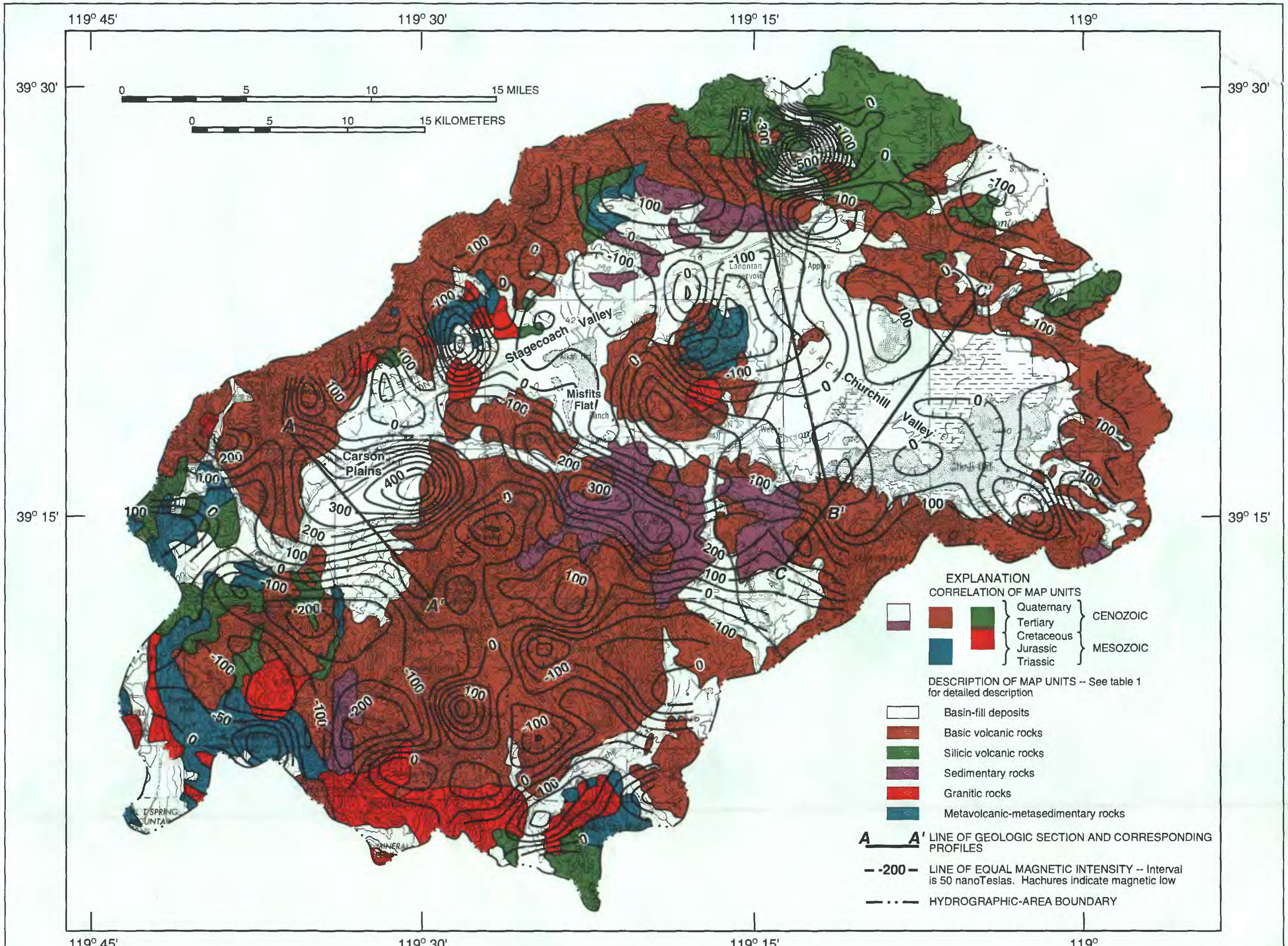


Base from U.S. Geological Survey, Reno 1:250,000, 1957, revised 1971
Contour interval 200 feet

Geology modified from Moore (1969), Willden and Speed (1964), and Stewart and Fraticelli (in press).
Gravity contouring by D.H. Schaefer

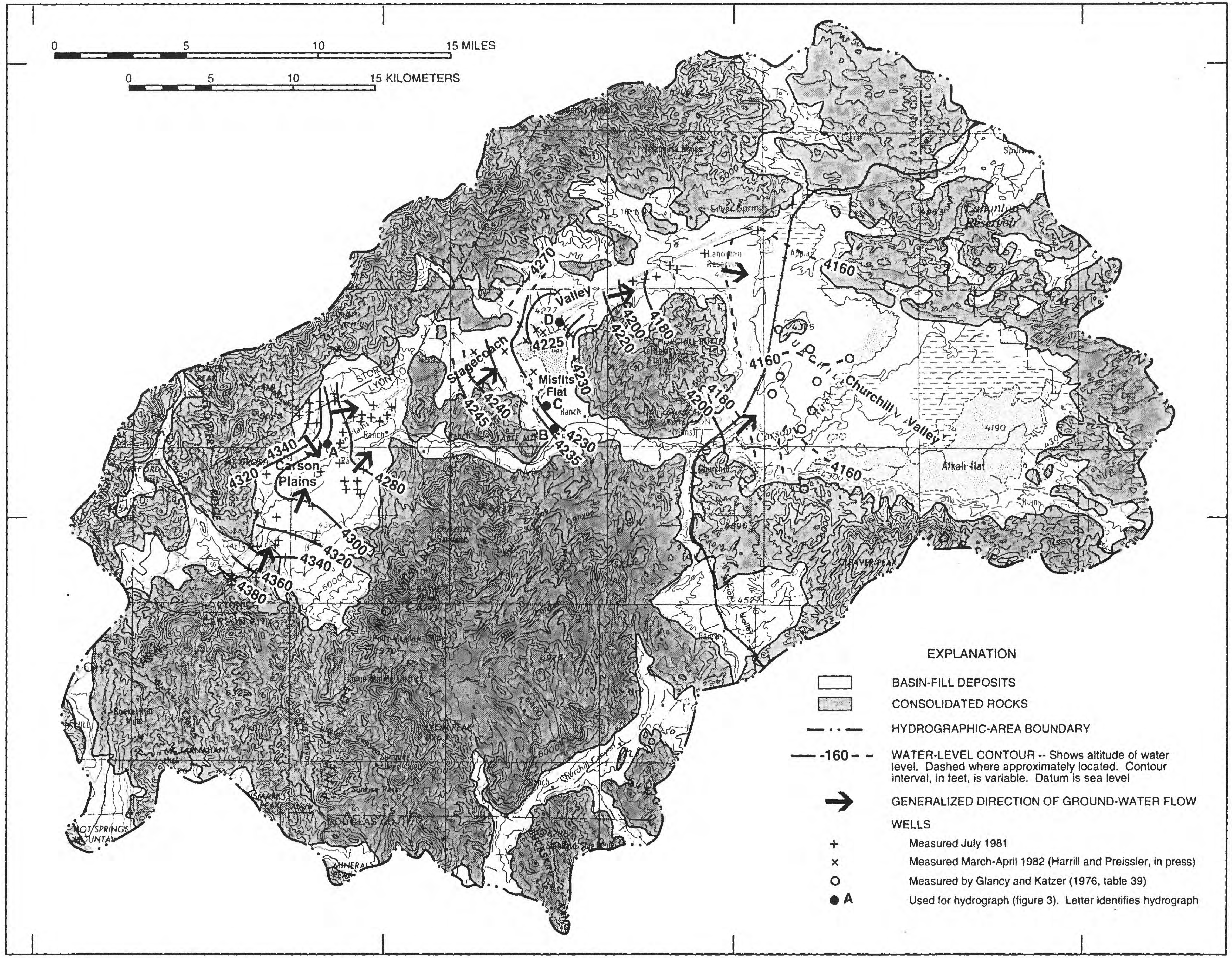
GENERALIZED GEOLOGY AND BOUGUER GRAVITY ANOMALIES, DAYTON AND CHURCHILL VALLEYS, NEVADA



Base from U.S. Geological Survey, Reno 1:250,000, 1957, revised 1971
Contour interval 200 feet

GENERALIZED GEOLOGY AND AEROMAGNETIC INTENSITIES, DAYTON AND CHURCHILL VALLEYS, NEVADA

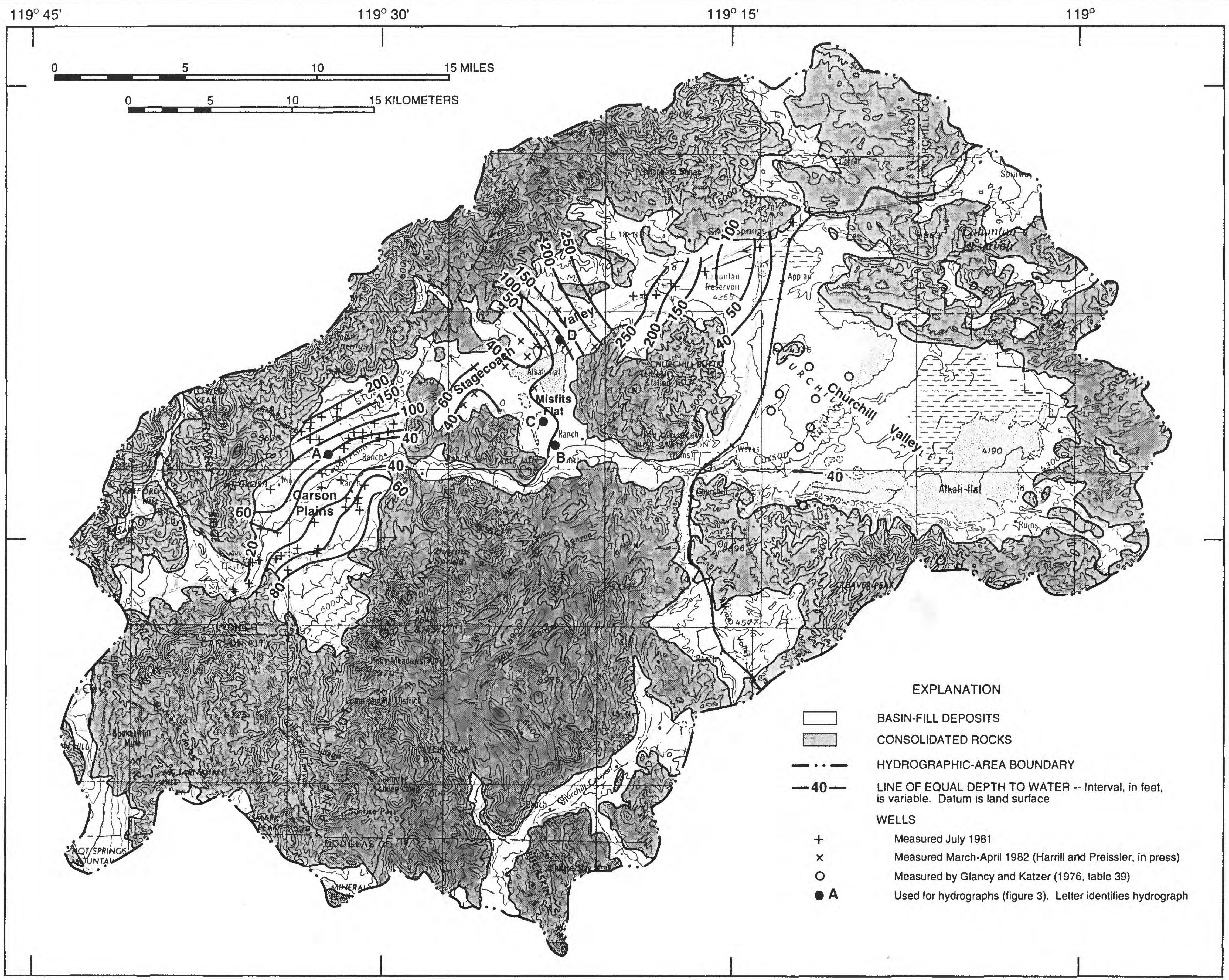
Geology modified from Moore (1969), Willden and Speed (1964), and Stewart and Fraticelli (in press). Aeromagnetic contouring by D.H. Schaefer; based on data from Hildenbrand and others (1983)



Basé from U.S. Geological Survey, Reno
1:250,000, 1957, revised 1971
Contour interval 200 feet

GROUND-WATER LEVELS IN BASIN-FILL DEPOSITS OF DAYTON AND CHURCHILL VALLEYS, NEVADA

Geology modified from Moore (1969), Willden and Speed (1964), and Stewart and Fraticelli (in press).
Hydrology by D.H. Schaefer, 1989



Base from U.S. Geological Survey, Reno
1:250,000, 1957, revised 1971
Contour interval 200 feet

DEPTH TO GROUND WATER IN BASIN-FILL DEPOSITS OF DAYTON AND CHURCHILL VALLEYS, NEVADA

Geology modified from Moore (1969), Willden and Speed (1964), and Stewart and Fraticelli (in press).
Hydrology by D.H. Schaefer, 1989.