Ground-Water Conditions in Las Vegas Valley, Clark County, Nevada

Part 1, Hydrogeologic Framework

United States Geological Survey Water-Supply Paper 2320–A

Prepared in cooperation with the Clark County Department of Comprehensive Planning

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By RUSSELL W. PLUME

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[Plates are in pocket]

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CONVERSION FACTORS AND ABBREVIATIONS

"Inch-pound" units of measure used in this report may be converted to International System (metric) units by using the following factors:

Inch-Pound Units	Multiply By	To Obtain SI Units
acres	0.4047	cubic hectometers (hm^3)
feet (ft)	0.3048	meters (m)
feet per second (ft/s)	0.3048	meters per second (m/s)
miles (mi)	1.609	kilometers (km)

ALTITUDE DATUM

The term "National Geodetic Vertical Datum of 1929" replaces the formerly used term "mean sea level" to describe the datum for altitude measurements. The geodetic datum is derived from a general adjustment of the first-order leveling networks of both the United States and Canada. For convenience in this report, the datum is also referred to as "sea level."

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By Russell W. Plume

Abstract

This report describes the lithology, thickness, and extent of valley-fill deposits in Las Vegas Valley, Nev. This information will be used to develop a hydraulic model of the valley's ground-water system.

Las Vegas Valley is a structural basin formed by bedrock that ranges in age from Precambrian through Miocene. Gravity data indicate that the deeper parts of the basin are filled with 3,000–5,000 feet of clastic sedimentary deposits that range in age from Miocene through Holocene. These deposits constitute the valley-fill aquifer and yield most of the water pumped in the valley. The upper 1,000 feet of this valley fill consist of coarse-grained deposits (sand and gravel), fine-grained deposits (silt and clay), and heterogeneous deposits that comprise either thinly interbedded coarse- and fine-grained deposits or mixtures of the two. Coarse-grained deposits, in places more than 1,000 feet thick, underlie the south and west sides of the valley and interfinger with fine-grained and heterogeneous deposits toward the center of the valley. Intervals of fairly thin heterogeneous deposits underlie parts of the valley, but they are not laterally persistent.

The distribution of coarse-grained and fine-grained deposits in three depth zones of the valley fill (0–200 feet, 200–700 feet, and 700–1,000 feet) suggests that: (1) the Spring Mountains and McCullough Range were the major sources of clastic material for the valley fill; (2) Frenchman Mountain and the Las Vegas Range were emplaced later than the Spring Mountains; (3) the east side of the Spring Mountains, which was originally closer to the center of the valley, has receded westward because of erosion; and (4) shallow, fine-grained deposits (0–200 feet deep) are more susceptible to subsidence than deeper ones.

The bedrock basin that underlies Las Vegas Valley consists of a deeply buried part that underlies most of the valley and a shallow bedrock surface on the west side of the valley. The deep part of the basin is bounded on the east by normal faults at the base of Frenchman Mountain, on the west by a possible normal fault that coincides with a zone of fault scarps, on the north by vertical or strike-slip displacement along the Las Vegas shear zone, and on the northwest by a bedrock high that underlies the area between Tule Springs and Corn Creek Springs. The shallow bedrock surface (as much as 1,000 feet deep) underlies the west side of the valley from La Madre Mountain to the McCullough Range.

Some of the fault scarps in the valley fill coincide with possible bedrock faults, which suggests a tectonic origin for some of the faulting of valley-fill deposits; however, the area of fault scarps on the west side of the valley also coincides with a rapid lateral change from incompressible bedrock to more compressible valley-fill deposits. Thus, both differential compaction and tectonic movement may be responsible for faulting of valley-fill deposits.

INTRODUCTION

Purpose and Scope

This report was prepared by the U.S. Geological Survey in cooperation with the Clark County, Nevada, Department of Comprehensive Planning. It presents the results of the first phase of a study of the ground-water system of Las Vegas Valley, Nev. The objectives of the overall study are to (1) develop a hydraulic model of the system that will simulate ground-water levels and reproduce observed historical changes, and (2) use the model to describe and quantify the hydrology of the basin. The accuracy and usefulness of such a model, however, depend in large part on an understanding of the hydrogeologic framework of the valley-fill deposits and bedrock basin. Thus, the objectives of this, the first phase

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of the study, are to characterize the lithology of the deposits that store ground water in Las Vegas Valley and to determine the shape and depth of the bedrock basin that underlies the valley. The second phase of the study will evaluate the hydrology of Las Vegas Valley.

This report consists of two main sections: a description of the geologic features of the study area and a discussion of the bedrock and valley-fill reservoirs, with emphasis on the lithology, thickness, and extent of the valley fill.

Methods

Several types of data were used during the course of this study. Well logs were used to estimate the lithologic properties of valley-fill deposits and to corroborate depths to bedrock determined using geophysical methods. Gravity data collected by Reidy and others (1978) and by the present author in 1980 were used to determine the shape of the bedrock basin and the thickness of valley-fill deposits. Seismic methods were used to independently determine the thickness of valley-fill deposits at four sites in the study area.

Location and Features of the Study Area

Las Vegas Valley is in southern Nevada about 20 mi north and west of Lake Mead and the Colorado River (fig. 1). The greater Las Vegas metropolitan area, which includes the cities of Las Vegas and North Las Vegas and the populated surrounding areas, is near the center of the valley. The city of Henderson is in the southeast part of the valley and Nellis Air Force Base is in the northeast part.

The study area can be divided into three physiographic units: mountains, piedmont surfaces, and valley lowlands. Las Vegas Valley is bounded on the west by the Spring Mountains, on the north by the southern ends of the Sheep and Las Vegas Ranges, on the east by Frenchman and Sunrise Mountains (collectively), and on the south by the River Mountains and McCullough Range. The highest points in the study area are the summits of La Madre Mountain, at an altitude of 8,154 ft above sea level on the east side of the Spring Mountains, and Gass Peak, at an altitude of 6,943 ft at the south end of the Las Vegas Range. Where mountain blocks meet piedmont surfaces, the change in slope is abrupt. The slope changes at altitudes ranging from about 2,000 ft at Frenchman Mountain to about 4,000 ft at the base of the Spring Mountains and Sheep Range.

Mountain blocks are separated from valley lowlands by long, gently sloping surfaces that are collectively referred to as piedmont surfaces (Bell, 1981, p. 10). These surfaces are nearly 10 miles wide on the west side of the valley and from 2 to 5 miles wide on the north, south, and east sides of the valley. The piedmont surfaces were interpreted as coalescing alluvial fans in early investigations (Maxey and Jameson, 1948, p. 32; Malmberg, 1965, p. 11, 12; and Longwell and others, 1965, p. 6). More recent studies, however, indicate that the piedmont surfaces are in part pediments of older, consolidated valley-fill deposits (Dinger, 1977, p. 18; and Bell, 1981, p. 10).

Piedmont surfaces terminate at the edge of the valley lowlands at altitudes ranging from about 1,500 ft a few miles northeast of Henderson to about 2,900 ft near Corn Creek Springs. Valley lowlands slope gently to the east and southeast except in the vicinity of fault scarps, where local relief is as much as 100 ft or, at Whitney Mesa, about 200 ft.

Las Vegas Valley is drained at its southeast end by Las Vegas Wash. Most tributaries to that stream are relatively small, unnamed washes. Exceptions are the larger drainages at the south end of the valley, which include Flamingo Wash, Tropicana Wash, and Duck Creek. The lower ends of these tributaries and Las Vegas Wash are now perennial streams for four reasons: (1) their channels intersect the water table; (2) storm drains collect unused lawn-irrigation water and other urban runoff and discharge into major drainages; (3) sewage-treatment plants discharge into Las Vegas Wash; and (4) a power plant discharges coolant water into Duck Creek. The upper parts of Las Vegas Wash and its tributaries flow only during and shortly after heavy rains.

In 1982, the valley lowlands were the most heavily populated of the three physiographic areas, although Las Vegas was growing rapidly to the south, west, and northwest onto the piedmont surfaces. In addition, Henderson is entirely on piedmont surfaces that originate in the River Mountains and McCullough Range.

Previous Investigations

The earliest hydrologic investigations in the study area were made by Mendenhall (1909) and Carpenter (1915). Both were water-resources surveys, although Carpenter also briefly discussed the geology of bedrock and thickness of valley-fill deposits (1915, p. 32–35).

The first detailed investigation of the study area was by Maxey and Jameson (1948). They mapped the geology of the area, used well logs to determine the lithology of valley-fill deposits, developed the first water budget for the Las Vegas Valley ground-water basin, and described the relationships between confined water and near-surface water. Malmberg (1965) modified some of these findings using data not available to Maxey and Jameson.

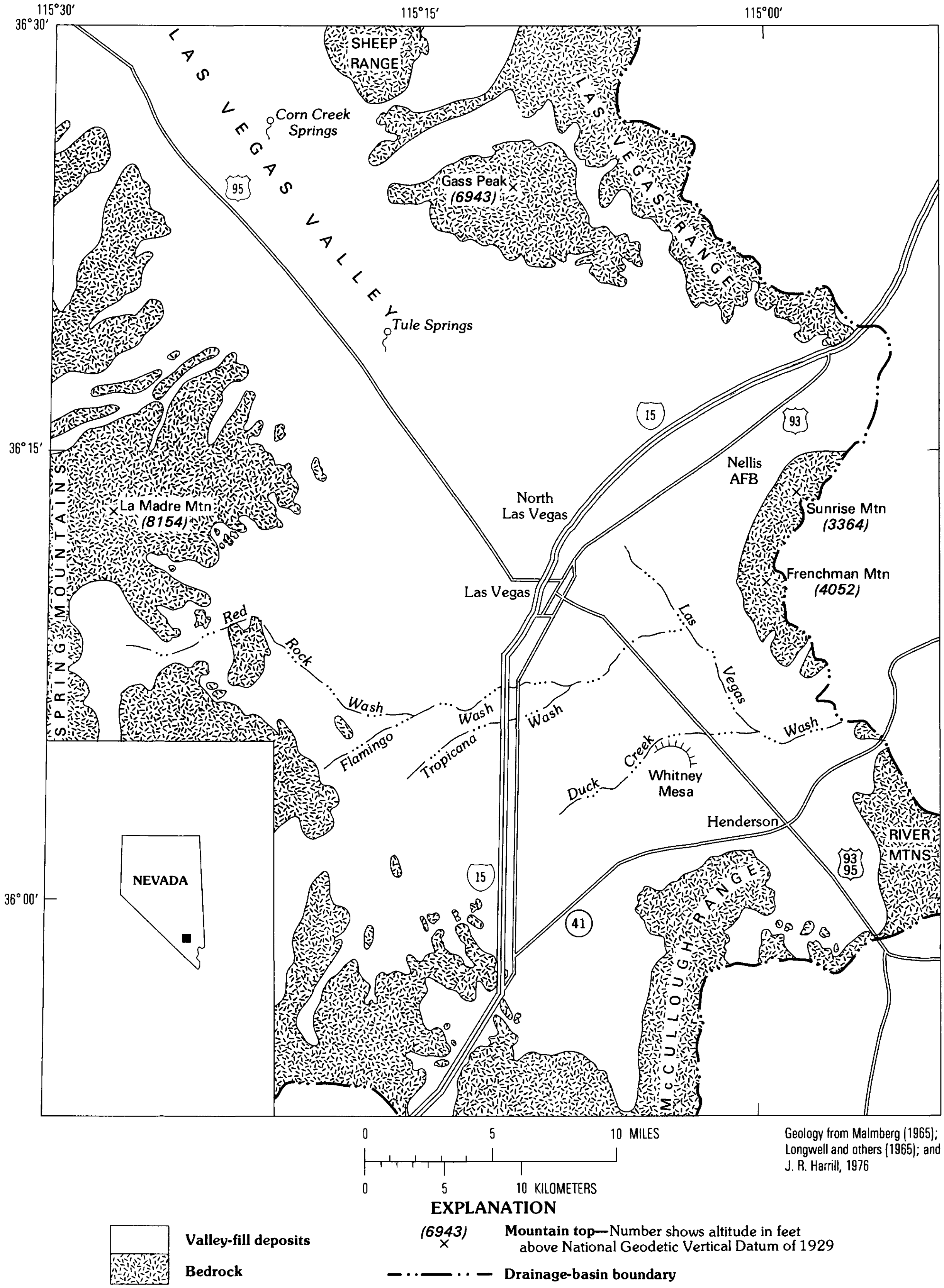


Figure 1. Location and features of the study area, Las Vegas Valley, Nev.

Domenico and others (1964) made the first attempt at simulating the ground-water system in Las Vegas Valley. They also analyzed the vertical and lateral variations in grain size of valley-fill deposits. Harrill (1976) simulated the ground-water reservoir, described storage depletion since Malmberg's study, and evaluated the possible effects of importing Lake Mead water to the valley.

The geology of the study area has been described by Longwell and others (1965), Haynes (1967), Tabor (1970), Dinger (1977), Bingler (1977), Bell and Smith (1980), and Bell (1981). These studies form the basis for the general descriptions in this report of the geology of bedrock and valley-fill deposits.

Land subsidence has been the subject of several studies in Las Vegas Valley. The literature on this subject is described in a later section of this report.

Location System for Wells

The location system used in this report is based on a hydrographic-area number and the rectangular subdivision of lands referenced to the Mount Diablo base line and meridian. Each well designation includes a hydrographic-area number, as defined by Rush (1968), and the township, range, section, subdivision of the section, and sequence number. For instance, in well designation 212 S21 E62 10BCD1, the first part (212) indicates that the well is in the Las Vegas Valley hydrographic area (Rush, 1968, p. 26). Subsequent numbers indicate that the well is in section 10 of township 21 south, range 62 east. The letters following the section number indicate specifically where the well is in section 10. The northeast quarter is represented by the letter "A," and the other three quarters in a counterclockwise direction are designated "B," "C," and "D," respectively. Each quarter can be similarly subdivided and so on; the usual limit is four letters, which define an area of 2 ½ acres, when the location is precisely known. The first letter in the sequence indicates the largest subdivision in the section and the last letter the smallest. The well just discussed is in the southeast quarter of the southwest quarter of the northwest quarter of section 10. Well designations include a sequence number following the letters, which is useful when two wells are so close together that they would otherwise have the same number. All wells referred to in this report are in Las Vegas Valley. Therefore, the hydrographic-area number (212) for each well location is omitted.

Acknowledgments

Several agencies of local and State governments contributed to the completion of this study. The Clark County Department of Public Works supplied 1:2,400-scale maps that were useful in determining the altitudes of gravity stations. The State Engineer's Offices in Las Vegas and Carson City provided most of the well logs. The State Computer Facility in Carson City was used to store and process the gravity data. John W. Bell, Nevada Bureau of Mines and Geology, and Martin D. Mifflin, Desert Research Institute, reviewed the manuscript and provided helpful suggestions.

GEOLOGIC FEATURES

Bedrock and valley fill are the major geologic units in the study area. Bedrock ranges in age from Precambrian through Miocene and consists of metamorphic rocks, carbonate and clastic sedimentary rocks, and volcanic and intrusive igneous rocks. Bedrock makes up the mountainous areas that adjoin Las Vegas Valley and it underlies the basin in which the valley fill was deposited. The valley fill ranges in age from Miocene through Holocene and consists mostly of fine to coarse clastic sedimentary deposits.

Bedrock is subdivided, on the basis of lithology, into four geologic map units (pl. 1). The valley fill consists of four formally named formations and unnamed Tertiary and Quaternary deposits that are subdivided on the basis of changes in grain size between mountain fronts and the valley lowlands (pl. 1). The following discussion relies mostly on previous investigations.

Bedrock

Bedrock consists of the following units: (1) Precambrian metamorphic rocks; (2) Precambrian and Paleozoic carbonate rocks; (3) Permian, Triassic, and Jurassic clastic rocks; and (4) Miocene igneous rocks. Precambrian crystalline rocks that consist of metamorphic rocks (gneiss and schist) and granite are exposed in the south and east parts of Clark County (Longwell and others, 1965, pl. 1). A small outcrop of gneiss at the base of Frenchman Mountain is the only known occurrence of such rock in the study area. However, Precambrian metamorphic rocks probably underlie the entire study area at depth.

The most widespread bedrock unit in the study area consists of Precambrian and Paleozoic carbonate rocks (pl. 1). The unit dominates in the Spring Mountains, Frenchman Mountain, the Las Vegas Range, and Sheep Range. Limestone and dolomite are, by far, the most common rock types in this unit, but clastic rocks such as conglomerate, quartzite, sandstone, and shale are locally common. The surface distribution of the Paleozoic carbonate rocks suggests that they underlie much of the northern part of Las Vegas Valley, and, to a lesser extent, the southern part as well.

Sandstone, conglomerate, shale, and limestone of Permian, Triassic, and Jurassic age are found on the lower slopes of the Spring Mountains north of Kyle Canyon, in the Blue Diamond area and farther south, and on the slopes of Frenchman and Sunrise Mountains (pl. 1). The distribution of this clastic unit suggests that it forms much of the bedrock underlying valley fill in the middle and southern parts of Las Vegas Valley. According to Tabor (1970, p. 9), the Moenkopi Formation was found at a depth of 3,100 ft in the Wilson-Federal 1 well (S21 E61 24BB1). The overlying material was described as older alluvium, although sandstone below 2,615 ft could be the Aztec Sandstone.

Igneous rocks in the study area consist mostly of volcanic rocks in the McCullough Range and River Mountains (but also include scattered dikes in the River Mountains) and a quartz monzonite intrusive in the McCullough Range west of Railroad Pass (pl. 1). Bell and Smith (1980) described volcanic rocks north and east of Henderson as flows and flow breccias of dacite, andesite, and basalt that range in age from early to middle Miocene. The flows are intruded by scattered dikes of similar composition (Bell and Smith, 1980).

Some well logs for the Whitney Mesa area (wells S22 E61 1DD1, S22 E62 6BC1, S22 E62 8CBD1, and S22 E62 15ACD1) show volcanic rocks interbedded with valley-fill deposits at depths between 18 and 270 ft. The wells penetrate units described by drillers as lava rock or volcanic formation that range in thickness from 16 to 312 ft. These volcanic rocks may be flows interbedded with Miocene clastic deposits or they may be the Fortification Basalt Member of the Miocene and Pliocene Muddy Creek Formation (see next section). They could also be beds of coarse alluvium eroded from volcanic rocks in the nearby mountains.

Valley-Fill Deposits

Miocene Clastic Deposits

Miocene clastic deposits occur on the lower slopes of the south and east sides of Frenchman Mountain, northeast of Henderson at the base of the River Mountains, and on the lower slopes of the Las Vegas Range (pl. 1). This hydrogeologic unit includes the Thumb Formation and the overlying Horse Spring Formation in the southeast part of the study area and unnamed clastic rocks in the Las Vegas Range. The Thumb Formation consists of interbedded siltstone, sandstone, conglomerate, claystone, freshwater limestone, gypsum beds, and lava flows (Bell and Smith, 1980). The Horse Spring Formation consists of freshwater limestone with interbeds of sandstone, siltstone, magnesite, gypsum, and lava flows (Bell and Smith, 1980; and Longwell and others, 1965, p. 46). The Miocene clastic rocks at the south end of the Las Vegas Range consist of conglomerate interbedded with sandstone and tuffaceous sediments, according to Longwell and others (1965, p. 47) who noted the similarity between these deposits and the Horse Spring Formation and the insufficient evidence to correlate them. The thickness of Miocene clastic deposits is estimated to range from 6,000 to 7,000 ft east of the study area, and is more than 5,000 ft north of the study area (Longwell and others, 1965, p. 42–47). The valley fill of Las Vegas Valley was generally believed to consist of Muddy Creek Formation and younger deposits (Maxey and Jameson, 1948, p. 53), although they suggested that the basal part of the valley fill could also consist of older deposits.

Muddy Creek Formation

The Muddy Creek Formation of Miocene and Pliocene age occurs in southern Nevada as valley-fill deposits that are coarse grained near mountains and progressively finer grained toward the center of valleys (Longwell and others, 1965, p. 48). In the study area, the Muddy Creek Formation has been recognized in several places: (1) clayey silt and silty clay northwest of Whitney Mesa (Bingler, 1977); (2) weakly bedded silt on the face of Whitney Mesa (Bingler, 1977); (3) interbedded gravel, sand, silt, and clay south and west of Frenchman Mountain (Bingler, 1977; Bell and Smith, 1980); (4) a fanglomerate east of Henderson (Bell and Smith, 1980); and (5) fine sandstone, siltstone, and clay north of Sunrise Mountain (Longwell and others, 1965, p. 48). Exposures of the Muddy Creek Formation are from 40 to 60 ft thick northwest of Whitney Mesa, more than 100 ft thick at Whitney Mesa, and more than 325 ft thick north and east of Henderson (Bingler, 1977; Bell and Smith, 1980). Price (1966, pl. 1) mapped a hilly area in North Las Vegas as the Muddy Creek Formation, but Tabor (1970, p. 15), though recognizing the similarity of these deposits with those of the Muddy Creek Formation, believed that the evidence was insufficient for such a correlation.

In addition to clastic sediments, the Muddy Creek Formation includes thick beds of gypsum and salt and basalt flows called the Fortification Basalt Member (Longwell and others, 1965, p. 48, 58). In the Lake Mead area, the Fortification Basalt Member consists of basalt flows and mafic dikes that range in age from 11 million to 4 million years (Anderson and others, 1972, p. 278, 281). These parts of the Muddy Creek are not exposed in Las Vegas Valley, although gypsum is reported by well drillers. As indicated in an earlier section of this report, volcanic rocks interbedded with valley-fill deposits at the south end of the valley may be the Fortification Basalt Member, or flows interbedded with Miocene clastic deposits, or coarse alluvium derived from volcanic rocks in the River Mountains and McCullough Range.

The top of the Muddy Creek Formation has not been clearly identified at depth in Las Vegas Valley. Early interpretations of drillers' logs placed its top at a depth ranging from land surface in southern parts of the valley to more than 1,000 ft below land surface at Las Vegas (Domenico and others, 1964, p. 10; Mindling, 1965, p. 36; Malmberg, 1965, p. 20, 21). Coarse- and fine-grained facies of the Muddy Creek Formation mapped by Bell and Smith (1980) northeast of Henderson, and by Laney (1981, p. 6–7) in the Lake Mead area, and interpretations by Longwell and others (1965, p. 48) suggest that some alluvial fans in the valley may be pediments consisting of coarse-grained Muddy Creek facies overlain by a thin veneer of younger gravel. This relationship has also been suggested by M.D. Mifflin (Desert Research Institute, written commun., 1981). Dinger (1977, p. 18), although not mentioning the Muddy Creek Formation by name, stated that coalescing alluvial apron materials are mostly pediments on which thin, unconsolidated gravels unconformably overlie older fine-grained deposits in the basin lowlands and consolidated gravels toward the margins of the valley. These interpretations suggest that the Muddy Creek Formation might be at or near land surface in much of Las Vegas Valley and more areally extensive than previously thought.

The thickness of the Muddy Creek Formation in Las Vegas Valley is mostly unknown because the top and bottom of the formation are difficult to identify. Estimates of thickness in the valley range from about 325 ft northeast of Henderson (Bell and Smith, 1980) to about 3,000 ft east of Whitney Mesa (Malmberg, 1965, p. 21). In the River Mountains northeast of Henderson and in the Lake Mead area, the thickness of the Muddy Creek Formation ranges from 0 to 4,400 ft (Longwell, 1963, p. 10).

Tertiary and Quaternary Sedimentary Deposits

Deposits of gravel, sand, and silt of Quaternary age and conglomerates of Tertiary and Quaternary age overlie older parts of the valley fill. These deposits are shown on plate 1 as coarse-grained deposits, heterogeneous deposits (mixtures or thinly bedded sequences of coarse- and fine-grained deposits), and fine-grained deposits. These units are surficial, however, and may not represent more than the upper 30–40 ft of valley fill.

Coarse-grained deposits are found on alluvial fans and pediments and along Las Vegas Wash. Most of the deposits are of Quaternary age and consist of poorly sorted, unconsolidated to cemented gravel and sandy gravel on alluvial fans and pediments and of fine sand along Las Vegas Wash (Haynes, 1967, pl. 1; Bingler, 1977; Dinger, 1977, pl. 1; Bell and Smith, 1980; Matti and Bachhuber, 1982; and Matti and Morton, 1982a, b). In the Henderson area, sand along Las Vegas Wash is less than 10 ft thick, and coarse-grained deposits on alluvial fans and pediments are generally less than 30 ft thick (Bell and Smith, 1980).

Coarse-grained deposits also include Tertiary and Quaternary conglomerates along Las Vegas Wash in the southeast part of the study area (Bell and Smith, 1980). These conglomerates correspond with what Laney (1981, p. 11) called the local gravel unit elsewhere in the Lake Mead area, including lower Las Vegas Wash. The gravels define the channels of streams tributary to the Colorado River during the late Tertiary and early Quaternary. The conglomerates are limited in extent in the study area and are not recognized in other parts of Las Vegas Valley.

Light-colored, heterogeneous deposits occur in parts of the valley lowlands from Corn Creek Springs southeast to the Paradise Valley area. They are a mixture of coarse- and fine-grained material that includes silty fine sand south of Whitney Mesa (Bingler, 1977); interbedded silt, sand, and gravel from Paradise Valley to North Las Vegas (Matti and Bachhuber, 1982; and Matti and Morton, 1982a, b); and silt, sand, and gravel in the north and northwest parts of Las Vegas Valley (Haynes, 1967).

In the northwest and north-central parts of Las Vegas Valley, the lowlands are underlain by fine-grained deposits (pl. 1) of white to light brown sandy silt and mudstone that range in age from 14,000 to 30,000 years (Haynes, 1967, p. 32). Longwell and others (1965, p. 50) named these deposits the Las Vegas Formation. The formation was originally thought to have been deposited in a lake (Longwell and others, 1965, p. 50, 52; Haynes, 1967, p. 32); more recent evidence suggests that the formation was deposited within a playa, possibly one with localized marshes (Mifflin and Wheat, 1979, p. 27).

As mentioned earlier in this section, deposits of Tertiary and Quaternary age shown on plate 1 are surficial and do not necessarily represent materials much deeper than 30–40 ft. Underlying deposits may represent either the upper parts of Quaternary valley fill or Pliocene and Miocene deposits. The thickness of Quaternary deposits has been estimated at 500–1,000 ft in and adjacent to Las Vegas (Malmberg, 1965, p. 21; Tabor, 1970, p. 21). However, evidence discussed earlier in the present report suggests that the top of the Muddy Creek Formation is at or near land surface throughout much of Las Vegas Valley (pl. 1). If this is true, the overlying Quaternary deposits would not be as thick as previous investigations indicated.

Structure

Prior to late Mesozoic, the Paleozoic carbonate rocks and the Permian, Triassic, and Jurassic clastic rocks were largely undisturbed. They were folded and offset by thrust faulting in late Mesozoic and by block and strike-slip faulting in Miocene and Pliocene. The Las Vegas Valley structural basin was formed during the Pliocene by normal faults at the base of Frenchman Mountain and perhaps by similar faults on the west side of the valley (which have not as yet been recognized). The basin is deep beneath the valley lowlands and shallow on the west side of the valley. The shape, depth, and structural control of the basin are discussed in a later section of this report.

The Las Vegas shear zone is a major structural feature in southern Nevada and may be hydrologically significant. The shear zone is a strike-slip fault along which right-lateral movement may have been as much as 45 mi (Fleck, 1970, p. 333). It trends northwest across the study area from Sunrise Mountain past Corn Creek Springs, and it roughly coincides with the deepest part of the bedrock basin. The Las Vegas and Sheep Ranges form the north boundary of the bedrock basin and were emplaced by strike-slip movement and, possibly, by vertical movement on the shear zone.

Fault scarps, some more than 100 ft high, occur in the valley-fill deposits of Las Vegas Valley (pl. 1). They are believed to have been caused by normal faults, although some of the scarps may have receded in places due to erosion and may no longer mark the fault lines (Bell, 1981, p. 13). The scarps trend north to northwest in southern parts of the valley, but their trend changes toward the northeast north of Charleston Boulevard. The origin of the faults is uncertain. The most common explanation is differential compaction of valley-fill deposits (Maxey and Jameson, 1948, p. 70; Domenico and others, 1964, p. 14). These investigators noted that the scarps on the west side of the valley coincide with abrupt lateral changes in grain size where coarse-grained deposits of alluvial fans interfinger with fine-grained deposits that underlie the valley lowlands. However, scarps farther east do not coincide with such grain-size changes. The tendency of the scarps to trend northeast in northern parts of the valley may indicate that the faults originated from bedrock structures related to the Las Vegas shear zone (John W. Bell, Nevada Bureau of Mines and Geology, oral commun., 1981). The relationships between faults in the valley-fill deposits and the shape and structure of the bedrock basin are discussed in more detail later in this report.

Land Subsidence

Subsidence in Las Vegas Valley was investigated by Maxey and Jameson (1948), Malmberg (1964 and 1965), Domenico and others (1964), Mindling (1965, 1971), and Harrill (1976). Bell (1981) summarized these reports in a comprehensive review that (1) shows how subsidence has changed with time in Las Vegas Valley, and (2) discusses the possible causes of subsidence and its related effects.

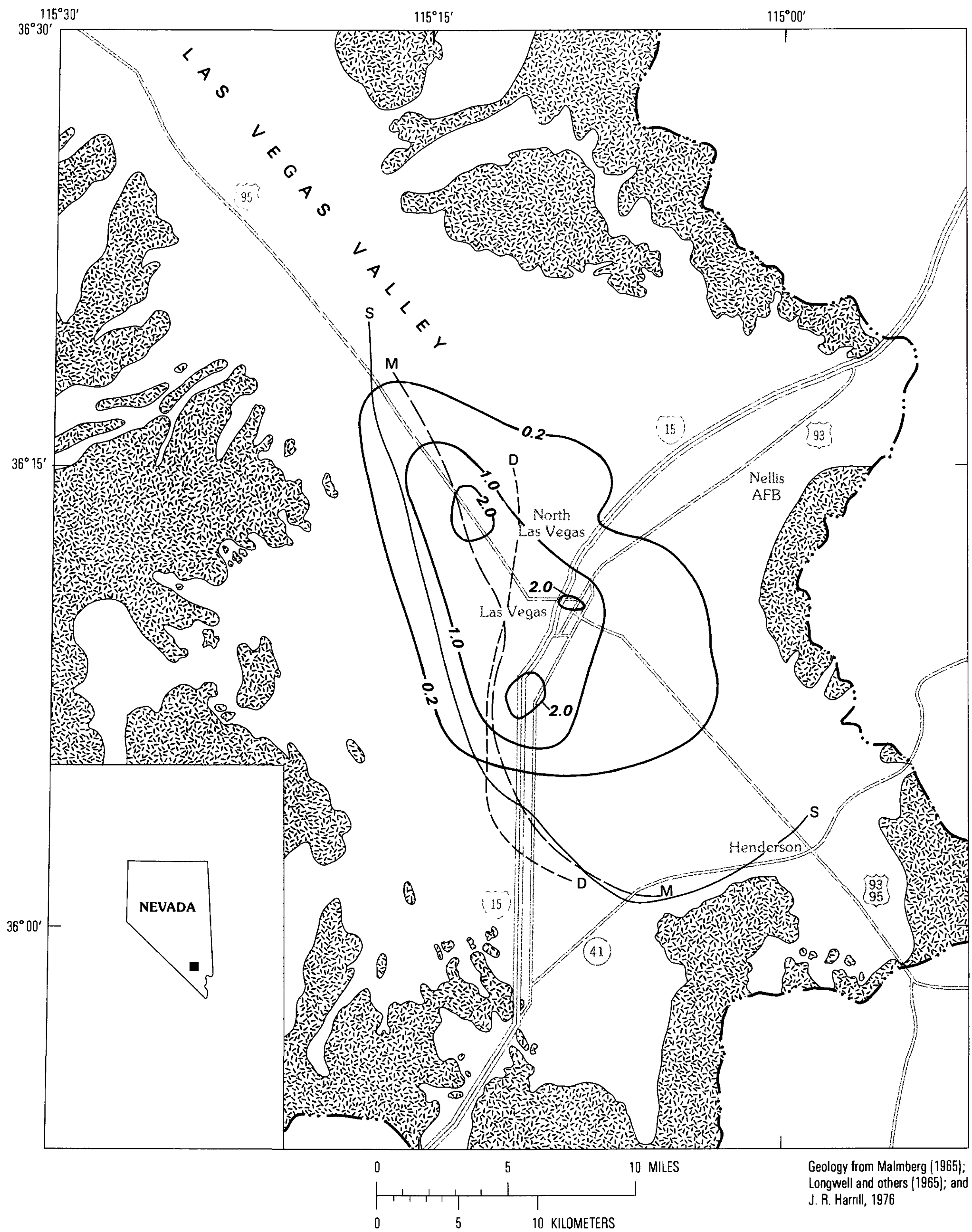
Compaction of fine-grained deposits caused by declining artesian heads is an important, if not primary, cause of subsidence in Las Vegas Valley (Malmberg, 1964, p. 5; Domenico and others, 1964, p. 35; Bell, 1981, p. 32). This type of subsidence began after 1906 when the first wells were drilled in the valley but could not be measured until first-order leveling was done in 1935. Since 1935, the area of subsidence has expanded and includes much of the valley lowlands (fig. 2). According to Bell (1981, p. 56), subsidence has been most severe in the vicinity of four areas of heavy pumping: in the Las Vegas downtown area (south-central part of T. 20 S., R. 61 E.), along Craig Road at the Nellis Air Force Base well field (secs. 2 and 3, T. 20 S., R. 61 E.), northwest of Las Vegas along U.S. Highway 95 (northeast part of T. 20 S., R. 60 E.), and along Las Vegas Boulevard near "The Strip" casinos (sec. 17, T. 21 S., R. 61 E.). Since 1963, subsidence has exceeded 2 ft along Las Vegas Boulevard near the casinos and along Highway 95 northwest of Las Vegas; since 1935, it may have been as much as 5 ft in downtown Las Vegas (Bell, 1981, p. 55, 56).

Fine-grained deposits (silt and clay) have long been recognized as being more susceptible to subsidence than coarse-grained deposits (Malmberg, 1964, p. 5; Bell, 1981, p. 36). However, Mindling (1965) was the first to determine physical properties of the valley-fill deposits in Las Vegas Valley and to use these properties to estimate the compressibility of the deposits. He showed that the valley-fill deposits are most compressible near the center of Las Vegas Valley and that deeper, fine-grained deposits are not as compressible as shallower ones (Mindling, 1965, p. 48–50; 1971, p. 13). Compaction-recorder data also show that shallower (0–200 ft) fine-grained deposits are more compressible than deeper ones (Mindling, 1971, p. 12–18), although significant compaction in deeper intervals is indicated at the Nellis Air Force Base well field (Harrill, 1976, p. 41).

GROUND-WATER RESERVOIRS

Bedrock Reservoir

Bedrock transmits ground water from recharge areas in the Spring Mountains and Sheep Range to valley-fill deposits in Las Vegas Valley. Paleozoic carbonate rocks and Permian, Triassic, and Jurassic clastic rocks form most of the bedrock basin (Miocene igneous rocks may form the southeast part). Carbonate rocks probably transmit most of the ground water to the



EXPLANATION

Valley-fill deposits

Bedrock

—*1.0*— **Line of equal land subsidence—** Number indicates net subsidence from 1963 to 1980, in feet (Bell, 1981, p. 55)

Western and southern limits of valley fill in which fine-grained deposits constitute at least 25 percent

—S— **Shallow zone (0-200 feet below land surface)**

—M— **Middle zone (200-700 feet below land surface)**

—D— **Deep zone (700-1000 feet below land surface)**—Shows western limits only

— · · — **Drainage-basin boundary**

Figure 2. Relationship between land subsidence, 1963–80, and distribution of fine-grained deposits in valley fill, Las Vegas Valley, Nev. (See figure 1 for names of features and towns.)

valley fill, whereas clastic rocks at the south end of the Spring Mountains may only transmit minor amounts. (See plate 2 for a summary of the water-bearing properties of the bedrock.)

Maxey and Jameson (1948, p. 42–50) considered Paleozoic carbonate rocks to be noncavernous and unable to store or transmit much water, except for the Sultan and Monte Cristo Limestones (pl. 1), which they believed are primarily responsible for transmitting water from recharge areas to valley-fill deposits. However, Winograd and Thordarson (1975, p. 11) found that Cambrian through Permian carbonate rocks in the vicinity of the Nevada Test Site (about 75 miles north of Las Vegas) have high fracture permeability. In addition, Hess and Mifflin (1978, p. 26–32) showed that carbonate rocks throughout the Paleozoic section of eastern Nevada are highly permeable. Therefore, permeable zones throughout the carbonate rocks probably transmit water from recharge areas to the Las Vegas ground-water basin.

Maxey and Jameson (1948, p. 49–51, 55) also considered Permian, Triassic, and Jurassic clastic rocks and Miocene igneous rocks in the study area to be generally impermeable. However, gypsum and limestone beds in the clastic rocks and fractured zones in volcanic rocks could also be permeable. Volcanic rocks interbedded with valley-fill deposits at the south end of the valley (see "Bedrock" section) seem to restrict the vertical movement of water. When wells S22 E62 8CBD1 and S22 E62 15ACD1 were drilled, water was first reported at the base of volcanic rocks, but final static water levels in the wells were much higher.

Valley-Fill Reservoir

This section of the report describes the lithology and thickness of the sedimentary deposits that make up the valley-fill reservoir. Drillers' well logs are used to describe the lithology of the deposits, and geophysical data are used to determine the thickness of the deposits. The water-bearing characteristics of the deposits are summarized on plate 2. Ground water and the hydraulic properties of the valley fill will be described in the second phase of this study.

Lithology

Although the drillers' well logs represent a valuable source of data in Las Vegas Valley, they are difficult to use because (1) drillers as a group do not use a standard set of terms for describing the various materials they drill through; (2) the valley fill is a complex sequence of interfingered and intermixed gravel, sand, silt, and clay; and (3) lithologic descriptions can differ because of differences in drilling methods. To overcome the first difficulty, the U.S. Geological Survey uses a standard set of terms to interpret logs (Baker and Foulk, 1975, p. B-62 to B-66). These terms have been grouped into three categories on the basis of grain size and degree of sorting (table 1).

As a result of difficulties 2 and 3, logs for adjacent wells might disagree with respect to the details of thickness and lithology of materials penetrated. The same two logs, however, might agree fairly well if the terms used to interpret them were grouped according to grain size (for example, fine, heterogeneous, and coarse).

Plates 2 and 3 illustrate the lithology of valley-fill deposits in Las Vegas Valley using data from about 240 well logs that were interpreted using the methods described earlier. The logs were selected on the basis of the detail of lithologic descriptions and the location and depth of the well. Plate 4 is an index map for plates 2 and 3 that shows the locations of all wells used in the study and the lines of geologic sections shown on plate 2.

The fence diagram (pl. 2) shows the vertical and lateral distribution of coarse-grained, fine-grained, and heterogeneous deposits in the valley fill. It was constructed by plotting detailed lithologic sections from well logs on the geologic sections that make up the diagram; although well-to-well correlation of the detailed lithology was impossible, correlation of gross lithology based on grain size was fairly successful. The units shown on the fence diagram represent composites of coarse- and fine-grained deposits; that is, coarse-grained units in places include thin interbeds of silt and clay, and fine-grained units in places include thin beds of gravel and sand. The designations (coarse-grained deposits and fine-grained deposits) represent the clearly dominant lithologic type in each unit. Heterogeneous deposits mostly represent poorly sorted clay, silt, sand, and gravel but also include sequences of thinly interbedded fine- and coarse-grained deposits. Heterogeneity was designated only where neither coarse- nor fine-grained deposits predominated.

The lithologic maps (pl. 3) show percentages of coarse- and fine-grained deposits in the valley-fill in the depth intervals of 0–200, 200–700, and 700–1,000 ft below land surface. These three intervals are based on interpretations by Maxey and Jameson (1948, p. 81, 82) of the vertical extent of the near-surface aquifer, confined aquifers of the shallow and middle zones, and confined aquifers of the deep zone, respectively. The maps were produced by calculating the percentages of coarse- and fine-grained deposits in each depth zone for each of the well logs used in the study. If a well was not deep enough to penetrate at least 90 percent of a specific depth zone, data from the well were not used for that zone. Lines of equal percentage delineate areas in each depth zone where coarse- or fine-grained deposits

Table 1. Terms, grouped according to grain size and degree of sorting, used in this study to interpret drillers' well logs

Coarse-grained deposits	Fine-grained deposits	Heterogeneous deposits[1]
Boulders.	Anhydrite.	Alluvium.
Boulders and sand.	Bentonite.	Boulders, silt, sand, and clay.
Cemented gravel.	Caliche.	Cobbles, sand, silt, and clay.
Cobbles.	Clay.	Clayey sand.
Cobbles and sand.	Claystone.	
Conglomerate.	Evaporite.	
Gravel.	Gypsum.	Gravel, sand, and silt.
Rubble.	Limestone.	Gravel, silt, and clay.
Sand.	Mud.	Sandy silt.
Sand and gravel.	Mudstone.	Soil.
Sandstone.	Sandy clay.	
	Shale.	
	Silt.	
	Siltstone.	
	Silty clay.	
	Tuff.	
	Volcanics.	

[1]Heterogeneous deposits also include sequences of thinly interbedded coarse- and fine-grained deposits.

constitute less than 25, 25–75, and greater than 75 percent of the valley fill. However, not all data points within a specific area and depth zone have percentage values that are within the range indicated by the lines. Such data points may be unreliable or they may indicate localized differences in grain size. The values do not affect the positions of lines of equal percentage because the maps are intended to show only the general distribution of coarse- and fine-grained deposits. The data are not reliable enough to show detailed changes in lithology.

Heterogeneous deposits are not shown on plate 3 because in places they consist of sequences of thinly interbedded coarse- and fine-grained deposits, as indicated earlier in this section and in table 1. Although the detail of such sequences cannot be shown on plate 2, that detail can be used to compute the percentages of coarse- and fine-grained deposits for plate 3. Because of this limitation, the pairs of maps on plate 3 cannot be used to estimate the percentage of heterogeneous deposits in the valley fill.

The fence diagram (pl. 2) shows the distribution of coarse-grained, heterogeneous, and fine-grained deposits in the valley fill to depths as great as 1,000 ft below land surface. Thick, coarse-grained deposits, which consist of unconsolidated to consolidated sand and gravel, are present on the south, west, and northwest sides of the valley from land surface to depths of nearly 1,000 ft. The deposits are at least 800 ft thick on the west and northwest sides of the valley and at least 600 ft thick on the south side. Toward the center of the valley, coarse-grained deposits thin rapidly and interfinger with heterogeneous and fine-grained deposits. A single interval of coarse-grained deposits underlies the southern part of the valley at depths of 400–600 ft. The thickness of this interval changes rapidly, but is a minimum of 50 ft northwest of Whitney Mesa. Between Las Vegas and Nellis Air Force Base, coarse-grained deposits comprise three intervals each ranging in thickness from 50 to nearly 150 ft; the intervals are separated by 150–200 ft of fine-grained deposits. The three intervals pinch out near North Las Vegas.

Several intervals of coarse-grained deposits are also present farther east in the vicinity of Nellis Air Force Base. They are at and near land surface and originate from Frenchman and Sunrise Mountains. Deeper intervals of coarse-grained deposits in this area may have originated from the west, but their continuity with the intervals near North Las Vegas cannot be determined from well logs.

Heterogeneous deposits comprise two or three intervals of the valley fill in the south part of Las Vegas Valley and one interval in the north part. The intervals are as much as 150 ft thick and range in depth from land surface to 600 ft. They are interbedded with coarse- and fine-grained deposits and do not seem to persist in any direction for more than several miles. They are certainly not as continuous as the coarse- and fine-grained deposits.

Fine-grained deposits (mostly silt and clay) constitute a large part of the valley fill in the east, southeast, and northeast parts of Las Vegas Valley (pl. 2). Toward the west side of the valley, these deposits interfinger with coarse-grained deposits; farther east, they are interbedded with thin intervals of coarse-grained and heterogeneous deposits that are not laterally continuous. The aggregate thickness of fine-grained deposits shown on plate 2 is at least 800 ft in the northwest part of the valley and 600 ft at Whitney Mesa. A well east of Whitney Mesa (S21 E62 22DD) was drilled through about 3,000 ft of valley fill, of which more than 2,000 ft were fine grained.

Maxey and Jameson (1948, p. 68) and Domenico and others (1964, p. 14, 15) identified a blue clay in the valley fill beneath much of the lowland area. This clay has been used as a stratigraphic horizon in the valley fill, and differences in its altitude are interpreted to be caused in part by faulting (Domenico and others, 1964, p. 14, 15). Some of the well logs used in the present study show one or more blue clays, and several logs in the North Las Vegas-Nellis area show three or four blue clays that range in depth from a few hundred feet to nearly 1,000 ft. These multiple clay layers make difficult the identification of blue clay horizons that are areally extensive. In addition, many well logs do not list colors for the deposits penetrated. For these reasons, the blue clays in the valley fill are not discussed in detail in this report.

The maps in plate 3 show that much of the valley fill on the west and south sides of the valley is composed of coarse-grained deposits. These deposits comprise 75 percent or more of the upper 1,000 ft of valley fill on the west side of the valley and 25 percent or more on the south side. The maps also show that fine-grained deposits predominate beneath the valley lowlands in areas that are located progressively eastward with increasing depth.

In general, plates 2 and 3 show that (1) coarse-grained deposits in Las Vegas Valley are roughly parallel to the Spring Mountains and possibly the McCullough Range (higher percentages are nearer the mountains), and (2) the proportion of coarse-grained deposits in the valley fill increases eastward with increasing depth. This suggests that the Spring Mountains and, to a lesser extent, the McCullough Range have been the major sources of clastic material for the valley fill in Las Vegas Valley. The east-to-west shifts in the distribution of coarse- and fine-grained deposits from deep to shallow zones suggest that the Spring Mountains were once more extensive to the east but receded westward due to erosion. The Las Vegas Range and Frenchman and Sunrise Mountains do not appear to have contributed much coarse material to the valley fill, which may indicate that mountainous areas did not exist in these parts of the valley until recently. However, the absence of coarse material may reflect the sparsity of data from the north and east sides of the valley.

The distribution of fine-grained deposits shown on plate 3 and figure 2 generally agrees with the distribution of fine-grained deposits shown by Mindling (1965, p. 42–44). Mindling's findings were based on physical properties of valley-fill deposits determined from drill cuttings. This agreement shows that well logs are useful for making general interpretations of the lithology of valley-fill deposits.

The areas of subsidence in Las Vegas Valley partly coincide with the distribution of fine-grained deposits in each of the depth zones of valley fill. The lines labeled with letters on figure 2 represent the lateral limits of the area in which valley fill consists of at least 25 percent fine-grained deposits in each of the depth zones. The line for the shallow zone (labeled S) encompasses most of the area in which subsidence exceeded 0.2 ft from 1963 to 1980 and all the area in which subsidence exceeded 1.0 ft during the same period. The lines on figure 2 that represent the middle (M) and deep (D) zones of valley fill encompass only part of the area in which subsidence exceeded 1.0 ft from 1963 to 1980. Thus, shallow, fine-grained deposits appear to be more susceptible to subsidence (more compressible) than similar deposits of deeper zones—a conclusion that agrees with Mindling's findings (1965, p. 48–50; 1971, p. 13).

Thickness and Extent

The shape of the valley-fill reservoir in Las Vegas Valley was determined using gravity data collected by Reidy and others (1978) and by the present author in 1980. The use of gravity data to understand subsurface geology is based on the principle that the force of gravity varies over the surface of the Earth. At any point it is the result of the attractive forces of the Sun and Moon, the altitude of the point, the effects of nearby topography, the latitude of the point, and the density of the rocks beneath the point. The gravity value, however, can be corrected for all these effects except density and reduced to a value for an arbitrary datum, usually sea level. The theoretical gravity at any point on the Earth can be calculated using a formula which assumes that the Earth is of constant density and is shaped like an oblate spheroid (a sphere slightly larger in diameter at the equator than at the poles). The difference between the observed and theoretical values of gravity, then, should be due only to the density of rocks beneath the point of measurement; this difference is called the Bouguer anomaly. A Bouguer gravity map of the Las Vegas area was prepared by Kane and others (1979).

The Bouguer anomaly can have more than one component. For instance, in Las Vegas Valley the gravitational effects of the valley fill are superimposed on a regional or bedrock gravity field. The residual gravity, due only to the valley fill, can be isolated by removing the regional effects. Residual anomalies can then be converted to thicknesses of valley fill.

The regional gravity field was approximated from bedrock gravity stations using trend-surface analysis, which was done with a computer program documented by Davis (1973, p. 332–334). The program results include a measure of the goodness of fit, which can vary from 0 to 1, and computed values of gravity for the bedrock stations. The goodness of fit for the regional gravity field in Las Vegas Valley (a fourth-order surface) is 0.88, which, according to Davis (1973, p. 336), is a good fit. However, computed values of gravity differed significantly from measured values (by 5–12 milligals) at three stations on Frenchman Mountain, five in the McCullough Range, and seven throughout the Spring Mountains. These stations represent 14 percent of the 107 bedrock stations used in the study. Although the regional surface is considered to be reliable, these particular stations may cause localized errors in the calculated depth to bedrock. Residual gravity fields and the use of trend-surface analysis are discussed in detail by Dobrin (1976, p. 435–454) and Davis (1973, p. 322–337).

The conversion of gravity data to bedrock depths (pl. 5) involved extensive use of a computer. Documented programs that were used include a gravity reduction and station plot (Paul Zabel and Minor Davis, U.S. Geological Survey, written commun., 1968, unpublished documentation of U.S. Geological Survey Computer Program No. W9204), a trend-surface analysis (Davis, 1973, p. 332–334), and an iterative three-dimensional solution of gravity anomaly data (Cordell, 1970).

The density contrast (difference between densities of bedrock and valley fill) is perhaps the greatest source of uncertainty in converting gravity data to valley-fill thickness. For this study, the densities of bedrock and valley-fill deposits are assumed to be 2.7 and 2.2 grams per cubic centimeter (g/cm^3), respectively. The value for bedrock is generally accepted as reasonable when more detailed data are not available (Zohdy and others, 1974, p. 98). The value for valley fill is based on analysis of a range of valley-fill densities.

A computer program for a two-dimensional model of valley fill was used to test a range of valley-fill densities, to determine which density produces the least error. The program and its use for this purpose is described by Schaefer and Maurer (1981, p. 8–14). Using residual gravity values along a profile and an assumed density contrast, the program computes values for thickness of valley fill at each gravity station.

Two profiles were chosen to coincide with wells that penetrate to bedrock so that computed thickness of valley fill can be compared with measured thickness. The results follow.

Measured thickness of valley fill (ft)	Density contrast (g/cm^3)	Computed thickness of valley fill (ft)
	Well S21 E62 22DD	
3,040:	0.4	4,300
	.5	3,400
	.6	2,800
	Well S21 E61 24BB	
2,615:	0.4	2,900
	.5	2,300
	.6	1,900

This tabulation shows that the computed thickness of valley fill fits the measured thickness at a density contrast between 0.4 and 0.5 g/cm^3 at one well and between 0.5 and 0.6 g/cm^3 at the other. These results suggest that a density contrast of 0.5 g/cm^3 (valley-fill density of 2.2 g/cm^3) is a reasonable estimate, at least for the area near the two wells. The difference between measured thickness and thickness computed using a density contrast of 0.5 g/cm^3 is 12 percent at both wells and is considered to be the approximate uncertainty of thicknesses shown on plate 5.

Seismic data collected during the course of this study were used to determine the depth to bedrock at four sites in the valley. Refraction methods were used at a site on the west side of the valley and reflection methods were used at a site on the east side and at two sites north of Las Vegas (pl. 5). Refraction methods were also used at two of the reflection sites to obtain the seismic velocity of valley-fill deposits. The seismic velocity of an elastic material is the velocity at which energy is transmitted through the material by compressional waves. For a more complete definition, see Sheriff (1973, p. 192).

The seismic velocities at the sites on the east side of the valley and north of Las Vegas are 6,200 ft/s (feet per second). Well logs near these two sites show that the valley fill consists mostly of unconsolidated, fine-grained and heterogeneous deposits. Seismic velocities at the site on the west side of the valley are 6,700 ft/s for valley-fill deposits and 12,000 ft/s for bedrock. Well logs near this site show mostly coarse-grained deposits, including more than 100 ft of cemented gravel, overlying bedrock. The small differences in seismic velocity of the valley fill between the three sites suggest that the density of valley-fill deposits may be fairly uniform.

Well and seismic data help corroborate the valley-fill thicknesses shown on plate 5. These data generally agree with the lines of equal thickness except at wells S20 E60 35DD and S22 E60 1DD on the west and southwest sides of the valley and at a seismic-reflection site north of Las Vegas. Well data indicate that the 1,000-ft isopach should be farther west in the southwest part of the valley. The thickness of valley fill determined at the seismic-reflection site (4,000 ft) indicates that thicknesses computed from gravity data may be in error by as much as 1,000 ft in this part of the valley; however, the thickness at a nearby seismic-reflection site (4,700 ft) agrees fairly well with the thickness computed from gravity data.

The structural basin beneath Las Vegas Valley consists of two parts: a deep (2,000- to 5,000-ft) depression beneath most of the valley and a shallow, east-sloping bedrock surface on the west side (pl. 5). The boundaries of the deep part generally coincide with the margins of Las Vegas Valley on the north, south, and east; to the west, in contrast, the deep part of the basin terminates 7–8 miles east of the valley margin. The deep part of the basin is bounded on the northwest by a bedrock high between Corn Creek Springs and Tule Springs that is within 1,000 ft of land surface.

The shallow bedrock surface underlies the western part of Las Vegas Valley from La Madre Mountain to the McCullough Range. The surface slopes gently eastward, and the valley-fill deposits that overlie it range in thickness from a feather edge at the valley margin to about 1,000 ft along the west side of Las Vegas.

Evidence for the structural control of the basin, especially the deep part, is indicated on plate 5, although the only direct evidence for bedrock faults is along the base of Frenchman Mountain. Valley-fill isopachs near Frenchman Mountain are closely spaced and change from a northwest trend to a northeast trend around the base of the mountain, coinciding with faults mapped by Longwell and others (1965, pl. 1), Bell and Smith (1980), and Bell (1981, pl. 1). Closely spaced isopachs along the north margin of the valley coincide with the approximate position of the Las Vegas shear zone and indicate that the Las Vegas Range was emplaced either by several thousand feet of vertical movement on the shear zone or by strike-slip movement along it.

The deep part of the basin is bounded on the west by closely spaced isopachs that extend from the Paradise Valley area to the North Las Vegas air terminal (pl. 5). This boundary may represent the trace of a normal fault. North of the air terminal, isopachs indicate a bedrock ridge that extends northeast across the valley—a possible indication of a northeast-trending fault. A bedrock high (2,000–3,000 ft deep) underlies the area southwest of the city of Las Vegas and generally separates the deepest part of the basin (more than 5,000 ft) on the north from the fairly deep part (more than 4,000 ft) beneath Henderson. Thus, in addition to being bounded by northwest-trending faults, the basin may be segmented by northeast- or east-trending faults.

Positions of fault scarps in the valley fill appear to be controlled by the shape of the structural basin (pl. 5). This control is most striking where scarps along the west side of Las Vegas Valley and at the base of Frenchman Mountain coincide with the margins of the deep part of the bedrock basin and where the Eglington scarp turns northeast over a northeast-trending bedrock ridge.

The apparent fault control of the deep part of the basin suggests that the valley-fill fault scarps on the east and west sides of Las Vegas Valley are of tectonic origin. However, the rapid change from bedrock to compressible sediments on the west side of the valley also supports the compaction hypothesis of Domenico and others (1964, p. 14). Faults in the valley fill may be related both to differential compaction and to structural displacement of the underlying bedrock (Bell, 1981, p. 43).

SUMMARY

This report describes (1) the lithology of deposits that constitute the valley fill of Las Vegas Valley, and (2) the shape and depth of the structural basin in which the valley fill was deposited. This information will be used to develop a hydraulic model of the ground-water system in the valley.

The structural basin that underlies Las Vegas Valley is composed of Precambrian crystalline rocks; Precambrian and Paleozoic carbonate rocks; Permian, Triassic, and Jurassic clastic rocks; and Miocene igneous rocks.

The carbonate rocks are probably the principal unit that transmits ground water from recharge areas in the Spring Mountains and Sheep Range to the valley-fill reservoir. Other bedrock units probably do not store or transmit much water. The valley-fill reservoir consists of as much as 5,000 ft of mostly clastic sediments that were deposited in the basin from as early as Miocene through Holocene.

The valley-fill reservoir consists of coarse-grained deposits (gravel and sand), fine-grained deposits (silt and clay), and heterogeneous deposits, so-called because they consist of mixtures or thinly interbedded sequences of coarse- and fine-grained deposits. Coarse-grained deposits underlie the west side of Las Vegas Valley to depths of at least 1,000 ft and interfinger with fine-grained and heterogeneous deposits as far east as North Las Vegas. Fine-grained deposits predominate beneath the valley lowlands to depths of at least 800 ft. Heterogeneous deposits comprise relatively thin intervals of the valley fill from land surface to depths of

600 ft. The thickness of valley-fill deposits, determined from geophysical data, ranges from less than 1,000 ft near valley margins to about 3,000 ft at Las Vegas, 4,000 ft at Henderson, and 5,000 ft in the northern part of the valley.

The distribution of coarse- and fine-grained deposits at different depths (pl. 2 and 3) suggests that (1) the east side of the Spring Mountains has receded westward due to erosion, (2) the Spring Mountains and McCullough Range have been the major sources of clastic material for the valley fill, and (3) the Las Vegas Range and Frenchman Mountain were emplaced later than the Spring Mountains. The distribution of fine-grained deposits in the uppermost 200 ft of valley fill coincides with patterns of subsidence shown by Bell (1981, p. 51–55) and indicates that shallow, fine-grained deposits are more compressible (susceptible to subsidence) than deeper ones.

The Las Vegas Valley structural basin generally conforms to the present shape of the valley, but it consists of two parts: a deep (2,000- to 5,000-ft) depression beneath most of Las Vegas Valley and a shallow (less than 1,000 ft) bedrock surface on the west side of the valley south of La Madre Mountain. The deep part of the basin is bounded on the east and possibly on the west by normal faults and on the north by the Las Vegas shear zone along which there may have been vertical displacement in addition to strike-slip displacement.

The fault scarps on the west side of the valley coincide with the western margin of the deep depression. In addition, the Eglington scarp coincides with a ridge of buried bedrock that trends northeast into the basin. These relationships suggest that bedrock structures are responsible for the faulting of valley-fill deposits; however, the abrupt lateral change from incompressible bedrock to more compressible valley-fill deposits on the west side of the valley also supports differential compaction as a cause of the faults. As Bell noted (1981, p. 43), both bedrock structure and differential compaction probably contributed to faulting of valley-fill deposits in Las Vegas Valley.

REFERENCES CITED

Anderson, R.E., Longwell, C.R., Armstrong, R.L., and Marvin, R.F., 1972, Significance of K-Ar ages of Tertiary rocks from the Lake Mead region, Nevada-Arizona: Geological Society of America Bulletin, v. 83, no. 2, p. 273–288.

Baker, C.H., Jr., and Foulk, D.G., 1975, National water data storage and retrieval system—Instructions for preparation and submission of ground-water data: U.S. Geological Survey Open-File Report 75–589, 159 p.

Bell, J.W., 1981, Subsidence in Las Vegas Valley, Nevada: Nevada Bureau of Mines and Geology Bulletin 95, 84 p.

Bell, J.W., and Smith, E.I., 1980, Geologic map of the Henderson quadrangle, Nevada: Nevada Bureau of Mines and Geology Map 67.

Bingler, E.C., 1977, Geologic map, Las Vegas SE quadrangle: Nevada Bureau of Mines and Geology Urban Maps Series, Las Vegas SE Folio, Map 3Ag.

Carpenter, Everett, 1915, Ground water in southeastern Nevada: U.S. Geological Survey Water-Supply Paper 365, 86 p.

Cordell, Lindreth, 1970, Iterative three-dimensional solution of gravity anomaly data: U.S. Geological Survey Computer Contribution 10, 13 p. Available only from National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161, as report PB–196 979.

Davis, J.C., 1973, Statistics and data analysis in geology: New York, John Wiley, 550 p.

Dinger, J.S., 1977, Relation between surficial geology and near-surface ground-water quality, Las Vegas Valley, Nevada: Reno, Nev., University of Nevada, unpublished Ph.D. thesis, 215 p.

Dobrin, M.B., 1976, Introduction to geophysical prospecting (3d ed.): New York, McGraw Hill, 630 p.

Domenico, P.A., Stephenson, D.A., and Maxey, G.B., 1964, Ground water in Las Vegas Valley: University of Nevada, Desert Research Institute Technical Report H–W 7, 53 p.

Fleck, R.J., 1970, Age and possible origin of the Las Vegas Valley shear zone, Clark and Nye Counties, Nevada: Geological Society of America Abstracts with Programs, v. 2, no. 5, p. 333.

Harrill, J.R., 1976, Pumping and ground-water storage depletion in Las Vegas Valley, Nevada, 1955–74: Nevada Division of Water Resources Bulletin 44, 69 p.

Haynes, C.V., 1967, Quaternary geology of the Tule Springs area, Clark County, Nevada, *in* Pleistocene studies in southern Nevada: Nevada State Museum Anthropological Paper 13, p. 15–104.

Hess, J.W., and Mifflin, M.D., 1978, A feasibility study of water production from deep carbonate aquifers in Nevada: University of Nevada, Desert Research Institute Publication 41054, 125 p.

Kane, M.F., Healey, D.L., Peterson, D.L., Kaufmann, H.E., and Reidy, Denis, 1979, Bouguer gravity map of Nevada, Las Vegas sheet: Nevada Bureau of Mines and Geology Map 61.

Laney, R.L., 1981, Geohydrologic reconnaissance of Lake Mead National Recreation Area—Las Vegas Wash to Opal Mountain, Nevada: U.S. Geological Survey Open-File Report 82–115, 23 p.

Longwell, C.R., 1963, Reconnaissance geology between Lake Mead and Davis Dam, Arizona-Nevada: U.S. Geological Survey Professional Paper 374–E, 51 p.

Longwell, C.R., Pampeyan, E.H., Bowyer, Ben, and Roberts, R.J., 1965, Geology and mineral deposits of Clark County, Nevada: Nevada Bureau of Mines Bulletin 62, 217 p.

Malmberg, G.T., 1964, Land subsidence in Las Vegas Valley, Nevada, 1935–63: Nevada Department of Conservation and Natural Resources Information Report 5, 10 p.

———— 1965, Available water supply of the Las Vegas ground-water basin, Nevada: U.S. Geological Survey Water-Supply Paper 1780, 116 p.Matti, J.C., and Bachhuber, F.C., 1982, Preliminary geologic map of the Las Vegas SW quadrangle: Nevada Bureau of Mines and Geology Open-File Map 82–6.

Matti, J.C., and Morton, D.M., 1982a, Preliminary geologic map of the Las Vegas NW quadrangle: Nevada Bureau of Mines and Geology Open-File Map 82–4.

———— 1982b, Preliminary geologic map of the Las Vegas NE quadrangle: Nevada Bureau of Mines and Geology Open-File Map 82–5.

Maxey, G.B., and Jameson, C.H., 1948, Geology and water resources of Las Vegas, Pahrump, and Indian Spring Valleys, Clark and Nye Counties, Nevada: Nevada State Engineer, Water Resources Bulletin 5, 121 p.

Mendenhall, W.C., 1909, Some desert watering places in southeastern California and southwestern Nevada: U.S. Geological Survey Water-Supply Paper 224, 98 p.

Mifflin, M.D., and Wheat, M.M., 1979, Pluvial lakes and estimated pluvial climates of Nevada: Nevada Bureau of Mines and Geology Bulletin 94, 57 p.

Mindling, Anthony, 1965, An investigation of the relationship of the physical properties of fine-grained sediments to land subsidence in Las Vegas Valley, Nevada: Reno, Nev., University of Nevada, M.S. thesis, 90 p.

———— 1971, A summary of data relating to land subsidence in Las Vegas Valley: University of Nevada, Desert Research Institute Report, 55 p.

Price, C.E., Jr., 1966, Surficial geology of the Las Vegas quadrangle, Nevada: Salt Lake City, Utah, University of Utah, unpublished M.S. thesis, 60 p.

Reidy, Denis, Kane, M.F., Healey, D.L., Peterson, D.L., and Kaufmann, H.E., 1978, Principal facts for a set of regional gravity data for the Las Vegas 1° by 2° sheet, Nevada: U.S. Geological Survey Open-File Report 78–1012, 40 p.

Rush, F.E., 1968, Index of hydrographic areas in Nevada: Nevada Division of Water Resources Information Report 6, 38 p.

Schaefer, D.H., and Maurer, D.K., 1981, Geophysical reconnaissance of Lemmon Valley, Washoe County, Nevada: U.S. Geological Survey Open-File Report 80–1123, 29 p.

Sheriff, R.E., 1973, Encyclopedic dictionary of exploration geophysics: Tulsa, Okla., Society of Exploration Geophysicists, 266 p.

Tabor, L.L., 1970, Geology of the Las Vegas area: San Francisco, Calif., John A. Blume & Associates, Research Division, 27 p.

Winograd, I.J., and Thordarson, William, 1975, Hydrogeologic and hydrochemical framework, south-central Great Basin, Nevada-California, with special reference to the Nevada Test Site: U.S. Geological Survey Professional Paper 712–C, 126 p.

Zohdy, A.A.R., Eaton, G.P., and Mabey, D.R., 1974, Application of surface geophysics to ground-water investigations: U.S. Geological Survey Techniques of Water-Resources Investigations Book 2, Chapter D1, 116 p.

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