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

Part I. Hydrogeologic Framework

U.S. GEOLOGICAL SURVEY

Open-File Report 84-130

Prepared in cooperation with the
CLARK COUNTY DEPARTMENT OF
COMPREHENSIVE PLANNING

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Carson City, Nevada

1984

UNITED STATES DEPARTMENT OF THE INTERIOR

WILLIAM P. CLARK, Secretary

GEOLOGICAL SURVEY

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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:

Multiply	*By*	*To obtain*
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 also is referred to as "sea level."

GROUND-WATER CONDITIONS IN LAS VEGAS VALLEY,
CLARK COUNTY, NEVADA

PART I. HYDROGEOLOGIC FRAMEWORK

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 help 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 to 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 consists of coarse-grained deposits (sand and gravel), fine-grained deposits (silt and clay), and heterogenous 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 relatively 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) suggest 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 relatively 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 Department of Comprehensive Planning. It discusses 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 develop a hydraulic model of the system that will simulate ground-water levels and reproduce observed historical changes, and use the model to describe and quantify the hydrology of the basin. The accuracy and usefulness of such a model, however, depends 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 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 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 miles north and west of Lake Mead and the Colorado River (figure 1). The greater Las Vegas metropolitan area, which includes the cities of Las Vegas and North Las Vegas and 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.

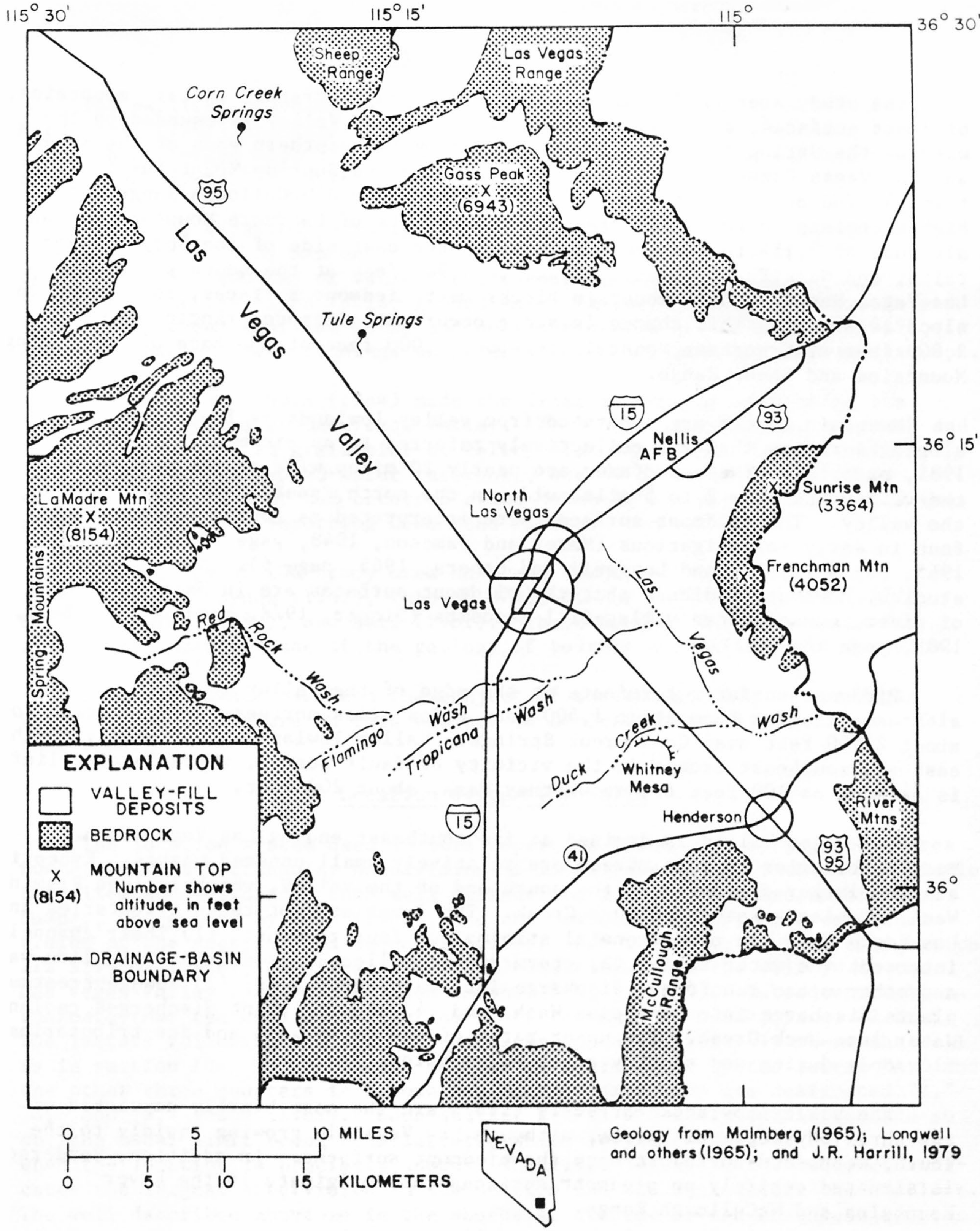

Figure 1.--Location and features of the study area.

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 feet above sea level on the east side of the Spring Mountains, and Gass Peak, at an altitude of 6,943 feet at the south end of the Las Vegas Range. Where mountain blocks meet piedmont surfaces, the change in slope is abrupt. This change in slope occurs at altitudes ranging from about 2,000 feet at Frenchman Mountain to about 4,000 feet 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, page 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, page 32; Malmberg, 1965, pages 11, 12; and Longwell and others, 1965, page 6). More recent studies, however, indicate that the piedmont surfaces are in part pediments of older, consolidated valley-fill deposits (Dinger, 1978, page 18; and Bell, 1981, page 10).

Piedmont surfaces terminate at the edge of the valley lowlands at altitudes ranging from about 1,500 feet a few miles northeast of Henderson to about 2,900 feet 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 feet or, at Whitney Mesa, about 200 feet.

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.

The valley lowlands currently (1982) are the most heavily populated of the three physiographic areas, although Las Vegas is growing rapidly to the south, west, and northwest onto the piedmont surfaces. In addition, Henderson is situated 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 discusses the geology of bedrock and thickness of valley-fill deposits (1915, pages 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.

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) also simulated the ground-water reservoir, and in addition he described storage depletion that had occurred 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 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, page 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 being four letters, which define an area of 2-1/2 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 described above 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. This 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 government 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 used in the study. The State Computer Facility in Carson City was used to store and process the gravity data used in the study. John W. Bell, of the Nevada Bureau of Mines and Geology, and Martin D. Mifflin, of the Desert Research Institute, reviewed the manuscript of this report and provided many 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 (plate 1). The valley fill consists of four formally named formations and unnamed Tertiary and Quaternary deposits that are subdivided on the basis of grain-size changes that occur between mountain fronts and the valley lowlands. The following discussion relies mostly on previous investigations. Plate 1 provides a summary of the stratigraphy of geologic units.

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, plate 1). A small outcrop of gneiss at the base of Frenchman Mountain is the only known occurrence of such rocks 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 Precambian and Paleozoic carbonate rocks (plate 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 (plate 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, page 9), the Moenkopi Formation was found at a depth of 3,100 feet in the Wilson-Federal 1 well (S21 E61 24BB1). The overlying material was described as older alluvium, although sandstone below 2,615 feet 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 (plate 1). Bell and Smith (1980) describe 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 (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 feet. The wells penetrate units described by drillers as lava rock or volcanic formation that range in thickness from 16 to 312 feet. These volcanic rocks may be flows that are 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 (plate 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, page 46). The Miocene clastic rocks at the south end of the Las Vegas Range consist of conglomerate with interbeds of sandstone and tuffaceous sediments, according to Longwell and others (1965, page 47), who note the similarity between these deposits and the Horse Spring Formation, but lack sufficient evidence to correlate them. The thickness of Miocene clastic deposits is estimated to range from 6,000 to 7,000 feet east of the study area, and the deposits are more than 5,000 feet thick north of the study area (Longwell and others, 1965, pages 42-47). The valley fill of Las Vegas Valley was generally believed to consist of Muddy Creek Formation and younger deposits, although Maxey and Jameson (1948, page 53) 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, page 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, page 48). Exposures of the Muddy Creek Formation are from 40 to 60 feet thick northwest of Whitney Mesa, over 100 feet thick at Whitney Mesa, and over 325 feet thick north and east of Henderson (Bingler, 1977; Bell and Smith, 1980). Price (1966, plate 1) mapped a hilly area in North Las Vegas as the Muddy Creek Formation, but Tabor (1970, page 15), though recognizing the similarity of these deposits with those of the Muddy Creek Formation, believes that the evidence is 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, pages 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, pages 278, 281). These parts of the formation are not exposed in Las Vegas Valley, although gypsum is reported by well drillers. As indicated in an earlier section, volcanic rocks interbedded with valley-fill deposits at the south end of the valley may either be the Fortification Basalt Member, flows interbedded with Miocene clastic deposits, or they may be coarse alluvium derived from volcanic rocks in the River Mountains and McCullough Range.

Except for areas of outcrop, the top of the Muddy Creek Formation is not well established 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 feet below land surface at Las Vegas (Domenico and others, 1964, page 10; Mindling, 1965, page 36; Malmberg, 1965, pages 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, pages 6-7) in the Lake Mead area, and interpretations by Longwell and others (1965, page 48), suggest that some of the alluvial fans in the valley may be pediments consisting of coarse-grained Muddy Creek facies overlain by a thin veneer of younger gravel. This has also been suggested by M. D. Mifflin (Desert Research Institute, written communication, 1981). Dinger (1977, page 18), though not mentioning the Muddy Creek Formation by name, states 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 very uncertain, mostly because the top and bottom of the formation are difficult to identify. Estimates of thickness in the valley range from about 325 feet northeast of Henderson (Bell and Smith, 1980) to about 3,000 feet east of Whitney Mesa (Malmberg, 1965, page 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 feet (Longwell, 1963, page 10).

Tertiary and Quaternary Sedimentary Deposits

Deposits of gravel, sand, silt, and clay 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 few tens of feet 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 fine sand along Las Vegas Wash (Haynes, 1967, plate 1; Bingler, 1977; Dinger, 1977, plate 1; Bell and Smith, 1980; Matti and Bachhuber, 1982; and Matti and Morton, 1982a and b). In the Henderson area, sand along Las Vegas Wash is less than 10 feet thick, and coarse-grained deposits on alluvial fans and pediments are generally less than 30 feet 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, page 11) calls the local gravel unit elsewhere in the Lake Mead area, including lower Las Vegas Wash. The gravels define the channels of streams that were tributary to the Colorado River during late Tertiary and early Quaternary. The conglomerates are very 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 consist of 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 and b); and silt, sand, and gravel in the north and northwest parts of the valley (Haynes, 1967).

In the northwest and north-central parts of the valley, the lowlands are underlain by fine-grained deposits (plate 1) of white to light brown sandy silt and mudstone that range in age from 14,000 to 30,000 years (Haynes, 1967, page 32). Longwell and others (1965, page 50) named these deposits the Las Vegas Formation. The formation was originally thought to have been deposited in a lacustrine environment (Longwell and others, 1965, pages 50, 52; Haynes, 1967, page 32); more recent evidence suggests that the formation was deposited within a playa, possibly one with localized marshes (Mifflin and Wheat, 1979, page 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 a few tens of feet. Underlying deposits may either represent the upper parts of Quaternary valley fill or Pliocene and Miocene deposits. The thickness of Quaternary deposits has been estimated at 500 to 1,000 feet at and adjacent to Las Vegas (Malmberg, 1965, page 21; Tabor, 1970, page 21). However, evidence discussed earlier in this report suggests that the top of the Muddy Creek Formation is at or near land surface throughout much of Las Vegas Valley (plate 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 this latter period 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 consists of two parts: a deep part below the valley lowlands and a relatively shallow part on the west side of the valley. The shape, depth, and structural control of the basin is discussed in a later section of this report.

The Las Vegas shear zone is a major structural feature in southern Nevada that may also be hydrologically significant. The shear zone is a strike-slip fault along which right-lateral movement may have been as much as 45 miles (Fleck, 1970, page 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, which form the north boundary of the bedrock basin, were emplaced by strike slip movement and possibly by vertical movement on the shear zone.

A number of fault scarps, some over 100 feet high, occur in the valley-fill deposits of Las Vegas Valley. 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, page 13). The scarps trend north to northwest in southern parts of the valley, but north of Charleston Boulevard their trend changes toward the northeast. The origin of the faults is uncertain. The mechanism most frequently used to explain the faults is differential compaction of valley-fill deposits (Maxey and Jameson, 1948, page 70; Domenico and others, 1964, page 14). These investigators note that the scarps on the west side of the valley coincide with rapid 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 originate from bedrock structures related to the Las Vegas shear zone (John W. Bell, Nevada Bureau of Mines and Geology, oral communication, 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 has been considered in a number of investigations, including those of Maxey and Jameson (1948), Malmberg (1964 and 1965), Domenico and others (1964), Mindling (1965 and 1971), and Harrill (1976). Bell (1981) has brought these reports together 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, page 5; Domenico and others, 1964, page 35; Bell, 1981, page 32). This type of subsidence began sometime after the first wells were drilled in the valley in 1906, but could not be measured until first-order leveling was done in 1935. Since then, the area of subsidence has expanded and includes much of the valley lowlands (figure 2). According to Bell (1981, page 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 (sec. 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 feet 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 feet in the downtown area of Las Vegas (Bell, 1981, pages 55, 56).

Fine-grained deposits (silt and clay) have long been recognized as being more susceptible to subsidence than coarse-grained deposits (Malmberg, 1964, page 5; Bell, 1981, page 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 shows 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, pages 48-50; 1971, page 13). Compaction-recorder data also show that shallower (0-200 feet) fine-grained deposits are more compressible (Mindling, 1971, pages 12-18), although significant compaction in deeper intervals is indicated at the Nellis Air Force Base well field (Harrill, 1976, page 41).

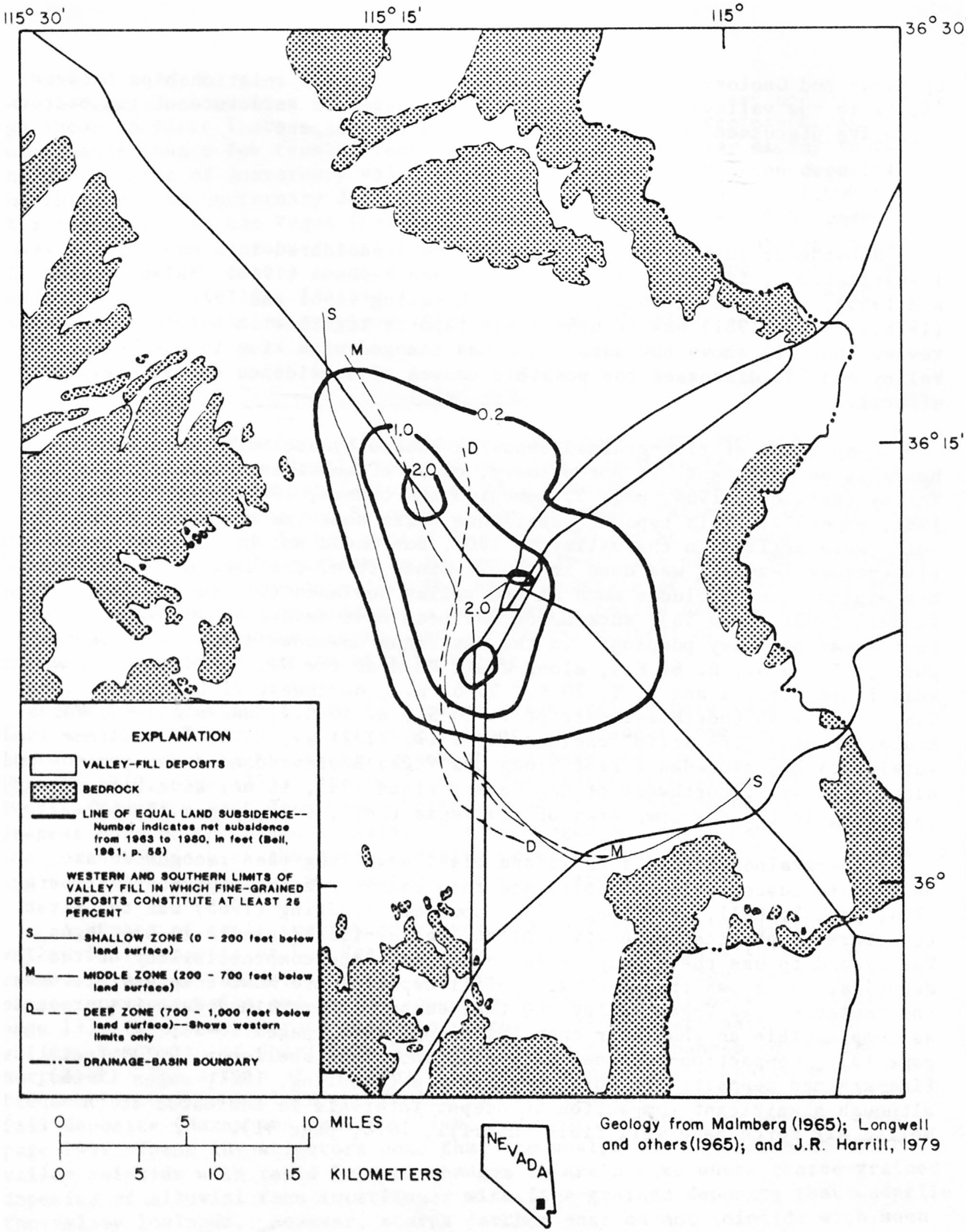

Figure 2.--Relationship between land subsidence, 1963 - 80, and distribution of fine-grained deposits in valley fill.

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

Except for the Sultan and Monte Cristo Limestones (plate 1), Maxey and Jameson (1948, pages 42-50) consider Paleozoic carbonate rocks to be noncavernous and unable to store or transmit much water. They believe the Sultan and Monte Cristo Limestones are primarily responsible for transmitting water from recharge areas to valley-fill deposits. However, Winograd and Thordarson (1975, page 11) have found that Cambrian through Permian carbonate rocks in the vicinity of the Nevada Test Site (about 75 miles north of Las Vegas) have relatively high fracture permeability. In addition, Hess and Mifflin (1978, pages 26-32) have shown that localized conditions of high permeability occur in carbonate rocks throughout the Paleozoic section of eastern Nevada. Therefore, permeable zones throughout the entire carbonate rock unit probably transmit water from recharge areas to the Las Vegas ground-water basin.

Maxey and Jameson (1948, pages 49-51, 55) also consider 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 be localized zones of high permeability. 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, first water was 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. Well drillers' 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. The occurrence of ground water and the hydraulic properties of the valley fill will be described in the second phase of this study.

Lithology

The lithology of valley-fill deposits was determined from logs of wells drilled in Las Vegas Valley. Although the logs represent a valuable source of data, 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) different drilling techniques yield different descriptions of lithology. To overcome the first problem, the U.S. Geological Survey uses a standard set of terms to interpret logs (Baker and Foulk, 1975, pages B-62 to B-66). These terms have been placed in three groups on the basis of grain size and degree of sorting (table 1).

As a result of the second and third problems, two carefully prepared logs for nearby 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).

TABLE 1.--*Terms, grouped according to grain size, that were used in this study to interpret drillers' 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	Clay	Cobbles, sand, silt, and clay
Cobbles and sand	Claystone	
Conglomerate	Evaporite	Clayey sand
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.

Plates 2 and 3 illustrate the lithology of valley-fill deposits in Las Vegas Valley. Data for the plates were obtained 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. It shows the locations of all wells used in the study, and the positions of geologic sections shown on plate 2.

The fence diagram (plate 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 and fine-grained deposits, reflect 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. This designation was used only where neither coarse- nor fine-grained deposits clearly predominated.

The lithologic maps (plate 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 feet below land surface. These intervals are based on interpretations by Maxey and Jameson (1948, pages 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 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. In either case, 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, the pairs of maps on plate 3 cannot be used to estimate the percentage of heterogeneous deposits in the valley fill.

The fence diagram (plate 2) shows the distribution of coarse-grained, heterogeneous, and fine-grained deposits in the valley fill to depths as great as 1,000 feet 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 feet. The deposits are at least 800 feet thick on the west and northwest sides of the valley and at least 600 feet 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 underlies the southern part of the valley at depths of 400 to 600 feet. The thickness of this interval changes rapidly, but is a minimum of 50 feet northwest of Whitney Mesa. Between Las Vegas and Nellis Air Force Base, coarse-grained deposits comprise three intervals that are from 50 to nearly 150 feet thick; the intervals are separated by 150 to 200 feet 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 feet thick and range in depth from land surface to 600 feet. 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 (plate 2). Toward the west side of the valley, these deposits interfinger with coarse-grained deposits; farther east, they are interbedded with relatively 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 feet in the northwest part of the valley and 600 feet at Whitney Mesa. A well east of Whitney Mesa (S21 E62 22DD) was drilled through about 3,000 feet of valley fill, of which more than 2,000 feet was fine-grained.

Maxey and Jameson (1948, page 68) and Domenico and others (1964, pages 14, 15) have identified a blue clay horizon in the valley fill beneath much of the lowland area. This clay has been used as a stratigraphic marker in the valley fill, and differences in its altitude are interpreted to be caused in part by faulting (Domenico and others, 1964, pages 14, 15). Some of the well logs used in this study show one or more intervals of blue clay, and several 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 feet. These multiple layers make difficult the identification of blue clay layers that are areally extensive. In addition, many well logs do not list colors for the deposits penetrated. For these reasons, the occurrence of blue clays in the valley fill is not discussed in detail in this report.

The lithologic maps (plate 3) show percentages of coarse- and fine-grained deposits in three intervals of the valley fill (0-200 feet, 200-700 feet, and 700-1,000 feet). The maps show that the valley fill on the west and south sides of the valley is comprised of significant proportions of coarse-grained deposits. These deposits comprise 75 percent or more of the upper 1,000 feet 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 shift eastward with increasing depth.

In general, plates 2 and 3 show that: (1) Coarse-grained deposits in Las Vegas Valley are distributed roughly parallel to the Spring Mountains and possibly the McCullough Range, with the higher percentages 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 of Las Vegas Valley. The east-to-west shifts in the distribution of coarse- and fine-grained deposits from the 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. This may reflect the sparsity of data points on the north and east sides of the valley; however, it could also indicate that mountainous areas of appreciable extent did not exist in these parts of the valley until relatively recently.

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, pages 42-44). Mindling's findings were based on physical properties of valley-fill deposits determined from drill cuttings. These comparisons show that well logs are useful for making general interpretations of the lithology of valley-fill deposits.

The distribution of subsidence in Las Vegas Valley partly coincides 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 where 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 foot from 1963 to 1980 and all of the area in which subsidence exceeded 1.0 foot during the same period. The lines on figure 2 that represent the middle and deep zones of valley fill encompass only part of the area where subsidence exceeded 1.0 foot from 1963 to 1980. This suggests that shallow fine-grained deposits are more susceptible to subsidence (more compressible) than those of deeper zones--a conclusion that agrees with Mindling's findings (1965, pages 48-50; 1971, page 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 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 of 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 with the shape of 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 has been 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. This was done with a computer program documented by Davis (1973, pages 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, page 336), is a very good fit. However, computed values of gravity differed significantly from measured values (by 5 to 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, pages 435-454) and Davis (1973, pages 322-337).

The conversion of gravity data to bedrock depths (plate 5) involved extensive use of a computer. Documented programs that were used include: A gravity reduction and station plot (Zabel and Davis, 1968); a trend-surface analysis (Davis, 1973, pages 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 involved 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, page 98). The value for valley fill is based on analysis of a range of valley-fill densities.

A computer program that develops 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, pages 8-14). Using values of residual gravity 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 to measured thickness. The results of the two profile models are shown below.

Well number	Measured thickness of valley fill (feet)	Density contrast (g/cm^3)	Computed thickness of valley fill (feet)
S21 E62 22DD	3,040	0.4	4,300
		.5	3,400
		.6	2,800
S21 E61 24BB	2,615	.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. This suggests 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 with a density contrast of 0.5 g/cm^3 is 12 percent in both cases, which 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 (plate 5). Refraction methods also were used at two of the reflection sites to obtain the seismic velocity[1] of valley-fill deposits. The seismic velocities at the sites on the east side of the valley and north of Las Vegas are 6,200 feet per second. Well logs in both areas 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 feet per second for valley-fill deposits and 12,000 feet per second for bedrock. Well logs near this site show mostly coarse-grained deposits including over 100 feet of cemented gravel, overlying bedrock. The small differences in seismic velocity of the valley fill between the three sites suggests that the density of valley-fill deposits may be relatively uniform.

In addition to the two wells discussed earlier in this section, other wells and seismic data help to 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. The wells indicate that the 1,000-foot 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 feet) indicates that thicknesses computed from gravity data may be in error by as much as 1,000 feet in this part of the valley; however, the thickness at a nearby seismic-reflection site (4,700 feet) 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-foot) depression beneath most of the valley and a relatively shallow, east-sloping bedrock surface on the west side (plate 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 to 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 feet 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 feet along the west side of Las Vegas.

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1 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, page 192).

Evidence for the structural control of the basin, especially the deep part, is indicated on plate 5. Although the basin has generally been considered a structural depression, 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 to north-east trend around the base of the mountain, coinciding with faults mapped by Longwell and others (1965, plate 1), Bell and Smith (1980), and Bell (1981, plate 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.

On plate 5, 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. 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 feet deep) underlies the area southwest of the city of Las Vegas and generally separates the deepest part of the basin (over 5,000 feet) on the north from the fairly deep part (over 4,000 feet) beneath Henderson. Thus, in addition to being bounded by northwest-trending faults, the basin may be segmented by northeast-or east-trending faults.

The position of some of the fault scarps in the valley fill appears to be controlled by the shape of the structural basin (plate 5). This 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, page 14). It is possible that faults in the valley fill may be related both to differential compaction and to structural displacement of the underlying bedrock (Bell, 1981, page 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 help 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.

Some of these units, most notably the carbonate rocks, probably transmit 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 feet of mostly clastic sediments that were 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 feet 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 feet. Heterogeneous deposits comprise relatively thin intervals of the valley fill from land surface to depths of 600 feet. The thickness of valley-fill deposits, determined from geophysical data, ranges from less than 1,000 feet near valley margins to about 3,000 feet at Las Vegas, 4,000 feet at Henderson, and 5,000 feet in the northern part of the valley.

The distribution of coarse- and fine-grained deposits at different depths (plates 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 feet of valley fill coincides with patterns of subsidence shown by Bell (1981, pages 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 shape of the valley, but it consists of two parts: a deep (2,000- to 5,000-foot) depression beneath most of Las Vegas Valley and a relatively shallow (less than 1,000 feet) 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 rapid lateral change from incompressible bedrock to relatively compressible valley-fill deposits on the west side of the valley also supports differential compaction as a cause of some of the faults. It is probable, as Bell notes (1981, page 43), that both bedrock structure and differential compaction contributed to faulting of valley-fill deposits in Las Vegas Valley.

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