

Prepared in cooperation with the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office under Interagency Agreement DE-AI52-01NV13944

Geologic Characterization of Young Alluvial Basin-Fill Deposits from Drill Hole Data in Yucca Flat, Nye County, Nevada

Open-File Report 2006–1390

U.S. Department of the Interior
U.S. Geological Survey

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By Donald S. Sweetkind and Ronald M. Drake II

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DIRK KEMPTHORNE, Secretary

U.S. Geological Survey
Mark D. Myers, Director

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the Nevada State Plane Coordinate System, central zone, North American Datum of 1927 (NAD27), in feet.

Altitude, as used in this report, refers to distance above the vertical datum.

Geologic Characterization of Young Alluvial Basin-Fill Deposits from Drill Hole Data in Yucca Flat, Nye County, Nevada

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Abstract

Yucca Flat is a topographic and structural basin in the northeastern part of the Nevada Test Site (NTS) in Nye County, Nevada, that has been the site of numerous underground nuclear tests; many of these tests occurred within the young alluvial basin-fill deposits. The migration of radionuclides to the Paleozoic carbonate aquifer involves passage through this thick, heterogeneous section of Tertiary and Quaternary rock. An understanding of the lateral and vertical changes in the material properties of young alluvial basin-fill deposits will aid in the further development of the hydrogeologic framework and the delineation of hydrostratigraphic units and hydraulic properties required for simulating ground-water flow in the Yucca Flat area. This report by the U.S. Geological Survey, in cooperation with the U.S. Department of Energy, presents data and interpretation regarding the three-dimensional variability of the shallow alluvial aquifers in areas of testing at Yucca Flat, data that are potentially useful in the understanding of the subsurface flow system. This report includes a summary and interpretation of alluvial basin-fill stratigraphy in the Yucca Flat area based on drill hole data from 285 selected drill holes. Spatial variations in lithology and grain size of the Neogene basin-fill sediments can be established when data from numerous drill holes are considered together. Lithologic variations are related to different depositional environments within the basin including alluvial fan, channel, basin axis, and playa deposits.

Introduction

Yucca Flat is a topographic and structural basin in the northeastern part of the Nevada Test Site (NTS) in Nye County, Nev. (fig. 1). Between the years 1951 and 1992, 659 underground nuclear tests took place in Yucca Flat (U.S. Department of Energy, 2000); most were conducted in large vertical excavations that penetrated alluvium and the underlying Cenozoic volcanic rocks (U.S. Department of Energy, 2000).

Radioactive and other potential chemical contaminants at the NTS are the subject of a long-term program of investigation and remediation by the U.S. Department of Energy (DOE), National Nuclear Security Administration, Nevada Site Office, under its Environmental Restoration Program. As part of the program, the DOE seeks to assess the extent of contamination and to evaluate the potential risks to humans and the environment from byproducts of weapons testing. To accomplish this objective, the DOE Environmental Restoration Program is constructing and calibrating a ground-water flow model to predict hydrologic flow in Yucca Flat as part of an effort to quantify the subsurface hydrology of the Nevada Test Site. A necessary part of calibrating and evaluating a model of the flow system is to compile and analyze data related to heterogeneity of the component hydrogeologic units. This report by the U.S. Geological Survey (USGS), in cooperation with the DOE, presents data and interpretation regarding the three-dimensional variability of the shallow alluvial aquifers in areas of testing at Yucca Flat, data that are potentially useful in the understanding of the subsurface flow system.

Purpose and Scope

The purpose of this study is to develop an understanding of lateral and vertical lithologic variability of Neogene sediments that make up the shallow basin fill of Yucca Flat. Understanding the configuration and character of the basin-fill sedimentary units is critical to delineating hydraulic properties and reducing uncertainty in three-dimensional simulations of ground-water flow in the Yucca Flat area. Recent stratigraphic studies of Cenozoic basins to the south of the NTS, including the Amargosa Desert Basin (Sweetkind and others, 2001; Taylor and Sweetkind, 2005) and the Pahrump Valley (Sweetkind and others, 2003) have shown that the three-dimensional stratigraphic variability of shallow alluvial sediments can be adequately characterized through interpretation of drill hole lithologic data. We hoped that the use of similar techniques would yield similar results in the Yucca Flat basin.

This report presents a summary and interpretation of alluvial basin-fill stratigraphy in the Yucca Flat area based on

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lithologic data from 285 drill holes that were selected from more than 890 drill holes in Yucca Flat. The drill holes that were used in this study were selected based on location (the need to produce a suitable spatial distribution of data) and the presence of high-quality lithologic descriptions that could be interpreted in terms of depositional environment and facies information. Drill hole lithologic data from the Neogene basin-fill sediments are evaluated in terms of lateral and vertical lithologic variations. These data are developed as geologic cross sections and 3D subsurface interpretations that show lateral and vertical changes in young alluvial basin-fill deposits, including spatial variations in lithology and grain size.

Description of the Study Area

Physiographic Setting

Yucca Flat is a topographically closed drainage basin that occupies much of the eastern part of the Nevada Test Site (fig. 1). The valley floor has no perennial surface water; Yucca Flat acts as a catchment for surface-water runoff and is a local depositional center for sediment. The low-relief topographic basin has a playa (seasonally dry lake) at the south end (fig. 2) and the basin is surrounded by low ranges that are underlain by Tertiary volcanic rocks and underlying Paleozoic and Late Proterozoic sedimentary rocks (fig. 2) (Slate and others, 2000). In general, the valley floor slopes upward toward the surrounding ranges on a series of coalescing alluvial fans that ring the margins of the basin. Large, active alluvial channels extend into the basin from topographic highlands of Rainier Mesa, the Eleana Range and the Halfpint Range (figs. 1 and 2).

Geologic Setting

The Cenozoic rocks in Yucca Flat consist of a thick alluvial section underlain by Miocene volcanic rocks and rare, thin prevolcanic sedimentary rocks, all of which lie unconformably on variably deformed pre-Cenozoic rocks. The Miocene volcanic rocks that form the lower part of the basin fill were originally erupted from source areas in the southwestern Nevada volcanic field (Byers and others, 1976; Sawyer and others, 1994). The volcanic rocks include variably welded ash-flow tuff, ash-fall tuff, and reworked tuff; the thickness and extent of these rocks vary greatly within the basin. The lower part of the sequence of volcanic rocks, including pre-Belted Range Group rocks, the Belted Range and Crater Flat Groups, and the Wahmonie Formation (stratigraphic designations from Sawyer and others, 1994), consists of bedded and reworked, nonwelded, commonly zeolitized tuffs. The upper part of the sequence of volcanic rocks, including rocks from the Paintbrush and Timber Mountain Groups, consists mainly of welded ash-flow tuff.

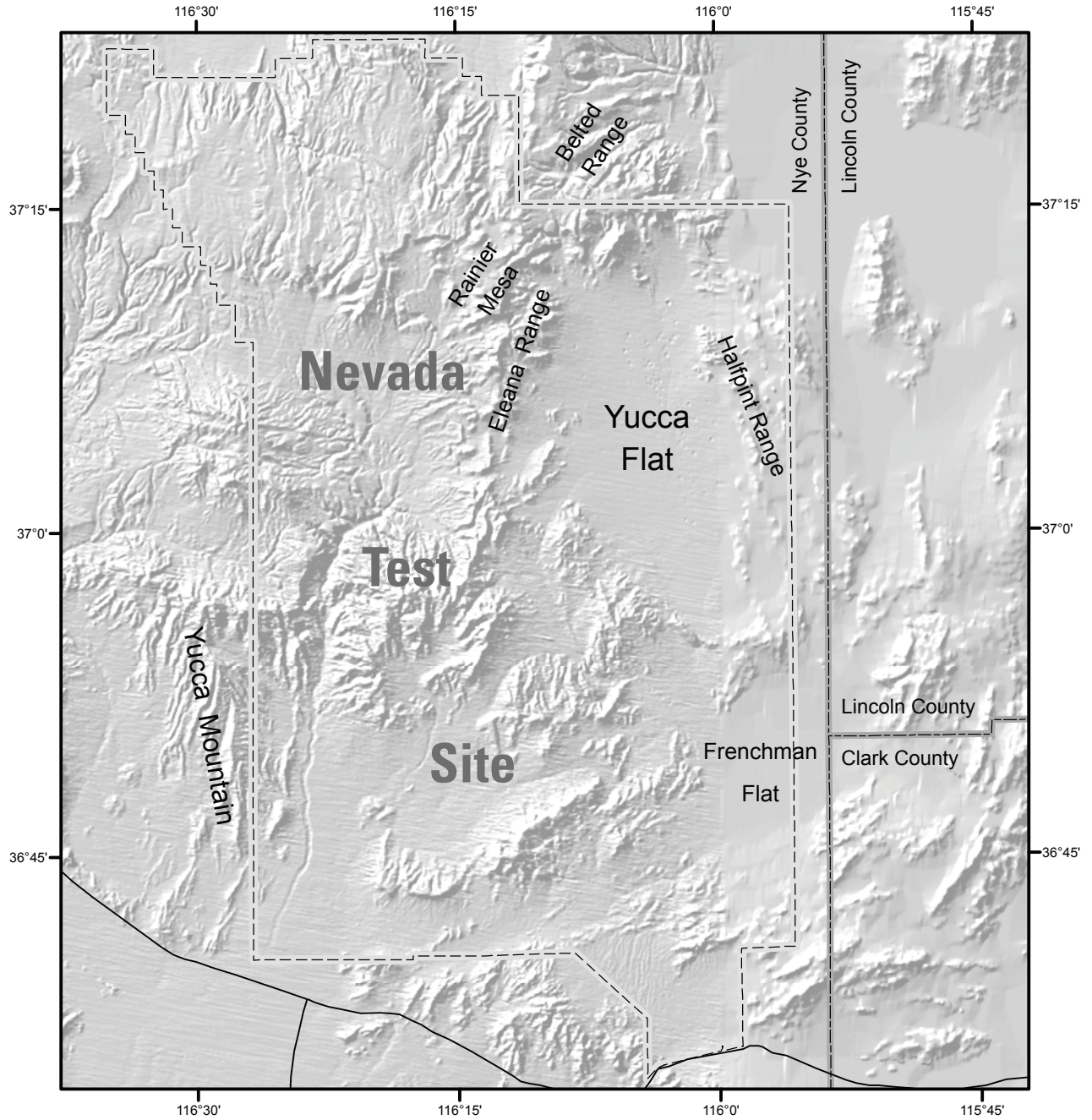
The largely postvolcanic sedimentary basin fill that is the subject of this report consists of a mixture of loosely

consolidated coarse-grained alluvial and colluvial deposits that were derived from the surrounding Cenozoic silicic volcanic and Paleozoic siliciclastic and carbonate sedimentary rocks, fine-grained basin axis and playa deposits, and localized eolian sand and rare basalt flows. Digital geologic map compilations of the Nevada Test Site at 1:120,000 scale (Slate and others, 2000) and 1:250,000-scale (Workman and others, 2002) have defined the map distribution and provided detailed descriptions for the surficial geologic units. As described by Workman and others (2002), coarse-grained surficial units consist of Holocene to Pliocene alluvium, colluvium, and minor eolian and debris-flow sediments associated with alluvial geomorphic surfaces (Swan and others, 2001; Potter and others, 2002). In general, fluvial deposits are predominantly sandy gravel, whereas alluvial fans typically show a gradational decrease in grain size from proximal to distal fan with distance from the mountain front (Workman and others, 2002). Local eolian accumulations consist of sand sheets or dune fields. Sediments generally are not cemented but tend to be more indurated with increasing depth. The fine-grained alluvial units consist of Holocene playa and (or) saltpan deposits that are commonly underlain by older playa or lacustrine sequences of middle to early Holocene and Pleistocene age (Workman and others, 2002). These rocks typically are mixtures of moderately stratified to well-stratified silt, clay, and fine sand.

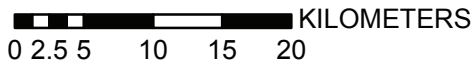
Structurally, the Yucca Flat basin is in general terms a simple half-graben dominated by north-striking, east-dipping, down-to-the-east normal faults of Cenozoic age such as the Yucca fault and the Carpetbag fault (Dockery, 1984; Carr, 1984) (fig. 2). Gravity models of the Yucca Flat basin define a Tertiary-Quaternary basin as much as 8,200 ft deep to the east of the Carpetbag fault, a mid-basin high to the west of the Carpetbag fault, and a shallower basin to the west of the high (Phelps and others, 1999; Ferguson and others, 1988). The Cenozoic volcanic units have been offset thousands of feet by the Carpetbag-Yucca fault system, and related smaller faults (Phelps and McKee, 1999). The gravity data indicate that the Yucca Flat basin is deepest at its south end where it abuts the dividing ridge with Frenchman Flat to the south (Dockery, 1984), although few drill holes penetrate the entire thickness of the Tertiary section in this area. Yucca Flat is enclosed at its north end, where anticlinally folded Late Proterozoic rocks in the Halfpint Range converge with Paleozoic siliciclastic rocks near the south end of the Belted Range (Hinrichs, 1968).

Interpretation of Drill Hole Data

Subsurface lithologic information was extracted from data tabulations from the numerous drill holes in Yucca Flat. For most of the holes, no cuttings are preserved for the alluvial fill, and the lithologic descriptions represent the primary data source. Covington and Berger (1997) produced an extensive compilation of lithologic descriptions from depth-specific sample intervals of core and cuttings samples collected from more than 890 drill holes located



Base from U.S. Geological Survey digital data, 1:250,000; Universal Transverse Mercator projection, Zone 11. Shaded-relief base from 1:250,000-scale Digital Elevation Model; sun illumination from northwest at 30° above horizon



EXPLANATION

- Highways
- County boundary
- - - Nevada Test Site boundary

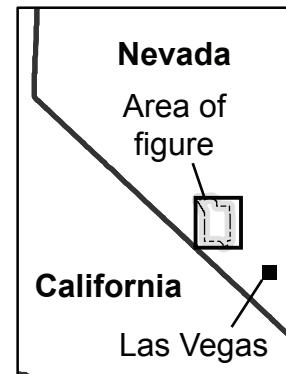
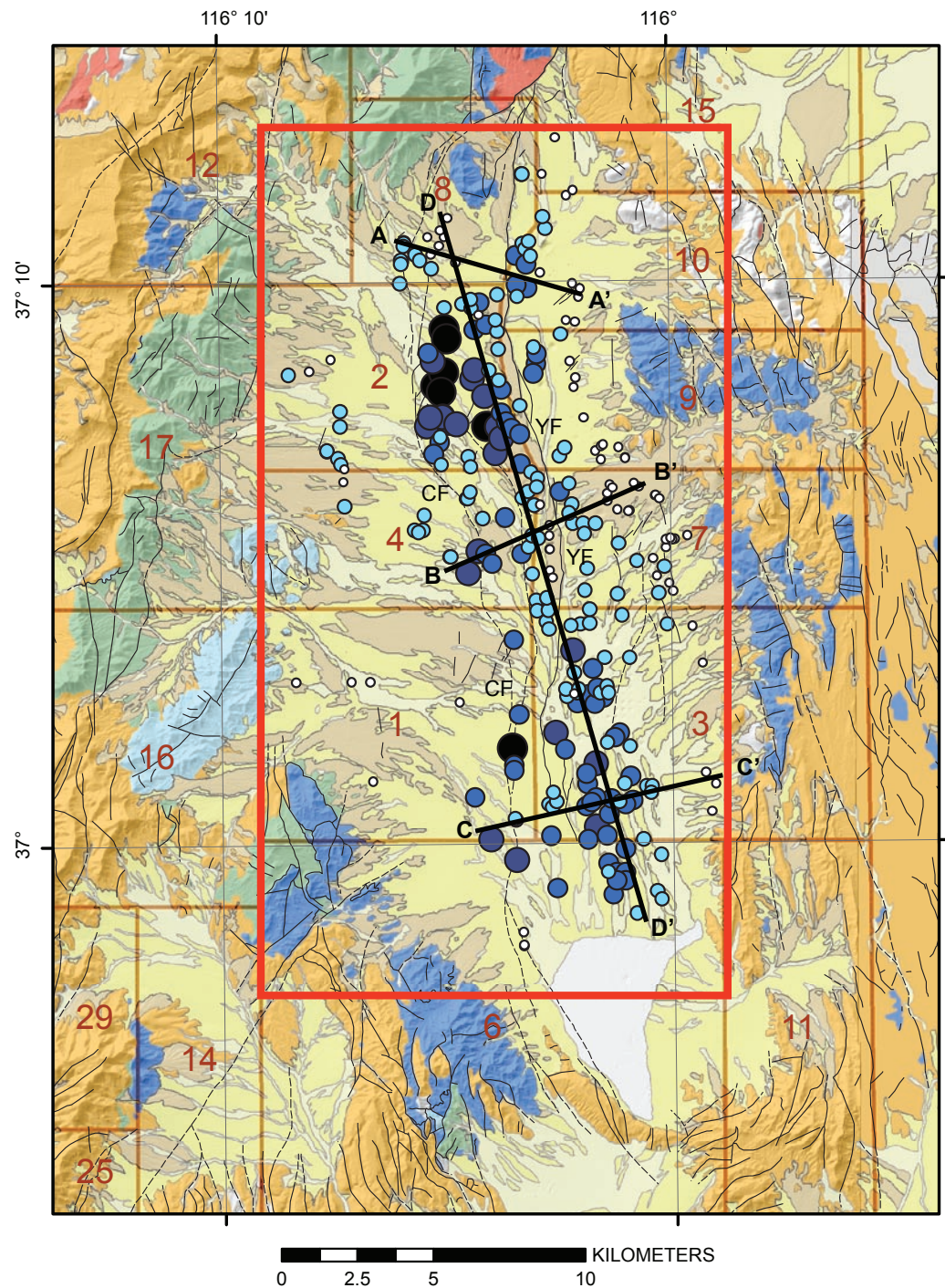


Figure 1. Index map of Yucca Flat and the Nevada Test Site, Nevada.



EXPLANATION

- Geologic Map Symbols**
(modified from Slate and others, 2000)
- Young alluvial deposits
 - Undivided alluvial deposits
 - Intermediate alluvial deposits
 - Playa deposits
 - Tertiary volcanic rocks
 - Granitic rocks
 - Pennsylvanian carbonate rocks
 - Mississippian and Devonian rocks
 - Cambrian to Devonian carbonate rocks
- Fault mapped in bedrock
- - - Fault, concealed
CF, Carpetbag fault
YF, Yucca fault
- Drill holes used in this study**
Showing thickness of alluvium penetrated, in feet
- 50 - 500
 - 500 - 1,000
 - 1,000 - 1,500
 - 1,500 - 2,000
 - 2,000 - 2,290
- Outer boundary of 3D lithology model
- A — A'** Line of section
- 3** NTS area boundaries

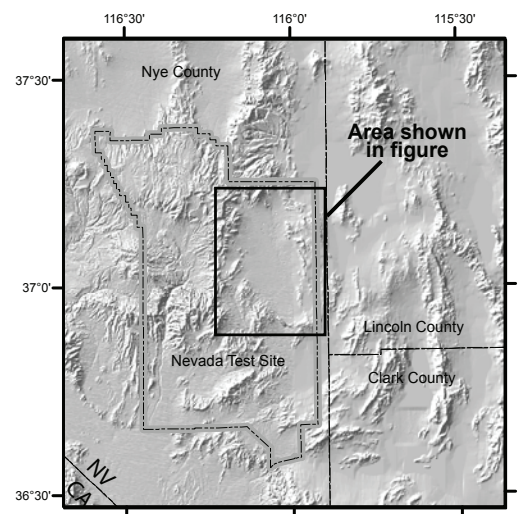


Figure 2. Geologic map of Yucca Flat showing drill hole locations, cross section lines, and boundary of 3D lithology model.

in Yucca Flat. These data, and additional data from more recently drilled holes, have been compiled in recent years in digital form by USGS scientists (David Wood, written commun., 2003) for incorporation in the Ground-Water Site Inventory (GWSD) subsystem of the USGS National Water Information System (NWIS). The digital compilation of the drill hole data is available at <http://nevada.usgs.gov/mercury/core.html>. For the purposes of this report, the many hundreds of drill hole lithologic logs from Yucca Flat were culled to a total of 285 holes. The holes from Yucca Flat that were used represented those that contained the greatest amount of detail in the description of each interval, had a large number of downhole intervals described (as opposed to a single long interval of “sand and gravel” or “alluvium”), were representative of downhole lithology of nearby holes, and represented a distribution of holes that were not clustered, but approximately equally distributed over the Yucca Flat area (fig. 2). The thickness of alluvium penetrated by the selected drill holes ranged from less than 100 ft to more than 3,000 ft (fig. 2). The thickness of alluvial fill for the 285 selected holes varies from about 1,000 ft on the alluvial fans near the basin margins to as much as 2,300 ft for holes drilled along the axis of the basin (fig. 2). The 285 holes selected contained a total of 1,430 lithologic intervals, or an average of just over 5 described lithologic intervals per hole.

The original driller’s descriptions were simplified to an internally consistent set of 12 general lithologic classes (table 1); lithologic classes were similar to, but fewer in number than, those generated from recent stratigraphic studies of Cenozoic basins to the south of the NTS (Sweetkind and others, 2001;

Taylor and Sweetkind, 2005). Lithologic descriptions show that subsurface lithology within the alluvial basin fill is dominated by generally coarse grained sediments; of the 1,430 total described lithologic intervals, 1,328 intervals, or 93 percent, were some combination of sand and gravel. However, the lithologic descriptions were sufficiently detailed to permit distinguishing cobble and boulder beds from three lithologic classes which contain differing proportions of gravel and sand (table 1). The relative proportions of sand and gravel in these lithologic classes differ from those in standard usage (Folk, 1954), but the proportions used gave a satisfactory distinction between intervals that were dominated by gravel, those where sand and gravel were subequal, and those where sand was more abundant than gravel (table 1). Of lesser total abundance, but important locally, are intervals of nearly uniform sand, in places accompanied by a very small amount of gravel or individual pebbles. Lithologic descriptions of the sand were often sufficiently detailed to distinguish coarse and fine sand (table 1). Intervals described as containing silt were assigned to the lithologic class fine sand.

The drill hole locations were intersected in a GIS with the surficial geologic units in Yucca Flat (Slate and others, 2000), in hopes of being able to correlate mapped surficial units with subsurface lithologic descriptions. No definitive correlation between mapped units and drill hole lithologic descriptions was apparent, in large part because surficial units defined by Slate and others (2000) are mapped on the basis of deposit age and degree of induration, rather than strictly by lithologic type or grain size.

Table 1. Generalized lithologic classes based on drill hole descriptions.

Lithology class	Drill hole intervals	Rationale for classification
Gravel	63	Used for cobble beds, boulder beds, and where gravel was reported as having no fine-grained matrix.
Sandy gravel	229	Used for sand and gravel mixtures where gravel, clasts, or cobbles were 70% or more of the total.
Gravelly sand	341	Used for sand and gravel mixtures where gravel, clasts, or cobbles were subequal in abundance to the sand component; used where sand was 30% to 70% of the total.
Sand and minor gravel	360	Used for sand and gravel mixtures where the sand component was much more abundant than gravel, clasts, or cobbles; typically sand was 70-80% of the total, often greater than 90% of the total.
Sand, clay and gravel	42	Used for sand and gravel mixtures where silt or clay was identified as an additional important component. Typically these intervals are dominated by the sand-silt component with relatively minor gravels.
Coarse sand	263	Used for sand sizes greater than 0.5 mm, typically greater than 1 mm, often with scattered pebbles up to 1 cm.
Fine sand	44	Used for sand sizes less than 0.5 mm, rare pebbles.
Clay and sand	12	Used for intervals where sands are interbedded with clay layers. Typically explicitly interpreted in the description as alluvial material interbedded with playa deposits.
Clay	2	Used for intervals described as almost completely clay. Typically explicitly interpreted in the description as playa deposit.
Clay and limestone	4	Used for intervals where clays are interbedded with thin-bedded limestone. Typically explicitly interpreted in the description as playa deposits.
Basalt	3	Used for intervals where basalt was specifically identified.
Nonwelded tuff	9	Used for intervals where nonwelded tuff was specifically identified.
No data	39	Intervals with no useful lithologic information, such as “alluvium”.

The level of subsurface detail present in the drill hole data and the interpreted lithologic classes are portrayed in four cross sections that incorporate drill hole data along three generally east-west sections (fig. 3) and one generally north-south section (fig. 4). The drill hole data on the cross sections are portrayed using general lithologic classes that were derived from the original descriptions (table 1). Drill hole data within 3,281 ft on either side of the section line are projected onto the line of section, such that each cross section integrates drill hole data within a 6,563 ft-wide swath. Portrayal of numerous drill holes on a single section is a relatively common way to look for overall patterns in subsurface lithologic data (Thorleifson and Pyne, 2004).

Cross section A-A' (fig. 3) at the far north end of Yucca Flat portrays a general progression from coarse, gravelly alluvium high on the alluvial fan on the west side of the basin to finer grained sediments at the basin axis. The coarse-grained alluvium is typically sandy gravel, with pebble to cobble-sized clasts. Many of the holes drilled on the fan are between 750 and 1,000 ft deep, yet the alluvial section is described in only one or two intervals. The progressive fining toward the basin center is represented by an increase in the proportion of sand and clay and represents the effects of progressive mechanical abrasion, diminishing depositional energy, and perhaps a greater contribution of fine-grained detritus weathering from volcanic rocks present to the north and east of Yucca Flat (fig. 2). The far east end of the cross section portrays an increased quantity of gravel as the fan on the east side of the basin is encountered.

Cross section B-B' (fig. 3) portrays lithologic data from drill holes along a northeast-southwest line near the center of the Yucca Flat basin. The drill holes on the east end of the section are shallow and dominated by gravelly sand from a very large alluvial fan that dominates this portion of the east side of the basin (fig. 2). The lithology reported in holes drilled on this fan varies from hole to hole and may represent lithologic variability within the fan, such as individual channels. Drill holes near the center of the section are at the toe of the fan and are dominated by coarse sand or sand with minor gravel, again showing a progressive fining trend toward the basin axis. Wells on the west side of the cross section are dominated by relatively coarse grained sediment; these sediments probably have their source in alluvial fans on the west side of the basin but may also show the influence of a large alluvial channel that originates in the northwestern part of Yucca Flat.

Cross section C-C' (fig. 3) portrays lithologic data from drill holes along an east-west line in the southern part of the Yucca Flat basin, north of the fine-grained sediments of the playa. The center part of section C-C' is characterized by drill holes that have a consistent lithology dominated by coarse and fine alluvial sand and sand with minor associated gravels. These fine, relatively uniform sands in the south-central portion of the valley must be the result of continued diminishing depositional energy within the alluvial system and also the result of particularly stable conditions of deposition over a relatively long period of time. On the west side of the section is a drill hole that contains one of the rare basalt flows that lie within the young alluvial fill.

Cross section D-D' (fig. 4) portrays lithologic data from drill holes along a generally north-south profile along the axis of the basin. The north half of the profile includes wells that lie to the west of the Yucca fault; the south half of the profile includes wells that lie to the east of the Yucca fault (fig. 4). Many of the holes possess only one or two described lithologic intervals; yet, when the data from multiple drill holes are taken as a whole, broad lithologic trends may be confidently established. The section displays a broad southward fining from gravel-dominated drill holes in the northern third of the section, to generally more sand-dominated intervals in the central and southern parts of the section. The north-to-south variation in lithology is complicated by the section's crossing numerous individual alluvial fans and channels. The lithologically homogeneous area of sand portrayed in the center of section C-C' is evident on this section as well, where a number of holes are dominated by coarse and fine sand and sand with minor gravel. The far south end of the section includes intervals of thinly bedded, fine-grained clay and limestone that represent the interfingering of the alluvial basin fill with the northernmost extent of playa deposits at the south end of the basin.

Figure 5 portrays three views of the interpreted lithologic data from the selected drill holes located in 3D space. In these views, the location and drilled depth of drill holes are represented as vertical cylinders; the cylinder diameter and color is varied for separate lithologic classes. In these figures, only the upper portions of the holes are shown in order to emphasize the young alluvium; deeper portions of holes that intercepted Cenozoic volcanic rocks and Paleozoic rocks are not shown. Drill holes are hung at their surface elevations; land surface is transparent so that the drill holes appear to hang in space. The shortened perspective of the east and south views makes holes collared at higher elevations on the west and north side of the basin appear anomalously high relative to the majority of drill holes. These views emphasize the gravel-dominated sections at the northwest end of the basin and the broad southward fining trend to generally more sand-dominated intervals in the central and southern parts of the basin. Intervals dominated by clay, clay and sand, or clay and limestone are only present in the southernmost drill holes in the study region (fig. 5).

3D Lithologic Modeling

Interpreted drill hole lithologic data were numerically interpolated between drill holes using a cell-based interpolation called horizontal lithoblending within the RockWorks 2004 software package (Rockware©, 2004). Grid nodes are sequentially assigned a value that corresponds to the interpreted lithologic classes based on the proximity to each drill hole. The interpolation routine looks outward horizontally from each drill hole in search circles of ever-increasing diameter. The algorithm assigns the lithology values from the drill hole data in each vertical interval to cells immediately surrounding each drill hole. Then the interpolation moves out by a cell, and assigns the next "circle" of cells a lithology value for each

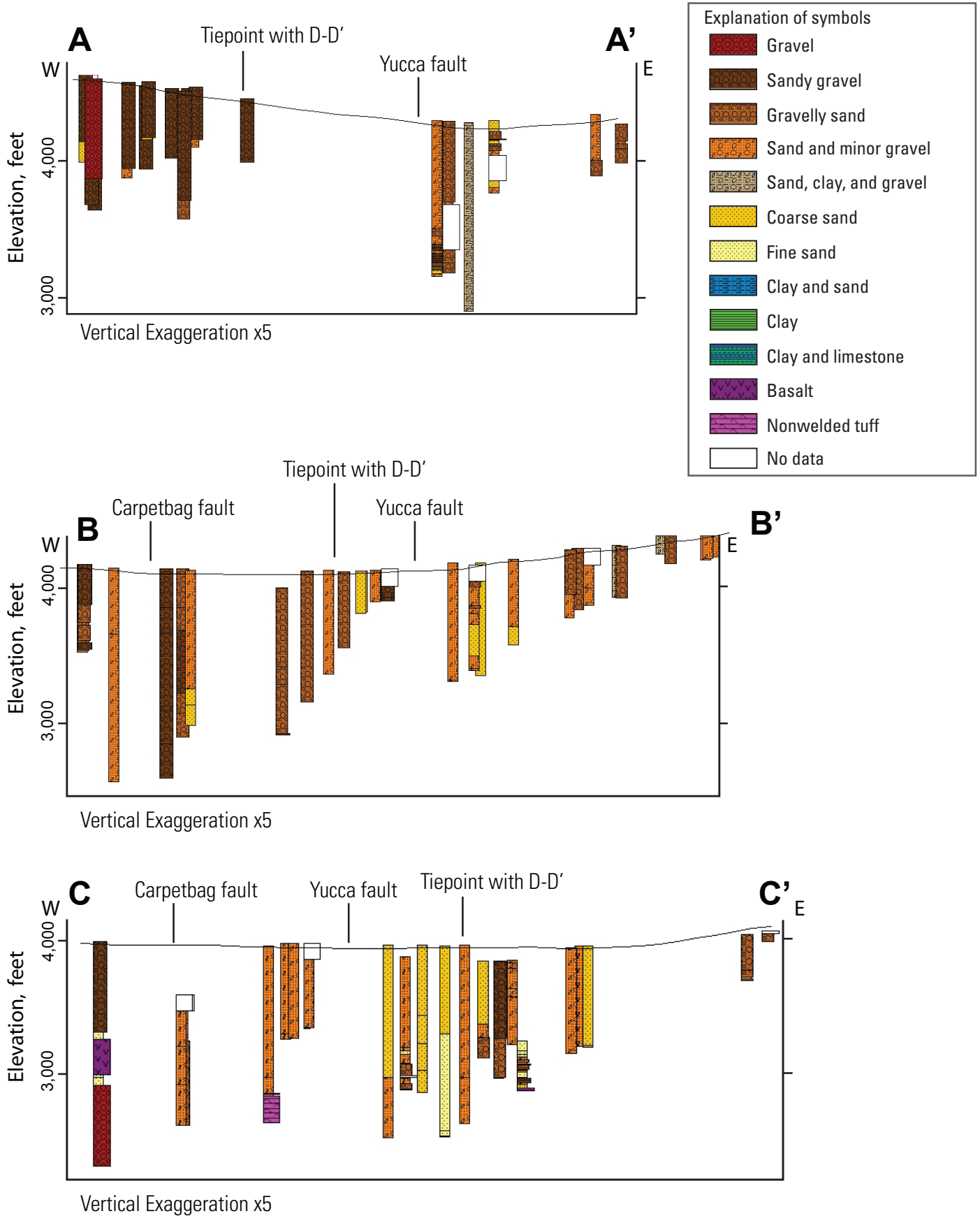


Figure 3. East-west cross sections (location, fig. 2) showing interpreted drill hole lithologic data.

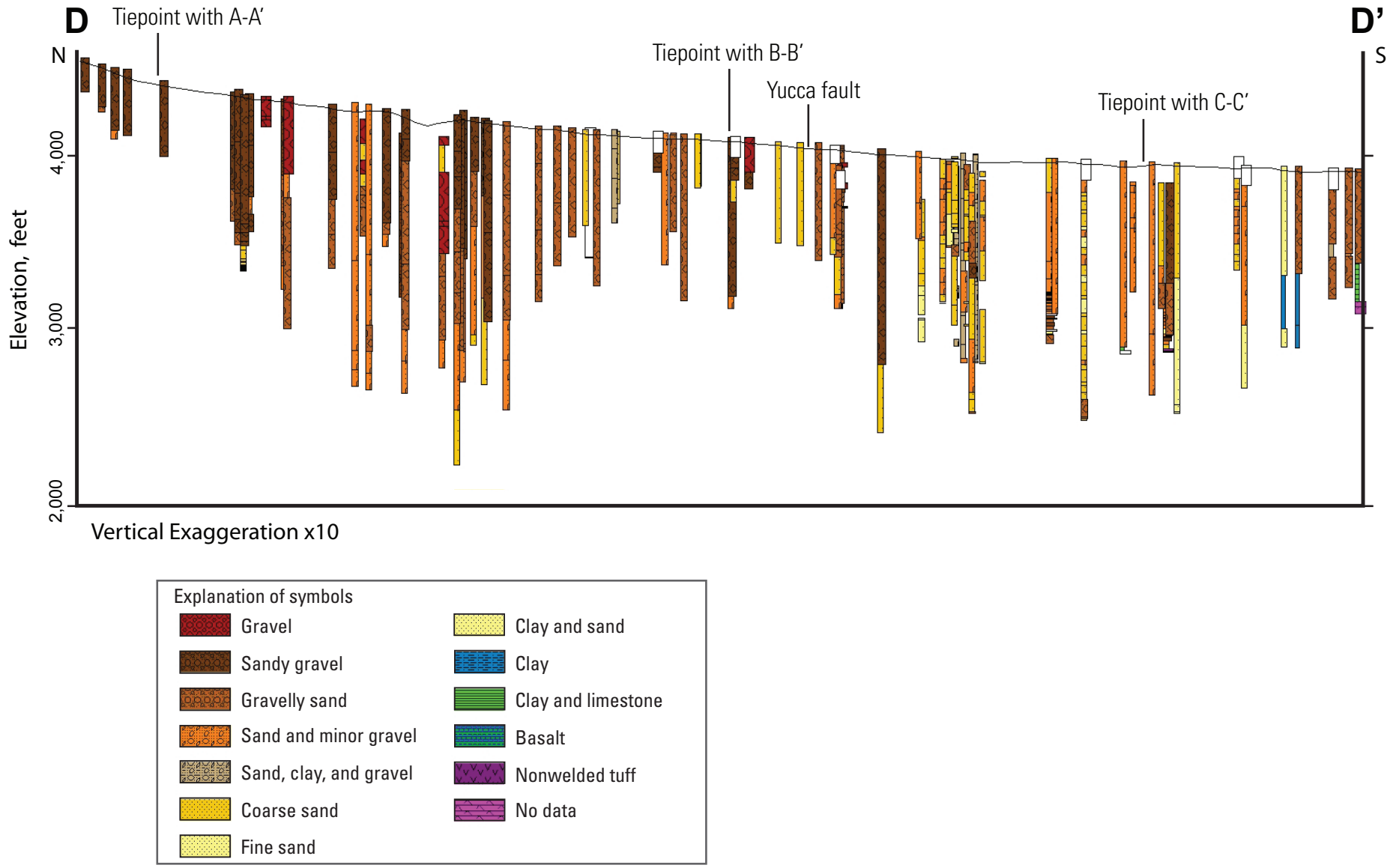
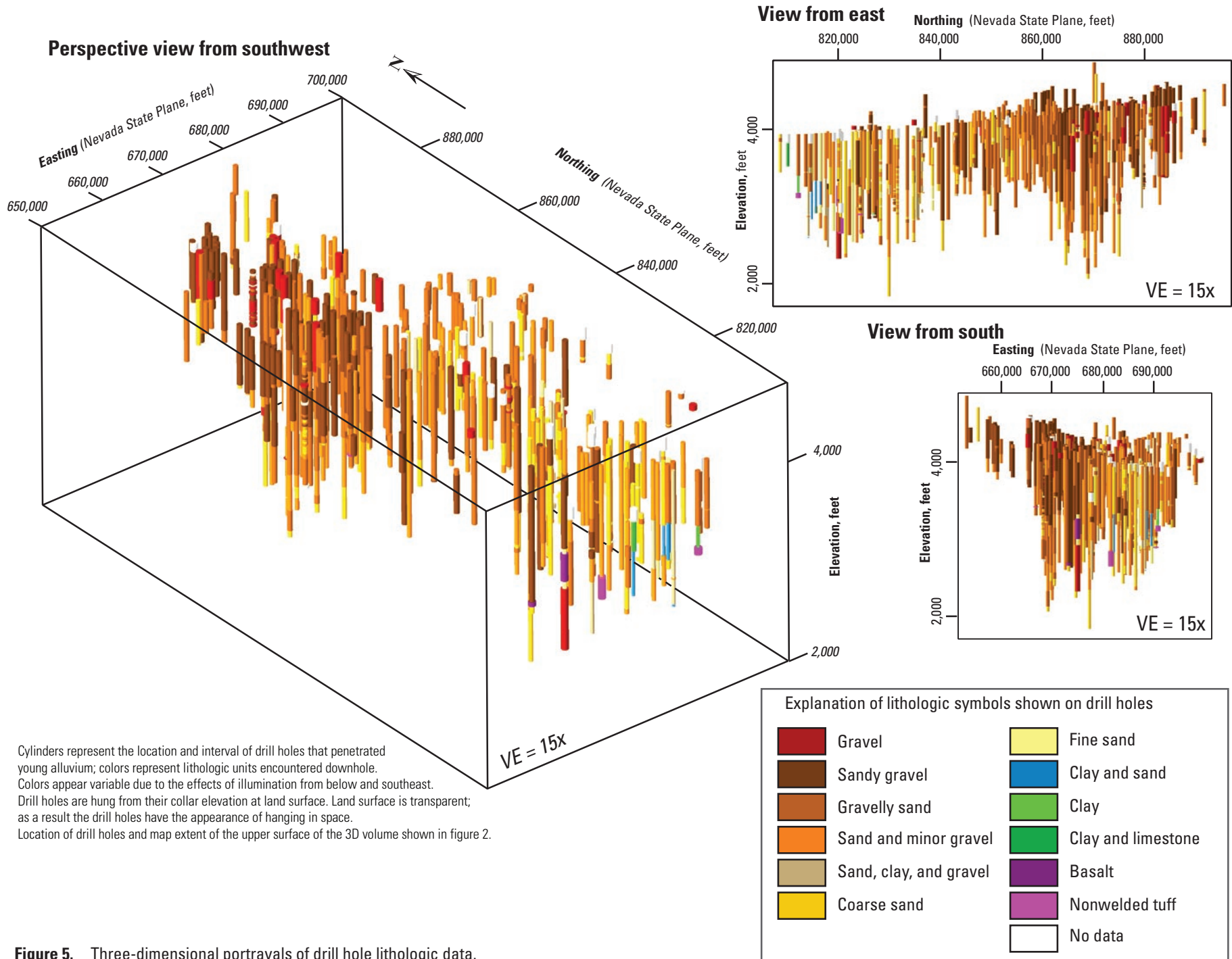


Figure 4. North-south cross section (location, fig. 2) showing interpreted drill hole lithologic data.



Cylinders represent the location and interval of drill holes that penetrated young alluvium; colors represent lithologic units encountered downhole. Colors appear variable due to the effects of illumination from below and southeast. Drill holes are hung from their collar elevation at land surface. Land surface is transparent; as a result the drill holes have the appearance of hanging in space. Location of drill holes and map extent of the upper surface of the 3D volume shown in figure 2.

Figure 5. Three-dimensional portrayals of drill hole lithologic data.

vertical interval. The interpolation continues in this manner until the program encounters a cell that is already assigned a lithology (presumably interpolating toward it from an adjacent drill hole), in which case it skips the node assignment step. Cell dimensions for the 3D interpolation were 3,281 ft in the horizontal dimensions and 33 ft in the vertical dimension. We trimmed the resulting model at the top by a grid representing land surface elevations and at the base by a grid that represents the smoothed base of alluvium encountered in the selected drill holes. Because there was no information regarding stratal dip in the alluvial section, strata were assumed to be horizontal in this 3D interpolation. The assumption of horizontality is likely more valid for the younger, upper parts of the basin fill than for the deeper parts of the alluvial section.

The strength of this method is that the interpolated data in the resulting 3D grid have the appearance of stratigraphic units, with aspect ratios that emphasize the horizontal dimension over the vertical. Also, the method preserves the local variability of the lithology encountered in each drill hole with no smoothing or averaging. Thus, where data are abundant, local lithologic variability is incorporated. One limitation of this numerical interpolation is the sensitivity to the distribution of the data, where values from an isolated drill hole tend to extrapolate outward to fill an inordinate amount of the model area. The effect is particularly noticeable where a small number of deep drill holes are interspersed with shallower holes; data from the deepest drill holes tend to over-extrapolate over the entire model area. We mitigated this effect by a trimming of the base of the model, using a grid that represents the smoothed base of alluvium encountered in the selected drill holes. Faults were not explicitly included in the creation of these solid models, due to the limitations of the software package used. However, the interpolation methods used here produce lithologic variations that approximate fault truncations of lithologic units where data density is high.

Six vertical cross sections (fig. 6) cut through the 3D model display the results of the numerical interpolation as a fence diagram that highlights lithologic variations within the basin fill. In the fence diagram, the cross sections are colored according to the interpreted geologic units (fig. 6); land surface is transparent so that the sections appear to hang in space. The upper surfaces of the six sections are clipped at the topographic surface using a digital elevation model; the base of the model is clipped using a generalized surface that encloses the drilled intervals of alluvial fill for the drill holes used in this study.

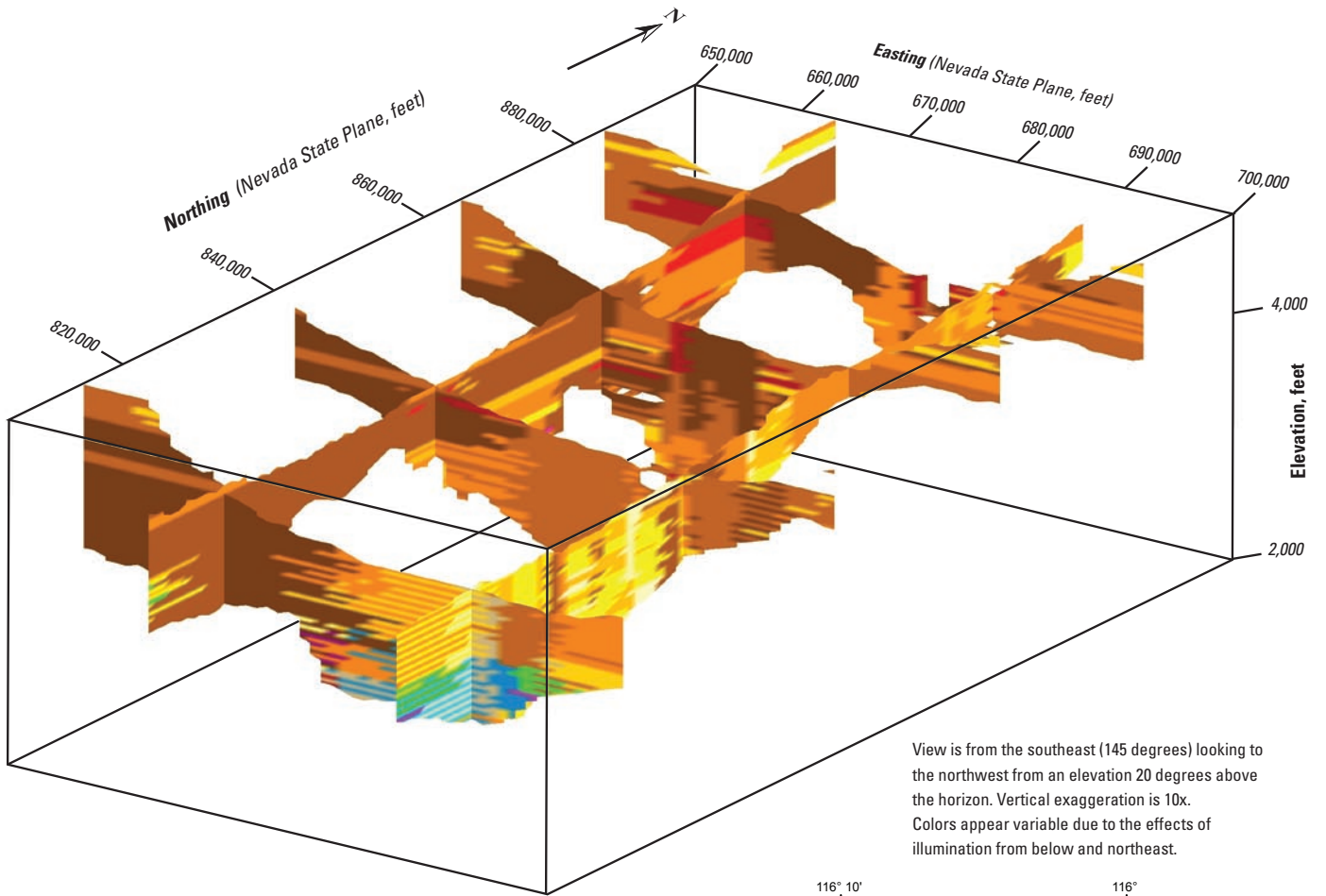
The alluvial section on the margins of the basin is represented by relatively thin sections that are dominated by sandy gravel, especially on the west and north, and gravelly sand on the east side of the basin. Deposition of these coarser grained rocks is largely on a series of coalescing alluvial fans which form poorly sorted to moderately sorted deposits in which particle size may range from clay to boulders. Based on surficial mapping (Slate and others, 2000), the lithologic units within these fan complexes tend to be discontinuous and interfingering. The limited number of described lithologic intervals in drill holes that penetrate these fans reveal only hints of the

actual lithologic variability. The alluvial fans tend to have a gradational decrease in grain size from proximal to distal fan where they interfinger with sandier units toward the basin axis. The section at 840,000 ft (fig. 6) displays this trend, with sandy gravels on the east and west side of the basin grading into gravelly sand along the basin axis. There is no clear overall change in grain size distribution with depth, although there is typically a change in clast lithology. Drill hole lithologic logs typically report a predominance of Paleozoic rock clasts in the upper parts of the alluvial sections, whereas volcanic rock clasts predominate lower in the alluvial section. Changes in clast lithology are probably a reflection of changes in the available source rock types as they are exposed to erosion in the surrounding uplands over time.

Several large, active alluvial channels are present around the margin of the basin, the most prominent of which is a surface channel as much as a mile wide that drains the highlands of Rainier Mesa in NTS area 12 in the northwest corner of the Yucca Flat basin (figs. 1, 2). A similar pattern of gravel-dominated sediment occurs in the subsurface in the northwestern part of the model (fig. 6). A well-defined gravel interval extends southeast and then south and brings gravel and sandy gravel into the axis of the basin as far south as 860,000 ft (fig. 6). Drill hole data from this subsurface gravel interval consist of coarse, boulder gravels with a mixture of Paleozoic and volcanic rock clasts. Correspondence of the subsurface gravel interval with the current surface drainage suggests that this drainage system is relatively long-lived.

A uniformly sandy section is present in the southeastern part of the modeled area (fig. 6). Drill hole data from this area are dominated by coarse and fine sand with rare occurrences of pebbles. Limited coring through this sandy interval (A.T. Fernald, written commun., 1983) reveals subhorizontal bedding and suggests a long-lived stable depositional environment to allow the accumulation of this thick interval of sand. Farther to the south, alluvial sediments interfinger with clay-dominated intervals (fig. 6) that represent the northern extent of sediment associated with the playa at the south end of the basin.

The modeled 3D subsurface distribution of each lithologic class is shown in figure 7. In these perspective views, only a single lithologic class is portrayed on each view, so the data appear to float in space. The basin fill is dominated by sandy gravel (fig. 7B) and gravelly sand (fig. 7C), especially at the basin margins. The gravel channel in the northwestern part of the basin is especially evident when the gravel class is viewed separately (fig. 7A); deeper gravel accumulations may be the result of older channel systems. Finer grained units including sand and minor gravel (fig. 7D) and sand, clay, and gravel (fig. 7G) tend to occur along the axis of the Yucca Flat basin. The predominance of the uniformly sandy section in the southeastern part of the model is well displayed by the interpolated lithologic data (fig. 7E). Clay-dominated sections occur exclusively at the south end of the model and represent the interfingering of playa sediments with the alluvial section. Rare basalts occur within the alluvial section (fig. 7H); nonwelded tuffs include airfall units near the base of the alluvial section.



Explanation of symbols shown on sections

- Gravel
- Sandy gravel
- Gravelly sand
- Sand and minor gravel
- Sand, clay, and gravel
- Coarse sand
- Fine sand
- Clay and sand
- Clay
- Clay and limestone
- Basalt
- Nonwelded tuff
- No data

Explanation of symbols shown on geologic index map (modified from Slate and others, 2000)

- Young alluvial deposits
- Undivided alluvial deposits
- Intermediate alluvial deposits
- Playa deposits
- Tertiary volcanic rocks
- Granitic rocks and gabbro dikes
- Pennsylvanian carbonate rocks
- Mississippian and Devonian rocks
- Cambrian to Devonian carbonate rocks
- 8 NTS area boundaries
- Outer boundary of 3D lithology model
- Location of vertical section cut through 3D lithology model

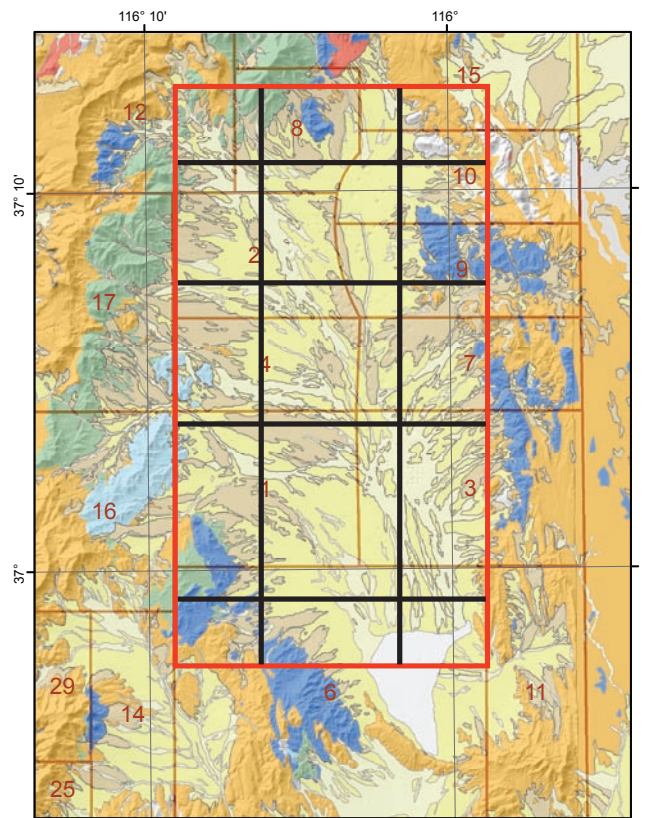


Figure 6. Perspective view of vertical sections cut through 3D lithology model of Yucca Flat.

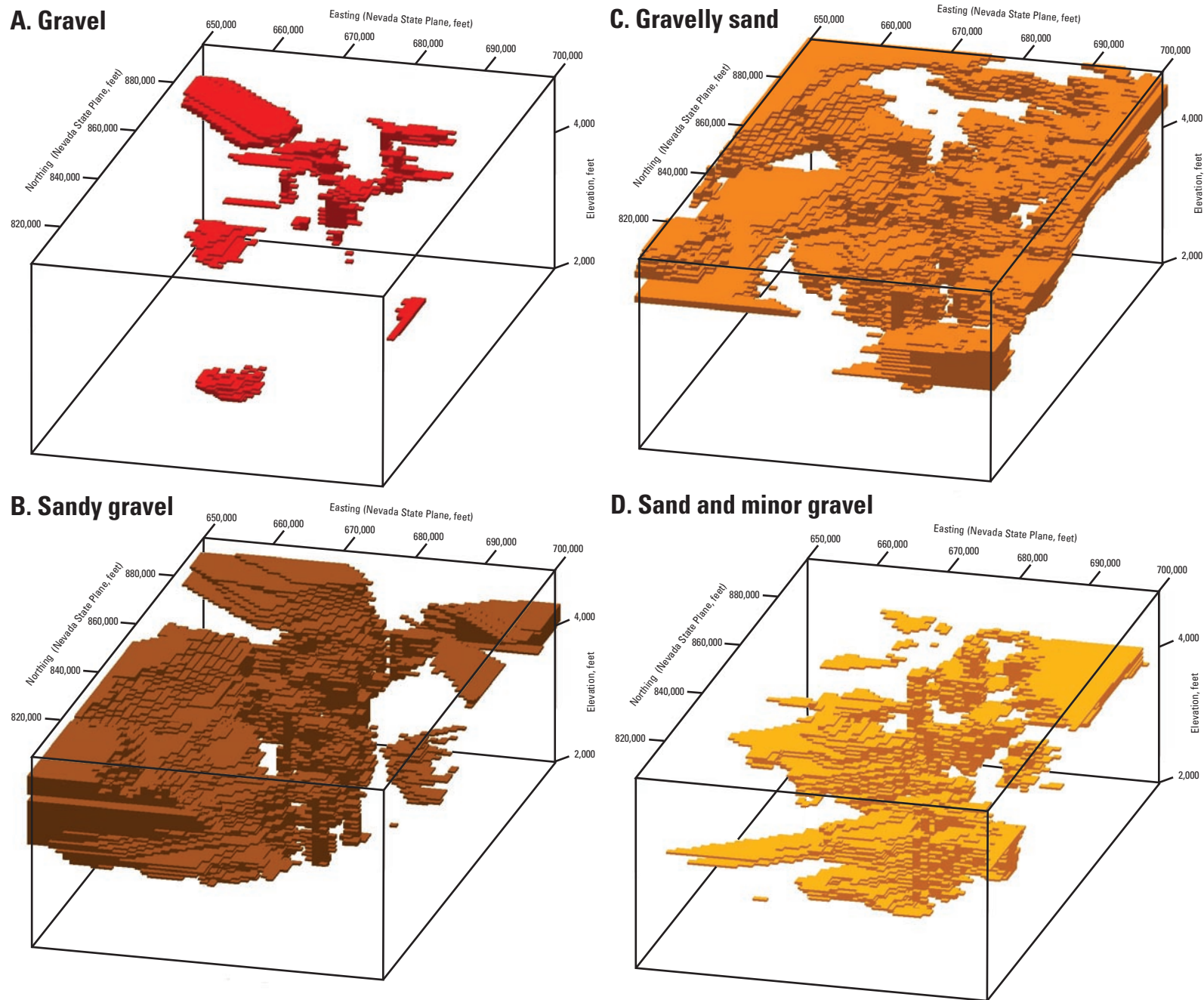
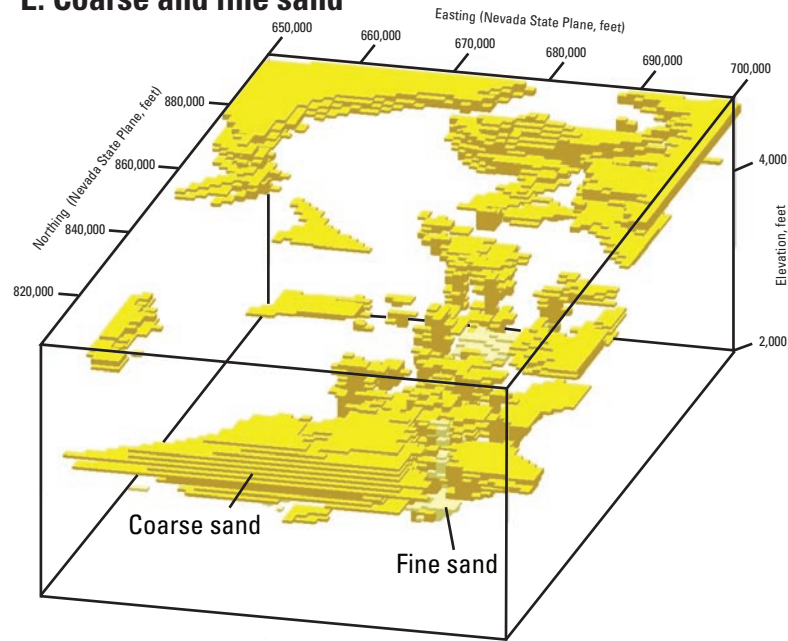


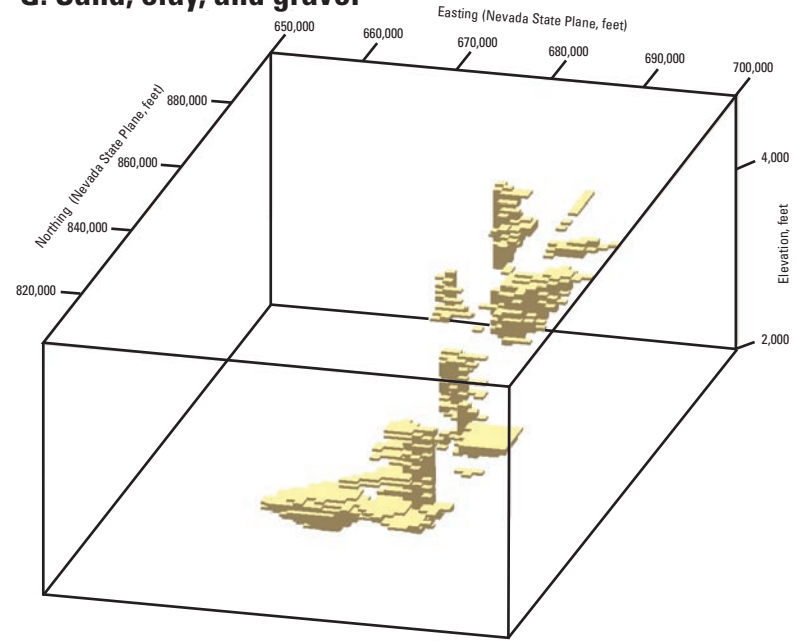
Figure 7. Perspective views of 3D lithologic model showing distribution of lithologic classes.

All views are from the southeast (145 degrees) looking to the northwest from an elevation 20 degrees above the horizon. Vertical exaggeration is 10x. Colors appear variable due to the effects of illumination from above and northeast.

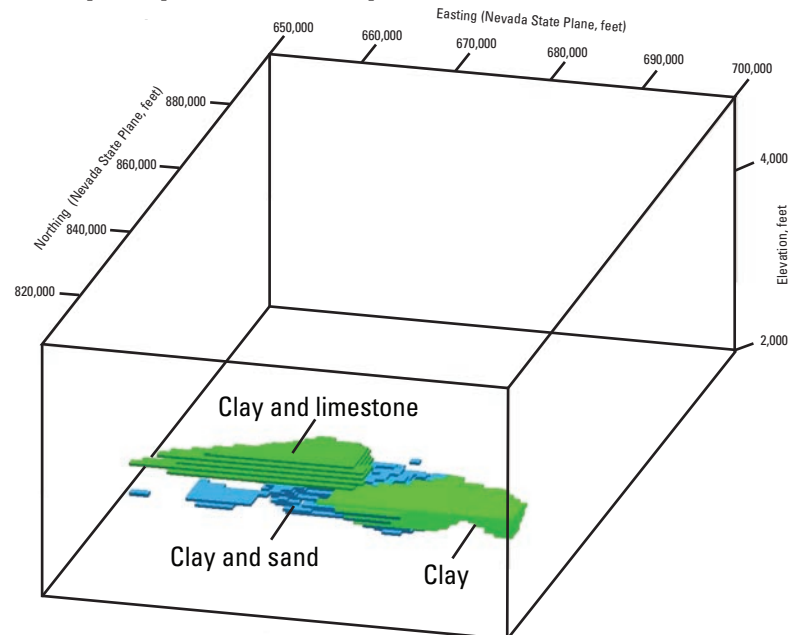
E. Coarse and fine sand



G. Sand, clay, and gravel



F. Clay; clay and sand; clay and limestone



H. Basalt; nonwelded tuff

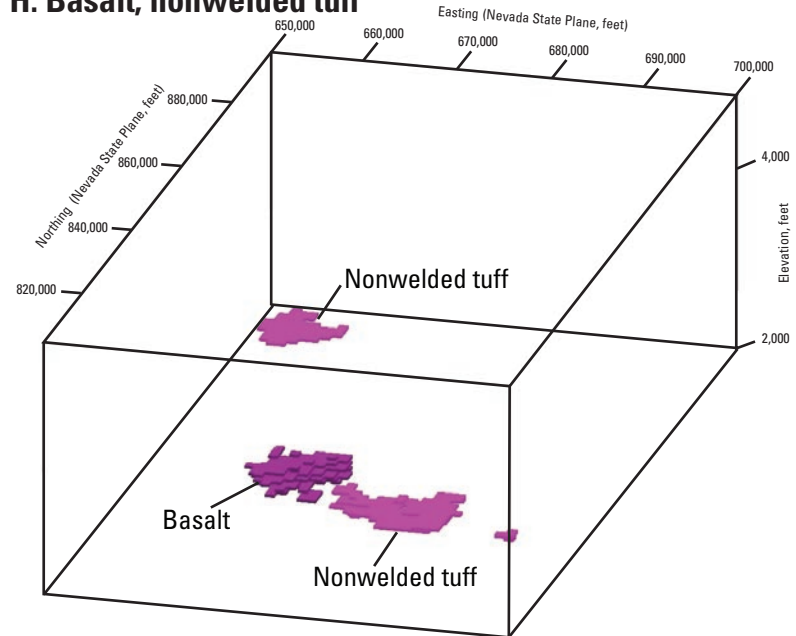


Figure 7—Continued. Perspective views of 3D lithologic model showing distribution of lithologic classes.

All views are from the southeast (145 degrees) looking to the northwest from an elevation 20 degrees above the horizon. Vertical exaggeration is 10x. Colors appear variable due to the effects of illumination from above and northeast.

Multiple vertical cross sections (fig. 8) cut through the 3D model display the overall lithologic variations within the basin fill. In the fence diagram, the cross sections are colored according to the interpreted geologic units (fig. 8); land surface is transparent so that the sections appear to hang in space. The upper surface of the model is clipped at the topographic surface using a digital elevation model; the base of the model is clipped using a generalized surface that encloses the drilled intervals of alluvial fill for the drill holes used in this study. The model was not truncated at the elevation of pre-Cenozoic bedrock and is allowed to extrapolate into areas known to be underlain by pre-Cenozoic bedrock near the margins of the model (fig. 8). These sections clearly depict the sandy gravels associated with alluvial fan complexes along the west and north margins of the basin; the subsurface extent of coarse gravels associated with the channel in the northwest part of the model is also visible.

Summary

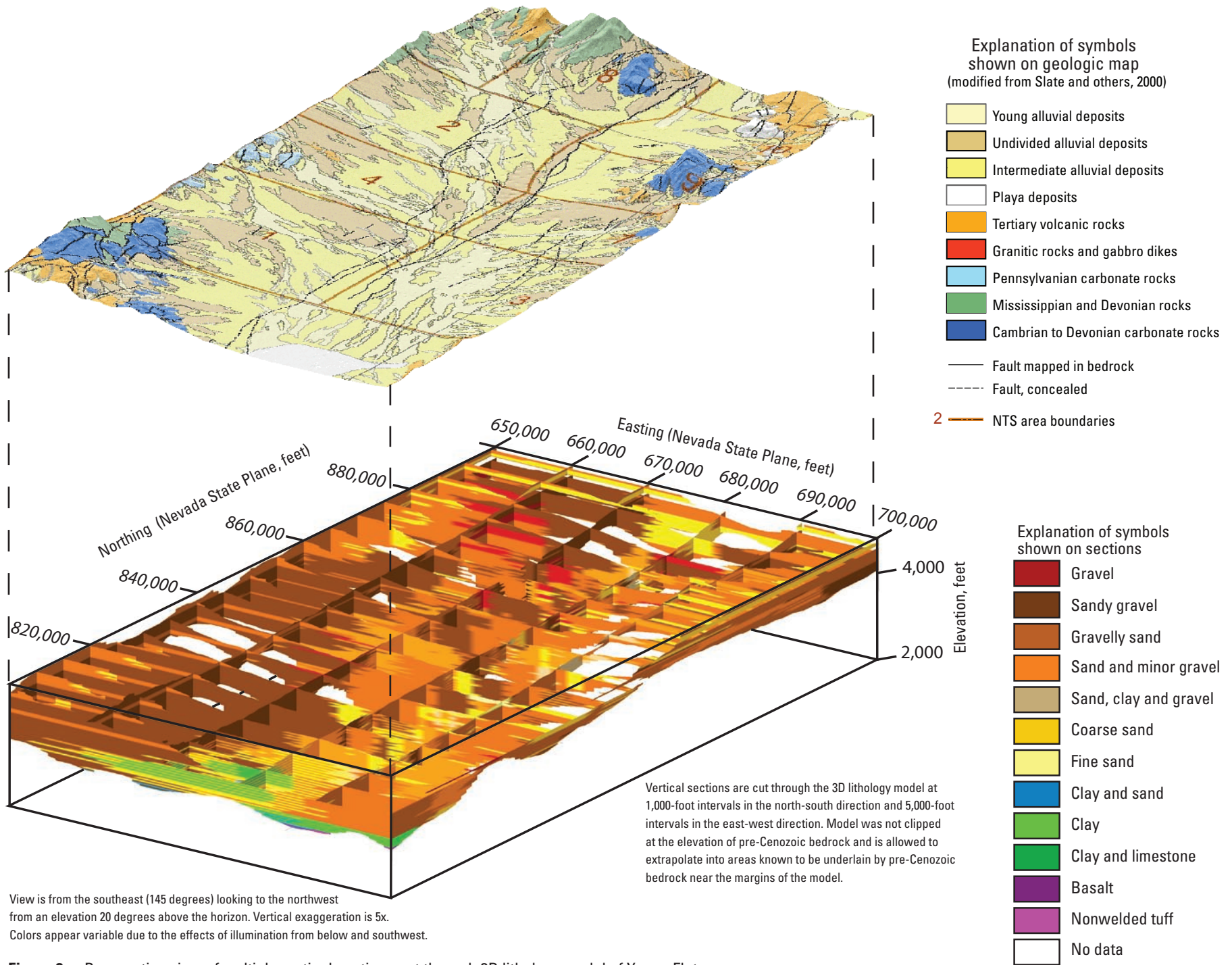
The purpose of this study is to develop an understanding of lateral and vertical lithologic variability of Neogene sediments that compose the shallow basin fill of Yucca Flat using a generalized classification of drill hole lithologic data. As shown in previous stratigraphic studies of Cenozoic basins to the south of the NTS, including the Amargosa Desert Basin (Sweetkind and others, 2001; Taylor and Sweetkind, 2005) and the Pahump Valley (Sweetkind and others, 2003), careful classification of lithologic data from drill holes can reveal broad subsurface lithologic trends within the basin. In the Yucca Flat basin, subsurface trends in general mimic the distribution of

surficial deposits, suggesting that depositional environments within the basin have remained stable for some time.

Deterministic modeling of the limited number of drill holes used produces broad lithologic trends, but it does not capture the lithologic details of highly discontinuous alluvial fan and channel complexes. Additional detail could possibly be arrived at through the use of additional drill holes and a finer model grid. However, many of the drill holes are as much as 1,000 ft deep and may be described in only two or three distinct intervals, so some method of improving the vertical lithologic resolution is needed. Analysis of downhole geophysical logs might be of use in defining additional discrete intervals that could be based on inferred grain size or sorting characteristics. Alternatively, it may be possible to use a stochastic approach where the drill hole data are used as a guide to the subsurface variability (Weissmann and others, 1999). Such an approach could incorporate geologic process by evaluating the tendency of specific lithologic units to be adjacent to each other in specific geologic environments.

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Explanation of symbols shown on geologic map (modified from Slate and others, 2000)

- Young alluvial deposits
- Undivided alluvial deposits
- Intermediate alluvial deposits
- Playa deposits
- Tertiary volcanic rocks
- Granitic rocks and gabbro dikes
- Pennsylvanian carbonate rocks
- Mississippian and Devonian rocks
- Cambrian to Devonian carbonate rocks
- Fault mapped in bedrock
- Fault, concealed
- NTS area boundaries

Explanation of symbols shown on sections

- Gravel
- Sandy gravel
- Gravelly sand
- Sand and minor gravel
- Sand, clay and gravel
- Coarse sand
- Fine sand
- Clay and sand
- Clay
- Clay and limestone
- Basalt
- Nonwelded tuff
- No data

Vertical sections are cut through the 3D lithology model at 1,000-foot intervals in the north-south direction and 5,000-foot intervals in the east-west direction. Model was not clipped at the elevation of pre-Cenozoic bedrock and is allowed to extrapolate into areas known to be underlain by pre-Cenozoic bedrock near the margins of the model.

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