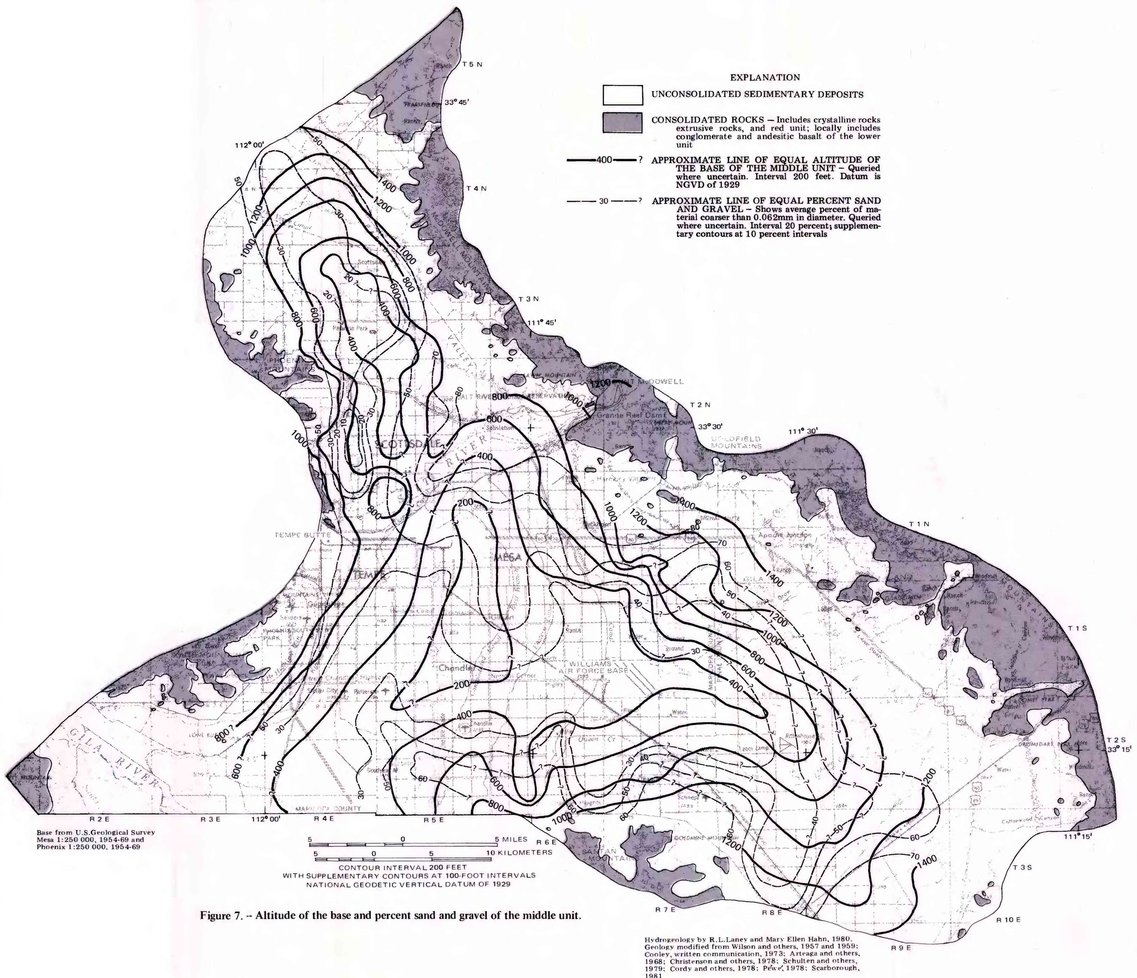

Figure 7. -- Altitude of the base and percent sand and gravel of the middle unit.

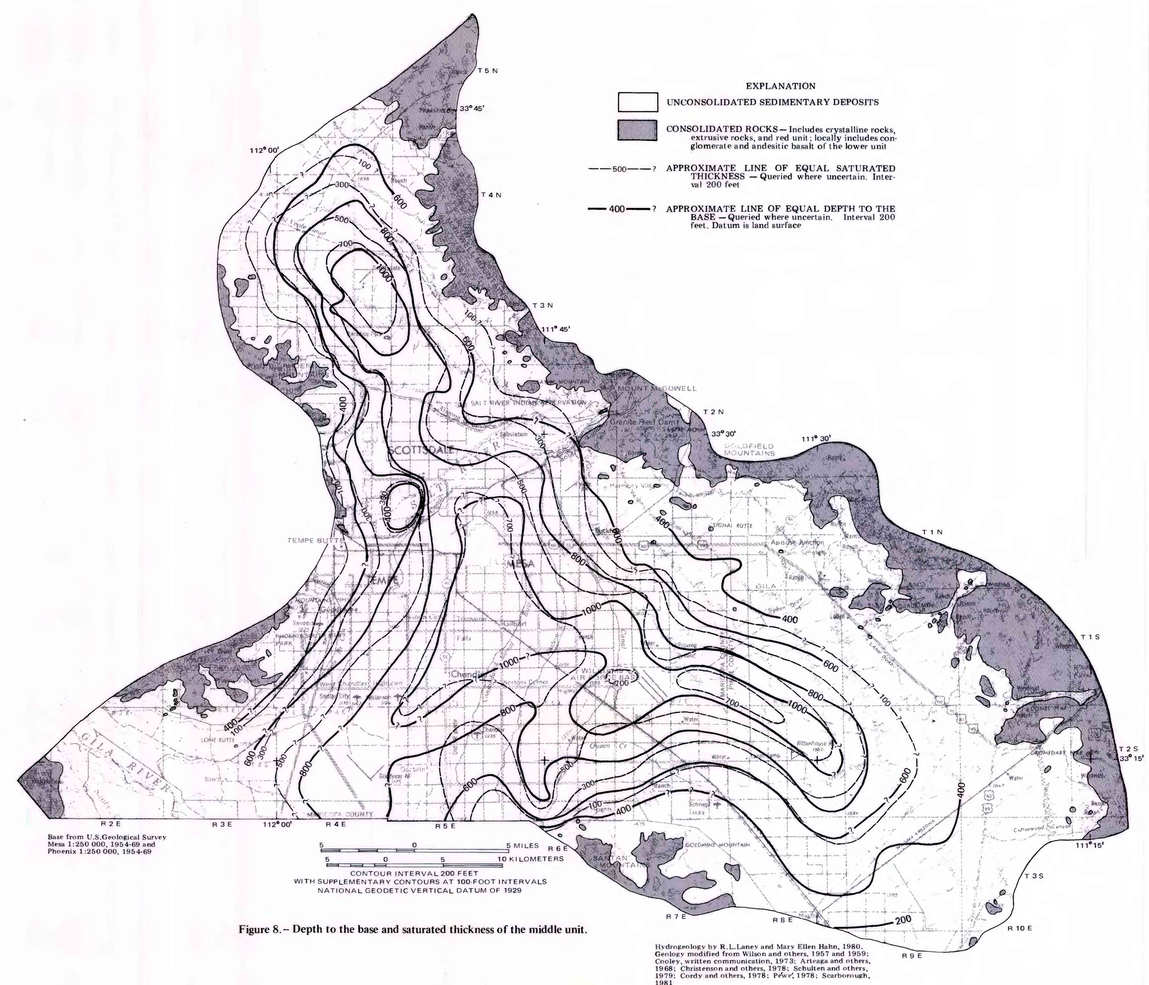

Figure 8.-- Depth to the base and saturated thickness of the middle unit.

Middle Unit

The middle unit includes playa, alluvial-fan, and fluvial deposits of silt, siltstone, and silty sand and gravel (figs. 6a-e). No surface exposures of the middle unit have been identified in the report area. Most of the unit is weakly consolidated, but moderately to well-cemented siltstone occurs locally. Calcium carbonate is disseminated throughout the deposits, although generally it is not visible as cement between grains. Deposits containing as much as 70 percent sand and gravel are present in the north-central part of the area, especially near the Salt River, and in the southeast (fig. 7). Near Scottsdale and in the central part of Paradise Valley, the deposits contain less than 30 percent sand and gravel.

The distribution of fine-grained sediments in the middle unit is, in a very general way, similar to that in the lower unit (figs. 4 and 7). The thickest and finest grained parts of each unit are located in the central parts of the basin near gravity lows. The distribution of sand and gravel is more irregular in the middle unit than in the lower unit because sediment sources were different. The drainage basin of the Salt River was a principal source of sediment for the middle unit, whereas material in the lower unit was derived largely from nearby mountains. An area of sand and gravel extends from the Salt River to several miles south of Mesa (fig. 7). Near Scottsdale the finest grained sediments are along the west margin of the basin. These sediments contain more than 90 percent silt and clay and virtually no gravel, and may be deposited against a fault surface of crystalline rocks (fig. 6b).

The middle unit ranges in thickness from less than 100 ft near the mountains to about 1,000 ft near Williams Air Force Base and is about 800 ft thick in central Paradise Valley. The sediment facies distribution and the location of the finest grained and thickest parts of the unit in the central areas of the basin near gravity lows indicate that a closed subsiding basin existed during deposition (figs. 3, 7, and 8).

Definition of the contact between the middle and lower units is critical to interpreting the paleogeography of the sediments in the basin and to separating units that have different water-bearing characteristics. In the center of the basin both units are composed of silt or finer material. Near the margins of the basin, however, the middle unit consists of silt to sand and gravel and the lower unit consists of sandy gravel to conglomerate. This relation is indicated by the distribution of sand and gravel in each unit (figs. 4 and 7). In the center of the basin where both units are fine grained, the following criteria were used to select the contact: (1) a downward decrease in grain size (increase in clay content) (fig. 6a, drill holes (D-1-6)27dad and (D-2-6) 10dcd2); (2) generally a marked decrease in resistivity on borehole electric logs at the same horizon as the textural change; (3) the presence of gypsiferous mudstone; the middle unit does not contain gypsum or anhydrite (fig. 6b, drill hole (A-3-4)25adc); and (4) a downward change in color from brown or light reddish-brown to a redder brown.

Near the margin of the basin, where the middle unit contains more silt and clay than the lower unit, the contact was placed near a marked downward increase in particle size (fig. 6b, drill holes (A-3-4)34cac to drill holes (A-3-4)36dcb), which is verified by an increase in resistivity on electric logs. The color may change from shades of light brown to grayish brown at the same horizon. Where both units are coarse grained, the contact could be identified on borehole geophysical logs by a downward increase in density and correlative decrease in porosity (fig. 6d, three drill holes at right end of section). In many areas, the clasts in the lower unit are more monolithologic than those in the middle unit. Generally, grain size decreases downward in the middle unit. However, the upper part of the unit contains a relatively greater amount of sand and gravel in the eastern part of the study area than in the northern part of the area. This particle size difference may be due to the presence of more active sediment source areas in the eastern part of the area, westward tilting of the basin, or other factors.

The middle unit is equivalent to, at least in part, or is in a similar stratigraphic position as the middle unit of Cooley in Arteaga and others (1968), the basin fill of Davidson (1961) and Cooley and Davidson (1963), the Pleistocene Fort Lowell Formation of Davidson (1973), and the upper alluvial unit of the U.S. Bureau of Reclamation (1977). No radiometric dates are available for the unit in the report area. However, about 600 ft of sedimentary deposits that contain 8- to 9-m.y.-old volcanic flows underlie the middle unit in T. 4 S., R. 9 E. just south of the boundary of the report area. On the basis of these radiometric dates, the unit is younger than 8 m.y.

Near Gillespie Dam on the Gila River, about 50 mi west of the report area (fig. 1), basalt flows overlie a gravel deposit (Lee and Bell, 1975). Multiple samples of the basalt flows have a mean age of 3.3 m.y. (Euge and others, 1978). The gravel under the basalt flows contains well-rounded quartzite clasts that may have been derived from quartzite deposits of Precambrian age in the present-day headwaters of the Salt River (John Bell, geologist, Nevada Bureau of Mines and Geology, oral commun., 1981). The age of the basalt flows and the gravel clast composition indicate that the Salt River was through-flowing as long ago as 3.3 m.y. ago. If the mean age is representative of the basalt directly overlying the river gravel, this is the only identified exposure of river gravel that indicates that the Salt River was a through-flowing stream at this early time. The middle unit was deposited in a closed basin prior to the development of through-flowing drainage on the Salt River and therefore is probably older than 3.3 m.y.

The sediments in the middle unit were derived from the Salt River and Queen Creek drainage areas, the drainage areas to the north of Paradise Valley, and the local mountains. The mountains bordering the basins were the principal sources of sediment during deposition of the lower part of the middle unit. The Salt River, Queen Creek, and the drainage area north of Paradise Valley were the principal sources of sediments during deposition of the upper part of the unit. The size of the principal drainages, especially that of the Salt River, may have increased during deposition of the middle unit, and could be the reason for an upward change of rock types.

Near Mesa the clasts in the upper part of the unit consist of quartzite, granite, intermediate to mafic volcanic rocks, and variable amounts of quartz, feldspar, gneiss, and schist. Near the Salt River, the quartzite clasts, which were derived from rocks in the headwaters of the Salt River in east-central Arizona, are rounded. Amounts of subangular clasts of granite, quartz, and feldspar generally increase with depth; they are the most abundant rock types in the lower part of the middle unit. Amounts of rounded quartzite and volcanic clasts decrease with increasing depth and quartzite clasts are rare in the lower part of the unit near the Salt River. This change in composition may be the result of an increase in the size of the drainage area of the Salt River by headward extension during deposition of the middle unit. The Salt River probably drained only the present-day lower Verde River area (fig. 1) at the start of the deposition of the middle unit (Cooley and Davidson, 1963, p. 30). The mountain ranges surrounding the lower Verde River are composed largely of granitic rocks (Wilson and others, 1957) and would have contributed sediment containing granitic clasts to the Salt River. Headward extension of the Salt River to the east continued during the deposition of the middle unit (Cooley and Davidson, 1963, p. 30). The river eventually reached its present-day headwaters in east-central Arizona, where quartzite is a common rock type (Wilson and others, 1959).

The clasts derived from the Queen Creek drainage are similar in both the middle and upper units and consist of varying proportions of felsic to intermediate pyroclastic and flow rocks, granite, schist, gneiss, quartzite, quartz, and feldspar. Rounded clasts are less common in the middle unit than in the upper unit at the same location near Queen Creek. Data from drill holes in the south-central part of the area show that the clast composition changes from virtually all granitic clasts in the lower part to the more mixed Queen Creek drainage rock types in the upper part of the middle unit. The expansion of the Queen Creek drainage, unlike the Salt River drainage, did not involve greatly different rock types and did not cause a drastic change in clast type during the deposition of the middle unit. Clasts of granitic rocks and schist are common in the middle unit near the Santan Mountains.

In the southeastern part of the area, mainly in T. 3. S., R. 9. E., the middle unit contains more than 70 percent sand and gravel. Clasts consist of gneiss, granite, schist, quartz, feldspar, and intermediate to mafic pyroclastic and flow rocks, some of which are rounded. The deposits in this area may have been derived from the Gila River drainage, southeast of the area. In Paradise Valley the sedimentary material in the middle unit was derived from drainage areas north of Paradise Valley and consists mostly of granitic material.

As much as 700 ft of the middle unit is saturated (fig. 8). The unit may yield from a few hundred to a few thousand gallons per minute of water to wells. Wells in the Salt River in east-central Arizona, are rounded. Amounts of subangular clasts of granite, quartz, and feldspar generally increase with depth; they are the most abundant rock types in the lower part of the middle unit. Amounts of rounded quartzite and volcanic clasts decrease with increasing depth and quartzite clasts are rare in the lower part of the unit near the Salt River. This change in composition may be the result of an increase in the size of the drainage area of the Salt River by headward extension during deposition of the middle unit. The Salt River probably drained only the present-day lower Verde River area (fig. 1) at the start of the deposition of the middle unit (Cooley and Davidson, 1963, p. 30). The mountain ranges surrounding the lower Verde River are composed largely of granitic rocks (Wilson and others, 1957) and would have contributed sediment containing granitic clasts to the Salt River. Headward extension of the Salt River to the east continued during the deposition of the middle unit (Cooley and Davidson, 1963, p. 30). The river eventually reached its present-day headwaters in east-central Arizona, where quartzite is a common rock type (Wilson and others, 1959).

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Upper Unit

The upper unit underlies most of the valley floor and includes channel, flood-plain, terrace, and alluvial-fan deposits that consist largely of gravel, sand, and silt. Most of the unit is unconsolidated, but the alluvial-fan deposits near the mountain fronts and the deposits underlying terraces near the major stream courses are in places strongly cemented by caliche. Deposits containing as much as 80 percent sand and gravel occur along the present-day course of the Salt River, south and southwest of the Salt River along its ancestral course, in the eastern and western parts of Paradise Valley, and along Queen Creek (figs. 9 and 10). Deposits of the upper unit contain less than 50 percent sand and gravel in the south-central part of the study area and in the west-central part of Paradise Valley. Data are insufficient to determine the extent of gravel in many small dissected alluvial fans that extend from the nearby mountains. The contact between the upper and middle units generally can be readily identified because the upper unit commonly has a higher percentage of gravel, contains more rounded clasts, and contains less calcium carbonate (except where gravel underlying terraces is cemented with caliche) than the middle unit. The contact is more difficult to determine near the margins of the basin, where deposits of the upper unit may form a thin veneer.

The upper unit is greater than 300 ft thick in the west-central part of the study area south of the Salt River and greater than 200 ft thick near Queen Creek and in Paradise Valley (fig. 9). The unit is thinnest near the mountain fronts where it may be only a few feet thick.

The upper unit is equivalent to the upper alluvium as defined by Cooley in Arteaga and others (1968). Most of the unit may be as old as 3.3 m.y., which is the mean radiometric age determination of multiple samples of basalt flows that overlie gravel terraces along the Gila River west of the report area.

The principal sources of sedimentary material for the upper unit were the Salt River and Queen Creek drainages and drainages to the north of Paradise Valley. The mountain ranges bordering the basin also contributed sediment to the upper unit but were not important sources as compared to the three principal drainage areas. Distinctive rock types were derived from the major drainages.

The sediments derived from the Salt River drainage consist largely of sand- to boulder-size clasts of quartzite, granite, and intermediate to mafic volcanic rocks, as well as variable amounts of quartz, feldspar, gneiss, and schist. Many of the clasts, especially the quartzite clasts, are well rounded. Sand and gravel deposits transported by the Salt River underlie an area as wide as 15 mi in the west-central and southwestern parts of the area (fig. 9). These deposits were subsequently covered by about 35 to 75 ft of silt and clay (fig. 6d).

The sediment from the Queen Creek drainage contains varying proportions of felsic to intermediate pyroclastic and flow rocks, granite, schist, gneiss, and quartzite, quartz, and feldspar. Many clasts are rounded but subangular clasts are more common than in the deposits derived from the Salt River drainage. The deposits near the lower reaches of Queen Creek north of the Santan Mountains may contain as much as 80 percent sand (largely of quartz and feldspar), 10 percent gravel, and 10 percent silt and clay.

Sedimentary material from drainages north of Paradise Valley is mainly granitic and, in parts of central and eastern Paradise Valley, is more than 80 percent sand and some gravel. The sand here and in the lower reaches of Queen Creek is some of the most well-sorted material in the upper unit. Along western Paradise Valley the upper unit contains clasts of granitic, metamorphic, and volcanic rocks that may have been derived from a drainage area northwest of the report area. The mountain ranges bordering the basin contributed their distinctive rock types to alluvial fans in the upper unit (Christenson and others, 1978). The mountain ranges contributed sediment to the upper unit in direct proportion to their altitude and drainage area. For example, substantial volumes of volcanic clasts from the Superstition Mountains were carried several miles from the mountain front, whereas small volumes of clasts from the lower less extensive Phoenix Mountains were carried only hundreds of feet.

The upper unit was deposited in a basin that had a through-flowing stream system. This was a departure from the depositional conditions of the middle and lower units, which formed in a closed basin. Queen Creek and the Salt River flowed southwestward toward the Gila River during most of the period of deposition of the upper unit. The Salt River changed course toward Tempe Butte late in the period, probably because the river could no longer transport its load southwest to the confluence with the Gila River. Regional tilting toward the west also might have contributed to the change in course. The 35 to 75 ft of silt and clay that overlies the sand and gravel deposits in most of the west-central and southwestern parts of the area probably was deposited by ephemeral streams and sheet flow after the Salt River shifted to its present course.

Deposits of silt and sand and gravel occur in two areas where the upper unit is thickest--south and southwest of Mesa and in Paradise Valley (figs. 9 and 10). The silt probably was deposited in an area frequently covered by overbank flooding. The thickest parts of the upper unit generally correspond to the thickest parts of the underlying middle and lower units. Subsidence that took place during deposition of the middle and lower units evidently continued during the deposition of the upper unit (Cooley and Davidson, 1963, p. 30 and 31; Cooley, 1977, pl. 1), but sufficient gradient was maintained to move material through and out of the basin.

Subsidence of the Salt River Valley area--and (or) uplift of the area to the northeast of the Salt River Valley--is indicated by the relation of terrace levels along the Salt River and Queen Creek and a comparison of the thickness of the upper unit in the Salt River Valley area with equivalent deposits along the lower reaches of the Salt and Gila Rivers. Three terraces along the Salt River and two along Queen Creek converge toward the southwest and are buried by deposits in the upper part of the upper unit (Péwé, 1978). Similar characteristics are shown by river terraces along other nearby streams--the Gila, Verde, and Agua Fria Rivers (fig. 1). The upper unit along the Salt and Gila River drainages in southern Arizona generally does not exceed 100 ft in thickness (Cooley, 1977, pl. 1) except in the Salt River Valley area where it is more than 300 ft thick. Davidson (1973, p. E35-E36) estimated tilting toward the northwest of more than 250 ft in 20 m.y. occurred after the Fort Lowell Formation was deposited in the Tucson basin. Very recent tilting of the central Arizona area is indicated by the rapid downcutting of streams in the upper reaches of the Gila River drainage as compared to that along streams in the lower reaches of the river. Tectonic movements that formed the basins and mountain ranges may have ceased in western Arizona but may still be active in eastern Arizona (Shafiqullah and others, 1980).

The distribution of silt and the sand and gravel in the upper unit affects the infiltration, movement, and availability of ground water. Although the unit has excellent water-bearing characteristics, most of it is drained of water because of extensive ground-water development that began in the 1940's. The upper unit now is saturated only in the southwestern part of the area. The sand and gravel, where saturated, may yield as much as 4,000 gal/min of water to wells. During floods along the Salt River and Queen Creek, the upper unit readily accepts large volumes of recharge except locally where the unit consists primarily of silt. In the south-central part of the area, ground water is perched in the upper unit where most of the deposits are silt (fig. 10). The perched water may originate as applied irrigation water or as flow from Queen Creek. Near Scottsdale, perched water occurs where the upper unit contains more than 80 percent sand and gravel; the perching may be caused by buried caliche-cemented terraces (Péwé, 1978).

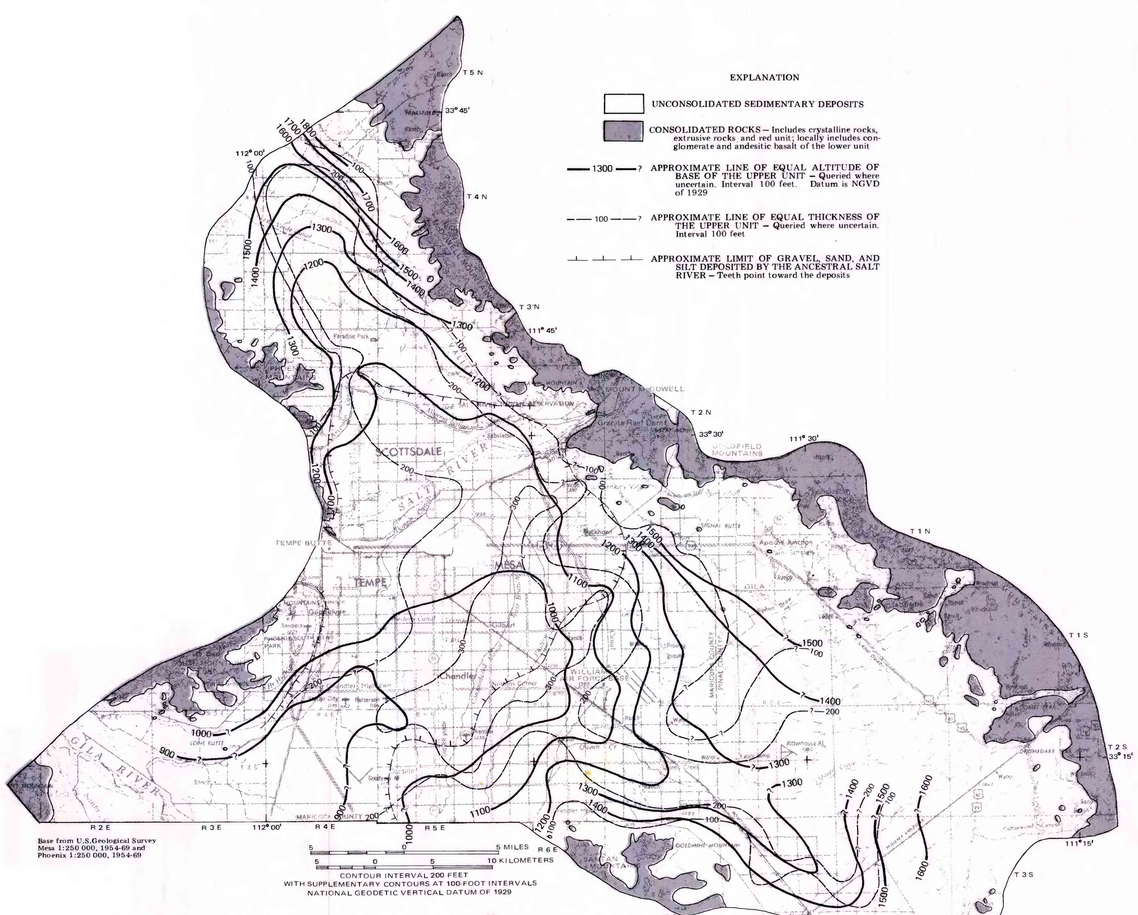

Figure 9. -- Altitude of the base, thickness of the upper unit, and distribution of Salt River deposits.

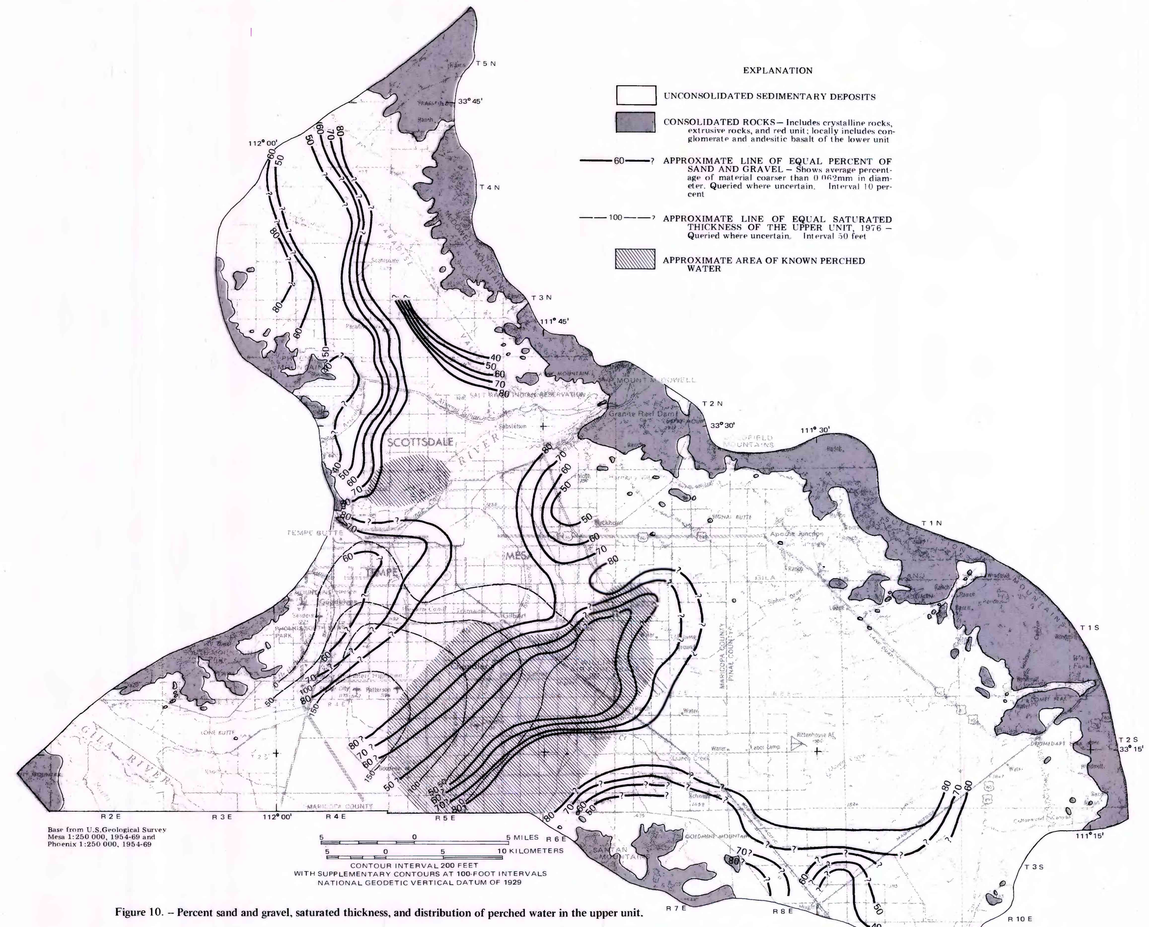

Figure 10. -- Percent sand and gravel, saturated thickness, and distribution of perched water in the upper unit.

HYDROGEOLOGY OF THE EASTERN PART OF THE SALT RIVER VALLEY AREA, MARICOPA AND PINAL COUNTIES, ARIZONA

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