TEXTURE AND DEPOSITIONAL HISTORY OF NEAR-SURFACE ALLUVIAL DEPOSITS IN THE CENTRAL PART OF THE WESTERN SAN JOAQUIN VALLEY, CALIFORNIA

U.S. GEOLOGICAL SURVEY
Open-File Report 89-235

REGIONAL AQUIFER SYSTEM ANALYSIS

Prepared in cooperation with the SAN JOAQUIN VALLEY DRAINAGE PROGRAM

This report was prepared by the U.S. Geological Survey in cooperation with the San Joaquin Valley Drainage Program and as part of the Regional Aquifer-System Analysis (RASA) Program of the U.S. Geological Survey.

The San Joaquin Valley Drainage Program was established in mid-1984 and is a cooperative effort of the U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, U.S. Geological Survey, California Department of Fish and Game, and California Department of Water Resources. The purposes of the program are to investigate the problems associated with the drainage of agricultural lands in the San Joaquin Valley and to develop solutions to those problems. Consistent with these purposes, program objectives address the following key concerns: (1) public health, (2) surface- and ground-water resources, (3) agricultural productivity, and (4) fish and wildlife resources.

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Sacramento, California 95825-1898

The RASA Program of the U.S. Geological Survey was started in 1978 following a congressional mandate to develop quantitative appraisals of the major ground-water systems of the United States. The RASA Program represents a systematic effort to study a number of the Nation's most important aquifer systems, which in aggregate underlie much of the country and which represent an important component of the Nation's total water supply. In general, the boundaries of these studies are identified by the hydrologic extent of each system, and accordingly transcend the political subdivisions to which investigations were often arbitrarily limited in the past. The broad objectives for each study are to assemble geologic, hydrologic, and geochemical information, to analyze and develop an understanding of the system, and to develop predictive capabilities that will contribute to the effective management of the system. The Central Valley RASA study, which focused on the hydrology and geochemistry of ground water in the Central Valley of California, began in 1979. Phase II of the Central Valley RASA began in 1984 and is in progress. The focus during this second phase is on more detailed study of the hydrology and geochemistry of ground water in the San Joaquin Valley, which is the southern half of the Central Valley.

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DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

For readers who prefer to use metric (International System) units rather than inch-pound units, the conversion factors for terms used in this report are listed below.

Multiply inch-pound unit	By	To obtain metric unit
ft (foot)	0.3048	m (meter)
in. (inch)	25.4	millimeter
mi (mile)	1.609	kilometer
mi^2 (square mile)	2.590	square kilometer

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ABSTRACT

Saline conditions and associated high levels of selenium and other soluble trace elements in soil, shallow ground water, and agricultural drain water of the western San Joaquin Valley, California, have prompted a study of the texture of near-surface alluvial deposits in the central part of the western valley. Texture is characterized by the percentage of coarse-grained sediment present within a specified subsurface depth interval and is used as a basis for mapping the upper 50 feet of deposits. Resulting quantitative descriptions of the deposits are used to interpret the late Quaternary history of the area.

Three hydrogeologic units--Coast Range alluvium, flood-basin deposits, and Sierran sand--can be recognized in the upper 50 feet of deposits in the central part of the western San Joaquin Valley. The upper 30 feet of Coast Range alluvium and the adjacent 5 to 35 feet of flood-basin deposits are predominantly fine grained. These fine-grained Coast Range deposits are underlain by coarse-grained channel deposits. The fine-grained flood basin deposits are underlain by coarse-grained Sierran sand. The extent and orientation of channel deposits below 20 feet in the Coast Range alluvium indicate that streams draining the Coast Range may have been tributary to the axial stream that deposited the Sierran sand and that streamflow may have been to the southeast.

The fining-upward stratigraphic sequence in the upper 50 feet of deposits and the headward retreat of tributary stream channels from the valley trough with time support a recent hypothesis of climatic control of alluviation in the western San Joaquin Valley.

INTRODUCTION

The ground-water-flow system and shallow deposits in the central part of the western San Joaquin Valley, California, became a focus of concern when high concentrations of selenium and other soluble trace elements were detected in soils and shallow ground water associated with alluvial fans of Coast Range streams (Deverel and others, 1984). Selenium has adversely affected waterfowl and aquatic biota at Kesterson Reservoir, which impounds shallow ground water drained from agricultural fields in the central part of the western valley (U.S. Bureau of Reclamation, 1984). The occurrence of selenium in the agricultural drain water has resulted in the shutting down of drainage facilities in part of the western valley. In the absence of adequate drainage, shallow ground water and associated saline conditions may adversely affect agricultural productivity. The primary purpose of this report is to assess the textural character of near-surface deposits in the central part of the western San Joaquin Valley (fig. 1). An understanding of the shallow deposits will provide information that is critical in assessing and quantifying the shallow ground-water-flow system in the area.

Textural data were compiled from lithologic and geophysical logs of wells inside and outside of the study area (fig. 1). Lateral and vertical variations in the texture of the upper 50 ft of sediment are evaluated to interpret the late Quaternary depositional history and stratigraphy of the region. Results of this study will be combined with similar but less detailed data from deeper parts of the system to assess vertical and lateral permeability distributions for a numerical ground-water-flow model of the area.

This study is part of a comprehensive investigation of the hydrology and geochemistry of the San Joaquin Valley by the U.S. Geological Survey. The studies are being done in cooperation with the San Joaquin Valley Drainage Program and as part of the Regional Aquifer System Analysis Program of the U.S. Geological Survey.

Description of Study Area

The study area, about 760 mi^2 of western Fresno County, is in the central part of the western San Joaquin Valley (fig. 1). The area is bounded on the west by the foothills of the Coast Range. The northern, southern, and eastern limits of the study area were determined partly by the boundaries of a ground-water-flow model being developed for the area and partly by the areal distribution of wells with lithologic and geophysical logs of acceptable quality.

In the rainshadow of the Coast Range, the study area has a semiarid to arid climate. Almost all the precipitation in the area occurs as rain that falls in the winter months. Average annual precipitation is 6 to 8 in. (Rantz, 1969).

The study area has two topographically distinct areas: (1) the piedmont alluvial plain of the western San Joaquin Valley and (2) the flood basin of the San Joaquin River and Fresno Slough. The San Joaquin River and Fresno Slough form the axial drainage of northern and central San Joaquin Valley. South of the study area, the San Joaquin Valley drains internally into the Tulare Lake and Buena Vista Lake basins (Davis and others, 1959). The foothills of the Coast Range are drained by many intermittent and ephemeral streams that deliver sediment to a coalescing system of alluvial

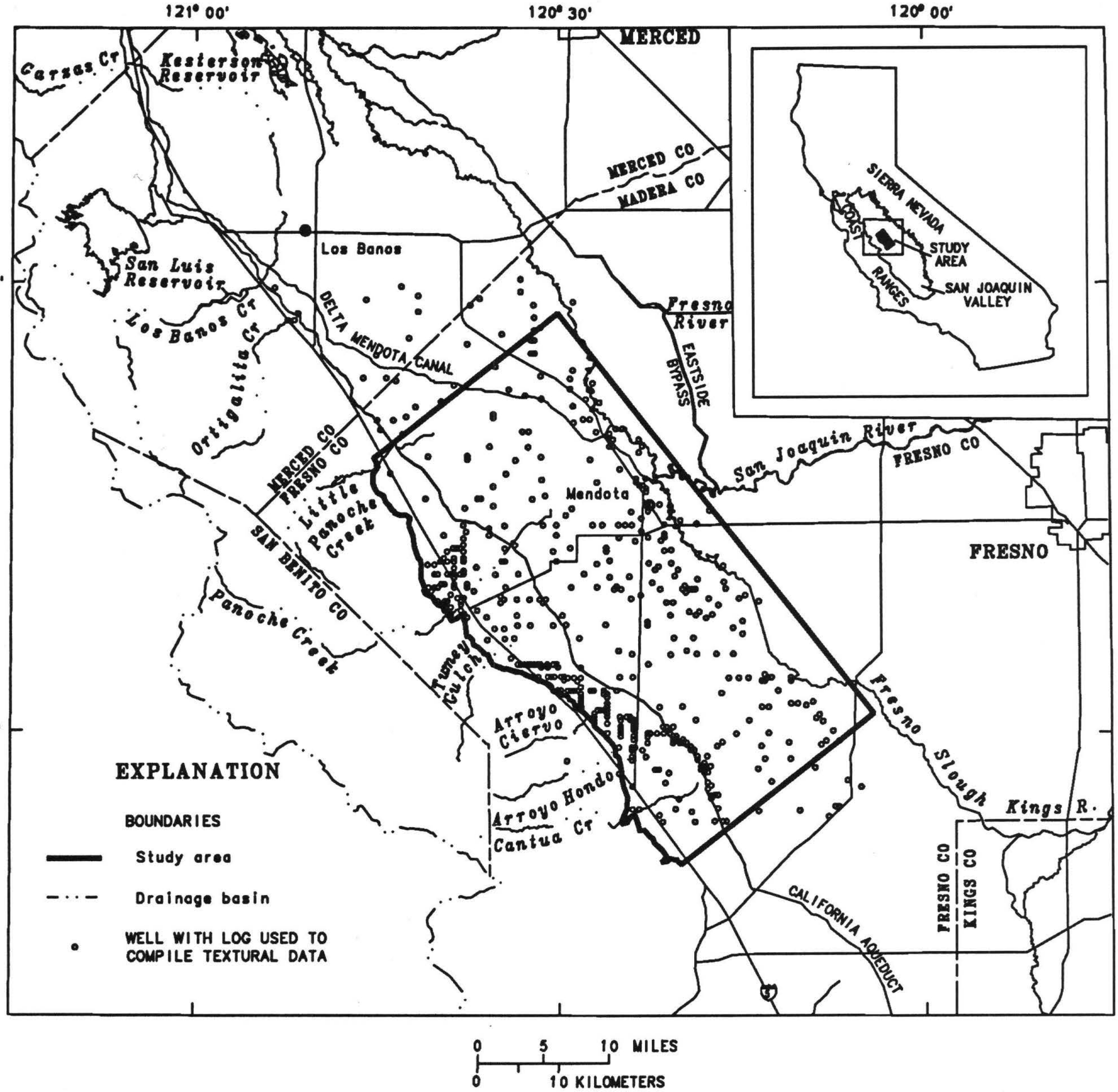

FIGURE 1.--*Location of the study area and areal distribution of wells with logs used to compile textural data.*

fans on the piedmont plain. The larger intermittent streams--Little Panoche, Panoche, and Cantua Creeks--have drainage basins that extend into the higher Coast Range. The smaller ephemeral streams have drainage basins in the foothills. These intermittent and ephemeral streams do not contribute surface discharge to the San Joaquin River under current climatic conditions (Bull, 1964a).

Geology

The San Joaquin Valley forms the southern two-thirds of the Central Valley of California and is between the Sierra Nevada to the east and the Coast Range to the west. The location and orientation of the valley is controlled primarily by a large, northwest-trending asymmetric syncline. The synclinal axis generally lies west of the topographic axis of the valley, indicating that the topographic axis is in dynamic equilibrium with sedimentation rates from bordering mountains rather than the rate of synclinal deformation or subsidence. The Sierra Nevada consists of mainly granitic and metamorphic rocks of pre-Tertiary age and sedimentary rocks of Tertiary age. Adjacent to the study area, the foothills of the Coast Range are composed of folded and faulted beds of mainly Cretaceous marine shale and sandstone in the north and mainly Cenozoic sandstone and shale in the south (Prokopovich, 1987). The valley deposits consist of Mesozoic and Cenozoic marine and continental sediments as much as 6 mi thick (Page, 1986). Continental sediments underlying the central San Joaquin Valley range in thickness from 900 to 3,300 ft (Miller and others, 1971) and are believed to be Pliocene to Holocene in age (Davis and others, 1959).

The Pleistocene Corcoran Clay Member of the Tulare Formation divides the ground-water-flow system of the western San Joaquin Valley into an upper semiconfined zone and a lower confined zone. In the semiconfined zone, Belitz (1988) recognized three hydrogeologic units: Coast Range alluvium, flood-basin deposits, and Sierran sand (fig. 2). The three units are distinguished by texture, hydrologic properties, and oxidation state. These characteristics are directly related to the modes of deposition of the units.

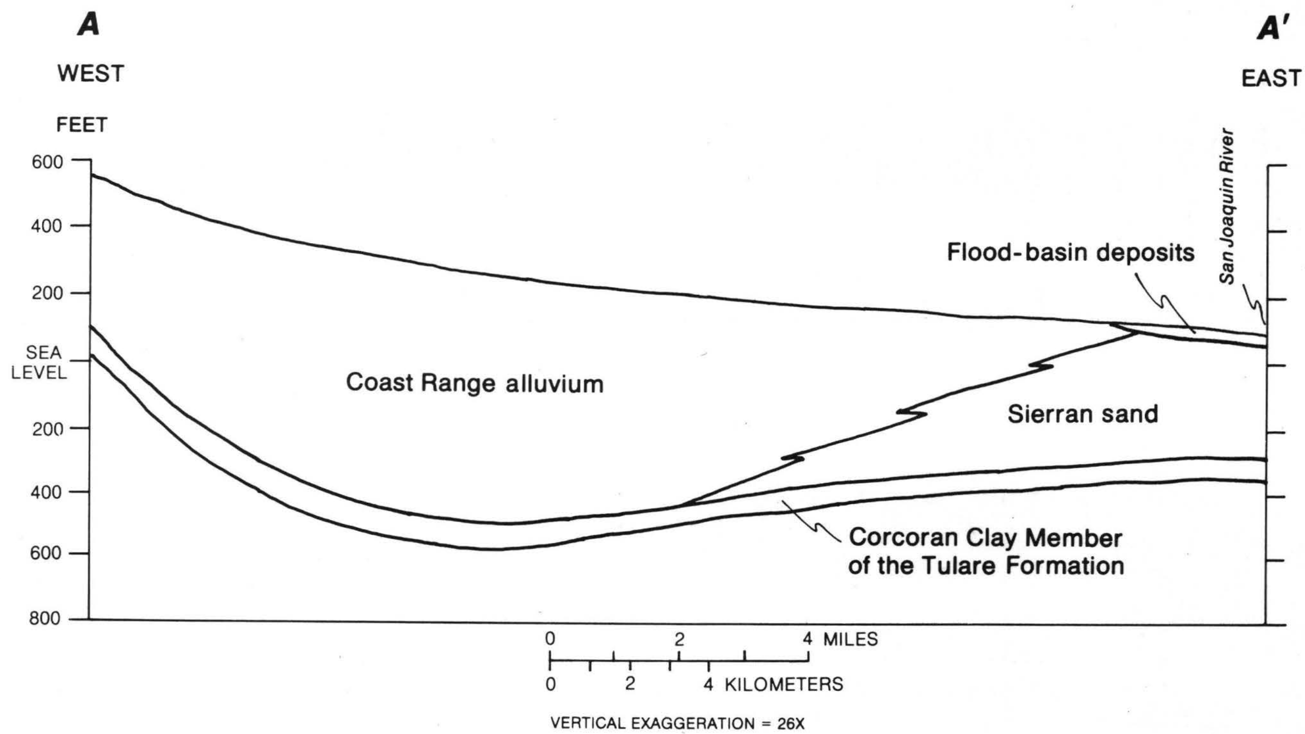

FIGURE 2.--*Generalized hydrogeologic section through the study area.*

The Coast Range alluvium comprises most of the sediment in the study area and was deposited as a system of coalescing alluvial fans on the piedmont alluvial plain (Meade, 1967) (fig. 3). Ancient and modern fan deposits are composed entirely of Coast Range material and were deposited by either water flow or mudflow (Bull, 1964b; Meade, 1967). At the surface, water-laid deposits are most common on the large fans of Little Panoche, Panoche, and Cantua Creeks; mudflow deposits are most common on the small, more steeply sloping fans of the ephemeral streams (fig. 3) (Bull, 1964a; 1964b). Water-laid sediment varies in texture from coarse to fine grained. Mudflow deposits are predominantly coarse grained and generally poorly sorted. Bull (1964b) estimated the median clay content of mudflow deposits in the study area to be 26 percent.

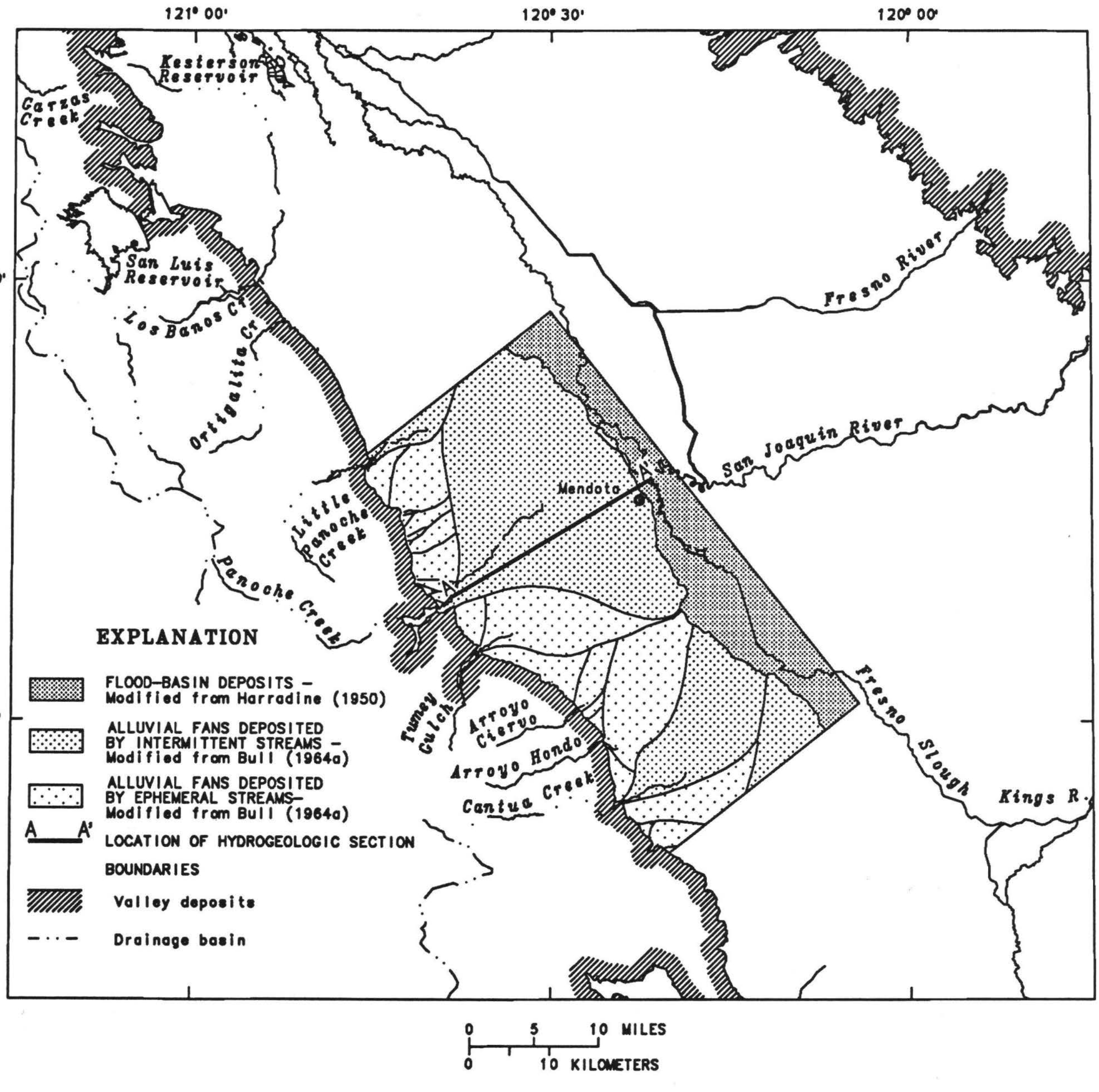

FIGURE 3.--*Alluvial-fan and flood-basin areas.*

At the surface and in the near subsurface, the Coast Range alluvium grades eastward into the fine-grained deposits of the flood basin in the valley trough (fig. 2). At depth, the Coast Range alluvium grades eastward into coarse-grained Sierran sand in the valley trough. Lettis (1982) tentatively correlated the near-surface Sierran sand with the Pleistocene Modesto Formation. The Sierran sand consists of fluvial deposits of the San Joaquin River and Fresno Slough and underlie the flood-basin deposits. The flood-basin deposits and Sierran sand consist mostly of arkosic detritus transported from the Sierra Nevada (Davis and Poland, 1957; Davis and others, 1959).

North of the study area, Lettis (1982, 1985, 1988) divided the deposits above and immediately below the Corcoran into five stratigraphic units primarily on the basis of relative age determined from geomorphic and pedologic criteria. From oldest to youngest, these units are the Tulare Formation (Watts, 1894; Anderson, 1905) and the informally named alluvium of Los Banos, alluvium of San Luis Ranch, alluvium of Patterson, and alluvium of Dos Palos (fig. 4). Lettis (1982, 1985, 1988) subdivided the alluvium of Los Banos into three informal members and alluvium of San Luis Ranch into two informal members (fig. 4) and proposed that each member represents, in part, a period of alluviation caused by a change from a humid glacial climate to an arid interglacial climate. Lettis (1982, 1985, 1988) recognized the upper member of the alluvium of San Luis Ranch and overlying alluvium of Patterson as a single aggradational unit.

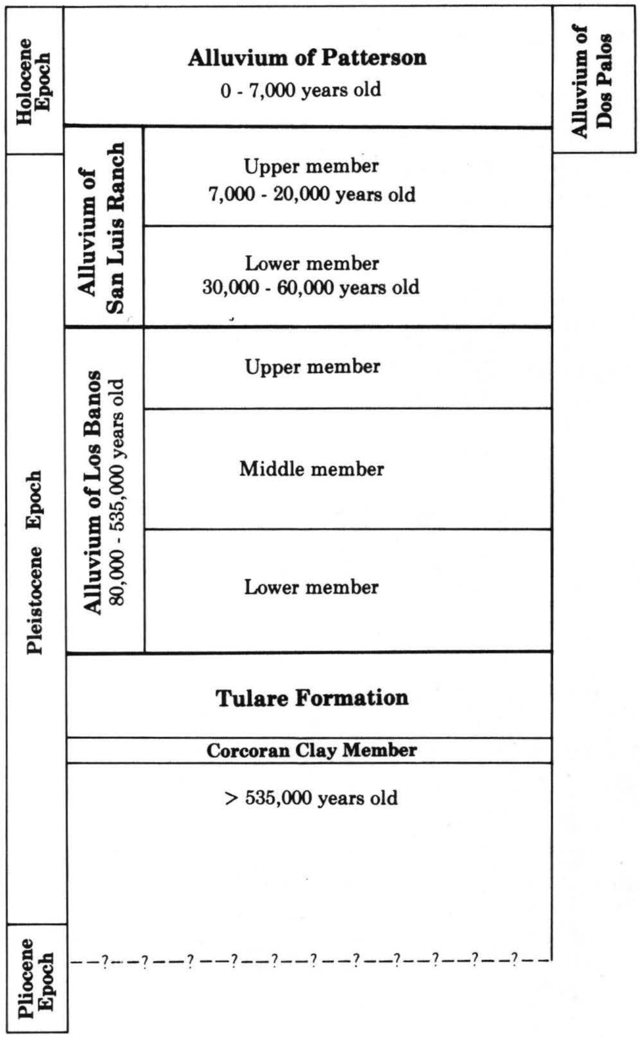

FIGURE 4.--*Stratigraphic alluvial units and their relative ages.*

PREVIOUS INVESTIGATIONS

Several regional and site-specific investigations of sediment texture have been done in the San Joaquin Valley. Regional studies of the San Joaquin Valley include those by Davis and others (1959) and Page (1986); a site specific study of the west central San Joaquin Valley has been done by Prokopovich (1987).

The investigation by Davis and others (1959) was the first extensive textural study of deposits in the San Joaquin Valley. The purpose of that study was to estimate the ground-water storage capacity of the valley on the basis of the texture and volume of the sediment. Using lithologic logs, they evaluated subsurface texture in depth intervals of 10 to 50 ft, 50 to 100 ft, and 100 to 200 ft. Davis and others (1959) used lithologic logs from wells for each 5 mi^2 in the region of our investigation. Elsewhere in the San Joaquin Valley, they used lithologic logs from wells for each 1 mi^2. In a follow-up study, Davis and others (1964) used textural data to estimate the storage capacity of those parts of the San Joaquin Valley considered for operation as a subsurface reservoir for the storage of surface water.

Page (1986) evaluated the texture of deposits in the entire Central Valley above the base of fresh water using 685 electrical geophysical logs. Texture maps, columns, and sections were made by computing and posting the percentage of coarse-grained sediment by quarter townships in successive depth intervals of 300 ft. Page noted that deposits underlying areas of high elevation generally have more gravel, and those underlying areas of low elevation have more sand. Page also noted that in some areas the texture of underlying sediment is fairly constant with depth. He concluded that in those areas, sources and depositional environments have not changed for long periods. Page suggested that the texture maps in his report can serve as a general guide for estimating transmissivity and coefficient of storage for ground-water models.

In a more detailed and local study, Prokopovich (1987) mapped the texture of near-surface alluvial sediment in western Fresno County. Texture was evaluated for the depth intervals 0 to 1.5 m (about 0 to 4.9 ft), 1.5 to 3 m (about 4.9 to 9.8 ft), and 3 to more than 4 m (about 9.8 to more than 13.1 ft). The northern part of his study area overlaps the southern two-thirds of our study area. Prokopovich used textural data from lithologic logs of about 1,130 wells drilled by the U.S. Bureau of Reclamation for a preconstruction study for underground pipelines. The wells were drilled on a 1-mile grid (at section corners) and on a 0.5-mile grid in the northern part of his study area.

The textural data used by Prokopovich (1987) may be considered reliable because the wells were logged from continuous core samples collected during drilling. A comparison of visual grain-size classifications from the logs with 388 corresponding laboratory determinations indicated only minor discrepancies in 5 percent of the classifications. On the basis of these lithologic data, Prokopovich (1987) produced contoured texture maps of sufficient detail to interpret source areas, modes of deposition, and changes in environment of deposition for his study area and study depth.

In our investigation, we use a similar approach as Prokopovich (1987) for the assessment of sediment texture. We describe the distribution of sediment facies on the basis of detailed lithologic data from water wells and boreholes from the central part of the western San Joaquin Valley. This area significantly overlaps the area investigated by Prokopovich. Our evaluation, however, assesses the distribution of sediment texture to a greater depth (50 ft) than that evaluated by Prokopovich (14 ft).

STUDY DESIGN

For sedimentary deposits, texture is the size, shape, and arrangement of grains. Typically, well logs report only the size aspect of texture. Therefore, in this report, texture is characterized by the percentage of coarse-grained sediment, interpreted from a well log, present in a given subsurface depth interval. Coarse-grained sediment is defined as consisting principally of sand, clayey and silty sand, gravel, and clayey, silty, and sandy gravel. Fine-grained sediment is defined as consisting principally of clay, silt, and sandy clay and silt. The definitions of the terms "texture," "coarse grained," and "fine grained" used in this report are virtually the same as those of Page (1986).

To evaluate the lateral and vertical distribution of deposits, texture maps of five successive 10-foot depth intervals were produced using data from 469 wells inside and outside of the study area (fig. 1). The procedure for creating the texture maps involved two basic steps. First, logs were coded according to the simplified classification system defined above, and the percentage of coarse-grained sediment was computed for each of the five depth intervals for every log. Second, texture maps of the five depth intervals were produced by contouring gridded textural values estimated using the Surface II[1] mapping package (Sampson, 1976).

Classification of Texture from Well Logs

The sources of data for the study were 446 lithologic logs and 23 electrical geophysical logs. Most of the lithologic logs were obtained from the U.S. Bureau of Reclamation, including some logs used by Prokopovich (1987). Most of the Bureau of Reclamation logs are for wells that were continuously cored during drilling. The descriptions in these logs are the most detailed in the data base but are mostly from wells less than 20 ft deep. The remaining lithologic logs, which include most of the data for the deepest parts of the system, are from wells drilled by various State and Federal agencies and from privately drilled wells. The logs of these wells were compiled from descriptions of drill cuttings and some cores collected during drilling.

[1]Use of brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Each lithologic log was divided into discrete coarse-grained and fine-grained intervals on the basis of the descriptions in the log and according to the simplified textural classification previously mentioned. The textural classification and thickness of each interval were coded for each log. Coded geophysical logs from the study area were taken from an existing data base compiled by Page (1986) for his study of Central Valley sediment.

Textural information on lithologic logs commonly is ambiguous and inconsistent because expertise, experience, and vocabulary of the people who write them varies greatly. Therefore, a subjective quality rating of poor, fair, good, or excellent was assigned to each lithologic log on the basis of the amount of detail in the descriptions (table 1). Preliminary analysis of the lithologic logs indicated that logs of poor and fair quality were of insufficient detail to map the texture of 10-foot depth intervals; thus, texture maps in this report were produced using logs of good and excellent quality only.

TABLE 1.--*Examples of descriptions of sediment from lithologic logs and their associated ratings*

[Ratings are based on the amount of detail in the description with more detailed descriptions receiving better ratings]

Description	Rating
Clay, sand	Poor
Silty clay, fine sand	Fair
Bluish silty clay, brownish-yellow fine sand	Good
Clay, light-olive gray 5Y5/2, silty, laminated; sand, olive-gray 5Y4/1, very fine to fine, some silt	Excellent

Production of Texture Maps

Texture maps of the five depth intervals were constructed using the Surface II mapping package of Sampson (1976). The Surface II package uses a moving average to estimate values of a surface at the nodal points of a rectangular grid. The grid used in this study was oriented with the long axis roughly parallel to the boundary of the valley deposits (fig. 4) and had a nodal spacing of 0.25 mi in the x and y directions. The area of the grid encompassed all 469 wells used in the study (fig. 1). The grid also was designed to coincide with a grid being used in a numerical ground-water-flow model of the area, so textural values could be used to estimate permeability distributions in the model. Textural values for each depth interval at each node were estimated by calculating a constrained distance-squared weighted average of the eight nearest data points. Texture maps were contoured from the gridded textural values and plotted.

The Surface II mapping package uses the size of the grid and the total number of data points to calculate the maximum allowable distance to the nearest data point and the maximum search radius for any neighboring data points used to estimate a value (table 2). If at any given node, neighbors are not within the maximum allowable distance, or if eight neighbors are not within the maximum search radius, Surface II does not calculate a value at the node. Within the grid for the different depth intervals, the maximum search radius ranged from 6.4 to 9.1 mi, and the maximum distance to the nearest data point ranged from 4.0 to 5.9 mi. In heterogeneous alluvial sediment, the assumption that texture at a point is related to texture at surrounding points several miles away may not always be valid. Therefore, in areas of sparse data, the texture maps should be regarded as only showing general trends. Conversely, in areas where data are variable and closely spaced, the Surface II package may produce smoothed estimates.

TABLE 2.--*Maximum allowable search radius for neighboring data points, maximum allowable distance to nearest data point, and total number of data points used for estimates of gridded textural values for each texture map*

[The area of the grid is 1,440 square miles]

Texture map depth interval (feet)	Maximum search radius for neighboring data points (miles)	Maximum distance to nearest data point (miles)	Total number of data points
0-10	6.4	4.0	450
10-20	6.4	4.1	446
20-30	7.2	4.5	356
30-40	7.7	4.8	312
40-50	9.1	5.9	219

The algorithm used by Surface II to weight data points is a function of distance and not of direction. Therefore, to minimize edge effects, the texture map boundaries were drawn well within the grid boundaries. The texture map area is about one-half of the grid area. Surface II also may map elongated or lobate features (such as mudflow or stream-channel deposits) as more rounded in shape than they actually are, especially in areas of sparse data. A visual comparison of the map of the 0- to 10-foot depth interval to the texture maps of Prokopovich (1987, fig. 13) indicate that elongated and lobate features on Prokopovich's maps appear more rounded on our map. This is because Prokopovich's data were more closely and uniformly spaced than the data used in this study.

TEXTURAL DISTRIBUTIONS AND DEPOSITIONAL HISTORY

Distribution of coarse- and fine-grained sediment in the upper 50 ft of deposits in the study area is shown in five texture maps (figs. 5-9). The extent and relative position of coarse- and fine-grained sediment are used to interpret the extent and position of stream channels; the principal modes of deposition; and, in certain places, the sources of sediment. Significant changes in the proportion of coarse- to fine-grained sediment with depth are used to interpret changes in the depositional environment of the region over time and to correlate sediment with the informal allostratigraphic units of Lettis (1988) (fig. 4).

Flood-Basin Deposits and Sierran Sand

Flood-basin deposits underlie the valley trough and consist mostly of clay, silty clay, and clayey silt of low permeability. The low permeability of these sediments impedes the downward movement of ground water (Belitz, 1988) and is part of the cause of agricultural drainage problems in the area. However, the clays are not vertically extensive or laterally continuous. Analysis of the lithologic logs indicates that the flood-basin clays in most areas are between 5 and 35 ft thick. In the valley trough, Miller and others (1971) mapped more than 500 ft of permeable sand of Sierran source below the flood-basin clays. They describe the Sierran sand as flood-plain deposits of the valley's axial drainage.

The abrupt textural change from flood-basin clays to Sierran sand is well defined. Valley-trough sediment is almost exclusively fine grained in the

0- to 10-foot depth interval (fig. 5), except in isolated areas southeast of Mendota where the Sierran sand probably is within a few feet of the surface. The percentage of coarse-grained sediment is significantly greater in the 10- to 20-foot depth interval, especially in the southeastern part of the valley trough (fig. 6). From 20 to 50 ft in depth, Sierran sand constitutes most of the sediment (figs. 7-9).

The flood-basin deposits may correlate with the alluvium of Dos Palos of Holocene age (Lettis, 1988) (fig. 4). Lettis defined this unit as the unconsolidated arkosic deposits covering the flood basin of the lower San Joaquin River. Lettis (1982, pl. 25) tentatively correlates the Sierran sand with the Pleistocene Modesto Formation to a depth of about 100 ft. According to Miller and others (1971), the modern streams that deposited the flood-basin clays were less competent than the ancient streams that deposited the Sierran sand. This textural change indicates that the volume of surface runoff from the Sierra Nevada was significantly greater prior to the time of deposition of the flood-basin deposits. Substantial decrease in discharge and sediment load in drainages from the Sierra Nevada are most likely the result of a transition from glacial to interglacial conditions.

Coast Range Alluvium

The texture of Coast Range alluvium varies with relative position on the alluvial fans. Due to differentiation of material during transportation from source areas, alluvial-fan sediment tends to be coarsest in the upper fan and finest in the lower fan. This characteristic distribution of coarse- and fine-grained sediment is apparent in figures 5-9. The upper fans generally are greater than 80- to 100-percent coarse grained and progressively decrease to 0- to 20-percent coarse grained on the lower fans. Prokopovich (1987) noted a similar decline in total thickness of sand beds and average sand fraction from the foothills toward the valley trough.

Because coarse-grained sediment in alluvial fans typically is associated with stream channels, the coarse-grained areas on the texture maps are most likely mudflow and (or) fluvial-channel deposits associated with large laterally migrating distributary channels of the fans. Areas shown on the texture maps that have coarse-grained sediments greater than 40 percent are interpreted as approximately defining the location and extent of stream-channel deposits in the fans. A greater than 40-percent coarse-grained sediment was selected as a definitive value because these areas generally have the elongate shape and orientation of stream channels. Fine-grained lower fans are most likely sheetflow deposits.

The most distinct trends evident in the Coast Range alluvium are the increased number and extent of stream-channel deposits and the overall increase in percentage of coarse-grained sediment with depth. In the 0- to 10-foot depth interval, predominantly coarse-grained deposits are evident in the upper and middle fans of Tumey Gulch, Arroyo Ciervo, Arroyo Hondo, and Panoche and Cantua Creeks (figs. 3 and 5).

Deposits in the fans north of the Panoche fan are fine grained throughout the upper 10 ft. Prokopovich (1987) also noted this trend in the upper 10 ft of Coast Range alluvium and suggested that the finer grained texture of fan deposits north of Panoche Creek is due to a corresponding finer grained texture of bedrock source materials. In this depth interval, deposits in the lower fans characteristically are fine grained with few exceptions.

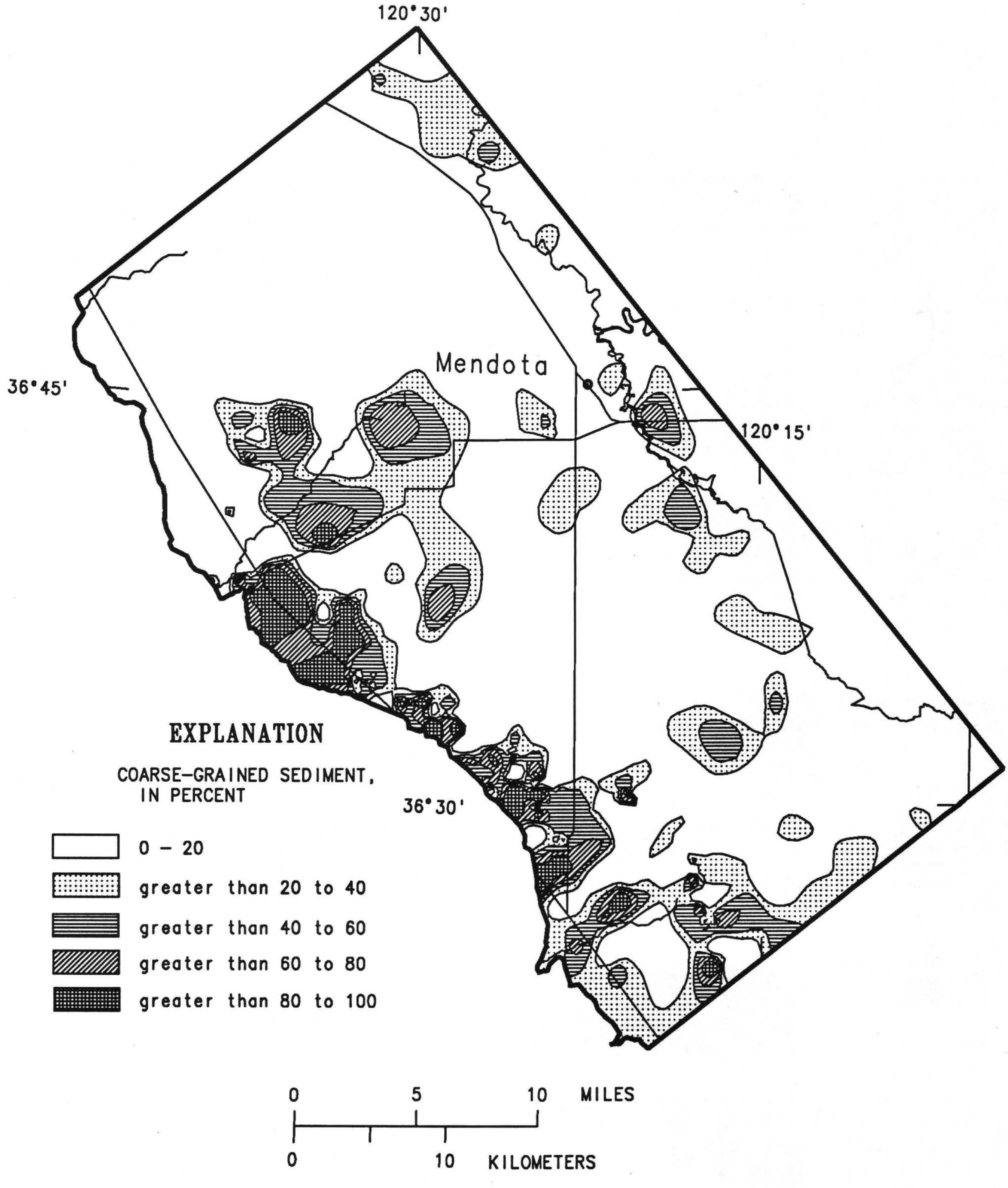

FIGURE 5.--*Sediment texture of the 0- to 10-foot depth interval.*

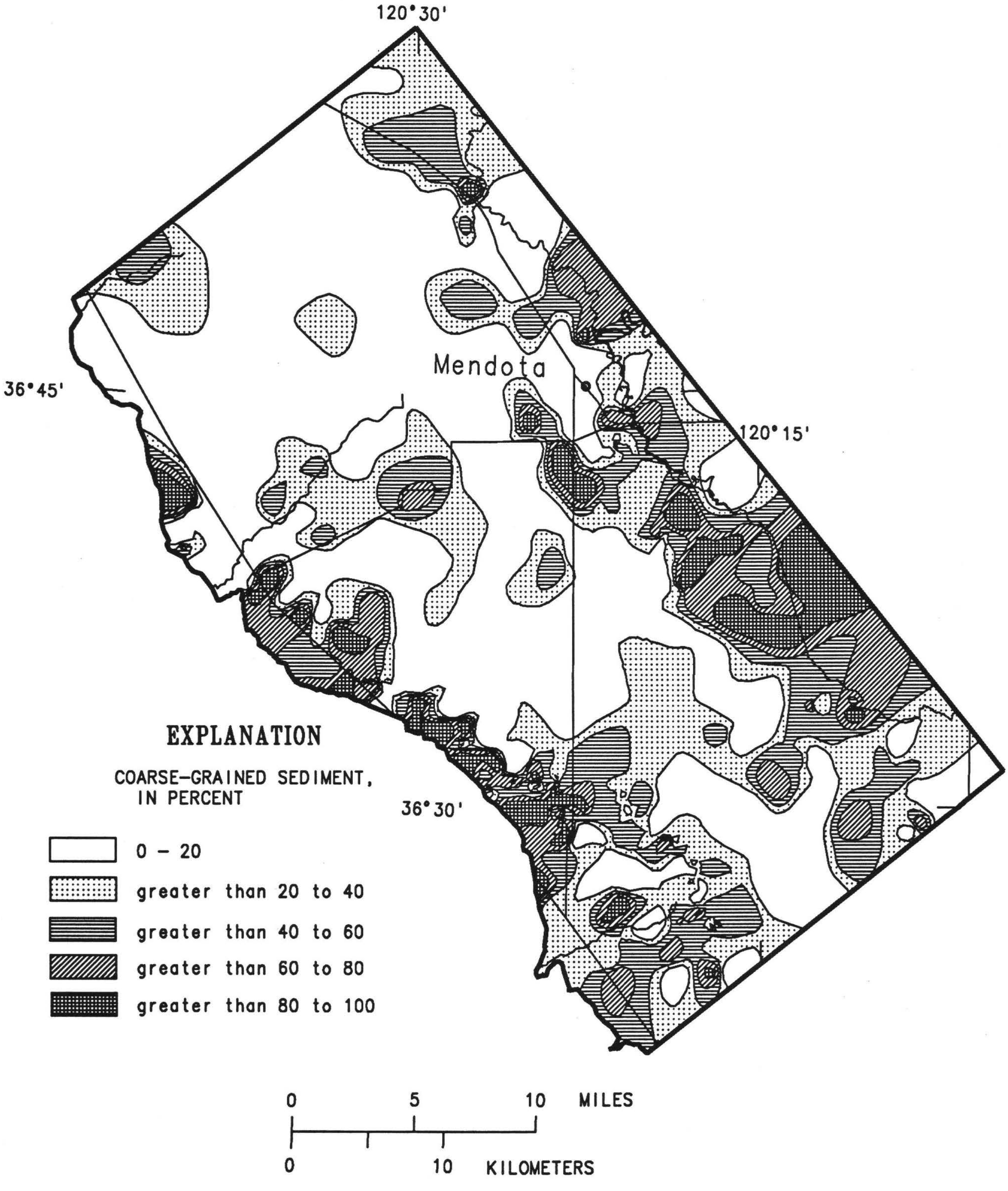

FIGURE 6.--*Sediment texture of the 10- to 20-foot depth interval.*

In the 0- to 10-foot depth interval, deposits of the large fans of Panoche and Cantua Creeks generally are finer grained than those of the small fans of the ephemeral streams. Prokopovich (1987) noted similar trends in total thickness of sand beds and average sand fraction and suggested two factors which contribute to this trend. Source areas for the large fans are in the Coast Range and are underlain predominantly by Cretaceous shales. In contrast, source areas for the small fans are in the foothills and are underlain by predominantly sandy Tertiary deposits. Mudflow deposits also are common on the more steeply sloping small fans associated with foothill streams and generally are coarser grained than the water-laid sediment common on the more gently sloping large fans associated with streams draining the higher Coast Range.

In the 10- to 20-foot depth interval (fig. 6), coarse-grained sediment is more extensive on the smaller Tumey Gulch and Arroyo Ciervo fans and on Little Panoche fan (fig. 3). A significant increase in coarse-grained sediment also is evident in the middle part of Arroyo Hondo fan. Deposits of the lower fans generally are fine grained from 10 to 20 ft, with notable exceptions in parts of Panoche and Cantua fans.

In the 20- to 30-foot depth interval (fig. 7), coarse-grained sediment defines a large channel deposit in the Panoche fan that extends the length of the fan and merges with deposits of Sierran sand in the valley trough. Prominent channel deposits also are evident in the Arroyo Hondo and Cantua fans. The junction of the channel deposits in the Panoche fan with the deposits of Sierran sand in the valley trough may indicate direction of streamflow in the axial drainage. Because streams generally bifurcate in the upstream direction, the junction of these deposits indicates that flow may have been to the southeast in the axial drainage when this sediment was deposited.

The 30- to 40-foot depth interval (fig. 8) has substantially more coarse-grained sediment than the 20- to 30-foot depth interval (fig. 7). On the Panoche fan, channel deposits are more laterally extensive, and the middle and lower fans have significantly more coarse-grained sediment than overlying deposits. The same trend is apparent on the Arroyo Hondo fan, which may have covered a larger area than the Cantua fan during deposition of sediment in this depth interval. The direction of bifurcation of the channel deposits in Panoche and Cantua fans and the deposits of Sierran sand in the valley trough may indicate flow to the southeast in the axial drainage of the valley when this sediment was deposited.

Although the San Joaquin River presently flows in a northwesterly direction, gradients along the valley trough are low in the study area. Van Winkle and Eaton (1910) reported that the San Joaquin River drainage basin is separated from the Tulare Lake basin by only a low alluvial divide. This divide is so low that at times the Kings River (fig. 1) has flowed northwestward into Fresno Slough and the San Joaquin River instead of southeastward into the Tulare Lake basin. The drainage divide may have been north of its present location when sediment in the 20- to 40-foot depth interval was deposited, and Coast Range drainages may have been tributary to the Kings River.

Coarse-grained sediment reaches its greatest mapped extent in the 40- to 50-foot depth interval (fig. 9). Channel deposits extend from the upper fan to the valley trough on Panoche, Arroyo Hondo, and possibly Tumey Gulch fans indicating that the streams that deposited the sediment may have been tributary to the axial drainage of the valley.

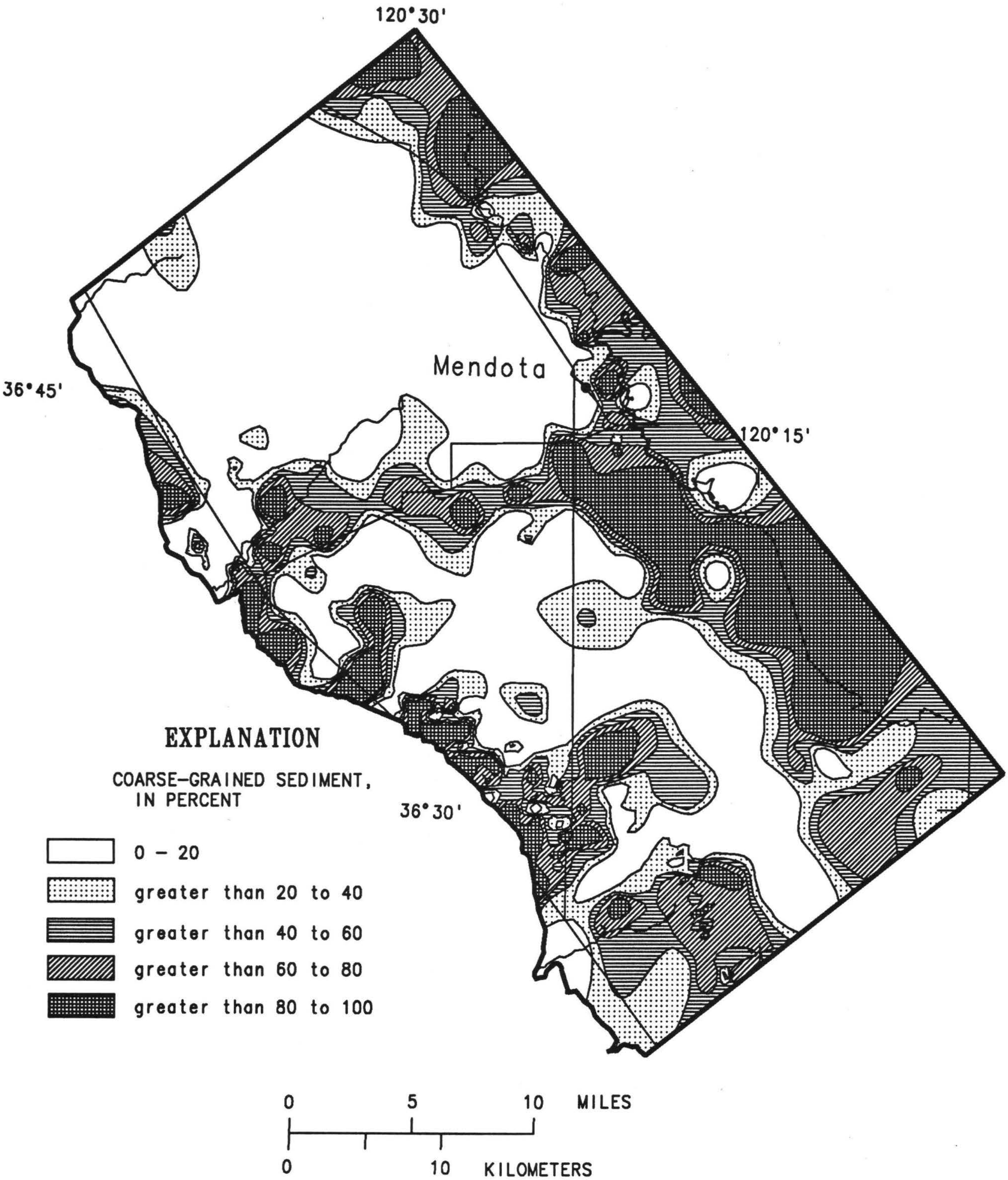

FIGURE 7.--*Sediment texture of the 20- to 30-foot depth interval.*

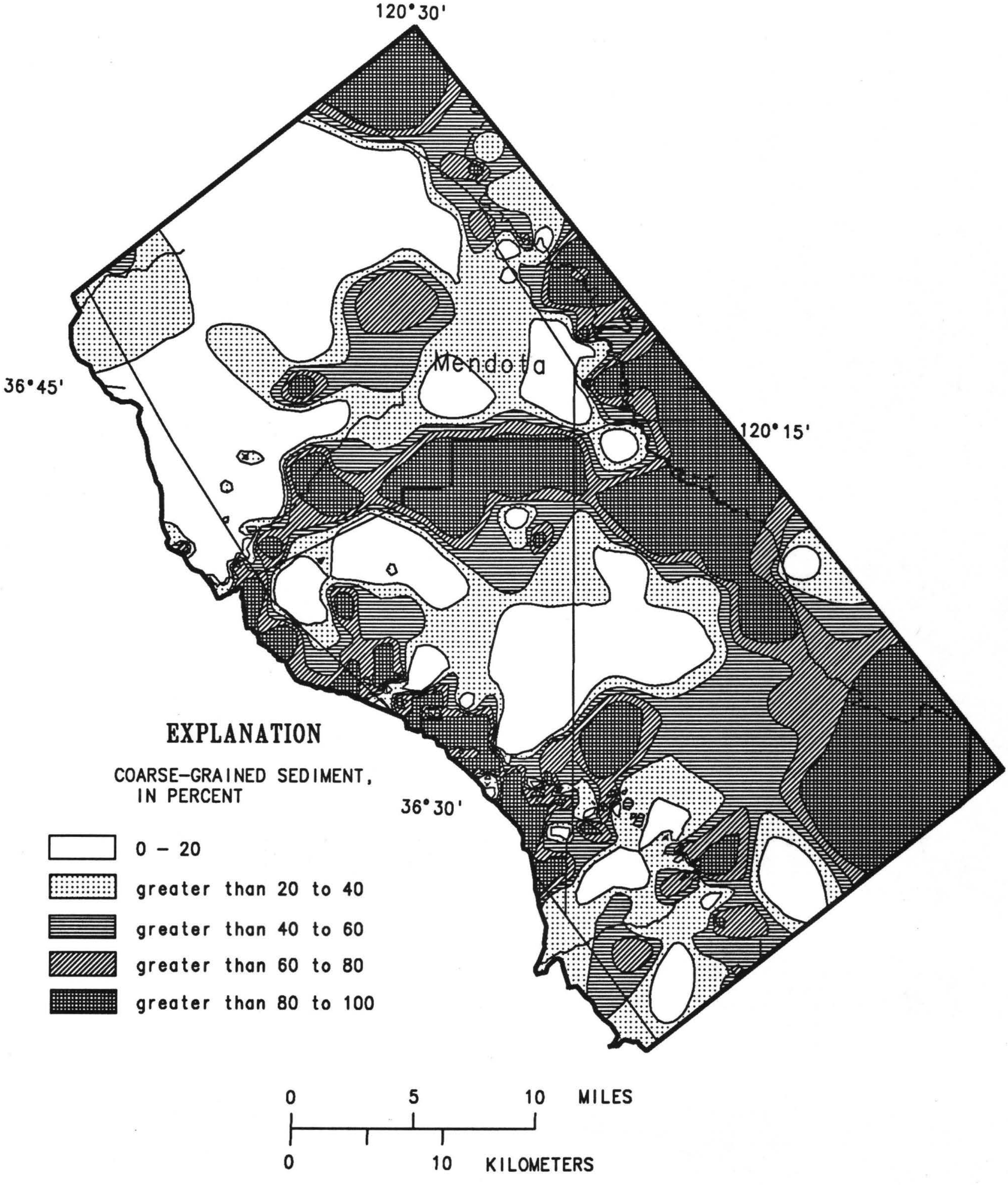

FIGURE 8.--*Sediment texture of the 30- to 40-foot depth interval.*

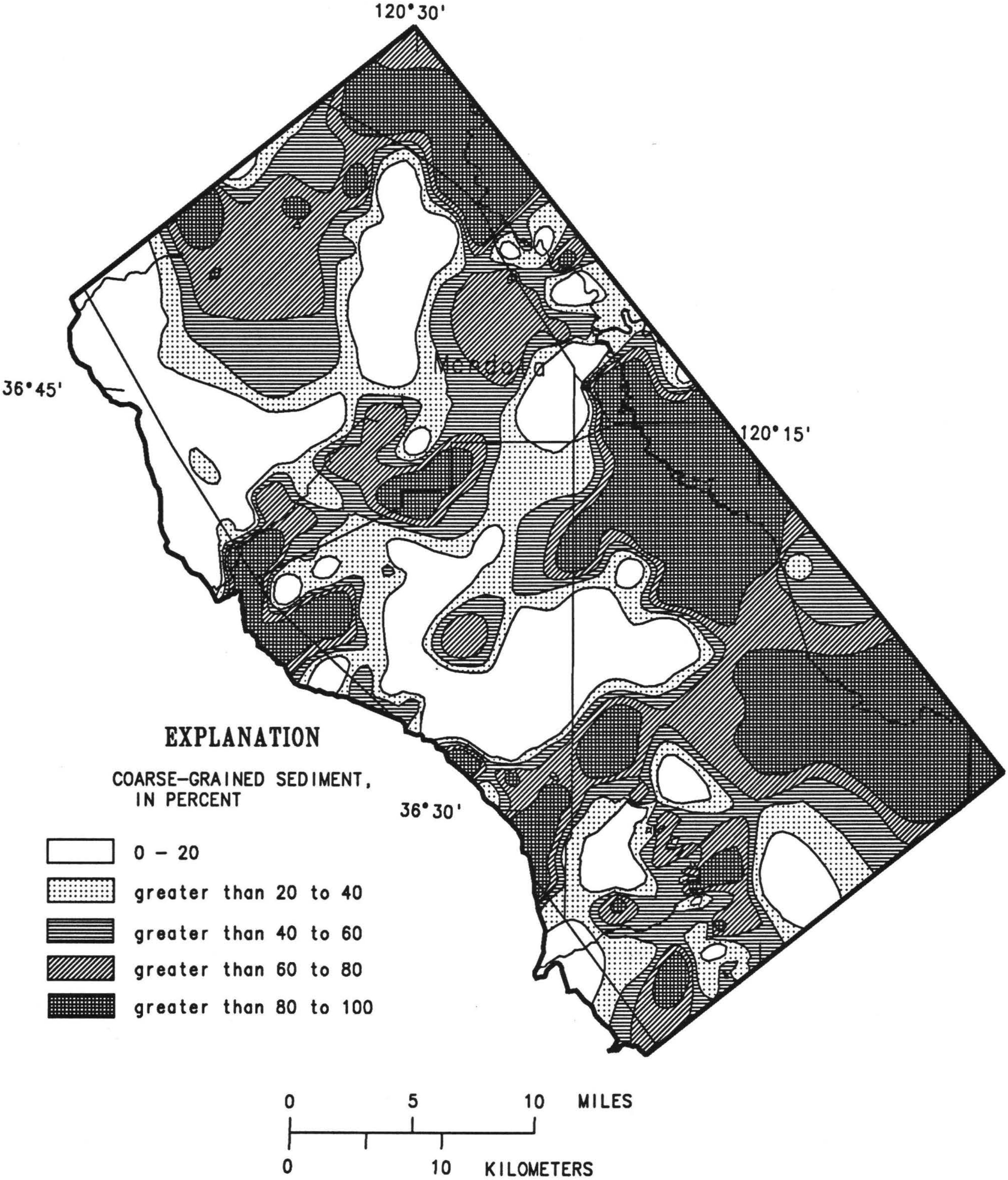

FIGURE 9.--*Sediment texture of the 40- to 50-foot depth interval.*

The five texture maps presented in figures 5-9 document a fining-upward sequence in the Coast Range alluvium and a headward retreat of Coast Range streams. These trends indicate a reduction in surface runoff with time that probably is related to the most recent transition from glacial to interglacial conditions. The Coast Range alluvium mapped in this report may represent a single aggradational event and may correlate with the informally named upper member of the alluvium of San Luis Ranch and alluvium of Patterson of Lettis (1982, 1985, 1988). On the basis of radiocarbon age dates and stratigraphic evidence, Lettis (1982, 1985, 1988) judged these deposits to be late Pleistocene to late Holocene in age with deposition probably beginning about 20,000 years ago.

Prokopovich (1987) and Bull (1964b) also noted changes in texture with depth in the Coast Range alluvium in western Fresno County. Prokopovich (1987) noted a "minor, frequent increase in total thickness of sand beds and the average content of sand fraction with depth" in the upper 14 ft of deposits and suggested that climatic or tectonic changes decreased the erosional and transportation capacity of local streams over time. Bull (1964b) analyzed cores from several test holes drilled from 18 to 30 ft deep on small alluvial fans of ephemeral streams. Bull (1964b) concluded that the depositional history of the fans changed from more common water-laid deposits at depth to more common mudflow deposits nearer the surface. Bull's (1964b) interpretation that the principal mode of deposition on the small fans changed from flowing water to mudflow in the upper 30 ft of deposits suggests a changing climate and decrease in surface runoff.

SUMMARY AND CONCLUSIONS

Texture is used as a basis for mapping the upper 50 ft of deposits in the central part of the western San Joaquin Valley. In the western valley, three hydrogeologic units can be recognized: Coast Range alluvium, Sierran sand, and flood-basin deposits. The Coast Range alluvium comprises most of the sediment in the study area and was deposited as a system of coalescing alluvial fans. At the surface and in the near subsurface, the Coast Range alluvium grades eastward into fine-grained flood-basin deposits. At depth, the Coast Range alluvium grades eastward into fluvial, coarse-grained Sierran sand.

The texture of the Coast Range alluvium varies from greater than 80- to 100-percent coarse grained at the upper fans to 0- to 20-percent coarse grained at the lower fans. Elongate areas of more than 40-percent coarse-grained deposits appear to define paleo-channels in the Coast Range alluvium. The flood-basin deposits range in thickness from 5 to 35 ft and typically are less than 20-percent coarse grained. The Sierran sand generally is greater than 40-percent coarse grained and contains a large proportion of deposits that are greater than 80-percent coarse grained.

Intermittent and ephemeral streams draining the Coast Range and adjacent foothills do not contribute surface discharge to the San Joaquin River under current climatic conditions. In the past, however, streams on the alluvial fans may have been tributary to the axial drainage of the valley. Tributary channel deposits are evident in the Panoche fan at depths of 20 to more than 50 ft, in the Cantua fan from 30 to 40 ft, and in the Arroyo Hondo fan from 40 to 50 ft.

Bifurcation of the channel deposits in the Coast Range alluvium and Sierran sand in the 20- to 40-foot depth interval indicates that flow may have been to the southeast in the valley's axial drainage when this sediment was deposited. If so, the low alluvial divide separating the San Joaquin River and Tulare Lake basin may have been north of its present position when this sediment was deposited. Coast Range drainages then would have been tributary to the Kings River into the internally drained Tulare Lake basin.

The headward retreat of Coast Range stream channels with time and the fining-upward sequence evident in the texture maps indicate a decrease in surface runoff and an increase in aridity with time. The decrease in runoff and increase in aridity can be interpreted as the result of a transition from glacial to interglacial conditions. This transition in climate has been postulated by Lettis (1982, 1985, 1988) to control alluviation in the central part of the western San Joaquin Valley.

The upper 50 ft of the Coast Range alluvium mapped in this investigation may be correlative with Lettis' (1982, 1985, 1988) upper member of the alluvium of San Luis Ranch and alluvium of Patterson. The 50 ft of flood-basin deposits and Sierran sand mapped in this investigation may be correlative with Lettis' (1982, 1985, 1988) alluvium of Dos Palos and Modesto Formation.

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