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DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division

GENERALIZED SUBSURFACE GEOLOGY OF THE WATER-BEARING DEPOSITS

NORTHERN SAN JOAQUIN VALLEY, CALIFORNIA

By

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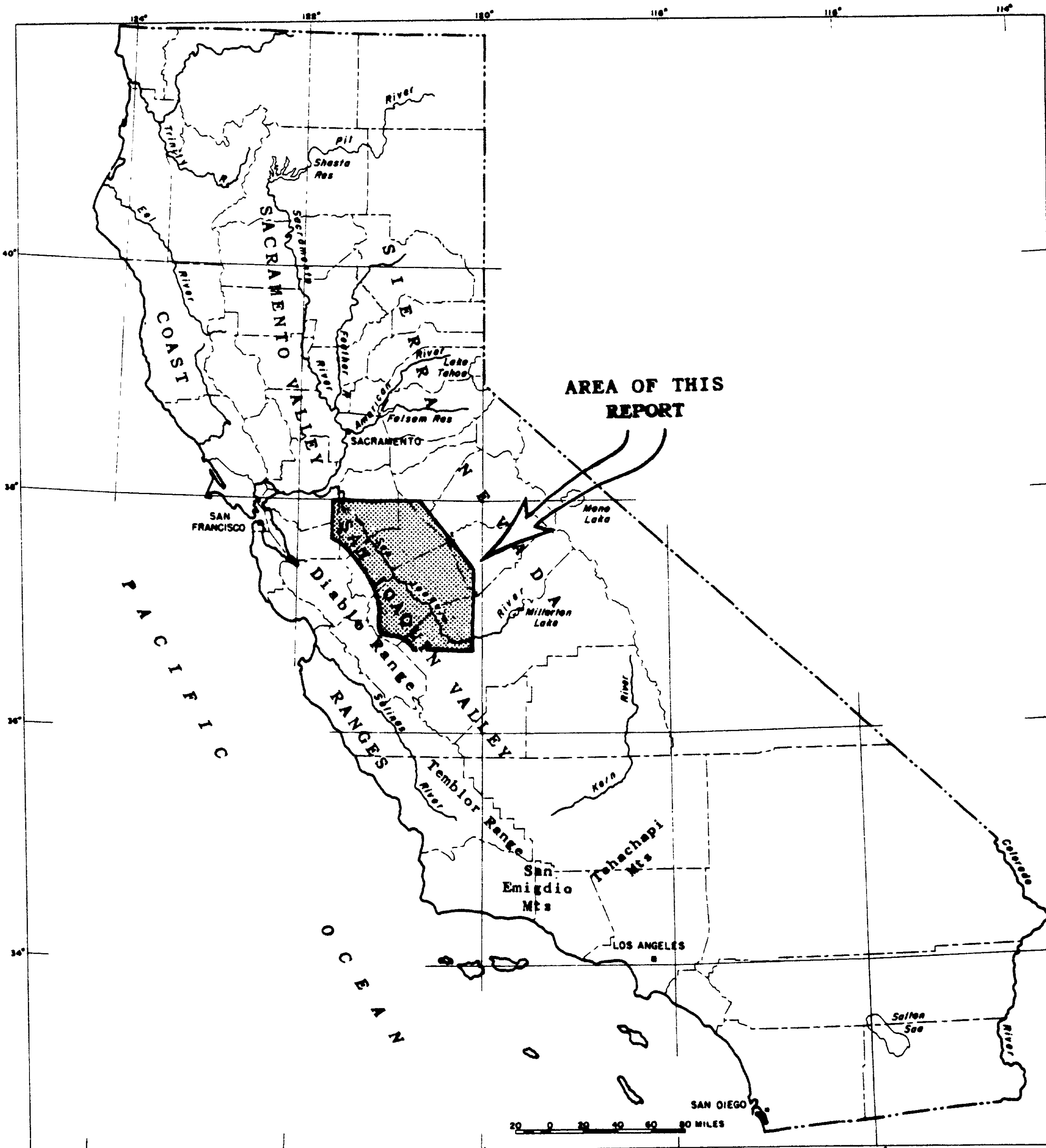


FIGURE 1.--Index map.

GENERALIZED SUBSURFACE GEOLOGY OF THE WATER-BEARING DEPOSITS NORTHERN SAN JOAQUIN VALLEY, CALIFORNIA

By Willaim R. Hotchkiss

ABSTRACT

The study area includes about 5,000 square miles of the northern part of the San Joaquin Valley, a broad structural trough drained by the San Joaquin River. Fresh ground water is mostly in unconsolidated deposits derived from the Coast Ranges on the west and the Sierra Nevada on the east. The interfingering of Coast Range and Sierran alluvium, together with the variability and lenticularity of each, causes variation in the hydrologic properties both vertically and horizontally in San Joaquin Valley deposits. A persistent confining stratum, the Corcoran Clay Member of the Tulare Formation, can be correlated through most of the study area. Informally, the deposits above the clay are termed the upper unit; the clay is termed the confining clay stratum; and the deposits from the bottom of the clay to the base of fresh water, where known, are termed the lower unit. The upper unit is composed of beds, lenses, and tongues of gravel, sand, and clay ranging in thickness from about 100 feet in the north to 500 feet at the south end of the study area. A distinctive "white clay," at or near the base of the upper unit, can be traced across the center of the valley. The confining clay stratum is the greenish to bluish gray lacustrine Corcoran Clay Member of the Tulare Formation; it ranges from 0 to 130 feet in thickness. No attempt to delineate the top and bottom of the Tulare Formation was made because of the thickness and similarity of deposits overlying and underlying the Corcoran. The lower unit is lithologically similar to the upper unit and ranges in thickness, where the base of fresh water has been mapped, from 90 to more than 1,400 feet.

INTRODUCTION

Location and General Features

The Central Valley of California consists of the San Joaquin and the Sacramento Valleys. The San Joaquin Valley (fig. 1), forming the southern two-thirds of the Central Valley, is a broad structural trough. It is bordered on the east by the Sierra Nevada, and on the west by the Diablo and the Temblor Ranges, which are parts of the Coast Ranges. The valley extends 250 miles southeasterly from the confluence of the San Joaquin and the Sacramento Rivers to the Tehachapi and the San Emigdio Mountains. The width of the valley ranges from 25 miles near the Kern River to 55 miles near the Kings River and averages about 35 miles. The study area, the northern half of the San Joaquin Valley, includes about 5,000 square miles.

The warm climate, rich soil, and extensive irrigation make the San Joaquin Valley the largest single agricultural area in the State and one of the most productive agricultural areas in the country. Water from wells makes up the sole irrigation-water supply for about half the irrigated land within the valley, and is a supplemental supply for another quarter of the irrigated area. Ground water is less important as a source of agricultural water in the northern half of the valley. Madera County utilizes ground water for more than half its agricultural demand, but west of the San Joaquin River, water delivered via canals is twice the quantity pumped from wells.

Purpose and Scope

The purpose of this investigation is to map impermeable lacustrine clay deposits in the northern part of the San Joaquin Valley and to describe the fresh-water aquifers briefly. The scope of the investigation includes delineation of major confining beds and associated fresh-water aquifers in the subsurface in sufficient detail to define and describe their thickness, lithology, and stratigraphic relations.

The investigation was made by the U.S. Geological Survey in cooperation with the California Department of Water Resources, as a part of a ground-water studies program in the San Joaquin Valley. The report was prepared under the general supervision of R. Stanley Lord and his successor, Lee R. Peterson, district chiefs in charge of water-resources investigations in California, and under the immediate supervision of Willard W. Dean, chief of the Sacramento subdistrict office.

Previous Studies

The search for oil spurred early systematic geologic investigations by Watts (1894) and Anderson (1912) in the southern part of the San Joaquin Valley. Since that time, most geologic work has been concerned with consolidated oil-bearing rocks of Cretaceous and Tertiary age. Consequently, many publications on the geology of numerous oilfields are available, most of which have been prepared by the California Division of Mines and Geology or the California Division of Oil and Gas. Unconsolidated deposits of late Tertiary and Quaternary age, the subject of this report, overlie the oil-bearing rocks.

Unconsolidated deposits of late Tertiary and Quaternary age have been mapped on the south and west sides of the valley at several places where they truncate the underlying oil-bearing rocks. These deposits were named the Tulare Formation in the Coalinga district by Anderson (1905), and in the Diablo Range by Anderson and Pack (1915). The Tulare Formation was mapped in the foothills of the Techachapi and the San Emigdio Mountains at the south end of the valley by Pack (1920), and by Hoots (1930). Detailed studies of the Tulare Formation have been made by Woodring and others (1932 and 1940) in the Elk and Kettleman Hills. Fresh-water-bearing deposits of late Tertiary and Quaternary age that occur in the vicinity of the Kern River were named the Kern River Beds by Anderson (1905) and were termed the Kern River Series by Diepenbrock (1933). Other important detailed geologic descriptions of surface and subsurface lacustrine and alluvial deposits of Pliocene and Quaternary age include papers by Barbat and Galloway (1934), Frink and Kues (1954), and Klausing and Lohman (1964). Geomorphic studies of alluvial fans in western Fresno County have been made by Bull (1964a and 1964b).

Several ground-water reconnaissance reports, prepared by Federal and State agencies, are available for the San Joaquin Valley. The earliest valley-wide reconnaissance reports, prepared by Mendenhall (1908) and Mendenhall and others (1916) were made when ground-water development was in its infancy. The reports outlined the state of ground-water development, ground-water use, and quality of the water. Later, Harding (1927) made a study of water conditions in the southern part of the valley and outlined areas of insufficient supply.

Davis and others (1959) made a study of ground-water conditions and storage capacity in the San Joaquin Valley. Their report outlined the principal geologic and hydrologic features that control the movement of ground water. They estimated the valley has a storage capacity of 93 million acre-feet available for cyclic storage of water in the interval between 10 and 200 feet in depth below land surface. Later, Davis and others (1964, p. 119) concluded that most of the 93 million acre-feet of ground-water storage capacity is usable, but that more basic information on rates of infiltration, geologic controls, and ground-water movement is needed before firm estimates of usable storage capacity can be made. Geologic and hydrologic reports of adjacent areas within the valley have been made by Davis and Poland (1957), Davis and others (1964), Page and others (1969), Croft (1969), Miller and others (1969), Mitten and others (1970), Bull and Miller (1971), and Hotchkiss and Balding (1971). California Department of Water Resources and U.S. Geological Survey personnel have made numerous investigations of geology and hydrology in the San Joaquin Valley.

Well-Numbering System

In California, the U.S. Geological Survey, the California Department of Water Resources, and other agencies, use a well-numbering system based on rectangular subdivision of public lands. Well 11S/10E-22F1 M (fig. 2), is assigned to a well 6.5 miles south of the city of Los Banos. The part of the number preceding the slash denotes township (T. 11 S.); the number between the slash and the hyphen denotes range (R. 10 E.); the number between the hyphen and the letter denotes the section (sec. 22); the letter following the section number denotes the quarter-quarter section (SE¼, NW¼), generally a 40-acre subdivision; the number following the quarter-quarter section denotes the serial number of the well within that subdivision and identifies the well in time rather than location. The northern part of the San Joaquin Valley lies wholly within the southern quadrant of the Mount Diablo base line and meridian denoted by the final M.

Acknowledgment

The collection of data and successful completion of the investigation for this report were made possible by the cooperation of public agencies, private companies, and individuals. Well logs were furnished by the U.S. Bureau of Reclamation, California Department of Water Resources, ground-water consultants, well drillers, and private-land companies. Copies of electric logs were obtained from commercial blueprint firms or, with the permission of well owners, were made available by Schlumberger Well Surveying Corp., Zublin Well Logging Corp., and the California Division of Oil and Gas.

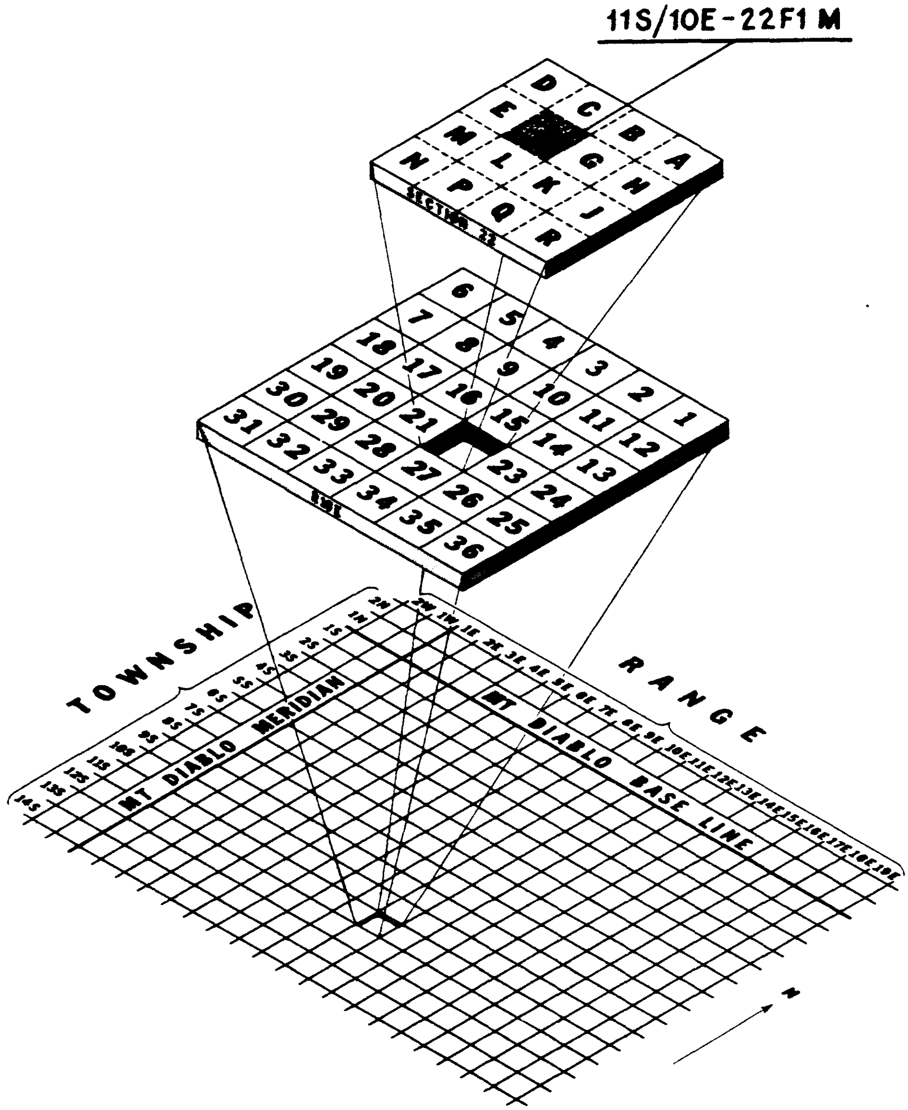


FIGURE 2.--Well-numbering system.

METHOD OF STUDY AND NATURE OF THE DATA

Field and office work for this report was begun in 1968 and completed in November 1971. Because other agencies and the U.S. Geological Survey have collected a vast quantity of well logs and other data, most of the information in this report was assembled from existing files.

The U.S. Bureau of Reclamation, the U.S. Geological Survey, and the California Department of Water Resources have cored, and made detailed lithologic logs of about 36 holes in the fresh-water-bearing deposits in the northern part of the San Joaquin Valley. Most of the core holes were electric logged. Figure 3 shows electric logs and lithology of two selected holes. In addition, the Geological Survey has copies of about 250 electric logs of water wells and logs of auger and reverse-rotary holes on file.

The techniques used for this study are similar to those used in general geologic mapping: beds are separated into informal units, and lateral and vertical changes in lithology and texture are described. Mappable units were identified in drillers' logs and logs of core holes, correlated with electric logs of the same or adjacent wells and then correlated with units in more distant wells. The stratigraphic relations of the deposits are illustrated in the generalized geologic sections (fig. 4). The areal extent of units including structure and thickness are depicted on figures 5 and 6. Electric logs and lithologic logs obtained from drillers were correlated with the few available logs from core holes and used to construct the areal maps and geologic sections.

Unconsolidated continental deposits compose the fresh-water-bearing sediments in the study area. These deposits have been referred to, wholly or in part, as younger alluvium, older alluvium, Turlock Lake Formation of Davis and Hall (1959), China Hat Gravel of Arkley (1962), North Merced Gravel of Arkley (1962), Laguna Formation, and Tulare Formation. Whatever name is locally applied to them, they consist largely of lenticular beds of sand, silt, and clay. In addition to differing widely in extent and thickness, the beds grade both laterally and vertically into one another. Only one persistent, confining stratum, the Pleistocene Corcoran Clay Member of the Tulare Formation, can be correlated through most of the northern San Joaquin Valley. Within the areal extent of this confining unit, an informal three unit subdivision of the fresh-water-bearing continental deposits can be made as follows: An upper unit extending from land surface to the top of the confining clay bed; the confining clay stratum; and a lower unit extending from the base of the confining clay down to the base of the fresh water.

For the purpose of this study, a specific conductance of 3,000 micromhos per centimeter (about 2,000 milligrams per liter dissolved solids) was selected as a measure of the base of fresh ground water (Page, 1971, p. 1).

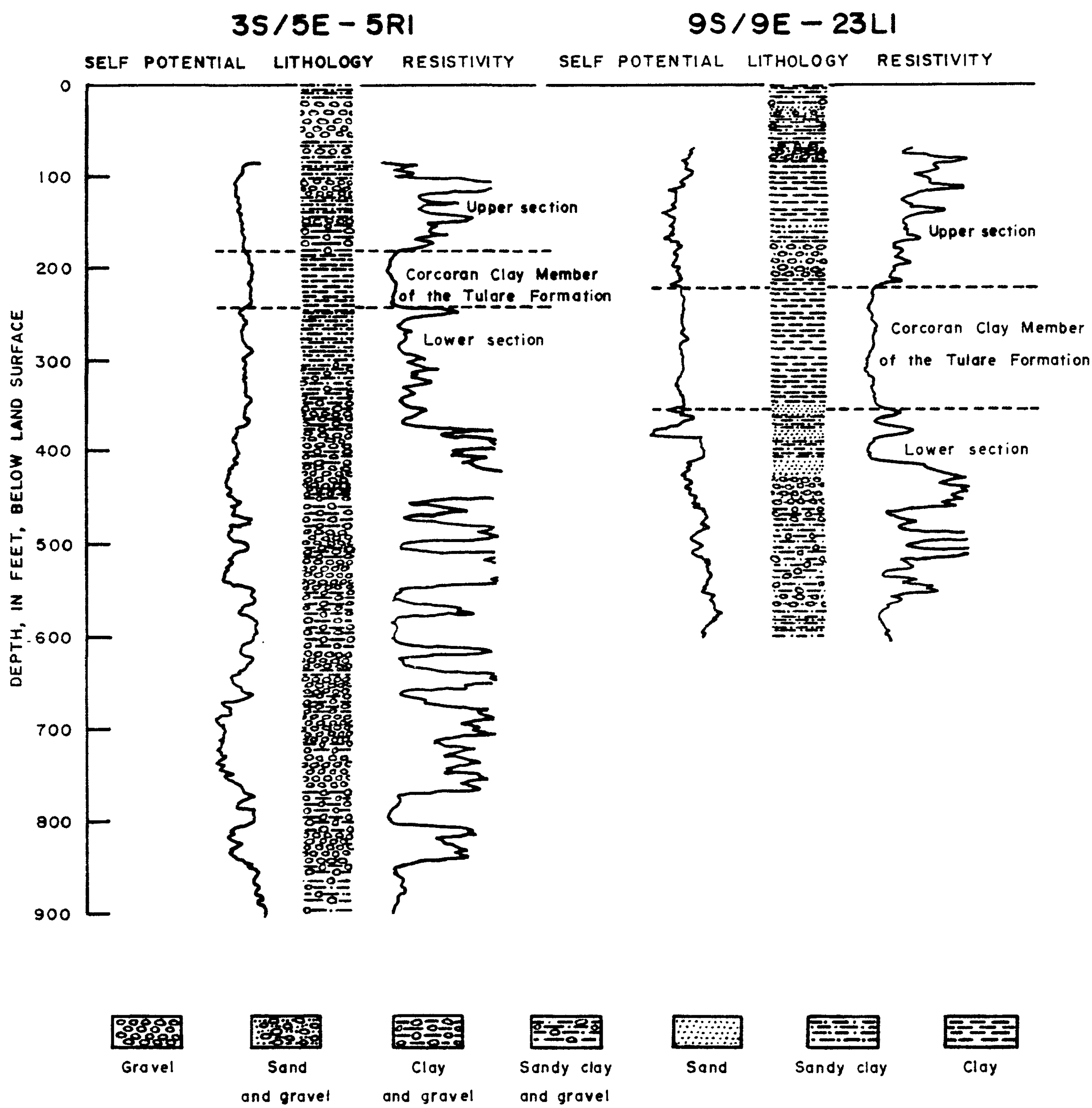


FIGURE 3.--Electric and lithologic logs.

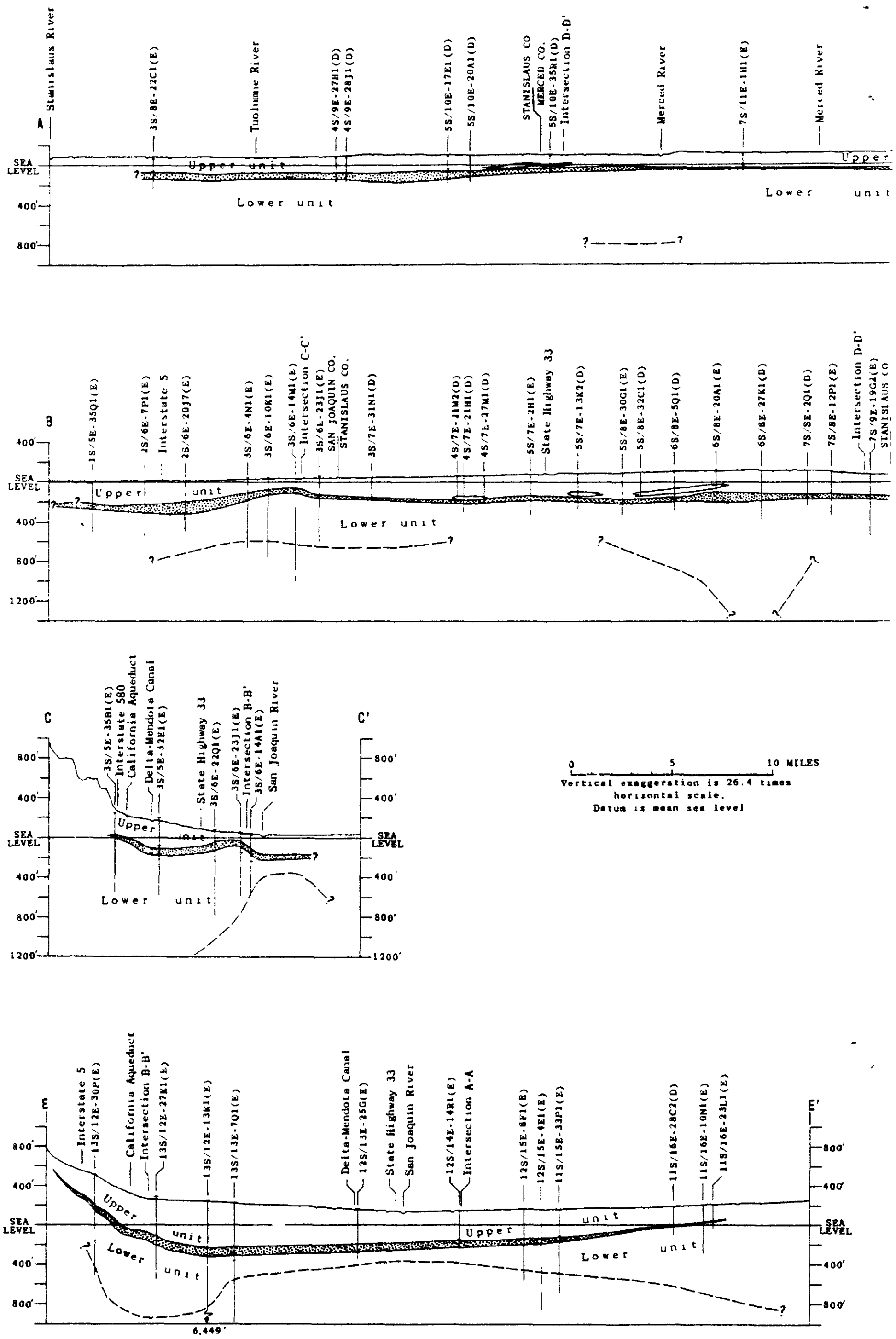
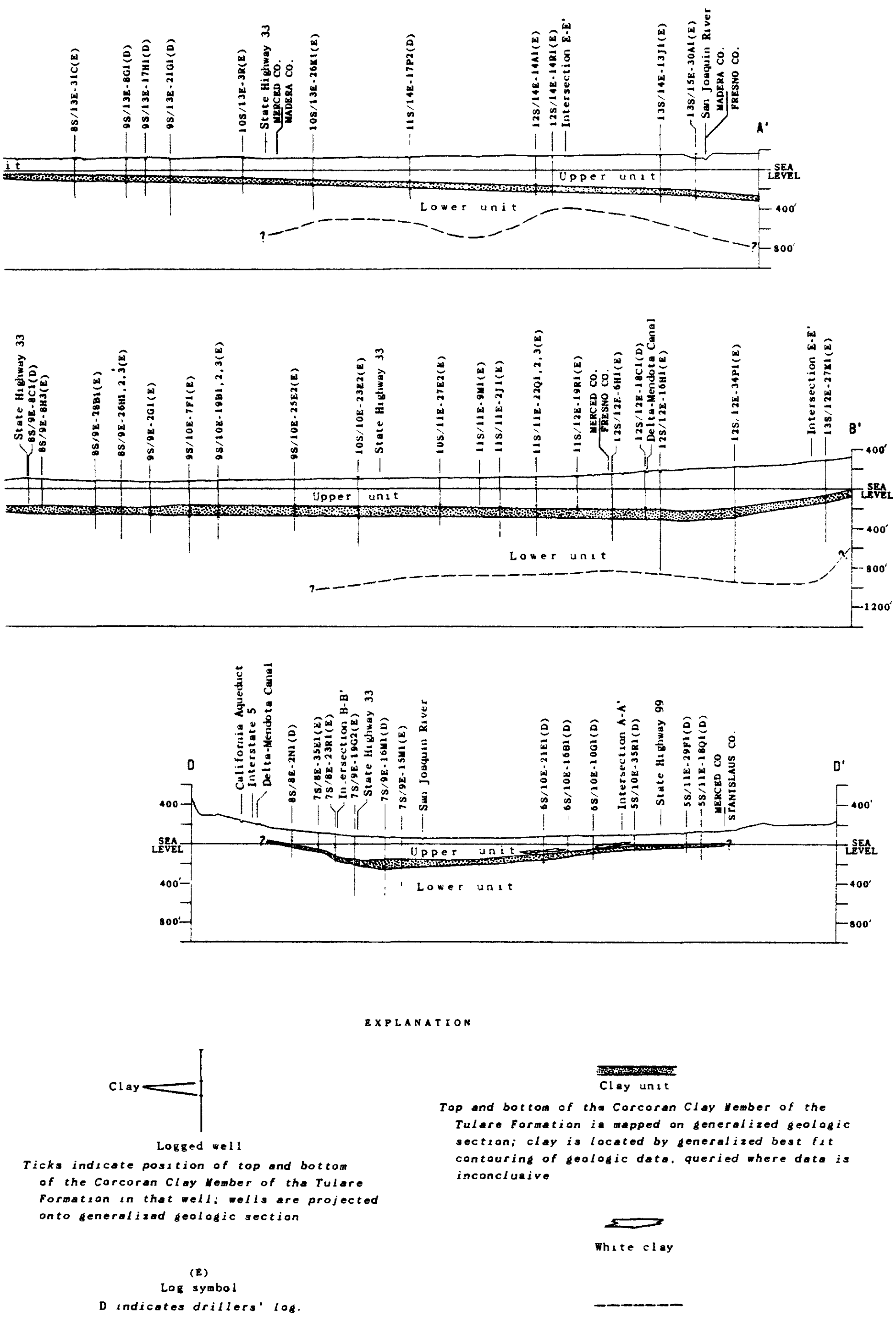
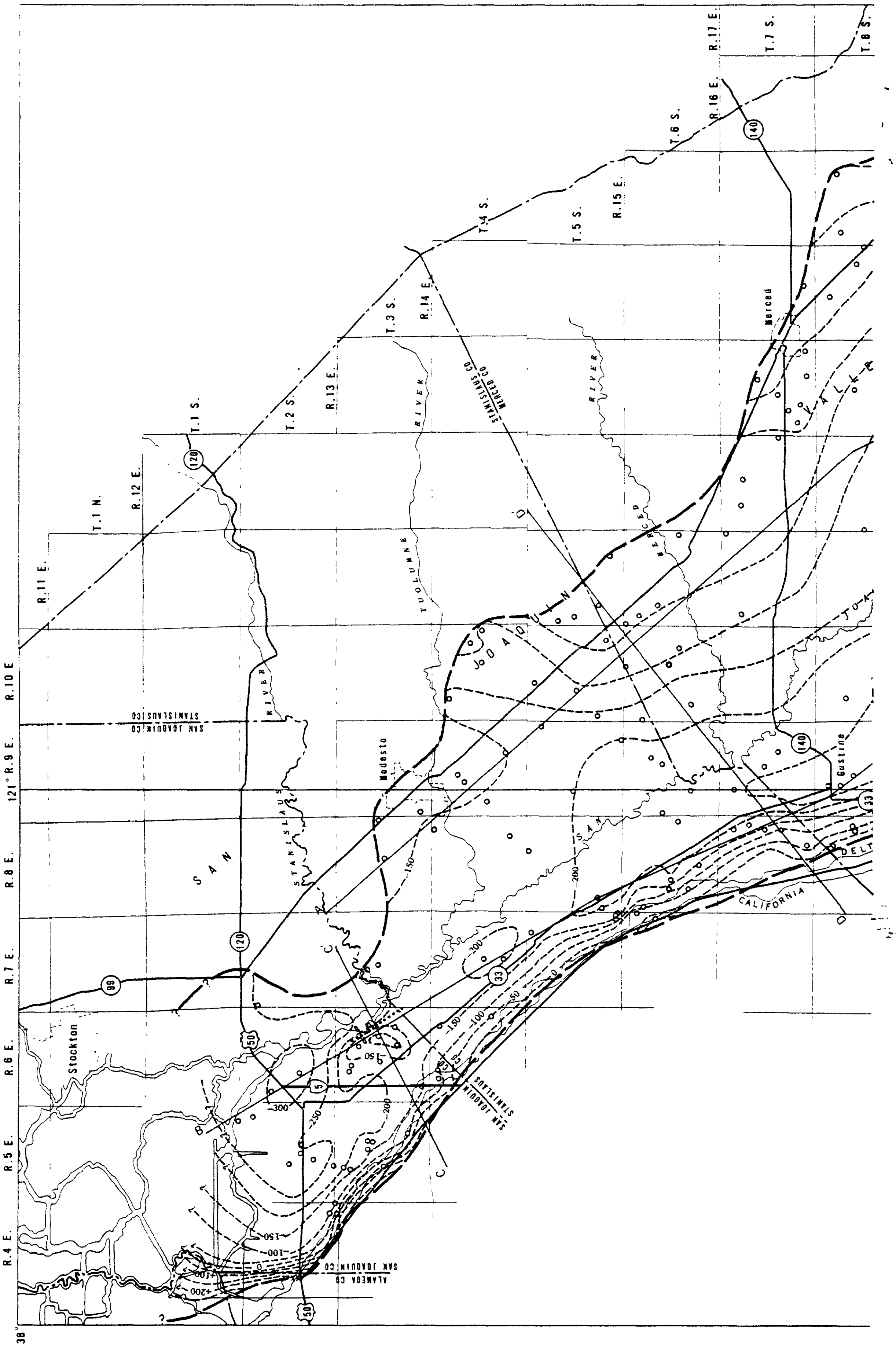


FIGURE 4.--Generalize



jeologic cross sections.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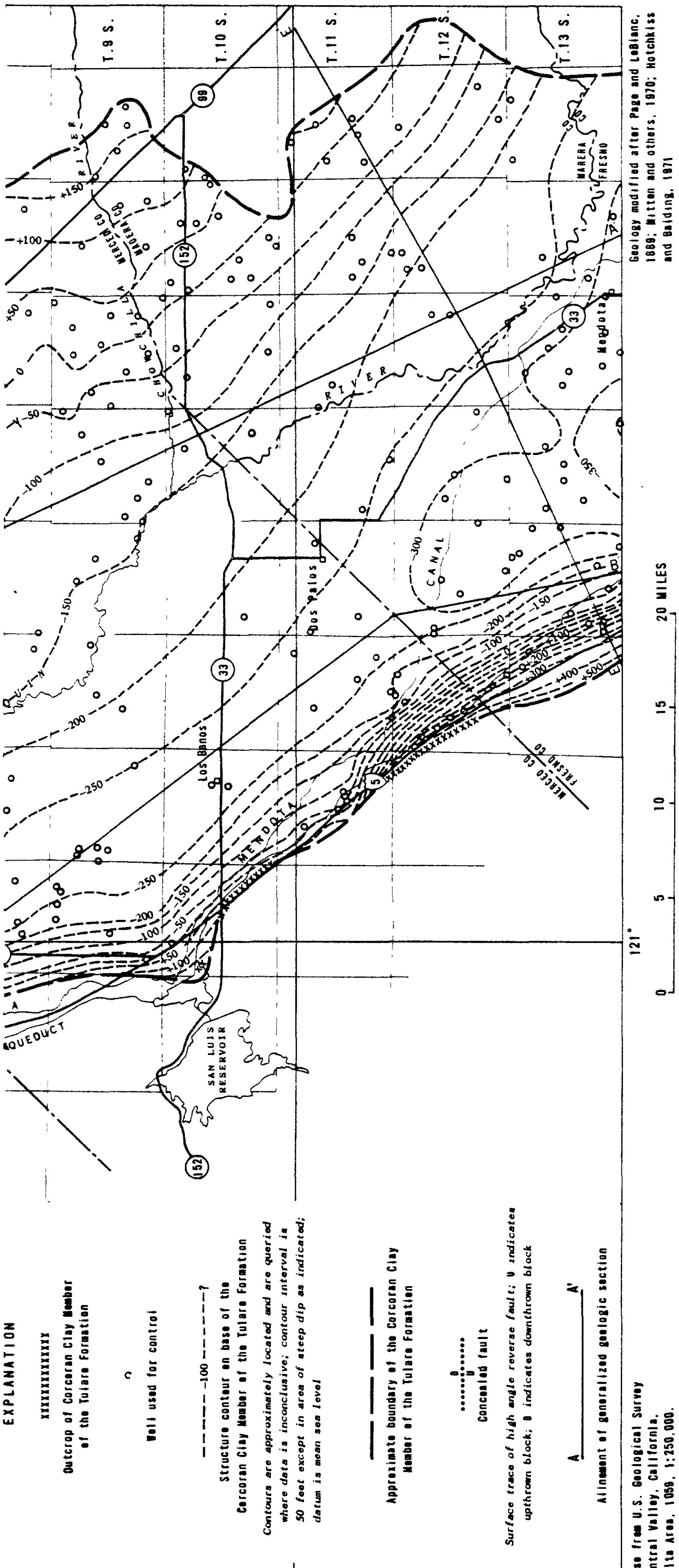
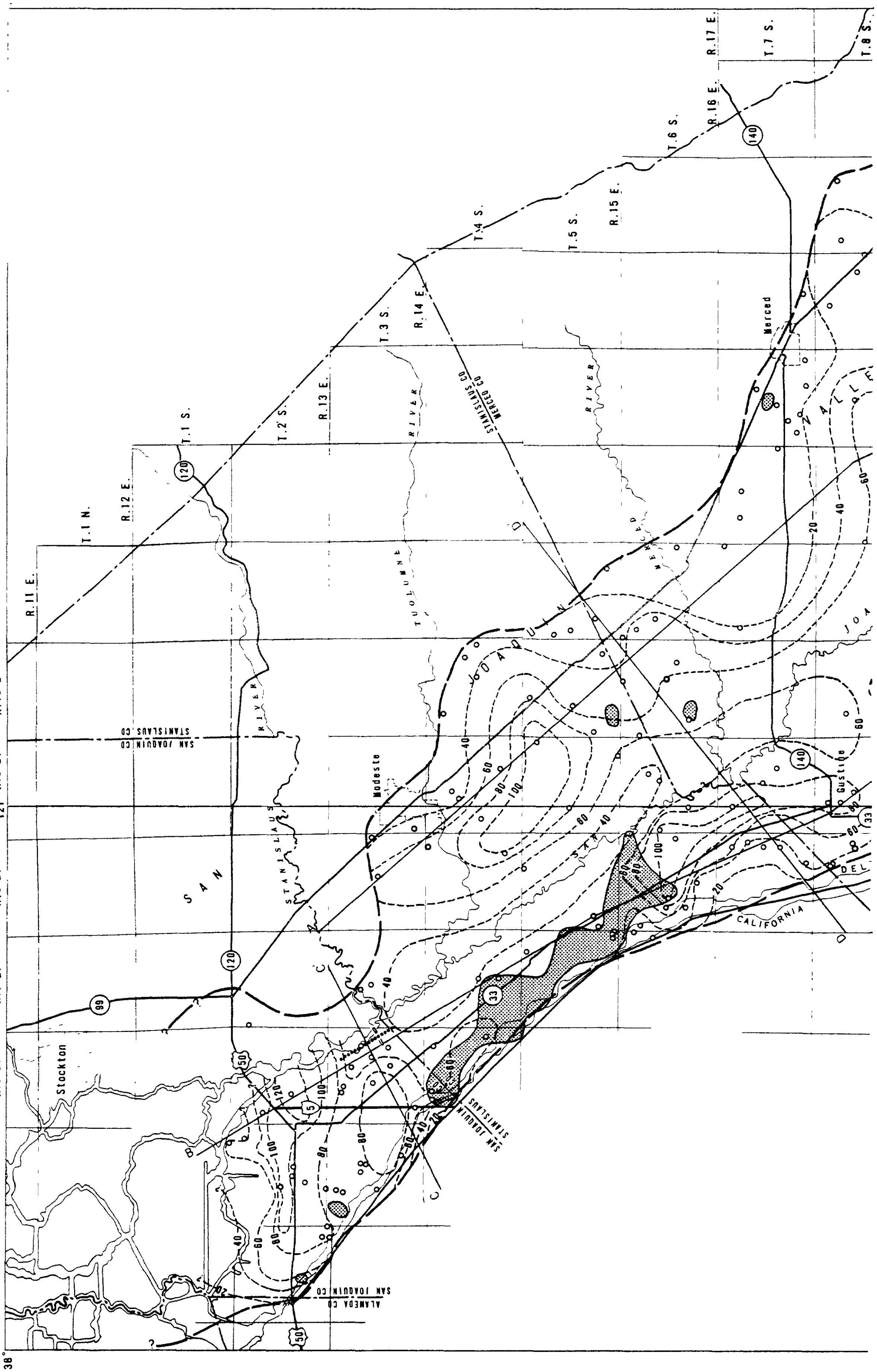


FIGURE 5.--Structure and extent of the Corcoran Clay Member of the Tulare Formation.



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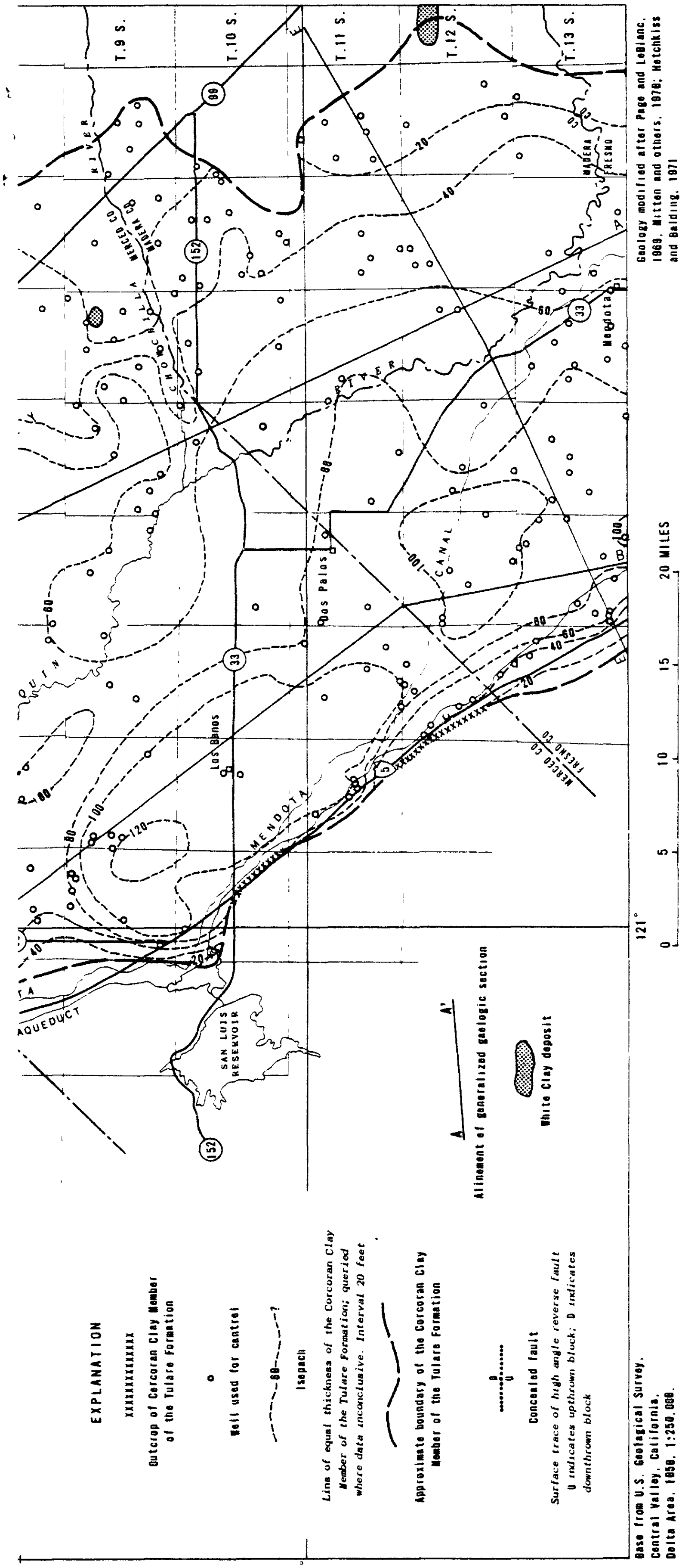

FIGURE 6.--Thickness of the Corcoran Clay Member of the Tulare Formation.

The upper unit consists of beds, lenses, and tongues of clay, sand, and gravel. Sedimentary material of the Diablo Range derived from the Franciscan Formation and from Cretaceous and Tertiary sedimentary rocks forms most of the material deposited west of the San Joaquin River. Arkosic Sierran deposits form most of the sedimentary material deposited east of the river. The complexity of interfingering of material from these two source areas in deposits along the valley axis is compounded by variability and lenticularity of each. Clay strata in excess of 60 feet in thickness, correlated by using drillers' logs, are locally traceable over several miles only to be truncated or undergo facies change between adjacent wells.

The upper unit ranges in thickness from zero where it is exposed along the western valley margin to 150 to 200 feet where it pinches out or is truncated in the subsurface on the east side of the valley (figs. 4 and 6). Except for the extreme northern end of the valley where the upper unit thickens near Tracy, the general trend is for the upper unit to progressively thicken southeastward from about 100 feet at the northern end of the area in T. 3 S. to more than 800 feet at the Tulare Lake bed about 48 miles southeast of the study area (Croft, 1969). The thickness of the upper unit at the southern end of the study area is about 500 feet.

A distinctive deposit of "white clay" (fig. 6) in the upper unit can be traced sporadically westward from a probable source near Friant on the east side of the San Joaquin Valley. In its most extensive deposit, on the west side of the valley in Tps. 4-6 S., the "white clay" ranges in thickness from 30 to 60 feet (Hotchkiss and Balding, 1971). The "white clay" is probably weathered Friant ash that Janda (1966, p. 131) correlated with a volcanic ash immediately overlying the Corcoran Clay Member of the Tulare Formation in the southern part of the San Joaquin Valley. The volcanic deposit exposed near Friant contained sanidine crystals which were dated by G. B. Dalrymple at 600,000±20,000 years, using the potassium-argon method. The same date is assumed to mark the earliest deposition of the upper unit.

A stratum of well-sorted diatomaceous greenish to bluish gray lacustrine clay, underlies the upper unit in the northern part of the San Joaquin Valley. Often referred to as the "blue clay" in drillers' logs, the clay stratum is contiguous with and referred to in this report as the Corcoran Clay Member of the Tulare Formation named by Frink and Kues (1954). The Corcoran was mapped by Miller and others (1969) in the southwestern part of the study area, by Hotchkiss and Balding (1971) in the western part of the study area, and Hotchkiss and Dutcher (1971) in the southeastern part of the area. Various authors have recognized or correlated the Corcoran Clay Member in the northeastern part of the study area, but have included it in formations other than the Tulare Formation. Davis and Hall assigned the lacustrine blue clay to their Riverbank Formation (1959) even though they correlated it with the Corcoran. Arkley (1962), working with geomorphology and soils, also recognized the Corcoran but assigned the clay to the Turlock Lake Formation of Davis and Hall (1959). The Corcoran Clay Member of the Tulare Formation is easily recognized from its characteristic resistivity curve on electric logs (fig. 3).

Structure contours on the base of the Corcoran (fig. 5) show the clay is warped broadly in an asymmetric syncline that may terminate to the north in a basin under the delta of the San Joaquin and Sacramento Rivers. To the south the syncline plunges toward the Tulare Lake bed south of the present study area (Croft, 1969). The structure of the clay generally represents the structure of the fresh-water-bearing deposits of the northern part of the San Joaquin Valley. The Corcoran crops out sporadically on the west margin of the valley where it has been arched up adjacent to the Coast Ranges. Beneath the eastern part of the valley, it pinches out or terminates abruptly in the subsurface. The thickness of the clay (fig. 6) ranges from 0 to 130 feet in the northern part of the San Joaquin Valley.

The lower unit underlies the confining clay stratum and is similar to the upper unit in texture and composition. It extends downward from the base of the Corcoran to the base of fresh water mapped by Page (1971, fig. 4). Data were insufficient to separate the Diablan and Sierran deposits, but they are assumed to be lenticular and interfingering similar to those of the upper unit. Immediately prior to deposition of the Corcoran, the river probably was east of its present position (Hotchkiss and Balding, 1971) and the interfingering of Diablan and Sierran deposits probably extended farther east during pre-Corcoran deposition. Where data are available on the base of fresh water, the thickness of the lower unit ranges from 90 to greater than 1,400 feet.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division
District Office
855 Oak Grove Avenue
Menlo Park, California 94025

January 22, 1973

BASIC DATA FOR THE CORCORAN CLAY MEMBER OF THE TULARE FORMATION IN THE NORTHERN PART OF THE SAN JOAQUIN VALLEY, CALIFORNIA

CONTENTS

PURPOSE AND SCOPE

This compilation presents data collected in the San Joaquin Valley, in cooperation with the California Department of Water Resources, on the depth and thickness of the Corcoran Clay Member of the Tulare Formation. Its purpose is to supplement the specific appraisal study, "Generalized Subsurface Geology of the Water-Bearing Deposits, Northern San Joaquin Valley, California," by W. R. Hotchiss, 1972.

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Table 1.-- *Data on depth, altitude, and thickness of the Corcoran Clay Member of the Tulare Formation*

[*Type of log:* *C* core, *D* driller's, *E* electrical, and *G* geologists]

Well number	Type of log	Depth below land surface (feet)			Altitude above (+) or below (-) mean sea level (feet)			Thickness (feet)
		Well	Top of clay	Base of clay	Land surface	Top of clay	Base of clay	
002S004E36L01M	DE	600	173	254	+154	-019	-100	081
002S004E36P01M	DE	695	68	138	+180	+112	+042	070
002S005E21D01M	DE	1148	203	308	+028	-175	-280	105
002S005E21Q01M	DE	895	211	309	+047	-164	-262	098
002S005E22Q01M	DE	1136	190	278	+050	-140	-228	088
002S005E28L01M	DE	930	244	338	+065	-179	-273	094
002S005E32R01M	DE	800	262	339	+080	-182	-259	077
002S006E07P01M	DE	655	235	325	+016	-219	-309	090
002S006E20J05M	DE	515	222	350	+017	-205	-333	128
002S006E20J06M	DE	515	224	349	+017	-207	-332	125
002S006E20J07M	DE	512	229	358	+016	-213	-342	129
002S007E07D M	E	10600	198	232	+023	-175	-209	034
003S005E02E01M	DE	837	270	346	+107	-163	-239	076
003S005E05J01M	DE	669	260	338	+128	-132	-210	078
003S005E15R01M	DE	883	248	310	+135	-113	-175	062
002S007E05R01M	D	325	242	280	+030	-212	-250	038
003S005E15D01M	DE	690	249	324	+157	-092	-167	075
003S005E15F01M	DE	755	255	330	+140	-115	-190	075
003S005E20A01M	DE	851	91	168	+234	+143	+066	077
003S005E26H01M	DE	782	268	348	+242	-026	-106	080
003S005E35R01M	DE	804	238	298	+253	+015	-045	060
003S006E04N01M	DE	600	127	214	+053	-074	-161	087
003S006E05R01M	DE	775	138	248	+057	-081	-191	110
003S006E08N01M	D	668	258	329	+070	-188	-259	071
003S006E10K01M	DE	800	115	172	+045	-070	-127	057
003S006E14A01M	DE	611	210	262	+028	-182	-234	052
003S006E14A02M	DE	389	206	258	+030	-176	-228	052
003S006E16E01M	D	718	246	340	+072	-174	-268	094
003S006E16L01M	DE	811	167	258	+073	-094	-185	091
003S006E17D01M	DE	600	216	293	+073	-143	-220	077
003S006E22Q01M	DE	879	112	183	+083	-029	-100	071
003S006E23J01M	DE	650	156	208	+060	-096	-148	052
003S006E32E01M	DE	800	288	356	+205	-083	-151	068
003S006E33Q01M	DE	555	198	275	+154	-044	-121	077
003S007E09P01M	DE	276	181	230	+035	-146	-195	049
003S007E16K M	E	11000	182	228	+046	-136	-182	046
003S008E13J01M	D	380	170	191	+078	-092	-113	021
003S008E22C01M	DE	310	125	191	+064	-061	-127	066
003S008E24C01M	D	467	223	229	+073	-150	-156	006
003S009E29R01M	D	260	175	200	+087	-088	-113	025
004S006E04F01M	DE	623	234	282	+188	-046	-094	048
004S006E05G01M	E	715	274	344	+214	-060	-130	070
004S006E24P01M	DE	475	130	200	+153	+023	-047	070
004S006E25F01M	DE	442	128	197	+175	+047	-022	069
004S006E36C01M	DE	475	133	188	+216	+083	+028	055
004S008E01D01M	D	250	175	240	+071	-104	-169	065
004S008E26R01M	D	230	130	230	+050	-080	-180	100
004S009E05P01M	D	195	158	190	+058	-100	-132	032
004S009E09K01M	D	240	172	204	+086	-086	-118	032
004S009E16D01M	D	244	172	208	+094	-088	-124	036
004S009E19H01M	D	245	145	237	+073	-072	-164	092
004S009E19N02M	D	248	165	246	+065	-100	-181	081
004S009E27H01M	D	248	170	238	+077	-093	-161	068
004S009E28J01M	D	260	183	260	+075	-108	-185	077
004S010E08C01M	D	515	250	271	+112	-138	-159	021
004S010E14H01M	D	505	178	214	+130	-048	-084	036
004S010E22R01M	D	504	200	240	+118	-082	-122	040
004S010E24R01M	D	372	208	246	+130	-078	-116	038
005S007E02H01M	DE	395	196	243	+085	-111	-158	047
005S007E36J01M	DE	807	242	302	+140	-102	-162	060
005S007E36K01M	DE	640	229	298	+141	-088	-157	069
005S007E36J02M	DE	608	239	285	+140	-099	-145	046
005S008E02R01M	D	222	168	181	+050	-118	-131	013
005S008E03A01M	DE	150	142	200	+053	-089	-147	058
005S008E30G01M	DE	423	262	320	+095	-167	-225	058
005S008E30L01M	D	500	251	295	+101	-150	-194	044
005S009E01Q01M	D	262	130	250	+081	-049	-169	120
005S009E27H01M	D	210	145	210	+066	-079	-144	065
005S009E35K01M	D	252	210	250	+067	-143	-183	040
005S009E35R01M	D	268	206	264	+065	-141	-199	058
005S010E01F01M	D	264	159	193	+116	-043	-077	034
005S010E04F01M	D	240	167	240	+099	-068	-141	073
005S010E15N01M	D	154	99	154	+094	-005	-060	055
005S010E17A01M	D	232	165	184	+093	-072	-091	019
005S010E17F01M	D	280	130	192	+087	-043	-105	062
005S010E20A01M	D	254	147	191	+088	-059	-103	044
005S010E25N01M	DE	226	110	142	+103	-007	-039	032
005S010E27R01M	D	250	165	204	+096	-069	-108	039
005S010E30F01M	D	265	163	236	+078	-085	-158	073
005S010E32A01M	D	255	170	215	+086	-084	-129	045
005S010E33F01M	D	240	160	210	+086	-074	-124	050
005S010E34J01M	D	320	175	204	+094	-081	-110	029
005S010E35R01M	D	176	150	176	+096	-054	-080	026
005S011E06Q01M	D	175	75	130	+120	+045	-010	055
005S011E07P01M	D	288	100	135	+115	+015	-020	035
005S011E18Q01M	D	272	106	140	+115	+009	-025	034
005S011E29F01M	D	278	115	146	+120	+005	-026	031
005S011E19R01M	D	304	100	128	+115	+015	-013	028
005S011E30K01M	D	162	105	160	+109	+004	-051	055
005S011E35Q01M	D	332	120	131	+138	+018	+007	011
006S007E01R01M	DE	702	182	208	+197	+015	-011	026
006S007E13R01M	DE	646	220	247	+303	+083	+056	027
006S008E07E01M	DE	657	208	244	+181	-027	-063	036
006S008E17P01M	DE	662	207	290	+155	-052	-135	083
006S008E20A01M	E	365	231	343	+145	-086	-198	112
006S008E28J01M	DE	937	245	272	+142	-103	-130	027
006S009E15E M	E	1383	236	276	+068	-168	-208	040
006S009E18E01M	DE	620	195	315	+076	-119	-239	120
006S009E29R01M	DE	235	217	284	+058	-159	-226	067
006S009E10R M	D	420	239	273	+061	-178	-212	034
006S010E03C01M	D	303	124	170	+089	-035	-081	046
006S010E04D01M	D	227	134	166	+084	-050	-082	032
006S010E05N01M	D	262	165	257	+075	-090	-182	092
006S010E05R01M	D	230	126	230	+080	-046	-150	104
006S010E07D01M	D	270	185	250	+071	-114	-179	065
006S010E07Q01M	D	272	140	265	+071	-069	-194	125
006S010E08H01M	D	242	128	242	+074	-054	-168	114
006S010E09R01M	D	266	119	235	+081	-038	-154	116
006S010E09Q02M	D	271	119	265	+084	-035	-181	146
006S010E10G01M	D	248	115	182	+085	-030	-097	067
006S010E11N01M	D	350	113	210	+090	-023	-120	097
006S010E12K01M	D	180	127	160	+097	-030	-063	033
006S010E15F01M	D	266	132	187	+085	-047	-102	055
006S010E15P01M	D	195	135	195	+085	-050	-110	060
006S010E15Q01M	D	130	172	226	+085	-037	-141	104
006S010E16R01M	D	270	142	270	+082	-060	-188	128
006S010E18J01M	D	250	148	250	+075	-073	-175	102
006S010E19C01M	D	190	115	190	+073	-042	-117	075
006S010E20J01M	D	280	152	280	+079	-073	-201	128
006S010E21E01M	D	280	190	260	+080	-110	-180	070

Table 1.--*Continued*

Well number	Type of log	Depth below land surface (feet)			Altitude above (+) or below (-) mean sea level (feet)			Thickness (feet)
		Well	Top of clay	Base of clay	Land surface	Top of clay	Base of clay	
006S010E23G01M	D	184	130	183	+095	-035	-088	053
006S010E23N01M	D	184	105	176	+095	-010	-081	071
006S010E29D01M	D	264	190	264	+074	-116	-190	074
006S011E05C01M	D	265	100	170	+111	+011	-059	070
006S011E06Q01M	D	252	105	150	+103	-002	-047	045
006S011E07Q02M	D	180	95	150	+105	+010	-045	055
006S011E09C01M	D	205	108	132	+122	+014	-010	024
006S011E16J02M	D	115	104	108	+120	+016	+012	004
006S011E17C01M	D	184	99	150	+101	+002	-049	051
006S011E24H01M	D	186	139	161	+140	+001	-021	022
007S008E01N01M	D	415	235	296	+104	-131	-192	061
007S008E12P01M	DE	427	246	283	+104	-142	-179	037
007S008E13N02M	DE	360	219	245	+107	-112	-138	026
007S008E22A01M	DE	305	80	99	+128	+048	+029	019
007S008E22R01M	E	230	108	131	+114	+006	-017	023
007S008E23R01M	DE	341	108	137	+106	-002	-031	029
007S009E35F01M	DE	219	138	180	+120	-018	-060	042
007S009E05Q01M	DE	401	210	310	+072	-138	-238	100
007S009E15M01M	DE	524	230	306	+065	-165	-241	076
007S009E16M01M	D	610	257	328	+071	-186	-257	071
007S009E17R01M	D	622	243	322	+072	-171	-250	079
007S009E19G02M	DE	621	250	293	+086	-164	-207	043
007S009E32F01M	D	600	250	402	+088	-162	-314	152
007S010E23K01M	GE	303	158	224	+090	-078	-144	066
007S011E01H01M	GE	200	118	130	+118		-012	012
007S011E07H02M	D	232	172	192	+099	-073	-093	020
007S011E21P01M	E	185	168	185	+093	-075	-092	017
007S012E06H02M	D	220	145	146	+127	-018	-019	001
007S012E08G01M	O	200	145	148	+125	-020	-023	003
007S012E10F01M	D	225	146	155	+140	-006	-015	009
007S012E24J01M	D	274	127	140	+136	+009	-004	013
007S013E15G01M	D	130	84	90	+158	+074	+068	006
007S013E21K01M	D	238	123	134	+150	+027	+016	011
007S013E29G01M	D	183	89	104	+140	+051	+036	015
007S013E30R02M	D	150	110	125	+135	+025	+010	015
007S013E32A01M	D	412	110	129	+140	+030	+011	019
007S013E34H01M	D	394	98	106	+145	+047	+039	008
007S013E36F01M	D	292	96	118	+156	+060	+038	022
007S014E34G M	E	4110	155	173	+192	+037	+019	018
007S014E35B01M	O	163	163	176	+192	+029	+016	013
008S008E02N01M	D	285	76	113	+146	+070	+033	037
008S008E13F01M	OE	279	136	194	+137	+001	-057	058
008S009E11H01M	DE	678	261	316	+072	-189	-244	055
008S009E26H01M	DE	582	269	346	+075	-194	-271	077
008S009E28B01M	DE	497	270	343	+090	-180	-253	073
008S009E28M01M	OE	801	270	321	+099	-171	-222	051
008S010E08P01M	E	430	240	292	+074	-166	-218	052
008S010E16E01M	D	642	281	315	+075	-206	-240	034
008S010E21L01M	DE	600	229	312	+075	-154	-237	083
008S010E29D01M	D	640	260	332	+074	-186	-258	072
008S011E36D M	E	405	172	235	+090	-082	-145	063
008S011E36H M	O	415	174	224	+091	-083	-133	050
008S012E19D M	E	270	161	222	+092	-069	-130	061
008S012E31D M	E	405	172	223	+090	-082	-133	051
008S012E31G M	D	415	162	230	+090	-072	-140	068
008S012E31M01M	D	415	174	224	+092	-082	-132	050
008S013E03G M	D	134	110	132	+141	+031	+009	022
008S013E16A01M	D	352	150	240	+134	-016	-106	090
008S013E16J01M	D	357	150	210	+135	-015	-075	060
008S013E31C01M	E	396	165	230	+115	-050	-115	065
008S014E04R01M	D	587	56	87	+175	+119	+088	031
008S014E13A01M	D	82	68	76	+195	+127	+119	008
008S014E14J01M	D	120	80	118	+186	+106	+068	038
008S014E24A01M	O	397	54	100	+193	+139	+093	046
008S014E26R M	E	4906	140	167	+186	+046	+019	027
008S015E07J01M	D	225	76	115	+205	+129	+090	039
008S015E07N M	E	3759	95	111	+205	+110	+094	016
008S015E11G01M	D	405	125	130	+230	+105	+100	005
008S015E25L M	E	280	35	68	+240	+205	+172	033
008S015E27J M	E	3353	59	74	+235	+176	+161	015

Well number	Type of log	Depth below land surface (feet)			Altitude above (+) or below (-) mean sea level (feet)			Thickness (feet)
		Well	Top of clay	Base of clay	Land surface	Top of clay	Base of clay	
009S009E02G01M	DE	520	269	342	+079	-190	-263	073
009S009E02L01M	DE	500	273	338	+081	-192	-257	065
009S009E03G03M	DE	308	267	324	+086	-181	-238	057
009S009E03R01M	DE	350	244	330	+084	-160	-246	086
009S009E13F01M	OE	560	250	370	+087	-163	-283	120
009S009E23L01M	DE	483	222	352	+100	-122	-252	130
009S010E06A02M	E	608	247	320	+078	-169	-242	073
009S010E07F01M	DE	729	246	353	+083	-163	-270	107
009S010E07K01M	OE	709	257	365	+081	-176	-284	108
009S010E18G01M	DE	702	265	370	+087	-178	-283	105
009S010E18M01M	DE	785	252	367	+084	-168	-283	115
009S010E18N01M	DE	644	253	273	+085	-168	-188	020
009S010E19B01M	DE	310	251	370	+084	-167	-286	119
009S010E25E02M	E	517	240	340	+089	-151	-251	100
009S011E12B M	E	942	195	250	+090	-105	-160	055
009S011E13D M	E	888	220	260	+094	-126	-166	040
009S011E16H01M	E	300	202	283	+091	-111	-192	081
009S011E20J01M	C	800	229	306	+089	-140	-217	077
009S011E29R M	E	400	230	305	+100	-130	-205	075
009S012E05C M	OE	560	158	232	+095	-063	-137	074
009S012E05G M	E	963	170	240	+096	-074	-144	070
009S012E05H M	E	408	193	252	+096	-097	-156	059
009S012E05P01M	E	800	195	243	+095	-100	-148	048
009S012E08H01M	E	452	178	235	+095	-083	-140	057
009S012E06D01M	E		185	240	+092	-093	-148	055
009S012E08P M	E	392	203	242	+095	-108	-147	039
009S012E08Q M	E	410	203	242	+096	-107	-146	039
009S012E09K01M	OE	528	198	240	+098	-100	-142	042
009S012E13G01M	E	660	197	242	+103	-094	-139	045
009S012E13R01M	E	670	197	242	+103	-094	-139	045
009S012E14F01M	E	590	184	243	+103	-081	-140	059
009S012E16F01M	E	470	194	243	+098	-096	-145	049
009S012E17H01M	E	700	180	240	+095	-085	-145	060
009S012E24Q01M	E	622	195	251	+102	-093	-149	056
009S012E25M01M	OE	600	198	258	+105	-093	-153	060
009S012E25L01M	E	700	199	256	+105	-094	-151	057
009S012E26G01M	E	627	195	257	+105	-090	-152	062
009S013E01J01M	D	339	140	178	+137	-003	-041	038
009S013E08G01M	D	400	188	240	+113	-075	-127	052
009S013E11K M	D	321	145	212	+131	-014	-081	067
009S013E17C01M	D	439	184	246	+111	-073	-135	062
009S013E19P01M	E	620	205	246	+104	-101	-142	041
009S013E21G01M	D	580	180	230	+117	-063	-113	050
009S013E21M01M	DE	550	180	240	+116	-064	-124	060
009S013E25D01M	D	280	156	230	+135	-021	-095	074
009S013E29L01M	DE	865	202	248	+110	-092	-138	046
009S013E30N01M	DE	576	203	261	+107	-096	-154	058
009S013E33C01M	DE	950	172	242	+114	-058	-128	070
009S014E09A M	E	347	128	142	+170	+042	+028	014
009S014E11C01M	D	256	90	110	+170	+080	+060	020
009S014E11P01M	D	262	170	200	+173	+003	-027	030
009S014E15L01M	D	236	138	160	+166	+028	+006	022
009S014E15P01M	D	237	134	160	+166	+032	+006	026
009S014E18A01M	D	206	134	206	+146	+012	-060	072
009S014E18F01M	D	240	130	240	+143	+013	-097	110
009S014E19D M	D		150	212	+142	-008	-070	062
009S014E20R01M	D	483	150	200	+155	+005	-045	050
009S014E22C01M	D	525	135	150	+166	+031	+016	015
009S014E23A01M	D	530	128	140	+178	+050	+038	012
009S014E26J01M	D	534	140	156	+177	+037	+021	016
009S014E27H01M	D	133	130	149	+170	+040	+021	019
009S014E29H01M	D	202	157	191	+155	-002	-036	034
009S014E33A01M	D	418	157	186	+161	+004	-025	029
009S014E34H01M	D	250	157	210	+166	+009	-044	053
009S014E34R01M	D	665	147	210	+167	+020	-043	063
009S014E36K01M	D	456	130	168	+179	+049	+011	038
009S014E36R01M	D	490	138	168	+181	+043	+013	030
009S015E13E02M	D	492	81	104	+230	+149	+126	023
009S015E21R01M	D	450	92	125	+211	+119	+086	033
009S015E22A01M	D	275	92	108	+220	+128	+112	016

Table 1.--*Continued*

Well number	Type of log	Depth below land surface (feet)			Altitude above (+) or below (-) mean sea level (feet)			Thickness (feet)
		Well	Top of clay	Base of clay	Land surface	Top of clay	Base of clay	
009S015E23J01M	D	204	70	98	+225	+155	+127	028
009S015E23J02M	D	573	82	119	+226	+144	+107	037
009S015E27H01M	D	317	86	110	+219	+133	+109	024
009S015E27J01M	D	900	100	110	+219	+119	+109	010
009S015E28H01M	D	254	98	122	+206	+108	+084	024
009S015E30G02M	D	434	119	152	+190	+071	+038	033
009S015E31F01M	D	348	136	164	+186	+050	+022	028
009S015E31J01M	D	166	130	156	+187	+057	+031	026
009S015E32Q01M	D	330	136	160	+195	+059	+035	024
009S015E33B02M	E	600	104	135	+209	+105	+074	031
009S015E35A01M	D	256	90	104	+219	+129	+115	014
009S015E36D03M	D	756	96	110	+222	+126	+112	014
009S016E15N01M	F	3085	72	82	+265	+193	+183	010
009S016E17B01M	D	550	68	78	+251	+183	+173	010
009S016E18F01M	D	363	76	88	+237	+161	+149	012
009S016E19H01M	D	323	82	91	+246	+164	+155	009
009S016E20H01M	D	372	76	92	+248	+172	+156	016
009S016E22R01M	C	331	76	80	+264	+188	+184	004
009S016E26E01M	D	590	64	104	+270	+206	+166	040
009S016E28A01M	D	616	78	88	+259	+181	+171	010
009S016E29B01M	D	230	82	90	+249	+167	+159	008
009S016E30B02M	D	825	93	102	+245	+152	+143	009
010S009E05C01M	DE	260	77	190	+143	+066	-047	113
010S009E05H01M	E	478	60	163	+140	+080	-023	103
010S010E14E01M	DE	520	292	403	+114	-178	-289	111
010S010E23E02M	DF	699	307	414	+120	-187	-294	107
010S011E27E02M	E	472	252	361	+101	-151	-260	109
010S013E01A02M	D	304	180	219	+135	-045	-084	039
010S013E03R M	F	358	196	251	+119	-077	-132	055
010S013E10J01M	D	431	198	270	+122	-076	-148	072
010S013E26K01M	DF	520	208	281	+122	-086	-159	073
010S013E35A01M	F	500	225	281	+122	-103	-159	056
010S014E02D01M	D	326	144	192	+167	+023	-025	048
010S014E03M01M	D	315	157	214	+160	+003	-054	057
010S014E08B01M	E	175	173	227	+151	-022	-076	054
010S014E34E01M	E	900	202	265	+143	-059	-122	063
010S014E36K01M	D	285	189	237	+154	-035	-083	048
010S015E03R02M	D	511	121	148	+208	+087	+060	027
010S015E06H02M	D	228	145	166	+185	+040	+019	021
010S015E07C01M	D	490	144	180	+181	+037	+001	036
010S015E10J01M	D	183	132	140	+209	+077	+069	008
010S015E13H01M	D	399	116	144	+211	+095	+067	028
010S015E14M01M	D	162	123	159	+197	+074	+038	036
010S015E19H01M	D	210	158	201	+178	+020	-023	043
010S015E20J02M	D	371	143	187	+177	+034	-010	044
010S015E22K01M	D	242	144	180	+189	+045	+009	036
010S015E30J01M	D	418	166	200	+167	+001	-033	034
010S015E33D01M	D	294	167	190	+169	+002	-021	023
010S015E34E01M	D	566	168	191	+180	+012	-011	023
010S016E07B01M	D	269	103	116	+223	+120	+107	013
010S016E18D02M	D	491	116	136	+212	+096	+076	020
011S010E08M01M	DE	475	152	242	+212	+060	-030	090
011S010E21A01M	E	470	170	270	+229	+059	-041	100
011S010E22A01M	DE	1200	212	312	+223	+011	-089	100
011S010E22F01M	DE	860	201	298	+234	+033	-064	097
011S010E22H01M	DE	720	183	265	+220	+037	-045	082
011S010E22D01M	DE	936	190	281	+247	+057	-034	091
011S010E23K02M	E	370	228	330	+202	-026	-128	102
011S011E02J01M	DE	600	288	369	+107	-181	-262	081
011S011E22D01M	DE	597	276	403	+114	-162	-289	127
011S011E32P01M	DE	701	190	273	+179	-011	-094	083
011S011E33R01M	DE	613	252	350	+146	-106	-204	098
011S012E07E02M	DE	488	279	374	+109	-170	-265	095
011S012E11J01M	DE	627	256	337	+115	-141	-222	081
011S013E30G01M	E	417	266	361	+122	-144	-239	095
011S013E34N01M	E	590	302	392	+129	-173	-263	090
011S014E07N02M	E	800	226	291	+130	-096	-161	065
011S014E17P02M	D	420	244	324	+130	-114	-194	080
011S015E04A01M	D	354	159	192	+171	+012	-021	033
011S015E19 M	D		247	308	+162	-085	-146	061
011S015E19R01M	D	375	239	289	+154	-085	-135	050
011S015E21R01M	D	326	226	274	+165	-061	-109	048
011S015E29A01M	D	294	251	269	+157	-094	-112	018
011S015E33P01M	E	290	275	327	+159	-116	-168	052
011S016E04M01M	D	512	161	164	+205	+044	+041	003
011S016E06P01M	D	540	130	167	+189	+059	+022	037
011S016E10N01M	DE	500	128	142	+206	+078	+064	014
011S016E22C01M	D	732	136	146	+206	+070	+060	010
011S016E22P01M	D	308	188	200	+206	+018	+006	012
011S016E23C01M	D	505	190	198	+213	+023	+015	008
011S016E17M02M	D	430	156	168	+191	+035	+023	012
011S016E23L01M	D	257	160	190	+214	+054	+024	030
011S016E26M01M	D	236	177	205	+210	+033	+005	028
011S016E27R01M	D	245	178	204	+204	+026	+000	026
011S016E27R02M	D	242	173	207	+205	+032	-002	034
011S016E28C02M	D	300	180	208	+194	+014	-014	028
011S016E29M01M	D	255	190	204	+186	-004	-018	014
011S016E29R01M	D	340	189	214	+191	+002	-023	025
011S016E32C01M	D	236	192	206	+187	-005	-019	014
011S016E33D01M	D	412	181	202	+193	+012	-009	021
011S016E34K01M	D	399	245	272	+201	-044	-071	027
011S016E35K01M	D	308	194	212	+210	+016	-002	018
012S011E03A01M	F	599	233	337	+147	-086	-190	104
012S011E04A01M	E	640	252	356	+153	-099	-203	104
012S011E04F01M	F	598	250	357	+183	-067	-174	107
012S011E06N M	C	198	124	179	+326	+202	+147	055
012S011E07G M	C	254	127	180	+351	+224	+171	053
012S011E10D01M	DE	725	198	303	+185	-013	-118	105
012S011E17D M	C	188	115	172	+357	+242	+185	057
012S011E17D M	C	400	81	139	+345	+264	+206	058
012S011E20J M	C	262	155	206	+327	+172	+121	051
012S011E34C M	C	297	80	124	+349	+269	+225	044
012S011E34R M	C	229	107	141	+347	+240	+206	034
012S011E34R01M	F	1117	106	150	+337	+231	+187	044
012S012E06H01M	F	690	361	441	+145	-216	-296	080
012S012E16H01M	CF	1007	379	480	+165	-214	-315	101
012S012E18C01M	C	465	364	459	+170	-194	-289	095
012S012E18D01M	D	812	295	430	+180	-115	-250	135
012S012E21E01M	D	931	375	530	+185	-190	-345	155
012S012E25H M	E	741	413	523	+180	-233	-343	110
012S012E34P01M	DE	1057	415	522	+198	-217	-324	107
012S013E09A01M	F	369	318		+141	-177		
012S013E17M01M	DF	622	369	468	+157	-212	-311	099
012S013E21C01M	DE	965	382	456	+158	-224	-298	074
012S013E25G01M	F	620	374	448	+157	-217	-291	074
012S013E33N01M	E	1218	447	531	+195	-252	-336	084
012S013E34Q M	C	240	182	240	+335	+153	+095	058
012S014E14A01M	F	405	292	357	+146	-146	-211	065
012S014E14R01M	F	405	309	366	+150	-159	-216	057
012S015E04F01M	F	1019	289	336	+158	-131	-178	047
012S015E05L01M	E	522	302	352	+154	-148	-198	050
012S015E08F01M	F	720	315	370	+154	-161	-216	055
012S016E04A02M	D	280	216	227	+195	-021	-032	011
012S016E21C01M	D	300	271		+186	-085		
012S016E21G01M	D	300	290		+189	-101		
012S016E26H01M	D	330	300	316	+201	-099	-115	016
012S016E34M02M	D	503	334	357	+191	-143	-166	023
012S017E08G02M	E	500	222	251	+229	+007	-022	029
012S017E30A01M	D	375	296	304	+215	-081	-089	008
013S011E02L M	C	200	110	142	+330	+220	+188	032
013S011E12D M	C	200	140	200	+334	+194	+134	060
013S012F20D M	C	681	318	406	+339	+021	-067	088
013S012E20D01M	E	1046	430	517	+198	-232	-319	087
013S012E02F01M	F	1164	434	520	+203	-231	-317	086
013S012F12R01M	DE	610	460	557	+216	-244	-341	097
013S012E13K M	E	6449	495	579	+258	-237	-321	084
013S012E20D01M	C	681	319	405	+347	+028	-058	086
013S012E27K01M	E	840	398	494	+287	-111	-207	096
013S012E30B M	E	5500	303	392	+455	+152	+063	089
013S012E30N01M	E	1860	269	335	+538	+269	+203	066

Table 1.--*Continued*

Well number	Type of log	Depth below land surface (feet)			Altitude above (+) or below (-) mean sea level (feet)			Thickness (feet)
		Well	Top of clay	Base of clay	Land surface	Top of clay	Base of clay	
013S012E30P M	E	1030	307	370	+525	+218	+155	063
013S012E30Q M	E	1380	310	383	+505	+195	+122	073
013S012E33C01M	OF	1408	370	459	+345	-025	-114	089
013S012E33F01M	E	1229	360	435	+356	-004	-079	075
013S012E35Q01M	E	1147	495	600	+322	-173	-278	105
013S013E07G01M	DE	1223	495	590	+228	-267	-362	095
013S013E10R01M	DE	1430	470	553	+211	-259	-342	083
013S013E16N01M	OF	1625	500	591	+235	-265	-356	091
013S013E16R01M	DE	1377	493	576	+288	-205	-288	083
013S013E20Q01M	E	1555	488	572	+252	-236	-320	084
013S013E36N01M	D	1525	641	656	+251	-390	-405	015
013S014E05R M	E	510	390	467	+167	-223	-300	077
013S014E13J01M	E	500	368	425	+156	-212	-269	057
013S014E14N M	E	540	391	459	+168	-223	-291	068
013S014E15D01M	E	897	394	468	+168	-226	-300	074
013S014E17N01M	E	987	441	529	+195	-246	-333	087
013S014E20A M	E	542	432	503	+188	-244	-315	071
013S014E28A M	E	550	433	514	+189	-244	-325	081
013S014E28N M	E	570	468	541	+211	-257	-330	073
013S014E33R M	F	570	469	538	+206	-263	-332	069
013S014E34A M	E	550	430	499	+186	-244	-313	069
013S014E36A M	E	520	430	499	+169	-261	-330	069
013S015E09M01M	E	691	345	394	+160	-185	-234	049
013S015E15G01M	D	384	369		+165	-204		
013S015E30A M	E	510	394	448	+157	-237	-291	054
013S015F35F01M	F	230	425	475	+166	-259	-309	050
013S016E02C01M	DE	405	340	354	+195	-145	-159	014
013S016F05C02M	D	316	361	412	+180	-181	-232	051
014S012E03P01M	DF	1146	460	475	+360	-100	-115	015
014S012F08H01M	DF	897	338	343	+469	+131	+126	005
014S012F11F01M	DF	1440	550	565	+350	-200	-215	015
014S012E23P01M	F	1710	535	545	+405	-130	-140	010
014S013F01N01M	DF	1475	593	673	+267	-326	-406	080
014S013E06P01M	DF	1153	742	753	+317	-425	-436	011
014S013F11D01M	GE	1500	620	701	+284	-33[illegible]	-417	081
014S013F11R01M	OF	1458	640	714	+279	-361	-435	074
014S013E13F01M	E	1486	663	736	+284	-379	-452	073
014S014F09D01M	F	1249	624	648	+230	-394	-418	024
014S014F10N02M	F	747	599	600	+221	-378	-379	001
014S014F12N02M	F	920	542	552	+188	-354	-364	010
014S015F03K01M	F	715	435	490	+162	-273	-328	055
014S015E11R M	E	530	450	499	+149	-301	-350	049
014S015E16D01M	E	762	448	501	+158	-290	-343	053
014S015F18F01M	DF	850	465	528	+178	-287	-350	063
014S015F18M01M	E	970	470	524	+178	-292	-346	054
014S016F08N M	F	530	466	486	+161	-305	-325	020
014S016E15R M	E	560	468	493	+174	-294	-319	025
014S016E16A M	F	530	455	480	+172	-283	-308	025
014S016E16N M	E	528	481	499	+166	-315	-333	018
014S016E24N M	E	560	485	509	+176	-309	-333	024