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Stratigraphic units distinguished in the Santa Ynez River basin and adjoining areas

	Geologic age	Formation and symbol on plates 2 and 3	Thickness (feet)	General character	Water-bearing properties
Quaternary.	Recent.	River-channel deposits (*Qrc*).	0-70	Coarse sand and gravel of fluvial origin lying in the flood channel of the Santa Ynez River. Predominantly gravel above Robinson Bridge, but predominantly sand downstream.	Loose and unconsolidated; permeability 425 to 4,320, as determined by laboratory tests; carries some underflow of the Santa Ynez River. Tapped by a few wells in and upstream from the Buellton subarea, which are capable of yielding 500 to 1,000 gallons a minute.
		Unconformity.			
		Younger alluvium (*Qyal*).	0-200	Gravel, sand, silt, and clay of fluvial origin underlying the alluvial plains of the Santa Ynez River outside the flood channel and of the tributary streams. Includes channel deposits of the tributaries. Locally comprises two members, of which the lower is of gravel and extends from the ocean upstream about to San Lucas Bridge.	Unconsolidated and largely saturated with water. Lower member is principal source of water in the valley and constitutes the main water-bearing zone beneath the Lompoc plain. Permeability 1,000 to 4,500 as determined by discharging well tests. Between Robinson Bridge and Solvang it carries most of the Santa Ynez River underflow.
		Unconformity.			
	Pleistocene.	Terrace deposits (*Qt*).	0-150	Gravel, sand, silt, and clay of fluvial origin capping terraces and flat hill summits along the Santa Ynez River and tributary streams. Includes some marine beach deposits along the ocean, also an extensive body underlying the Santa Ynez upland.	Generally above the zone of saturation. Locally can transmit some rainfall to underlying permeable deposits. The body in the Santa Ynez upland contains water, and yields moderate supplies to wells.
		Unconformity.			
		Orcutt sand (*Qo*).	0-300	Unconsolidated sand and clay with some gravel, mainly non-marine. Underlies hills and terraces bordering the Lompoc plain, and locally extends beneath the plain. Includes local indurated caps of reddish eolian and marine beach sand, which are genetically distinct but nearly coextensive with rest of the formation.	Saturated only near and beneath the Lompoc plain, where it is tapped by a few wells. Generally of low permeability, but some gravel beds locally yield water readily.
	?	Unconformity.			
?	Pleistocene (?) and Pliocene.	Paso Robles formation (*Tpr*).	0-2,800±	Fluvial clay, silt, sand, and gravel; poorly assorted and compact, in lenticular beds. Underlies the entire valley; crops out along the flanks of the Purisima and Santa Rita Hills, and of the San Rafael Mountains. Lower part largely clay and silt; upper part composed of alluvial-fan deposits.	Generally less permeable than the younger alluvium. Sand and gravel beds yield water to numerous wells of moderate capacity in Santa Ynez upland. In the Lompoc subarea, lenses of sand and gravel in the lower part supply water to a few wells of fair yield.
Tertiary.	Pliocene.	Careaga sand (*Tc*).	450-1,000±	Fine-grained to medium-grained, uniform, massive, marine sand with some gravel and limestone. Locally fossiliferous. Crops out in flanks of Purisima and Santa Rita Hills and San Rafael Mountains.	Generally not tapped by wells. Permeability 70 as determined by laboratory tests. Rain infiltrating on outcrop areas transmitted in considerable amounts to main water-bearing zone in Lompoc subarea.
		Local unconformity.			
	Pliocene to Eocene.	Undifferentiated Tertiary rocks (*Tu*) which include Foxen, Sisquoc, Monterey, Rincon, Vaqueros, Sespe, and Tejon formations.		Predominantly consolidated mudstone and shale, in part diatomaceous and siliceous, with some limestone, sandstone, conglomerate, and volcanic rocks. Mostly marine in origin but in part continental.	Essentially not water-bearing except for local beds of sand and fractures. Not tapped by water wells.
		Unconformity.			
Cretaceous and Jurassic (?)		Knoxville and Franciscan formations (*JK*).		Consolidated dark sandstone and shale; also serpentine and other metamorphic and igneous rocks.	Essentially not water-bearing except for fractures. Not tapped by water wells.

From: Geology and Water Resources of the Santa Ynez River Basin, Santa Barbara County, Calif. by Upson and Thomasson, 1951, USGS Water Supply Paper 1107

GEOLOGY

By J. E. Upson

EARLIER WORK

Considerable geologic work has been done in the Santa Ynez River basin, nearly all of it by petroleum geologists employed by private companies and nearly all of it unpublished. The main features of the geology are shown on the geologic map of California by Jenkins (1938), and many minor features are described in the comprehensive book by Reed (1933). Fairly detailed studies of older consolidated rocks were made by Arnold and Anderson (1907) in their so-called Santa Maria district, which included all the area shown on plates 2 and 3. Recently Woodring and others (Woodring, Bramlette, Lohman, and Bryson, 1944) have completed a detailed map of the Santa Maria valley and adjoining areas, which includes some of the western and northern parts of the Santa Ynez River basin. A summary of this work has been published. A small part of the Santa Ynez River valley has recently been mapped by the Geological Survey as part of its investigation of petroleum resources (Woodring, Loofbourow, and Bramlette, 1945). Kew (1919) described the consolidated rocks in part of the upper Santa Ynez River district in 1919; that area, together with the extreme eastern part of the Santa Ynez subarea as here defined, has been mapped in some detail by Nelson (1925, pp. 327–396).

DESCRIPTIONS AND WATER-BEARING CHARACTERISTICS OF THE ROCKS

GENERAL FEATURES AND SUCCESSION

On the basis of their capacity to contain and yield ground water, the rock units of the Santa Ynez River basin are divided into two classes—those that are consolidated and can yield appreciable quantities of water only from cracks and fractures, and those that are unconsolidated and have continuous interstices which may yield appreciable quantities of water. In upward succession the unconsolidated water-bearing deposits are the Careaga sand of Pliocene age, the Paso Robles formation of Pliocene and Pleistocene (?) age, the Orcutt sand of Pleistocene age, and alluvial deposits of Pleistocene and Recent age. The Careaga sand is marine, but all the other formations are essentially continental. The consolidated non-water-bearing rocks underlie the Careaga sand and are Tertiary and Mesozoic in age. These older rocks were not mapped in any detail but were examined briefly because the younger formations contain materials derived from them.

The chart (pp. 28–29) summarizes the stratigraphic units. The distribution and relations of the units are shown in detail on the geologic maps, plates 2 and 3, and in the geologic cross sections, plates 2 and 4.

JURASSIC (?) AND CRETACEOUS ROCKS

Rocks of the Franciscan formation occur in a few small isolated bodies in the central part of the Santa Ynez Mountains, but they form nearly all the south front of the San Rafael Mountains. There they consist chiefly of altered basic volcanic rocks, with some jasper, quartz, and dense greenish chert. Considerable serpentine is associated with them. At the range front these rocks are upfaulted against the Careaga sand and Paso Robles formation.

Upper Cretaceous marine sandstone and shale occur in several bodies north of the crest of the Santa Ynez Mountains. A few bodies of sedimentary rocks assigned to the Knoxville formation have been mapped in the broad west-central part of the range.

A small body of old marine deposits, not studied thoroughly, occurs near the head of Happy Canyon on the south flank of the San Rafael Mountains. It consists of layers of dark-brown evenly bedded shale in alternation with thin beds of massive sandstone. The body is upfaulted against the Paso Robles formation on the south and is downfaulted against chert of the Franciscan formation and associated serpentine on the north. It is overlain probably unconformably, by a small body of Careaga sand. These rocks were called Knoxville, by Nelson (1925, p. 339 and geologic map) and are shown as Lower Cretaceous on the geologic map of California (1938).

CONSOLIDATED TERTIARY ROCKS

Consolidated Tertiary rocks predominantly of marine origin make up the main part of the Santa Ynez Mountains and occur locally in its foothills; also they occur in the central part of the Purisima Hills and of the Santa Rita Hills. At most places they include the Monterey, Sisquoc, and Foxen formations as defined by Woodring (Woodring, Bramlette, and Lohman, 1943, pp. 1345–1355), although in some small areas they include the older Rincon, Vaqueros, Sespe, and Tejon formations.

The Monterey shale, of Miocene age, underlies large areas in the lower foothills of the Santa Ynez Mountains, the Santa Rita Hills, the Purisima Hills, the Burton Mesa, and the Lompoc Terrace. It consists predominantly of white porcelaneous chert and banded silicified mudstone and diatomite. Most of the formation is silicified and very tough, but some parts are only moderately compact. A body of altered volcanic rocks occurs locally at the base of the formation.

The Sisquoc and Foxen formations occur throughout the Purisima Hills and the Santa Rita Hills; also locally in the foothills of the Santa Ynez Mountains. Neither formation is silicified. Characteristically, the Sisquoc formation is massive to very thin bedded, white diatomaceous mudstone, and the Foxen is gray or tan massive mudstone. Both formations are very fine grained and quite compact.

These several consolidated rocks of Tertiary age are not water-bearing at most places, but contain some water in fractures. Such as is obtainable is small in amount and uncertain in location. No wells derive water exclusively from them; and a few wells obtain water of a chemical quality unsuitable for some agricultural uses. Essentially, these rocks constitute relatively impermeable sides and bottoms for overlying bodies of water-bearing deposits.

UNCONSOLIDATED DEPOSITS OF TERTIARY AGE

CAREAGA SAND

CHARACTER, EXTENT, AND STRATIGRAPHIC RELATIONS

The Careaga sand is a body of fine- to coarse-grained massive marine sand that ranges in thickness from 450 to 1,000 feet, overlies the Sisquoc and Foxen formations, and underlies the Paso Robles formation. It can be traced into the Santa Ynez River basin from the type locality on the north flank of the Purisima Hills, where it has been defined recently by Woodring (Woodring, Bramlette, and Lohman, 1943, pp. 1355–1358), and assigned to the upper Pliocene. Two members distinguished by Woodring in the Santa Maria oil district also seem to be distinct throughout the Santa Ynez River basin but were not mapped separately there. The Careaga is distinguished from the underlying formations by its coarser grain and by its lesser degree of consolidation. It is distinguished from the overlying Paso Robles formation by uniformity of its grain size and by its contained marine fossil shells.

The Careaga sand was deposited in an arm of the sea that extended eastward and southeastward to and beyond Santa Cruz Creek. It crops out along the south flank of the Purisima Hills, along the north flank of the Santa Rita Hills, in a few hills along the south side of the Lompoc plain, and in a large area north of Buellton. At the east end of the Purisima Hills north of Solvang, a large body of coarse and apparently unfossiliferous sand is assigned to the Careaga. In the Santa Ynez and Headwater subareas it crops out discontinuously in a narrow band along the flank of the San Rafael Mountains and in another narrow belt north of the Santa Ynez River from the valley of Santa Agueda Creek eastward.

The formation rests with slight unconformity on the underlying Sisquoc and Foxen formations, is locally faulted against the Monterey formation, and is in fault contact with the Franciscan and Knoxville formations along the south flank of the San Rafael Mountains. It is conformable with and occurs everywhere beneath the Paso Robles formation. Where the Paso Robles formation is eroded through, the Careaga sand is overlain directly by alluvial deposits of Recent age. Most extensive of such areas is beneath the east half of the Lompoc plain where the alluvial deposits rest directly on the Careaga sand over several square miles. (See pl. 5.) Locally it is overlain uncomformably by the Orcutt sand and by terrace deposits.

The Careaga sand consists almost entirely of uniform massive sand, white to light yellow or cream in color. The sand grains range in size from coarse to fine, and at most places they are coarser in the upper part of the formation. Beds of clay and silt are characteristically absent, but the formation contains thin lenses of pebbles, which are chiefly quartzite but of which some are porcelaneous chert, volcanic rocks, or the banded silica characteristic of the Monterey formation. Locally the formation contains scattered shells or lenses of shells. In many places the sand is only faintly stratified although locally it is cross-bedded, and the pebbles and fossil shells are mostly in distinct lenses. Although surficially indurated in most exposures, in very fresh cuts and as encountered in wells, the Careaga sand seems quite unconsolidated except for a few zones cemented by calcium carbonate. Individual grains are somewhat rounded and consist mainly of quartz, but many are of diatomaceous and siliceous shale derived from the Monterey and Sisquoc formations. The pebbles are mostly well-rounded and less than 2 inches in diameter.

About 100 feet below the top of the formation a persistent zone of cobbles, pebbles, coarse sand, and numerous fossil shells is nearly continuous along the north side of the Santa Rita Hills and at some places consists entirely of shell fragments. This zone, or another similar zone, occurs far to the east between Santa Agueda Creek and Cachuma Creek. There, the zone is from a few feet to a few tens of feet thick and at most places is cemented by calcium carbonate. In some outcrops only a few "ghosts" of the original shells remain.

WATER-BEARING PROPERTIES

The Careaga sand is penetrated by wells mainly beneath the Lompoc plain. There, almost invariably it has been cemented off by the well driller, both because the loose, fine sand tends to enter the wells when pumped and because the overlying younger alluvium yields water much more readily. Accordingly, data regarding its water-bearing properties are lacking in the well logs. However, laboratory tests of permeability were made on 12 samples collected from outcrops of the Careaga sand in the area bordering the Lompoc plain. When tested with a variable-head apparatus, similar to that described in Water-Supply Paper 887, the permeability was found to range from 7 to 89 gallons per day per square foot. Of the samples collected some are considered not typical of the formation and others were indurated and doubtless yielded abnormally low values of permeability. Table 5 summarizes the test data on four samples thought to be typical of the nonindurated formation.

TABLE 5.—*Permeability of samples of Careaga sand*

Number	Location	General character	Permeability (g. p. d. per sq. ft.)
CS-8	East fork Purisima Canyon near head of valley plain. NW¼NE¼ sec. 12, T. 7 N., R. 34 W.	Uniform medium sand, somewhat iron stained.	73
CS-9	Cebada Canyon near crest of Purisima Hills. NE¼SE¼ sec. 6, T. 7 N., R. 33 W.	Fine yellow sand	89
CS-13	East fork Purisima Canyon above valley plain. NW¼SW¼ sec. 6, T. 7 N., R. 33 W.	Loose massive yellow sand with scattered pebbles.	23
CS-14	West fork Purisima Canyon near head of valley plain. SW¼SW¼ sec. 1, T. 7 N. R. 34 W.	Loose medium sand; white and cross-bedded.	88

It is believed the average of the four values in the table, about 70 gallons per day per square foot represents approximately the order of magnitude of the permeability of the formation. This means that 70 gallons of water a day would pass through a section of the Careaga sand 1 mile wide and 1 foot thick under a hydraulic gradient of 1 foot per mile. (Wenzel, 1942, p. 7).

PASO ROBLES FORMATION

CHARACTER AND SUBDIVISIONS

The term "Paso Robles" was applied by Fairbanks (1898, pp. 565–566) in 1898 to extensive upper Tertiary continental deposits in San Luis Obispo County, Calif. It has come to be applied to similar late Tertiary continental deposits in Santa Barbara County, although the deposits have not been traced to the original Paso Robles area. The Paso Robles of the Santa Ynez River basin, however, is continuous with deposits so identified by Woodring and others (Woodring, Bramlette, and Lohman, 1943), in the Santa Maria oil district and is herein defined accordingly. It conformably overlies the Careaga sand and is considered to be upper Pliocene and lower Pleistocene(?) in age. It is overlain by the Orcutt sand and locally by terrace deposits and the younger alluvium.

At most places the Paso Robles formation is distinguished from the underlying Careaga sand by its heterogeneity and by the absence of

marine fossils. However, in the area 3 to 4 miles northwest of Buellton the lower part of the Paso Robles consists mainly of sand that closely resembles the Careaga sand. Lithologically some strata of the Paso Robles formation are very similar to parts of the overlying Orcutt sand, but the Paso Robles is distinguished from most overlying formations, all of which are unconformable upon it, by its greater degree of deformation.

The Paso Robles formation is composed of coalescing alluvial fans laid down by streams flowing from the Santa Ynez and San Rafael Mountains. Probably early in the deposition, a continuous, westward-flowing stream occupied the axial part of the basin of deposition, but evidence that it continued during all the deposition is not at hand. The formation now occurs throughout the Santa Ynez River basin where it lies in general within the outcrop of the Careaga sand. (See pls. 2 and 3.) It crops out on the south flank of the Purisima Hills and the north flank of the Santa Rita Hills. It underlies a large area north of the Santa Ynez upland in the Santa Ynez subarea and in the Headwater subarea, where it has been dissected into a fairly rugged terrane. In the Santa Ynez upland and in the Buellton subarea the formation is concealed by terrace deposits and by the younger alluvium; and in the Lompoc subarea much of it is covered by the Orcutt sand. The top of the Paso Robles is eroded everywhere, so its original thickness is unknown. The existing thickness ranges from a feather edge to about 2,800 feet. It is thickest in the northeastern part of the Santa Ynez subarea near the fault contact with the older consolidated rocks. (See pl. 2, section *A–A'*.) In the Lompoc subarea it pinches out to the west beneath the younger formations. (See pl. 4.)

The detailed characteristics of the Paso Robles formation differ considerably in different parts of the valley. In general the lower part consists of clay, silt, and sand, whereas the upper part consists of sand and gravel with minor amounts of clay and silt. In the Lompoc and Santa Rita subareas the lower part of the Paso Robles is composed of beds of dark greenish clay interbedded with strata of massive and cross-bedded coarse white to light-yellow sand, thin fresh-water limestone, and locally coarse fairly clean gravel. (See following sections.) This part of the formation is probably not more than about 100 feet thick. Massive clay and lenses of fresh-water limestone nearly everywhere mark the base of the Paso Robles formation. The limestone, indicated by scattered nodules on the land surface, occurs eastward as far as Buellton, and at a few places in the easternmost part of the Purisima Hills near Los Olivos.

Section of strata in lower part of Paso Robles formation, exposed in SE¼SW¼ sec. 16, T. 7 N., R. 33 W.

	Feet
Clay	1
Gravel, lenticular; pebbles of chert, sandstone, quartzite, and granite	3
Sand, massive, somewhat compact, reddish buff; discontinuously exposed	30
Clay, massive, olive green	2
Sand, as above	5
Clay, massive, olive green	2
Sand, massive, compact, light yellow	20
Total	63

Section of strata in lower part of Paso Robles formation, exposed in SE¼SW¼ sec. 29, T. 7 N., R. 33 W.

	Feet
Clay, dark greenish brown, massive	2
Gravel, clayey; large rounded pebbles and cobbles	2
Sand, fine, white to light yellow, massive, compact	10
Clay, sandy; dark olive green, massive, compact	2
Sand, fine; white to light yellow; locally streaked with limonite	3
Total	19

In the Buellton, Santa Ynez, and Headwater subareas the lower part of the Paso Robles is generally somewhat finer grained than in the Lompoc and Santa Rita subareas. It is best exposed in the hills east of Santa Agueda Creek north of the Santa Ynez River, but it also crops out in the vicinity of Buellton. There it is several hundred feet thick, is predominantly red to orange buff, and consists mainly of massive clay and silty clay, with some scattered pebbles and lenses of cross-bedded pebble gravel. Most of the pebbles are of diatomaceous and siliceous shale derived from the Monterey formation, but some are of jasper, chert, and basic volcanic rocks derived from the Franciscan formation.

The upper part of the Paso Robles formation overlies all the lower part here described and occurs throughout the area. It is composed of typical alluvial-fan deposits and is relatively coarse grained near the mountains. Also, it differs somewhat in composition from place to place according to the source rock. Typically it is light cream to light orange buff and is composed of clayey sand with scattered pebbles and lenses of pebble gravel and cobble gravel. Certain beds of clayey silt are several feet thick, massive, and distinctively orange buff. The sand and gravel are in massive to crudely stratified and locally cross-bedded lenses. At the land surface they are moderately compact. The gravel lenses are fairly coarse grained and contain

pebbles, cobbles, and boulders which average about 2 inches in diameter and most of which are rounded or flattish fragments of diatomaceous and siliceous Monterey shale. Commonly a few of the pebbles are of jasper, serpentine, and basic volcanic rocks derived from the Franciscan formation and associated rocks, and some are of sandstone from the Eocene or Cretaceous rocks. All these source rocks are exposed in the San Rafael Mountains and in the upper drainage basin of the Santa Ynez River. In exposures near the south flank of the San Rafael Mountains, the deposits are much coarser, as the gravel beds contain rounded and angular boulders as much as 2 feet in diameter, and the fine-grained beds are nearly all sand. Nearly all the boulders are of altered basic volcanic rocks, serpentine, and some jasper; the sands consist of smaller grains of the same materials. Therefore the Paso Robles formation here is dark gray or black, whereas elsewhere it is almost white because it is composed largely of particles from the Miocene and Pliocene rocks.

In the western part of the Santa Rita Hills the upper part of the Paso Robles formation contains thick lenses of gravel that are cross-bedded and that include rounded cobbles and boulders as much as 1 foot in diameter. Here, most of the included boulders are of sandstone or banded chert; however, some are of volcanic rocks, jasper, or quartzite and a very few are of grantic rock. In these features, this part of the Paso Robles resembles channel deposits of the Santa Ynez River. Similar deposits are exposed nearly 25 miles to the east. In a belt of prominent hills which is about 2 miles north of the Santa Ynez River and which trends nearly eastward across the valley of Santa Agueda Creek, another coarse-grained zone about 100 feet thick occurs just above the lower part of the Paso Robles. It is mainly of gravel but contains some thin strata of buff silt. The gravel beds are somewhat consolidated in exposures and consist of coarse sand, pebbles, and boulders as much as 1 foot in diameter. About 40 percent of the pebbles and boulders are of siliceous shale; the remainder are of jasper, serpentine, and basic volcanic rocks. These coarse-grained deposits also resemble the modern river-channel deposits and, with those in the Santa Rita Hills to the west, probably were laid down by some through-flowing stream in the Paso Robles basin of deposition.

Thus, the deposits that compose the Paso Robles formation reveal a varied history. The lower part of the formation probably was deposited in ponds and swamps in the western part of the valley, but on the flood plains of sluggish creeks in the eastern part. For a time thereafter the basin was probably occupied by a large master stream flowing to the ocean. However, with increased uplift of the adjacent highlands this river probably was disrupted as fans of coarse alluvium were built by side streams which flowed from the mountains.

WATER-BEARING PROPERTIES

As indicated in the foregoing description, the Paso Robles formation contains a large proportion of fine-grained material and is composed chiefly of discontinuous, lenticular, and poorly assorted alluvial-fan deposits. Of these, the clay, silt, and pebbly silt are too fine grained to yield water readily. Even the lenses of gravel contain enough clay and silt to impede the flow of water. However, beneath the easternmost part of the Lompoc plain the massive sand and coarse gravel that are interbedded with clay in the basal part of the formation yield water to drilled wells at rates up to 200 to 300 gallons a minute. (See pl. 5, section *F–F′*, logs of wells 7/34–24N1, 7/34–25D1, and 7/34–26F2.[1])

Most of the wells that tap the formation in the eastern part of the area (see table 26, logs of wells 6/31–1B2 and 7/30–32H1) penetrate considerable clay or "clay and gravel" and yield less than 200 gallons a minute. The most productive well, No. 6/30–2N1, is in the lower valley of Santa Agueda Creek and penetrates about 1,300 feet into inclined strata of the Paso Robles formation (the stratigraphic thickness penetrated is about 1,000 feet). By report, its casing is perforated opposite all the gravel bodies, and its pumping yield is about 1,300 gallons of water per minute at a drawdown of about 90 feet. These figures indicate its specific capacity to be about 15 gallons a minute per foot of drawdown. In contrast, some wells drilled in clayey parts of the formation yield only a few gallons a minute and are inadequate even for supplying water to stock.

Thus, the Paso Robles formation at most places is much less permeable than some of the younger alluvium (p. 45), but where it contains considerable gravel it can sustain wells of a yield adequate for moderate

[1] In this report the numbers or symbols ascribed to wells show locations according to the rectangular system for subdivision of public land. For example, in the symbol for well 7/34–24N1, the part that precedes the dash indicates the township and range (T. 7 N., R. 34 W.), the digits following the dash indicate the section (sec. 24), the letter indicates the 40-acre subdivision of the section as shown in the accompanying diagram, and the final digit is the serial number in the particular 40-acre tract. Thus, well 7/34–24N1 is the first well to be listed in the SW¼SW¼ sec. 24, T. 7 N., R. 34 W. Inasmuch as the maps show the townships, ranges, and sections, ordinarily the well symbols given on the maps include only the elements after the hyphen; and on small-scale maps they include only the letter and serial number.

D	C	B	A
E	F	G	H
M	L	K	J
N	P	Q	R

irrigation. Furthermore, the formation underlies the large foothill area north of the Santa Ynez upland, there receives infiltrate from rain, and there constitutes a large ground-water reservoir.

PLEISTOCENE AND RECENT DEPOSITS

ORCUTT SAND

The Orcutt sand is a body of unconsolidated sand and clayey sand with scattered pebbles or stringers of pebbles. It occurs discontinuously in the western part of the Santa Ynez River basin, was first named by Hoots and Herold (1935, p. 156) and more recently has been studied and defined by Woodring (Woodring, Bramlette, and Lohman, 1943, p. 1359). The type locality is near the town of Orcutt, on the south side of the Santa Maria Valley.

In the Santa Ynez River basin the Orcutt sand occupies the central part of the trough between the Santa Rita Hills and the Purisima Hills and extends east to the divide between Santa Rita Creek and Santa Rosa Creek. To the west it caps the broad Burton Mesa north of the Lompoc plain, also underlies much of the corresponding Lompoc terrace to the south. Along the southwest side of the Lompoc plain the formation dips northward at a low angle and passes beneath the alluvium forming the plain.

The Orcutt sand rests on an erosion surface cut on the deformed Paso Robles and older formations and in turn is overlain unconformably by terrace deposits and the younger alluvium. It is itself somewhat warped, dips as great as 5° being known. Its greatest known thickness is about 200 feet in the central part of its area where, between depths of 199 and 398 feet, well 7/35–25P1 penetrates deposits assigned to the Orcutt sand. From there it thins to feather edges at the margins of its outcrop. (See pl. 3.) Woodring (Woodring, Bramlette, and Lohman, 1943, p. 1359) considers the Orcutt sand to be of upper Pleistocene age.

The Orcutt sand generally is poorly exposed and is difficult to distinguish from much of the Paso Robles formation, which it resembles lithologically. In general, the Orcutt is the less deformed but as mapped may include some Paso Robles beds where dips are low.

Although the Orcutt sand consists almost entirely of sand and clayey sand with scattered pebbles and stringers of pebbles, locally it contains lenses of clay and of gravel. For example, wells in the central part of the Lompoc plain, such as 7/35–35C2 and 7/35–24B2 penetrate gravel strata assigned to the formation (pl. 5). In most outcrops the sand is moderately coarse and consists of rounded to subangular grains of quartz and rounded grains of diatomaceous and siliceous shale. Contained pebbles are mostly rounded and of diatomaceous shale or porcelaneous chert, but a few are of quartzite. Their average diameter is about 1 inch. These several materials occur commonly in massive or indistinctly bedded lenses, though locally the sand is somewhat cross-bedded. In color, the beds are generally almost white to very light yellow, but the upper 10 to 20 feet are stained a dark brownish red by coatings of iron oxide on the grains. At most places the beds contain sufficient clay so that in road cuts and stream cuts they stand at fairly steep slopes. On these, rain-wash develops a characteristic rilled or fluted form mentioned by Woodring (Woodring, Bramlette, and Lohman, 1943, 1359).

Like the Paso Robles formation, the bulk of the Orcutt sand is irregularly and indistinctly stratified and is considered to be essentially of continental origin. However, north and northeast of the Lompoc plain its uppermost part, a zone from 5 to 10 feet thick, is massive sand that contains rounded and angular fragments of jasper, quartzite, and chert. Nearly everywhere it is indurated and iron-stained, evidently as a result of weathering. Many of the pebbles are darkly stained, and the surfaces of nearly all the pebbles and cobbles are highly polished and minutely pitted, presumably by the action of wind-blown sand. The lack of stratification, and the haphazard scattering of pebbles throughout, suggest that this uppermost part of the Orcutt is a beach deposit. If so, it would seem that after the deposition of most of the Orcutt the sea advanced briefly and then retreated at least locally.

Because the Orcutt sand is unconsolidated and contains considerable loose, coarse sand, it can hold a relatively large quantity of water. However, many of its lenses contain silt or clay, so that the formation probably can neither transmit water rapidly nor yield water copiously to wells. Nonetheless, a number of wells on the southwestern part of the Lompoc plain derive water from the formation.

Because it occurs chiefly in hills and terraced areas which are undeveloped agriculturally, the Orcutt sand is not tapped widely by wells, and, with respect to ground water, it serves chiefly as a large catchment area for rain. Specifically, most of the outcrop area is mantled with coarse, loose sand which has washed down the hill slopes from the upper part of the formation. This mantle presumably absorbs rain readily, as there is virtually no runoff from the outcrop area during ordinary storms. Rain so absorbed passes in part beyond the reach of plant roots, is stored in the Orcutt sand, and ultimately is probably transmitted to the underlying Paso Robles formation.

TERRACE DEPOSITS

The terrace deposits include numerous isolated bodies of clay, sand, and gravel that cap hilltops, benches, and upland areas along the Santa Ynez River and its larger tributaries. They occur at several altitudes above present sea level and present stream grades. Several other bodies of terrace deposits are believed to lie beneath the southern part of the Lompoc plain. All these deposits rest with angular unconformity on the older rocks and deposits. Mainly they are thin, of small extent, and only locally conceal the underlying formations. However, one large and rather complex body forms and underlies the Santa Ynez upland. Along the river and its main tributaries the terrace-forming materials are remnants of former river-channel and flood-plain deposits; elsewhere, they are alluvial-fan deposits.

These terrace deposits consist largely of clay, silt, and gravel. Where deposited as local alluvial fans by small streams they are rather poorly assorted, but where deposited by the perennial Santa Ynez River they are generally well-sorted and contain much coarse clean gravel. They range in thickness from a feather edge to as much as 150 feet. Their lower part is mostly coarse gravel, and their upper part is sand and silt. Usually they are unfossiliferous, but at a locality about 3 miles west of Buellton, in the deposits on the lowest of the river terraces, the writer found the lower two-thirds of the thigh-bone of an extinct camel, which has been identified by C. W. Gilmore [2] of the National Museum as belonging to the genus *Camelops* and which is considered to be of Pleistocene age. As the containing deposits are those of the lowest, or youngest terrace, all the terrace deposits are at least as old as Pleistocene.

In the southeastern part of the Lompoc plain a number of wells pass through the younger alluvium, then penetrate bodies of gravel 10 to 20 feet thick immediately above the Careaga sand. (See pl. 5, sections *G–G′* and *H–H′*; also logs of wells 7/34–31J1, 7/34–31Q2, 7/34–33L1, and 7/34–33D1, and others.) These bodies seem to occur at a common horizon and are believed to belong to a common stratigraphic unit. Their inferred extent is shown on plate 5. Possibly these particular bodies of gravel are basal beds of the Orcutt sand, offset by faulting from the rest of the formation, but it seems more likely that they are remnants of a separate body of younger terrace deposits as here described. The well logs show them to consist almost entirely of coarse gravel with some sand. The casings of numerous wells are perforated in the gravel; and the wells derive considerable water from the deposits. Accordingly, they are here called the secondary water-bearing zone in the Lompoc subarea of the Santa Ynez River basin.

The most extensive bodies of terrace deposits underlie and in part compose the Santa Ynez upland of the Santa Ynez subarea (pl. 2). There the terrace deposits were laid down by short streams flowing

[2] Reeside, J. B., written communication, Dec. 2, 1943.

south or southwest and graded to several successively lower levels of the Santa Ynez River. Their deposition in the early stages may have been in part induced by late minor warping of the Tequepis syncline. These deposits occur at several levels and are genetically different from each other but are lithologically indistinguishable and are mapped as a single body. They rest unconformably upon the upturned and eroded edges of the Paso Robles, Careaga, and older formations. They are largely separated by the consolidated rock barrier from the lower terrace deposits along the river; but a tongue appears to extend through a gap in the barrier at Zanja Cota Creek, and there the deposits extend almost to the river.

The terrace deposits of the Santa Ynez upland are not well-exposed, but as indicated by the few exposures and by logs of wells they consist of lenses of poorly assorted gravel, sand, and silt with some clay or fine silt. Some logs report a large proportion of clay. In this area the terrace deposits very much resemble the Paso Robles formation but are deformed only slightly if at all. Their fine-grained materials are stained orange buff, and on the higher hills are somewhat indurated like the upper part of the Orcutt sand. The pebbles are chiefly white flattish but rounded fragments of porcelaneous chert and diatomaceous shale. However, some are of jasper, serpentine, and basic volcanic rocks derived from the Franciscan formation and associated rocks. Most of the pebbles are from 1 inch to 2 inches in diameter. The deposits are moderately compact at the land surface.

The terrace deposits are at least 30 feet thick, as stream valleys of that depth do not cut the underlying material. Locally, they are probably much thicker. At one well drilled recently near the center of the upland the driller reported a change in character of gravel about 100 feet below the land surface. Although a lithologic break was not obvious from the cuttings, it is possible that the drill passed from terrace material into the underlying Paso Robles formation at that depth. The record of well 7/30-32H1 (table 26) reveals a change in general lithologic character at 156 feet; and other wells show changes at comparable depths. Hence it is inferred that the maximum thickness of the terrace deposits beneath the northern part of the upland is about 150 feet.

Because they have a considerable proportion of fine-grained material, also because their beds of gravel are unassorted and lenticular, the terrace deposits are inferred to be only moderately permeable. Probably they are about as permeable as the underlying Paso Robles formation. The wells drilled on the Santa Ynez upland derive water in large part from the terrace deposits but also from the Paso Robles formation. (See logs of representative wells, table 26.) As discussed in later paragraphs on the ground water of the Santa Ynez subarea, there is some evidence that the beds of clay in this body of older alluvial fill greatly retard the downward percolation of water that infiltrates below the land surface.

YOUNGER ALLUVIUM

General character.—The younger alluvium of this report includes the several bodies of alluvial fill of Recent age that underlie and form the Lompoc plain and that extend upstream along the Santa Ynez River and into the valleys of tributary streams. It is termed younger alluvium because it is younger than the Orcutt and Paso Robles formations, which are largely of alluvial origin. The deposits that constitute the younger alluvium are known chiefly from well logs and consist of unconsolidated clay, silt, sand, and gravel. They range in thickness from a feather edge to a maximum of about 200 feet, and they rest unconformably on all the older formations heretofore described.

The younger alluvium was deposited in valleys carved by former streams that flowed toward a shoreline at least 200 feet below present sea level. Evidence for this conclusion is drawn mainly from well logs, which show that for a distance of 5 miles back from the present shore the base of the alluvial deposits rests on consolidated rocks of Tertiary age at depths of from nearly 200 to 150 feet below sea level. (See pl. 5.) According to local residents, corresponding deposits in the south coastal valleys of the county locally have been deposited to thicknesses of 10 to 20 feet. Hence the deposition of this alluvium is considered nearly if not quite the most recent geologic event in this region; and the cutting of the older terraces is considered to occupy much of the middle and late Pleistocene. Therefore, the younger alluvium was probably deposited during the rise of sea level that accompanied the retreat of the last, or Wisconsin, glaciers elsewhere on the continent and is considered to be of Recent age. This age determination is corroborated elsewhere in southern California, particularly in the Long Beach-Santa Ana area, where analogous bodies of alluvium were deposited in former valleys that had been cut in deposits of latest Pleistocene age. (Poland and Piper, in preparation.)

The thickest and most extensive body of the younger alluvium is that which forms and underlies the Lompoc plain in the western part of the valley. (See pl. 3.) This body is nearly continuous but becomes progressively thinner along the Santa Ynez River upstream to about San Lucas Bridge. In these areas the younger alluvium contains the most productive water-bearing beds in the valley. However, at most places along the river upstream from San Lucas Bridge the younger alluvium forms veneers of silt and sand on the bedrock surface, is only a few feet thick, and probably is largely cut out and replaced by the river-channel deposits. Contiguous tongues also lie along the perennial tributary streams such as Santa Agueda, Santa

Cruz, and Alisal Creeks. Other thick bodies form the valley floors of intermittent tributary streams such as those which drain the Purisima Hills. In those areas it is not highly productive of water.

The younger alluvium rests on and is flanked on each side by consolidated rocks through almost its entire extent. For a few miles in the vicinity of Buellton it rests in part on the Paso Robles and Careaga formations; and beneath about the eastern two-thirds of the Lompoc plain it rests on and against the Orcutt, Paso Robles, and Careaga formations. (See pl. 5.) In the part of the valley below San Lucas Bridge the younger alluvium is made up by two fairly distinct members —a lower member predominantly of coarse sand and gravel, and an upper member chiefly of fine sand, silt, and clay. (See pl. 5; also logs of wells along the river given in tables on p. 168 and p. 189.)

Lower Member.—The lower member, which is known only from well logs, occurs throughout the reach downstream from San Lucas Bridge, and downstream from the vicinity of Solvang it is continuous and fairly thick. Its thickness ranges from a feather edge along its margin to about 45 feet near Solvang and about 110 feet beneath the Lompoc plain. The increase in thickness of the lower member is progressive downstream. For example, in the Santa Ynez subarea at well 6/30-30A1 (pl. 2), the younger alluvium is 62 feet thick, and its lower member is 44 feet thick. At well 6/30-30B1 the corresponding thicknesses are 75 feet and 55 feet, respectively. Downstream in the Buellton subarea the thickness of the whole formation ranges from 32 to 86 feet, and that of the lower gravel member is from 10 to about 60 feet. (See log of well 6/32-11L1, table 27.) In the succeeding Santa Rita subarea, well 6/33-12L1 (table 28) penetrates 78 feet of younger alluvium, of which the lower 72 feet is reported to be gravel. At The Narrows, well 6/34-2A1 (table 28) penetrates 184 feet of alluvial deposits, of which all the lower 79 feet is reported to be gravel.

Beneath the Lompoc plain the lower member is even thicker and more extensive. It lies beneath about the northern two-thirds of the plain except on the east, where it is constricted sharply to a tongue that extends into and through The Narrows; also except on the west, where it seems to lie beneath about the south half of the plain. (See pl. 5.) Near the ocean it is about 75 feet thick.

Thus, the lower member of gravel occurs nearly everywhere throughout the river course. However, in a few places it is thin, and locally it may be absent. For example, in secs. 14 and 15, T. 6 N., R. 33 W., several wells penetrate only 10 to 15 feet of the gravel. Also, beneath the southern third of the Lompoc plain it probably exists only as separate tongues that extend to and into the several tributary canyons.

From the logs and yields of wells, also because well-rounded cobbles from 3 to 6 inches in diameter have been obtained in drilling certain wells, it is evident that the lower member of the younger alluvium consists of coarse gravel containing cobbles and boulders, doubtless some sand, but very little silt or clay. This seems to be true throughout its reach downstream from San Lucas Bridge.

Along the Santa Ynez River, from San Lucas Bridge downstream to the Lompoc plain, the lower member of the younger alluvium supplies water to numerous irrigation wells of which some have large capacities. For example, about 3 miles downstream from San Lucas Bridge, well 6/30-30A1, 16 inches in diameter, penetrates 44 feet of gravel and reportedly yields 1,350 gallons a minute; and well 6/30-30B1 reportedly yields 1,800 gallons a minute from 53 feet of gravel. (See pl. 2.) Downstream, in the reach between Buellton and The Narrows, the yield of well 6/33-12L1 has been measured as 790 gallons a minute, of well 6/33-9J1 as 730 gallons a minute, of well 6/33-16A1 as 485 gallons a minute, and of well 6/34-2A1 as 650 and 700 gallons a minute, respectively, on each of two dates. As determined by well-discharge tests, the permeability of the lower member ranges from about 1,000 to 4,500 gallons per day per square foot (see p. 76).

Along most of this reach from San Lucas Bridge downstream nearly to the Lompoc plain the upper member of the younger alluvium has been cut through, and the lower member is overlain directly by river-channel deposits. Still farther downstream, and beneath the entire Lompoc plain, the upper member intervenes between the lower member and the channel deposits, but as far downstream as about 3,000 feet beyond Robinson Bridge the intervening part of the upper member is coarse-grained. (See pl. 5, cross section *E-F-E'*.) Thus, throughout its reach from San Lucas Bridge downstream to about 3,000 feet beyond Robinson Bridge, no thick impermeable strata intervene between the bed of the Santa Ynez River and the lower member of the younger alluvium. Accordingly, throughout that reach there is free interchange of water between the river and the lower member of the younger alluvium. Therefore the lower member contains and transmits river underflow. Also, as its cross-sectional area is much greater than that of the river-channel deposits, the lower member transmits the bulk of that underflow. In a later section of this report the quantities of underflow transmitted are estimated.

Beneath the Lompoc plain, the lower member of the younger alluvium supplies water copiously to about 75 irrigation wells whose yields range from 500 to 1,000 gallons a minute. Thus, it is highly permeable and, because it supplies the bulk of the water withdrawn from wells, is termed the "main water-bearing zone." The water is confined throughout nearly all the plain (p. 147), but only at the extreme west end of the plain and in the middle of the plain opposite Rodeo Canyon is the head sufficient to cause flowing wells.

Upper member.—The upper member of the younger alluvium underlies and forms the alluvial plain about Lompoc, here called the Lompoc plain; it also forms the separate alluvial flats upstream along the Santa Ynez River at least as far as San Lucas Bridge and in the canyons of tributary streams that enter the Lompoc plain from the south. It overlies the lower member everywhere except within the actual channel of the river along the reach from San Lucas Bridge downstream nearly to Robinson Bridge.

The upper member of the younger alluvium is exposed only in the fronts of the low terraces along the river channel and locally along the tributary streams. In these exposures it consists of unstratified or faintly stratified clay, silt, and sand with enclosed stringers of pebbles at a few places. Elsewhere, especially in the Lompoc subarea where the member is thickest and most extensive, well logs indicate that extensively it is composed largely of clay and silt, with some strata of sand. (See pl. 5 and table 29.) Sand or gravel is the principal constituent of the member only near the mouths of the foothill streams along the south margin of the Lompoc plain such as San Miguelito Canyon; along the Santa Ynez River in the easternmost part of that plain; and along the north edge of the plain, about opposite Rodeo Canyon. The distribution of fine-grained and coarse-grained materials, here summarized so briefly, is critical with respect to the occurrence and movement of ground water and, accordingly, is developed more fully in several following paragraphs.

In most drillers' logs the topmost 30 to 40 feet of the upper member is reported as "soil," a nondescriptive term. However, some descriptive data are available from 15 observation wells, some as much as 45 feet deep, bored by the Geological Survey in the easternmost part of the Lompoc plain, and from 6 observation wells bored in the central and western parts of the plain. Logs of these wells are given in table 30. In wells drilled in the easternmost part of the plain the dry material above the water table was found to consist very largely of alternating beds of loose sand and silt but in some part of compact clay. The material penetrated by the wells in the western part of the plain is not markedly finer grained but seems to consist of somewhat more clay and silt and less sand. At least beneath the easternmost part of the Lompoc plain nearly all these materials, which form the topmost part of the upper member, are slightly to moderately permeable from the land surface to and below the water table. Similar conditions doubtless prevail over most of the Lompoc plain, although the average permeability of the materials probably diminishes westward, or toward the coast, except in the area near the north edge of the plain opposite Rodeo Canyon. Locally, as at one of the bored observation wells just described, compact clay occurs above and confines the shallow ground water; however, it is believed that such conditions do not occur extensively.

At greater depths the upper member of the younger alluvium contains beds of clay which are from 10 to 60 feet thick, and which are probably continuous over fairly broad areas beneath the central and western parts of the Lompoc plain—for example, at well 7/35–16N1 in cross section *J–J′* (pl. 5), at well 7/34–31A2 in cross section *H–H′*, and at wells 7/35–18J1 and 7/34–30L1 in cross section *E–E′*. As reported by drillers, some of the clay is "tough" or "compact." Similarly, "clay and sand" or "sandy clay" (drillers' terms thought to signify loose clay or silt with some sand) occurs in locally thick bodies, especially beneath the central part of the plain. Thus, although some sand is reported in nearly all well logs (see pl. 5) and in all areas except one rather small area to be described, silt and clay seem to predominate in the upper member across the full width of the Lompoc plain from the coast inland (eastward) about to Rodeo Canyon; also, across the northern two-thirds of the plain from Rodeo Canyon eastward to and possibly somewhat beyond the H Street Bridge across the Santa Ynez River, due north of Lompoc. Thus, the clay and silt predominate beneath about half the total extent of the plain.

Under hydraulic gradients of ordinary magnitude silt transmits water slowly, but compact clay transmits essentially none. Therefore, within the area just described, which spans roughly half the Lompoc plain, these fine-grained materials are essentially non-water-bearing. Even though the thin beds of sand that are enclosed have been tapped by a few domestic wells of small capacity, in the particular area the upper member of the younger alluvium has a very low average permeability, effectively retards the downward movement of water from the land surface, and under natural conditions generally confines the water in the permeable lower member under relatively low head. Likewise it confines water locally in the buried terrace deposits and in the Orcutt sand.

Beyond the thick and extensive beds of clay or silt—that is, beneath the southern third of the Lompoc plain from Rodeo Canyon eastward to Lompoc, and beneath the full width of the plain east of the H Street Bridge—the upper member of the younger alluvium consists extensively of silt, sandy silt, and sand. These deposits are somewhat permeable, sufficiently so to afford some hydraulic continuity between the unconfined water at shallow depth and the water of the highly permeable lower member. Thus, wherever and whenever the water table is higher than the static level of the water in underlying permeable zones, some water doubtless can percolate downward through the upper member. Such percolation doubtless is greatest when the pressure level of the deeper water body is drawn down by pumping from wells.

Locally within these areas—in particular, opposite the tributary canyons along the south margin of the Lompoc plain and along the Santa Ynez River—the upper member of the younger alluvium is predominantly sand and gravel and contains only thin, discontinuous beds of clay or silt. (See table 29, logs of wells 7/34–33L1 and 7/34–31J1.) The coarsest deposits of all are those penetrated by wells along the river within a few thousand feet downstream from Robinson Bridge, where very little silt or clay intervenes between the river-channel deposits and the lower member of the younger alluvium. (See pl. 5, cross section *E–F–E'*, wells 7/34–27K1, 7/34–34H1, and 7/34–35F5; also well 6/34–2A1.) These local coarse-grained deposits of the upper member absorb and transmit water fairly readily and probably do not effectively confine any underlying water-bearing zone. Along the south margin of the Lompoc plain they absorb all the low-water flow of the streams in San Miguelito Canyon, Rodeo Canyon, and other canyons; there, doubtless they transmit some water downward and laterally to the deeper-lying lower member of the younger alluvium. Along the Santa Ynez River, in the 3,000-foot reach downstream from Robinson Bridge, they likewise afford continuously permeable material from the channel deposits of that major stream downward to the lower member or "main water-bearing zone."

In the area at the north edge of the Lompoc plain opposite Rodeo Canyon, in secs. 23 and 24, T. 7 N., R. 35 W., the upper member seems to be largely sand, as at wells 7/35–23B1, 7/35–24H1, and 7/35–24K2 (see pl. 5, cross section *I–I'*), although the log of a shallow well bored by the Survey, 7/35–24K3 adjacent to 7/35–24K2, shows a high proportion of clay and silt in the uppermost 24 feet. There also the local coarse-grained deposits of the upper member probably afford some continuously permeable conduits between channel deposits of the river and the lower member of the younger alluvium.

Along the south flank of the Purisima Hills east of the Lompoc plain and north of the Santa Ynez River (see pls. 2 and 3), relatively broad tongues of younger alluvium floor the valleys of the several intermittent streams. In the main these tongues are essentially alluvial-fan deposits. As exposed in the fairly deep trenches reportedly cut in large part during the prolonged and heavy rains in the winter of 1940–41, the deposits appear to consist mainly of indistinctly bedded or lenticular strata of clayey or silty sand, which encloses scattered pebbles and small lenses of pebbles. Sand is the dominant ingredient, as the deposits were derived mainly from the Careaga sand,

Paso Robles formation, and the Orcutt sand. The contained pebbles are in part reworked from those older formations and in part derived from the Foxen, Sisquoc, and Monterey formations. They consist chiefly of diatomaceous and siliceous shale, but some are of sandstone, quartzite, jasper, or other rocks.

These alluvial-fan deposits are loose and absorb the flashy runoff of their respective intermittent streams in winters of average or less-than-average rainfall. At most places they are too thin and of insufficient extent to contain much water, but at least locally in the Santa Rita Valley they are believed to be relatively thick and may store a fairly large volume of water. However, because they are unassorted, lack thick and continuous strata of gravel, and are predominantly of sand and silt these particular bodies of younger alluvium are not highly permeable, even though porous. They are penetrated by only a few wells for domestic and stock use. With respect to ground-water resources, probably they serve chiefly to absorb rainfall and runoff and to transmit the water to underlying formations.

RIVER-CHANNEL DEPOSITS

The river-channel deposits comprise the materials intermittently transported by the present river and form the lowest alluvial plain, which is at times completely covered during floods and hence called the flood channel. They occur in a shallow valley carved in the younger alluvium and locally rest unconformably on the terrace deposits and older formations. They are the youngest deposits of the area and hence late Recent in age. Channel deposits also exist along the smaller streams but are generally only a few feet wide and thick and are not distinguished from the younger alluvium.

Along the Santa Ynez River the river-channel deposits range in width from 300 feet to about 3,000 feet. At most places there is no information as to the thickness, but a few wells penetrate the deposits, and drill cores have been made at the Santa Rosa dam site. In the Santa Ynez subarea wells 6/30–20H1 and 6/30–20H2 probably were drilled to bedrock and have measured depths of 48 feet. In the vicinity of Buellton wells 6/32–11L1 (table 27) and 6/32–11R2 encountered shale about 55 feet and 65 feet, respectively, below the surface of the deposits. Drill cores at the Santa Rosa dam site penetrated 70 feet of deposits above the shale. If all this material belongs to the river-channel deposits, they are therefore at least 70 feet in maximum thickness. This figure seems excessive, however, and it is likely that the lowermost strata belong to the younger alluvium, although distinguishing features have not been recognized. The channel deposits are probably 30 to 40 feet in maximum thickness.

Lompoc plain as a very shallow trough and probably to die out beneath the Lompoc Terrace.

The Santa Ynez River does not occupy either of these main synclines. In the Headwater and Santa Ynez subareas the river is south of the Tequepis syncline. In the Buellton subarea it crosses the east end of the Santa Rita syncline but shortly abandons that structural trough to enter its broad valley across the upfolded consolidated rocks of the Santa Rita subarea. Below The Narrows the river leaves the upfolded area, and in the Lompoc subarea swings across the west end of the Santa Rita syncline. Thus, only near Buellton and in the Lompoc subarea, where it crosses the two ends of the Santa Rita syncline—that is, for only about 18 miles of its entire course—is the Santa Ynez River in direct contact with the major bodies of water-bearing deposits in its valley. These seemingly anomalous features are explained in the following treatment of geomorphic history.

GEOLOGIC AND GEOMORPHIC HISTORY

The early events that bear on the development of the ground-water basins in southern Santa Barbara County took place in the early and middle parts of the Tertiary period of geologic time. In the Eocene, Oligocene, and Miocene epochs there accumulated over the area the marine and continental deposits of mud, sand, and gravel that have become the consolidated Tejon, Sespe, Vaqueros, Rincon, and Monterey formations. With the end of the Miocene this long period of nearly continuous deposition ended and in the ensuing early Pliocene the area of the Santa Ynez Mountains began to rise in a great anticlinal fold. Thus began the first stage in delimitation of the present ground-water areas.

North of the rising arch, over the area of the present Santa Ynez River basin, the sea remained as a broad shallow inlet whose south edge lay beyond the present course of the Santa Ynez River and whose north edge lay well beyond the present San Rafael Mountains. In this trough fine mud, in part diatomaceous, accumulated throughout early and middle Pliocene time to form the Sisquoc and Foxen formations. As brought out by Woodring and others (Woodring, Bramlette, and Lohman (1943, pp. 1353–1356), the site of the Purisima Hills apparently began to develop as a small anticlinal fold but evidently did not rise above the sea.

In the late Pliocene, however, the sea became even more shallow and the bordering land masses rose higher, so that sand and a small amount of gravel accumulated in the trough to form the Careaga sand. Near the end of the Pliocene the sea retreated entirely. At first lime deposits accumulated in fresh- or brackish-water ponds on these plains but later, streams flowing from the rising land masses began to deposit predominantly silt and mud, with a small amount of sand and gravel on the low coastal plains. These fine-grained deposits became the lower part of the Paso Robles formation.

The early earth movements accompanying these events were slow and gradual, and probably deformation was mainly by folding. However, with the transition from marine to continental deposition the uplift of the San Rafael Mountains became localized along the fault system bordering its south side. With continued uplift, streams flowing from this range and others from the north slope of the Santa Ynez Mountains built extensive coalescing alluvial fans in the intervening depression. These fans merged westward into a broad coastal alluvial slope which extended westward and northwestward for many miles. The deposits thus accumulated, in places nearly 3,000 feet thick, are the widespread Paso Robles formation.

This epoch of deposition ended in early or early middle Pleistocene time with intensified crustal movements. The San Rafael Mountains rose essentially to their present altitude by movement along the bordering fault system, cutting and strongly tilting the upper beds of the Paso Robles formation. Concurrently, these beds were arched over the Purisima Hills and the Santa Rita Hills and downfolded between. The Santa Ynez Mountains were further arched, with some of the movement localized along faults so that the Paso Robles formation and the Careaga sand dipped steeply off its north flank. Thus, the Santa Ynez Valley was established about in its present structural form.

Following this strong deformation of early or middle Pleistocene time, a widespread erosion surface was developed over all the lowland trough and much of the mountainous area. This erosion surface covered at least the westernmost part of the Santa Ynez Mountains and probably extended up the ancestral Santa Ynez trough far into the present Headwater subarea. Late in the development of this surface, streams deposited on its lower 20 miles material worn largely from the exposed edges of the Paso Robles and Careaga formations. The material thus deposited—sand with some clay and pebbles—constitutes the bulk of the Orcutt sand. Subsequently the sea may have advanced briefly inland and then retreated, leaving on the Orcutt sand the veneer of massive sand and scattered pebbles which now forms the indurated upper layer. Perhaps at the same time, local streams deposited a thin blanket of alluvium over the area of the Santa Ynez upland farther inland. Thus, there was formed a broad surface, at least in part depositional, extending from the sea far up into the Santa Ynez Valley and probably fairly high onto the north flank of the Santa Ynez Mountains. Before through drainage was established this surface evidently was tilted slightly southward, probably owing to renewed uplift of the San Rafael Mountains. Accordingly, when through drainage did develop (essentially in the present pattern) the ancestral Santa Ynez River was established far to the south close against the Santa Ynez Mountains and without regard to the major synclines.

Probably with renewed general uplift the river began to incise itself through the veneer of terrace deposits and the Orcutt sand; and except in the 5-mile reach across the present Buellton subarea and in the eastern part of the Lompoc subarea it became superimposed on the consolidated rocks underlying the north flank of the Santa Ynez Mountains. Correspondingly, its tributaries from the north were superimposed on the consolidated rocks in their lower reaches.

In subsequent downcutting the Santa Ynez River and its tributaries have developed the present valleys. The process was interrupted by several stages of relative stability, during which the inner valley was widened somewhat and narrow plains of alluvial sand and gravel were deposited along the river and less extensively along the tributary streams. With downcutting renewed after each period of stability these alluvial plains were dissected, and remnants were formed at successively lower levels along the deepening valleys. These remnants, the terrace deposits of today, include those buried beneath the south side of the Lompoc plain. In general, the successive sets of river terraces correspond to two prominent marine-cut terraces along the coast—one formed at a stand of the sea 60 to 90 feet above present level and the other about 300 feet above present level. The lower marine terrace probably corresponds to the lowest river terrace, in the deposits of which the fossil camel bone was found near Buellton.

Near the close of Pleistocene time the crustal movements died out almost completely. Also, probably concurrently with the advance of the latest continental glaciers, the sea withdrew along the entire coast and stood at least 200 feet below its present level. The Santa Ynez River and its tributaries cut sharp valleys into the underlying formations, but, as this low stand of the sea was relatively brief, those valleys were broad only in the unconsolidated deposits. Across the consolidated rocks only rather narrow canyons were incised.

As the sea returned about to its present level, the river and tributaries then aggraded their courses. The first deposits of aggradation were entirely coarse gravel, which now constitutes the lower member of the younger alluvium, but the material laid down subsequently was sand, silt, and clay. During this later stage of aggradation, the sea may have invaded the Lompoc subarea briefly and intermittently to form a shallow lagoon or tidal swamp in which the deposits were mainly clay but most of the upper member is considered continental.

So were deposited the predominantly fine-grained materials that make up the greater part of the upper member of the younger alluvium in the Lompoc subarea. At the same time, the side streams were de positing sand, gravel, and some clay to form the marginal alluvia fans. Ultimately a broad alluvial plain was formed in the previousl carved valley, of which the chief remnants are the Lompoc plain an the corresponding cultivated benches upstream along the Santa Ync River.

In recent years the Santa Ynez River has incised its course as muc as 45 feet below that plain. Along that entrenched course, in it flood channel, the river intermittently deposits and transports th coarse sand and gravel which are distinguished as river-channel de posits. The transport of this material is the latest event of the regio except for the local accumulation of dune sand blown in from th beach.

SURFACE-WATER RESOURCES

By H. G. Thomasson, Jr.

RUNOFF IN THE SANTA YNEZ RIVER BASIN

GENERAL CHARACTERISTICS

Because its land forms range from a ruggedly mountainous headwater terrane to relatively extensive lowland plains, because the water-holding capacity of its surficial materials and underlyiug rocks ranges greatly, and because its rainfall occurs largely in a few storms during a rainy season that extends about from December through the following April, runoff within the basin of the Santa Ynez River varies greatly among its several subareas (pl. 1) and fluctuates exceedingly each year. Flash runoff concurrent with storms and progressive depletion through the dry season of summer and autumn are characteristic. From year to year, runoff varies even more widely than rainfall (pp. 7–9). Based on computed virgin flow, the greatest yearly runoff in the Santa Ynez River near Lompoc (at Robinson Bridge) has been at least 120 times the least yearly runoff—the known extremes are those for 1930–31 and for 1940–41, respectively. At the same station, measured monthly runoff has been as great as 309,000 acre-feet (March 1911) and as little as 72 acre-feet (December 1929).

MEASURED STREAM FLOW

Table 6 identifies the stations at which measurements of stream flow have been made along the main stem of the Santa Ynez River; also, table 7 shows the scope of the records obtained at continuing gaging stations, both on the main stem and on tributaries. As table 7 shows, on the main stem of the river gaging stations have been maintained discontinuously from 1904 through 1920 and continuously thereafter