UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division

GEOHYDROLOGIC RECONNAISSANCE OF THE SOQUEL-APTOS AREA, SANTA CRUZ COUNTY, CALIFORNIA

By

J. P. Akers and J. J. Hickey

Prepared in cooperation with the Soquel Creek County Water District, the city of Santa Cruz, and the county of Santa Cruz

67-3
OPEN-FILE REPORT

Menlo Park, California
March 25, 1967

CONTENTS

Page

ILLUSTRATIONS

1. All illustrations are at end of report. Page number given is that of first principal reference to the illustration in the text.

TABLES

GEOHYDROLOGIC RECONNAISSANCE OF THE SOQUEL-APTOS AREA, SANTA CRUZ COUNTY, CALIFORNIA

By J. P. Akers
and
J. J. Hickey

ABSTRACT

This report summarizes existing knowledge on the geohydrology of the Soquel-Aptos area, near, and including the eastern part, of Santa Cruz, California, and outlines work necessary for making a complete appraisal of the water resources of the area.

The area is underlain mostly by marine and continental sedimentary deposits of Tertiary and Quaternary age. A small section in the northeastern part of the area on the eastern side of the San Andreas fault is underlain by sedimentary and metamorphic rocks of Cretaceous or older age. Quartz diorite, probably of Cretaceous age, underlies a considerable part of the area, but crops out only in small exposures along canyon bottom south of the Zayante fault.

The Soquel-Aptos area consists of two main structural blocks--one, downthrown on the northeast side of the Zayante fault; the other, upthrown on the southwest side of the fault. The main water-bearing formations in the southwestern structural block are the Santa Margarita and Purisima Formations. The Purisima, the most widespread of these units in this area, contains water under water-table and artesian conditions and furnishes water to most wells. The water-bearing character of the rocks in the northern structural block is unknown.

Presently available geohydrologic data are too limited for detailed evaluation of the ground-water potential in the Soquel-Aptos area. Work needed for a detailed evaluation includes: (1) Geophysical exploration and test drilling at selected locations, (2) pumping tests of selected existing wells and possibly of specially drilled test wells, (3) study and reconnaissance measurements of spring and streamflow, (4) chemical analysis of water samples from selected wells, streams, and springs, and (5) establishment of a program for monitoring water quality and water levels in key wells.

INTRODUCTION

Location and General Features

The Soquel-Aptos area as considered in this report extends from Branciforte Creek and the San Lorenzo River on the west to La Selva Beach on the east, and from the San Andreas fault on the north to Monterey Bay on the south. The eastern boundary is the drainage divide separating the Pajaro River basin from the drainage basins lying to the west (fig. 1).

The area lies between lat 36°55' and 37°10' N. and long 121°45' and 122°05' W., and includes the eastern part of the city of Santa Cruz which is about 70 miles south of San Francisco. Other towns within the area are Soquel, Aptos, Capitola, Rio Del Mar, and La Selva Beach. The major roads leading into the area are California State Highway 1 and 17.

The northern part of the Soquel-Aptos area is formed of the rugged Santa Cruz Mountains--here as much as 3,000 feet above sea level--that give way southward to rolling hills and ridges ranging from about 200 to 800 feet above sea level. The rolling hills terminate against relatively flat terraine formed on terrace deposits that overlie marine terraces. Sea cliffs as much as 100 feet high fall away from the terraces to narrow beaches which parallel Monterey Bay.

The area is drained principally by Branciforte, Soquel, and Aptos Creeks.

Precipitation in the Soquel-Aptos area is almost entirely rainfall. The infrequent snowfalls that occur in the higher elevations have little influence on runoff. The precipitation pattern over the area indicates a large variation in areal distribution; the annual means range from 20 to 28 inches along the coast and from 52 to 64 inches along the northern boundary. More than 80 percent of the precipitation occurs between November and March, and less than 20 percent occurs between April and October. Precipitation varies widely from year to year as indicated in the cumulative departure curves (fig. 2) for the U.S. Weather Bureau stations at Santa Cruz and Wright's. These curves also indicate the groupings of wet and dry years for the higher elevations (Wright's) and for the lower elevations (Santa Cruz). Data from selected precipitation stations (table 2) further indicate the variability in precipitation. Precipitation stations which have data for the years corresponding to the period of available streamflow data are shown on table 3.

Purpose and Scope

Water for municipal, irrigation, and industrial use in the Soquel-Aptos area between La Selva and that part of the city of Santa Cruz east of Branciforte Creek is obtained from both ground-water and surface-water sources. In the past these sources have been adequate to supply the required water needs, but in anticipation of increased water demands, plans to develop additional surface-water supplies are being made. However, until these plans can be realized increased demand in areas not served by the city of Santa Cruz must be met largely from ground-water sources.

The prospect of increasing ground-water withdrawals has caused concern to the water-service agencies because the magnitude and distribution of the ground-water resource is not adequately known. Previous studies have been hampered by a lack of data on which to predict the quantities of withdrawals that could be made before some adverse condition affected the supply. In a 1963 report to the city of Santa Cruz, the consulting firm of Brown and Caldwell points out this lack by noting that their estimate of ground-water availability was based on meager data, and that "large scale production of ground water, with substantial dewatering of aquifers should not be attempted until such a time as additional data are obtained with respect to subsurface and hydrologic conditions."

Accordingly, the city of Santa Cruz and the Soquel Creek County Water District entered into a cooperative agreement with the U.S. Geological Survey to make a reconnaissance study of the area and review existing knowledge of the ground-water resource in order to design a full appraisal study. The scope of the project included: (1) A review of existing published and unpublished geologic and hydrologic reports for the area, (2) compilation of a geologic map of the area from existing reports and data supplemented by additional geologic mapping by the Geological Survey, (3) a canvass of selected water wells, (4) establishment of a water-level-measuring network in key observation wells, and (5) preparation of this report summarizing the preliminary findings based on items 1-4, and outlining a program to collect the additional data necessary to complete the appraisal of the ground-water supply for the city of Santa Cruz.

Most of the effort in this study was directed to amassing and evaluating existing data relating to ground water in the area. Little fieldwork, other than a limited canvass of wells and some minor geologic mapping to aid in delineating aquifers, was done. The geologic map (fig. 1) was compiled from unpublished U.S. Geological Survey maps by T. W. Dibblee, Jr., and modified from published material and by mapping by the authors. Geologic cross sections were prepared from this map and from logs of wells. The sources of these hydrologic data are summarized in table 1. The data are on file in the Menlo Park Subdistrict office of the Water Resources Division, U.S. Geological Survey.

Acknowledgments

A considerable part of the data incorporated in this report was obtained from the files and unpublished reports of private firms. Especially helpful reports were:

1. Investigation of water-supply projects, City of Santa Cruz water system, City of Santa Cruz, 1959, by Brown and Caldwell, consulting engineers, San Francisco, Calif.
2. A study of water supply, treatment, and distribution for Santa Cruz and vicinity, 1963, by Brown and Caldwell, consulting engineers, San Francisco, Calif.
3. Report on Soquel Highlands investigation--water resources survey 1961, by Creegan and D'Angelo, civil engineers, San Jose, Calif.

Well logs, data on yield, and data on quality of water were made available from the files of several drilling firms and Charles S. McCandless and Co., consulting engineers, Palo Alto, Calif.

Helpful information regarding surface water and the lithology of the Purisima Formation was obtained from a duplicated report, "Survey Report for Flood Control and Allied Purposes, Soquel Creek, Santa Cruz County, California," 1963 (revised 1965), by the U.S. Army Corps of Engineers, San Francisco District.

Neither the geology nor the hydrology of the entire Soquel-Aptos area has been studied in detail by any agency or individual. However a small part of the area near Branciforte Creek was included in a description of the Santa Cruz quadrangle (Branner, Newsom, and Arnold, 1909). Also, general geologic information has been briefly summarized in reports of the California State Water Resources Board (1953) and California Department of Water Resources (1959). Detailed information on the geology of small areas is available in three unpublished reports prepared as parts of Stanford University student research projects. These are: "The Stratigraphy of the Capitola-Sunset beach Area, Southern Santa Cruz County, California," by C. G. Davis and F. B. Henderson, 1957; "Geology of Southwest Portion of Laurel Quad," by John J. Sislar, 1960; and "Stratigraphy and Structure of the Glenwood Basin Area, Santa Cruz Mountains, Santa Cruz County, California," by R. O. Burford, 1961.

Also, special thanks are due to T. W. Dibblee, Jr., whose helpful discussions and suggestions contributed substantially to the sections of this report on geology and ground water.

SUMMARY OF PRESENTLY AVAILABLE DATA

Geology

The Soquel-Aptos area is underlain mostly by marine and continental sedimentary deposits of Tertiary and Quaternary age. These deposits consist of clay, silt, sand, and conglomerate of various degrees of consolidation. In general, those of Miocene age or older are moderately to well consolidated and they do not yield water readily to wells. The sand and conglomerate units in Pliocene and younger deposits, in general, are poorly consolidated and are good aquifers.

A small section in the northeastern part of the area on the eastern side of the San Andreas fault (fig. 1) is underlain by sedimentary and metamorphic rocks of Cretaceous or older age. These older rocks yield very small amounts of water, if any.

The Tertiary sedimentary deposits on the western side of the San Andreas fault and north of the Zayante fault (fig. 1) may be more than 6,000 feet thick. Present geologic data indicate that much of the thickness of older Tertiary strata south of the Zayante fault was removed by erosion prior to deposition of younger rocks, and that a maximum thickness of about 1,000 feet remains.

In this report, the geologic units are discussed from oldest to youngest with special reference to the geohydrologic properties (table 4).

Stratigraphy and Water-Bearing Character of the Rocks

Igneous rocks.--Igneous rocks, mostly quartz diorite of Cretaceous age, underlie a considerable part of the report area at various depths (figs. 3 and 4) and crop out in canyon bottoms of Hester, West Branch of Soquel, and Soquel Creeks 1.5 to 2 miles upstream from the junction of West Branch of Soquel and Soquel Creeks, in three small exposures near Happy Valley School, and a few hundred feet south of the 1,600-foot well on the upthrown side of Zayante fault.

Wells at the northeast edge of Santa Cruz encountered rock, logged as "granite," at depths ranging from 130 to 794 feet. An oil-test well in the head-waters of Bridge Creek about 4 miles north of Aptos bottomed in "granite" at a depth of 1,600 feet; another nearby and to the north bottomed in sedimentary rock at a depth of more than 4,500 feet.

Water in the igneous rock occurs in fractures which may or may not be intercepted by a given well. Even those wells that do intercept fractures in the quartz diorite usually have very low yields--usually less than 10 gpm (gallons per minute).

Sedimentary rocks of Cretaceous age.--Rocks of Cretaceous age include sedimentary types that have a very small capacity to accept and transmit water. These rocks are upthrown and exposed in a small area in the northeastern corner of the report area northeast of the San Andreas fault.

Small supplies of water (1-10 gpm) can be developed from these rocks in places where they are jointed and fractured, but they are unimportant for municipal supplies.

Sedimentary rocks of Tertiary age older than the Santa Margarita Formation.--Rocks of Tertiary age older than the Santa Margarita Formation include the Butano Sandstone, of Eocene age, the San Lorenzo Formation, of Eocene and Oligocene age, the Vaqueros Formation, of Oligocene (?) and of Miocene age, unnamed clay and shale, of Miocene age, and the Monterey Shale, of Miocene age. These formations are exposed in bands trending northwest parallel to the San Andreas fault.

Of these rocks, the Butano Sandstone has the best potential for the development of ground-water. The Butano contains boulder and cobble conglomerate interbedded with coarse-grained conglomeratic sandstone near its base. Scattered throughout the formation are shaly interbeds that might hinder the percolation of water and thus limit recharge, but properly constructed wells in the Butano would possibly yield several tens of gallons per minute.

Sandstone units in the other older Tertiary formations, in general, are fine grained and well cemented and have limited potential for development of large supplies of ground water. Their included shaly beds are, for all practical purposes, impermeable, so that the units are not considered aquifers.

The Vaqueros Formation appears to be permeable enough to yield small supplies, but this potential has not been tested.

Santa Margarita Formation.--The Santa Margarita Formation, of late Miocene age, crops out within the Soquel-Aptos area in Blackburn Gulch, in a valley tributary to the West Branch of Soquel Creek, and in a small exposure just east of Branciforte Creek near the northwest corner of Santa Cruz. The distribution of the formation toward the east in the subsurface is not known, but it is known to extend westward to a point several miles west of Scotts Valley.

The Santa Margarita appears to be the most permeable formation in the Soquel-Aptos area. It is composed, in its lower parts, of well sorted, medium to granule-sized subrounded grains of quartz and feldspar, no doubt derived from the quartz diorite which, in places, it overlies. Where exposed in Blackburn Gulch the unit contains several extensive lenses of sandy mudstone near the top.

The thickness of the Santa Margarita is variable because it was deposited on an erosion surface having several hundred feet of relief. The maximum exposed thickness in Blackburn Gulch is about 300 feet. In a few localities the igneous rocks are exposed in contact with the Purisima Formation of late Tertiary age, indicating that in these localities the Santa Margarita was never deposited.

Several wells in Scotts Valley obtain water from the Santa Margarita Formation. Some of these have yielded as much as 1,200 gpm (gallons per minute) for short periods, but the sustained yield of these wells probably is considerably lower, perhaps half as much.

Purisima Formation.--The Purisima Formation, of Pliocene age, underlies the southern two-thirds of the Soquel-Aptos area and is the most widespread aquifer in this area. It is a heterogeneous formation containing numerous marine fossils; a few sandstone beds contain so many mollusk shells that they resemble coquina. The Purisima consists mostly of crossbedded sandstone, but contains numerous interbeds of pebble conglomerate, siltstone, and mudstone. Pebble and granule conglomerate makes up several hundred feet of the Purisima along the high ridge paralleling Aptos Creek on the east. The sandstone is composed largely of fine to medium, fairly well-sorted grains of volcanic material of basaltic or andesitic composition. These volcanic materials make up a large part of the so-called "blue" or "black" sandstone beds from which much of the water in the Purisima is derived. Pebbles commonly occur as stringers along cross laminations in the sandstone units.

The Purisima Formation is poorly consolidated in most areas. Commonly it is so friable that "running" sand conditions are a problem in drilling and well-development operations.

The Purisima in the northern part of the Soquel-Aptos area north of the Zayante fault is more than 2,000 feet thick--possibly as much as 3,000 feet. South of the Zayante fault the maximum thickness is probably about 1,000 feet. The thickness beneath the terrace deposits in the southwestern part of the area is about 200 to 400 feet; beneath the terrace deposits near Aptos, the thickness is more than 900 feet.

The Purisima is a good aquifer and contains water in most of the Soquel-Aptos area. Logs of wells indicate that water in the Purisima occurs under both water-table and artesian conditions. Impermeable or moderately impermeable sandstone and shale beds, some of which are fossiliferous, act to confine water in the black sand beds from which most of the artesian water is obtained. Logs of wells and reports by drillers that water levels changed as successive strata were penetrated indicate that the Purisima may contain more than one artesian aquifer. The nature of the water table above the uppermost confining beds and the effect of these beds on recharge to the Purisima, are unknown.

Aromas Red Sands of Allen (1946).--The Aromas Red Sands of Allen (1946), of Pleistocene age, crop out only in the southeastern corner of the report area in the Trout and Valencia Creek drainage areas. This formation consists of friable, fine- to coarse-grained, red to brown arkosic and clayey sandstone. The thickness of the Aromas is not known exactly, but an inspection of contours (fig. 1) indicates that beneath the highest point on the ridge between Valencia and Trout Creeks the thickness is at least 500 feet.

The Aromas is a good aquifer near Watsonville, outside the report area, and probably also in the area of this report east of Aptos. However, the contact between the Aromas and Purisima is gradational, and it is difficult to determine from available logs if any wells in the Aptos area obtain water exclusively from the Aromas.

Terrace deposits.--Marine- and river-terrace deposits occur at levels of 20 to 100 feet, and between 200 and 300 feet above sea level in the Soquel-Aptos area. The lower levels form an irregular band of terraces ranging from 1 to 2 miles wide along the coast. The higher levels are preserved atop ridges between Aptos, Soquel, and Branciforte Creeks in irregular patches about 2 to 3 miles inland from the coast. The terrace deposits consist of gravel, sand, silt, and clay. They range from a few feet to as much as 100 feet in thickness. These deposits are not important as aquifers even though in several places they supply small domestic water needs.

Alluvium.--Recent alluvial deposits are restricted largely to parts of the valley bottoms along the main stem of Soquel, West Branch Soquel, Aptos, and Branciforte Creeks. They consist of unconsolidated gravel, sand, silt, and clay deposits ranging from a few feet to more than 100 feet thick. These deposits contain water and are the source for numerous small domestic water supplies. They are advantageously located to receive recharge from the nearby streams and have some potential for supplying limited amounts of water for irrigation.

Structure

The Soquel-Aptos area consists of two main structural blocks--one to the southwest and one to the northeast of the Zayante fault (shown on figures 1, 3, and 4 as the northern block and southern block). Logs of oil test wells indicate that the northern block has been downdropped more than 4,500 feet relative to the southern block. The northern block is characterized by faulting, folding, and steeply dipping strata that are overturned near the San Andreas fault at the northeast side of the block. This block consists of a base of unknown composition overlain by several thousand feet of sedimentary rocks.

The main folds in the northern block are a syncline traceable for 9 miles across the report area, and a short anticline. Both these features are near the southwest boundary of the block. The trend of all structures in this block is southeastward.

The southern block is characterized by gentle southeasterly dips--except near the Zayante fault--and little or no faulting. This block is formed of quartz diorite overlain by sedimentary rocks of unknown thickness, but, as indicated by outcrops of quartz diorite and by well logs, the deposits probably have a maximum thickness of about 3,000 feet. These sedimentary rocks are probably thickest in the area between Aptos and Soquel.

Ground Water

Occurrence and Movement

Nearly all fresh ground water in the Soquel-Aptos area comes from precipitation within the boundaries of the area. Possibly, a small amount moves into the area from Scotts Valley and from the upper drainage areas of Corralitos Creek and Pleasant Valley.

The logs of wells, and records of water levels in wells which obtain water from different zones, indicate that the water in the Purisima Formation occurs under different conditions of confinement at different depths. In the shallower zones the water is unconfined and occurs under water-table conditions; in the deeper zones it is confined and occurs under pressure or artesian conditions. Logs of some wells indicate that two or more artesian zones are present in the Purisima in some areas. Previous studies (California State Department of Water Resources, 1953) indicate that the confining stratum, or strata, that separates the shallow water from the confined water in the Purisima consists of firmly cemented, sometimes fossiliferous sand of unknown areal extent and continuity. Where the confining layers have a sporadic distribution, or are themselves moderately permeable, the water probably occurs locally under artesian conditions.

Information is not now available to determine whether ground water occurs under water-table or artesian conditions within the Aromas Red Sands in the study area. However, because the Aromas is in depositional contact with the Purisima Formation, and both are permeable, the two probably are hydraulically connected.

As in other central California coastal areas (California State Department of Water Resources, 1953, pl. 17), the confining layers probably wedge out landward and in the area landward of the wedge the ground water is not separated into zones, but occurs as a continuous body under water-table conditions. This area landward of the wedge is the recharge area for the confined aquifers. Figure 5 is a cross section portraying hypothetical relations of the aquifers and aquicludes to water-table and piezometric surfaces and to recharge areas.

Probably considerable water from direct precipitation and from runoff enters the very permeable Santa Margarita Formation where it is exposed in Blackburn Gulch in the northwestern part of the southern structural block. The direction in which this water moves after entering the Santa Margarita is not known. The exposures of igneous rock (fig. 1) suggests that a buried granite ridge may extend between the exposure near Happy Valley School and those near Sugar Loaf Mountain. If this ridge exists, then it would form a barrier to ground-water movement and little, if any, of the water entering the Santa Margarita could move southeastward toward pumped areas near Soquel and Aptos. If the ridge does not exist, probably a considerable amount of water is directed down the trough into the Purisima Formation between Soquel and Aptos.

Most of the water that enters the formations in the northern block enters the Purisima Formation, which is more permeable than the other formations. Water-level contour maps in California State Department of Water Resources Bulletin 5 indicate that most of this water is directed southeastward along the syncline in which the Purisima is confined, so that it moves out of the Soquel-Aptos area into the Pajaro ground-water basin. Some water may move southward across the Zayante fault into the Purisima of the southern structural block.

Some of the ground water in the Soquel-Aptos area is removed by pumping; some is discharged from seeps or springs to become base flow of the perennial streams; and some is discharged by evapotranspiration. Probably additional discharge occurs as underground flow into Monterey Bay.

Aquifer Properties

Available data indicate little about the properties of aquifers in the Soquel-Aptos area except that the permeability of the Purisima Formation seems to vary widely from place to place. Wells have specific capacities ranging from 1 to as much as 80 gpm/ft (gallons per minute per foot) drawdown. Some of this wide difference might be attributable to well construction or to withdrawal of water from different "black sand" beds, but probably most is attributable to the heterogeneous lithology of the Purisima. In some places, the higher specific capacity might be related to the occurrence of the Santa Margarita Formation within the section penetrated by the well. Probably a well that intercepts the Santa Margarita at depth under the Purisima would have a higher specific capacity than a similar well obtaining water solely from the Purisima.

The difference in yield of wells in the various well fields may also relate to differences in the environment in which the Purisima was deposited. Specific capacities of wells indicate lower permeabilities in the well fields of the Sea Cliff area near Black Point and Soquel Point than in those of Soquel-Capitola and Aptos-Rio del Mar areas. Possibly the Sea Cliff area represents a deeper water facies of the Purisima, laid down in parts of the basin that were deeper than those in which the sediments of the other well fields were deposited. Commonly, only the finer grained, less permeable materials are deposited in deep-water areas.

Depth to Water

Perched water bodies may occur above impermeable beds in the upper parts of the aquifer sequence, and in these areas shallow wells having small yields might be developed even on ridges or hills. Wells in the water-table zone seaward of the terraces (fig. 1) have water levels usually less than 15 feet below the land surface. Wells in the artesian zones in this same area have water levels that range from several tens of feet below the land surface to a few feet above the land surface.

Fluctuation of Water Levels

Water levels in two wells in the Soquel-Aptos area have been measured periodically by the State of California Department of Water Resources since December 1946, and for various shorter periods by other agencies. However, because construction data on the wells are incomplete, it is not known which aquifer the measured water levels represent. The changes in water levels in these wells, therefore, cannot be related to regional or areal trends; they reflect conditions in the individual wells only.

Quality of Water

Analyses of water from wells indicate that water in confined aquifers in the Soquel-Aptos area is, in general, suitable for irrigation. However, it is hard and in some localities contains amounts of iron and manganese that make it objectionable for municipal supplies. Little information is available about chemical quality of water from the unconfined aquifers. However, numerous exposed beds in the Purisima Formation are heavily stained by iron, and iron oxide cements some units. Commonly, iron staining marks the location of seeps and springs. This suggests that most water within the Purisima has an appreciable iron content.

Representative analyses of water from selected wells are listed in table 5.

Surface Water

Streamflow records for the Soquel-Aptos area are available for various periods, generally within the past 15 years. Measurements were made for short periods prior to that time at a few special project sites, but only recently have continuous records been collected for the major streams of the area. Influent and effluent reaches of the streams, which are indicative of the interrelations of surface and ground water, have not been determined. Additional records of streamflow characteristics of the principal streams are needed to identify these reaches.

Available Streamflow Data

Four continuous streamflow measuring stations are maintained by the U.S. Geological Survey within the study area (fig. 1). The longest periods of record, January 1940 to September 1943, and March 1952 to date, are for the station on Branciforte Creek at Santa Cruz. The station on Soquel Creek at Soquel was established in May 1951 and the streamflow record is continuous to date. The station on West Branch Soquel Creek near Soquel was established in October 1958 and has operated continuously since that time. The station on Aptos Creek at Aptos was established September 1958 and a continuous record of streamflow has been maintained to date. The California State Department of Water Resources measured streamflow in the vicinity of the present locations of the U.S. Geological Survey streamflow measuring stations on Soquel Creek and West Branch Soquel Creek from 1949 to 1950, and 1948 to 1950, respectively. The Monterey Bay Water Co. made flow measurements near the present location of the Soquel Creek station, and at the site of the proposed Upper Soquel Creek dam, from 1936 to 1941. Brown and Caldwell in 1963, and the U.S. Army Corps of Engineers (1965) extrapolated, by correlation methods, the available streamflow data to estimate the amount of water that could be developed by dams and reservoirs on Soquel and Aptos Creeks. The California State Water Resources Board (1951 and 1953) used correlation procedures to estimate the mean seasonal runoff, 1894-95 to 1946-47, for Branciforte, Soquel, and Aptos Creeks. Streamflow data are given in table 6.

ADEQUACY OF AVAILABLE GEOHYDROLOGIC DATA

Presently available geohydrologic data are too limited for detailed evaluation of the ground-water potential of the Soquel-Aptos area. Previous ground-water investigations of Santa Cruz County have been general in scope. Geological studies also have been of a general nature, or have been confined to only small parts of the area. Although water-level records have been kept by several agencies during approximately the past decade, well-construction data are not sufficient to identify the aquifers in individual wells that are being pumped. Drillers' logs are available for a considerable number of wells, but few contain detailed lithologic descriptions or needed information about perforated intervals, changes in water levels as drilling progressed, or water levels during pumping. Test data from which to compute coefficients of permeability and storage are not available.

Reliable streamflow hydrographs can be constructed for the periods for which there are continuous streamflow records. However, other surface-water information, such as identification of the influent and effluent reaches of streams, is needed to allow definition of the relationship between surface water and ground water.

Data relating to chemical quality of municipal water supplies have been obtained by various water-service agencies, but few chemical data are available for individual domestic and irrigation water supplies. The present distribution of sampling points is inadequate to permit knowledgeable assessment of the liklihood of sea-water intrusion in the Soquel-Aptos area. However, quality-of-water records of the water-service agencies indicate that there is no sea-water intrusion into pumped areas at the present rate of withdrawal.

A preliminary network of wells for the measurement of ground-water levels was established after collecting and evaluating all available well data for the area (table 7). The wells chosen for the network are primarily in the coastal part of the area, as shown in figure 1. The primary objective of the water-level measuring network is to monitor water-level changes in the various water-table and artesian zones of the area. The distribution of existing wells and the data available from them are insufficient to meet these objectives. The preliminary network is the best that can be designed with available data, but additional geologic and hydrologic information as well as data gathered from the network must be obtained before meaningful interpretation is possible.

GEOHYDROLOGIC PROBLEMS AND WORK NECESSARY FOR THEIR SOLUTION

Geology

Basin Configuration

The structural blocks on either side of the Zayante fault constitute separate ground-water basins. The configuration and boundaries of these basins are coincident with the contacts of the permeable formations and the underlying non-water-bearing igneous rock or indurated sedimentary formations. The configuration of each basin must be determined before the saturated thickness of the formations and the amount of water stored in the formations can be determined.

To some extent, the configuration of the basins determines the direction that water moves within the formations. The presence or absence of the ridge of granite just east of the exposures of the Santa Margarita Formation (see section on ground-water occurrence and movement) must be established before it will be possible to determine direction of movement and potential recharge to the southern block.

Field investigation, involving detailed mapping of geologic contacts, geophysical exploration to identify and map subsurface contacts, and test drilling at selected locations to verify subsurface conditions will be required to determine basin configuration.

Stratigraphy and Lithology

The extent of the clay, silt, sand, and gravel beds in the various water-bearing units of the permeable formations has not been determined. This information is necessary for estimating ground-water availability, storage capacity, and yields of aquifer units. Also, the extent, thickness, and nature of contacts of the various subsurface formations have not been determined. Test drilling at selected locations, geophysical studies, and detailed geologic mapping of outcrop areas and contacts will be needed to determine these factors. Drill holes must be carefully logged, and samples of drill cuttings and outcrop material must be studied in the laboratory to develop correlation criteria.

Stratigraphic, lithologic, and basin-configuration data must be combined with adequate hydrologic information to provide a basis for estimating the magnitude and availability of the ground-water resource.

Ground Water

Occurrence

The number, position, and continuity of artesian zones within the permeable formations have not been determined. Available logs of wells indicate that several artesian zones might be present near Soquel and Aptos.

The nature of the occurrence of ground water--whether in perched, water table, or artesian zones--in the Aromas Red Sands of Allen (1946) is not known. Water levels and yields of wells that obtain water from the Aromas in the Rob Roy Junction area differ widely. This difference might be due to well structure, incomplete development, the fact that the wells obtain water from different water-bearing zones, or combinations of the factors named.

Water-table levels and piezometric surfaces of water in the various units of the Purisima Formation cannot be correlated using present available data. The water levels in most wells in the Soquel-Aptos area cannot be identified with a particular water-bearing zone.

This information is necessary to determine yield characteristics of aquifer units; areas of recharge; the direction of ground-water movement; and changes in storage due to pumping, natural discharge, or recharge.

A detailed study of all available electric, lithologic, and drillers' logs, supplemented with data from test drilling and additional field studies, is necessary to identify the aquifers, and to determine which of the aquifers contribute water to specific wells. Details of well construction--perforated intervals, gravel packing, sealing--must be known for a given well to determine which aquifer the water level in that well represents.

A program of regular measurement of water levels in selected observation wells must be carried on to determine seasonal and long-term changes in the quantity of water stored in the aquifers and the direction of movement of ground water. These data will aid interpretation of recharge and discharge relationships, rates of change of water in storage, and long-term availability of the ground-water resource. Some wells will be measured twice each year to determine conditions during the wet and dry season, some monthly to monitor short-term storage change, and a few will be equipped with continuous water-level recorders.

Aquifer Characteristics

Coefficients of permeability and storage are not known for any of the aquifers in the Soquel-Aptos area. These factors, in addition to the extent and hydraulic interconnection of the various artesian zones, must be known to determine the amount of water moving through the aquifer to the sea or to other points of discharge; to project draw-downs in time and space at given rates of withdrawal; and to anticipate changes in the quantity of water stored in the aquifers.

Specially conducted pumping tests of selected existing wells, or of wells specifically drilled for testing, must be made to establish field coefficients of permeability and storage. These coefficients may then be used to calculate areal conditions of water availability.

Relation of Surface Water to Ground Water

Influent and effluent reaches of streams are not now defined. These should be known to aid in determining the effect that ground-water withdrawals may have on stream discharge; the control that geologic structure has on the movement of ground water; the influence the geology has on the base-flow characteristics of the streams; and in estimating the potential ground-water recharge from streamflow.

Measurements of increase or decrease of streamflow along the major streams, along with base-flow hydrographs and flow-duration curves, will be needed to aid determination of the relation of surface water to ground water. A study of the springs of the area will also provide data on this relationship.

Quality of Water

The chemical quality of water in areas of potential ground-water development, and in some areas where domestic, agricultural, and industrial supplies are presently withdrawn, is not well known. Heavy minerals in "black sand" beds are suspected as one cause of a high concentration of iron and manganese observed in ground-water in certain localities of the study area. However, nearly all water from artesian zones is reported to come from "black sand," but only locally does the water have large iron and manganese concentration.

The data indicate that under present conditions of pumping in the Soquel-Aptos area water levels have not been drawn down below sea level for prolonged periods, and salt-water intrusion has not yet occurred. However, if additional drafts of ground water are made as is planned, a potential for salt-water encroachment may be created. Several irrigation wells just southeast of La Selva are reported to have been rendered unusable by salt-water encroachment. The limited data now available indicate that corrosion and fouling problems affect some of the public water-supply systems in the area. These problems include deterioration of well screens and casing, iron in water pumped, and clogging of well screens. Additional studies are to be made of the conditions causing these problems.

A quality-of-water surveillance program should be established in areas where a potential salt-water intrusion problem exists. Samples of water from wells between the shore and heavily pumped areas should be analyzed periodically to detect changes in chemical quality that would indicate intrusion.

Major streams should be sampled at least once, during low flow, at selected intervals along their courses to determine changes in chemical quality that might be related to geology. Determination of the relation of the chemical quality of the ground water to the geology is helpful in determining which of the various aquifers contribute to streamflow. This information also is helpful in planning surface-water facilities.

SELECTED REFERENCES

Allen, J. E., 1946, Geology of the San Juan Bautista quadrangle, California: California Div. Mines Bull. 133.

Baldwin, T. A., 1951, Geology of the Santa Cruz Mountains [abs.]: Am. Assoc. Petroleum Geologists Bull., v. 35.

Beveridge, A. J., 1960, Heavy minerals in lower Tertiary formations in the Santa Cruz Mountains, California: Jour. Sed. Petrology, v. 30, no. 4.

Bramlette, M. N., 1946, The Monterey formation of California and the origin of its siliceous rocks: U.S. Geol. Survey Prof. Paper 212.

Branner, J. C., Newson, J. F., and Arnold, Ralph, 1909, Description of the Santa Cruz quadrangle, California: U.S. Geol. Survey Geol. Atlas, Folio 163.

California Department of Water Resources, 1958, Sea-water intrusion in California: California Dept. Water Resources Planning Bull. no. 63.

______1959, Ground-water conditions in central and northern California, 1957-58: California Dept. Water Resources Planning Bull. no. 77-58 XIV.

California State Water Resources Board, 1951, Water resources of California: Bull. no. 1.

______1953, Santa Cruz-Monterey Counties investigation: Bull. no. 5.

Davis, F. F., and Jennings, 1954, Mines and mineral resources of Santa Clara County: California Jour. Mines and Geology, v. 30.

Fitch, A. A, 1907, The geology of Ben Lomond Mountain: California Univ. Dept. Geol. Sci. Bull.,v. 21.

Galliher, E. W., 1932, Sediments of Monterey Bay, California: State Mineralogist California Rept., Mining in California.

Gribi, E. A., Jr., 1957, Santa Cruz basin holds important promise: Oil and Gas Jour. v. 55, no. 13.

Hubbard, H. G., 1943, Mines and mineral resources of Santa Cruz County: California Jour. Mines and Geol., v. 39, no. 1.

Jones, W. F., 1911, The geology of the Sargent oil field: California Univ. Dept. Geol. Sci. Bull., v. 6.

Lael, W., and Cory, W. H., 1932, The Vaqueros formation of lower Miocene of California: California Univ. Pub. Geol. Sci., v. 22.

Martin, Bruce, 1916, Pliocene of middle and northern California: California Univ. Dept. Geol. Sci. Bull., v. 9, no. 15, p. 223.

Michelin, James, 1943, Sargent oil field: California Div. Mines Bull. 118, p. 475-476.

Newsome, J. F., 1903, Clastidikes: Geol. Soc. America Bull., v. 14, p. 227-228.

Page, B. M., and Holmes, C. N., 1945, Geology of the bitiminous sandstone deposits near Santa Cruz, Santa Cruz County, California: U.S. Geol. Survey Oil and Gas Inv. Prelim. map 27.

Society of economic palenontologists and mineralogists, 1959: Guidebook ann. field trip, Pacific Section S.E.P.M., April 24-25, 1959.

Storie, R. E., and others, 1944, Soil survey of the Santa Cruz area, California: U.S. Dept. Agriculture Soil Survey, Ser. 1935, no. 25, p. 90.

Taliaferro, N. L., 1943, Geologic history and structure of the central coast ranges of California: California Div. Mines Bull. 118, p. 126.

UNPUBLISHED THESES

Alexander, C. S., 1950, The marine and stream terraces of the Capitola-Watsonville area, California: Univ. California, Berkeley, Calif.

Brabb, E. E., 1960, The geology of the Big Basin area, California: Stanford Univ., Stanford, Calif.

Bradby, W. C., 1956, Marine terraces and sedimentation in the Santa Cruz area, California: Stanford Univ., Stanford, Calif.

Burchfeil, B. C., 1958, Geology of the Two Bar Creek area: Stanford Univ., Stanford, Calif.

Burford, R. O., 1961, Stratigraphy and structure of the Glenwood Basin area of the Laurel 7.5 minute quadrangle, Santa Cruz Mountains, California: Report on student research proj., Stanford Univ., Stanford, Calif.

Davis, C. G., and Henderson, F. B., 1957, The stratigraphy of the Capitola-Sunset beach area, southern Santa Cruz County, California: Report on student research proj., Stanford Univ., Stanford, Calif.

McAndrews, M. G., 1948, Petrography of upper Miocene sandstones, southern Santa Cruz County, California: Univ. California.

Park, F. B., 1961, A gravity investigation of the Soquel Creek area, California: Report on student research proj., Stanford Univ., Stanford, Calif.

Sislar, John J., 1960, Geology of southwest portion of Laurel Quad: Report on student research proj., Stanford Univ., Stanford, Calif.

Travers, W. B., 1959, Geology of the Newell Creek area, Boulder Creek, California: Stanford Univ., Stanford, Calif.

Vickery, F. P., 1919, The physiography of the Santa Cruz quadrangle: Stanford Univ., Stanford, Calif.

Table 1.--Sources of data relating to geology and hydrology of the Soquel-Aptos area

Source of data	Type of data										
	Geologic			Hydrologic					Other		
	General	Well logs	Maps	General	Ground water	Surface water	Water quality	Water use	Climatologic	Dam site	Soil-type maps
California Department of Water Resources	X		X		X	X			X	X	
California Division of Mines and Geology	X		X								
University of California, Geology Department Library, Berkeley	X		X								
University of California, Water Resources Archives, Berkeley	X	X	X	X	X	X	X	X	X	X	X
Santa Cruz County Department of Public Works					X						
Santa Cruz City Water Department		X									
Stanford University	X		X								
U.S. Army Corps of Engineers	X	X			X	X					
U.S. Bureau of Reclamation						X				X	
U.S. Department of Agriculture											X
U.S. Geological Survey	X	X	X	X	X	X			X		
U.S. Weather Bureau									X		
Consultants' reports	X				X	X			X	X	
Electric power companies								X			
Scientific journals	X										
Water conservation districts		X						X	X		
Water service agencies		X			X	X		X			
Well drillers	X	X			X						

Table 2.--Mean, maximum, and minimum seasonal precipitation at selected stations in the Soquel-Aptos area

(Data from U.S. Weather Bureau)

Station	Altitude[1] (ft above mean sea level)	Location: Latitude, N.-longitude, W. / Public-land net	Period of record	Seasonal precipitation (inches)		
				Mean	Maximum / Minimum	Season / Season
Aptos-Beth Mar Nursery	50	36°58.5'-121°43.6' SE¼ sec. 18, T. 11 S., R. 1 E.	1928-54	27.74	53.65 15.18	1940-41 1930-31
Pajaro Unit-Bean Hill	1,175	37°02.1'-121°50.4' SE¼ sec. 27, T. 10 S., R. 1 E.	1926-41	38.80	62.73 20.88	1930-41 1930-31
Day	475	36°59.8'-121°41.3' NE¼NE¼ sec. 9, T. 11 S., R. 1 E.	1935-65[2]	31.36	69.90 14.63	1940-41 1960-61
Freedom	1,495	37°03'-121°40'	1952-65	38.33		
Santa Cruz	125	36°58'-122°01'	1878-1965	28.25	61.62 10.33	1940-41 1923-24
Soquel Creek	330	37°03.2'-121°55.5' NW¼ sec. 24, T. 10 S., R. 1 W.	1929-43	38.39	60.69 19.05	1940-41 1930-31
Wright's	1,600	37°08'-121°57'	1919-66	45.74	79.60 26.52	1940-41 1960-61

1. Interpolated from U.S. Geological Survey topographic quadrangle maps.
2. Incomplete record.

Table 4.--Stratigraphy and water-bearing character of rocks in the Soquel-Aptos area

	Age	Geohydrologic unit	Water-bearing character
QUATERNARY	Recent	Alluvium	Unconsolidated gravel, sand, silt, and clay. Contains water in sufficient quantities for domestic and small irrigation supplies.
QUATERNARY	Late Pleistocene	Terrace deposits	Poorly consolidated gravel, sand, silt, and clay. Yield small supplies suitable for domestic use in some areas.
QUATERNARY	Pleistocene	Aromas Red Sands of Allen (1946)	Poorly consolidated brown-to-red arkosic and clayey, fine-to-coarse grained sandstone. Contain water, but yield or potential in Soquel-Aptos is not known.
TERTIARY	Middle Pliocene	Purisima Formation	Variegated, cross-bedded, friable, fine-grained sandstone, conglomerate, siltstone, and claystone. Contains numerous marine fossils. "Black sand" beds at several horizons contain water under artesian pressure. Most widespread and best aquifer in area.
TERTIARY	Miocene	Santa Margarita Formation	Very friable, medium-to-coarse grained sandstone grading upward into fine grained, silty sandstone. Good aquifer, but may be present only in western part of area.
TERTIARY	Eocene, Oligocene, and Miocene	Sedimentary rocks of Tertiary age older than the Santa Margarita Formation. Includes sandstone and conglomerate, Butano Sandstone, San Lorenzo Formation, Vaqueros Formation, clay and shale, siliceous shale, and Monterey Shale.	Consist mostly of fairly well consolidated sandstone and siltstone and a few minor limestone, breccia, and volcanic deposits. Yield small supplies of water in some areas. Butano Sandstone has fair, but unproved, potential for moderate yields.
CRETACEOUS		Sedimentary rocks	Well-indurated clay, shale, sandstone, and conglomerate. Have little potential for ground-water development in Soquel-Aptos area. Probably yield small domestic supplies in some areas.
CRETACEOUS		Igneous rocks	Mostly quartz diorite; contains water in fractures. Yields adequate for small domestic supplies from wells intercepting fractures.

Table 5.--Chemical analyses of water from selected wells in the Soquel-Aptos area

Source of data: BWC, Beltz Water Co.; SC, Soquel Creek County Water District; CSC, City of Santa Cruz

Well	Date Collected	Parts per million (ppm)																	Specific conductance (micromhos at 25°C)	pH	Source of data
		Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Manganese (Mn)	Dissolved solids: Calculated (Sum of determined constituents)	Dissolved solids: Residue on evaporation at 180°C	Hardness as $CaCO_3$	Noncarbonate hardness as $CaCO_3$			
Rohr	10-18-56	62	5.6	73	29		37	140	0	202	41		0		569	572	303	119	703	7.2	CSC
Beltz No. 3	6- 2-65		1.18	66	9	32		104	0	88	54	0.1		0.23	445		202			7.5	BWC
Cliff Drive	10-18-65		.1								25			<.05			184	112	476	8.0	SC
Maplethorpe	4-21-65		.2	86	21	83		293	0	120		.3	0	.07		575	300		855	7.3	SC
Aptos Creek	4-13-65		<.02	22	19	69		244	0	34	34	.1	1	.1		349	133		521	7.6	SC
La Selva No. 1	10-16-64		.3								9			<.05			92	50	215	7.6	SC

Table 3.--Precipitation stations which have data corresponding to the period of available streamflow data.

Agency abbreviations: SCCDPW, Santa Cruz County Department of Public Works, SCCFCWCD, Santa Clara County Flood Control and Water Conservation District; SCS, U.S. Department of Agriculture, Soil Conservation Service, Watsonville; USWB, U.S. Weather Bureau

Map index No.[1/]	Agency	Agency No.	Station name	Location
11	SCCDPW	----	Soquel	37°03'36" 121°56'10"
12	SCCDPW	----	Skyline	36°09'10" 121°59'45"
13	SCCFCWCD	851300	Station Ranch	37°06.1' 121°59.5'
14	SCCFCWCD	347301	Glenwood 1NE	37°06.3' 121°58.8'
15	SCCFCWCD	483600	Laurel Dodge	37°06.1' 121°57.9'
16	SCCFCWCD	512490	Los Gatos Wright	37°07.4' 121°56.0'
17	SCCFCWCD	563700	Mill Berry	37°07.0' 121°55.1
18	USWB	7916	Santa Cruz	36°59' 122°01'
19	USWB	3232	Freedom 8NNW	37°03' 121°49'
110	USWB	9814	Wrights	37°08' 121°57'
111	USWB	2048	Corralitos	36°59' 121°48'
112	USWB	3953	Highland	37°03' 121°48'
113	SCS	12	Day	36°59'55" 121°51'10"
114	SCS	44	Buzzard Lagoon	37°01'36" 121°49'45"

1 Keyed to figure 1.

Table 6.--Streamflow data

Source of data: DWR, California Department of Water Resources; GS, U.S. Geological Survey, Water Resources Division.

Map index number	Station	Location Latitude, N. / Longitude, W.	Altitude [1] (ft above mean sea level)	Drainage area (sq mi)	Period of record	Average discharge [2] Cfs	Average discharge [2] Acre-ft per year	Source of data
21	Soquel Creek at Soquel, Calif.	36°59'29" / 121°57'17"	40	40.2	1950, 1952-66	43.4 (13 yrs)	31,420	DWR GS
22	West Branch Soquel Creek near Soquel, Calif.	37°03'05" / 121°56'20"	220	12.2	1949-50 [3], 1959-66	10.6 (6 yrs)	7,670	DWR GS
23	Aptos Creek at Aptos, Calif.	36°58'35" / 121°54'05"	10	12.2	1959-64	6.75 (6 yrs)	4,890	GS
24	Branciforte Creek at Santa Cruz, Calif.	36°58'00" / 122°01'00"	11	17.3	1940-43, 1952-66	20.5 (15 yrs)	14,840	GS

1. Interpolated from U.S. Geological Survey topographic quadrangle maps.

2. Period of record and average discharge computed on basis of water year October 1 to September 30.

3. Incomplete record.

Table 7.--Description of wells in preliminary water-level measuring network

Map index number: Number assigned to wells on map showing Hydrologic-data Stations.

Well number: Well number assigned by U.S. Geological Survey, Water Resources Division. The numbers are tentative pending completion of a detailed canvass as a part of continuing studies.

Owner or name of well: Name of well owner or local name by which the well is known on date of measurement.

Year completed: Completion date of well as reported on driller's log.

Altitude: Altitude determined by surveying altimeter with a maximum error of ±5 feet.

Depth: Well depth as reported on driller's log.

Casing diameter: Well-casing diameter as reported on driller's log.

Use: D, domestic; Ir, irrigation; U, unused; Ps, public supply.

Water-level: Date and depth below land-surface datum of first water-level measurement made by U.S. Geological Survey, Water Resources Division.

Interpretative value of water-level measurement: Good, when well construction data as reported on driller's log allowed the water-bearing horizon to be discriminated. Poor, when well construction data was not available to allow water-bearing horizon to be discriminated.

Table 7.--Description of wells in preliminary water-level measuring network-Continued

Map index number	Well number	Owner or name of well	Year completed	Altitude (ft above mean sea level)	Depth (ft below land surface)	Casing diameter (in.)	Use	Water-level		Interpretative value of water-level measurement
								Date	Feet below land-surface datum	
					T. 10 S., R. 1 W.					
31	10S/1W-23Q1	Holm	1964	266	340	6	D	2-17-66	12.6	Good
32	35L1	Unknown	1950	a660	340	10	D	3-16-66	280.3	Poor
					T. 11 S., R. 1 W.					
33	11S/1W- 3C1	Angell	1954	134	200	10	D	2-16-66	59.9	Good
34	9L1	Rohr Well	----	126	---	14	U	2-15-66	58.8	Poor
35	12R1	Bonora	----	179	405	12	Ir	4- 6-77		Poor
36	15A1	Nutter	1950	61	168	8	D	2-16-66	30.5	Good
37	15D1	Burjas	1950	93	99	8	D	3-16-66	84.1	Good
38	21B1	C.L. Beltz Water System	1954	55	137	10	Ps	2-15-66	47.6	Good

See footnote at end of table.

Table 7.--Description of wells in preliminary water-level measuring network-Continued

Map index number	Well number	Owner or name of well	Year completed	Altitude (ft above mean sea level)	Depth (ft below land surface)	Casing diameter (in.)	Use	Water-level		Interpretative value of water-level measurement
								Date	Feet below land-surface datum	
				T. 11 S., R. 1 E.						
39	11S/1E- 4Q1	Central Santa Cruz Water District	1952	286	248	10	U	2-18-66	103.8	Good
310	15D1	Unknown	1955	369	587	12	U	3-16-66	500	Poor
311	16N1	Waugman	1961	145	294	18	U	3-16-66	124.7	Good
312	17M1	Palmer well	1953	188	500	10	U	4- 6-66		Good
313	18P1	Beach well	1924	13	---	12	U	2-14-66	2.1	Poor
314	27L1	Delucchi	----	260	360	12	U	3-16-66	249.7	Poor

a. Interpolated from U.S. Geological Survey topographic quadrangle maps.

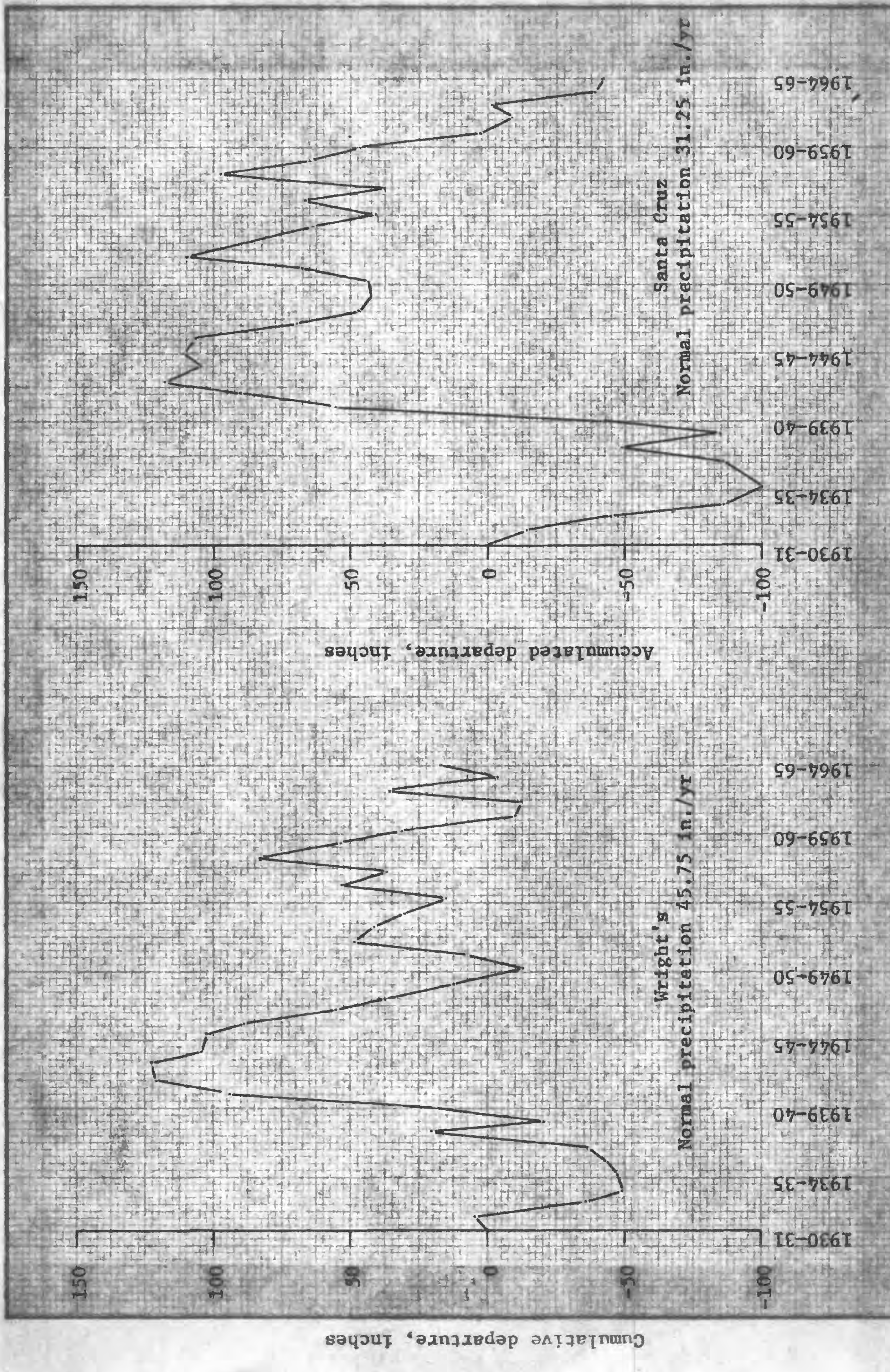

Figure 2.-- Cumulative departure from 30-year normal seasonal precipitation at Wright's and Santa Cruz, Santa Cruz County, California.

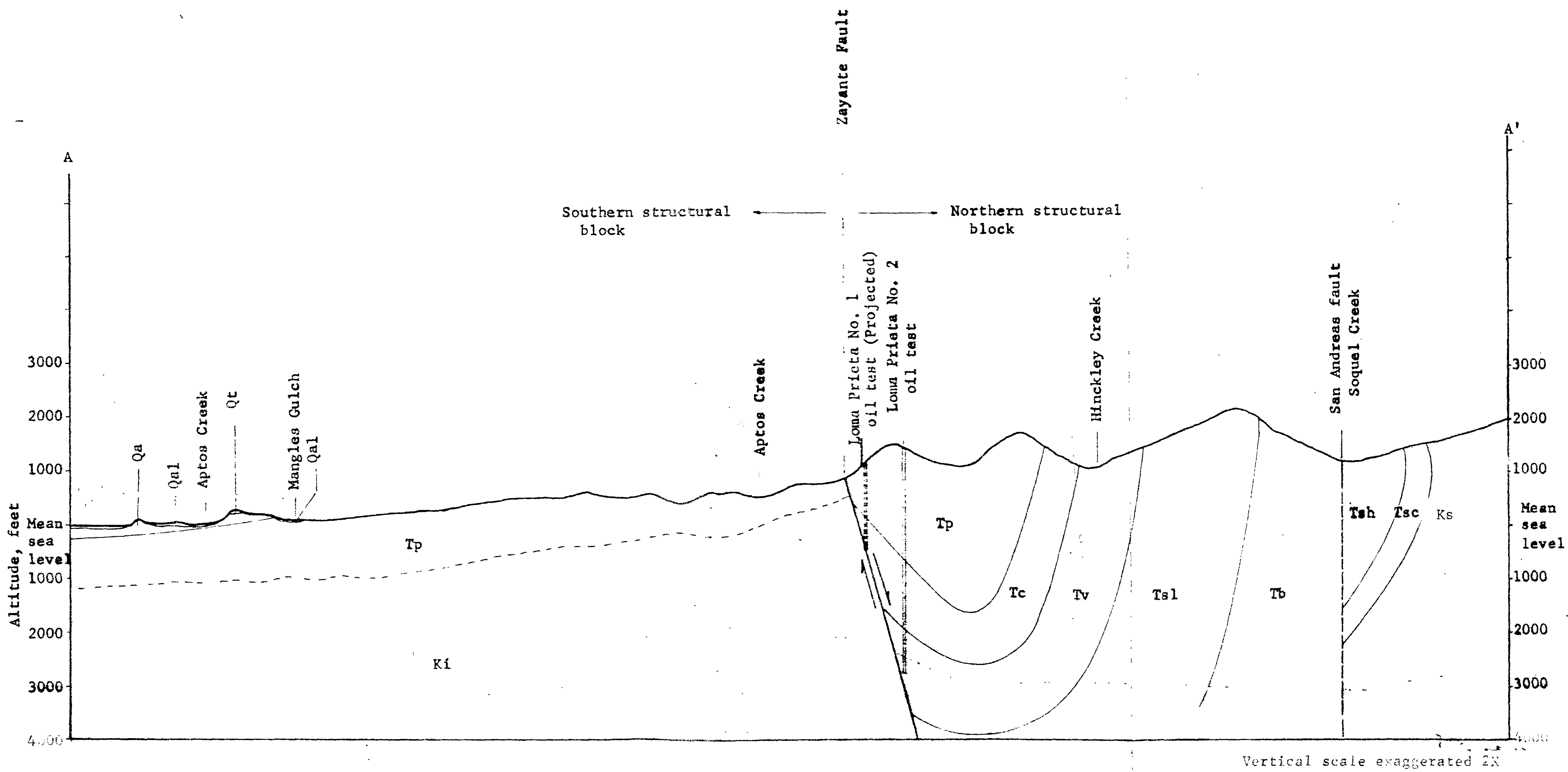

Figure 3.--Generalized cross section along A-A' (see Figure 1 for location). Igneous rock (Ki), shale, sandstone, and conglomerate of Cretaceous age (Ks), shale of Tertiary age (Tsh), sandstone and conglomerate of Tertiary age (Tsc), Butano Sandstone (Tb), San Lorenzo Formation (Tsl), Vaqueros Formation (Tv), clay and shale of Tertiary age (Tc), Purisima Formation (Tp), terrace deposits (Qt), alluvium (Qal).

67-3

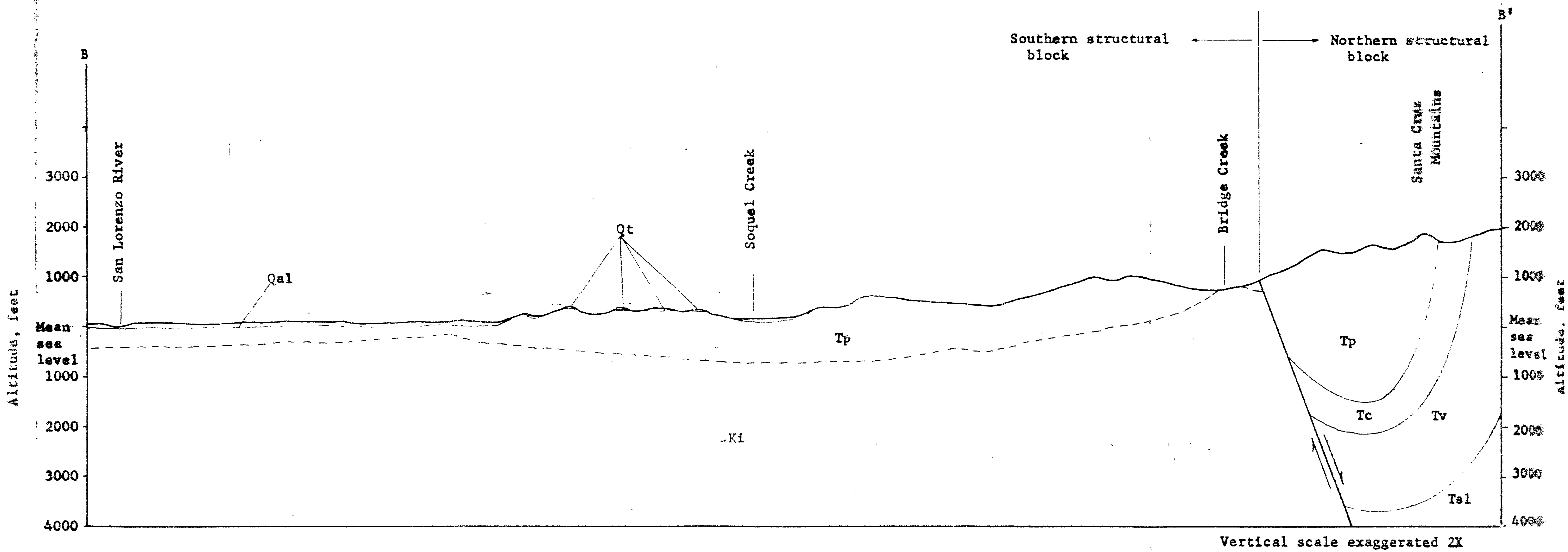

Figure 4.--Generalized cross section along B-B' (see geologic map for location). Igneous rock (Ki), San Lorenzo Formation (Tsl), Vaqueros Sandstone (Tv), clay-shale (Tc), Purisima Formation (Tp), terrace deposits (Qt), alluvium (Qal).

67-3

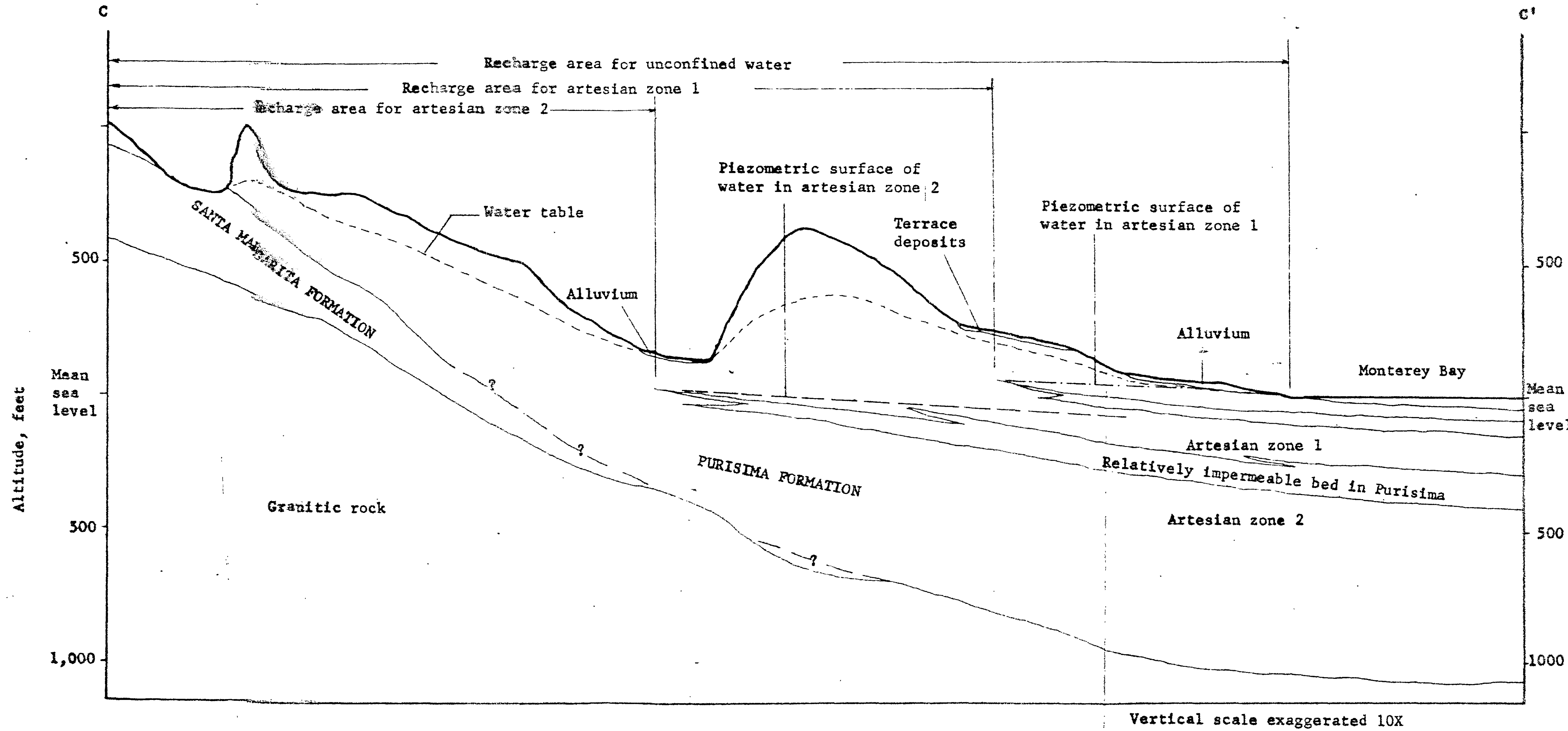

Figure 5.--Cross section along C-C' (see geologic map for location) showing hypothetical relations of water-table and artesian zones in the Purisima Formation and hypothetical relation of Santa Margarita Formation to Purisima Formation and granitic rock. Number and positions of artesian zones and impermeable beds, and their extent, are postulated only.

67-3