PHYSIOGRAPHY OF THE VENTURA REGION, CALIFORNIA

Thesis by

William C. Putnam

In Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy,
California Institute of Technology
Pasadena, California

1937

- C O N T E N T S -

- LIST OF ILLUSTRATIONS -

ABSTRACT

The Ventura region is of interest for its great thickness of Tertiary sediments, and for the nearly complete record it affords of events in the pleistocene. This Pleistocene history may be divided into four major episodes; depostion of 4700 feet of marine sediments, deformation of all the rocks in the region, erosion to a surface of late maturity, designated as the Rincon Surface, and uplift which initiated the present erosion cycle.

The late-Pleistocene intermittent uplift is recorded by terraces in the Ventura River valley, and by marine terraces along the coast. Both sets of terraces are warped, and reach their maximum elevation where the most intense deformation of the underlying rocks has occurred.

Fossils of birds, plants, vertebrates, and marine invertebrates found on the lowermost of the marine terraces at Carpinteria are believed to have accumulated approximately 30,000 years ago in the waning phase of the last Pleistocene glaciation. The plant fossils may have been introduced by small streams in time of flood; the vertebrates are a tarpit accumulation.

Changes in the appearance of the Ventura shoreline during the period of uplift, and at the present time, follow a definite sequence. The recognition of this sequence as part of an erosion cycle applicable to steeply sloping shorelines of emergence is an outgrowth of this study. This new cycle differs materially from the one previously described for gently sloping emergent shorelines.

Some evidence is found in the Ventura region favoring a recent eustatic lowering of sea level. The fluctuations of sea level during the last glaciation have also been recorded. The development and preservation of coastal terraces is determined by the nature of the bedrock. The best preserved terraces have been cut in the siliceous shales of the Modelo formation. The marine terraces have a local, rather than regional distribution, and owe their altitude to both vertical uplift and warping. Attempts to correlate marine terraces on this coast with glacial oscillations of sea level are not successful.

Deformation, both faulting and warping, has continued into the present in the Ventura region. The Coast Ranges in this section of Southern California are to be regarded as a growing mountain range.

Plate I

Ventura, California (Spence Air Photos)

August 10, 1935

The City of Ventura occupies the narrow coastal plain in the foreground. The Ventura County Courthouse is visible near the center of the photograph.

The prograded shoreline in the foreground is Pierpont Beach. The low bluff marks the shoreline at approximately the time that Cabrillo discovered this coast.

The mouth of the Ventura River is near the left margin, and its valley extends diagonally across the picture. The derricks in the Ventura Avenue oil field are near the right margin. The axis of the Ventura Avenue Anticline connects these wells with the ones in the sea at the upper left margin.

The dark ridge in the middle distance is Red Mountain. Rincon Mountain is visible beyond it at the coastline. The distant mountains are the Santa Ynez Range.

The promontory nearly touching the left margin is Pitas Point, beyond the oil wells is Punta Gorda, and the third headland of the series is Rincon Point.


©SPENCE
Air Photos

THE PHYSIOGRAPHY OF THE VENTURA REGION, CALIFORNIA

by

WILLIAM C. PUTNAM

INTRODUCTION

The Ventura region provides a record of many of the events in the history of the Southern California Coast Ranges during the Pleistocene epoch. The area is unique in the Coast Ranges for the relative completeness of this record, and the unequivocal nature of much of the evidence. The economic importance of the production of petroleum early concentrated the attention of California geologists on the district. Although a great deal of field work has been done, little of the work is published, and none is united in a single comprehensive report. Most effort has been devoted to problems of stratigraphy and oil accumulation. No investigation of the physiographic development of this coastal section of California has so far been undertaken.

The purpose of this study is threefold: 1) to determine the nature of the changes affecting the

Ventura region during the latter part of the Pleistocene, with special emphasis on the development of the shoreline, 2) the introduction of a general scheme for the cycle of erosion of steeply sloping shorelines of emergence, and 3) the placing of events in the geologic history of the area in an orderly sequence which may be correlated with the standard Pleistocene chronology.

The writer's interest in these problems was first aroused in 1928 as the result of field work with the Stanford Geological Survey. A return was made to the area in the summer of 1929 and spring of 1930. During the winter of 1931 field work for the Associated Oil Company of California was restricted to problems of stratigraphy and structure, but some physiographic work also was accomplished. Study of the area was continued during the summers of 1932, 1934, 1935, and 1936 and during the winters of 1935 and 1936.

Acknowledgements

It is a pleasure to recall the helpful criticism of Dr. J. P. Buwalda, of the California Institute of Technology both in the separate stages of the preparation of this report, and in the field. The counsel of Dr. Chester Stock was of help in the problem of the age of the Carpinteria fossils.

The assistance of Dr. Eliot Blackwelder, Dr. Hubert G. Schenck, and Dr. Siemon Muller, all of Stanford University is gratefully acknowledged. Dr. Paul F. Kerr, of Columbia University, gave much assistance and advice in the field.

Among others to whom a debt is acknowledged for information, or assistance are Dr. U. S. Grant of the University of California at Los Angeles, Dr. R. D. Reed and Mr. Loring Snedden of the Texas Company of California, Dr. T. L. Bailey of the Shell Oil Company of California, Mr. F. W. Hertel of the Associated Oil Company, and Mr. E. M. Sheridan of the Ventura County Pioneer Museum. The offices of the Ventura County Surveyor and the Ventura City Engineer provided recent surveys of the shoreline.

Previous Work

Little attention has been paid to the physiography of the Ventura Region. Most of the work done in the area has been devoted to problems of structure, stratigraphy and oil accumulation. This circumstance is not restricted to the Ventura region, for it is a curious fact that more attention was paid to Coast Range physiography a generation ago than in the past decade.

The first important paper on the physiography of the Coast Ranges was by Lawson (1), who recognized the

(1) Lawson, A. C., "The post-Pliocene deformation of the Coast Range of Southern California," Bull. Dept. of Geol., Univ. of Calif., Vol. 1, no. 4, pp. 115-160, 1893.

nature and late geologic date of their deformation.

The earlier works of W. S. T. Smith (2) are

(2) Smith, W. S. T., "A topographic study of the islands of Southern California," Bull. Dept. of Geol., Univ. of Calif. Publ., Vol. 2, no. 7, pp. 179-230, 1900.

among the first studies devoted to the characteristics of a steeply sloping and recently emerged shoreline.

Harold W. Fairbanks (3) visited this area,

---

(3) Fairbanks, H. W., "Geology of northern Ventura, Santa Barbara, San Luis Obispo, Monterey, and San Benito Counties," California State Mining Bureau, Report 12, pp. 493-526, 1894.

---

and became particularly interested in shoreline problems in the San Luis Obispo region. He advocated a coastal elevation of 2000 feet, followed by a depression of an equal amount. (4)

---

(4) Fairbanks, H. W., "Oscillations of the coast of California during the Pliocene and Pleistocene." America Geologist, Vol. 20, pp. 213-245, 1897.

_____________, "Description of the San Luis Quadrangle, California, " U. S. Geol. Survey, Geologic Atlas, San Luis Folio 101, 14 pp., 1904.

Some of the characteristics of the Ventura region were described by Eldridge and Arnold (5) in

---

(5) Eldridge, G. H. and Arnold, Ralph, "The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, Southern California," U. S. Geol. Survey, Bull. 309, 266 pp., 1907.

Eldridge, G. H., "Origin and distribution of asphalt and bituminous rock deposits in the United States," U. S. Geol. Survey, Bull. 213, pp. 306-321, 1903.

---

their investigation of the north side of the Santa Clara Valley.

Among the more recent publications, one of the most valuable is the joint monograph by Grant and Gale.(6) This paper was especially helpful in compiling

(6) Grant, U. S. and Gale, H. Rl, "Catalogue of the marine Pliocene and Pleistocene Mollusca of California," Memoirs of the San Diego Society of Natural History, Vol. 1, 1036 pp., San Diego, California, Nov. 3, 1931.

the Pleistocene chronological table in this thesis. The monograph also contains a lucid account of the more important events in the Pleistocene history of Southern California.

Other publications which deserve particular notice are:

7) Reed, R. D., "Geology of California," Amer. Assoc. Petrol. Geol., 355 pp., 1933. A good statement of the problems of Coast Range structure, stratigraphy, and physiography, with some emphasis on the Ventura region.

8) Bailey, T. L., "Lateral change in fauna in the lower Pleistocene," Bull. Geol. Soc. of America, Vol. 46, no. 3, pp. 489-502, Mar. 31, 1935. An excellent account of some of the problems encountered in establishing the contact between Pliocene and Pleistocene formations.

9) Kerr, P. F. and Schenck, H. G., "The significance of the Matilija overturn," Bull. Geol. Soc. of America, Vol. 39, pp. 1102, Dec. 30, 1928. Includes a brief discussion of some of the more important features of the structural history.

10) Kew, W. S. W., "Geology and oil resources of a part of Los Angeles and Ventura Counties, California," U. S. Geol. Survey, Bull. 783, 202 pp.

11) ____________, "Los Angeles to Santa Barbara," XVI International Congress, Guidebook 15, pp. 48-68, 1932. These two publications are the most detailed in their treatment of the structures and stratigraphy of the Ventura region and adjoining areas.

The following bibliography includes titles which are not cited elsewhere in the text.

Bibliography

12) Antevs, Earnest, "Quaternary marine terraces in non-glaciated regions and changes of level of sea and land," Amer. Jour. of Science, Vol. 17, pp. 35-49, Jan. 1929.

13) Arnold, Ralph, "Paleontology and Stratigraphy of the marine Pliocene and Pleistocene of San Pedro, California," Mem. Calif. Acad. of Science, Vol. 3, 420 pp. 1903.

14) ____________, "Environment of the Tertiary faunas of the Pacific Coast of the United States", Jour of Geology, Vol. 17, pp. 509-533, 1909.

15) Arnold, Ralph, and Hannibal, Harold, "The Marine Tertiary Stratigraphy of the North Pacific Coast of America," Proc. Amer. Phil. Soc., Vol. LII, no. 212, pp. 359-605, 1913.

16) Blackwelder, Eliot, "A summary of the orogenic epochs in the geologic history of the United States," Jour. of Geology, Vol. 22, pp. 633-654, 1914.

17) Bolton, Herbert E., "Spanish Explorations in the Southwest, 1542-1706," Original Narratives of Early American History, Chap. XVII, Chas. Scribner's Sons, New York, 1916.

18) Bowie, William, "Comparison of old and new triangulation in California," U. S. Coast and Geodetic Survey, Special Publication 151, 1928.

19) Carson, C. M., "Pliocene faunal zones in Southern California," Pan American Geologist, Vol. 43, no. 4, pp. 265-270, May, 1925.

20) Cartwright, Lon D., "Loss of color of red sandstone upon deposition," Bull. Amer. Assoc. of Petrol. Geol. Vol. 12, no. 1, pp. 85-87, Jan. 1928.

21) Chaney, Ralph, "Quantitative Studies of the Bridge Creek Flora in Relation to the Modern Redwood Forest," Amer. Jour. of Science, Vol. 8, pp. 127-144, 1924.

22) Clapp, C. H., "Contraposed Shorelines," Jour. of Geol., Vol. 21, pp. 537-540, 1913.

23) Clark, Alex, "Environment of Marine Mollusca Living off Long Beach, California, and its bearing on Pleistocene Correlations," (abstract) Pan American Geologist Vol. 59, no. 5, pp. 379, June, 1933.

24) Clark, Bruce L., "The Marine Tertiary of the West Coast of the United States; its sequence, paleogeography, and the problems of correlation," Jour. of Geology, Vol. 29, no. 7, pp. 583-614, Oct.-Nov., 1921.

25) __________, "Tectonics of the Valle Grande of California," Bull. Amer. Assoc. of Petrol Geol., Vol. 13, no. 3, pp. 199-238, March, 1929.

26) __________, "Tectonics of the Coast Ranges of Middle California," Bull. Geol. Soc. of America, Vol. 41, no. 4, pp. 747-828, Dec. 31, 1930.

27) __________, "Classification of physiographic surfaces," (abstract), Pan American Geologist, Vol. 55, no. 5, pp. 366-367, June, 1931.

28) Cloos, Hans, "Bau and Bewegung der Gebirge im Nord-amerika, Skandinavien und Mitteleuropa, Fortschritte der Geologie und Paleontologie, Bd. 7, H. 21, pp. 241-327, 1928.

29) Cushman, J. A., and Laiming, Boris, "Miocene Foraminifera from Los Sauces Creek, Ventura County, California," Jour. of Paleontology, Vol. 5, pp. 79-120, 1931.

30) Daly, R. A., "The Changing World of the Ice Age," 271 pp. Yale Univ. Press, New Haven, 1934.

31) Davidson, George, "The submerged valleys of the coast of California," Proc. of Calif. Acad. of Science, Vol. 3, pp. 73-103, 1897.

32) Dorf, Erling, "Pliocene floras of California," Carnegie Inst. of Washington, Pub. 412, pp. 1-112, Sept., 1933.

33) Eaton, J. E., "Ventura Oil field, California; a brief review of its stratigraphy and structure," Oil Bulletin, Vol. 12, no. 5, pp. 521-524, May, 1926.

34) __________, "Geology and oil fields of Ventura County, California," Oil Age, Vol. 23, no. 11, pp. 16-18, Nov., 1926.

35) __________, "The By-Passing and Discontinuous Deposition of Sedimentary Material," Bull. Amer. Assoc. of Petrol. Geol. Vol. 13, no. 7, pp. 713-762, July, 1929.

36) __________, "Decline of the Great Basin, Southwestern United States," Bull. Amer. Assoc. of Petrol. Geol., Vol. 15, no. 1, pp. 1-49, Jan., 1932.

37) Edwards, Everett C., "Pliocene conglomerates of Los Angeles Basin and their paleogeographic significance," Bull. Amer. Assoc. of Petrol. Geol. Vol. 18, no. 6, pp. 786-812, June, 1934.

38) English, W. A., "The Fernando group near Newhall, California," Univ. of Calif. Publ., Bull. Dept. Geol. Vol. 8, pp. 205-218, 1914.

39) Ford, H. C., "Specimens of coniferous wood saturated with bitumen," Bull. Santa Barbara Soc. of Natural History, Vol. 1, no. 2, p.11, 1890.

40) __________, "Solfatards in the vicinity of Santa Barbara," Bull. Santa Barbara Soc. of Natural History, Bull. 1, pp. 53-56, 1890.

41) Hanna, Marcus A., "Geology of the La Jolla Quadrangle, California," Univ. of Calif. Publ. Bull. Dept. Geol. Sci., Vol. 16, no. 7, pp. 187-246, Nov. 20, 1926.

42) Hay, O. P., "The Pleistocene of North America and its vertebrated elephants," Carnegie Inst. of Wash., Publ. no. 322, 1923-1927.

43) Hershey, O. H., "Some tertiary formations of Southern California," American Geologist, Vol. 29, pp. 349-372, 1902.

44) Hertel, F. W., "Ventura Avenue Oil Field, Ventura County, California," Bull. Amer. Assoc. of Petrol. Geol., Vol. 12, no. 7, pp. 721-742, 1928.

45) Hilgard, E. W., "Report on the asphaltum mine of the Ventura Asphalt Co.," California State Mining Bureau, 10th Annual Report of the State Mineralogist, pp. 763-772, 1890.

46) Hill, Mason L. "Mechanics of faulting near Santa Barbara, California," Jour. Geol., Vol. 40, no. 6, pp. 535-556, Aug.-Sept., 1932.

47) Hill, R. T., "Southern California Geology and Los Angeles Earthquakes," So. Calif. Acad. of Sci., 232 pp. Los Angeles, California, 1928.

48) Hotchkiss, William and Ingersoll, L.R., "Post glacial time calculations from recent geothermal measurements in the Calumet copper mines," Jour. Geol., Vol. 42, no. 2, pp. 113-122, Feb.-March, 1934.

49) Johnson, Douglas, "Principles of Marine Level Correlation," Geographical Review, Vol. XXII, no. 2, pp. 294-298, April, 1932.

50) Johnson, Douglas, "Supposed two-meter bench of the Pacific Shores," Inter. Geog. Congr., Comptes Rendus, tome 2, fasc. 1, pp. 158-163, 1933.

51) King, Philip B., "An Outline of the Structural Geology of the United States," XVI International Geological Congress, Guidebook 28, pp. 1-54, 1932.

52) Lawson, A.C., "The Mobility of the Coast Ranges of California, and exploitation of the elastic rebound theory," Univ. of Calif. Publ., Bull. Dept. Geol. Sci., Vol. 12, no. 7, pp. 431-473, Jan 11, 1921.

53) Lawson, A. C., "The continental shelf off the Coast of California," Bull. Nat'l Research Council, Vol. 8, pt. 2, no. 44, 23 pp., April, 1924.

54) Louderback, G.D., "The Monterey Series in California," Univ. of Calif. Pubs., Bull. Dept. Geol., Vol. 7, no. 10, pp. 177-241, Feb. 26, 1913.

55) Louderback, G.D., "An outline of earth movements in the central coast region of California in late Pliocene and post-Pliocene time," Proc. Fourth Pac. Sci. Cong., Java, 1929, Vol. 2B, pp. 841-848, 1930.

56) McMasters, John Herbert, "The Eocene Llajas Formation, Ventura County, Calif.," (abstract), Bull. Geol. Soc. of America, Vol. 44, pt. 1, pp. 217-218, Feb. 28, 1933.

57) Natland, Manley L., "The Temperature and Depth Distribution of some Recent and Fossil Foraminifera in the Southern California Region," Bull. Scripps Institution of Oceanography, U. of Cal. Pubs., Technical Series, Vol. 3, no. 10, pp. 225-230, 1933.

58) Nelson, R.N., "Geology of the Hydrographic Basin of the Upper Santa Ynez River, California," Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., Vol. 15, no. 10, pp. 327-396, May 27, 1925.

59) Peckham, S.F., "Examination of bituminous substances occuring in Southern California," California Geological Survey, Vol. 2, Geology, Appendix, pp. 49-90 1882.

60) Ransome, F.L., "The Tertiary orogeny of the North American Cordillera and its problems," Problems of American Geology, Yale Univ, Press, New Haven, pp. 287-376, 1915.

61) Reed, Ralph D., "Miocene Paleogeography in the Central Coast Ranges (California)", Bull. Am. Assoc. of Petrol. Geol., Vol. 10, no. 2, 1926.

62) Reed, Ralph D., "Pleistocene history in the Carpinteria District," (abstract), Pan-American Geologist, Vol. 59, no. 4, p. 306, May, 1933.

63) Reed, Ralph D., "Unsolved geological problems of the Pacific Coast," Pan-American Geologist, Vol. 61, no. 3, pp. 179-186, April, 1934.

64) Rogers, David Banks, "Prehistoric man of the Santa Barbara coast," Santa Barbara Museum of Natural History, Santa Barbara, Calif., 1930

65) Smith, J.P., "Salient events in the geological history of California," Science, n. s., Vo.. 30, pp. 346-351, 1909.

66) Smith, J.P., "Geologic Range of Miocene invertebrate fossils of California," Proc. Calif. Acad. of Sci., Sec. 4, Vol. 3, pp. 161-182, 1912.

67) Smith, J.P., "Climatic relations of the Tertiary and Quaternary faunas of the California region," Proc. Calif. Acad. Sci., Ser. 4, Vol. 9, pp. 122-173, 1919.

68) Smith, W.S.T., "Marine Terraces on Santa Catalina Island," Am. Jour. Sci., 5th Ser., Vo.. 25, no. 146, pp. 123-136, Feb., 1933.

69) Stock, Chester, "Exiled elephants of the Channel Islands, California," Scientific Monthly, Vol. XLI, pp. 205-214, September, 1935.

70) Stocke, Yda (Addis), "A Memorial and Biographical History of the Counties of Santa Barbara, San Luis Obispo, and Ventura, California," Lewis Publ. Co., Chicago, 1891.

71) Taliaferro, N.L., "Notes on the geology of Ventura County, California," Bull. Amer. Assoc. of Petrol. Geol., Vol. 8, no. 6, pp. 789-810, Nov., 1924.

72) Tieje, A.J. and Cassell, Dorothy, "Magafauna and microfauna of the Pleistocene and Pliocene formations of Southern California as revealed in a deep well near Ventura," (abstract), Pan-American Geologist, Vol. 59, no. 5, p. 376, June, 1933.

73) Trask, J.B., "On earthquakes in California from 1812-1855," Amer. Jour. Science, 2nd series, Vol. 22 pp. 110-116, 1856.

74) Trask, J.B., "On earthquakes in California in the year 1857," Amer. Jour. Science, 2nd series, Vol. 26, pp. 296-298, 1858.

75) Trask, P.D., "Geology of Point Sur Quadrangle, California," Univ. of Calif. Publ., Bull. Dept. Geol. Sci., Vol. 16, no. 6, pp. 119-186, Nov. 10, 1926.

76) Vickery, F.P., "The interpretation of the physiography of the Los Angeles Coastal Belt," Bull Amer. Assoc. of Petrol. Geol., Vol. 11, no. 4, pp. 417-424, April, 1927.

77) Vickery, F.P., "Consequent Streams," Bull. Amer. Assoc. of Petrol. Geol., Vol. 12, no. 5, pp. 515-526, May, 1928.

78) Willis, Robin, "Physiography of the California Coast Ranges," Bull. Geol. Soc. of America, Vol. 36, no. 4, pp. 641-678, Dec., 1925.

79) Woldstedt, P., "Das Eiszeitalter," Stuttgart, 1929.

80) Woodring, W.P., " Pliocene Deposits North of Simi Valley," Proc. California Acad. Sci., 4th Ser., Vol. 19, p. 62, 1930.

81) Yates, Lorenzo, "Notes on the geology and scenery of the islands forming the southerly line of the Santa Barbara Channel," Ameriwan Geologist, Vol. 5, pp. 43-52, 1890.

82) Zierer, C.M., "The Ventura Area of Southern California," Bull. Geographical Soc. of Philadelphia, Vol. XXX, no. 1, pp. 26-58, Jan., 1932.

GEOGRAPHY

Location and Transportation

The area covered by this study is included within the limits of the Ventura and Santa Paula Quadrangles of the U.S Geological Survey. The principal city is Ventura, a seacoast town, near the eastern end of the Santa Barbara Channel. Ventura is 69 miles northwest of Los Angeles and 27 miles east of Santa Barbara.

Two other towns of importance, Ojai and Santa Paula, are inland. Santa Paula, 13 miles east of Ventura, is on the north bank of the Santa Clara River. Ojai, 11 miles north of Ventura, is the market center for the Ojai Valley. These towns are connected with each other and with Los Angeles and Santa Barbara by excellent paved highways. The dirt secondary roads are adequate, although often impassable in the winter.

All the area may be reached by road, except the Santa Ynez Mountains. One difficulty encountered in field work in the Ventura Region is that the land is privately owned. All the area south of the Ojai Valley is fenced, and many landowners do not tolerate geological trespassers. In fact, some ranches are inaccessible. This difficulty has increased as a result of a number of severe forest fires in the past years, and particularly so after the Sulphur Mountain fire in 1930.

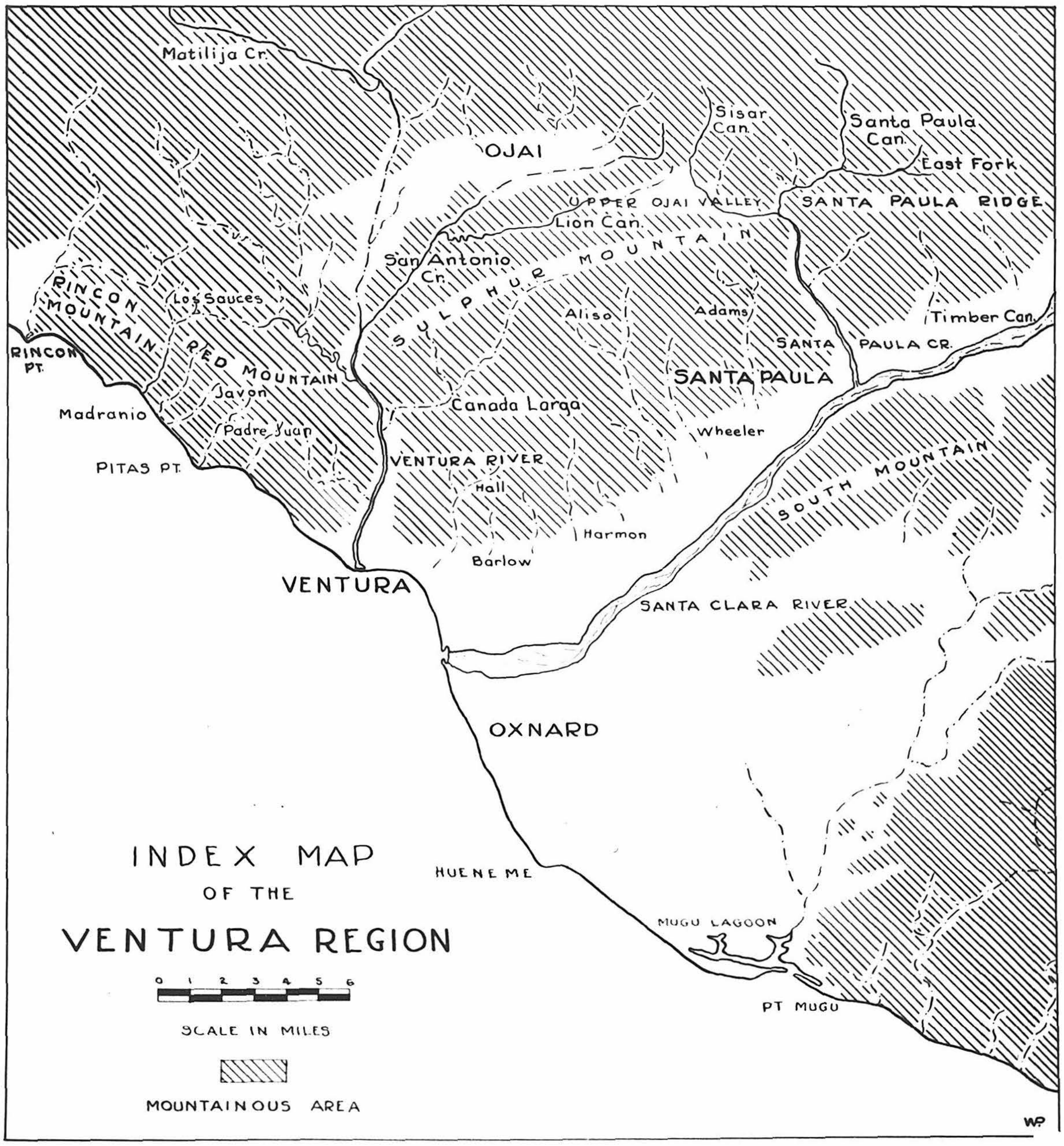
Regional Geography and Physiographic Subdivisions

The Ventura region, with a surface area of 450 square miles, covers most of the Santa Paula and Ventura Quadrangles (Scale 1:62500). The southern part of the Ventura Quadrangle is divided in half by the diagonal, northwest-trending shoreline of the Pacific Ocean. Most of the land is hilly or mountainous. The only important flat areas are the east-trending Santa Clara Valley, the valley of the Ventura River, the Ojai intermont basin, and a small strip of the Santa Barbara coastal plain near the western border of the area.

The Santa Ynez Mountains traverse the region from east to west across the northern border. They are the highest range, and rise to 6351 feet at the summit of Topatopa Bluff. The only break through their barrier is the water gap of the Ventura River.

Plate II

Index map of the Ventura Region, California



Matilija Cr.
OJAI
Sisar Can.
Santa Paula Can.
East Fork
UPPER OJAI VALLEY
SANTA PAULA RIDGE
Lion Can.
San Antonio Cr.
SULPHUR MOUNTAIN
RINCON MOUNTAIN
Los Sauces
RINCON PT.
RED MOUNTAIN
Aliso
Adams
Timber Can.
SANTA PAULA CR.
SANTA PAULA
Javon
Canada Larga
Madranio
Padre Juan
Wheeler
PITAS PT.
VENTURA RIVER
Hall
SOUTH MOUNTAIN
Harmon
Barlow
VENTURA
SANTA CLARA RIVER
OXNARD
INDEX MAP
OF THE
VENTURA REGION
HUENEME
MUGU LAGOON
0 1 2 3 4 5 6
SCALE IN MILES
PT MUGU
MOUNTAINOUS AREA
WP

4.) <u>The Coastal Hills</u>: The low, hilly area adjoining the coast and extending inland behind Santa Paula.

5.) <u>The Santa Clara Valley</u>: The broad flood plain of the Santa Clara River which parallels the southern boundary of the region.

These province names were suggested by Paul F. Kerr, and are useful in describing the structural and physiographic development of the district. Their characteristics and history will be described in detail in the section on Regional Physiography.

The largest stream is the Santa Clara River, with its source nearly 100 miles east of its mouth at Montalvo. The principle tributaries are Piru, Sespe, and Santa Paula Creeks. Santa Paula Creek is the only one of the three in the Ventura region.

The Ventura River is important in this study for the well preserved terraces in its valley. The river flows nearly due south for 12 miles from the base of the Santa Ynex Mountains until it enters the sea at the western city limit of Ventura. The maximum width of the valley is 1.2 miles.

The flow of the streams is variable. Most of the year their gravel filled channels are dry. Water flows all year only in places where bedrock rises near the surface. The winter rains may temporarily fill some of the streams with water, but this flow dwindles away in the spring, and the stream bed is dry throughout the summer. There is a correlation between rainfall and run-off to be expected where the seasonal rainfall is variable and no permanent storage basins of surface water exist. Run-off in acre feet for Santa Paula Creek and the Ventura and Santa Clara rivers, as recorded by the Ventura County Investigation is:[83]

---

(83) "Ventura County Investigation," State of California, Department of Public Works, Div. of Water Resources, p.6, Dec. 1, 1931.

Run-off in Acre Feet

Station	1927-28	1928-29	1929-30	1930-31
Ventura Drainage				
Matilija Cr.	5,380	3,650	3,630	1,950
San Antonio Cr.	840	337	330	257
Coyote Cr.	808	1,430	1,720	563
North Fork		1,270	1,160	698
Casitas			2,830	271
Santa Clara R. at Montalvo	15,700	29,400	15,500	15,850
Santa Paula Creek	3,500	3,680	3,150	3,540

This table illustrates the variation in total discharge of one year compared with another. The loss through percolation and exaporation of the water which enters the Ventura River drainage is also indicated. Instead of totaling 6,840 acre feet in 1930, the run-off at Casitas is only 2,830. In 1931, it is 271, rather than 3,468 acre feet as it would have been had no loss occurred.

Climate and Vegetation

The Ventura region has a semi-arid mesothermal climate. The temperature range, both diurnal and seasonal, is moderate and the rainfall is variable. As is characteristic in Mediterranean Climates, most of the rain falls in the winter between October and May. Showers may occur during the summer, but are rare and usually unimportant.

Three distinct climatic types are recognized by Russell.(84)

The lowland areas, like the Santa Clara and Santa Paula valleys

---

(84) Russell, R. J., "Climates of California," Univ. of Calif. Publication in Geog., Vol. 2, no. 4 1926.

---

have a Hot Steppe (Bsh) type, the mountains and the Ojai Valley a Hot Summer Mediteranean (Csa) type, and the coastal belt between Ventura and Carpinteria, a Fog Belt (Csn) type. The principal climatic difference of the coast from the inland areas is the summer fog. The summer coolness is distinctive, and the fogs cause the maximum temperature to be delayed until August. June is often warmer than July, and no month has a mean temperature greater than 62.4 degrees F.

The rainfall record for the past nine years at Ventura and Ojai, and the temperature record at Ojai, where a Weather Bureau station is maintained, follows:

	Ventura	Ojai	
	Rainfall	Rainfall-	Temperature
1927	18.98	26.59	60.7
1928	8.89	13.90	62.3
1929	6.02	7.69	62.5
1930	12.11	16.49	62.3
1931	20.65	28.96	63.8
1932	9.76	12.66	61.1
1933	13.79	18.38	60.8
1934	11.75	17.16	62.0
1935	14.18	16.43	59.2

The average temperature at Ventura is 58.2 degrees, and at Ojai 59.2 degrees. The table indicates that Ojai, at an altitude of 900 feet, consistently received a greater rainfall than Ventura on the coast at sea level. For the year 1935 the climate at Ojai had the following characteristics:

Highest temp.	104	August 9
Lowest temp.	26	January 30
Greatest rain	4.79"	January
Least rain	0.00	June-July
More rain than .01 inch	38 days	

Clear	187 days
Partly cloudy	125 days
Cloudy	53 days

The first table emphasizes the variability of the rainfall in this semi-arid region. In the nine year period covered, the rainfall had a variation of 14.63 inches between maximum and minimum at Ventura and 21.27 inches at Ojai. Droughts have frequently alternated with destructive floods. In 1863-64 was recorded the worst drought in the history of the county. Almost all the cattle perished, the large landholders were impoverished, and many of the land grants were broken up. The almost equally severe drought of 1876-77 ended grazing as the principal industry, and from that time to the present the most important agriculture carried on is in the irrigated bottom lands.

One of the severest floods within the past two centuries came in the winter of 1861-63. The Ventura River occupied the full width of its flood plain, and undercut the steep slope on the east side of Ventura Avenue and behind the Serra Cross. The almost equally severe flood of 1884 shifted the course of the Ventura River to the east channel. In the storm and flood of 1914 the west branch of the Ventura River cut through the Southern Pacific tracks and a new bridge had to be built. The amount of sediment carried by the river into the sea, and shifted eastward by the littoral current, is said to have built the shore out 400 feet opposite Seaside Park. This beach remained until destroyed by the storm of 1926.

The vegetation is sparse, even at comparatively high altitudes. Due to the light, seasonal rainfall, most of the plants are xerophytic. Only in areas where the ground water level is close to the surface do trees grow in profusion. Almost all the native shrubs are evergreens, and are typical of a Mediterranean climate. The trees include live-oaks, willow, black walnuts, sycamores, cottonwoods, and at higher elevations in the Santa Ynez Mountains, a few scattered pines. The lower hill slopes are mantled by olive green sage, and by chapparal at a slightly greater height.

Most of the ridges have an east-west trend. As a consequence, there is a marked difference in the appearance of the northern and southern slopes. The south side receives the full strength of a nearly vertical sun, and is usually bare. The north side of the same ridge often presents a strong contrast with dense groves of trees and a bushy undercover.

The nature of the bedrock exerts a marked control over the distribution of plants. Sandstone ridges support a thicker cover of larger plants than corresponding areas of shale. The Eogene and Oligocene sandstones are covered with impassable thickets of chapparal. The siliceous Miocene shales support a scanty growth of low, silvery-gray sage; and in favored spots, live-oak, and black walnut trees. The characteristic vegetation of the tawny hills underlain by the impervious Pliocene clay shales is a scanty covering of grass, wild mustard, and sage. The ecologic differences imposed by some of these rock units are great enough that contacts may be roughly outlined in the field of differences in vegetation.

History and Place Names

One of the outgrowths of field work in the Ventura region is an appreciation of the manner in which the natural environment controls human activities. Physiography determined the location of the principal towns, the distribution of the ranchos, and the communications pattern of the entire area. This control operated in pre-Columbian times, as well as the present, and determined the location of most of the Indian rancherias. The historic background of Ventura County is worth recording for its own sake, as well as for the illustration it affords of the physiographic control of the region.

Probably the first white man to see the Ventura coast was Juan Rodrizuez Cabrillo. He stopped at Ventura between Tuesday, October 10, and Friday, October 13, 1542, fifty years to a day after Columbus' landfall at San Salvador. Cabrillo left Santa Monica Bay on the 9th on his northward passage, stopped at Point Mugu south of Hueneme, and coasted north by the mouth of the Santa Clara River, until he anchored off the present site of Ventura. At that time it was occupied by three important Chumash villages; one known as Xucu, near the present site of Pierpont Inn; the second, or Mitz-khan-a-khan, in the lower part of the city; the third near the mouth of the Ventura River. The great number of large seaworthy canoes engaged in trade with the Channel Islands excited Cabrillo's admiration, and he named the village of Xucu, Punta de los Canoas.

Cabrillo is said to have landed at the present end of Palm and Figueroa streets. The site of Mitz-khan-a-khan was marked by a kitchen midden as late as 1875, and traces of it survive in the shell-filled black soil surrounding the Associated Oil Company's foamite tanks.

Sixty years later, the next visitor, Sebastian Vizcaíno, arrived in December 1602. His three ships stood off and on for a day, and the point named by Cabrillo was recognized. One hundred sixty seven years passed before the arrival of another party of Spaniards. This was the expedition of Gaspar De Portola in 1769, the first to come overland. The party had marched from San Fernando, and reached the coast by way of the Santa Clara River, Fray Juan Crespi, a keen and accurate observer, left an account of the visit in his diary, that records the impressions of an intelligent man in the strange and barbarous country that Ventura County was one hundred sixty years ago. A curious coincidence, and a worth while measure of material progress, is that the interval between the visits of Vizcaino and Crespi, and the latter's visit from the present day is precisely the same, 167 years.

The account of the visit given below is taken from the translation by Dr. Herbert E. Bolton (85).

---

(85) Bolton, Herbert E., "Fray Juan Crespi, Missionary explorer of the Pacific Coast, 1769-1774," University of California Press, pp. 158-164, Berkeley, California, 1927.

"Monday, August 14, 1769,--At seven in the morning we left the camp accompanied by three heathen who came to show us the next watering place. We followed the plain [Santa Clara Valley] to the west-southwest, and after traveling two hours and a half we arrived at the shore, where we saw a regular town, the most populous and best laid out of all that we had seen on the journey up to the present time [Ventura]. It is situated on a tongue or point of land runnings out on the same beach [Pierpont, or as it was then known, Punta de los Canoes] which stands so high that it seems to dominate the waters. We counted thirty large and spacious houses of a spherical form, well constructed and roofed with grass. According to the number of people whom we say and who came down to the camp, there were not less than four hundred souls.

"They are of good figure and disposition, active, industrious and inventive. They have surprising skill and ability in the construction of their canoes, which are made of pine planks, well joined and of a graceful shape, with two prows. They handle them with equal skill; three or four men go out into the open sea in them to fish, and they hold as many as ten men. They use long oars with two blades, and row with incredible lightness and speed. All the things which they make are neat and well finished; and the surprising thing is that they have no other tools for working the wood and stone than those made of flint, for they are ignorant of the use of iron and steel. Yet we saw among them some pieces of knives and sword blades, which they use for nothing but to cut meat and open the fish they take from the sea. The soldiers traded beads with them in exchange for baskets, pebbles, and wooden plates which would not be more graceful if they were turned with a wheel. They gave us a lot of fish, expecially very savory bonito. Judging from the great abundance of it and the ease with which it was caught, this must be the season for it."

"A short distance from the town we pitched camp near the bank of a river [Ventura], the waters of which come in a deep bed from the mountains and reach the sea. To the north it runs through a valley which has good lands, so that they make use of the abundance of water. In the afternoon some chiefs came from the mountains, having come from their country purposely to see us. Some islanders from the Santa Barbara Channel, who happened to be in this town, came also, and they told us that twelve canoes had gone to the islands to bring from there the people who wished to see us. I called this town La Asuncion de Nuestra Senora, [also known as La Asumpta] and I hope that such a fine site, where nothing is lacking, will become a good mission through the intercession of this great lady. I observed the latitude and it came out for me thirty-four degrees and thirty-six minutes and for Senor Constanzo thirty-four degrees and thirteen minutes [a remarkably accurate determination as the actual position is 34°15'50.5"]."

"Tuesday, August 15.--We two priests said Mass, which everybody heard, and at two in the afternoon we set out, taking the road to the west along the edge of the sea. At the start we crossed the river, which gave us some trouble on account of the stones and the large amount of water which ran above them. We traveled about two leagues over the sand of the beach. The space between the sea and the rugged, bare mountains that we have on the right is in some parts broad and in others narrow, so narrow indeed that it gives no room to pass without trouble. After traveling two hours we stopped near a small village which had a few little grass houses. All the water they have is a small pool [mouth of

Padre Juan Creek_7. There was a canoe, which might be seven varas long, in which they were fishing; the people of the village immediately called them and they came to land, with very many large fish."

"The chief, with all his village, came to the camp with the fish and many seeds, which he gave to the governor, who returned the gift with his present of beads, and they were well pleased. They brought more food than all the people could eat. During the night they disturbed us and kept us awake playing all night on some doleful pipes or whistles, which caused our sentinels to be more watchful. I named this village Santa Conefundis (Santa Conefundis was near Pitas (whistles) Point. The name has persisted)."

"Wednesday, August 16.--About half past six we started, following the same road to the west, which is the direction the beach runs here, and after traveling two leagues we came to another town larger than Asuncion, for we counted sixty houses, well built, and of the same construction as those of the first town. It has a fine arroyo of good running water which flows into the sea, although a little above, on account of a small eminence, it is damned up and becomes a sort of estuary /The mouth of Rincon Creek. Water is prevented from entering the sea by a barrier beach built by waves across the stream channel_7. Near the village there are no lands on the seashore except enough for building the town. The hills in the neighborhood are of good soil and are covered with good grass. I do not know whether or not there may be an arroyo or plains above in the openings between the hills. It is necessary to explore the region for if it has them it would be a good place for a mission. The Indians are very mild and friendly; we observed that they had seven canoes in the sea in which they were fishing."

* *

"Thursday, August 17.--We set out from this place at half-past seven and followed the road to the west. We climbed some steep hills of good grassy land, which end at the beach in a steep declivity, although between them and the beach there is a passage along the sand dunes. We must have traveled about half a league when we came to a point of land, which with the other at the town mentioned make a little bay in the shore. On this point we found another very large town in which we counted thirty-eight houses of the kind already described, some of them so large that they housed many families. At the edge of the town all the people were awaiting us, the number being no less than those at Asumpta. We went on to the village to greet them, and the commander gave the chief a present of some beads. We pitched the camp not very far from the village in a plain that must measure, from north to south about a league of good, black soil, well covered with grass [Carpinteria Plain]. From east to west it is four leagues long. The place has many willows, cottonwoods, alders, and some live-oaks. It is well provided with firewood, and the high mountains [Santa Ynez] that it has to the north seem to have a supply of wood in some parts but are bare in others."

"Just about north an arroyo comes down [Carpinteria Creek]. My companion went to see it, and he says that it has a good stretch of water at the foot of the mountains. The soldiers and explorers said there was another good village of heathen. Not far from the town we saw some springs of pitch. The Indians have many canoes, and at the time were building one, for which the soldiers named this town La Carpinteria, while I christened it with the name of San Roque. It is only one league distant from the last camping place. As soon as we arrived they brought us so many bonito fish--fresh, dried, and roasted--that they exceeded the gifts of the preceding towns. Opposite the place was seen an island, but on account of the fog it was impossible to make out with certainty what one it was."

Although it had been the hope of Fr. Junipero Serra to early establish a mission at Ventura, the enterprise was delayed by Indian uprisings at San Diego and on the Colorado. When San Buenaventura Mission was finally dedicated on March 31, 1782 it was the ninth, and last to be planted by Father Serra. The great California earthquake of 1812-13 destroyed the church which has been completed on the present site in 1809. This earthquake is of expecial interest because it was apparently accompanied by a tsunami, as described by Fr. Engelhardt from the account of Fr. Senan in the Baptismal Register for January 9, 1813 (86).

(86) Engelhardt, Zephyrin, "San Buenaventura, the mission by the sea," Mission Santa Barbara, p. 30, Santa Barbara, California, 1930.

"I administered Baptism in the temporary church erected of poles and twigs on the site called San Joaquin and Santa Ana distant a little less than three-fourths of a league from the Mission. To this place we retired on account of the terrible earthquakes and because the ocean, owing to the shocks was running so high that we feared its waters would flood the Mission."

And later in his Biennial Report of April 9, 1813;

"These little hardships have been increased greatly by the terrible earthquakes that have been experienced by the southern portion of this province, and that will be remembered as constituting an epoch of great disasters. Their violence as well as their continuance have been extraordinary. They began on December 8, 1812, and continued until last February with great violence. Since then they have been considerable, although they did not occur with such force and frequency."

The small temporary church known as Santa Gertrudis, stood until 1868 at Casitas. Casitas received its name from the great number of little Indian houses clustered beneath the live-oak trees at this oasis on the Ventura River. No trace of this once populous settlement survives in what today is Foster Park. Santa Gertrudis was used again when the mission walls were thrown down in the almost equally severe earthquake of 1857.

The Casitas Oasis was particularly important to the San Buenaventura mission as a permanent water supply. Between Sulphur Mountain and the coast the river bed is dry during the summer. A small spring near the Ortega adobe, and the seepage from Hall and Kalorama canyons were the only dependable water sources near the mission. When an extensive agricultural program was started, it proved necessary to bring in an outside supply. A five mile aqueduct was built from the oasis at the mouth of Canada larga to the pueblo of Ventura. The aqueduct skirted the base of Gosnell Hill, and the steep slope east of the avenue, turned east at Poli Street, and ended in a weir and settling basin from which the water was distributed to the mission and the principal houses in the settlement. The filter stands today in the Valdez alley west of the mission.

Among other interesting relics are the two palm trees on Columbo Street, one half block south of Main. They are the only survivors of the once beautiful mission garden, admired by Captain George Vancouver and Richard Henry Dana. John C. Fremont camped not far from the garden on his way to Los Angeles, and his camp-site is reputed to be opposite the Cabrillo Hotel and near Vine Street. Four well preserved adobes survive. They are interesting to visit and to observe how carefully they were placed with regard to the natural slope and the presence of running water. According to Rensch (87) three of them are located

(87) Rensch, H. E. and E. G., "Historic spots in California the Southern Counties," Stanford University Press, p.240, Stanford University, California, 1932.

as follows:

"La Casa de la Riva still stands across the river beyond Foster Park about eight miles from Ventura. The house set on a sloping meadow below wooded hills, is a substantial structure graced by broad Spanish balconies. On what was formerly the Lower Ojai Rancho stands the Lopez adobe, called the 'Barracks' because it once defended the lower Ojai Valley from the Matilija Indians. On the Old Creek Road to Ojai, ten miles from Ventura, stands the Santa Ana Rancho house of Don Jose de Arnaz."

The fourth, and best preserved, is the Olivas adobe built in 1841 on Rancho San Miguel, one and one half miles south of the highway, three miles southeast of Ventura.

The mission had its greatest prosperity from 1810 to 1820, and harvested its largest yield of 13,483 bushels of assorted crops from a planting of 523 bushels in 1818. The greatest number of livestock recorded was in 1816, and numbered 41,390 head. From 1822 the mission declined rapidly, and was secularized by the decree of August 9, 1834. After a turbulent period the lands were sold to Jose Arnaz on June 8, 1846 for $12,000.

The mission had an unusually favorable location. The Ventura River, an important trade route for the Indians, provided the only outlet for a large region to the north. The Tulares from the San Joaquin Valley made their way down it to the coast, and bargained with the Channel Islanders at the meeting ground of Ventura. The Santa Clara Valley provided similar access to the sea for the Mojave tribes, and Indians as far east as the Colorado often visited Ventura. The Ventura area supported a large, and unusually progressive Indian population at the time the mission was founded.

The mission flourished with an abundant labor supply, adequate water, grazing and agricultural land that extended inland as far as Piru. For a time it was one of the wealthiest of the chain. It is interesting to speculate on the causes which led to its decline, and the greater success of Santa Barbara; for Ventura would at first appear to have been the better endowed of the two. Santa Barbara is favored by a more sheltered position on the coast, a broader coastal plain, the Santa Ynez Mountains provide a good lee for the northwest gales of winter, and there is less coastal fog. In the summer the Santa Clara Valley acts as a wind chute into the arid interior, and a moderate sea is almost always running off the Ventura coast. The Boston ships in the days of the hide trade preferred to anchor off the Santa Barbara coast, where there was less danger of driving on a lee shore, and Mission Santa Barbara profited as a consequence.

Santa Barbara was made one of the four presidial pueblos in 1782, and attracted more merchants than Ventura. This fact may have had as much to do with the comparative success of the two settlements as differences in the natural environment. It is an interesting problem why Ventura, with its excellent connections to the hinterland, should lag behind Santa Barbara in importance, even into the present time.

Economic Geography

The population of the Ventura region is unusually concentrated for an agricultural area. Most of the people live in one of the three towns, or in the Santa Clara or Ojai Valleys. The mountainous interior is virtually uninhabited, and the only men encountered are range riders or farmers living in isolated valleys. The reason for the urban concentration is the second industry of the area, the production of petroleum. Most of the oil workers for the Ventura Avenue field live in Ventura. The development of the field in the 1920's is responsible for the rapid growth of the city, as shown by the U. S. Census of 1930.

	1930	1920	1910
Ventura	11,603	4,156	2,910
Santa Paula	7,452	3,967	2,216
Ojai	1,468	----	----

Agriculture is the dominant industry. During the Spanish period the most important form was grazing. The droughts of the middle '80's killed most of the cattle, and their place was taken by dry farming. For many years the Santa Clara and Ojai Valleys were covered with grain, which was shipped from Hueneme. This unprotected landing place ranked second only to Contra Costa as a wheat port.

Irrigated tree crops increased in importance after the beginning of the Twentieth Century. The most productive area is the Santa Clara Valley between Santa Paula and Montalvo. Lemons flourish near the coast where they benefit from the fog. Oranges replace them farther inland, and are also grown in the eastern end of the Ojai Valley. They seem to require a hot summer for a large production. The valleys in the Coastal Hills, between Ventura and Santa Paula, are occupied by appricot orchards. Grazing remains important even today in the mountainous interior. Favored hill slopes, and the surfaces of the larger coastal terraces are planted to lima beans.

A serious water shortage is near. Wells have lowered the water table of the Santa Clara Valley nearly to the economic limit. The drawdown has been great enough near the coast that salt water is now encroaching beneath the Oxnard Plain. Many suggestions have been offered for a new water source. Chief among these is a project for driving tunnels through the Santa Ynez Mountains to tap the drainage of the Santa Ynez River. This has already been done in the western part of the area, inland from Carpinteria, and a tunnel diverts the water of Juncal Creek into the water system of Santa Barbara. Another alternative is to buy water from the Owens Valley aqueduct of the City of Los Angeles.

The recovery of petroleum has been an important factor in the growth of the Ventura region. The first well was drilled in 1865 by T. R. Bard of Lacrosse. It produced nothing but sulphur water. Five other wells were drilled in succession around the northern slope of Sulphur Mountain. The last one was successful, and oil was encountered in the vicinity of the large seeps south of Sisar Canyon.

Asphaltum had been recovered as early as 1854. It was mined for a time at Carpinteria and sent by sailing ship to San Francisco to be used in road paving. Oil was also recovered in 1877 from a serious of tunnels, shallow wells, and springs on the south side of Sulphur Mountain at the head of Wheeler and Adams Canyon. The two most important fields of the pioneer period were the so-called "Silver Thread" field at Santa Paula mineral springs, and the "Tip-top" field at the west end of Sulphur Mountain above Fresno Canyon.

The most important fields at the present time are grouped along the axis of the Ventura Avenue anticline, a structure developed entirely in Pliocene strata. The largest of the series in the Ventura Avenue field; west of it are the San Miguelito, Javon, and Rincon or Seacliff fields. The first well drilled at Ventura Avenue was Lloyd no. 1, and was started on January 20, 1914. The well was wrecked by gas pressure, and the same fate was encountered by the next 7 or 8 wells. All that was proved after three years' work was the presence of a great quantity of natural gas. The Shell Oil Company leased almost the entire productive area in 1916, and after the expenditure of nearly $1,000,000 quitclaimed most of it. In 1917 the General Petroleum Company met with equally discouraging results. It was not until the Associated Oil Company was able to complete Lloyd no. 5 at a depth of 4,000 feet, and a production of 2,000 barrels a day that the field was established.

At present there are 216 producing wells in the Ventura Avenue field, with an average monthly production of 1,000,000 barrels of oil; 6 wells at San Miguelito produce 42,000 barrels per month; and 32 wells at Seacliff produce 62,000 barrels.

STRATIGRAPHY

The various rock units in the stratigraphic succession of this area are treated systematically for a number of reasons. The development of the present landscape is controlled primarily by the rock types in the various sedimentary formations exposed in the area. In order to have a systematic bases for description, it is necessary to resort to the use of local formational names.

The determination of the various formations exposed in the area, and the age significance of their fossil content lies outside the province of this study and will be discussed only in sufficient detail to indicate the type of rock involved and its place in the section.

According to Kerr (88), the thickness of sedimentary rocks exposed near Ventura totals 43,600 feet, of which

---

(88) Kerr, P. F., Schenck, H. G., and Muller, Siemon, "Geology of the Ventura Quadrangle, Calif." (abstract) Bull. Geol. Soc. of America., Vol. 42, No. 1, p. 186 March, 1931.

37,400 feet are confined to Tertiary sediments, 14,580 feet are Pliocene, and nearly 4,700 feet are in the Quaternary.

In the following descriptions it is necessary to bear in mind that two great difficulties are encountered in separating these Tertiary formations in the field: 1) These strata form a gradational sequence, as there has been nearly continuous deposition from the Miocene to the Pleistocene, and probably no marked disturbance in the sedimentary record since the Cretaceous. 2) Since the majority of these sediments were accumulated in a similar environment, the lithologic differences are not pronounced. Therefore, in many cases the separation must be based on the often quite meager fossil evidence.

In the systematic descriptions of the various formations the emphasis is placed, not upon problems of stratigraphy, but upon the relative erosional resistance of the separate unit.

Plate III

Generalized Columnar Section for the Ventura Region

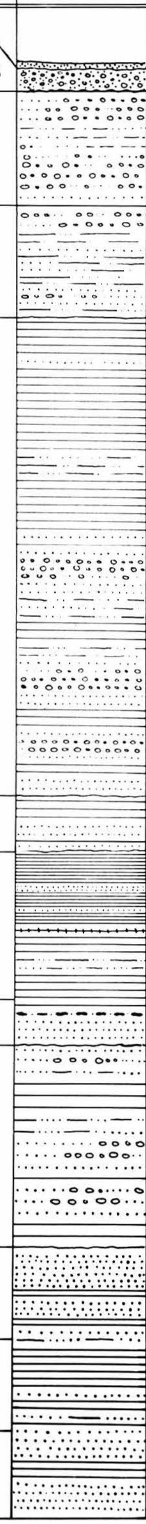
GENERALIZED COLUMNAR SECTION

FOR THE

VENTURA REGION

EPOCH	FORMATION		DESCRIPTION
RECENT	ALLUVIUM		
PLEISTOCENE	BENCH GRAVELS		
	SAN PEDRO		UNLITHIFIED CONGLOMERATES AND GRAVEL BEDS WITH INTERBEDDED SAND AND CLAY
	SANTA BARBARA		BUFF SANDSTONE, GRAVEL BEDS, AND ARENACEOUS SHALES
PLIOCENE	PICO		BLUISH GRAY AND BLACK CARBONACEOUS SHALE WITH INTERBEDDED BUFF SAND-STONE LENSES LENTICULAR CONGLOMERATES AND GRAVEL BEDS DERIVED FROM OLDER FORMATIONS
MIOCENE	STA. MARGARITA		CHOCOLATE BROWN SANDY SHALE AND GRAY SANDSTONE.
	MODELO AND RINCON		LAMINATED TAN SILICEOUS SHALES AND INTERCALATED WHITE SANDSTONE. STEEL GRAY TO BLACK ARGILLACEOUS SHALES.
	VAQUEROS		GRAY, CROSS BEDDED SANDSTONE
OLIGOCENE	SESPE		VARIEGATED RED AND BUFF, NON-MARINE, CONGLOMERATE, SANDSTONE, AND SHALE
EOCENE	TEJON	COLDWATER	WHITE, WELL SORTED, MASSIVE SANDSTONE
		COZY DELL	GREENISH BROWN, SANDY SHALE
		MATILIJA	MOTTLED GREEN SANDSTONE WITH INTERCALATED BROWN SHALE

ROCKS



0 2 4 6000

FEET

WCP 1936

CRETACEOUS SYSTEM

Crectaceous (?) Undifferentiated

Lithology and distribution

These rocks outcrop in the summit region of the Santa Ynez Range and are nowhere exposed within the southern part of the Ventura or Santa Paula Quadrangles. There is considerable question as to their age, and they have been assigned alternately to the Cretaceous and Eocene. At present the balance of favor seems to be in the direction of an Eocene age, at least for the upper portion, and they were tentatively assigned to the Juncal formation by Kerr in 1931.

Although these rocks play only a passive role in the physiographic history of the area, they are important in the formation of the late Pleistocene terraces. Much of the material transported downstream by the Ventura River has come from North of Matilija Springs. Many of the rock types characteristic of this terrane may be recognized in the later gravels.

In general, the oldest rocks exposed in the northern part of the Ventura Quadrangle are black, laminated shales, with thin stringers of intercalated brown sandstone. The regularity of this stratification over a considerable range, both vertically and horizontally, is particularly noteworthy, and shows such uniformity as to suggest an annual effect. At both the bottom and top of the section, sandstome becomes an increasingly important rock. In the upper portion, where it often occurs in white, massive layers, with a reddish surface stain, there is trouble in distinguishing it from the overlying Eocene strata.

At the base of the formation 150 feet of conglomerate is the most significant unit for it provides the most clearly recognized rock type found in the Ventura terrace gravels. These cobbles and boulders of the conglomerate are distinct from the rocks formed during later epochs. For the most part, they are fragments of granite, grano-diorite, four or five types of quartzite, grey and black rhyolite with light colored phenocrysts, occasional greenstones, and a scattering of limestone pebbles. The matrix is blue and grey sand, so completely indurated as to be almost quartzitic. Such an assemblage of rock type indicates a Franciscan derivation, but a different one from the source of the San Onofre Breccia. No chert pebbles, a common rock type in the Sespe conglomerates, were found.

Relation to Physiography

Since they are outside of the area investigated, the physiographic importance of these rocks has been slight. Their indirect influence, as a source of sediment for the terrace gravels, is of some importance, and they do afford a valuable criteria for determinging the ancient course of the Ventura River. The rock types of the Cretaceous conglomerate provide a quantitative measure of the distance the Ventura River has been able to transport its sediment.

TERTIARY SYSTEM

EOCENE SERIES

Tejon Formation

Lithology and distribution

These rocks have an areal distribution similar to the Cretaceous (?) formations. Across the northern border of the area where they dip steeply, they show an east-west paralelism. In the northeast corner, east of Topatopa Bluff, this parallelism vanishes, as here the strata are flat-lying.

The only available description of these Eocene deposits are by Kerr (89) and Kew (90).

---

(89) Paul F. Kerr and Hubert G. Schenck, "The Significance of the Matilija Overturn." Bull. Geol. Soc of America, Vol 39, pp. 1087-1102, December 30, 1928

(90) W. S. W. Kew, "Geology and Oil Resources of a part of Los Angeles and Ventura Counties, California, " U. S. Geol. Survey, Bull.753, pp. 26-30, 1924.

According to Kerr, these sediments, totaling 7500 feet, are divisible into three lithologic units: The Matilija Sandstone (2500'), the Cozy Dell Shale (2500'), and the Coldwater Sandstone (2500'). Of the three units, the only previously described is the Coldwater, first named by Watts (91).

---

(91) W. L. Watts, "Oil and Gas Yielding Formations of California," Calif. State Mining Bureau, Bull. 11, 1896, Bull. 19, 1900

The Matilija Sandstone, the oldest of the trio, has its type locality at Matilija Springs on the Ventura River, north of Ojai. Here it rests conformably upon the Crecaceous (?) or upper Eocene deposits mentioned above.

In the Matilija member of the Tejon, sandstone predominates over shale. This dominance may be more apparent than real, as all the sandstone strata are separated by intercalated shale stringers which often attain an appreciable thickness. The sandstone is a white, or faintly mottled green arkose and the strata exhibit an unusual uniformity in thickness over long distances.

The Cozy Dell is almost exclusively shale, with minor amounts of sandstone. Although occasional sandstone strata reach the dimensions of those in the Matilija, they have been less able to resist deformation due to the incompetency of the shale which surrounds them. Most of the shale is arenaceous, contains thin partings of sandstone, and has a characteristic chocolate brown color, with occasional greenish lenses. This shale is intricately fractured, often with a conchoidal surface, and becomes nodular on weathering.

The Cold Water Member, the first subdivision of the Tejon to be named, has its type locality in Cold Water Canyon one of the tributaries of Sespe Creek. It is sharply differentiated from the brown shales of the Cozy Dell, for it is a white, massive, somewhat friable, arkosic sandstone. Individual beds reach a thickness in excess of 20 feet; inter-bedded shales are red and green. The entire member extends in a continuous band for a lateral distance of over 40 miles.

The upper limit is difficult to determine, for the white sandstone of the Cold Water has been stained red from the overlying Sespe. This creates a difficult problem in correlation, for the uppermost portion of the Tejon is a distinctive oyster bed and overlies red sandstones. This red-stained stratum was originally placed in the terrestrial Sespe by Eldridge and Arnold [92], but is now generally considered an integral part of the Tejon.

---

(92) Eldridge, G. H. and Arnold, Ralph, "The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, Southern California," U.S. Geol. Survey Bull. 309, 1907

The Eocene age of the Tejon, in this area, is shown by the following fossils, according to Kerr and Schenck[93].

For the Matilija member:

---

(93) op. cit. pp. 1090-1091.

Turitella uvasana (Conrad), Meretrix hornii (Gabb), Pitaria uvasana (Conrad), Glycymeris sagittata (Gabb), Psammobia hornii (Gabb), and Spatangus tapinus (Schenck).

For the Cozy Dell member:

Amaurellina moragai Stewart, Ectinochilus (Cowlitzia) canalifer (Gabb, and Ficopsis hornii (Gabb).

For the Cold Water:

Turitella uvasana Conrad, Venericardia hornii Gabb, and Pecten calkinsi Arnold.

Relation to Physiography

The Tejon Formation plays a more significant role in the physiographic history of the Ventura District than the Crataceous (?). The hard, almost quartzitic, sandstones of the Matilija member where they are nearly horizontal are cliff makers. The sheer escarpment of Topatopa Bluff and the steep cliff immediately north of the East Fork of Santa Paula Creek are developed in these rocks.

The Cozy Dell shale is readily eroded and occupies a less important position. Where it crops out, the slopes are more rounded, less abruptly inclined. Where the strata are steeply inclined it often produces valleys, or saddles between the more resistant Cold Water and Matilija.

The Cold Water is a rock unit as unique as the Matilija and perhaps even more readily recognized at a distance. Due to its distinctive white color and massive nature, it stands out as a white band trending across the southern face of the Santa Ynez Mountains. Where its elevation is sufficient above the valley floor, and where its dip is steep, as at White Ledge Peak, it forms narrow, comb-like ridges, with long and rather uniform dip slopes leading to the crest.

Combined, the three units of the Tejon are responsible for the character of the southern slope of the Santa Ynez. They are revealed in complete, although inverted order, north of the Ojai Valley in the Matilija overturn. The steep-sloping pinnacle of White Ledge Peak is developed in the Cold Water. The cliff of Topatopa makes the even stratification of the Matilija Sandstone visible from more than 30 miles. All three units are laid bare on the upthrust mass of Santa Paula Ridge and San Cayetano Peak in normal sequence.

On account of the homogeneity of the various members of this formation, similar land forms have been developed, although separated by a great lateral distance. Where the massive sandstones are flat-lying, cliffs are cut; where they are steeply tilted, strike ridges form.

OLIGOCENE (?) SERIES

Sespe Formation

Lithology and Distribution

No stratigraphic unit in the area occupies a more anomalous position than the Sespe Formation. From a lithologic standpoint, it is one of the most distinctive, with its variegated buff and red sandstones, anddark red or greenish shales. In contrast to its distinctive physical characteristics, it has proved to be a difficult unit to place in its proper position in the stratigraphic column, In fact, when first described by Watts (94), it was con-

(94) Watts, W. L. "The Oil and Gas Yielding Formations of California," Calif. State Mining Bureau, Bull. 11, pp. 22-38, 1897.

sidered to be "underlain, with apparent conformity, by white sandstone, and overlain, also with apparent conformity, by drab sandstone. It is of Tertiary age, and younger then rocks containing Eocene fossils and older than beds containing

Miocene fossils." Later work by Kew (95) has shown that the

(95) op. cit. pp. 30-39.

"white sandstone" of Watts corresponds to the Tejon, and the "drab sandstone" to the Vaqueros.

Outside of its intermediate position between known Miocene and Eocene strata, little of the age of this formation is known in the vicinity of the Ojai Valley. In the Ventura area it contains no marine fossils, although rocks similar to these grade into marine Oligocene deposits west of Gaviota Pass.

The best evidence for the age of similar rocks south of Ventura is afforded by the work of Chester Stock (96).

(96) Stock, Chester, "Discovery of mammalian remains in Sespe Beds near Santa Paula, California," (alst.) Bul, Geol. Soc. of America, Vol 36, P. 201, 1925.

_______________, "Oreodonts from the Sespe deposits of South Mountain, Ventura County, California," Carnegie Institution of Washington, Pub. 404, pp, 27-42, 1930.

_______________, "An Upper Oligocene Mammalian Fauna from Southern California," Proc. Nat'l Acad. of Science, Vol. 18, No. 8, pp. 550.554, Aug. 1932.

He shows that the vertebrates occurring in the Sespe south of Santa Clara River indicate not only the Oligocene age for the majority of these strata, but also that they grade down into the upper Eocene. Some of the more important vertebrates from

the Los Posas portion of South Mountain are:
Subhyracodon, Miohippus, Hypertragulus, Nimravus, Hoplophoneus, Mesocyon, Temnocyon, Pseudocynodictus, Paleolagus
The uppermost portion extends into the Miocene, with a gradational contact between the Sespe and Vaqueros formations.

The lithologic character of the Sespe is perhaps its most unique characteristic. Wherever it crops out, it usually may be recognized by its reddish or deep brown color, most pronounced in the shale part of the formation. The sandstones, which are often red, may occasionally be buff or even yellow-grey.

The numerous layers of gravel and thin conglomeratic lenses contain pebbles of jasper, limestone, (Lithothamnium, probably derived from the Eocene), quartzite, gneiss, mica-schist, and fragments of chert, expecially in the Ojai Valley. The sand grains in the sandstone are angular to subangular, are coated with ferruginous material, and have a quartz-feldspar ratio of nearly 1:1.

The minerology of these deposits is believed by Reed (97) to indicate that they have derived from an area of

---

(97) Reed, R. D. "The Sespe Formation," Bull. Amer. Assoc. of Petrol. Geol., Vol. 13, pp.489-507, 1929.

granitic rocks, and conditions of weathering removed the ferromagnesium minerals. The minerological evidence is believed by Reed to be not inconsistent with a climate of moderate humidity at the time of deposition. In this respect he is at some variance with Gianella (98) and Reinhart (99),

---

(98) Gianella, Vincent P. "Minerals of the Sespe Formation, California, and their bearing on its origin," Bull. Amer. Assoc. of Petrol. Geol., Vol 12, pp. 747-752, 1928.

(99) Reinhart, Philip, "Origin of the Sespe Formation of South Mountain, California," Bull. Amer. Assoc. of Petrol. Geol., Vol. 12, pp. 743-746, 1928.

---

who advocate conditions of aridity on rather meager evidence.

The most generally held opinion at present is that the Sespe formation was deposited in a series of somewhat isolated, intermont basins, and was formed by coalescing alluvial fans, intermittent-stream and flood plain deposits in a climate with a moderate rainfall and temperature regime.

Next to the Pliocene and Pleistocene strata of the Coastal Hills, the Sespe formation is the most widely occurring cartographic unit in the Ventura Area. It trends in a broad east-west band across the central part of the Ventura and Santa Paula Quadrangles. The first important area is the top of the plateau between the canyons of Santa Paula and

Sespe Creeks. This inaccessible region is not far from Watts' type locality and its rocks can be traced directly into the type section.

The second, and most significant exposure is the Ojai Intermont Basin. The valley is underlain by the reddish sandstones and shales of the Sespe. This formation lies not only beneath the valley floor, but also is exposed at the base of the Santa Ynez Mts. to the north, and in Lion Mountain and the Upper Ojai Valley to the south.

The third, and almost equally important area, is the summit of Red Mountain, and the mountainous area west of the Ojai Valley, between the Santa Ynez Range and the sea.

Relation to Physiography

The degree of physiographic control exercised by the Sespe formation is a difficult matter to evaluate. Not only does it underlie a region of moderate relief as the Ojai Valley, but also it crops out in areas of as strong relief as the East Fork of Santa Paula Creek, and the summit of Red Mountain. In spite of the fact that it contains massive layers of sandstone, this rock presents little erosional resistance. The reason for this is the extreme lenticularity of the beds. A sandstone stratum 30 feet thick, lenses out in perhaps 50 to 60 feet and is replaced by arenaceous shale. Furthermore, most of the coarser grained rocks in the Sespe are friable and break down when exposed for some time to a mild atmospheric attack. This is well shown in the Bryce Canyon-like gorges of Willard and Morgan Canyons on the northern face of South Mountain.

The Sespe does not possess the degree of erosional resistance of the Tejon, or even of the Modelo shales. In most cases where it is exposed, it produces an open, gently rolling landscape, typified by the western Ojai Valley and the Santa Ana Valley. This tendency to form lowlands and broad valleys is difficult to reconcile with the occurrence of the Sespe on Red Mountain. These same rocks form as pronounced a ridge as Sulphur or Rincon Mts., and with as uniform an elevation. Not only do they underlie one of the most prominent mountains in the Ventura area, but they outcrop on the western side of the Ventura water gap, the most constricted part of the river course south of the Santa Ynez Mts.

This behavior cannot be explained on the basis of unequal erosional resistance, for the Sespe in the Ojai and Red Mountain areas is identical in every recognizable characteristic. The apparent prominence in one area and insignificance in the other is related to the recent deformational history of the area. The Rincon, Red, and Sulphur Mt. arc has recently been uparched, while the Ojai Valley has been depressed.

The Red Mountain Sespe owes its height to the recent uparching of this part of the Coastal area, and to the structure of the mountain. This is an overturned anticline, and has proved more resistant to erosion than it would be if the underlying rocks were horizontal or homoclinal. The same analogy holds in the case of Lion Mt., which, on a smaller scale, closely resembles Red Mountain. The anticlinal structure has probably been the salvation of both these mountains, coupled with the recency of the last deformation responsible for their elevation.

Two other characteristics of the Sespe formation which set it apart from its neighbors are worthy of mention. The first is the red color which persists even after the entire rock has been destroyed by weathering. All the areas, in which residual soil still covers the Sespe formation have a characteristic maroon tinge which indicates these rocks in the absence of definite outcrops. The second characteristic is well shown on Red Mountain and concerns the unequal rate of destruction of the Sespe shales and sandstones. The summit of the mountain is pitted with a large number of undrained depressions superficially resembling sag ponds. These are caused by differential movement of the large, lenticular masses of sandstone within the more incompetent shale, as the result of the folding of the Red Mountain anticline. The more closely jointed shale, between the sandstone lenses, has less resistance, and is the more readily removed.

This same unequal rate of erosion is responsible for the ribbed effect visible on the southern and south-eastern face of the mountain. Here the sandstone layers stand out in distinct ridges and show a pronounced curvature around the plunge of the fold. The mountain, viewed in a proper light from across the Ventura River, resembles a gigantic onion, with the sandstone ridges fulfilling the role of concentric skins.

MIOCENE SERIES

Vaqueros Formation

Lithology and Distribution

The Vaqueros formation is important from the stratigraphic standpoint, and but slightly from the physiographic. Stratigraphically it is the first formation discussed with which a state-wide correlation can be made. The Vaqueros formation crops out in a narrow, east-west band through the central part of the Ventura and Santa Paula Quadrangles. It appears on both sides of the Upper Ojai Valley, is exposed along the banks of San Antonio creek, crosses the Ventura River, and divides when it reaches the Red Mountain Anticline. It crops out on both limbs of this fold, unites again to the west of Red Mountain, and finally disappears beneath the Pleistocene deposits mantling the surface of the Carpinteria Plain.

Almost everywhere that the Vaqueros crops out it is buff, coarse and medium grained, rather friable lenses of sandstone at the base, and steel-gray, minutely fractured, modular shales in the middle and upper portions. These shales often contain large, limonite-stained dolomite conscretions which follow a single stratum for distances of several hundred feet. Near the top of the Vaqueros the formation includes black, finely-laminated carbonaceous shales.

The Vaqueros as exposed in the Ventura region bears a close resemblance to the type locality described by Hamlin (100)

(100) Hamlin, Homer, "Water Resources of the Salinas Valley," U. S. Geological Survey, Water-Supply Paper 89, 1904

and its fossils and age relationship have been treated in great detail by Loel and Corey. (101)

---

(101) Loel, Wayne and Corey, W. H., "The Vaqueros Formation of California, "Univ. of Calif. Pubs., Bull. Dept. of Geol. Sci., Vol. 22, No. 3, pp.31-410, Dec. 31, 1932; reference pp. 82-84

For this dictrict the authors consider some of the more important mega-fossils to be:

Upper Ojai Valley: *Turitella inezana sespeensis*, *Pecten sespeensis*,

San Antonio Creek: *Pecten magnolia*, *Rapana*, *Cardium*, *Crassitellites*, *Dosinia*, *Ostrea titan subtitan*.

Ventura River: *Ostrea vespertina loeli*, *Scutella fairbankse*, *Scutella andersoni*, *Ostrea venturana*.

Relation to Physiography

Of the stratigraphic units in the area, the Vaqueros Formation shows the least amount of physiographic control. The primary reason is its gradational character. It is neither dominantly shale or sandstone, but about an equal amount of both rock types. Then too, the outcrop width is too slight for these rocks to exert any widespread influence. They are exposed on the surface in a lowland belt at the base of adjoining ridges, rather than in upland or summit areas.

These sediments are readily eroded, but not as much as the Pico or San Pedro formations of the Coastal Hills.

MIOCENE SERIES

Modelo Formation

Lithology and Distribution

No formation in the Ventura region occupies so distinctive a position as the Modelo. These rocks occupy an intermidiate position in space and time, since they outcrop across the central area, and were deposited in the upper and middle Miocene. Their most important feature is the dominance of siliceous shale. The second significant feature is the erosional resistance of these fissile shales.

The Modelo formation is exposed in a band of moderate width through the Sulphur, Red, and Rincon Mountain arc. It disappears east of Santa Paula Creek where it has been covered by Eocene rocks brought up along the San Cayetano Thrust Fault. The maximum breadth and the most typical exposures of the Modelo Formation are in Sulphur Mountain, where in an area of 15 miles wide and two miles broad, these rocks crop out. West of the Ventura River, the Modelo formation occupies a more constricted zone where it has been involved in the belt of intensive faulting on the southern flank of the Red Mountain anticline. These rocks reappear in Rincon Mountain, where they regain something of the importance they possessed in Sulphur Mountain. The Modelo formation~~s~~ disappears, however, on crossing Rincon Creek, except for isolated exposures along Creek bottoms, and the face of the present sea cliff.

The lithologic character of these rocks is so distinctive that in a limited area they may be recognized on ~~just~~ this basis alone. There is scarcely any resemblance between the strata exposed at Ventura and those of the type locality at Modelo Canyon on Piru Creek. In the area to the north of the Ventura Region, the most distinctive rock types are coarse, well-washed and sorted, snow-white arkosic sandstones, buff sandstones, and dark terrigenous shales. In the Ridge Route area are extensive deposits of dark gray, carbonaceous shales.

In the Ventura area, the resemblance to the Monterey formation of the Carmel region, the Maricope shales on the west-side of the San Joaquin Valley, and the Puente Shales of the Los Angeles Basin, is more pronounced than in the areas east and north of Ventura. The reason is that these occurrences represent accumulations in an environment similar to the Ventura Basin. Their fine-grained sediments supposedly were laid down in protected, shallow water embayments, bordered by land masses of low relief. The

Modelo Canyon-Piru area presumably was nearer the continental edge, and deposition occurred in a littoral environment.

In Sulphur Mountain, the Modelo formation consists of fine-grained, white to tan, platy, siliceous shales, which weather to buff or brown on long exposure. Often these shales are well indurated, and separate into brittle, plate-like leaves. At other times they are punky and disintegrate into powder. Their characteristics are well described by Hoots (102(for the Santa Monica Mountains.

(102) Hoots, H. W., "Geology of the eastern part of the Santa Monica Mountains, Los Angeles, County, California," U. S. Geol. Survey, Prof, Paper 165 pp. 83-134, 1931

Occasionally layers of sandstone are intercalated. These are usually arkosic, and frequently include coarse gravels one inch or more in diameter. Although some layers of the shale have been converted to almost pure silica, others still retain their organic nature, and might well be classed as Diatomite or foraminiferite.

There is less organic matter in these shales than indicated by earlier writers who dealt with the problems of the organic shales of the Miocene and other epochs of the Tertiary. The ideas advanced by Taliaferro (103) and

Anderson[104] that the major portion of the finely comminuted

---

(103) Taliaferro, N. L., "The relation of volcanism to deatamaceous and associated siliceous sediments," Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., Vol. 23,No.1, pp. 1-56, March 25, 1933.

(104) Anderson, Robert van Vleck, "The Diatomaceous and fish bearing Beida Stage of Algeria," Journal of Geology, Vol. 41, No. 7, pp. 673-698, Oct-Nov. 1933.

---

siliceous material in these shales is stratified, water-laid volcanic ash seem substantiated. That it has been altered and devitrified is true, but the original characteristics are still discernible.

There is included in these shales much organic material most of it microscopic. It consists of forminifera, diatoms, algae, fish scales, plant remains, etc.. This organic content has been considered of great importance in the problem of petroleum accumulation for the Modelo is widely believed to represent one of the most important source rocks. The role of principal contributor has been assigned to the diatoms, but according to Anderson[105], the entire

---

(105) Anderson, Frank, "Origin of California Petroleum", Bull. Geol. Soc. of America, Vol. 37, No. 4, pp. 585-614, Dec. 30, 1926.

---

plankton is responsible.

The paucity of the fossil record has lead to trouble in determining the stratigraphic position of the Modelo. This formation was first established by G. H. Eldridge (106)

(106) Eldridge, G. H., "The Santa Clara Valley, Puente Hills, and Los Angeles, oil districts, Southern California," U. S. Geological Survey Bull. 309, 1907.

and Modelo Canyon chosen as the type locality. Later work by Kew (107) established the fact that Eldridge had included

(107) Kew, W. S. W., "Geology and Oil Resources of a Part of Los Angeles and Ventura Counties, Calif.," U. S. Geol. Survey Bull. 753, 1924.

within the Modelo formation strata then the true Vaqueros. These strata were later separated from the Vaqueros and placed in the Modelo. The careful field work of Hudson and Craig (108) and their associates has indicated (1) that the

(108) Hudson, Frank and Craig, E. K., Geologic Age of the Modelo Formation, California," Bull. American Assoc. of Petrol. Geol., Vol. 13, No. 5, pp. 509-518, May 1929.

Modelo Formation is properly separated into three divisions, each with the rank of a formation; and (2) that there has been continuous deposition from the Vaqueros to the end of the Miocene. The threefold division proposed to supplant the older term Modelo is:

Hudson and Craig	
Santa Margarita	Modelo
Modelo	
Topanga	

The term "Rincon Shale" was introduced, as a result of a study of the microfauna of the Lower Medelo by Loring Snedden, to correspond to the Topanga, or more properly the Temblor of the northern Coast Ranges, and was first described by Kerr (109).

---

(109) Kerr, P. F., "Bentonite from Ventura, California", Economic Geology, Vol. 26, No. 2, pp. 153-168, March-April, 1931.

The Santa Margarita may be represented by the brown shale which separates the uppermost portion of the Modelo from the lower Pico. It grades imperceptibly into both in the southern face of Sulphur Mountain.

For the purposes of this study, these problems of Miocene stratigraphy are not particularly germane. On the geologic map)Plate IV) all the upper and middle Miocene formations have been grouped together, and treated as a unit, since their physiographic expression is much the same.

Relation to Physiography

The reason for the apparent resistance to erosion of these platy, siliceous shales is obscure. As stated before, it probably is dependent on their impermeability, their high silica content which renders them comparatively immune to weathering, and the tough, gumbo-like residual soil they produce. About all that can be said is, that once a particular land form is developed, it tends to survive for a much longer period of time when it is underlain by these rocks.

PLIOCENE SERIES

Pico Formation

The Pliocene and Pleistocene deposits of the Coastal Hills are unique (1) for their great thickness of approximately 20,000 feet, (2) for their economic importance, and (3) for the problem of their proper correlation.

The presence of oil in these sediments has concentrated attention on the distribution, structure, and fossil content of these strata. The problem of their age relationship has been complicated by the nature of these sediments, and the manner of their accumulation. They were deposited rapidly, in water of comparatively shallow depth, and in a restricted and subsiding basin of deposition. They show marked variations in the type of sediment, both vertically and laterally; conglomerates with boulders several feet thick grade into clay shale. In the upper part of the formation are thousands of feet of essentially uniform mudstones and clay shales, monotonously identical everywhere they are exposed, and devoid of fossils. The few fossils contained show an ecoligic control as great as any age significance they possess. It is difficult enough to interpret the significance of depth, temperature, and salinity of the water in which they lived before an attempt may be made to work out their stratigraphic value.

The Pico Formation was first named, and its Pliocene age determined by Kew (110), although the first use of

(110) Kew W. S. W., "Geoligic Formations of a part of Southern California and their correlation," Bull. American Assoc. of Petrol. Geol., Vol. 7, No. 4 pp. 411-420, July-August, 1923.

____________ "Geology and Oil Resources of a part of Los Angeles and Ventura Counties, Calif." U. S. Geol. Survey Bull., 753, pp. 70-81, 1924.

the term appeared in a short article by Clark (111) in which

(111) Clark, B. L., "The Marine Tertiary of the West Coast of the United States, its sequence, paleography, and the problems of correlation," Journal of Geology, Vol. 29, No. 7, pp. 583-614, October, November, 1921.

Kew's terminology was employed in advance of his publication. The term Pico as originally defined by Kew included all deposits of Pliocene age within this area, and in this sense it is employed in this paper. It is not the intention of this study to enter into the controversy surrounding the proper subdivision of the Pliocene-Pleistocene deposits of this area. It is of interest, in passing, to point out some of the reasons for its existance. The two principal difficulties are (1) the paucity of any traceable fossil horizons in this great thickness of sediment, and (2) the gradational contact between the Pliocene and Miocene deposits below, and Pliocene and Pleistocene ones above.

The Miocene-Pliocene contact is gradational along the southern margin of Sulphur Mountain in those areas where faulting has not occurred. In most places it is marked by a distinctive chocolate brown shale with coarse, white, arkosic sandstone lenses. These strata contain foraminifera which resemble those of the Santa Margarita Ranch locality, as well as Pecten discus. However, the determination of the presence or absence of the Santa Margarita remains unsettled, although it appears to be present to the east, where littoral conditions were common in the late Tertiary.

It is on the Pliocene-Pleistocene contact that most geologic work in this area has foundered. The most significant and decisive paper dealing with the problem is by T. L. Bailey (112) and is based on extended and detailed field

(112) Bailey, Thomas L., "Lateral Change of Fauna in the Lower Pleistocene," Bull. Geol. Soc. of America, Vol. 46, No. 3, pp. 489-502, March 31, 1935.

observations. He concludes that the difficulty arises from the fact that during the late Pliocene-early Pleistocene the water became increasingly shallow, and therefore warmer inland from the coast. Warm water species, characteristic of the marine Pleistocene, are found in Pliocene deposits in the eastern portion of this area. These forms were contemporaneous with the typical coldwater Pliocene apecies which lived in deeper water farther westward in the area about Ventura.

The ecologic control of the depth of water and temperature on fossil and living organisms was largely ignored until Natland (113) showed that among the living species of

(113) Natland, Manley L., "The temperature and Depth distribution of some Recent and Fossil Foraminifera in the Southern California Region," Bull. Scripps Institution of Oceanography, Univ. of Calif. Pub., Technical Series, Vol. 3, No. 10, pp.225-230, 1933.

formaninifera in the Catalina Channel it was possible to recognize 5 distinct faunal zones. The same phenomenon held true for the fossil micro-fauna of the Ventura Pliocene and Pleistocene and indicated a gradual shallowing of the basin, as well as a probable time difference.

Bailey concludes that this migration of facies fauna across bedding must be taken into account in any rational attempt to separate the uppermost Pliocene from the lowermost part of the Pleistocene; especially when it can be shown that in the central and eastern parts of this area Pleostocene fossils occur in Pliocene (?) strata.

Bailey places the upper 3000 to 3500 feet of the strata in the San Pedro formation and considers it to be the equivalent of Pressler's (114) Las Posas. Below the San Pedro

---

(114) Pressler, E. D. "The Fernando Group in the Las Posas-South Mountain District, Ventura County, California," Univ. of Calif. Pubs., Bull. Dept. of Geol. Vol. 18, No. 13, pp. 325-345. March 30, 1929.

---

may be distinguished the 2900 to 3500 feet of the Santa Barbara Formation, which is transitional Pliocene-Pleistocene with the contact occurring about the middle of the formation. The Upper Pico formation of Cartwright (115), Driver (116),

---

(115) Cartwright, L. D., "Sedimentation of the Pico Formation in the Ventura Quadrangle, California," Bull. Amer. Assoc, of Petrol. Geol. Vol. 12, No. 3 pp. 239-248, March 1928.

(116) Driver, Herschel, "Foraminiferal section along Adams Canyon, Ventura County, California," Bull. Amer. Assoc. of Petrol. Geol., Vol. 12, No. 7, pp. 753-756, July, 1928.

and Waterfall[117] is considered to be synonomous with the Santa Barbara formation. Gale[118] has chosen to retain the

(117) Waterfall, L. N., "A contribution to the Paleonotology of the Fernando Group, Ventura County, California," Univ. of Calif. Pubs., Bull. Dept. of Geol. Sci., Vol. 18, No. 3, pp. 71-92, April 6, 1929.

(118) Grant, U. S. and Gale, H. R., Catalogue of the marine Pliocene and Pleistocene Mollisca of California," Memoirs of the San Diego Soc. of Natural History, Vol. 1, pp. 1-1036, Nov. 3, 1931.

original usage of Kew and places the Santa Barbara formation entirely in the Pliocene. He also treats the Las Posas formation as the marine equivalent of the terrestrial Saugas formation. A somewhat equivalent usage will be followed in this paper, and on the map the Pliocene-Pleistocene contact is drawn near the top of the Santa Barbara formation, or the old Pico-Saugus contact of most workers in this area. For the sake of simplicity, if not accuracy, only two formations will be considered as embracing the Pliocene and lower Pleistocene. The Pico is to include the true Pico and the lower half of the Santa Barbara; and the San Pedro is to include the upper Santa Barbara, as well as the San Pedro, or Las Posas, depending on which terminology is utilized.

The Pico formation has the greatest areal extent of any formation in the district with the exception of the Sespe. It crops out in a broad band across the area from

Rincon Mountain on the west to Timber Canyon on the east, and underlies the Coastal Hills. The outcrop width is rather constant, save for the broadest part north of Ventura, where it has been increased by folding on the Ventura Ave. anticline and the Canada Larga syncline.

The formation in the field is separable into two distinct units. The lower member appears to be equivalent to the Repetto of the Los Angeles Basin according to Kew (119)

(119) Kew, W. S. W., "Los Angeles, to Santa Barbara," <u>XVI International Geological Congress</u>, Guidebook 1S, Excursion C1, pp. 48-68, 1932.

and is lower Pliocene in age. The upper part of the Pico, middle and upper Pliocene in age, was termed the Mud-Pit member by Kerr after its excellent exposure in the large rotary mud-pits near the California School for Girls.

The lower is distinctly coarser than the upper part, and the separation between the two is made upon a lithologic basis. In the lower Pico, sandstones and conglomerates are the dominant rock types, while the upper Pico is composed of several thousand feet of drab, monotonously uniform clay shales in which almost all structure and stratification is obscured.

The Pico conglomerates occur principally in the area between the Ventura River and the head of Adams Canyon, with the grestest thickness to the north of Sexton and Harmon Canyons. These conglomerates are a prominent feature of the landscape in this portion of the Coastal Hills, for they stand up to form parrallel, rampart-like ridges.

The conglomerate boulders are well rounded, and range from 1 foot in diameter down to a few inches. In any given layer they are generally quite well graded. The boulders include representatives of all the rocks exposed in the area, up to the Pliocene, and include grano-diorite, rhyolite, lithothamnium, limestone, Cold Water sandstone, chert pebbles, fragments of Modelo shales, etc. Cartwright, on the basis of a pebble count of the various rock types in these conglomerates concludes that they have been derived from all the older formations exposed in this area, including the Modelo.

From the lenticularity of these deposits it is reasonable to believe that the conglomerates originally were delta channels near the margin of the slowly subsiding Pliocene marine basin. This belief is further supported by the lack of marine fossils in the conglomerate, by the presence of cross-bedding in its sandier facies, and by the rapid lateral variation of these deposits.

Figure 1

Ridge of lower Pico conglomerate

at head of Wheeler Canyon

The sandstones of the lower Pico are arkosic. They are buff to gray, friable, poorly sorted, contain many gravel lenses, and are discontinuous over any great distance. In scattered localities thay are comparatively fossiliferous. On the whole, the formation is lacking in any great accumulation of fossils. What few zones occur are widely separated, confined almost exclusively to the sandstones, are never found in the conglomerate, and rarely in the shales.

Figure 2

Outcrop of lower Pico conglomerate at head of Wheeler Canyon. Sulphur Mountain on left margin of photograph

The upper Pico, or the mud-pit member, is dominantly shale, although stringers of coarse to gravelly sandstone are not infrequent. No trace remains of the coarse lentils of conglomerate of the lower portion. Fresh exposures of shale are dark, bluish gray. On weathering they soon acquire a drab yellowish-brown color. Almost all trace of the rock structure is obliterated in areas underlain by the Pico clay shales, and field work in this area is difficult. The hills are all rounded, their surfaces are covered with wild mustard and sage, and no solid rock is visible.

A characteristic feature of the mudstone member of the Pico is the great number of small, nodular limonitic residual soil. The residual soil is a yellowish, sticky clay when wet and a powdery, dusty soil when dry. It is too impervious for any extensive plant cover to flourish, and this same impermeability, provides an ideal environment for the formation of large active slumps and landslides.

The Pliocene age of these sediments has been demonstrated by most of the workers in this area, and perhaps best by Grant and Gale [120]. They conclude that the Pliocene

(120) op. cit.; pp. 29-36.

may be subdivided into three zones, which are, from oldest to youngest, the Jacalitos, San Diego, and Santa Barbara. The Jacalitos is roughly equivalent to Kew's Repetto, and the San Diego-Santa Barbara to the mud-pit member. The Santa Barbara, furthermore has been shown by Bailey to extend into the Pleistocene.

The sandy facies of the middle Pico contains Pecten (Pallium) swiftii, Pecten (Aequipecten) deserti, Pecten (Janiri) bellus, Ostrea vespertina, Turitella vanvlecki, Dosinia jacalitosana, Pecten (Aequipecten) purpuratus, *Pecten (Lyropecten) estrellanus*, *Pecten (Patinopecten) healeyi*, *Venus (Chione) securis* variety fernandoensis, and others as listed by Gale.

The uppermost Pliocene or Santa Barbara zone has a coldwater fauna containing species with their habitat today in Puget Sound and Alaskan waters. Some of the more diagnostic of these are: *Pecten (Platinopecten) caminus*, *Pecten islandicus*, *Pecten beringianus*, *Natica (Tectonatica) clausa*, *Neptunea andersoni* variety *hawleyi*, *Neptunea venturaensis*, *Thracia trapezoides*, and *Pandora glacialis*.

Relation to Physiography

The characteristic land forms of the Coastal Hills are controlled by the fact that this portion of the Ventura district is underlain by the clay shales, sandstones and conglomerates of the Pico Formation. When these landforms are recognized, the occurrence of these rocks may be predicted, even if no surface outcrops are visible.

The accordant summits of these hills, the sharp crested divides, smoothly contoured slopes and flat-floored valleys are described in the section dealing with the Coastal Hills. The conglomeritic members of the lower Pico form district, parallel ridges across the northern part of the area where the base of the section is exposed. The greatest thickness of conglomerate in the Pico formation outcrops on the northern limb of the Canada Larga syncline.

In areas where the middle and lower portions of the section are exposed and sandstone is a significant element, a more variable topography is produced than in the uppermost part of the Pico formation. The sandstone layers stand up better than the intercalated shales. As a result, a ribbed effect is achieved if these rocks stand nearly vertical, a cuesta-like profile if they are inclined, and amphitheaters if they are nearly horizontal. This development of cirque-like valleys is particularly noteworthy along the axis of the Ventura Ave. Anticline and is well shown at Hall Canyon in the Ventura Ave. Oil Field, and at the Amphitheater immediately east of the San Miguelito Field. These steep-walled valleys are produced by the sapping effect of incompetent shale layers underlying more resistant sandstone strata.

In the mud-pit member of the Pico one of the most curious landscapes of the entire area is produced. For the most part, these shales make a succession of rounded hills, mantled by a thin, sterile soil, but one sufficiently thick to obscure all rock exposures. The most unusual feature of the shale portion of the section is not the prematurely aged appearance of this landscape, but the landslides, slumps,

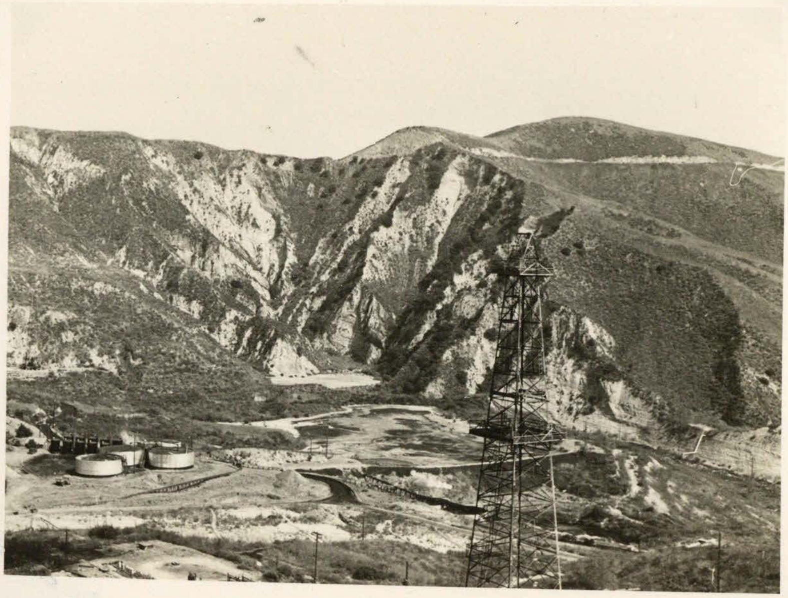


Figure 3

Rejuvenated area underlain by Pico clay shales. West of Hall Canyon and on south limb of Ventura Avenue anticline

and ripped areas which diversify its surface. For several square miles the surface is monotonous, and fully graded, then it suddenly is gullied and ravined by deep, vertical-walled arroyos. Large areas on the steeper slopes glide down hill in broad, semi-circular slumps, bounded by steep slump-scarps. Some of these are active and have caused the dislocation of roads and necessitated the relocation of oil wells.

The reasons for the derangement of a well balanced area that appears to be in late youth in its present erosion cycle are obscure, and no single explanation is adequate. Among the principal factors responsible are: (1) the surface vegetation has been destroyed by over-grazing, (2) its scanty natural distribution even in its native state has seriously limited the equilibrium, (3) the impervious nature of the fine sediment in the Upper Pico allows water to penetrate only to a shallow depth. This produces flowage between the saturated surface layers above and the unsaturated below, (4) lastly, the downcuting of the larger streams in the area has steepened the gradient of the adjoining hillslopes enough so that many of their lesser watercourses are rejuvenated, and in extreme instances landslides form.

QUATERNARY SYSTEM

PLEISTOCENE SERIES

San Pedro Formation

Lithology and Distribution

To deal with the Pliocene Epoch and to separate the sediments deposited then from those laid down in the

Pleistocene is a problem of great complexity. In the first place, the contact between the Pliocene-Pleistocene deposits is gradational. Secondly, supposedly typical warm water San Pedro forms have made a lateral migration down the section into strata which may be traced with no discontinuity into beds containing a cold water Santa Barbara fauna. To further confuse the situation, more names and division points have been suggested for the Pleistocene deposits in this area than there have been workers in the field.

When the deposits in this area, now considered Pleistocene, were first studied, they were lumped with the Pliocene into the Fernando Group, named by Eldridge and Arnold (121), and English (122). Kew (123) divided the Fernando

---

(121) Eldridge, G. H., and Arnold, Ralph, "The Santa Valley, Puenta Hills and Los Angeles oil districts, Southern California," <u>U. S. Geol. Survey, Bull. 309</u>, pp. 22-28,

(122) English, W. A., "The Fernando group near Newhall, California," <u>Univ. of Calif. Pubs., Bull. Dept. of Geol. Sci.</u>, Vol. 8, pp. 205-218, 1914

(123) Kew, W. S. W., "Geology and oil resources of a part of Los Angeles and Ventura Counties, Calif. U. S. Geol. Survey, Bull. 753, pp. 69-89, 1924.

---

into two units, the Pico formation (4000') and Saugus formation (2000'), both separated by an unconformity, and representing the Pliocene and Pleistocene Epochs respectively.

The major problem encountered in an attempt to correlate the strata in the Ventura district with those in the vicinity of Newhall and Saugus arises from the fact that the deposits in Ventura are terrestrial, behind Santa Paula transitional, and immediately north of Ventura and continuing westward, littoral and marine. This difficulty of correlation is further increased by the variation in thickness of these deposits, and by the paucity of fossils. Also, the ecologic control over distribution of these fossils has been shown to be greater in some instances that their time significance.

In the Ventura area there has been notable divergence of opinion among most of the paleontologists working in the region. Eaton (124) attempted to divide the Pleistocene

(124) Eaton, J.E., "Divisions and Duration of the Pleistocene in Southern California," Bull. Amer. Assoc. of Petrol. Geol., Vol. 12, No. 2, pp.111-141, February, 1928.

into three alleged formations. Waterfall (125) and Pressler (126)

(125) Waterfall, L. N., "A contribution to the Paleontology of the Fernando Group," Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., Vol. 18, No.3 pp. 71-92, April 6, 1929.

(126) Pressler, Edward, "The Fernando Group in the Las Posas-South Mountain district, Ventura County, California," Univ. of Calif. Pubs., Bull. Dept. of Geol. Sci., Vol. 18, No. 13, pp. 325-345, Sept. 30, 1929

recently have studied the fossil content of these strata and conclude that they are Pleistocene. Waterfall retains the terminology of Kew, but Pressler introduces a new stratigraphic nomenclature. Most of the strata considered as San Pedro are termed Las Posas by him, and the subjoined correlation is made between his three units and the previously accepted one.

	Pressler		Arnold
Pleistocene	Las Posas	Long Canyon	Upper San Pedro
			Lower San Pedro
		Kalorama	"San Pedro Pliocene"
	Santa Barbara		
	Lower Pico		

Bailey (127) returns to Arnold's original usage of

(127) Bailey, T. L., "Lateral change in Fauna in the lower Pleistocene," Bull. Geol. Soc. of Amer. Vol. 46, No. 3, pp. 489-502, March 31, 1935.

San Pedro although, as he states, "the type San Pedro probably comprises only a meager fragment of the Ventura San Pedro. This is not much more inexact than the use of 'Vaqueros' and 'Martinez' for these formations far from their type localities."

This terminology will be employed in this paper, and the San Pedro will be considered as the marine and littoral equivalent of the terrestrial Saugus. According to

Bailey[128], the total thickness of these early Pleistocene

(128) op. cit., p. 290.

sediments is 3000 to 3500 feet, for the most part consisting of "poorly consolidated, light-gray to buff, fine to coarse sands and gravels, buff weathering sandy silts, and greenish gray, drab gray, and locally, grayish-maroon clays and silty clays. Over 75 per cent consists of sands and pebble to cobble gravels."

The gradational nature of the contact between the terrestrial and the marine portions of these Pleistocene sediments is shown by the pinching out of the fossiliferous marine portion of the section eastward. At Hall Canyon, behind the eastern edge of Ventura, the lower 1950 feet contain marine fossils; 4.5 miles farther east, at Harmon Canyon, only the lower 1000 feet are marine; and finally 7 miles east at Aliso Canyon only the lower 50 to 200 feet contain marine fossils intact. The upper portion of the San Pedro, according to both Pressler and Bailey, contains scattered teeth of <u>Equus</u> cf. <u>occidentalis</u> Leidy, which establishes its Pleistocene age.

Relation to Physiography:

Little difference exists between the Pliocene and Pleistocene deposits of the Coastal Hills in the degree of induration. Both are barely consolidated clays, sandstones, and shales, and being steeply tilted, are exposed to the maximum degree of atmospheric attack.

The San Pedro is less perfectly sorted than the mud-pit member of the Pico, and also is composed of much coarser sediments. Even if the same week degree of induration were possessed by both formations, the San Pedro would still tend to weather more readily, as it is slightly less well cemented and is unable to offer serious resistance to erosion. So readily does it succumb, that behind Ventura it is impossible to distinguish between steeply tilted early Pleistocene strata, and nearly horizontal late Pleistocene terrace gravel. In the field an approximate separation of the Pliocene and Pleistocene strata is possible on the basis of vegetation. This is a lithologic control, and in the eastern part of the area is inaccurate from a faunal point of view. However, it does afford a rough check in the field for tracing an otherwise extremely difficult contact. The San Pedro, because of its greater porosity, has a higher ground water content than the impervious clay shales of the mud-pit member of the Pico. As a consequence, these

Pleistocene deposits are mantled by a thicker growth of wild sage, cactus, live oaks, yucca, and other semi-arid plants.

On the coast to the North and East of Ventura, where marine terraces have been cut in the steeply inclined San Pedro, it is impossible to discriminate between these early Pleistocene deposits and the horizontal terrace gravels. Lithologically, the two sediments are identical, and in some instances, both have the same fossil content.

PLEISTOCENE SERIES

Terrace Gravels

This section is concerned primarily with the stratigraphic position of the terrace gravels, rather than with their physiographic history. As a rule, they are comparatively non-fossiliferous, and contain only scattered, broken shells in the case of the marine, and a few teeth and isolated bones for the river gravels. The one notable exception is the Carpinteria tar pits, which are found on the westward extension of the I level of Rincon Mt..

One of the most recent discoveries is that made by T. L. Bailey of Elephas imperator and Equus cf. occidentalis in titled upper Pleistocene terrace gravels near the mouth of Barlow Canyon. Elephant remains also have been recovered in the excavations for some building foundations in Ventura.

The marine terraces above Ventura are fossiliferous, particularly in the vicinity of the reservoir, and contain a great number of comminuted, scattered shell fragments dissiminated through a blanket of powdery, yellow-brown, silty sand. They are so badly broken as to make identification impossible; but a number of them may represent reworked San Pedro forms.

A few marine fossils have been collected by Grant (129)

---

(129) Grant, U. S., and Gale, H. R., "Catalogue of Marine and Pleistocene Mollusca of Calif.," Memoirs San Diego Soc. of Nat. Hist., Vol. 1, 1036pp., Nov. 3, 1931. Reference p. 101; San Diego Soc. Nat. Hist. Locality No. 78 equals Stanford Univ. locality No. 536

---

from the low terrace at the foot of the sea cliff at the Rincon Oil Field, and seem to be comparable to the fauna of the essentially Recent Goleta terrace described by Oldroyd and Grant (130).

---

(130) Oldroyd, I, S. and Grant, U. S., "A Pleistocene Molluscan fauna from near Goleta, Santa Barbara, California," Nautilus, Vol. 44, No. 3, pp. 91-94, Jan., 1931.

PLEISTOCENE SERIES

The Carpinteria Formation

The tar pits on the surface of the Carpinteria Plain, between the Southern Pacific R. R. tracks and the present sea cliff, were first mined as a source of asphalt for road material. The discovery of fossil remains by the late Ralph Hoffman of the Santa Barbara Museum of Natural History has made this area an extremely important late Pleistocene horizon on account of the correlation afforded by plant, vertebrate, bird, and molluscan fossils. This find was first described in a series of preliminary articles in Science.(131)

---

(131) Hoffman, Ralph, "The finding of Pleistocene Material in an Asphalt Pit at Carpinteria, Calif.," Science, n. s. Vol. 66, No. 1702, P. 155, Aug. 12, 1927.

Stock, Chester, "Pleistocene Fauna and Flora," idem, p. 156.

Miller, Loye, "Bird Remains," idem., p. 156.

Chaney, Ralph W. and Mason, Herbert, L., "Fossil Plants," idem., pp. 156-157.

These preliminary abstracts have recently been followed by a more complete series dealing with the significance of each fossil group(132).

---

(132) Grant, U. S. and Strong, A. M., "Fossil Mollusks from the Vertebrate bearing asphalt deposits at Carpinteria, California," Bull. So. Calif. Acad. of Sci., Vol. 23, Part 1, pp. 1-5, Jan-Apr. 1934.

Miller, Loye, "Pleistocene Birds from the Carpinteria Asphalt of California," <u>Univ. of Calif. Pubs., Bull. Dept. Geol. Sci.</u>, Vol. 20, No. 10, pp. 361-374, Aug. 4, 1931.

Miller, Alden H., "The Fossil Passerine Birds from the Pleistocene of Carpinteria, California," <u>Univ. of Calif. Pubs., Bull. Dept. Geol. Sci.</u>, Vol. 21, No. 7, pp. 169-194, Feb. 26, 1932.

Chaney, Ralph and Mason, Herbert L., "A Pleistocene Flora from the Asphalt Pits at Carpinteria, California," <u>Carnegie Inst. of Wash.</u>, Pub. No. 415, pp. 45-79, March, 1933.

Wilson, Robert W., "Pleistocene Mammalian Fauna from the Carpinteria Asphalt," <u>Carnegie Inst. of Wash.</u>, Pub. No. 440, pp. 59-76, May, 1934.

The concensus of all these papers is that the majority of the forms represented are living, but not necessarily in the climate which now prevails at Carpinteria. In fact, since their burial there has been a marked increase in temperature and aridity.

The earlist of these fossils are the molluscs, found in a 3 to 4 inch layer of sand and sandy gravel resting directly upon the leveled edge of upturned Miocene strata. This shell bearing layer is covered by a 15 to 20 foot, thick asphalt impregnated deposit of sand and loam which blankets the terrace surface. It is in this upper layer that the vertebrate, bird, and plant remains are found.

Although the shells were deposited while the Pacific still covered this portion of the Carpinteria Plain, they may not antedate the beginning of coastal uplift, for the distance from here to the original coastline is some 1.2 miles. Grant indicates that most of them are littoral and lagoonal forms, and so, as the coast was elevated, this accumulation may represent a temporary halt of the receding shoreline. As stated by Grant (133):

(133) op. cit., pp. 4-5

"The ecologic requirements of these molluscan species suggest that they probably lived in a semi-sheltered cove or open embayment embracing rocky tide pools and lagoonal conditions in close proximity. Such a varied habitat can be found at many places along the present California coastline where small canyons meet the sea along rocky coasts."

"Of the 57 forms represented in the above list, 46 are definitely determined species, including the 5 Amphineura. All are still living and most of them include Santa Barbara County in their known Recent ranges. At first sight the fauna appears to represent a typical southern California assemblage but the Tachyrhynchus (questionably identified as reticulatus) might be the northern species and the two chitons, Mopalia sinuata (Carpenter) and Tonicella lineata (Wood), are primarily northern in their range though the latter has been recorded as far south as San Diego. Though the fauna is small it precludes the possibility of warmer marine conditions than the present for it does not include the well known living southern forma such as Laevicardium elatum Sowerby, L. procerum Sowerby, Mulinia modesta Dall, Tellina rubescens Hanley, Chione gnidia Broderip and Sowerby, Crassispira amathea Dall, Eupleura muriciformis (Broderip), Macron aethiops kellettii (A. Adams), Centrifuga leeana (Dall), and Purpura monoceros (Sowerby) which are present in the warm water late Pleistocene Palos Verdes formation of Los Angeles County. Thus, the Carpinteria fossil mollusks suggest marine conditions probably slightly cooler than the present.

Geologic Age

"In regard to the age of the deposit, the lack of extinct species would place it in the late Pleistocene, later than the Palos Verdes formation which has some extinct species and which has been correlated with the Sangamon interglacial stage of the Pleistocene. But the small number of definitely determined species makes this conclusion somewhat questionable for there may be extinct species in the deposit which have not been preserved, or at least have not been collected. On other grounds, however, a late Pleistocene age appears to be a safe conclusion, for out of 25 species of plants only one is extinct and the vertebrates are also suggestive of the late Pleistocene. In view of the apparent recency of all the organisms, and their climatic significance, the Carpinteria asphalt deposit may be tentatively dated toward the latter part of the late Wisconsin glacial stage of the Pleistocene when the lowest temperature had been passed and conditions were becoming somewhat ameliorated."

Alden Miller (134), in his study of the passerine

(134) op. cit., p. 188.

birds, concludes that, of the 23 kinds represented, 21 are living species, and only two may be extinct. Furthermore, approximately one third of these Passeriformes are no longer to be found in this area, but either range farther north, or at higher elevations. In fact, the avifauna bears a marked resemblance to that living in the vicinity of Monterey.

Thus, according to Miller (135), "we may picture a

(135) op. cit., p. 187

a region at Carpinteria which was like the lower part of the Carmel River Valley, Monterey County, where within a short distance pine forests provide the habitats of nuthatches, Steller Jays, chickadees, Pine Siskins, and Red Crossbills, and where also areas dominated by live oaks form suitable places for California Jays and Yellow-billed Magpies. Chaparral-covered slopes or brush in a river bottom must have been present to attract Wren-tits, Spotted Towhees, and Fox Sparros. A small grassy opening in the brush or forest would have supplied suitable conditions for meadowlarks. Thus, all the fossil passerine species in so far as their probable habits are known, may be fitted into such a picture with the exception of the Northwest Crow. Since Pleistocene time this bird has retreated to the north to a greater degree than the coniferous forests which have remained along the coast of central and northern California. Robins do not breed today near Monterey but breed under conditions uninfluenced by the agencies of man in Marin County one hundred miles to the northwest."

Chaney and Mason have made a study of the late Pleistocene fossil flora for both the Carpinteria occurrence and for its contemporary across the Santa Barbara Channel at Willow Creek on Santa Cruz Island. Both floras are considered by them to represent a cooler and more humid environment than that existing here today. For Santa Cruz Island some 30 miles south of here they have the following to say (136):

---

(136) Chaney, Ralph W. and Mason, Herbert L., "A Pleistocene Flora from Santa Cruz Island, Calif." <u>Carnegie Inst. of Wash.</u>, Pub. No. 415, pp. 1-24, October, 1934.

"The Willow Creek flora of Santa Cruz Island is made up of nine species, all of which are still living in California. The modern forest most closely approximated by the fossil assemblage is found on the California Coast near Fort Bragg, 440 miles to the north-northwest of Santa Cruz Island. The rainfall of the Fort Bragg region is considerably higher and the mean temperature is considerably lower than on Santa Cruz Island today, and the conclusion is reached that the Willow Creek flora represents a southward extension of the northern forest which is probably to be correlated with one of the glacial epochs of the Pleistocene. A landward connection of the Channel Islands to the mainland on the east is indicated by the flora--fossil and living, by the associated elephant remains, and by the general geologic relations. The Pleistocene age of the Willow Creek flora is established by its close relation to other Pleistocene floras of California, and by its association with elephant fossils. The discrepancies in the ranges of most of the Willow Creek plants as compared with those of the species today are sufficient in themselves to indicate a considerable lapse of time."

The plant remains at Carpinteria were recovered from two pits between the Southern Pacific Railroad tracks and the present sea cliff. Pit No. 1, as described by Chaney (136), reveals the following section:

---

(136) Chaney, Ralph and Mason, Herbert L., "A Pleistocene Flora from the Asphalt Deposits at Carpinteria, California," Carnegie Inst. of Wash. Publ. No. 415, pp. 45-80, October, 1934.

Section exposed at Pit No. 1

Center of Asphalt Mine

	Feet
1. Recent	
Dark gray, fine sands containing a small amount of asphalt, with shells and implements representing midden deposits.	5
2. Pleistocene-Carpinteria formation	
Light colored sand, well cemented and asphalt stained; no fossils observed.	7
Sand heavily impregnated with asphalt, containing abundant fossil plants and animals.	10

while pit No. 2 exposes the following:

Section exposed at Pit No. 2

325 feet west of Pit No. 1

Figure 4

The Carpinteria Terrace.

The tar pit from which the fossils were recovered is near the base of the trees.

1. Recent	Feet
Dark gray, fine sands containg a small amount of asphalt.	7
2. Pleistocene-Carpinteria formation	
Cross-bedded sands, with scattered pebbles and pockets of fine gravel; heavily impregnated with asphalt, containing abundant fossil plants and animals. . .	14

Figure 5

The Carpinteria tar pit. Rincon Mountain is in the distance. The excavation site has been destroyed by the quarrying operations

The flora contined in the asphalt impregnated sands comprised 25 species divided between 21 genera and 18 families, and includes a fern, 8 species of conifers and 16 species of dicotyledons.

On the basis of habitat there are 11 species of trees, 8 of shrubs, and 6 of herbs. These are subdivided as follows:

Trees

<u>Cupressus goveniana</u>

<u>Juniperus californica</u>

<u>Myrica californica</u>

<u>Pinus muricata</u>

<u>Pinus radiata</u>

<u>Pinus remorate</u>

<u>Pinus sabiniana</u>

<u>Pseudotsuga taxifolia</u>

<u>Quercus agrifolia</u>

<u>Sequoia sempervirens</u>

<u>Unbellularia californica</u>

Shrubs

<u>Arctostaphylos glauca</u>

<u>Arctostaphylos spp.</u>

<u>Ceanothus thyrisflorus</u>

<u>Eriodictyon californicum</u>

<u>Ganya elliptica</u>

<u>Pyrus hoffmani</u>

<u>Rhus diversiloba</u>

<u>Sambucus glauca</u>

Herbs

<u>Arcenthobium campylopodum</u>

<u>Chorizanthe pungens</u>

<u>Corethrogyne sp.</u>

<u>Cymopterus littoralis</u>

<u>Pteris aquilina</u>

<u>Xanthium calvum</u>

The wood from these plants has been investigated by Dr. Irma W. Webber, in a companion study. She consludes that the woods shows the effects of wear, and attributes this to transportation for considerable distances. Furthermore, because of decay the wood is believed to have been deposited in valley alluvium, which was later impregnated by asphalt, rather than to have been accumulated in an asphalt pit. ~~And~~

~~finally~~, in regard to the climate of the period of accumulation, Chaney remarks that:

"It may be concluded that the climate of Carpinteria during the Pleistocene, as judged from the nature of its vegetation, was cooler and slightly more humid than it is today, and was more like that on the coast 200 miles to the northwest, where the summers are moist and cool. A similar conclusion has been reached regarding the climate on Santa Cruz Island. The region was covered with a Douglas fir forest and appears to have had a still lower temperature and a much higher rainfall than at Carpinteria during the Pleistocene; this was probably due to its more exposed situation near the end of a peninsula which appears to have formed the seaward side of the embayment in which Carpinteria was located. The cooler and more humid type of climate at both localities during the Pleistocene may be interpreted as the result of glacial conditions, and the southward shift of the forests along the coast for a distance of several hundred miles may be considered to be as direct a result of glacial climates as the advance of glaciers elsewhere in the northern hemisphere. The return of milder conditions has resulted in the shifting of the southern limits of these forests to their present position on the Monterey Peninsula.

The topography of Carpinteria during the Pleistocene, as indicated by the fossil flora, was not unlike that in the region at the present time. A gradual seaward slope was occupied by the forest, with <u>Pinus muricata</u> and <u>Cupressus goveniana</u> more common toward the top, and with <u>Pinus radiata</u> more dominant in the middle and lower portions. The local abundance of <u>Quercus agrifolia</u> at low levels is indicated by the abundance of leaves of this species at the bottom of Pit II. Numerous shallow valleys crossed the plain, in which the <u>Umbellularia californica</u>, <u>Sambuscus glauca</u>, <u>Myrica californica</u>, and other broad-leafed species modified the dominant coniferous aspect of the vegetation."

The vertebrate fossils which are included with the plant remains possess a decided climatic significance, and have been given a somewhat different interpretation from the plant fossils. 1) They indicate somewhat less humid conditions, and 2) they give stonger evidence of being a tar pit accumulation that the plants. These vertebrates are well described by Wilson (137):

(137) Wilson, Robert W., "Pleistocene Mammalian fauna from the Carpinteria asphalt," Carnegie Inst. of Washington, Publ. No. 440, pp. 56-76, May, 1934.

"The mammalian assemblage includes only four extinct types, namely, _Aenocyon_ near _dirus_, _Felis_ probably _atrox_, _Camelops_ cf. _hesternis_, and _Equus_ near _occidentalis_. _Sorex_ cf. _trowbridgii_, _Onychomys_, species and _Bison_ species, do not now range in the area about the brea deposits. The remaining mammals in the fauna, so far as can be determinted, do not differ from those existing in the region at the present time. Thus the constituency of the Carpinteria assemblage offers no salient facts mitigating against a late Pleistocene age.

A survey of the fauna reveals the presence of certain mammals whose inferred habits and habitats substantiate the ecologic conditions at the Carpinteria locality postulated from a study of the plants and avifauna found in the asphalt. In addition to these are other mammals that normally inhabit semi-arid regions. Presence of the latter appears to reflect an influence which is not so apparent from the constitution of the plant or avian assemblage. Proximity of the locality of occurrence to a forest border with perhaps fluctuations in the amount and extent of the plant and tree cover during the period of accumulation may account for this association of mammals.

The presence of a relatively large number of individuals of the genus Dipodomys is interesting, since this form occurs typically on arid and semi-arid plains of the California region at the present time. Assuming that the fundamental habits and habitat of the Kangaroo-rats have undergone no great change since late Pleistocene time, the occurrence of these creatures at Carpinteria furnishes some of the more striking evidence in support of the view that the forest cover in the region of asphalt accumulation was broken by areas in sparse vegetation."

There are a number of points of disagreement in the evidence of the plant and vertebrate fossils:

1). The plants show signs of transportation and decay.

2). The vertebrate reamins, minute, fragile bones and teeth for the most part, show little attrition and seem to be a tar-pit accumulation.

3). The plants indicate a cool-humid climate, comparable to the present climate of the Montery Penninsula.

4). The climatic significance of the vertebrates is not so great, but the presence of Dipodomys indicates a sparser covering of vegetation and a semi-arid climate.

Unfortunately the pits from which the fossils were recovered have been destroyed, but a complete enough section is revealed in the sea cliff and the asphalt quarry that some interpretations may be made of the environment at the time the fossils accumulated. The sea cliff section of the Carpinteria formation shows:

1). The vertically dipping Modelo formation in the lower part of the sea cliff has an irregular upper surface which decreases in elevation westward.

2). The greatest irregularity in the bedrock surface is the cross section of a former stream valley 20 feet wide and 8 feet deep, 600 feet east of the asphalt pit. Boulders and cross-bedded gravelly sands are the deposit filling the channel. The largest boulders are at the narrow, V-shaped bottom of the stream course, and reach a maximum diameter of 4 feet.

3). In general the Carpinteria formation, or terrace covering, which overlies the Modelo formation is coarser east of the asphalt mine. Eastward the formation consists of boulder-cobble gravel and cross-bedded sand lenses. Westward, the formation is almost entirely gravelly sand which grades into silt 0.5 mile west of the pit. The silty sand is tar-impregnated and contains abundant mollusk fossils. South of the townsite the Carpinteria formation passes below the level of the present beach as a result of the tilting of the Carpinteria Plain.

4). Not all parts of the Carpinteria formation are tar-impregnated, and in some parts of the sea cliff section while the lower part of the formation may be saturated, the upper is free of tar. Oil seeps have been intermittently active through the area, and in an individual seep, periods of activity have alternated with times of quiescence.

Figure 6

The Composite Carpinteria Sea Cliff. The lower part of the cliff is steeply dipping Modelo shale, the darker band at the top is the horizontal alluvial capping of the Carpinteria formation.

It may not be difficult to reconcile the apparent conflict in the fossil evidence if the physical conditions of the area are considered. The environment of deposition for the Carpinteria formation was as follows:

Figure 7

Cross section of stream channel revealed in sea cliff east of tar pit. The largest boulder is four feet long.

1). The sea withdrew from the tar-pit area as a result of the elevation of the I terrace level. The former presence of sea water is indicated by the stratum containing the fossil mollusks which overlies the Modelo and underlies the Carpinteria formations.

2). Consequent streams, following much the same course as present day Carpinteria Creek, crossed the surface of the exposed sea floor. One well marked channel was cut across the plain, and later filled with flood deposits, decreasing in coarseness upwards.

3). The surface of the platform is covered with silt and sand deposited outside the stream channel by flood waters. This sediment is finest at the greatest distance from the stream course.

4). Tar seeps were active from the first deposition of Pleistocene sediments to the present day.

5). The plant remains are ubiquitous, the vertebrate fossils restricted. The plants were introduced from areas outside the site of their burial. The vertebrates were trapped and buried without transportation.

These seeps may have been replicas of those active on the north side of Sulphur Mountain and elsewhere in the Ventura region. These present-day oil seeps on the banks of many woodland streams trap rodents and birds today and may duplicate conditions at the Carpinteria brea pits in the Pleistocene.

<u>Summary:</u>

In the late Pleistocene the Carpinteria area was a gently sloping coastal plain with the shoreline nearly 2 miles south of its position today. The plain was covered with numerous small streams which flowed through well-defined channels. During the occasional floods the water rose until it overflowed the low banks and deposited a blanket of fine sediment over the surface of the plain.

The park-like vegetation consisted of copses of trees, concentrated near stream courses, and scattered through an open savannah country. The slopes of the higher inland ridges covered with low bushes, were comparatively barren. Near the coast, and in the fog belt, the trees were more closely spaced, with Pinus muricata, Pinus radiata, and Cupressus goveniana dominant, although Quercus agrifolia and related types were also present at a low altitude.

Tar seeps were scattered through the woodland, and trapped birds, rodents, and juvenile vertebrates. Occassional floods introduced plant material, and also buried the earlier fossil accumulation beneath a blanket of new sediment. This cover became saturated with tar in turn, and the process was repeated. Such a succession of events may explain the non-transported vertebrate remains occurring in the same pit with abraded and transported plant fossils.

The Age of the Carpinteria Fossils

The age ~~of~~ determination of the fossils in the Carpinteria formation is a matter of some interest. The assemblage is one of the most important horizons of the later Pleistocene, and a determination of its age relationship to the similar accumulations at Rancho la Brea and McKittrick is especially valuable.

The problem is made difficult from lack of knowledge of the rate of change in the processes that operated here. There is no method of measuring the length of time required by the sea to withdraw from the position of the tar pits of its former shoreline, or to cut inland to the present coastline.

The nature of the changes is readily determinable; it is their duration which is difficult to estimate. The sea covered the Carpinteria Plain at the time the mollusk-bearing strata accumulated. After this episode, the sea withdrew to a point 10,000-15,000 feet south of the present coastline on account of the uplift of the land.

This distance was estimated by projecting the present terrace surface until it intersects the surface of the sea. The estimate will be in error and should be increased if if the withdrawal of the sea was aided by the glacial lowering of the sea level. The return of sea level to approximately its present position in post-glacial times may have compensated for the greater seaward movement of the strandline.

The length of time required by the sea to cut inland from the late Pleistocene shoreline to the present position might be calculated from the formula cited by Vaughan [138]

(138) Vaughan, T. W., "Rate of seacliff recession on the property of the Scripps Institution of Oceanography at La Jolla, California," *Science*, n.s., Vol. 75, No. 1939, p. 250, Feb. 26, 1932.

for a similar cliffed coast. According to Vaughan the expression,

$$y = 138x^{-.635}$$

fitted the circumstances at La Jolla. Y is equal to the recession rate in inches per year and x is the cliff height. This expression was integrated by Dr. Samuel E. Urner, of the mathematics department of the Los Angeles Junior College, for a cliff height of 45 feet and a recession distance of 10,000 feet. It was found that T, or time in years was equal to:

$$T = \frac{10{,}000\ (45)^{1.635}}{45\ (1.635)\ (11.5)}$$

T= 5,963 years.

and that for a maximum value of 50 feet for the cliff height and 15,000 feet of recession;

$$T = \frac{15,000\ (50)^{1.635}}{50\ (1.635)\ \ (11.5)}$$

T= 9,544 years

These values are high compared to the U.S. Coast and Geodetic Survey tracings for this coast. In the interval of 64 years between 1869 and 1933 this shoreline shows an average recession of less than 30 feet, or under 6 inches per year. In this same interval the La Jolla Cliff would have receded at an average rate of 1 foot per year, or nearly 60 feet.

In short, the present knowledge of this coast is not sufficient to warrant submitting it to mathematical analysis. The time required for the recession to the present coastline may be of the order of magnitude of 20,000 years. The age of the Carpinteria fossils is in the neighborhood of 30,000 years if a further 10,000 years were required for the withdrawal of the sea from the tar pits to its late Pleistocene position. This places the fossils in the latter part of the Wisconsin glaciation. The amelioration of the climate in the early Recent may explain the disappearance of the colder climate forms. The relative abundance of Dipodomys may be attributed to the increase in aridity. The appearance of a dryer climate was heralded by a greater frequency of the semi-arid elements of the flora, and a consequent dimunition in the importance of the Monterey Peninsula types.

STRUCTURE

No discussion of physiography in the Ventura Region is complete unless the underlying geologic structure is taken into account. Most of the land forms developed in this area are surface reflections of the bedrock, and the type of structure formed in any portion of the area is largely conditioned by the type of rock.

The structural development of the area is of great interest, in its own right. This is a good region in which to test the various hypotheses of Coast Range Structure. The structures developed are of large size and often readily accessible for study. It is a critical area to determine from which direction the stress responsible for the formation of the structures in the area was applied.

An inspection of the structural map (Plate IV), wi shows an en echelon arrangement of the major axes in this area. Furthermore, these trend lines parallel the trace of the San Andreas fault west of Lebec.

Other significant features pointed out by Kerr and Schenck (139) for this area are summarized as follows:

---

(139) Kerr, Paul F. and Schenck, Hubert G., "Significance of the Matilija Overturn," Bull. Geol. Soc. of America, Vol. 39, pp. 1087-1102, Dec. 30, 1928.

" 1) The variation of the character of the deformation is greatly influenced by differences in the type of material deformed.

2) The individual structural features of the district are not continuous for great distances.

3) In general, the structural axes show an <u>en echelon</u> parallelism.

4) The axial planes of most of the overturned folds and many of the faults are not vertical, but dip to the north or northeast.

5) The major release of pressure on overthrust blocks is probably from inland toward the coast."

Several of these conclusions merit consideration before a detailed discussion of individual structures. The principal ones to be treated will be 1, 4, and 5.

1) The influence of the rock type on the type of deformation is one of the most noteworthy features of Coast Range geology, and is a problem which merits more study than it has received.

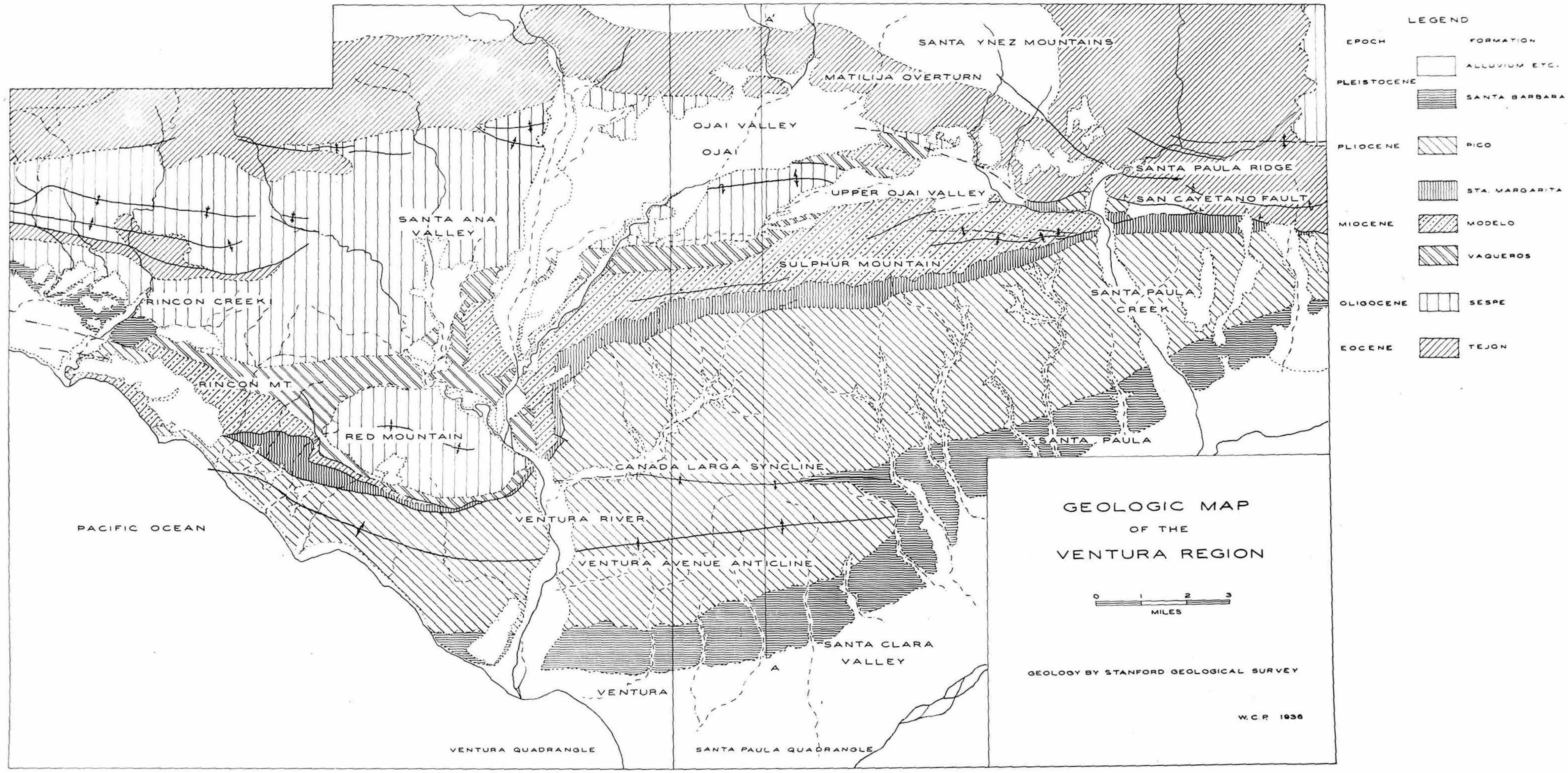
In this area of three major structural provinces, the relation between rock types and deformation is particularly clear: 1) The Santa Ynez Upland and the Ojai Valley, 2) the Sulphur Mountain Upland, and 3) the Coastal Hills. In the Santa Ynez Upland the resistant sandstones of the Tejon formation have served as bulwarks against the stress. For the most part, they have retained their form, unless subjected to severe pressure, and have served as a support for the incompetent shale intercalated between them.

The Santa Ynez type of structure developed in resistant sandstones, varied by incompetent shale, may be a broad open fold, like Topatopa Bluff, when the stress is moderate; an overturn, when it is more intense, like Matilija; or a thrust fault under severe pressure, like the San Cayetano fault. These structures are impressive in their uniformity when observed from a distance. Closer inspection reveals that this large scale simplicity was accomplished by a complex pattern of minor fractures within the framework of the larger structure.

The second structural type is the close folding of the Modelo Shales in the Sulphur Mountain Upland. In the areas where Miocene siliceous shales have been subjected to stress, a very characteristic type of structure is produced. That of Sulphur Mountain is quite simple, a south dipping homocline; but in detail it is extraordinarily complex--so

Plate IV

Geologic Map of the Ventura Region


LEGEND
EPOCH
FORMATION
PLEISTOCENE
ALLUVIUM ETC.
SANTA BARBARA
PLIOCENE
PICO
STA. MARGARITA
MIOCENE
MODELO
VAQUEROS
OLIGOCENE
SESPE
EOCENE
TEJON
SANTA YNEZ MOUNTAINS
MATILIJA OVERTURN
OJAI VALLEY
OJAI
A'
SANTA PAULA RIDGE
SAN CAYETANO FAULT
UPPER OJAI VALLEY
SULPHUR MOUNTAIN
SANTA ANA VALLEY
RINCON CREEK
SANTA PAULA CREEK
RINCON MT.
RED MOUNTAIN
SANTA PAULA
CANADA LARGA SYNCLINE
VENTURA RIVER
PACIFIC OCEAN
VENTURA AVENUE ANTICLINE
SANTA CLARA VALLEY
A
VENTURA
VENTURA QUADRANGLE
SANTA PAULA QUADRANGLE
GEOLOGIC MAP
OF THE
VENTURA REGION
0 1 2 3
MILES
GEOLOGY BY STANFORD GEOLOGICAL SURVEY
W.C.P. 1936

complex, in fact, that at first glance the rocks appear as if deformed by plastic flow.

The close-folding, fanfolds, overturns, and numerous minor structures are related to the thin,platy, fissile character of the siliceous shales. These shales are brittle, and it might at first appear difficult to flex them into such involved structures as they form. If they are observed closely, it will be seen that between most of the resistant shale members are thin partings of clay shale. These thin, earthly partings provide flexibility, and allow the siliceous shale laminae to glide past one another. The siliceous shale belt of the Sulphur Mountain Upland is an area of complex, strongly squeezed, local structures.

The third type of deformation is the simple structural type developed in the Coastal Hills. This area is underlain by a thick series of poorly indurated mudstones, clay shales, sandstones, and lenticular conglomerates. These rocks appear to be comparatively incompetent, so that drag folding and the development of minor structures comparable to those in the siliceous shales would be expectable. The broad, comparatively open folds in the Pleocene and Pleistocene strata of the Coastal Hills appear, therefore, as rather unexpected features. Although in many exposures these strata are vertical, practically no local corrugations are developed.

The Ventura Avenue Anticline, with a length of 25 miles and a breadth of 5, is a structure to be expected in an area of hard sandstones, competent enough to lift a load of 10-15,000 feet of sediment. Presumably, the reason for the appearance of so regular a structure in these rocks is related to their lithologic uniformity, and the moderate degree of pressure to which they were subjected.

5) The northward dip of the axial planes of the majority of faults and overthrusts in this area is particularly significant. The principal exceptions to this northward trend are those faults and axial planes which are vertical. This fact is interpreted by Kerr (140) as an

---

(140) op. cit., p. 1099

---

indication that the release of pressure responsible for the formation of these structures has been directed from inland to the coast. This statement, supported by field evidence, is expecially important, for it is in opposition to the generalizations of Willis (141), which call for a submarine

---

(141) Willis, Bailey, "A Study of the Santa Barbara Earthquake of June 29, 1925," Bull. Seismological Soc. of America, Vol. 15, No. 4, pp. 255-278, Dec. 1925.

______________, "Folding or Shearing, which?" American Assoc. of Petrol. Geol., Vol. II, No. 1, pp. 31-47, Jan., 1927.

______________, "Geotectonics of the Pacific," Proc. Third Pan Pacific Sci. Congress, Tokyo, 1926, Vol. 1, ppl 358-369, 1928

_______________, "Seismicity of California and Chile," idem., pp. 389-394, 1928.

---

thrust from the Pacific floor directed inland towards the coast.

6) This is somewhat untenable hypothesis as indicated by the evidence presented by Kerr. His most conclusive points are the northward dip of the structural axes, and the weak Pliocene and Pleistocene rocks nearest the coast which show the least amount of deformation. It would be difficult for a force directed from the Pacific inland not to cuase a great amount of severe deformation in these unconsolidated sediments. Especially is this true in the Ventura area, for the incompetent rocks would be forced against the more resistant sandstones of the Oligocene and Eocene deposits farther inland.

One of the most telling features in the structural development of this area is that the majority of structures were produced within a time interval of extremely short duration. As shown in the section on Stratigraphy, the majority of the formations exposed in this area are conformable. None of the cartographic units are separated by large angular discordance; and there has been nearly continuous deposition from the Eocene to the middle Pleistocene.

All the formations in the area are nearly conformable up to the close of San Pedro deposition, and the major diastrophism which affected them dates from the middle Pleistocene.

In the sections to follow the same system will be followed in discussing the individual structures that ~~was~~ is employed in describing the physiographic provinces. The reason for this approach is that the physiographic development of the area is intimately connected with problems of rock structure and erosional resistance.

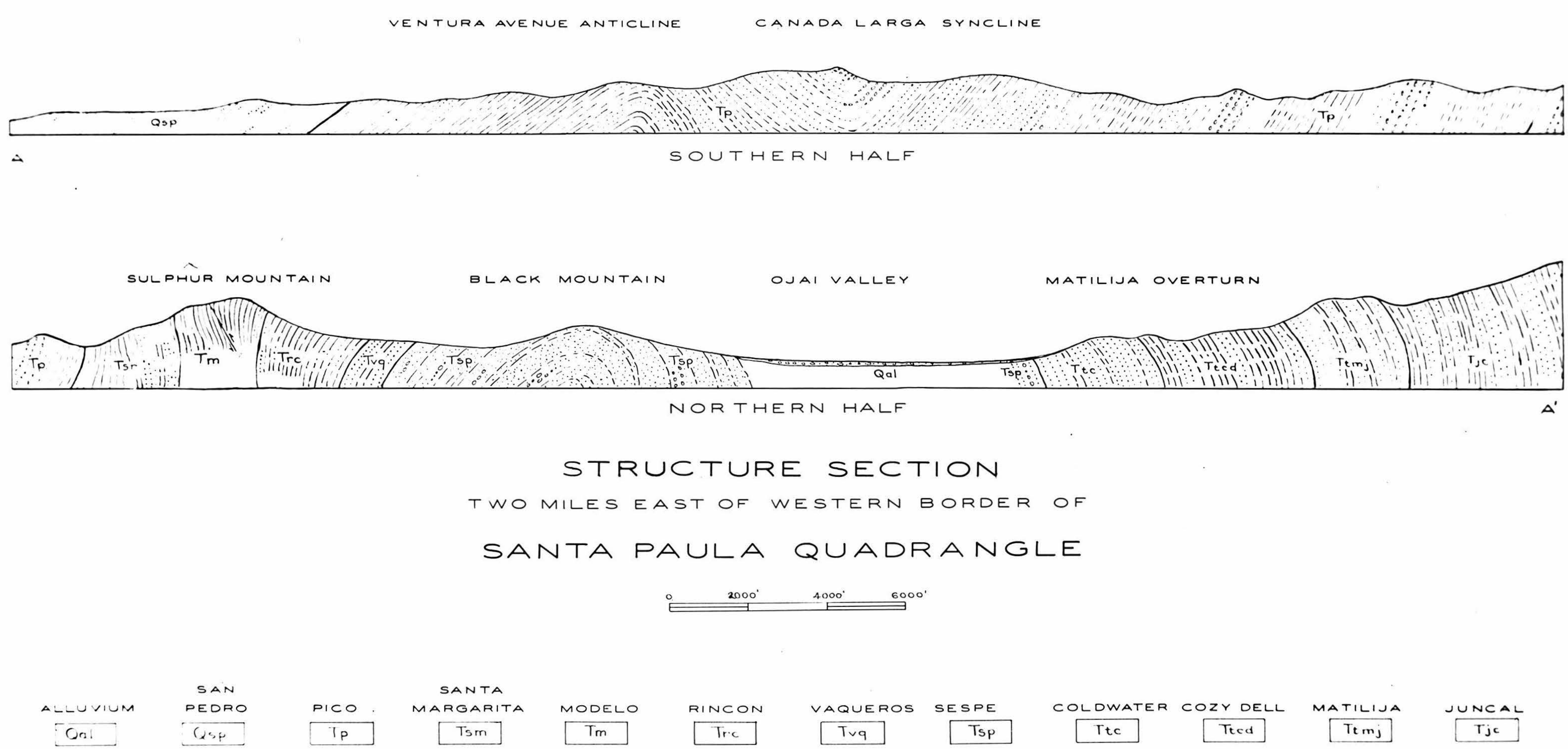
The Western Santa Ynez Mts. and the Matilija Overturn

It was early recognized that the Santa Ynez Range had an arched or anticlinal structure. This is an important factor in any interpretation of the later structural history of the southern part of the range. The tendency of this anticlinal structure to persist for over 40 miles, from north of Santa Barbara to beyond Sespe Creek, is remarkable when the intensity of deformation in this area is considered.

The fact that overturning has occurred was first appreciated by Arnold[142], who stated, "The great anti-

Plate V

Structure section two miles east of western border of Santa Paula Quadrangle



STRUCTURE SECTION

TWO MILES EAST OF WESTERN BORDER OF

SANTA PAULA QUADRANGLE

(142) Arnold, Ralph, "Geology and Oil Resources of the Summerland District, Santa Barbara County, Calif." U. S. Geol. Survey, Bull. 321, 1907.

cline of the Santa Ynez Range is believed to be the westward continuation of the overturned anticline which affects the rocks of the Topatopa Range north of the Ojai Valley, 15 miles east of the Summerland district."

In this area it is the overturned southern limb of the anticline which is of primary importance. Kerr and Schenck (143) show that this structure produces an inversion

(143) op. cit.

in the normal stratigraphic succession. Eocene beds apparently overly Oligocene and there is little question that it is essentially the overturned southern limb of a large anticline. Willis (144), however, was led astray by the stratigraphic reversal and considered the southern face of the Santa Ynez as a fault scarp.

(144) Willis, Bailey, "A Study of the Santa Barbara Earthquake of June 29, 1925," Bull. Seismological Soc. of America, Vol. 15, No. 4, pp. 255-278, Dec., 1925.

The strata exposed on the southern face of White Ledge Peak have a strong southern dip of 30-50 degrees.

From White Ledge Peak to Divide Peak the stratigraphic succession is normal until a point north of Santa Ana Creek is reached. At this critical point is an extensive sheer zone, and here the transition is accomplished from a normal to an overturned section. East of Santa Ana Creek to the base of Topatopa Bluff the Eocene and Oligocene strata show an inverted relationship and are the Matiluja Overturn. This fold occupies a total length of 15 miles and has an arcuate trend, convex to the north.

Wherever the strata involved in this structure are revealed in a deep gorge, their overturned relationship is clearly apparent. In the section visible along the walls of Gridley Canyon a single stratum of sandstone resembles a gigantic bow with its convex side pointed upstream, or to the North. Near the crest of the divide the dip is strongly north, halfway down the cliff, vertical, and near the canyon floor, to the South.

While the structure of the overturn is comparatively simple, it does contain within its framework a host of lesser complexities. This is particularly true of the shale portions of the formations involved, for the majority of them include a great number of isoclinal folds.

Probably one of the most unusual features of the Matilija Overturn is its structural swing in the area about

Matilija, which is shown on the Geologic map (Plate IV). All the strata involved in the fold make an almost right angle change in strike, from east-west to almost north-south, and then back again to east-west. As pointed out by Kerr and Schenck (145), this change in strike parallels a similar

(145) op. cit., p. 1095-1096.

but broader flexure in the San Andreas fault, 30 miles north, ~~is~~ the transition between the Matilija Overturn and the normal sequence of strata revealed in the face of Topatopa Bluff is an outstanding structural feature of the area. This relationship is shown in the block diagram by Paul F. Kerr, included in W. S. W. Kew's account of the area in the International Congress' Guidebook for Southern California (146).

(146) Kew, W. S. W. "Los Angeles to Santa Barbara", XVI International Geological Congress, Guidebook 15, Excursion C-1, pp. 48-68, Plate 14, 1932.

The apparently horizontal strata of Topatopa Bluff possess a quite pronounced south dip, steepest in the neighborhood of La Broche Canyon. Just before the canyon is reached, these strata in Topatopa Bluff are terminated by a fault. This fault separates the normal south dipping sequence of Topatopa Bluff from the north dipping overturned one to the west.

Most of the movement in the Matilija Overturn has taken place in the incompetent lower Eocene shale. West of

Topatopa Bluff these rocks succeeded in overturning the cover of less flexible Upper Eocene Sandstones. In Topatopa, and in the area to the east, the stress applied may have been no less, but the rigid cover surviving intact moved as a more brittle mass to the southward and made the San Cayetano Thrust.

The Eastern Santa Ynez Mts. and the San Cayetano Thrust

The area surrounding the gorges of Santa Paula Canyon, the East Fork of Santa Paula Creek, and Santa Paula Ridge retains the same large scale structural development as that of the western half of the range. For the most part the structures involved are simple in their larger aspect, but complicated in their details.

The principal structure of the area east of Topatopa Bluff is the southern limb of the Topatopa Anticline, flexed sharply down into the narrow Pine Canyon Syncline, and then as abruptly bent up to form Santa Paula Ridge and the San Cayetano Thrust. This large structure is diversified by a number of rather important faults and other minor complications, but in the main, the structure indicated above is dominant.

The Topatopa anticline, the central structure of the Santa Ynez Range, plunges eastward, and in this area is encircled by progressively younger strata. For example, the cliff of Topatopa is made of Matilija strata; a short distance east of its crest, the Cozy Dell shale member outcrops; behind it, the Coldwater; and overlying this sequence is the Sespe of the Bear Heaven Plateau. East of Sespe Creek the Vaqueros and Modelo overly the entire sequence where the fold finally dies out.

The southern limb of the anticline behind Topatopa increases in dip from 10 degrees near the crest to 25-30 degrees near the base of the exposed section. Along the axis the strata are essentially horizontal, and farther to the east form the high and uninhabited Bear Heaven Plateau overlooking the gorge of Sespe Creek.

The Pine Canyon syncline, mapped by Kew in the Piru Quadrangle, extends into this area as a narrow, steep sided fold whose axis nearly coincides with the present position of the East Fork. There has been normal faulting along its axis which increases in intensity as the disturbed area west of Echo Falls Canyon is approached. The synclinal axis does not extend beyond Santa Paula Canyon. The Coldwater anticline barely reaches the eastern border of the Santa Paula Quadrangle.

The San Cayetano Thrust and Related Structures

The San Cayetano fault, exposed near the base of the steep upper slope of Santa Paula Ridge, is possibly the most important single structural feature of the entire area. It has been traced far to the east of here by Kew (147), and

(147) Kew, W. S. W., "Geology and Oil Resources of a part of Los Angeles, and Ventura Counties, Calif." U.S. Geol. Survey Bull. 753, p. 100, 1924.

there is some reason to believe that a related fracture extends to the westward through the Ojai country into the region north of Ventura. Kew states for the eastward connections of this fault, "The San Cayetano-Santa Susana-Sierra Madre fault is one of the major structural features of the region, as it forms a distinct dividing line between two areas that are somewhat different both structurally and stratigraphically. . . . . . . West of Sespe Creek it is known as the San Cayetano Fault. East of the Santa Susana Mountains it extends along the south side of the San Gabriel Mountains, where it is called the Sierra Madre Fault. The faulting is of the reverse type--that is, the older beds are elevated relative to the younger beds and in some places are thrust over them. . . . . . . West of Sespe Creek the Eocene strata have been shoved over the lower Pliocene Pico formation."

The passage cited above points out the two salient features which deserve emphasis. 1) the great distance over which this zone of reverse faulting may be traced, and 2) the magnitude of the displacement involved. The second of these points is particularly well shown in the case of the San Cayetano fault between Santa Paula and Sespe Creeks. Here the quartzitic lower Eocene rocks which crop out on the upper part of Santa Paula Ridge overlie steeply tilted, overturned Pliocene clay shales. The Tertiary section present in this area between the Eocene and Pliocene has been hidden by displacement along this fault which is measurable in several tens of thousands of feet.

Furthermore, so severe has been the force exerted to accomplish this displacement that the soft, loosely consolidated Pliocene and Pleistocene sediments against which the thrust was directed have been overturned in the area between the Santa Clara River and the base of the steeper section of Santa Paula Ridge.

The surface reflection of the San Cayetano fault is a good example of the correlation between structure and physiography. The thoroughly indurated sandstones of the Matilija formation maintain a steeper slope than the Pico mudstones. The fault trace, along which the two formations are brought in contact, is marked by a pronounced and readily recognizable break in grade. It is visible for miles from the Santa Clara Valley, and is clearly apparent from South Mountain directly across the valley floor.

Near the western end of Santa Paula Ridge the structure is increasingly complex, and becomes more so at the extreme western end of the mountain, where it is separated from Sulphur Mountain by Santa Paula Creek. That a great deal of faulting has occurred is apparent, but the amount and nature have not been satisfactorily determined. The thick section of siliceous shales in the Modelo formation is cut out, Eocene rocks are carried across all the younger deposits, and in the midst of these older strata occurs a little inlier of Pico deposits in the vicinity of the Santa Paula Mineral Springs. There is good reason to believe that a branch of the San Cayetano fault continues through this area along the northern face of Sulphur Mountain across the Upper Ojai Valley, and eventually disappears beneath the Ojai Valley, at the base of Black Mountain.

It is displacement along this westward extension of the San Cayetano fault zone which Kew believes reponsible for the difference in elevation between the two Ojai Valleys (148).

---

(148) Kew, W. S. W., "Los Angeles and Santa Barbara," XVI International Geological Congress, Guidebook 15, p. 63, 1932.

The Ojai Lowland

The structural details of the Ojai Valley are obscrued by the veneer of alluvial fan deposits and valley fill covering the floor. Any interpretation of its true character must remain largely speculative. The northern border of the valley is the Matilija Overturn, and it is bounded on its southern rim by the Black Mountain anticline and related structures. In both these marginal structures the only rocks visible are the red sandstones of the Sespe. Except where they are overturned, these strata dip towards the axis of the valley. Even where overturning has taken place, there is evidence for believing that at depth this same convergent dip prevails. The structure of the valley is largely synclinal. There may or may not be a significant amount of faulting at depth, but no evidence is available for it. Doubtless, if a branch of the San Cayetano fault system continues through this physiographic province, there has been some displacement, but no conclusive surface reflection of it is visible between Black Mountain and the Santa Ana Valley. Some evidence for faulting is found in the Santa Ana Valley, and on his geologic sketch map Kew carries a branch of the Arroyo Parida fault of the Santa Barbara area as far east as the western Ojai Valley.

The Black Mountain anticline ~~is~~ developed in Sespe rocks, is crossed by the Ojai-Santa Paula highway, and the axis is at the summit of the Black Mountain grade. The fold is interesting on account of its physiographic expression, both flanks are almost perfect dip slopes, and becuase it stands as a barrier between the two Ojai Valleys. The fold is short, with a length of 3.5 miles, and extends between San Antonio Creek and a short distance east of the main highway. On its eastern end it is a normal fold, but in the western half it has been overturned far enough for Vacqueros strata to crop out at the base of the Lion Mt. grade.

The Sulphur--Rincon Mt. Arc.

No structural province within the region presents so great a degree of complexity as this area. The reason for its complexity is the incompetency of the siliceous shales, the principal rock type involved. The structures in this area trend across the Ventura and Santa Paula Quadrangles in an arc convex to the south, between Santa Paula Ridge, and the sea at Rincon Point. These structures have an almost east-west strike, but at the Ventura River they have a structural sinuousity paralleling the larger one in the Matilija Overturn. As a result of this flexure, the structural axes trend north-south along the Ventura River and do not resume their east-west trend until they reach Red Mountain.

The strata of Red Mountain, on the west side of the Ventura River, have been displaced a greater distance to the south than have the strata to the east. Also, it is the western half of the two segments that the evidence for thrust faulting is most clear.

In general, the structures developed in the Rincon, Red, and Silphur Mt. arc are related to thrust faulting and overturning. There are areas, however, along the southern face of Sulphur Mt., in which no evidence is available to indicate anything more than a normal, south-dipping homocline.

Sulphur Mountain

Some authors have considered this mountain a wedge squeezed up between faults which bound it to north and south. The evidence is poor, and the hypothesis has yet to be proved. The present altitude of the central ridge of Sulphur Mt. is adequately explained on the basis of the extra resistance of the Modelo shales over the Pico, and the strong south dip of the underlying rocks.

Faulting has occurred about the margins of Sulphur Mountain. The evidence is obvious in road-cuts along the Santa Paula-Mineral Springs highway. However, most of the visible faulting is confined to either the eastern or western extremities of the mountain.

At the eastern end a zone of thrusting, overturning and close-folding, is visible as far west as the head of Salt Marsh Canyon on the southern side of the mountain. On the northern side a fault system apparently extends up Big Canyon, and probably is related to the line of tar seeps as far east as the Santa Paula Mineral Springs.

From the head of Wheeler Canyon as far west as Hammond and Sulphur Canyons the strata are comparatively undisturbed. In fact, this is the area of gradational contacts between the Modelo and the Pico formations. Although there has been a good deal of overturning, the structure in the central part of Sulphur Mountain is a south-dipping homocline, with the Modelo shales overlying the Vaqueros to the north, and underlying the Pico to the south.

The large cliff-like exposure above Rocky Flats on the Ventura River shows that the western end of the mountain is fully as complex as the eastern. Here can be seen the contortions and close-folding which are typical of the Modelo shales when they have been subjected to stress. The pronounced southward swing in the strikes of the rocks here exposed points out that this has been an area of strong stress. This is the area along the Ventura River in which the sinuous structural trend occurs which is probably related to the Red Mt. anticline.

A fault marks the southern face of Sulphur Mountain in this area, and is presumed to be part of the Red Mountain thrust. It parallels Weldon Canyon, cuts through Sulphur Mountain, and according to Kew, continues across the Ventura River in the vicinity of La Crosse. It is a circumferential fault bounding the Red Mountain uplift.

Red Mountain

The rock structure of Red Mountain is an overturned anticline developed in the Sespe formation, and bounded to the south by a thrust fault. The anticlinal axis and the summit of the mountain do not coincide, and the axis of the fold lies a quarter of a mile to the north of the divide. The anticline merges on its southern flank with the Red Mountain Thrust.

This fault is a continuation of the zone of weakness extending from San Cayetano Mountain to the sea. In this particular instance, Oligocene and lower Miocene strata have been brought into contact with upper Miocene and Pliocene formations. The Red Mountain Thrust strikes WNW until it disappears beneath the Pacific near Punta Gorda. It is accompanied by a related group of branching fractures, one of which, the so-called Red-line fault, is marked by areas of burned Modelo oil-shale.

Rincon Mountain

Of the three mountainous areas in this province the structure of Rincon Mountain is the most obscure. It is underlain almost entirely by Modelo shale, although a broad band of Vaqueros and Rincon shale crops out along its northern slope. The 500 feet terrace on the southwestern corner of the mountain is cut in the Pico formation, and a small patch of Santa Barbara occupies a synclinal depression south of Rincon Creek and at about the same level as the higher two of the marine terraces.

Not only is the stratigraphy of the mountain complex, but the structure, where it is decipherable, shows a number of confusing relationships. There is a zone of faulting exposed in the sea cliff between Punta Gorda and Rincon Point, marked by burned oil shale. The Southern Pacific Rail Road has had some difficulty in subduing the fire which is still burning at the spot known as El Azurre. This fault zone is supposedly related to the Red Mountain system of thrusts.

Another shear zone extends up the small canyon shown on the Ventura Quadrangle immediately north of the first N of El Rincon. This is related to the fault which has produced the recent scarp that interrupts the surface of the Carpinteria Plain. Another somewhat related fault may parallel this larger one in the next canyon to the south, or towards the coast. These faults are important for having disturbed the surface of the Carpinteria terrace.

The Coastal Hills and The Ventura Ave. Anticline.

In contrast to the Sulphur-Rincon Mt. area, the Coastal Hills have a simpler structure. Over broad areas the outcropping strata show a uniform inclination. The folds that are present are open, persist for long distances, and show few complications. There are exceptions to this general simplicity, chiefly in the area to the west of the Ventura River, and to the east of Santa Paula Creek. In both these areas the Pliocene section is bounded to the north by a zone of intense thrusting. As a result the Pico has been overturned or closely folded.

The strata in the area east of Santa Paula Creek are inverted as a result of the southward thrust delivered by the force responsible for the San Cayetano Fault. They present the anomolous appearance of dipping away from the synclinal trough of the Santa Clara Valley, as well as outcropping in a reversed sequence. Pliocene deposits in this case overlie Pleistocene. In the section revealed by the undercutting of Santa Paula Creek, immediately east of Santa Paula, the Pleistocene strata are in normal succession with a south dip of 70 degrees. North of Santa Paula the

Pico strata are vertical, and in the vicinity of Mud Creek Canyon they are overturned to the north.

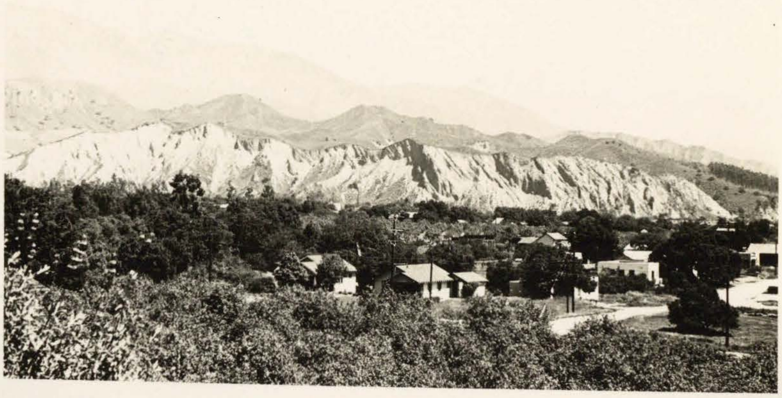


Figure 8

South dipping section of Pleistocene strata undercut by Santa Paula Creek.

West of Santa Paula Creek, and between it and Aliso Canyon, is the most uniform area in the entire region. This part of the Coastal Hills is underlain by a nearly complete Pliocene section, and has been described by Driver (149).

(149) Driver, H. L., "Foraminiferal Section along Adams Canyon, Ventura Co., California," Bull. Amer. Assoc. of Petrol Geol., Vol. 12, No. 7, pp. 753-756, 1928

There is no folding, and the faulting that has occurred is of little significance. All the strata have a south dip towards the Santa Clara Valley. The amount of inclination increases toward Sulphur Mountain, until along its southern front some of the strata are overturned. Near the mouth of Adams Canyon the amount of inclination is 30 degrees, midway it increases to 55 degrees, and at the base of Sulphur Mountain is as much as 80 degrees, and occasionally is overturned to the north.

The Ventura Avenue Anticline

West of Aliso Creek the Pliocene strata show an increase in structural complexity. Here they are warped upwards to form the Ventura Ave. Anticline and downwards between its crest and Sulphur Mt. to make the Canada Larga Syncline. Of these two folds the anticline is of much greater importance because of its greater extent.

The anticline has a length along its axis of 25 miles, between the point where it disappears beneath the

Pacific at Sea Cliff and its eastern terminus at Peppertree Canyon. Over most of the area crossed by this fold it forms a readily recognizable feature, especially in the area where its axis is crossed by the Ventura River. On either side of the oil field, strata may be seen dipping in opposition, but on the axis of the fold itself they lie flat.

The structure is assymetrical, with the more gentle dip to the south, the steeper to the north, especially in the areas where the Canada Larga syncline is absent. The broadest portion of the fold is 5 miles wide in the area crossed by the Ventura River. It narrows, and becomes correspondingly steeper west of the river.

As a rule, strata exposed along the flanks strike parallel to the axis of the structure, and there is not much evidence on the surface of convergence. The eastward plunge is clearly expressed by the swing of the Pliocene strata around the east nose. This is shown, on the geologic map (Plate IV), by the Pico-San Pedro contact, and is so pronounced that it finds expression on the topographic map in the deflected course of Peppertree, Harmon, Lake, and Sexton canyons. In the field this structural curvature is made visible by cuestas in which a few of the resistant beds in the Pico stand up to form crescent-shaped ridges which circumscribe the axis at the eastern end.

The fold is narrow and steeply inclined. The dips on its flanks average 35-45 degrees, and locally may be as great as 50-60 degrees. The attitudes of the strata are much the same at depth as at the surface, and they are now known to a depth of ~~nearly~~ two miles through deep drilling in the Ventura Ave. oil field.

When the incompetent nature of the Pico shales is considered, the extraordinary feature of this structure is its uniformity. It is all the more remarkable when the varying degree of stress to which these strata have been subjected is taken into consideration. These forces have been intense in the area west of the Ventura River, and only moderate to the south of Sulphur Mt., and yet the trend of the axis is scarcely deflected. The deviation that it does show is toward the area of most intense deformation.

The Canada Larga Syncline

This lesser fold parallel to the Ventura Ave. Anticline lies between it and Sulphur Mt., and extends from Aliso Canyon to the western border of the Canada Larga or Verde Rancho. The total length is 6.5 miles. It is a rather distinctive feature in the area east of the Ventura River and south of Sulphur Mt., The eastern end is more apparent than the western, as may be seen from the geologic map.

Since the plunge is eastward, a long tongue of the San Pedro extends a considerable distance along the axis where it has been pinched in the fold. To the west the structure ends abruptly at the Ventura River, and no counterpart is visible on the west bank, as in the case of the anticline. The fold has been cut off by the fault system which extends up Weldon Canyon.

In the San Miguelito area, west of the Ventura River, the Coastal Hills structures are more difficult to interpret. The reason is the close approach of the Red Mountain thrust. Much of the force transmitted along it found an escape through the development of a host of minor structures in the Pico formation. This fault did not respect stratigraphic boundaries in like degree to that of the San Cayetano system.

In spite of the surrounding complex structure, the Ventura Ave. anticline has succeeded in maintaining its identity. It is faulted to some degree, as is apparent in the cross-section revealed in the amphitheater, and there have been a number of lesser domes and saddles developed along its axis. Among the most important domed areas are the Rincon, Javon, and San Miguelito fields.

The intricate nature of the structure increases westward and reaches its maximum between Sea Cliff and Punta Gorda, well revealed in the sections in Madranio and Los Sauces Canyons. This intense deformation has produced some surface expression in the development of a series of undrained depressions, wedge-shaped slivers, and a number of slumps and landslides.

The Santa Clara Valley

Although there is a large store of information concerning the structure of the Santa Clara Valley, little of it is accessible. For the most part, the structure of the valley, bounded on its southern margin by the Oak Ridge-South Mountain fault, is synclinal. The isolated, mound-like ridges in the western part, near Montalvo, are indications of recent deformation. There is some evidence of a few structural highs at depth, and a number of steep tests have been drilled in the area adjoining the delta region of the Santa Clara River.

Conclusion

Some points, relating to the structural development of the Ventura Area, worthy of special emphasis are:

1) The extreme recency of the deformation and its continuance in parts of the area at the present time.

2) All the important structures in the area were developed in a diastrophic episode occurring in the middle Pleistocene.

3) The stress responsible for the compression was applied from inland towards the coast.

4) Variations in the direction of the San Andreas Fault find here a reflection in the trend of structural axes.

5) There are two zones of reverse faulting and overturning, a) the San Cayetano-Matilija Overturn system along the northern border, and b) the Red Mountain thrust through the central portion.

6) There exists a parallel alignment between structural axes and the surface distribution of the various formations.

7) The character of deformation is controlled to a large extent by rock types, illustrated by the Matilija overturn in the Tejon, the close folding of the Modelo, and the Ventura Ave. Anticline in

the Pico.

8) For the most part, folding is more important than faulting.

9) None of the structures continue for a length of more than 25 miles without either changing in character, or disappearing.

10) The relationship between the structural and physiographic history is particularly close. In fact, no adequate interpretation of the physiography is possible without an understanding of the structural foundation upon which it rests.

REGIONAL PHYSIOGRAPHY

Physiographic Types of the Ventura Region

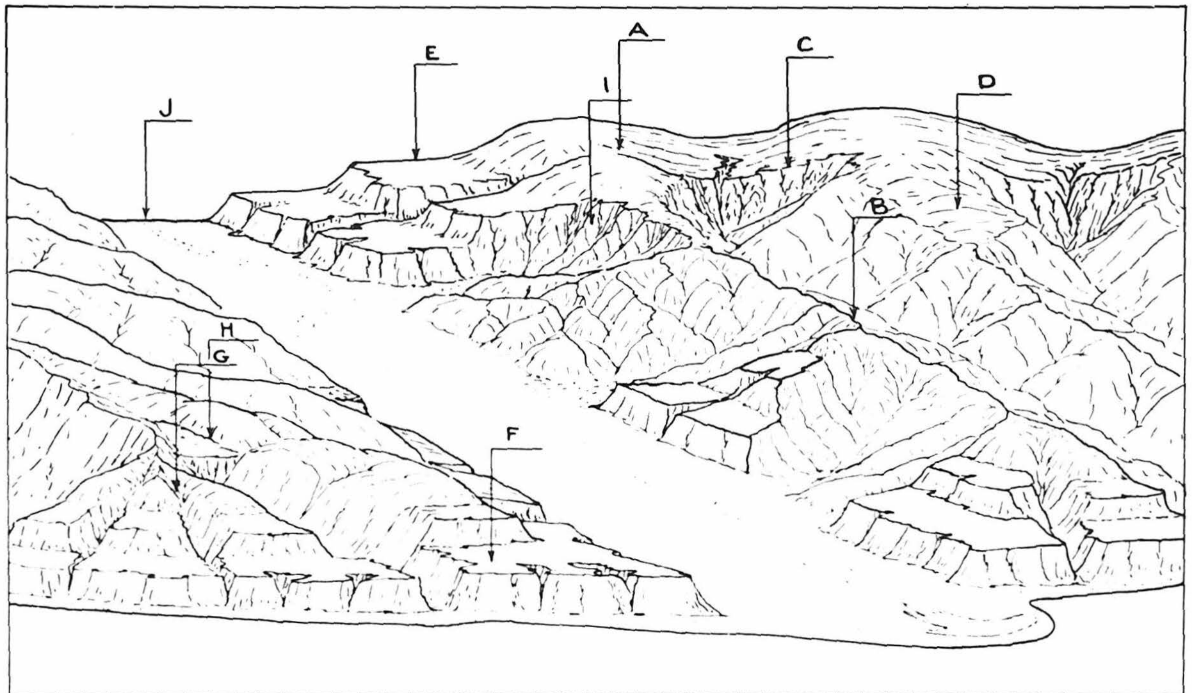
The diagram, accompanying this section, of a hypothetical landscape was prepared to show the typical physiographic features of the coastal part of the Ventura Region. This area is underlain by deformed sedimentary rocks of moderate resistance; exposed to the atmospheric attack of a semi-arid, mesothermal climate. The region had reached the stage of late maturity in an earlier erosion cycle, was rejuvenated as a consequence of intermittent regional uplift, and is now in the stage of late youth in the second cycle.

The imaginary area, combining most of the features of the Ventura Region, includes a large stream valley and a short strip of coastline. Most of the land surface is hilly, and the shorter tributary streams have a steep gradient and an intermittent flow. Both the larger stream valley and the coastline are terraced as a result of a pulsatory uplift. The typical characteristics of the area are discussed in the order indicated below the diagram.

A) Upland areas, underlain by resistant rocks have preserved with little modification, the late mature

Plate VI

Phsyiographic Types of the Ventura Region



PHYSIOGRAPHIC TYPES OF THE VENTURA REGION

A. Old erosion surface preserved on resistant rocks.
B. Accordant summits preserved on weaker rocks.
C. ~~Pseudo~~ scarp developed by differential erosion.
D. Remnant of old erosion surface preserved on weaker rocks.
E. River terraces.
F. Marine terraces.
G. Stream, more mature in upper part of course than lower.
H. Terrace, remnant of broad valley stage.
I. Amphitheater valley.
J. Present river valley.

W.P.

ridges of the Coastal Hills are examples of this category.

C) A distinct excarpment forms at the contact between erosional resistant and non-resistant formations. This steep face starts as the result of the more rapid downcutting of stream channels through the non-resistant area. The stream gradient soon becomes discordant, and the portion of the stream channel that crosses the resistant area is left hanging.

Subsequent tributaries develop at the base of the escarpment, and work outward from the master consequent in both directions. The divide may eventually be consumed by the subsequent tributary streams, and leave an escarpment to mark the contact between the two rock units. This cliff may become so pronounced a feature that it may be described as a fault scarp. This is true of the south face of Sulphur Mountain.

D) If the sapping action of the subsequent streams has not gone to completion, a remnant of the initial surface may survive across the contact between the resistant and non-resistant rocks. Then a small island-like remnant of the initial surface is preserved temporarily in the belt of weak rocks. As a rule it is encircled by steep slopes, and its destruction is an imminent event.

Such a residual of the first cycle surface crossing the contact scarp is one of the best physiographic arguments against the presence of a fault scarp. A good example of this variety of ridge crest is found between Hammond and Aliso Canyons, and on both sides of Canada de Aliso on the south side of Sulphur Mountain.

E) The sides of the larger stream valleys are interrupted by a number of step-like terraces. These were cut during the periods of still-stand in the intermittent uplift of the area. Besides indicating a regional uplift, they often, since they are frequently tilted, show a local warping. The terraces of the Ventura River fit in this classification.

F) Marine terraces found on the coastline, have an origin similar to the river terraces. Their elevation of more than 1000 feet probably precludes an eustatic shift of sea level as the reason for their existence. Warping has deformed them in a fashion similar to the river terraces. They have an erratic distribution, are lacking in rocks of great or slight erosional resistance, and are well preserved in rocks of moderate strength. These terraces are well developed on Rincon Mountain. At the mouth of the Ventura River they grade into the river series.

G) Streams crossing a series of terraces are more mature in their upper courses than their lower since they have been exposed a longer time to sub-aerial erosion.

H) In the upper section of many of the larger coastal streams, flat-floored remnants of the broad valleys of the first cycle may still survive, although the lower section of the old valley has been consumed in its rejuvenation. An excellent example of this variety of terrace is at the head of Padre Juan Canyon.

I) Amphitheater valleys have been cut in many places in the belt of non-resistant rocks. They are large-scale examples of the destruction of a graded surface by the headward erosion of a stream system with a steeper gradient.

J) The larger stream valleys in the semi-arid climate of the Ventura Region depart from the traditional V-shaped profile. The narrow flood plain is bordered by steep often nearly vertical, slopes. The flat valley floor, produced by lateral planation, is underlain by a thick

50-60 foot deposit of gravel through which most of the water percolates. As a result the braided, shifting channel is dry throughout most of the year, and is filled only during occasional rainstorms, or at oases where bedrock rises close to the surface. The Ventura River is a stream of this type.

THE SANTA YNEZ MOUNTAINS

The section of the Santa Ynez Mountains described in this paper includes only a small part of the most important of the Transverse Ranges. The Santa Ynez Mountains were early recognized to be a great, and comparatively open, anticline. The section in the Ventura Area is the southern limb of the fold, but has yielded to deformation to such an extent that it has been overturned in the Matilija Overturn. The influence of the underlying geologic structure on the physiographic form of this mountain range is important.

In the western part of the area, from White Ledge Peak to the coast, the succession of strata is normal with a steep southerly dip. From White Ledge Peak to Sisar Canyon the strata are overturned in the Matilija Overturn, and from Topatopa Bluff to Santa Paula Ridge the succession is again normal. The strata are flexed sharply downward in a narrow syncline behind Santa Paula Ridge. The Santa Ynez mountains swing in an arc across the northern third of the area, and are broadest at the eastern and western margins (7.5 and 6 miles), and narrowest in the center (2.5 miles).

The highest elevations are near the areas of most intense deformation in the range. The greatest height, 6351 feet on the summit of Topatopa Bluff, occurs at the sharp break between the overturned rocks in the central part of the area and the normal series to the east. Santa Paula Peak (4959 feet) is above the San Cayetano Fault, and White Ledge Peak (4615 feet) stands west of the shear zone forming the western boundary of the Matilija Overturn.

The even altitude of the summit ridges of these mountains is a noteworthy feature in the range. The uniform elevation of the divide north of the Ojai Valley extending from Nordhoff Peak to Topatopa Bluff is shown in the accompanying panorama ( ). Many of the higher ridges preserve remnants of an erosion surface on their summits, expecially the plateau extending eastward behind Topatopa Bluff, around the canyon of Santa Paula Creek, and culminating above the Sespe Gorge.

This summit erosion surface of the Santa Ynez Mountains is unique, when the intensity, as well as recency, of deformation are considered. In no other area in the district have the rocks been deformed to a like extent. It is difficult to determine: 1) how erosion produced in a short period, so uniform a surface over this highly disturbed area, 2) what became of the quantity of detritus supplied by the stripping and, 3) is the erosion surface on the summit of the Santa Ynez Mountains the same as the Rincon Surface of Sulphur, Red, and Rincon Mountains?

(1) The restoration of folded structures cannot give an estimate of the height of a mountain range in its first cycle. Erosion lags but slightly behind deformation and it is possible that a mountain range in its first cycle may be quite unimpressive. An example of this process of simultaneous deformation and degradation is the series of low anticlines folded during the late Pleistocene and early Recent along the western margin of the San Joaquin Valley. As Woodring has shown, the Elk Hills are very recent and are still growing. The hills now rise only 1800 feet, and yet the top 900 feet of the underlying strata have been removed.

In the Santa Ynez Mountains the rocks are more indurated than the barely consolidated Pleistocene sediments of the Elk Hills. Not only are these rocks harder, but the degree of deformation they have suffered is greater. At the close of the mid-Pleistocene period of diastrophism the Santa Ynez area may have been a region of pronounced relief, even if not so great as a projection of the truncated structures in these mountains would call for.

The relation of deformation in the Santa Ynez Mountains to the structural development of the area to the south is vital, and not yet completely solved. Kerr and Schenck show that the force responsible for the formation of structures in the Ventura region came from the north.

This diastrophism may have been progressive. It decreased in intensity from north to south, and had its inception in the Santa Ynez Range some time before its effect was felt in the Coastal Hills. One reason for this belief is the sudden increase in coarseness of the boulders and gravels of the San Pedro formation. This points to a steepened gradient in the streams supplying sediment to the restricted seaway of the early Pleistocene.

(2) The second point, is the removal of the large amount of debris supplied by the rising Santa Ynez Mountains. Some of this material may be in the 4000 feet of the San Pedro formation. Since these rocks stand at angles as great as 45°, and are overturned east of Santa Paula, the great mass of material swept off the Santa Ynez Mountains lies buried elsewhere.

The quantity of gravels in the terraces along Santa Paula Creek and the Ventura River is insignificant.

The depth of sediment on the floor of the Ojai Valley may be slight. Very little gravel or recent sediment exists in other parts of the area; all the Coastal Hills, for example, are erosion surfaces. The material was removed during the period when the Rincon Surface was forming and most of the work was accomplished before the present drainage system developed. The Ventura River by itself is unable to dispose of more than a fraction of this detritus.

(3) The last important problem in the physiographic development of the Santa Ynez Mountains is the relation between its erosion surface and that developed on the summits of Rincon, Red, and Sulphur Mountains. The relationship between these two surfaces is indicated by the three profiles in the diagram below: Profile B is west of Topatopa Bluff, and Profile C crosses the summit of Santa Paula Ridge.

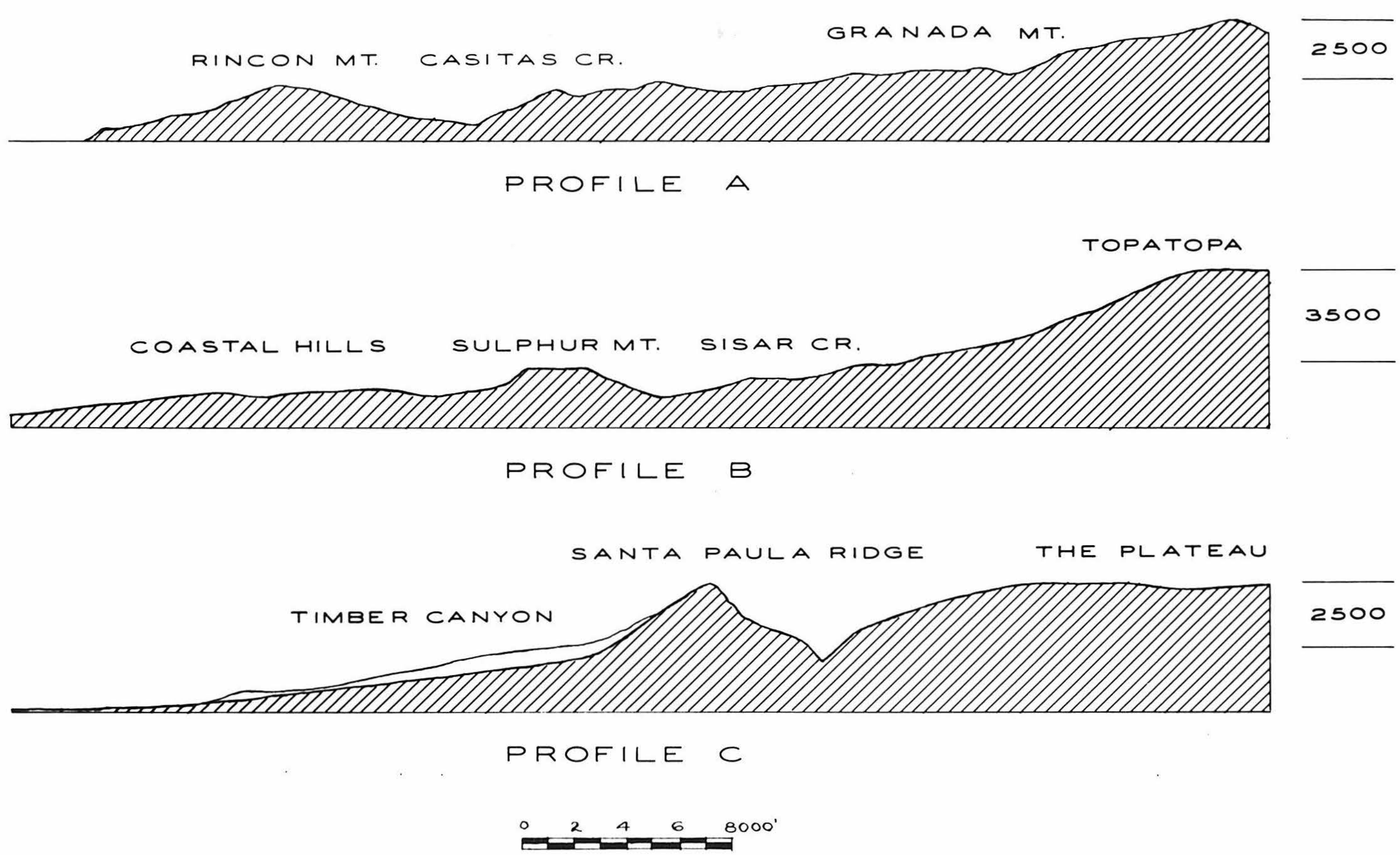
These profiles show the distinct break, along the southern front of the Santa Ynez Mountains, that separates their summit upland from the lower Rincon Surface. The Rincon Surface stands at an elevation of 2500 feet, and the summits of the Santa Ynez are 2000 to 2500 feet above it. The break is most pronounced at the foot of Santa Paula Peak where diastrophism has been active into recent times. The amount of separation decreases westward, after reaching its maximum at Toptopa Bluff, but is still distinct in the

Plate VII

Profiles showing relationships of Rincon and

Santa Ynez Surfaces

PROFILES SHOWING RELATIONSHIP OF RINCON AND SANTA YNEZ SURFACES



mountainous country west of the Ojai Valley.

The two surfaces are independent, and will be treated separately. The term "Rincon Surface" is restricted to the late mature surface in the southern part of the area, and the term Santa Ynez Surface, is applied to the accordant summits of the upper part of the Santa Ynez Mountains. Its characteristics are described in the section following.

The Santa Ynez Surface

This erosion surface has been developed on an area underlain by rocks of widely diverse natures and degrees of deformation. Over most of the area this surface has been destroyed. Only the summits of the higher, roughly parallel ridges preserve remnants of its former wide extent.

The important facts about the Santa Ynez Surface are:

(1) Its present considerable elevation, 5000 to over 7000 feet.

(2) Its widespread extent; remnants of it exist throughout most of the central part of the range.

(3) It was a surface of maturity when its cycle of erosion ended, and possessed a moderately strong relief.

It was not a peneplain.

(4) Although developed in the same general interval of time, it is an older surface then the Rincon, and exists independently in this area.

In the following sections, the characteristics of this surface are described in detail for three areas: 1) west of the Ventura River, 2) north of the Ojai Valley, 3) east of Topatopa Bluff.

West of the Ventura River

Little of the Santa Ynez Surface in this section has been preserved. The one important surviving ridge extends from Noon Peak to the Ventura River with a continuous length of 25 miles in the Ventura and Santa Barbara Quadrangles. This continuous crest maintains an average elevation of 3500 feet and reaches a maximum height of 4867 feet. There is no significant break from its elevation of 1500 feet above the Ventura River until La Cumbre Peak north of Santa Barbara is reached. Through most of its length it is a strike ridge developed in Eocene rocks with a nearly vertical, and occasionally overturned south dip. It is ravined by steep-walled canyons cut by a number of parallel, consequent streams. Some of these intermittent streams drop 2000 feet in the first mile. The fact that their canyons are deeper on the southern side of the range is probably due to the greater amount of rainfall on the seaward side of the mountains combined with a steeper gradient.

As a result of this vigorous attack, little trace of the Santa Ynez Surface survives. It is indicated by the uniform elevation of most of the higher peaks along the ridge. The only portions of the surface preserved as recognizable remnants are the two patches north of Divide Peak and White Ledge Peak. The maximum width is 0.2 miles and is less in most cases.

From the crest of the divide the slope down the ridge to the present canyon of the Ventura River is gradual. Near Ojai the Ventura River Canyon is a "two-story" valley. Its upper slopes are gentle, and widen into a mature V-shaped profile. Below an altitude of 2000 to 5000 feet the canyon slopes steeply into the narrow gorge of the rejuvenated Ventura River. This change in gradient of the valley walls occurs at the same level as the Rincon Surface, and is 2000 to 2500 feet below the average elevation of the Santa Ynez Surface.

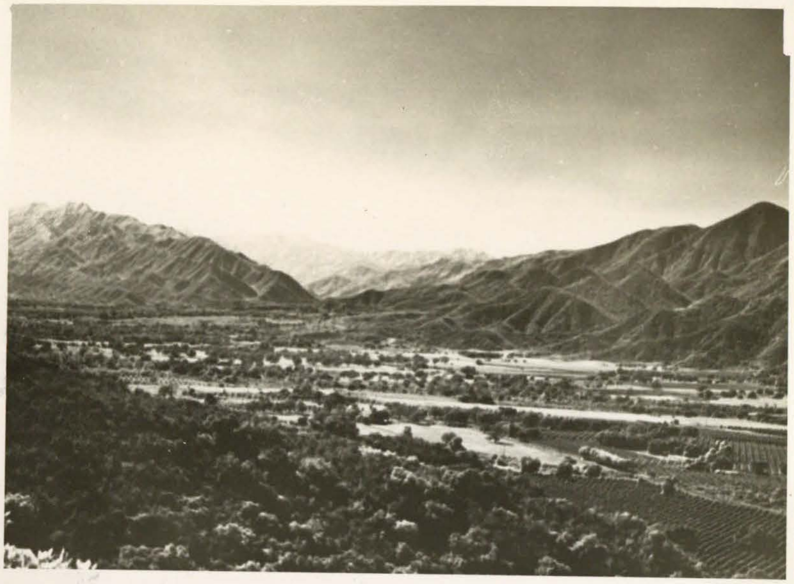


Figure 9

Western end of Ojai Valley and Canyon of Ventura River. The sharp ridges on the west side of the river are underlain by the steeply dipping strata of the Matilija Overturn.

The relationship between the Santa Ynez and the Rincon Surfaces in the area west of the Santa Ana Valley is particularly critical. Nowhere else do they approach one another so closely, and nowhere else is the structural foundation so undisturbed. North of Casitas Pass and south of the main Santa Ynez Mountains, both the Eocene and

Oligocene rocks exposed have a homoclinal south dip, and most of the parallel ridges are cuestas. They are steeper on the northern than on the southern slope. This is true of White Ledge Peak, Chismahoo Mountain, and the 2500 foot ridge east of the latter.

The abrupt declivity separating the two surfaces on the southern face of the Santa Ynez Mountains is a modified dip slope and follows the contact between the Sespe and Tejon formations. That the break between the two erosion levels is not due entirely to the relative erosional resistance of these rocks, is shown by the equal reduction of both to a common altitude where they crop out in the Snowball anticline.

North of the Ojai Valley

The western border of this part of the Santa Ynez Range is the steep canyon of the Ventura River, and the eastern is the escarpment of Topatopa Bluff. The Matilija Overturn reaches its maximum development directly north of the Ojai Valley. All the strata are overturned and dip back into the range in inverted order, with Oligocene strata exposed at the base and Eocene on the summit. The elevations of the main divide are remarkably uniform. The ridge connecting Nordhoff Peak with Topatopa Bluff appears in profile as a horizontal line.

The temnants of the Santa Ynez Surface are more numerous and recognizable east of the Ventura River. The summits of most of the principal divides stand at accordant elevations and preserve the appe.rance of maturity in their gently sloping summits. The south trending spurs in this area gradually decrease in elevation until an altitude of 3000 feet is reached. From here to the floor of the Ojai Valley the slope is precipitous.

This transition from the summit upland to the steep escarpment overlooking the Ojai Valley is sharp, and is clearly descernible from an vantage point to the south. Above the line of demarcation, broad surface areas are preserved at the heads of most of the principal valleys, while below, the slopes increase in steepness.

The break separating the area of the Santa Ynez Mountains north of the Ojai Valley from the portion lying east of Topatopa Bluff is one of the most significant in the Ventura Region. On the physiographic map (Plate VIII) the surface contours west of this break are not continued beyond the crest of the ridge immediately east of Sisar Creek. This break is related to the Sisar Fault, one of the important structures in the region. It separates the overturned limb of the Santa Ynez Anticline from the normal southern limb visible in the cliff of Topatopa. It may be that the difference in elevation of the Santa Ynez Surface on opposite sides of the Sisar fault is due to vertical movement along the Sisar fault in which the eastern side has been upthrown.

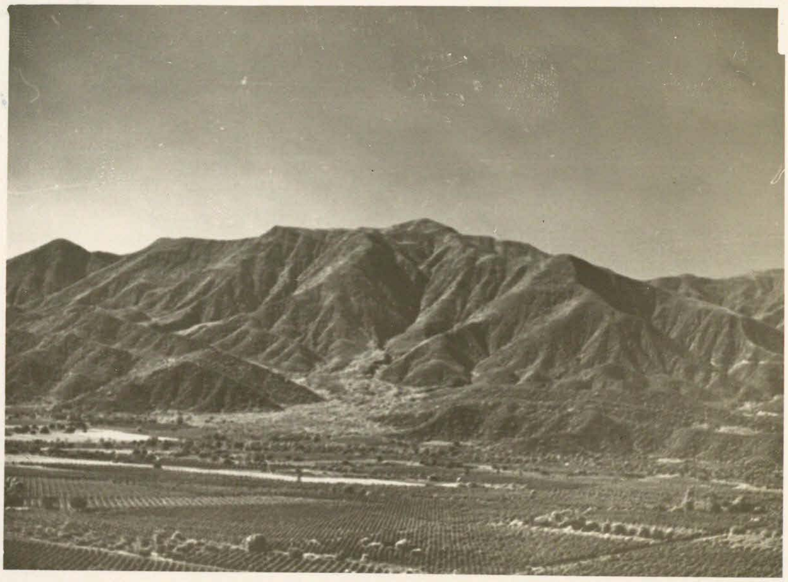


Figure 10

North side of Ojai Valley. Sulphur Springs fan in middle distance. Nordhoff Peak in background.

That there has been some vertical displacement is likely, but none of this magnitude has occurred since the

Santa Ynez erosion cycle was concluded.

The sharp break in the continuity of the erosion surface is due to differential erosion, controlled by structural differences on opposite sides of the Sisar fault. The sharply flexed and incompetent strata of the Matilija Overturn, since their broken edges are bared, are exposed to rapid erosional attack. The gently dipping series of massive sandstones and shales east of Topatopa Ridge form a broad arch, whose surface is not readily breached.

East of Topatopa Bluff

In no other part of the Ventura Region is the control exercised by the geologic structure over the development of land forms more clearly apparent than in the northeastern area. The plateau along the northern border of the Santa Paula Quadrangle is underlain by massive Eocene and Oligocene strata. These are bent sharply downward in the narrow Pine Canyon Syncline, whose axis almost coincides with the East Fork of Santa Paula Creek and then are flexed upward again in Santa Paula Ridge.

The plateau surface extending into the Piru Quadrangle stands at an altitude of nearly 5000 feet, and is well described by W. S. W. Kew[150]. It is a flat and

(150) W. S. W. Kew, "Geology and Oil Resources of a part of Los Angeles and Ventura Counties, California"U. S. Geological Survey, Bull. 753, pp. 30-32, 1924.

desolate region, covered with dense brush. The preservation of this plateau is due to the nearly flat lying strata of its foundation. Where these have been sharply downwarped, as in the case of the Pine Canyon Syncline, their erosive resistance is largely imparied, and the amphitheater-like valley of the East Fork, excavated 2000 feet below the plateau surface, now forms a broad embayment extending back into the plateau.

The type of stream erosion active here ressembles that described for the Kaiparowits Region in Utah by Gregory and Moore.[151] Large sections of the interstream areas are unaffected by erosion. The stream courses are widely spaced, lack tributaries and cut narrow, steep-sided gorges, deeper than they are broad. Where erosion has operated for some time, the flat-lying, sedimentary rocks exposed in the valley walls have receded with vertical cliffs occas$ionally interrupted by cirque-like coves

(151) Herbert Gregory and Raymond C. Moore, "The Kaiparowits Region, a Geographic and Geologic Reconnaissance of Parts of Utah and Arizona," U.S. Geological Survey Professional Paper 164, 1931.

The narrow Santa Paula Ridge stands at the same altitude as the high plateau shown on Profile B.

The benches on both sides of the narrow inner gorge of the East Fork are aligmed with the Rincon Surface on the Timber Canyon side, of Santa Paula Ridge is 2250 feet above the upper limit of the Rincon Surface. The steepness of the southern slope of the ridge as well as its elevation are due to movement along the San Cayetano fault. This is illustrated by the faulted alluvial fans at the head of the canyon east of Timber Canyon.

Although Santa Paula Ridge is narrow, its uniform elevation and the sharp break in gradient between its summit and the lower slopes of the tributary ridges indicate that it is part of the Santa Ynez Surface. Its former maturity is shown by the little valley with gently sloping sides and slight gradient which flows southward from Santa Paula Ridge. This valley runs along the crest of one of the narrowest subsidary ridges, formed in the latest cycle of erosion, and is terminated abruptly in space. The water flows through its shortlived course and plunges over the brink in a long cascade to the floor of the newer canyon now destroying the old.

The existence of the Santa Ynez Surface is shown by more than the apparent accordance of the higher ridge summits. As pointed out by Daly (152) and Buwalda (153)

(152) R. A. Daly, "The accordance of summit levels among alpine mountains," Jour. of Geol. Vol. 13, pp. 105-125, 1905.

(153) J. P. Buwalda, "Even-crested ridges as evidences of peneplanation," Bull. Geol. Soc. of America, Vol. 35, no. 1, p. 167, 1924.

even-crested ridges, taken by themselves, do not prove the existence of an uplifted erosion surface. Such accordance may be achieved by other means; for example, the reduction of the higher elevations of a ridge crest at a more rapid rate than the lower, or the protection of weaker belts of rock by stronger "boundary formations".

The evidence for the presence of a former erosion surface is strengthened if extensive flat areas truncating deformed rocks are found in the summit region. This is the case with the Santa Ynez Mountains. The broadest remnant of the surface is "the Plateau", a gently sloping highland whose surface bevels the edges of strata folded in a large syncline and the Topatopa anticline.

Older stream valleys crossing upland areas of the Santa Ynez Mountains have a more mature longitudinal and transverse profiles than valleys cut by streams in the present cycle. "Two-story" valleys are numerous, and many of the older valleys truncated by the present drainage are left with discordant profiles.

The Santa Ynez Surface had reached late maturity by the close of its erosion cycle. It is approximately the same age as the Rincon Surface, developed at a lower altitude in weaker rocks. The Santa Ynez Surface owes its greater height to the more resistant nature of the rocks which underly it, and to the greater altitude to which the Santa Ynez Mountains were elevated.

THE OJAI LOWLAND

The Ojai Valley has a central position in the mountainous region north of Ventura. The steep wall of the Santa Ynez Range to the north stands in contrast to the flat floor of the valley. The gently rolling surface of the lowland is covered with orange groves interspersed with pasture land. The western portion is a park-like landscape of meadows, dotted with liveoaks.

The valley trends slightly north of east with a total length of 11.5 miles and a maximum breadth of 3 miles. The Ventura River crosses the valley at right angles to the major axis at one third of the total length measured from the western end. On the map this vertical intersection gives the valley the shape of a large T.

The floor of the valley appears level, but is diversified by a group of low hills in the western portion. South of Ojai are alluvial fans and the drainage systems of three south flowing streams cross the valley surface. The province is divided into three lesser units: 1) The Santa Ana Valley, west of the Ventura River, 2) The Ojai District, including the low hills on which the town of Ojai is situated, and 3) The eastern Ojai Valley including the drainage of San

Antonio Creek. These areas are described in detail in the sections to follow:

The Santa Ana Valley

This triangular area, west of the Ventura River, is an extension of the Ojai Valley. Steep mountains surround the area except on the east side. The valley floor is interrupted in the center by a low range of east-west trending hills, whose summits are 750 to 1000 feet high. Their crests are part of the Rincon Surface, now largely destroyed in this valley. The gradual decrease in elevation of the sediment of the scattered residual hills at lower altitudes than the main Rincon Surface to the south and west indicate not only its former presence, but also its downwarping to the east.

With an upstream inclination immediately east of the Santa Ana Valley, the Ventura River Terraces strengthen the hypothesis that the Rincon Surface has been downwarped to pass beneath the eastern floor of the Ojai Valley. This same upstream inclination is expecially pronounced in the triangular terrace at the junction of Santa Ana and Coyote Creeks. The Santa Ana Valley has been elevated, tilted and uparched recently, at the same time the eastern Ojai Valley was depressed.

The Santa Ana Valley, which stands above the present temporary base level of the Ventura River, is being eroded. Coyote and Santa Ana creeks cross the surface through deep trenches. Everywhere in this valley the soil is thin, and its reddish color indicates the presence of the underlying Sespe sandstone slightly below the surface. Actual rock outcrops are numerous, even in the flat floor of the valley.

All this evidence summarized points out that the Santa Ana Valley portion of the Ojai Lowland has been tilted to the north and east. Remnants of the Rincon Surface preserved on the crests of the low hills in this region, decrease in altitude to the NE. Finally, this area is undergoing active erosion, in contrast with the eastern half of the Ojai Valley, which is a site of deposition.

The Ojai District

This subdivision includes the area between the town of Ojai and the Ventura River. It has much the same relief as the Santa Ana Valley to the westward. The average slope of the valley floor from Long Valley north is to the east, away from the Ventura River and toward the eastern, depressed part of the Ojai Valley. Most of the area stands 100 to 150 feet above the flood plain of the Ventura River.

Very little drainage makes its way directly into the river, but follows a more roundabout path through San Antonio Creek.

The group of tilted terraces in the La Crosse sector of the Ventura River Terrace is the southern part of this area. These terraces are warped against the gradient of the Ventura River, and in the case of the lower I level, merge with the present valley floor north of Long Valley. The II level is preserved on the summits of the low, undulating hills, with flattened summits 750 to 800 feet high, to the south and west of Ojai. Krotona Hill, the long ridge immediately north of Long Valley, and the group of rolling hills included in the grounds of the Ojai Country Club show an eastward decrease in elevation.

The hills preserving traces of the II level rise above the valley floor and grade into the eroded remnant of an old alluvial fan south of McDonald Canyon. The reddish, weathered gravels underlying the dissected surface of the fan are visible in road cuts along the Maricopa-Ventura Highway. Where the attitude of this deposit can be measured, it may be seen that the fanglomerate has been tilted towards the valley. These older gravels are being swept away and their place usurped by the newer alluvial fan building out at the mouth of Stewart Canyon. These older, deformed fan deposits are equivalent to the upper levels of the Ventura Terraces and have been tilted southward in sympathy with the downwarping of the Ojai Valley.

The characteristic residual soil of this section of the Ojai Lowland is similar to that of the Santa Ana Valley. Except in stream valleys where it is transported, the soil throughout this area shows the brick-red color derived from the Sespe formation. On hill slopes, bed rock appears frequently on the surface.

The central portion of the Ojai Valley supports the evidence presented in the Santa Ana Valley for the eastward tilting of the valley floor and the downwarping of the entire intermont basin.

Eastern Ojai Valley

This portion of the Ojai Lowland is economically more important than the remainder of the province. Most of the citrus groves are concentrated here and a more intensive type of agriculture is practised. The valley floor has a different appearance from the western sections. For a distance of two miles east of Ojai, or to the limits of the first orange groves, it is nearly level. From here the elevation of the floor increases rapidle eastward up the alluvial fans built from the mouths of Senor and Horn Canyons. These alluvial fans are the most distinctive objects in the landscape of the Eastern Ojai Valley. Their outlines are defined by the groves of orange trees on their rocky, fertile surfaces. Although the amount of labor required to clear fields for planting is serious, it has been justified on account of the supply of ground water in the fans, the air drainage provided by their sloping surfaces, and the comparative freedom from frost.

Alluvial fans are found only at the east end of the Ojai Lowland and at the base of the Santa Ynez Mountains east of Ojai. Their absence elsewhere is not explained by the lack of steep mountain front to supply detritus, for the mountains overlooking the Santa Ana Valley are equally high. The localization of a great quantity of debris in one end of the lowland is evidence that this portion of the valley has been warped below the temporary base level for the province. As a consequence of this downwarping, the short mountain canyons which empty into the valley have their gradients sharply reduced upon reaching the valley floor. They are forced to aggrade and have built up an extensive bajada. In the Santa Ana Valley, where the valley surface is being eroded, the depth to bedrock is slight. Most of the larger streams, as Coyote Creek and Santa Ana, are permanent and transport their load of sediment across the lowland.

The soil of the Eastern Ojai Valley is unlike that of the Santa Ana Valley of the Ojai District. The characteristic red color of the residual soil is absent, and is replaced by buff or brown, unweathered rock fragments with little or no humus. This type of sediment is associated with bajada slopes throughout semi-arid Southern California. Feldspar grains are among the more numerous constituent minerals and they are practically unweathered. The higher slopes of the piedmont alluvial plains are boulder fields crossed by branching and rebranching distributaries.

Summary of the Ojai Lowland

The Ojai Valley is a little modified, structural depression. It owes its existence to strong folding in the underlying rocks, and is not a graben. This folding has produced a deep synclinal trough at the foot of the Matilija Overturn.

Where deformation has been most pronounced, the Sespe strata on both the north and south sides of the valley are overturned and dip away from the center of the depression. This indicates that a considerable downward stress has been exerted near the axis of the valley. The downthrusting is concentrated in the center of the region immediately east of Ojai and south of the Gridley Canyon section of the Matilija Overturn. It is also due north of the overturned axial plane of the Lion Mountain anticline. A reasonable interpretation for the contemporaneous and recent deformation of the valley is a fan folded syncline in which there is a tendency for the center to be depressed as the margins of the fold yield to further compression. It may be demonstrated that there is a close correlation between the physiographic form of the Ojai Valley and its geological structure.

The physiographic evidence for recency of movement in the Ojai Valley and tilting of its floor towards the eastern end may be summarized as follows:

1) The thin residual soil in the western and central parts is evidence that these areas are now being degraded.

2) The slope of the main valley floor is away from the Ventura River, and the drainage escapes by San Antonio Creek.

3) The low hills in the western half of the low-land preserve remnants of the Rincon Surface on their summits. The decrease in elevation of these hills towards Ojai indicates that this surface has been warped downward towards the north-east.

4) The downwarping of the Rincon Surface is substantiated by the upstream tilt of the Ventura River terraces in the south extension of the Ojai Lowland.

5) The alluvial fans in the eastern end show that this sector has served as an area in which detritus accumulates, more rapidly than it is removed.

6) The large volume of groundwater in the eastern end indicates a reservoir of porous gravels below the valley surface. The scarcity of water in the western half is a result of the shallow depth of the soil mantling the bedrock.

7) The ephemeral streams in the eastern half disappear at the foot of the mountains, to reappear as cienagas at the head of San Antonio Creek where it crosses the Lion Mountain anticline. This disappearance of the surface drainage is further evidence of the depth of the valley fill.

8) In contrast, the streams of the western half flow permanently across the Santa Ana Valley.

9) The fanglomerates of the dissected McDonald Canyon fan northwest of Ojai are tilted towards the valley more steeply than the angle of deposition, and indicate that the downwarping has proceeded from both margins toward the valley axis.

10) The slopes of the marginal hills surrounding the eastern end of the valley intersect its surface at a high angle. They give the appearance of being partially submerged beneath the alluvium. There are no large foothills in this area. The reverse is true in the western half. The hills of Santa Ana Valley rise with gradual slopes from the plain and appear to be integral part of it. The mountains surrounding the lowland decrease gradually in elevation and possess many outlying foothills.

The Ojai Valley is a synclinal trough in which diastrophism is still active. At the present time the eastern valley floor is being downwarped. The greatest movement is taking place where the maximum deformation has occurred.

The Capture of Santa Paula Creek

One of the most interesting physiographic changes in the recent history of the Ventura Region was the capture of the western half of Santa Paula Creek by one of the south-flowing consequent streams of the Coastal Hills. Until near the close of the Rincon Cycle, Santa Paula Creek flowed west along the northern slope of Sulphur Mountain to join eventually the Ventura River. This stream will be called the Santa Paula River to distinguish it from the present day Santa Paula Creek.

When regional uplift started, Santa Paula Creek was rejuvenated, and downcut rapidly through the distrubed rocks at the east end of Sulphur Mountain. These rocks are the most complex structurally in the entire region. This is the point at which the San Cayetano fault truncates the Sulphur Mountain structures.

Because of the shattered nature of the bedrock at the east end of Sulphur Mountain, Santa Paula Creek had an advantage over similar consequent streams flowing through the Coastal Hills. With the factors of a steep gradient and an easily eroded foundation operating in its favor, Santa Paula Creek out through the low divide between Sulphur

Mountain and the north side of Onlauf Canyon to tap the drainage of the Santa Paula River.

Santa Paula River was deflected, and now has a right angle bend in its course at Sulphur Mountain Mineral Springs. The abandoned channel is marked by terraces, and by traces of the old valley floor in the Upper Ojai Valley.

One of the most distinctive groups of terraces is between La Broche and Bear canyons, north of Sisar Creek. These terraces merge with alluvial fans built out from the steep slope of Topatopa Bluff. The terrace surfaces lie between 2200 and 1800 feet, they are 0.7 miles broad at the maximum, and have a total length of 1.9 miles. Most of the surface is covered with large (5-10 foot) boulders, usually sub-rounded, and poorly sorted. These old, high-level terraces are part of the valley of the former Santa Paula River. Since their abandonment, they were covered by alluvial fans built out from the Santa Ynez Mountains. As Santa Paula Creek lowered its gradient, after Santa Paula River was captured, the short streams north of the mineral springs were rejuvenated. They have cut back into the terraced area and are now dissecting it. Deep ravines have been incised through the former valley floor of the Santa Paula River, and the alluvial fan material on its surface.

Sisar Creek has had an interesting history as a result of the capture. This stream had been a tributary of the Santa Paula River. When the capture took place, Sisar Creek built an alluvial fan completely across the eastern end of the Upper Ojai Valley. There is reason to believe that it still drained westward through the upper Ojai Valley and down San Antonio Creek. As Santa Paula Creek downcut through the old floor of Santa Paula River, a subsequent tributary advanced westward along the trace of the fault paralleling the northern base of Sulphur Mountain. Sisar Creek was added to the drainage area of Santa Paula Creek, and now runs down the east side of its fan, skirts the southern border of the fan built out from Bear Canyon, and joins Santa Paula Creek at the mineral springs. Part of its water still reaches the drainage basin of the Ventura River. This water escapes from a small cienaga on the western side of the Sisar fan and joins the small stream crossing the Upper Ojai Valley.

The Upper Ojai Valley is the most completely preserved part of the former drainage system of Santa Paula River. It is a narrow, elliptical basin, encircled by low hills to the south, and is open to east and west. The valley is 4.5 miles long, and has a maximum width of 0.9 miles. Most of the valley floor lies between 1250 and 1500 feet above sea level, and has a gentle westward inclination. The valley is floored with deep, brownish-red soil in which rounded gravel and cobbles frequently occur.

One important feature of the Upper Ojai Valley is its relation to the main Ojai Valley. The two are separated by a low divide, steepest on the north side, and almost non-existent on the south. A gently slope rises from the Upper Ojai Valley to the crest of the divide, and would continue into space over the Ojai Valley were it to persist. Kew (154)

(154) Kew, W. S. W., "Los Angeles to Santa Barbara," XVI International Geological Congress Guidebook, Excursion Cl. Guidebook 15, p. 63, 1934.

ascribe this difference in elevation to faulting at the northern base of the divide. Whatever may be the cause for the difference in elevation, it is related to the recent downwarping of the eastern half of the Ojai Valley.

Evidence for the former course of the Santa Paula River is difficult to find west of the Upper Ojai Valley. Terraces occur on the north side of Sulphur Mountain, and on the southern slope of Black Mountain. They are narrow benches compared to the La Brocke terraces, or the broad floor of the Upper Ojai Valley. One terrace is found on the narrow shelf indicated by Section No. 18, and another by No.

18, and another by No. 13, north of Lion Canyon in the Santa Paula Quadrangle. Gravel is found on the 1000 foot ridge east of San Antonio Creek, and on some of the spurs on the north side of Sulphur Mountain.

At San Antonio Creek the record disappears, and no further trace of these high-level gravels is found on Sulphur Mountain. If they were originally present they have been removed in the deepening and widening of San Antonio Canyon. It may be that the Santa Paula River terraces are related to the III level of the Ventura River series. If this is true, the two drainage systems were united at the 1000 foot ridge west of San Antonio Creek.

It is unfortunate that no terrace levels are found between Lion Canyon and La Crosse on the north side of Sulphur Mountain. Their absence makes it difficult to relate the 850 foot terrace on Fresno Canyon either to the Santa Paula or Ventura River canyon. The Fresno Canyon terrace is believed to be a branch of the Ventura River during the time that it was joined by Santa Paula River, and had a correspondingly greater volume of water.

Summary:

Near the close of the Rincon Cycle of erosion the

Santa Paula River was captured by a tributary of the Santa Clara River. This capture was made possible by the favorable course of Santa Paula Creek through the belt of shattered rocks at the eastern end of Sulphur Mountain. Traces of the former route of Santa Paula River are found in terraces and in the old valley floor of the Upper Ojai Valley.

THE SULPHUR MOUNTAIN UPLAND

This upland is an arcuate belt across the central part of the area, and stands well above the lower Ojai Lowland to the north and the Coastal Hills to the south. Although no point is higher than 2600 feet, the relatively low altitude is belied by the abruptness with which the summits of the three mountains in the upland rise above their surroundings. This is particularly true of Sulphur Mountain, the eastern one of the trio. Next in order, and the first west of the Ventura River, is Red Mountain, followed in sequence by Rincon Mountain, the westernmost of the series.

The most distinctive feature of the upland is the erosion surface of late maturity preserved on the summit. It is best shown on Sulphur Mountain by the mature profiles of the stream courses, the gently rolling divides separating them, and the abrupt transition to the youthful canyons in the Coastal Hills.

The erosion surface preserved on these mountain summits is the Rincon Surface. It is an important feature in the area, and owes its preservation to the nature of the underlying bed rock. The rock type responsible for the perfection with which this surface has been preserved is the fissile, diatomaceous shale of the Modelo Formation. This property of preserving land forms is also illustrated in the marine terraces on the southern slope of Rincon Mountain. Two of the three mountains in this province are underlain by the Modelo Formation. These two are Rincon Mountain and Sulphur Mountain. They are higher and have shown more resistance to the destruction of the old land on their summits than Red Mountain, underlain by the Sespe Formation.

Rincon Mountain

The dome-like summit of Rincon Mountain, which is the western end of the Sulphur Mountain Upland, rises abruptly above the eastern margin of the Carpinteria Plain. The elevation of Rincon Mountain is not the most distinctive feature, as it rises only 2165 feet, but the steepness of its slopes, compared to the gentle contours of the upper surface, and its isolation from its neighbors, are among its more notable characteristics. No feature is more prominent than the sharp break between the arched summit, and the canyon walls surrounding it on three sides. This transition between the Rincon Surface, and the rejuvenated canyons of the present cycle, is at an elevation of 1500-1750 feet. It is most pronounced on the northeast slope of the mountain, overlooking the Casitas Valley at the outlet into the gorge of Los Sauces Creek. The marine terraces on the south-western face of the mountain are described in detail in the section dealing with Pleistocene shorelines. Their highest level stands 400 to 500 feet below the Rincon Surface on the summit of the mountain, and is separated from it by a battered sea cliff. still retaining its original declivity.

No trace remains of the upper, more mature portions of the radially consequent streams encircling the summit ridge at the crest of the mountain. The surface is a gently rolling upland, diversified by scattered basins, a number of which are undrained. They are structural depressions, rather than erosional features, and are caused by differential movements, as gravity faults, warping, etc. within the mountain. The surface of this summit upland is nearly flat in profile. The most notable feature is the gradual increase in elevation eastward from an altitude of 1250 feet to the domed summit at 2165 feet. This increase in elevation may be an inherited irregularity of the Rincon Surface, but it is suggestive that the summit exhibits a uniform westward inclination from the crest. It may be a further confirmation of the westward tilt of the mountain indicated by the warping of the marine terraces on the southern slope.

Summary:

Rincon Mountain, as a physiographic unit in the Sulphur Mountain Upland, is a west tilted block, underlain by contorted Miocene and Pliocene shales, preserving on its summit a remnant of the Rincon Surface. and terraced on its southern slope by elevated and warped marine strand lines formed by the recent pulsatory uplift of the mountain.

Red Mountain

This mountain is the most conspicuous single feature on the west bank of the Ventura River between the Ojai Valley and the sea. It is underlain by more porous sandstones, and supports a denser cover of vegetation than either Sulphur or Rincon Mountains. The effect of insolation is pronounced as a result of the east-west trend. The southern slope is comparatively bare and outcrops of red sandstone stand out in relief. The northern slope is covered with a forest of oak trees and chapparral, in contrast to the denuded southern slope.

This ridge is the surface reflection of the Red Mountain anticline developed principally in the Sespe sandstone. Although the Sespe sandstone ordinarily has a low order of erosive resistance, in Red Mountain it has proved an unusually competent rock type. This may be a consequence of its comparatively uniform texture, compared to the variation it exhibits on South Mountain. Exposures near the summit of Red Mountain are predominantly sandstone with only minor amounts of intercalated shale. The sandstone is free from joints, stratification is rudimentary, and bedding planes are widely spaced. The anticlinal structure has proved fairly resistant to erosive attack and the center has not yet been breached. The appearance of the mountain is nearly controlled by the rock foundation. The layers of sandstone crop out in concentric layers where they converge around the axis of the anticline, as a result of its eastward plunge. As these layers weather they resemble a partially peeled onion, or a large scale example of exfoliation.

The summit of Red Mountain, 2158 feet high, is within 7 feet of the altitude of Rincon Mountain. The summit upland is not so regular, nor does it preserve the Rincon Surface as completely, except in the eastern half, where a plateau-like remnant occurs at the highest point.

This residual surface may be due to the attitude of the nearly horizontal strata, near the axis of the anticline.

The western half of Red Mountain, and the country lying between its summit and that of Rincon Mountain, is more varied than the summits of either of the two mountains. It is still part of the Rincon Surface, but is interrupted be the rejuvenated floors of a number of formerly mature stream valleys. These were occupied by antecedent streams which have trenched deep gorges across the Sulphur Mountain Upland, subsequent to the recent coastal uplift. Chief among these is Los Sauces Canyon, whose pre-uplift limits are shown on the contour map of the Rincon Surface. The sharp break between the broad-floored valley and the precipitous slopes of the present gorge is a confirmation of the recency of uplift.

Madranio Canyon is another rejuvenated consequent stream but has not succeeded in cutting through the axis of uplift to the degree accomplished by Los Sauces Creek. The stream still heads in its former mature valley and has not excavated a canyon across the Sulphur Mountain Upland. Padre Juan Canyon is similar to Madranio. It has been rejuvenated and has nearly destroyed its mature valley floor formed during the Rincon Cycle. The only surviving valley remnant of any consequence is at the head. A rock-defended part of its old floor is preserved between several massive sandstone ledges at the base of Red Mountain.

A number of undrained basins resembling those of Rincon Mountain occupy the summit of Red Mountain. On Red Mountain these sag ponds are caused by differential movement and settling between the competent and incompetent strata in the Red Mountain anticline. Many of the larger sandstone layers have moved differentially in the more plastic shales. This slight local shifting and readjustment between the various rock types is probably responsible for the restless topography of the surface.

Summary:

Red Mountain owes its elevation to the underlying anticlinal structure. Its summit merges with the general Rincon erosion surface and its crest does not coincide with the structural axis. The mountain is a subsequent feature, and owes its configuration and elevation to renewed erosive attack on the Red Mountain anticline, now in its second cycle. The consequent streams of the first cycle have been rejuvenated, and in the present cycle are modified in pattern by the rock structure, although they still retain a radi¢al arrangement.

Sulphur Mountain

Few natural features in the Ventura Region are more remarkable than the east-west ridge of Sulphur Mountain. The difference between the mature surface of graded valleys preserved on Sulphur Mountain, and the sharp ridges and alluviated valleys of the Coastal Hills is apparent even from as great a distance as Point Mugu. The line separating the two unlike regions follows a linear course across the southern face of Sulphur Mountain and in most cases is a low cliff. Faceted spurs are common, and most of the ridges on the summit of Sulphur Mountain are as abruptly terminated as though sliced off by faulting.

Little trace of faulting of the magnitude called for by the escarpment can be found. Through most of the length of the southern slope, the Pico and Modelo formations are in disconformable contact. In the eastern end of the mountain the strata are overturned, but there is no evidence of a major fracture. In the central part, north of Wheeler Canyon, it is difficult to determine the contact between the Miocene and Pliocene formations, as it is entirely gradational.

Where movement has occurred, it is of minor importance and is caused by the differences in competency of the two formations in resisting deformation. Most of the numerous small fractures encountered along the Sulphur Mountain scarp are slippage planes, except at the extreme eastern and western ends, where there is strong evidence of faulting.

Figure 11

Sulphur Mountain Scarp. The Coastal Hills stand at a lower elevation on the right margin. A hanging valley is visible on the Sulphur Mountain crest near the right margin.

The Sulphur Mountain Scarp, with its hanging valleys and mature surface standing above a youthful one at a lower elevation, is the result of differential erosion. This difference in the rate of erosion is determined by the nature of the Modelo and Pico shales. The Pico mudstones are more rapidly destroyed. Even though valley sides appear to be in equilibrium and have graded slopes, landslides are not infrequent and much gullying and ravining has occurred. Over most of the Coastal Hills remnants of the Rincon Surface no longer exist. The result is that the contact of the two rocks has been etched out to form a continuous scarp on the southern face of Sulphur Mountain.

The subdued land forms produced on the summit upland of Sulphur Mountain are difficult to explain, especially when contrasted with the almost vertical cliffs surrounding the mountain. The two may be reconciled, however, for both are consequences of the erosion of this type of rock. In spite of its fissility and degree of fracturing, it still remains one of the most impervious rocks in the region. The siliceous shale has a low percentage of voids. Water is not able to penetrate for a great distance, and the surface is covered with a thin veneer of residual soil grading down to bed rock.

In the transition area between the top soil and solid bed rock, the darker, organic partings between the shale laminae succumb to weathering first. As a result, joint blocks of unweathered siliceous shale weather out and survive unscathed until they reach the surface. They seem almost completely immune to chemical weathering, and in the dry, temperate climate of this district mechanical weathering, ~~and in the dry, temperate climate of this district~~ mechanical weathering is virtually non-existent. These small, flat-surfaced, angular joint blocks are firmly embedded in the thin residual soil. As this soil is washed away, many of these unaltered rock fragments are left behind and cover the surface.

The soil produced from the weathering of the Modelo shales is a thin, black-to-gray residual veneer. When wet, it is plastic, but in drying out forms a tough, resistant adobe. The shale fragments scattered through it act as an aggregate. The fact that the soil extends down into bed rock with no perceptible separation gives it an unusually firm foundation. Its cohesiveness is another element in the erosive resistance; for when dampened it behaves like plaster.

A combination of these is probably responsible for the erosive resistance of this structurally incompetent rock. The impervious nature of these finely stratified siliceous shales, coupled with the adhesive properties of the residual soil derived from their decay, has resulted in the preservation of a land surface which is less suspetible to the ordinary process as of denudation.

Figure 12

Sulphur Mountain Scarp at head of Wheeler Canyon. The contact is gradational between Pliocene strata in the foreground and overturned Miocene rocks in the distant scarp.

The rejuvenation of all the radially consequent streams may cause the destruction of the surface. These

These streams lowered their channels more rapidly across the Coastal Hills. By headward erosion they sought to accomplish the same feat on Sulphur Mountain, but the resistant nature of the Modelo Shale checked their progress. As a consequence, most of the south-flowing streams in the Coastal Hills have acquired subsequent tributaries in their headwaters, which have etched out the Sulphur Mountain Scarp. It is the down-cutting of these subsequent streams on their east-west courses paralleling the Miocene-Pliocene contact zone which is responsible for the production of this escarpment.

The erosive resistance of the shales underlying Sulphur Mountain is responsible for the 800 to 1000 foot drop in the longitudinal profile of all south-flowing streams where they cross the scarp and enter the Coastal Hills. This differential between the profile of the alluviated floors of the streams in the Coastal Hills and the older hanging valleys of Sulphur Mountain is so great that the latter are now invariably being rejuventated. All the older valley floors are trenched by deep gorges. These have not as yet attained a unified gradient with their Coastal Hills segment, and affect a junction by cascades and dry falls. This rejuvenation has had little effect on the interstream areas and the principal divides. Streams have concentrated on downcutting in this area, and widening of their channels remains a secondary process until equilibrium is achieved with their course.

The summit upland, while less impressive than the southern scarp, is geologically as significant. It presented a subdued landscape of gently rolling hills, broad valleys, and graded slopes. In Maxson and Anderson's (155)

(155) Maxson, John H. and Anderson, George H., "Terminology of Surface forms of the Erosion Cycle." Journal of Geology, Vol. XLIII, No. 1, pp. 88-96 1935.

terminology it would be classed as a matureland. Traces of this landscape still survive over the entire summit, but perhaps with the best perfection in the eastern half of the range. At no point is the summit one mile wide, and its narrowest part is only 0.3 mile. One of the most noticeable characteristics is that the present water divide is the northern edge of the upland on the side overlooking the Upper Ojai Valley. Another phenomenon of some importance is the general slope from the northern rim of the upland to the brink of the southern scarp. Because of this prevailing southern slope, all the mature valleys cut in the Rincon Cycle cross the Sulphur Mountain Upland from one side to the other, except for the last few humdred feet of their uppermost courses. The upper courses of some have been destroyed by the retreat of the northern side of Sulphur Mountain as a result of the later development of the Upper Ojai Valley, and in all cases their lower sections have been annihilated by the rejuvenated stream system of the Coastal Hills.

Only one important section of the medial ridge which formed the water divide in the Rincon Cycle survives. This is a prominent narrow ridge in the western half of the upland. It culminates in the high peak immediately north of Aliso Canyon at an altitude of 2750 feet. Its domed summit falling away rapidly on all sides resembles Rincon Mountain more than any part of the Sulphur Mountain crest. The old medial ridge runs from this peak in a narrow spur, decreasing in elevation westward until it ends north of Sulphur Canyon at an altitude of 2602 feet. To east and west of this central segment, the central divide has been destroyed and many of the stream valleys inherited from the previous cycle cross the entire upland until they are beheaded on its northern rim.

From the area north of Hammond Canyon to the eastern end of the mountain the elevation of the summit remains about the same through its length. Its average height is 2500 feet and, although interrupted by stream valleys cut across it, has a level profile. This is not true of the western end, for the altitude of the central divide decreases 1600 feet in the distance of three miles separating the peak at the head of Sulphur Canyon from the high level terraces of Fresno Canyon.

These terraces are remnants of the old valley floor of a branch of the Ventura River. The decrease in elevation of the Sulphur Mountain summit is gradual between these terraces and the central part of the ridge, and they may be considered part of the Rincon Surface.

The characteristics of Sulphur Mountain are summarized below:

1) The structure is a south dipping homocline, underlain by siliceous Modelo shales, which have been deformed by close folding, minor faulting, and overturning.

2) Because of the erosional resistance of these impervious shales, Sulphur Mountain is separated from the Coastal Hills by a 500 to 800 foot scarp, the result of differential erosion rather than diastrophism.

3) As a further consequence of the erosional resistance, the Rincon Surface is preserved on

the summit of Sulphur Mountain.

4) The cycle of erosion responsible for the formation of this surface had progressed to late maturity or early old age, and is contemporaneous with the formation of the high-level terraces at Fresno Canyon.

5) The Rincon Surface on Sulphur Mountain is being destroyed by the headward erosion of rejuvenated streams on the southern margin.

THE COASTAL HILLS

The Coastal Hills are a wide belt of foothills, underlain by tilted Pliocene and Pleistocene sediments. They extend across the central part of the area from the eastern margin of the Santa Paula quadrangle and end at the sea south of Rincon Mountain. The northern limit is the southern escarpment of Sulphur Mountain, and the southern border is the broad synclinal depression of the Santa Clara Valley. These dimensions enclose an area with a length of 25 miles and a maximum breadth of 7.5 miles.

The province is subdivided into three lesser units by the valleys of the Ventura River and Santa Paula Creek which cross it normal to the major axis. West of the Ventura River are the San Miguelito Hills, named for the Spanish land grant which included most of this area. The sector between the Ventura River and the Santa Paula Creek is the Buena Ventura Area, after the Ex-Mission San Buena-Ventura Grant. The remaining segment, east of Santa Paula Creek is the Timber Canyon Area. The broad alluvial fan which occupies Timber Canyon is one of the most distinctive features of this subdivision.

The entire province is a homogeneous unit in spite of its tripartite division. This uniformity exists because the district is underlain by the clay shales and sandstones of the Pico formation, with only a thing band of closely related San Pedro deposits along the southern margin. These readily eroded sediments form a landscape of narrow ridges, separated by steepsided, but comparatively flat-floored, alluviated valleys with gentle gradients.

Most of the streams in this area have lowered their courses to base level, and have started only recently the process of lateral planation in their lower courses They have developed valleys deep enough for their slopes to intersect in narrow ridge crests, on which no actual part of the Rincon Surface survives. As a result of the attainment of grade by all the major consequent streams in this area, and the destruction of the initial surface of the present erosion cycle, the entire province in entering early maturity.

The principal reason for the more rapid advancement in the present erosion cycle than in the case of the area to the north is the lack of erosional resistance of the Pico clays, shales, and mudstones. This lack of resistance depends upon two of the properties possessed by these rocks. The first is their lack of induration, and the second, their low porosity. This last characteristic results in the sparse covering of vegetation on these hills. No other province within the Ventura region is more barren than the desolate slopes of the Coastal Hills. During the rainy season they are green for a few weeks, or months; then the scanty crop of annual grass withers, and during the balance of the year they are cloaked with scattered, dusty sage, dry mustard stalks, and dormant perennial plants. Few trees occur on the hill sides in this area. Stream valleys, where the drainage is better, the soil more porous, and a higher water table is present, support a moderate stand of live oaks and sycamores. Elsewhere, few plants larger than bushes grow, and practically none of these on southern slopes.

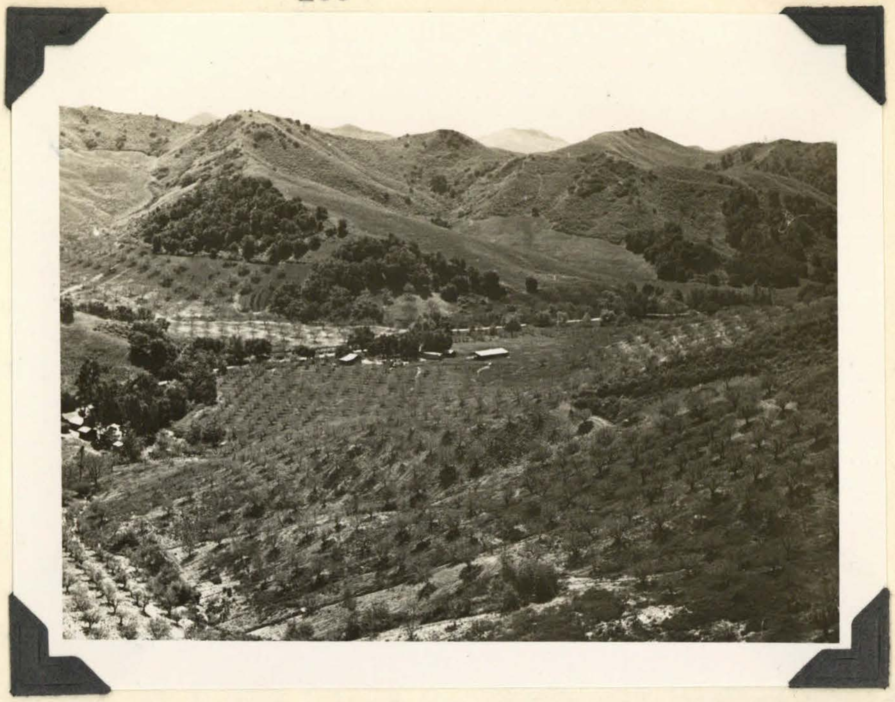


Figure 13

Wheeler Canyon, a typical mature valley in the Coastal Hills. The alluviated valley floor is occupied by apricot orchards. No trace of the Rincon surface survives on the accordant ridge crests.

This lack of protection, causes erosion at rapid rate in parts of this area, assisted by the non-indurated nature of the Pico clay shales. Badland topography is of minor importance in the Coastal Hills. On most of the hills, exposed surfaces are rounded and smoothed to form a particularly subdued landscape. Two of the principal erosional processes in the mudstone area of the Coastal Hills are slumping and solifluxion. The steeply inclined shale strata, particularly where massive and poorly indurated sandstone layers are intercalated in them became lubricated by ground water seeping along the bedding planes. When support in removed, through side-cutting by streams or waves, a large area of these steep-dipping sediments may slide outwards. When this type of gliding occurs, a semicircular area, bounded by gravity faults, moves forward in a jumbled, hummocky mass; and produces reverse dips and numerous minor structures within its limits. A number of these large slides occur in the Ventura Avenue Oil Field and near the heads of Seton and Harmon Canyons. Two other notable landslips are on the sea coast west of the Ventura River, where wave attack has undercut the seaward dipping Pico shales and allowed them to glide coastward.

There are numerous areas throughout the Coastal Hills in which an excessive amount of rejuvenation has occured. This is shown by ripped topography, gullying, and by narrow ravines entrenched below the more uniformly graded surface. In some areas erosion attacks from below, and undermines the ground above. Depressions resembling the cirque-like amphitheatres cut in the flat-lying sedimentary rocks of the Grand Canyon, and funnel-shaped valleys with cliffed walls are produced. Vertical slopes cut in the partially consolidated Pico shales and sandstones frequently hold up quite well under the attack of the weather and form a characteristic part of the landscape. The smoothly flowing slopes of the Coastal Hills are usually interrupted at some point within the field of view by one of these abnormal, rejuvenated areas.

Summary:

Over most of the Coastal Hills the land surface is approaching late youth or early maturity in the current cycle. This province has been dissected more rapidly than its neighbors on account of lack of resistance in the bed-rock foundation. Due to the imperviousness of the clay shales in the Pico formation, and the general lack of coherence, there are local areas where slumping, soil creep, and accentuated gullying and cliff formation have been aided by recent rejuvenation.

The San Miguelito Hills

This triangular segment of the Coastal Hills extends from the Ventura River valley westward to the sea at Los Sauces Creek. The shoreline is the southern boundary and the northern limit is the southern slope of Red Mountain. The area is a right angle triangle with the seaward side forming the hypotenuse. The northern boundary is distinct and the Red Mountain Thrust, brings Miocene and Oligocene rocks in contact with Pliocene. The contact is indicated by the abrupt change in the vegetation on opposite sides; live oaks and related plants on the north; and sage, wild mustard, etc. to the south.

Ridge crests in this area are accordant. All trend in nearly the same direction and are underlain by homogeneous rocks. The average elevation of most of their summits is between 1000 and 1500 feet. The slopes are from abrupt from ridge crest to valley floor. Most of the streams crossing this area flow 800 to 1000 feet below the summit old land in narrow steep-walled valleys. The walls of these canyons in the coastal part of the area are steeper than the angle of repose for the clay shales here exposed. As a result, soil creep and slumping is especially pronounced in the area between Pitas Point and the Ventura River. The main watershed extends parallel to the coast in a narrow cuesta between the shoreline and Canada del Diablo. Because of the vigorous wave attack and the steep seaward dip of the Pliocene strata, the seaward slope of this coastal cliff that slopes back from the base at an angle of 45 to 55 degrees, is practically a dip slope.

As a consequence of the steep declivity, the rapid attack of the sea, and the readily eroded nature of the rocks, the streams flowing directly into the sea have steep gradients and comparatively short lengths. These streams are continuously being shortened through wave erosion. Nowhere else are nearly vertical-walled gorges developed to the extent that they are in the area between the amphitheater and the Ventura Valley. The deepest is west of the broad terraces on the western side of the river. Its nearly vertical walls drop 500 feet into a gorge which reveals nearly a complete sequence of upper Pliocene sandstones and shales in disconformable contact with the San Pedro formation.

The largest and most impressive of these recently rejuvenated valleys is the funnel-shaped amphitheater midway between Pitas Point and the Ventura River, Although it breaches the faulted axis of the Ventura Avenue Anticline, the major portion is cut in the southern limb. The origin of this steep-walled gorge in an area of incompetent rocks is difficult to explain. The solution may be the strong seaward dip of the strata, but it is probably a result of the occurrence here, in the upper part of the Pliocene section, of a series of comparatively resistant sandstone strata. These have been brought farther up in the section than in the areas to the east or west of here by doming along the anticlinal axis. When these sandstones were penetrated by stream erosion, the softer clay shales underlying them were withdrawn by accelerated erosion from below.

Figure 14

The Amphitheater. The faulted axis of the Ventura Avenue anticline is visible near the left margin.

In short, the traingular San Miguelito Area of the coastal Hills is crossed by the axis of the Ventura Avenue Anticline developed in steeply tilted, Pliocene and Pleistocene strata. Because of nearness to the coast, the consequent increase in the effectiveness of stream erosion and wave attack has produced the maximum amount of slumping and canyon cutting of any area in the Coastal Hills. This process reaches its culmination in the amphitheater, an unroofed section of the anticlinal axis where the softer core of the mud-pit member of the Pico formation has been bared by the removal of the more indurated sandstone cover.

Ex-Mission San Buena Ventura Area:

This rectangular area, the largest unit in the Coastal Hills province, has a length of fourteen miles and a breadth of seven miles. The eastern limit is the valley of Santa Paula Creek, and the western, the Ventura River. The southern escarpment of Sulphur Mountain bounds it to the north, and the southern margin is the synclinal depression of the Santa Clara Valley.

This subdivision is quite homogeneous when viewed either close at hand or from a distance. This uniformity is expressed in stream valleys of almost equal length, ridges of accordant height, and hill slopes of the same declivity. This is an area of tawny, narrow crested hills, which would form a broad and undulating plain sloping away from the face of Sulphur Mountain, if all the valleys which dissect its surface were to be filled.

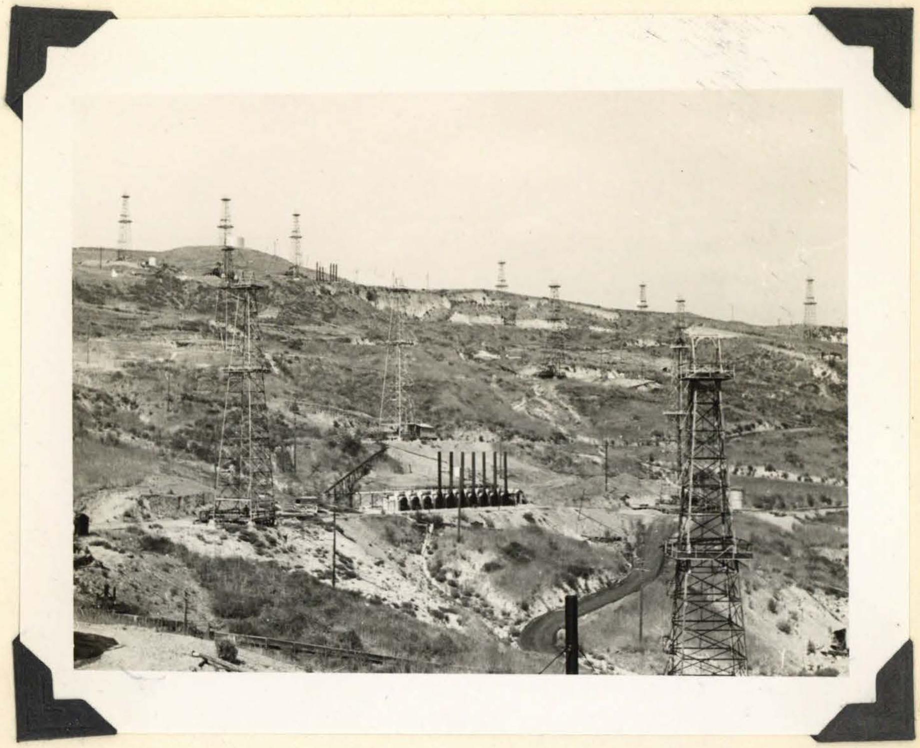


Figure 15

Surface of a large slide in Ventura Avenue oil field. The scarp parallels the skyline, and the hummocky surface of the slide covers the foreground.

(indicated above)

A smaller slide west of the larger, is particularly interesting for its rapid movement and destructive effect. It is situated below the Associated Oil Company's gasoline plant, and a low ridge separates it from the larger slide to the east. Fixed points on its surface have shifted 50 feet between 1929 and 1936, with the movement averaging 6 feet per year. The casing in one well, Lloyd 22, was sheared completely through, and the fittings, valve, etc, were carried 25 feet from the point of failure. There were 5 strings of pipe in the hole at the time, with the 8 5/8" casing the minimum size. The conductor and stove-pipe casing broke at the contact between the slide bottom and the stationary surface of the ground. The three inner strings, including the tubing, broke 4 feet below the surface with a sharp fracture. A narrow road, formerly on the north side of the location, is now on the south side.

Figure 16

Lloyd 22 slide. The landslide surface in the foreground was formerly part of the ground surface beneath the tank.

A new derrick was recently erected and Lloyd 22 was again placed on production. The foot of the slide is encroaching on the north side of the pit excavated for the well, and in a short time the well will be endangered.

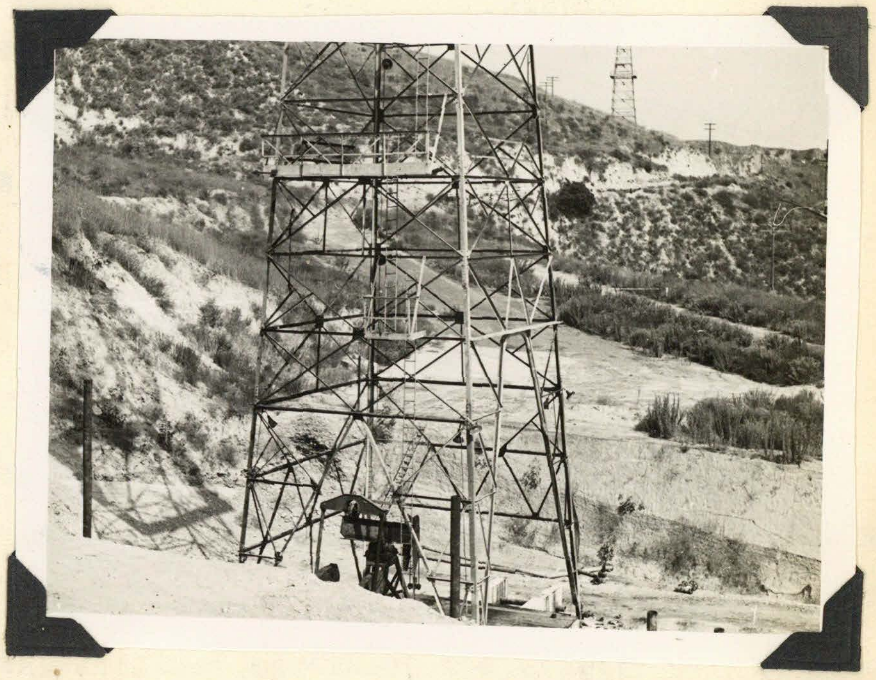


Figure 17

~~The narrow road beyond the derrick for Lloyd 22 formerly was to the left of the location, and has been shifted to its present position by the slide.~~

In structure the Buena Ventura area is simple when contrasted with the highly deformed rocks of the Sulphur Mountain Upland. The area is divisible into two parts, The eastern half, between Wheeler Canyon and Santa Paula Creek, is underlain by a consistently south dipping homocline. Under an areal extent of thrity square miles all the strata encountered dip to the south between extremes of 90 to 30 degrees. In general, the dip decreases southward towards the Santa Clara Valley. Along the Sulphur Mountain or northern margin of the Coastal Hills the attitude of the rocks is nearly vertical, and near the eastern edge of the mountain, the strata are overturned.

West of Wheeler Canyon the Buena Ventura area is underlain by two simple structures, the Ventura Avenue Anticline; and its accompanying homolog, the Canada Larga Syncline. Both these folds plunge east, and die out under the uniformly inclined strata of the eastern half. These structures are usually open and symmetrical. The Ventura Avenue Anticline, has a length of over 25 miles, and a maximum width of 5 miles. The axis of the fold trends nearly east-west, with only a slight southward deflection where it crosses the Ventura River.

Although differential erosion is of slight importance in the rocks exposed in the Coastal Hills, they do control to some degrees the topographic development of the area in which they outcrop. At first glance the dissected surface appears to be a plain with a gently slope to the south. This apparent uniformity is interrupted by two important features. 1) the erosional control exercised by the folded rocks of the western part of the Buena Ventura Area, and 2) the occurrence of several ledges of exceptionally resistant conglomerate in the lower Pico.

The topographic control of the underlying structure is well shown in the western part of the area. The plunge of the Ventura Avenue Anticline is marked by a corresponding swing of the whole southern front of the Coastal Hills at Aliso Canyon. An arcuate lobe extends beyond the main trend of the hills out into the Santa Clara Valley on the anticlinal axis. The eastward deflection of all the canyons occupied by south flowing streams where they cross the anticline is clearly apparent. These streams are subsequent, and parallel the outward bend of the strata converging across the anticlinal nose. This reflection of the rock structure in the stream pattern is best shown by the courses of Pepper-tree, Harmon, Lake, and Sexton Canyons. The surface evidence for the presence of the Canada Larga Syncline is no less apparent in the Buena Ventura Area than for the Ventura Avenue Anticline. The synclinal axis is outlined by the southern half of the Canada Larga which has an almost east-west trend in its lower course. Some trace of the axial lowland is shown by the east-west direction of the tributaries to the main south-flowing consequent streams in the area south of Leon Canyon and between Aliso Canyon and the Canada Larga.

The curious fact about the Canada Larga Syncline is that through most of its length east of Canada Larga, its axis is marked by a distinct ridge. Not only does this eastward trending ridge stand above the country to north and south, but its northern extension, only a slight distance from the synclinal axis, rises 1900 feet, the greatest elevation in the Coastal Hills. This highest ridge in Section 8, T3N., R22W. stands well above its neighbors, and owes its more complete preservation to the fact that it is underlain by one of the most resistant rock types of the entire Pliocene section. This is the lower Pico conglomerate, part of the facies cropping out in the area between Leon Canyon and Sulphur Mountain.

These conglomerates have sufficient lithologic uniqueness to constitute mappable units. When they are plotted on a map, their lenticular nature in obvious. They grade both laterally and vertically into sandstones, and are probably not particularly continuous with depth. The comparatively high degree of sorting, the well-rounded character of the cobbles and gravel, the cross-bedding in the sandy phases, the uniform texture of the sandy matrix, and the lenticularity of the strata indicate that these conglomerates are probably deltaic.

Figure 18

Lower Pliocene conglomerate reef west of Wheeler Canyon.

The four principal conglomerate horizons of the lower Pico are indurated enough to form distinct ridges trending across the country, until the conglomerate strata either lens out or are terminated by faulting, as north of the Canada Larga in the vicinity of Canada de Aliso. In no place do these conglomerate layers form a more distinctive part of the landscape than at the head of Wheeler Canyon. A short distance south of Sulphur Mountain, one vertical reef of conglomerate makes a narrow, almost cliff-sided ridge, which stands like a wall extending for two miles across the country. It has been breached in three places by south flowing streams which have cut portals through the barricade of conglomerate.

THE VALLEY OF THE SANTA CLARA RIVER

In some respects this part of the Ventura Region is the most interesting studied, yet the most obscure. It is a perplexing province, for the most significant features lie buried several thousand feet below the surface of the flood plain. In this section of comparatively recent subsidence deposition predominates over degradation.

The valley is a structural trough occupied, but not excavated, by the Rio Santa Clara del Sur, the largest stream in the Ventura Region. It flows 70 miles in an east-west course before emptying into the Pacific ocean west of Montalvo. It is a typical example of the larger water courses in the semi-arid sections of Southern California. Most of the year its bed is dry, except for scattered pools, and occasional narrow, branching and re-branching channels. In 1928 its desolate appearance was further increased by the destructive force of the water liberated through the failure of the San Francisquito Dam. After the flood crest subsided the exposed channel of the Santa Clara River reappeared as a broad white strip half a mile or more wide and devoid of vegetation. The region was wilderness of barren rocks, jagged stumps, and shattered wreckage of bridges, buildings and houses.

Eight years after the disaster few traces of the damage remained. The majority of the bridges undermined by the floor have been restored, and new vegetation has replaced the old. The floor of the river is marked by a dense thicket of willows, water maples, and cottenwoods. All are of the same age. For some years they will grow at the same rate and in this respect resemble the trees planted in the devastated area of France.

The significant feature of the Santa Clara River is not the braided nature of its channel, nor the recent flood, but its anomalous position on the southern side of the valley. Instead of occupying the center of the depression, it is crowded against the southern and eastern margin. The stream hugs the base of one of the steepest slopes in the region, the northern escarpment of South Mountain.

This unique behavior may be explained by a comparison with the Owens River as it flows parallel to the base of the Sierra Nevada, north of the Alabama Hills. The Owens River has been pushed from its position in the center of the valley by the superior force of the streams issuing from canyons in the Sierra, and has been crowded against the equally precipitous, but more arid Inyo Range.

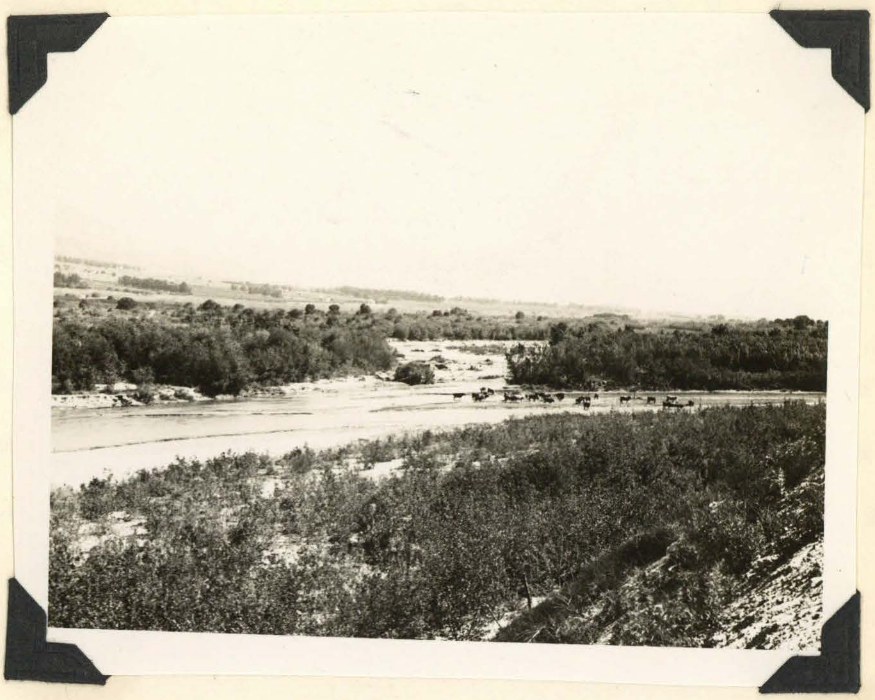


Figure 19

The Santa Clara River

The eccentric position of the Santa Clara River is partly due to the fact that the streams flowing from the Coastal Hills have a greater depositional strength than the shorter ones on the steep face of South Mountain. The dominant cause for the river's shift is related to the recent geological history of the valley. The valley is a structural rather than an erosional feature and in its simplest terms is a synclinal trough, faulted on its southern margin with the northern side of the fault downthrown one. The trace of the fault, in the portion of the valley considered in this investigation, is closely followed by the river. The northern margin of the valley is a normal syncline, somewhat overturned east of Santa Paula Creek. Throughout its length the Pliocene and Pleistocene strata disappear beneath the surface of the valley floor with a south dip and do not reappear within the confines of the valley. Instead, they are next seen, considerably attenuated in thickness, far above the valley on the summit of the Oak Ridge and South Mountain, at whose base the Sespe Formation is exposed.

Figure 20

Santa Paula Ridge and the Timber Canyon fan from the Santa Clara Valley

There is good evidence in the abruptness of the northern face of South Mountain, in the linear pattern of its base and the stratigraphic displacement involved, for the presence of the Oak Ridge Fault as already described by Kew. The significant relationship between the fault and the position of the river is the fact that the axis of the syncline and the downdropped side of the fault coincide with the southern rather than the central portion of the valley. That this has been an area of subsidence since the early Pleistocene is indicated by the greater thickness of the San Pedro formation here than in the Coastal Hills. There is reason to believe that this sinking has been operating in the Recent and has determined the location of the Santa Clara River.

The subsidence of the floor of the Santa Clara Valley is shown by the drilling of deep oil wells and by geophysical work carried on in recent years. This evidence indicates that the Pleistocene deposits, both marine and non-marine, are several times thicker beneath the valley than where they are exposed in the Coastal Hills.

Simple subsidence is not the entire story, for the surface of the Santa Clara Valley to the west and south is interrupted by a number of isolated, small elevations. As a rule, these are low dome-like hills, similar to the Dominguez and Rosecrans Hills in the Los Angeles Basin. On account of this fancied resemblance, the majority of them have been tested for oil, but so far has proved to be non-productive. They are the result of recent folding, and a few examples, as the Camarillo Hills and the two slighter ones in the vicinity of Montalvo seem to possess an anti-lineal structure. Revealed by drilling and geophysical surveys, there are other subsurface indications that deformation is now in progress below the surface of the valley.

The floor of the Santa Clara Valley shows more variation than a first view discloses. The area south of Montalvo joins the Oxnard Plain and is almost entirely level. It is a delta plain, built up by flood plain deposition of the Santa Clara River and rests upon a subsiding foundation. The accumulation of sediment has kept pace with the sinking, and has succeeded in prograding the shoreline.

The plain to the north of the Santa Clara River has a different appearance on account of its uniform southward inclination. From Ventura eastward to Santa Paula this part of the main valley is a piedmont alluvial plain built out by detritus carried down by the intermittent streams flowing from the Coastal Hills. The line of demarcation between the two plains, the Oxnard to the south and the piedmont alluvial plain to the north, is in the vicinity of Montalvo. The lower limit of the alluvial plain parallels the 100 foot contour between Montalvo and Ventura. The break in grade between the two plains is evident from the hills behind Ventura. From here the long bajada built out from the Coastal Hills may be seen sloping towards the Santa Clara River until it merges with the surface of the Oxnard floor plain. From this vantage point it is evident that the alluvial plain is the younger and is encroaching upon the surface of the lower and older plain as it builds outwards.

The extent to which modern stream channels have entrenched themselves in deep, narrow arroyos cut through the surface of the plain is noteworthy. A number of these arroyos are 40 to 50 feet deep and maintain nearly vertical walls. Not only are the majority of the lesser streams in the Santa Clara Valley rejuvenated, but the main Santa Clara River in its lower portion, particularly in the vicinity of the Montalvo Bridge, is flowing between vertical banks 30 to 50 feet in height. Whether this is the result of local uplift, or eustatic lowering of sea level, a climatic change, or overgrazing is difficult to determine.

Summary:

The Santa Clara Valley is a synclinal trough, bounded on its western margin by the fault responsible for the elevation of South Mountain. The fact that the maximum depression of its floor has been along its southern margin is responsible for the eccentric position of the Santa Clara River. The valley widens west of South Mountain to merge with the surface of the Oxnard Plain, built of marine and flood plain deposits accumulated on a sinking foundation. This plain has a piedmont alluvial plain, built out from the Coastal Hills, covering its northern border, and extending along the northern side of the Santa Clara Valley.

THE RINCON SURFACE

The literature dealing with the physiography of the Coast Ranges makes frequent mention of the mature surface preserved on their summits. Various attempts have been made to correlate these erosion remnants, but not with a notable degree of success. The explanation is the wide separation of the individual ranges, as well as the differential movement they have undergone. These erosion surfaces were mentioned by Fairbanks, Lawson, Willis, Branner, Arnold, and others in the earlier period of California geology. Little effort was made to more than point out the fact that they were formed after the principal Coast Range orogeny, and before the elevation of the Coast Range to its present height.

In this area the two most important papers to call attention to the post-deformation surface are by Kew (156) and Grant and Gale (157). The most important section

---

(156) Kew, W. S. W., "Geology and Oil Resources of a part of Los Angeles and Ventura Counties, Calif." U.S. Geol. Survey. Bull 753, 1924.

(157) Grant, U. S. and Gale, H. R., "Catalogue of the Marine Pliocene and Pleistocene Mollusca of California," Memoirs of the San Diego Society of Natural History, November 3, 1931.

---

dealing with the erosion surface, is the introductory chapter by Gale[158], in which the term Timber Canyon Surface is

(158) op. cit.

introduced:

"All of these occurrences taken together seem to outline in a general way an old land surface that had been subjected to considerable erosion since the deformation of the region and that was later uplifted essentially undisturbed and cut into by streams with a lower base level. For this surface the name Timber Canyon Surface is proposed because one of its most clearly preserved remnants is the surface of the Timber Canyon fanglomerate."

On page 37, preceeding this section, the statement is made that,

"This old surface is marked by high-level terraces and deposits of older alluvium or fanglomerate that were formed at the base of the upthrust mountains. One of the best of these remnants is a deposit of reddish fanglomerate occurring on the tops of ridges and bevelling the edges of the upturned marine beds west of Timber Canyon on the north side of the Santa Clara Valley. This deposit was formed at the base of Santa Paula Peak, a mountain composed of abnormally hard Eocene strata with a present altitude of almost 5000 feet, that was folded and upthrust during the mid-Pleistocene diastrophism. As the fanglomerate passes undisturbed across the trace of the fault, it is evident that the movement along the fault had ceased before the deposition of the fanglomerate."

The first, and most serious objection to the term Timber Canyon Surface is that the Timber Canyon fan is not a surface of erosion, but of deposition. The surface to be described was produced by long continued erosion, and if the term suggested by Gale is utilized, it is described in terms of a deposit on it. These two are not of equivalent age, nor are they produced by the same process.

A minor objection is that the surface of the fan has been displaced by recent movement along the San Cayetano fault. This is shown on the spur of San Cayetano Peak east of Boulder Creek. Here the reddish fanglomerate has been displaced between 75 and 100 feet to form a vertical scarp developed in the bench gravels. This evidence discounts the antiquity of the San Cayetano Fault, as is implied by Gale.

The area adjoining Timber Canyon is not suited for the establishment of a physiographic type locality for the erosion surface. In the first place, severe deformation has continued into the Recent. There have been at least two, and possibly three, epochs of deleveling, with the development of long, glacier-like tongues of fanglomerate, which occupy the valleys developed in a previous cycle. The erosion surface which truncates the Pliocene and Pleistocene strata exposed here has a much steeper gradient than it does to the west. It rises 2500 feet in a horizontal distance of 2.5 miles; to the west of Santa Paula Creek, 8 miles are required to reach the same elevation.

Lastly, the Timber Canyon area is isolated from the rest of the region and is correspondingly difficult to to correlate with it, on account of its unique tectonic history, and the development of the large alluvial fans built out from the steep face of Santa Paula Peak. They occur nowhere else on the same scale.

It is desirable to apply a new name to the erosion surface of the southern and coastal portions of the Ventura Region. Sulphur Mountain Surface would answer, for no other locality in the area shows the characteristics of this surface as well. However, this suggestion was abandoned in the interest of euphony and the term Rincon Surface selected.

The summit of Rincon Mountain preserves a remnant of the erosion surface in almost as perfect detail as on the crest of Sulphur Mountain; and is in direct contact with the most completely developed series of coastal terraces. An opportunity is provided to correlate the close of the late Pleistocene period of erosion with the beginning of the terrace cycle.

It is suggested that the name Rincon Surface be used in preference to the original term, Timber Canyon Surface, first proposed by Gale, since the area in which the Timber Canyon Fan is located is remote from this area. Its later geologic history is complex and not fully understood, and finally, the surface of the fan is one of deposition, not erosion, and has a later age than the erosion surface upon which it has been deposited.

The even-crested ridge of Sulphur Mountain and the accordent summits of the Coastal Hills are best seen from South Mountain on the southern border of this area. It is a simple matter to point out the broader features of this surface, but another story when an effort is made to describe it in detail. To overcome the difficulty of a lack of quantitative data the construction of a contour map was undertaken to show the relief of the Rincon Surface as it would appear had no erosion occurred since its elevation.

This idea, first used by George Otis Smith and Bailey Willis (159) in Central Washington, was carried on in

(159) Smith, G. O. "Geology and Physiography of Central Washington," U.S. Geol. Survey Prof. Paper 19, pp. 9-39, 1903

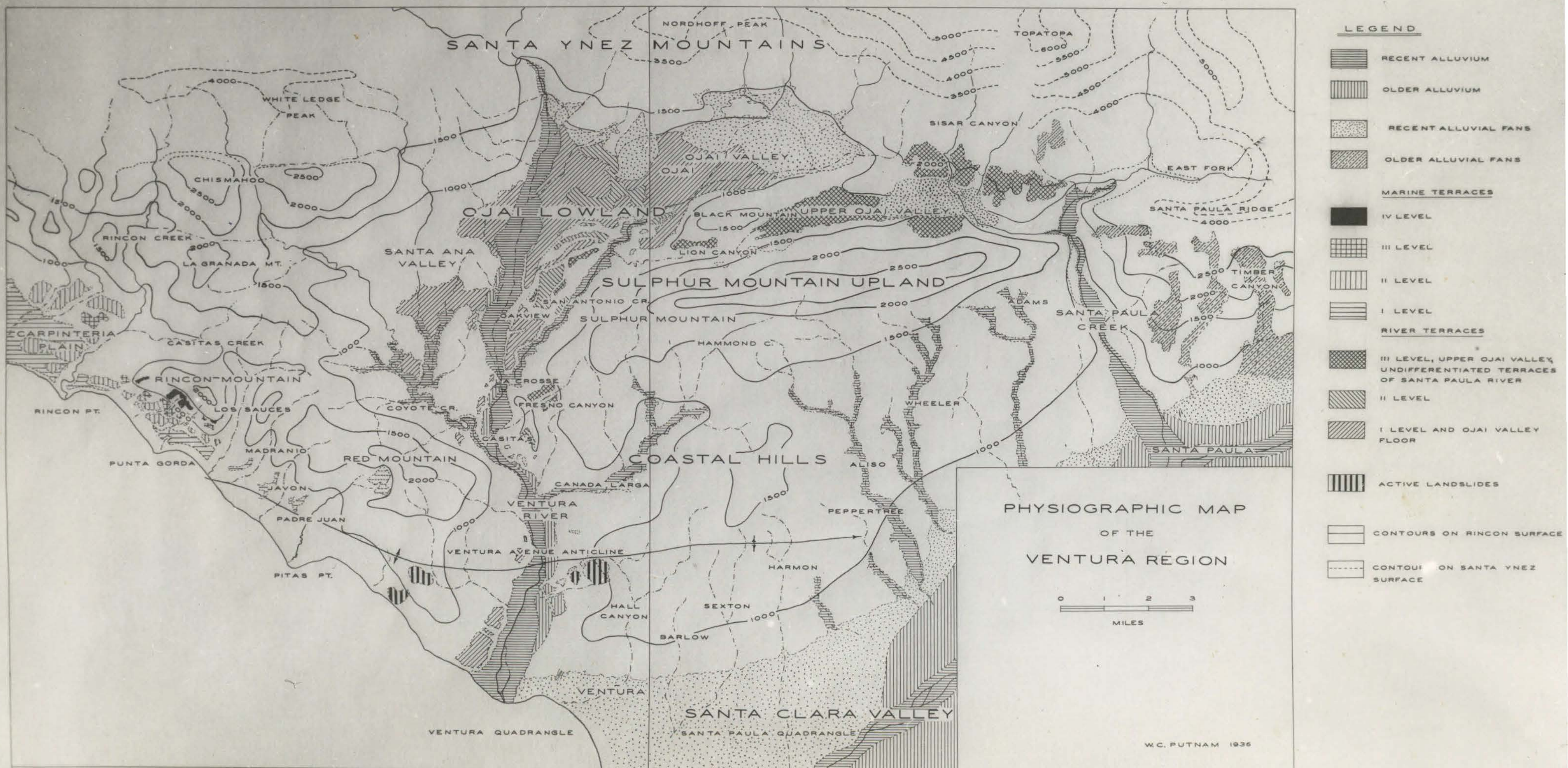
a more complete form by Wallace W. Atwood and K.F. Mather (160)

(160) Atwood, W. W., and Mather K. F., "Physiography and Quaternary Geology of the San Juan Mountains, Colorado," U.S. Geol. Survey Prof. Paper 166 1932.

in the San Juan Mountains of Colorado. The same technique was employed in the course of this study, and the important

Plate VIII

Physiographic map of Ventura Region


PHYSIOGRAPHIC MAP
OF THE
VENTURA REGION
0 1 2 3
MILES
W.C. PUTNAM 1936
LEGEND
RECENT ALLUVIUM
OLDER ALLUVIUM
RECENT ALLUVIAL FANS
OLDER ALLUVIAL FANS
MARINE TERRACES
IV LEVEL
III LEVEL
II LEVEL
I LEVEL
RIVER TERRACES
III LEVEL, UPPER OJAI VALLEY, UNDIFFERENTIATED TERRACES OF SANTA PAULA RIVER
II LEVEL
I LEVEL AND OJAI VALLEY FLOOR
ACTIVE LANDSLIDES
CONTOURS ON RINCON SURFACE
CONTOURS ON SANTA YNEZ SURFACE
SANTA YNEZ MOUNTAINS
NORDHOFF PEAK
TOPATOPA
SISAR CANYON
EAST FORK
SANTA PAULA RIDGE
WHITE LEDGE PEAK
CHISMAHOO
RINCON CREEK
LA GRANADA MT.
OJAI LOWLAND
OJAI VALLEY
OJAI
BLACK MOUNTAIN
UPPER OJAI VALLEY
LION CANYON
SULPHUR MOUNTAIN UPLAND
SULPHUR MOUNTAIN
SAN ANTONIO CR.
OAKVIEW
SANTA ANA VALLEY
TIMBER CANYON
ADAMS
SANTA PAULA CREEK
HAMMOND C.
CARPINTERIA PLAIN
CASITAS CREEK
RINCON MOUNTAIN
RINCON PT.
LOS SAUCES
LA CROSSE
FRESNO CANYON
COYOTE CR.
WHEELER
SANTA PAULA
MADRANIO
RED MOUNTAIN
CASITAS
COASTAL HILLS
ALISO
PUNTA GORDA
JAVON
CANADA LARGA
VENTURA RIVER
PEPPERTREE
PADRE JUAN
VENTURA AVENUE ANTICLINE
HARMON
PITAS PT.
HALL CANYON
SEXTON
BARLOW
VENTURA
SANTA CLARA VALLEY
VENTURA QUADRANGLE
SANTA PAULA QUADRANGLE

physiographic features were mapped as accurately as though an areal survey were being made.

Difficulty was encountered in the attempt to restore the Rincon Surface. The amount of deformation responsible for its elevation to the present height varies from point to point, and in a number of places the Rincon Surface has been warped. Lastly, the erosional resistance of the underlying bedrock varies widely, and results in a more complete destruction of the Rincon Surface in some places than in others. Three factors, the inherited irregularities, the unequal amount of deformation, and the differential rate of erosion, make the attempt to restore the original surface difficult.

Two important considerations determined the control used in drawing the contours, 1) what had been the original appearance of the Rincon Surface and 2) how much had the present cycle changed the original drainage pattern, relief, etc.? An effort was made to determine if a point through which a contour was drawn represented an actual remnant of the original surface, or one lowered by erosion to its present altitude. If erosion had occurred, the amount of reduction the surface had undergone was estimated and a correction applied.

In the sections to follow the characteristics of the Rincon Surface areas will be discussed. The first and most westerly of the three areas in which the Rincon Surface appears is the triangular one west of the Ventura River.

West of the Ventura River:

This section includes the summit of Rincon Mountain. The surviving areal extent of the Rincon Surface is indicated by the 500 foot contours superimposed over the actual surface. A point which needs explanation is the fact that the lower limit of the Rincon Surface apparently coincides with the 1000 foot contour. This is an attempt to compromise reality with the limitations imposed by a map. The 1000 foot contour is an arbitrary choice of elevation for the lower limit of the surface. In some instances the surface is above, at other times below this level. That it does coincide reasonably well with actuality is shown on the western side of Rincon Mountain, where the lowermost contour matches the elevation of the highest of the marine terrace series.

The group of closed contours between Carpinteria and the Santa Ana Valley encircle the summits of residual mountains which rose above the level of the Rincon Lowland at the close of the Rincon Cycle. They owe their higher elevation to their structure, which is cuesta-like, and to the resistance of the lower Sespe and Coldwater sandstones underlying them. The character of the Rincon Surface is more difficult to determine in this area than in any other. It shows here the least complete development, because of the greater erosional resistance of these well-indurated sandstones.

The deep indentations in the 1000 foot contour in the vicinity of Casitas Creek, and West and East Casitas Passes at the head of Los Sauces Creek are important. They mark a belt of weaker rocks in the Sespe or Lower Vaqueros formations. A series of nodular shales with intercalated stringers of lenticular sandstone has proved less resistant than the siliceous Modelo shales to the south, or arkosic Sespe and Tejon sandstones to the north.

The particular significance of the pattern shown by the 1000 foot contour is the indication it gives of the former drainage of Los Sauces, Casitas, and the east flowing tributaries of Coyote Creek. During the Rincon Cycle they existed long enough to develop a trellis drainage pattern and arrived at almost complete adjustment with the rock structure.

With the coastal uplift responsible for the initiation of the modern cycle these streams were rejuvenated.

Their antecedent character is shown by the parallel course of the 1000 foot contour as it turns inland along the steep gorge of Los Sauces Creek, and less completely along Madranio Creek. The position of the contour is approximate, for all direct evidence of the actual presence of the Rincon Surface has vanished with the trenching of these streams.

The domed nature of the summit of Rincon Mountain is shown by the almost complete closure of the 1000 foot contour, and the completely closed 1500 and 2000 foot contours. The assymetric appearance of the mountain is indicated by their closer spacing on the eastern end of the ridge, where the slope between the summit of the mountain and Los Sauces Creek is especially abrupt.

The antecedent nature of Madranio Creek is not so obvious as in the case of Los Sauces, but a study of the behavior of the 1000 and 1500 foot contours shows the existance of a mature valley which formerly separated the 1866 foot hill from the larger ridge of Red Mountain. The structural control of the Red Mountain anticline over the course of Madranio Creek is shown by the curvature of its path around the anticline nose.

The long coastal ridge of Red Mountain is delimited by the 1000 foot contour. When viewed from either the seaward side or from the Santa Ana Valley, it forms a continuous, slightly domed crest, resembling the strike ridges of the Appalachians. Remnants of the Rincon Surface are fairly abundant on the summit and so the accordant summits of these hills indicate the former existence of the original surface, although they stand at a lower altitude.

Sulphur Mountain and the Buenaventura Hills

Nowhere else in the entire region is the Rincon Surface more completely preserved than in the sector lying between the Ventura River and Santa Paula Creek. If all the valleys excavated by the present cycle were to be filled, a gently undulating surface of low relief in the last phase of maturity would appear.

Sulphur Mountain

The monadnock-like summit of Sulphur Mountain is outlined by the 1500, 2000, and 2500 foot contours. All of these are completely closed and indicate an elongate, east-west ridge. From a distance it does not present as uniform a skyline as Red Mountain, but this lack is compensated for by the remarkable fidelity with which even the minor features of the Rincon Surface have been preserved.

Broad, glade-like valleys, a gently rolling, subdued topography, slopes mantled with a residual soil, and a landscape with the appearance of considerable geological antiquity survives 500 or more feet above the adjoining lowlands.

Figure 21

Summit of Sulphur Mountain

The higher Santa Ynez surface on the summit of Santa Paula Ridge is visible on the distant skyline.

The characteristics of the mountain, as well as the cliff along its southern face, have been discussed in the physiographic section, but there are a number of features worthy of note which are shown by the contours. The most significant is probably the 1000 foot contour$ on the northern and western sides of the mountain. Of especial interest is the closed contour at the extreme western end of the mountain between Fresno Canyon and the Ventura River. The two III level terraces, the highest in the river series, hold this small island-contour away from the main mass of Sulphur Mountain. This occurrence relates the terrace sequence to the Rincon Surface. The broad valley stage of the Ventura River represented by the highest, or III stage, is contemporaneous with the last phase in the formation of the Rincon Surface, as these terrace gravels rest upon it. This connection between the terraces and the erosion surface is further supported by the peat bog which occurs at an altitude of 1050 feet on the western side of the 1000 foot island, and is related to the Ventura River drainage in the Rincon Cycle.

The deep indentation of the 1000 foot contour in Lion Canyon is part of the drainage system of the former Santa Paula River. In fact, the entire course of the 1500 foot contour along the northern flank of Sulphur Mountain marks the course of the Santa Paula River. This continuation is due to the fact that the Rincon Surface has been buried here by the accumulation of Recent gravels heaped by the by the alluvial fan built out by Sisar and the unnamed creek to the west of it. In short, the upper Ojai Valley is an integral part of the Rincon Surface and is to be considered as an inherited part of the landscape.

The close spacing of the 2000 and 2500 foot contours on the southern face of Sulphur Mountain reflects the presence of the southern escarpment. To give a true representation of the original gradient of the Rincon Surface, the 2000, as well as the 1500, foot contours would be shifted southward. The present surface represented in the accordant crests of the Coastal Hills is a reflection of the original Rincon Surface, but at a lower elevation. Therefore, to more closely approach their true position, the 2000 and 1500 foot contours are moved south to compensate for the loss in elevation.

The Buenaventura Area

Although the Coastal Hills are some 500 to 800 feet lower than the top of Sulphur Mountain, they have an almost equal uniformity of elevation and preserve the original gradient of the Rincon Surface. Its gentle slope is revealed by the fact that a distance of 5.5 miles is required to drop 500 feet, a slope of less than 100 feet to the miles. This is shown over most of the area by the wide spacing of the 1000 and 1500 foot contours.

Figure 22

Accordant summits of the Coastal Hills, Point Mugu and the delta of the Santa Clara River are visible in the distance. The eastern end of the Ventura Avenue anticline is in the middle of the foreground

The pattern of the 1000 foot contour is significant. Its short distance from the outer margin of the hills is worth noting, and indicates the amount of downwarping of the Santa Clara Valley. It is interesting to observe the control of the underlying structure on the position of the 1000 foot contour. The distinct swing in its course at Peppertree Canyon is a reflection of the eastward plunge of the Ventura Avenue Anticline. The sharp bend in the 1000 foot contour at Santa Paula Creek may not be completely justified, as quite obviously the canyon is a part of the present erosion cycle. Nevertheless, the initiation of the southward drainage of the Santa Paula River, following its capture, is part of the Rincon Cycle and should be recorded.

Figure 23

Conglomerate ridge on axis of Canada larga syncline

The deep embayment is the 1000 foot contour at Canada Larga is a result of the presence of the Canada Larga syncline. That this portion of the syncline produced a basined effect on the topographic surface is hard to rationalize with the fact that east of Canada Larga, at the head of Leon Canyon, it has made a topographic high. This is indicated by the spearhead-shaped pattern of the 1500 foot contour, a completely closed one. The reason for this elevated area on a synclinal axis is the extra resistence of the rocks outcropping here. As indicated in the Structure section (Plate V), the 1950 foot peak in the center of the elevated area is underlain by one of the conglomerate reefs of the lower Pico. It is similar to the line of ridges paralleling the southern face of Sulphur Mountain developed in the conglomeratic facies of the Pico formation.

The Ventura and Ojai Valleys

That the Ventura River and Ojai Valleys are inherited features in the present landscape is shown by the behavior of the 1000 foot contour. This swings up both sides of the Ventura Valley, encircles the Ojai Valley, and coincides with the actual position of the Rincon Surface. It marks the lower limit of the surface as far as Casitas, and very nearly its upper limit in the northern part of the Ojai Valley. According to this interpretation, the topography of the Santa Ana Valley is derived from the Rincon Cycle, and the same holds true for the Ojai Valley as far east as Ojai. The Rincon Surface in the easternmost part of the Ojai Valley has been downwarped below the present level of the Valley floor, and is obscured by the alluvial fans built out from Senor and Horn Canyons.

The 1500 foot contour in the northern part of the Ojai Valley is probably part of the Rincon Surface, but stands some distance above the upper limit. It delimits the base of the Santa Ynez Range, and separates it from the upper extent of the Rincon Surface.

The Timber Canyon Area

Although the type locality for Gale's Timber Canyon Surface, it is the poorest area for an example of the Rincon Surface. That deformation has continued into the Recent and has not allowed the Rincon Surface to develop uninterrupted is indicated by the building out of tongues of fanglomerate which choke the stream channels cut in the Rincon Surface. The surface climbs to an altitude of 2500 feet in a lateral distance of 3 miles.

The Timber Canyon sector of the Rincon Surface never had a full opportunity to develop, and the advance reached in the cycle was little more than late youth or early maturity, as contrasted to late maturity elsewhere.

Summary

An analysis of the various subdivisions of the Ventura Region show that a late-Pleistocene erosion surface of moderate altitude has a widespread occurrence, with the exception of the Santa Ynez Mountains and the Santa Clara Valley. The name Rincon Surface is suggested to supersede the name Timber Canyon Surface proposed by Gale. The following characteristics of the Rincon Surface may be emphasized:

1) It was a surface of late maturity over most of the area in which it developed.

2) It was contemporary of the III and IV terrace levels in the river and marine series, and also a contemporary of the capture of Santa Paula River.

3) The surface reaches its best development on the summits of Rincon, Red, and Sulphur Mountains which swing in a clearly defined arc across the central portion of the Ventura area.

4) The surface, while destroyed over the Coastal Hills, still has its former presence indicated by the accordant heights of their summits.

5) It has shared in the Recent deformation which the area has undergone, and has been uparched along an axis coinciding with Rincon and Sulphur Mountains, and downwarped in the eastern end of the Ojai Valley.

6) Locally, the stage reached in the erosion cycle has been influenced by differences in rock resistance or structure.

7) The degree of preservation has in large measure been controlled by the underlying bedrock, with the best preservation in areas underlain by the siliceous shales of the Modelo.

8) The age of the Rincon Surface is considered as late Pleistocene. If follows the time of regional deformation and preceded the period of vertical uplift.

VENTURA RIVER TERRACES

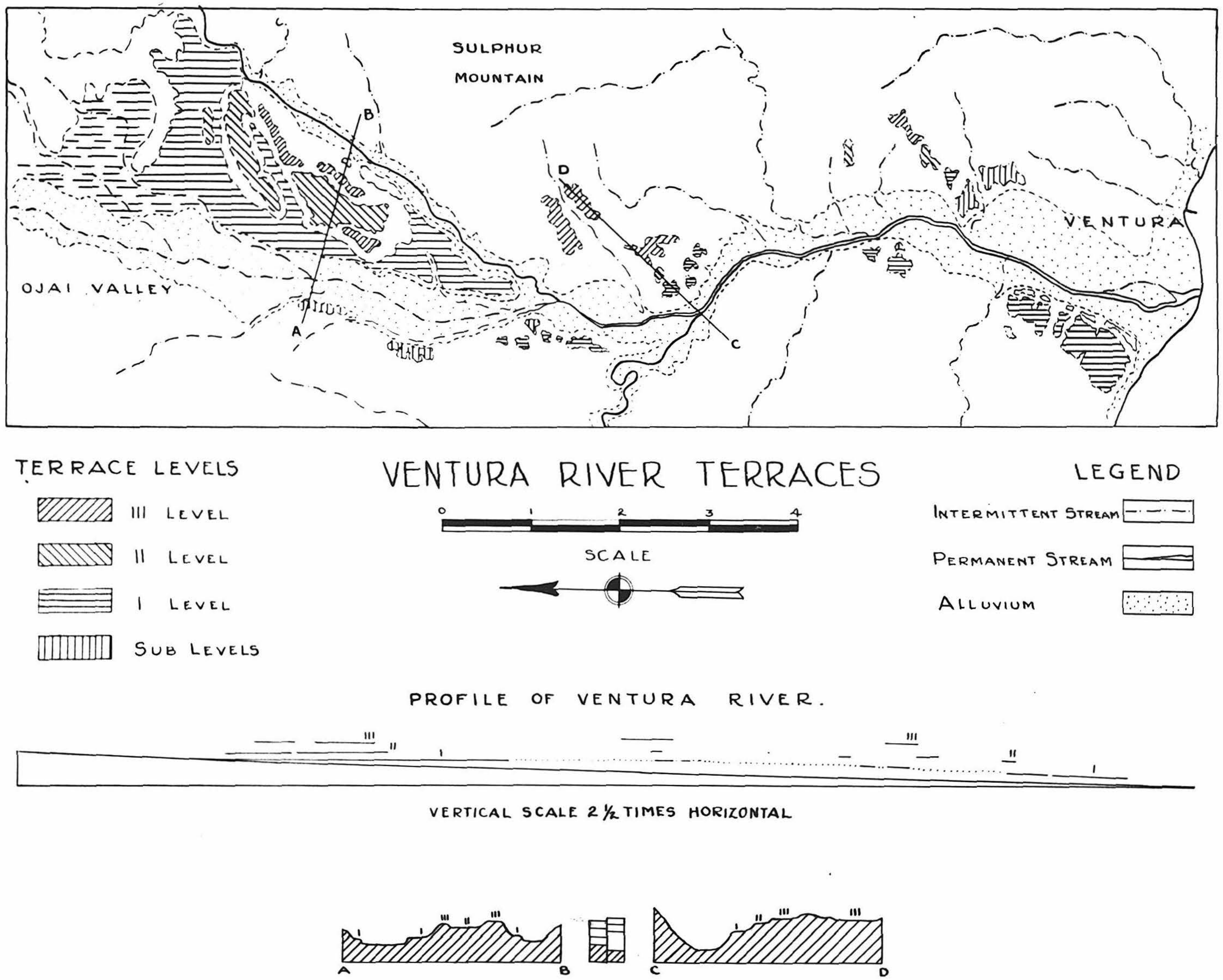
The terraces on the slopes of the Ventura River Valley provide a record of recent changes in level in the interior of the Ventura District, where the datum plane of sea level is not available for comparison. The distribution of terraces indicated on the accompanying map show that they are most numerous in the southern part of the Ojai Valley. Elsewhere they are widely scattered and harder to identify. On the map there are three distinct levels, preserved with sufficient completeness to be indicated as separate units. In addition to the three major terraces, among a host of minor ones, too small to be represented, one, the so-called "sub-level", merits individual notice and occurs near the central part of the area.

The longitudinal profiles of the separate levels, below the map, show a distinct warping as well as a regional uplift. This warping has been an uparching at right angle to the course of the Ventura River, with the axis at the western end of Sulphur Mountain.

This deformation, akin to the slow growth of a broad anticline, has proceeded to such an extent that terrace levels in the lower part of the Ojai Valley are now

Plate IX

Ventura River Terraces


SULPHUR
MOUNTAIN
VENTURA
OJAI VALLEY
A
B
C
D
TERRACE LEVELS
III LEVEL
II LEVEL
I LEVEL
SUB LEVELS
VENTURA RIVER TERRACES
0 1 2 3 4
SCALE
LEGEND
INTERMITTENT STREAM
PERMANENT STREAM
ALLUVIUM
PROFILE OF VENTURA RIVER.
VERTICAL SCALE 2 ½ TIMES HORIZONTAL

opposite sides of the valley appearing to be equivalent, may not prove to be so and may not even represent a still-stand or pause in the uplift. Rather they may be alluvial shoulders built out from the stream abandoned side of the valley towards that occupied by the stream.

In the following sections, the terrace levels along the Ventura River are described in individual sectors. These subdivisions are treated in order, starting with the Ojai Valley and ending at the coast near Ventura.

Ojai Valley

The Ventura River as it issues from the Santa Ynez Mountains and enters the western Ojai Valley flows through a narrow gorge in steeply inclined Eocene sandstones exposed in the Matilija overturn. After leaving the mountains its valley widens rapidly until it reaches a maximum width of 0.6 mile west of the railroad siding of Matilija. At this point the river flows in a series of braided channels across a boulder strewn flood plain.

The flood plain is bounded on both sides by nearly vertical walls revealing a cross section of poorly sorted gravels, boulders and cobbles. This deposit, 30-50 feet thick, is a representative sample of the type of material underlying the floor of the Ojai Valley. The significant points about the debris exposed in the low cliff on both sides of the river are: that it is the material deposited on the I, or lower terrace level, and that this I level grades into the floor of the present Ojai Valley. The Ventura River now flows below the level of the major portion of the Ojai Valley. The valley, which has been tilted away from the river, sends its drainage down San Antonio Creek.

This lower terrace, synonomous with the main valley floor, stands 50 feet above the river bed and slopes up to the Santa Ynez Mountains. It grades into the foot of the dissected, alluvial fan east of McDonald Canyon. The town of Ojai stands on the surface of a similar fan one canyon farther east. Both these fans are being eroded. With their surfaces channeled and gullied they no longer are building outwards. They are contemporaries of the II level. At least, they are older than the I level, since they were truncated at their base before the deposition of the terrace gravels which partially bury them on the I level.

The I level continues on both sides of the river as far as La Crosse. No comparison is possible as to the

Figure 24

Terrace gravels west of Oakview revealed by side cutting of Ventura River

the degree of preservation on opposite banks of the Ventura River. Terraces are almost lacking on the west side, and one of the most remarkable terraces in the Ventura Area is on the east bank.

The west side of the Ojai Valley is covered by residual soil, and the Sespe bedrock is revealed in many places. This erosion surface slopes toward the river in the direction it has been tilted, and is fronted by a narrow, gravel-covered terrace 30-40 feet above the river.

On the east bank the terrace commencing at Long Valley continues for 4 miles to La Crosse. It stands 25 feet above the present river floor at Long Valley, and by the time it reaches La Crosse, the height above the river bed has increased to 236 feet. This slope when plotted in profile is inclined back against the present gradient of the river. The amount of inclination averages 3 degrees. This inclination is the result of tectonic activity in the form of uparching, the axis of which lies south of Long Valley. The I level is preserved in almost its entirety as well as the two higher ones in this section of the Ventura River. A description of the characteristics of each for the Ojai Valley district is given below.

<u>I Level</u>

This level grades into the valley fill of the Ojai Valley at Long Valley. Its elevation increases southward until at La Crosse it stands above the junction of the Ventura River and San Antonio Creek in a wedge-shaped mesa. This mesa is an unusual sight, with its flat, cultivated surface breaking off abruptly in steep cliffs on the south, west and eastern sides.

On the Ventura River side the terrace is steeply cliffed. In one vertical bluff undercut by the river, north of the Devil's Gulch, a section of river gravels 150 feet thick is revealed. Individual gravel layers show a large variation in thickness, and range from a maximum of 100 feet down to 3 or 4 feet. Gravel is exposed at the summit of the grade from La Crosse to the terrace surface, by road cuts in Oakview, and in numerous other places. In almost every instance the gravel consists of an extremely coarse accumulation of unsorted boulders, gravel and sand, showing little stratification. Usually the boulders are scattered through a sandy matrix, and show almost as complete a lack of gradation in size as in glacial till or mudflow deposits.

The principal difference between the terrace gravels, and the other types of unsorted sediments, is that the boulders embedded in these deposits show a considerable degree of rounding. Many resemble roundshot, few are elliptical and angular ones are rare. Boulders a foot or more in diameter are encountered and some two feet through are not uncommon. All are stained reddish brown, and the sandy matrix has the

Figure 25

Terrace of I level at junction of San Antonio Creek and Ventura River. San Antonio Creek in foreground, view is to northwest or upstream.

has the same color. This staining by iron oxide is the most important weathering that seems to have occurred. Feldspar has survived either in sand grains or in rock fragments.

Figure 26

Terrace of I level at junction of San Antonio Creek and Ventura River.

The surface of this horizon, although level for the most part, shows some variation in slope. This is true of the area north of Devil's Gulch. The highway and railroad follow the edge of a low bluff below which, on a lower level stands Mirror Lake. The lake is a rush- and silt-filled depression. Enough of its former outline persists so that it may be recognized as an abandoned meander, or oxbow lake. The low cliff followed by the highway is the former cut bank.

II Level

The second level occupies the central portion of the island-like area between San Antonio Creek and the Ventura River. It stands between 750 and 800 feet above sea level, 450 feet above the present river floor. The II level presents a unique appearance, for it preserves in its entirety a cross section of a former stream valley. This cross section is best shown north of Oakview at the top of a 250 foot slope. The old valley floor is flat, covered with rounded gravels, and flanked on both sides by low eminences, capped by gravels of the III terrace.

The surface of the II level is almost flat, but is divided through the middle by a 50 foot cliff, produced by the meandering of the stream which crossed it. The soil on the surface is more deeply weathered than on the I level and contains a higher content of humus. The occasional boulders embedded in this sandy soil are weathered on their upper surfaces, and frequently exfoliation spalls may be pried off.

III Level

The highest level, while the poorest preserved of the series is in many ways the most important. Only three readily identifiable remnants survive. There are two at 900 and 950 feet on both sides of the II level at its lower end, while the third stands some distance to the NE above San Antonio Creek at an elevation of 1000 feet. From here it drops off abruptly in a steep cliff which reveals a cross section of terrace capping. The III level is floored with the largest boulders. Many exceed 2 feet in diameter and there is a scattering of 3 foot boulders. All are deeply weathered and stained a dark reddish brown.

The surface of this III level is aligned with the higher series of San Antonio Creek, and the upper Ojai Valley. To the south it stands at the same level as the two exceptionally high ones on Sulphur Mountain at Fresno Canyon. A contemporary of the Rincon Surface, it is also part of the same drainage system as the former channel of Santa Paula Creek on the north side of Sulphur Mountain.

La Crosse to Canada Larga

This is the most critical part of the Ventura

River Valley, as the axis of uparching passes through the center of the section. The various nearly horizontal terrace levels attain the greatest elevations.

In this area the valley of the Ventura River is narrowest, and has a breadth at one point near Foster Park of 0.2 mile. The steepwalled canyon through which the river flows is due in part to the resistance of the rocks it has here encountered, but probably of more importance is the fact that this point is the focus of the most pronounced uplift athwart the river's course. The river has been barely able to maintain its course against the elevation of Sulphur and Red Mountains. Because of this uplift, the river's prime concern has been to reduce its gradient, and little chance has been provided for a blanket of sediment to accumulate. Bedrock rises close to the surface of the river. There is no reservoir of gravels to absorb the water which even during the summer months runs in an open stream through the oasis extending from La Crosse to Canada Larga.

Because of the narrowness of the Ventura River canyon south of La Crosse, and the steepness of the slopes of Red Mountain and Sulphur Mountain, the terraces are little more than shelf-like remnants perched on the valley wall. The majority of them are confined to the west end of Sulphur Mountain with none of any significance occurring on Red Mountain.

The first large terraces south of La Crosse are on the west side of the Ventura Valley and extend in a fairly well preserved bench along the top of the ridge between the Ventura River and Coyote Creek. In this group only the I level is preserved with any degree of completeness, and shows a progressive increase in elevation to the south. At La Crosse it starts at 500-515 feet (214 feet above the river), and by the time a point overlooking Coyote Creek is reached, it stands at 550-600 feet (300 feet above the river) No trace of this I level exists east of Rocky Flats, as Sulphur Mountain ends here in a vertical cliff.

South of Rocky Flats no important levels are west of the river, and all the recognizable horizons are confined to the somewhat gentler slope of Sulphur Mountain. Although little more than benches, all the levels identified in the Ojai Valley are recognizable here and stand about the same relative distance apart.

The I level is best preserved on the shoulders of the two ridges, one of which stands behind Casitas, the other back of th entrance to Weldon Canyon. The I level is readily recognized on the Casitas ridge, where it stands as a distinct bench 630-650 feet above sea level (300 feet above the river). The II level stands at approximately 800-850 feet, and is more difficult to recognize.

The III level here is the most significant of the entire series, and is a remnant of the valley floor of the Ventura River at the time that the Rincon Surface was nearing the close of its erosion cycle. It stands below the old valley walls but has the open, almost flat character of the gently rolling landscape of that time.

At the westernmost point of Sulphur Mountain, overlooking the modern canyon of the Ventura River, the oldest level is at an altitude of 1050-1100 feet above sea level, or 725 feet above the river's floor. The type of sediment preserved on the III level has a peculiar interest, since it indicates something of the middle Pleistocene landscape. The reason is that the debris on the surface of this terrace accumulated on the floor of a former swamp or peat bog. The sediment is a fine grained, well-sorted silt and sandy clay, or loam, darkly stained with carbonaceous matter. It is the type of detritus expected in the still waters of a back swamp or bayou. The particular interest

Figure 27

III level terrace above Fresno Canyon at western end of Sulphur Mountain

attached to this accumulation is that the organic matter preserved in this stream deposit consists of plant leaves and stems. The majority of these are conifers, and indicate a cooler, and quite possibly a rainier climate than the present one. The Rincon Surface may be the product of a more humid climate than prevails in this region today.

Immediately east of the III level of the Ventura Terraces is a low ridge sloping east towards a somewhat lower saddle on both sides of Fresno Canyon. It stands at an average altitude of 900-950 feet above sea level, and if the ravine cut across it by the Fresno Canyon is ignored, has a length of 0.5 mile and a breadth of 0.7 mile. The surface of this broad platform is floored with black, silty loam in which are embedded reddish-brown sandstone boulders often several feet in diameter. These boulders are Eocene, Coldwater Sandstone. The distance to the nearest outcrop of the formation from which they are derived, indicates that they have been transported at least 10, and possibly 12 miles.

This double terrace, located below the old Tip Top Oil Field (of more historic than economic interest) is part of the Ventura River Series. It is separated from the Ventura River Valley by a distinct ridge, and may belong to an independent drainage system or a branch of the Ventura River. The occurrence of these sandstone boulders make it appear a drainage system of more than local origin. That it was extensive is indicated by the breadth of the old valley floor, by the size of the boulders, and by the distance which they have travelled.

Although the connecting levels are missing, there is little doubt that this terrace represents a part of the channel of west-flowing Santa Paula Creek along the north slope of Sulphur Mountain, before the capture and diversion took place as described in the section dealing with Santa Paula Creek.

Canada Larga to the Pacific

One other series of levels in this area is worthy of notice. It consists of a number of small independent terraces, none of any great size, and all standing below the I level. They are most distinct in the Sulphur Mountain area, and form a series of 3, and possibly 4 minor levels. It would be appropriate to term these the sub-level series, since they can not be traced for the length of the river.

They are most numerous in the canyon area for two reasons; 1) this is the area of maximum uplift, which presumably has taken place here at the most rapid rate; 2) in the narrow space available the river swung at a correspondingly more rapid pace from side to side than it did to north or south, and left a greater number of meander benches.

These sub-level terraces are well developed along the Foster Park Road on the west side of Rocky Flats. At least 3 levels occur, the highest as much as 100 feet above the river, the lowest only 25 or 30 feet. They are quite numerous at Casitas on the east side of the river. A large one is apparent in a road cut near the Edison Company substation. These sub-levels are best developed in the small embayment on the west slope of Sulphur Mountain south of the junction of the Ojai and Foster Park roads. The highest of the sub-levels stands at an elevation of 350 feet above sea level (100 feet above the river), a second slightly above the level of the highway and two lesser ones below.

These groups of smaller levels are reminders of the temporary presence of a rapidly downcutting stream, forced to exert the principal measure of its force to overcome the elevation of a mountain barrier across its path.

Canada Larga to the Coast

South of Sulphur Mountain, the valley of the Ventura River broadens rapidly until it has a width of one mile. In this final stretch, the river cuts through the thick section of Pliocene sandstones and clay shales exposed by the folding of the Ventura Avenue Anticline, whose axis strikes normal to the river's course. Because of the limited erosional resistance of the Pico formation, many of the terrace levels have been destroyed in this region.

This destruction of terraces is practically complete in the area between Canada de las Echinas and Canada Larga. No traces of the higher levels are preserved, and only two fairly extensive benches of the sub-levels are found, one at the level of the highway and the other nearer the river. The tops of the ridges nearest the valley edge stand at accordant elevations and appear to be part of the same surface. No gravel covers them and they are not mapped as terraces.

South of Canada de las Encinas are a number of notable terraces. The first and most distinctive is west of the river at the northern limit of the Ventura Avenue field. Its flat mesa-like summit is the most outstanding landmark on the west side. The terrace itself is a double one. The larger part is the higher and slopes from 500 to 600 feet. This upper portion is a remnant of the valley floor equivalent to the I level of the Ojai Valley and Sulphur Mountain. The lower level stands at 350 feet, or 150 feet above the present valley floor, and is one of the higher sub-levels.

The problem of correlating this higher level with those of the upper river is made difficult by the lack of any large terraces in the 2.5 miles separating it from Sulphur Mountain. A consideration of the natural slope, elevation, and appearance leaves little doubt that this is a correlative of the I level.

On the east side of the river, on the axis of the anticline, and in the middle of the Ventura Avenue field are a number of well preserved terraces. Their dark brown, horizontal cappings may be seen in road cuts made for the numerous well locations. Three major levels appear to be present, the highest standing at 900 feet, the intermediate at 750 feet, and the lowest at 450 to 500 feet.

The most interesting of this series is the sub-level projecting in a distinct promontory, known as Gosnell Hill, over which the road climbs immediately after leaving the Pacific-Western Company's lease and before dropping down grade to the Shell Oil Company's field office. The horizontally stratified boulders of this level rest in a sharp angular unconformity on bevelled edges of steeply tilted Pico sandstone. This sub-level slopes from 200 to 250 feet above sea level (100 feet above the river) and continues across the School Canyon Road to form the slope upon which the California School for Girls is built. No other terraces are found on the east side of the valley. The river has been actively undercutting long enough to produce a steep 675 foot slope, cut in material about the consistency of clay.

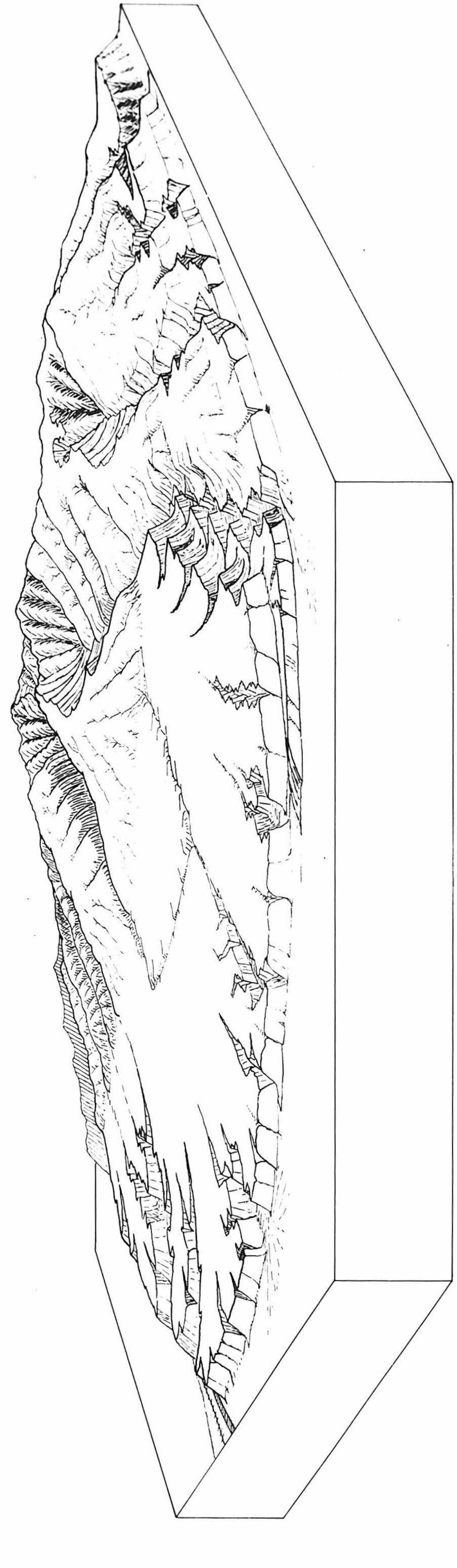
On the west side of the river is one of the most complete series of terraces in the entire area. They are as well developed as those of Rincon Mountain or the Ojai Valley, and provide the only connection between river and marine terraces. This group extends in an apron 0.7 mile broad and 1.5 miles long at the base of the 1100 foot peak on the west bank of the Ventura River at its mouth. The appearance of this series is shown on the block diagram in Plate X.

The series consists of three distinct levels, of which the central is the most prominent. All have a strong seaward inclination, with a more pronounced slope than the present river gradient. This apparent tilting is a conse-

Plate X

Block Diagram of river and marine terraces

at mouth of Ventura River



quence of the recent uparching with its axis near Sulphur Mountain. These terraces are on the southern limb and have been tilted seaward.

Of the three levels visible, the central is presumed to be the equivalent of the I level of the Ojai Valley, and is equal to the isolated remnant opposite Canada de las Encinas. The lowest level finally disappearing near the coast is the last remnant of the sub-level. The II is the only one of the higher levels to have endured, and it is imperfectly preserved. The I level slopes from 350 down to 250 feet in its longest dimension with a fall of about 100 feet to the mile.

The curious thing about these levels, as may be seen from the accompanying block diagram, is the extent to which they are blanketed by alluvial fan material washed over their surfaces. Another difficulty is the fact that the streams which cross the terraces have excavated their canyons to such unequal depths. The two northernmost streams have cut deep gorges, while the southernmost, although it broadens out to form a large valley in its upper reaches, has produced little more than a shallow trench across the terrace surface. The explanation for this unequal rate of erosion is not known.

PLEISTOCENE ELEVATED STRAND LINES

In the following sections the elevated marine terraces, one of the most distinctive physiographic features of the Ventura Region, are described in detail. The series is not to be described as a whole, for the coastal district has been subdivided into a number of lesser units. These are, in order from West to East; the Carpinteria Plain, Rincon Mountain, Los Sauces Creek to Padre Juan Canyon, Pitas Point to the Ventura River, and the area east of the Ventura River.

The marine terraces along the coast are numbered in sequence, with the lowest, the I level, and the highest, the IV level. The system is based on the arrangement that the terraces are numbered in the order in which they are encountered in climbing from the base of the series to the top.

Carpinteria Plain

This physiographic province is the westernmost coastal area included in the discussion. It is an elongate plain of marine abrasion, covered with a thin veneer of alluvial deposits, and tilted westward. The part of its surface investigated has a length of five miles, a width of three, and an average elevation of 300 feet on the landward side.

The plain, crossed through the center by the arroyo of Carpinteria Creek, is terminated to the east by the valley of Rincon Creek. On the seaward boundary it is abruptly ended by a sea cliff, which rises to a height of 200 feet at Rincon Creek , and decreases in elevation to sea level at the Estero of Carpinteria Creek on the west. Its northern limit is the southern slope of the Santa Ynez Range. At this point the Coastal Hills and the Sulphur Mountain Upland, have disappeared and left only the higher mountains of the interior. The Santa Ynez Mountains continue parallel to the coast until they end at Points Conception and Arguello.

The Carpinteria Plain is the easternmost portion of the narrow piedmont coastal strip on which the City of Santa Barbara stands. The line of demarcation between its relatively gently sloping surface, and that of the southern escarpment of the mountains is sharp. As a rule the mountain streams in this area have built no large alluvial fans. Instead of aggrading at the present time all are downcutting in their effort to reach grade.

No recognizable marine terraces occur along the mountain front in this area. Their absence is difficult to explain, especially as they are so prominent farther east on Rincon Mountain. The explanation is probably the greater resistance of the rocks in the Santa Ynez Mountains. Little more than a narrow bench was excavated in one terrace epoch, to be destroyed in the following one. The declivity of the mountain slope has been increased through wave attack and the majority of the spurs are faceted. The streams cross the plain in narrow arroyos, and the lack of alluvial fans of any great size is due to the recency of uplift.

The surface of the plain, instead of presenting a uniformly sloping gradient, is considerably diversified. There are two types of land forms interrupting it.

The first, is the series of so-called "mesas" at the foot of the mountains, and the second, are two parallel ridges near the shore which rise to 250 feet and parallel the coast.

The "mesas" occur in a belt along the northern side of the area and reach a maximum elevation of 700 feet. They are marine terraces, cut across the surface of strongly tilted, early Pleistocene fanglomerates. Some of these alluvial fan deposits, composed largely of Sespe and Tejon boulders, have dips as high as 30 degrees. In addition to these older deformed gravels deposited at the foot of the rising Santa Ynez Mountains, some of the larger terraces, particularly, the one west of Shepherd's, bevel Miocene strata.

The surfaces of the older terraces are now covered with reddish, poorly sorted gravels; some of the boulders included are more than one foot in diameter. They appear to have been deposited by torrential streams of high gradient whose velocity was checked in crossing a fairly gently sloping surface.

These terraces, largely confined to the area between Carpinteria and Rincon Creeks, belong to an earlier period than the plain. They stand in two distinct levels, and are presumably correlatives of the II and III levels on Rincon Mountain, and are also related to the series developed on the southern side of the valley of Casitas Creek. The highest level stands at an elevation of 600 to 700 feet and the lower ranges from 250 to 500 feet.

The parallel coastal ridges mentioned above, standing about 0.1 to 0.2 mile apart, are separated from the nearest mesa by about 0.4 mile. The highest and also nearest the mountains, reaches a maximum height of 310 feet, the lesser, nearest the coast rises to 290 feet. The highest is covered with a reddish brown sandy soil in which cobbles with a diameter of 3 to 4 inches are frequently found. The one nearest the coast is blanketed with a layer of grayish black sand, occasionally well saturated with bituminous matter. A large number of broken shell fragments are concentrated in places, but most of these are confined to edible varieties of shellfish and are a midden deposit. Some rock fragments are scattered through the sand, particularly on the side twards Rincon Creek, and are about the size of coarse gravel, 1 to 3 inches in diameter. The sand which covers this lower ridge is cross bedded, and quite likely is a late Pleistocene dune sand.

The landward slope of the higher ridge is abrupt and straight throughout its length. It is aligned with a fault zone on Rincon Mountain, and also exposed on the bank of Rincon Creek. Between the two ridges is an undrained basin which is a sag pond. In the highway excavation, to the west of the causeway over the railroad tracks, is an exposure which reveals one of the most remarkable faults in the area. Highly contorted, Miocene Modelo shale is thrust over comparatively undisturbed Pleistocene dune sand. The sandy veneer covering the ridge surface extends undisturbed over both sides of the fault.

Records of wells drilled in this area are significant. In the Scott well, Pliocene material was found thrust over Pleistocene deposits. In a Texas Company of California well drilled near the coast a fault was encountered whose dip, projected to the surface, intersects the base of the scarp which forms the boundary of the northernmost ridge.

The Carpinteria plain of marine abrasion has undergone a marked degree of deformation by faulting since its uplift. Displacements certainly occurred in the late

Pleistocene, and may have continued into the Recent. The surface of the Carpinteria Plain has recently emerged from the sea, and is covered with only a thin blanket of sand and loam. Near the coast where this cover is exposed on the sea cliff it is seldom more than 20 feet thick, and is as a rule, underlain by rounded cobbles and boulders. The whole surface deposit rests on nearly vertical, truncated Miocene strata.

The sea cliff is particularly significant for its pronounced increase in elevation to the eastward. At Rincon Creek it is 240 feet high and slopes westward down to sea-level at Carpinteria Estero, distant 3 miles. There is little doubt that the plain has been tilted westward. In fact, the area about Carpinteria has been depressed below sea level, and at the Estero converted into an embayed shoreline of submergence.

The date of the most recent uplift of the Carpinteria Plain and its closely related neighbor, Rincon Mountain, responsible for the I terrace level, occurred in the last part of the Pleistocene and may readily have continued into recent times.

Summary

The sequence of events which occurred in the Carpinteria area is somewhat different from that elsewhere along the coast, and is as follows:

1.) The anticlinal uparching of the Santa Ynez Mountains in the middle Pleistocene supplied a quantity of detrital material to the streams on their southern slope. This was deposited in a series of overlapping alluvial fans.

2.) Uplift continued and faulting deformed these fanglomerates by tilting them as much as 30 degrees.

3.) Their surface was bevelled by two terrace levels, produced by the intermittent uplift of the Coastal region.

4.) This uplift continued until the Carpinteria Plain was laid bare in the late Pleistocene.

5.) In sympathy with the rise of the Rincon Mountain area, the entire plain was tilted westward. The western portion was depressed below sea level, the eastern part elevated to a maximum height along the coast of 250 feet.

6.) Faulting continuing into the Recent has elevated some parts of the surface to form ridges, depressed others to produce sag ponds.

Rincon Mountain

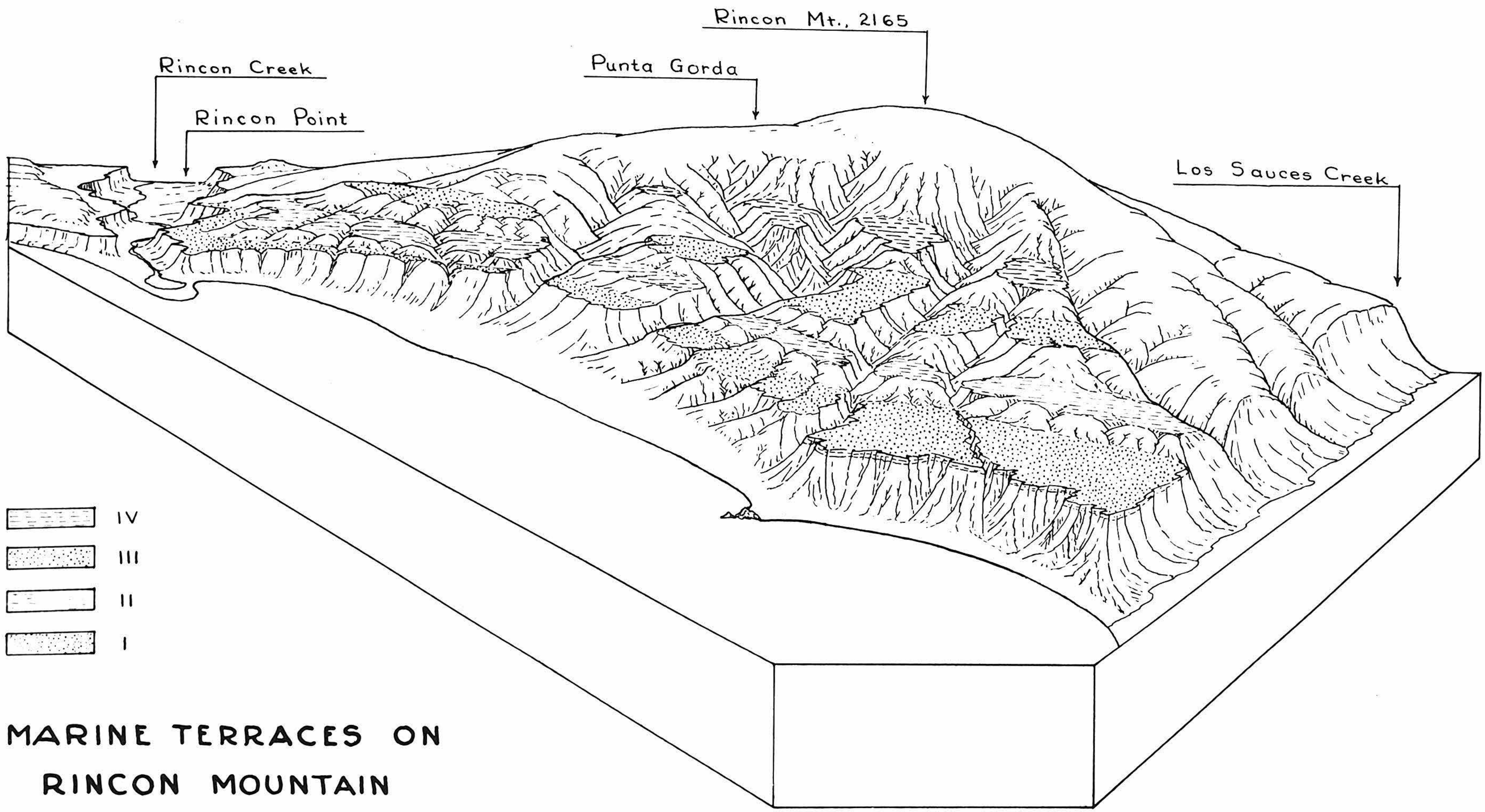
One of the most distinctive landmarks of the entire region is the isolated, bald summit of Rincon Mountain which stands 2165 feet above the sea at its base. The crest of the peak is a rounded dome, increasing in elevation to the eastward with a very gentle gradient. The slope from the water divide of the mountain to the base is abrupt, notably on the eastern and western ends where it is bounded by Los Sauces Canyon and the Carpinteria Plain.

The mountain presents the most remarkable appearance on the ocean, or southern, side. From the summit remnant of the Rincon Surface the slope is precipitous for a maximum vertical distance of 750 feet. Then the declivity becomes less abrupt, and the front of the mountain slopes down in a series of broad steps, much like the treads and risers of a stairway. This more gradual profile is abruptly terminated at the coast line by a sea cliff, which rises to an elevation of 550 feet and is one of the highest in Southern California.

The step-like benches on Rincon Mountain between its summit and the coastal sea cliff provide the greatest

Plate XI

Block Diagram of marine terraces on Rincon Mountain



MARINE TERRACES ON
RINCON MOUNTAIN

interest for they are elevated marine terraces. They are neither so broad, nor so readily recognizable as the San Pedro Hill series, but therj significance is fully as great. No other place between Santa Barbara and San Pedro preserves as complete a sequence.

Of the many points in common in the two terrace series, San Pedro and Rincon, probably the most significant is that both were cut in a practically identical rock type. In both instances the foundation is provided by highly contorted, intensely deformed Miocene shales. In this series the main rock type is a platy, brittle, white or tan colored siliceous shale.

It would seem that the erosional resistance of these siliceous shales is related first to their imperviousness; and secondly, to the fact that when they decompose they yield a sticky, coherent, gumbo-like black soil. Instead of washing away readily, the soil plasters itself firmly in place and forms a tight bond over the bedrock beneath. When this surface covering is broken, rills and gullies form rapidly and aided by the great number of joints, narrow and deep stream channels are soon excavated.

Figure 28

Recent gully cutting sea cliff behind Punta Gorda

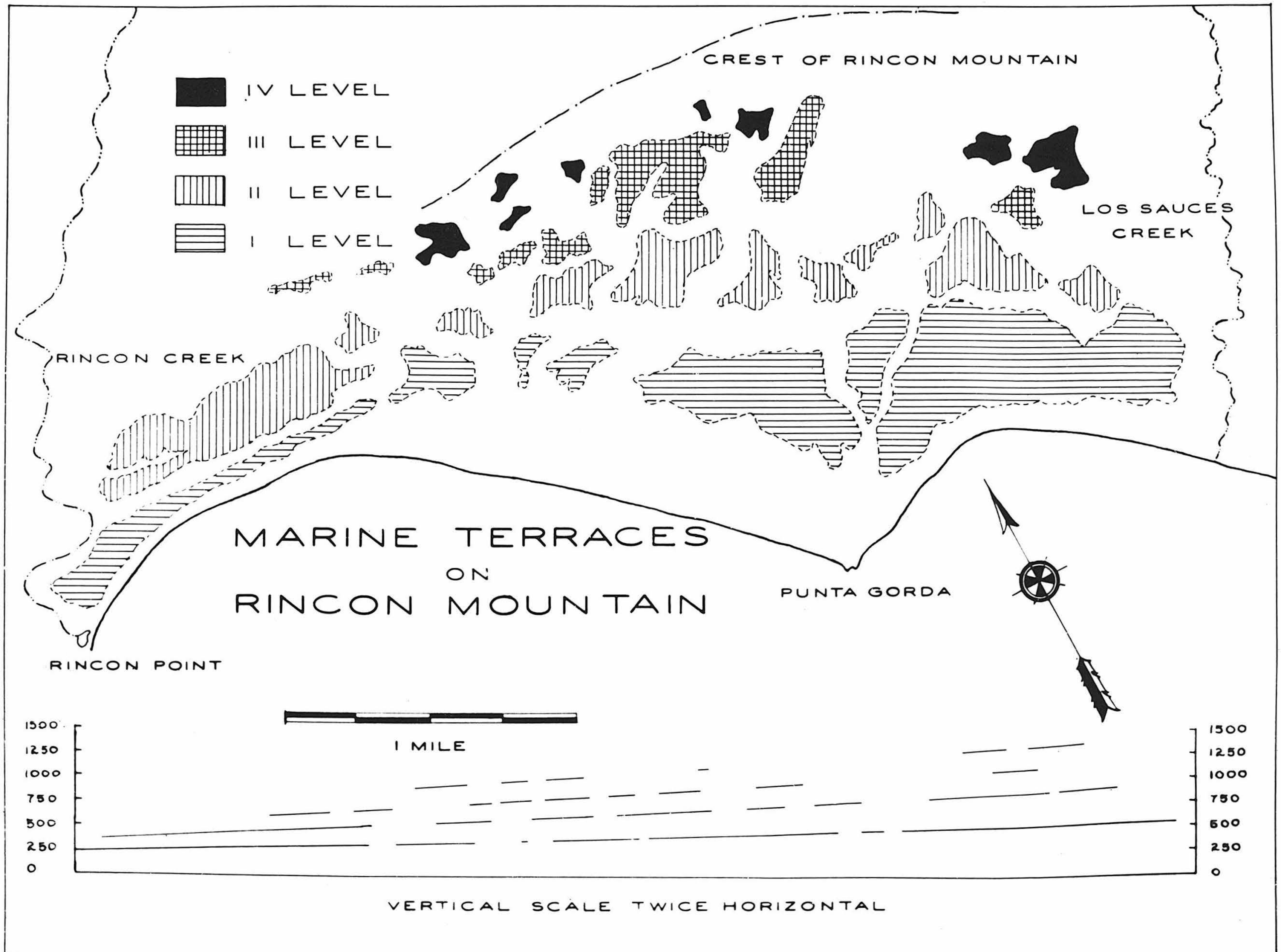
The stream channels which dissect the surface of these elevated strand lines provide an interesting study as they are more mature in their upper courses than in their lower. The reason is that the upper terraces have been subjected to subaerial erosion for a longer period of time than the lower. Four comparatively deep gorges have been cut in the present sea cliff of Rincon Mountain, and of these four streams only one has succeeded in cutting a canyon across the I terrace level. It drops at the rate of 900 feet per mile in its lower course, and has an even steeper gradient in the upper portion. The others cross the lower terrace in narrow ravines. Many of the lesser streams which have formed fairly open channels through the upper levels, make only the faintest impression on the lowest. Not one of the streams on this southern slope of the mountain reaches the sea. All disappear at the foot of the sea cliff and their water sinks into the beach sand.

The marine terraces of the southern slope of the mountain are the most important feature of this area. They are cut in the sloping portion of the mountain between the summit cliff and the present sea cliff. There are four major levels, and their most notable characteristic is the eastward increase in elevation. They indicate a pulsatory elevation of the land in comparatively recent times, and an appreciabel amount of warping in addition to the vertical uplift.

This eastward increase in elevation as well as the distribution and elevation of the various levels, is shown on Plate XII. This map is an approximation, for one

Plate XII

Map of marine terraces on Rincon Mountain


MARINE TERRACES
ON
RINCON MOUNTAIN
IV LEVEL
III LEVEL
II LEVEL
I LEVEL
CREST OF RINCON MOUNTAIN
LOS SAUCES CREEK
RINCON CREEK
PUNTA GORDA
RINCON POINT
1 MILE
1500
1250
1000
750
500
250
0
VERTICAL SCALE TWICE HORIZONTAL

of the problems in mapping terraces developed on this type of foundation is the difficulty of identifying levels and correlating them over distances. There has been a great deal of soil wash and slumping. The outlines of old sea cliffs are blunted and the surfaces of wave cut platforms are buried beneath detrital material. The uplift of this portion of the shoreline has been comparatively rapid. The distance separating any two strand lines is slight, and as a result of tilting they merge with one another.

Four terrace levels are distinct enough to warrant a place on the map. They are best spoken of as terrace zones; for each of these major levels includes some minor ones. These terraces were located on a series of Fairchild Aerial Survey's 8" x 10" contact prints on a scale of 1:24,000. Elevations on the upper surfaces of the various levels were obtained by an aneroid barometer, and compared with the U. S. G. S. topographic map of the Ventura Quadrangle. Neither of these methods is very accurate but the limit of error does not exceed the thickness of the terrace capping. At no point was the abraded rock surface of the terrace accessible.

The same nomenclature applied to the river terraces is here utilized. No attempt is made to correlate these marine terraces with those of the river, other than to point out that such a relationship as indicated below may hold:

Rincon Mountain	Ojai Valley
Marine	River
IV	III
III)	
)	II
II)	
I	I

First Level

This is the youngest and most readily recognized level of the series, for it has been least eroded following its uplift. It is the broadest level on Rincon Mountain, and is fronted by the highest sea cliff. This cliff increases in elevation from 200 feet at Rincon Creek to 550 feet at Los Sauces Creek on the eastern end of the mountain, a rise of 350 feet in 3.5 miles or 100 feet per mile.

The level is best preserved behind Rincon Point on the western end, and from a position midway between Rincon Point and Punta Gorda to Los Sauces Creek on the eastern. It is lacking in the central part, and here the sea cliff rises to the second level, which extends across the I level in a salient similar to that still present at Punta Gorda.

Figure 29

Rincon Point with the Carpinteria Plain in the distance. The sea cliff and lower terrace levels of Rincon Mountain in the foreground.

The eastern and most interesting portion of this level is broad enough to be represented on the topographic map. This segment has a length of 1.5 miles and a width of 0.5 mile. The nearly vertical 500 and 550 feet sea cliff of Punta Gorda has been cut into it. This cliff reveals a landward dipping section of the Pico formation, surmounted by a 40 to 60 foot capping of horizontally stratified terrace gravel. The angular unconformity separating the two series is visible from the highway 500 feet below. The terrace deposits are light colored, unconsolidated sands, silts, and gravels. The latter are composed of wave rounded fragments of Modelo shale and Pico sandstone often riddled with Pholad borings.

Incipient stream erosion has commenced the raving of the surface of the terrace. The majority of the streams which empty into this level from the upper levels are now constructing small alluvial cones. The few gullies across it working back by headward erosion from the sea cliff appear to have been aided by the cultivation of lima beans on the terrace surfaces.

Figure 30

Horizontal terrace capping of the I level

Figure 31

Sea cliff behind Punta Gorda

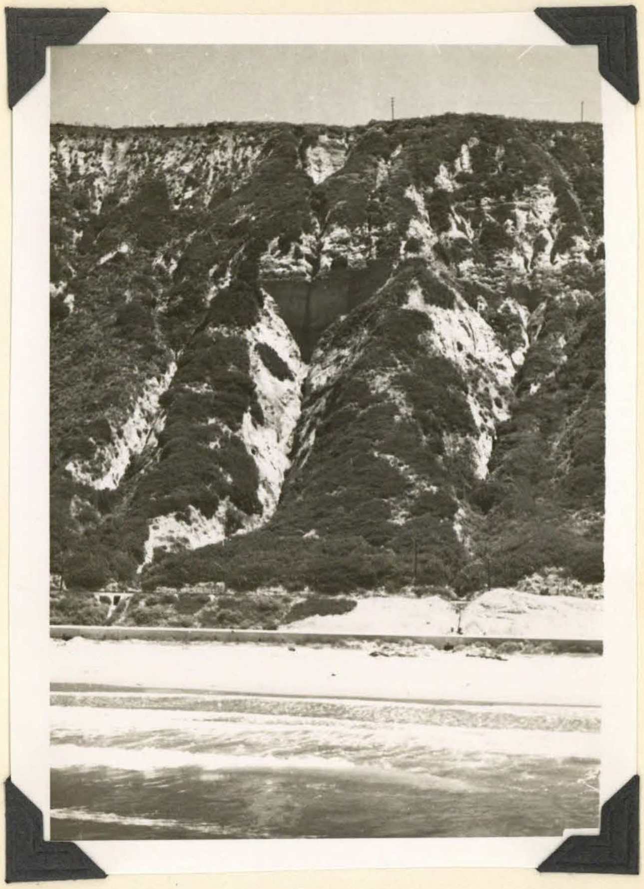


Figure 32

Steep ravines on face of Punta Gorda sea cliff

Figure 33

Surface of I level behind Punta Gorda

II and III levels on skyline.

Figure 34

Punta Gorda and the I level of the Rincon Terraces.

Second and Third Levels

The connection between these two levels is the closest of the series, and as a consequence the greatest difficulty is encountered in separating them. The sea cliff dividing these two levels is 50-100 feet high, and has lost its original steep profile.

Figure 35

Pitas Point and the I level from the II level.

These two levels with a number of closely related sub-levels are best preserved in the central part of the Rincon area. This is particularly true of the II level, which extends completely out to the sea cliff and replaces the I level in a promontory similar to Punta Gorda.

Figure 36

Battered sea cliff separating the II and III levels.

The III level has been modified by soil creep, gullying and stream dissection. Only scattered remnants of this once continuous strand line survive. These are best preserved near the central part of Rincon Mountain where their distribution closely parallels that of the II level. In both these levels most of the terrace capping has been stripped leaving only occasional rounded pebbles and boulders, a few of which are riddled by Mollusc borings.

Fourth Level

This elevated strand line is among the more interesting of the group. It is the oldest, and now stands at the highest altitude of the entire series. It has undergone the greatest amount of denudation and obliteration. A few remnants survive at the extreme eastern end of the mountain, where two large patches are visible; in the center and in a few isolated levels, or bevelled ridges on the western edge of Rincon Mountain.

The western occurrence of this level is interesting for the surface is frequently covered with fossil shells, both complete and fragmented. These are principally Pelecypods, with a scattering of Gastropods, and

Figure 37

The III and IV levels at the eastern end of Rincon Mountain.

sea urchin spines. Found in place they occur in a petroliferous brown sand with some silt and clay. The deposit in which they originate is unconsolidated and has a synclinal structure. This unconsolidated deposit in which the terrace levels have been cut is part of the Santa Barbara formation. It is latest Pliocene or earliest Pleistocene and contains a cold water fauna. The organisma preserved in this deposit antedate the terracing epoch. They accumulated on the floor of a small bight, which then covered the present area of the Carpinteria Embayment and extended over the flank of Rincon Mountain. They were deposited in shallow water at no great distance from shore.

The battered sea cliff behind the IV level extends to the domed summit of the mountain 750 feet above. Were this cliff restored it would be one of the highest and most continuous of the inter-terrace cliffs. Given the same rock type, the height of a sea cliff provides a measure for comparison of the distance two shorelines may have retreated and the breadth of the wave cut and built platform. The IV level, now the poorest preserved, at the time of its origin was the broadest of the series, with the exception of the submerged platform at the base of the modern sea cliff.

Comparisons of the Elevations of the Rincon Levels

The significant point for the determining of terrace elevations is the abraded rock platform at the base of the sea cliff, and not the surface of the detrital material which blankets it. This diagnostic point is nowhere visible on the slopes of Rincon Mountain since the majority of the levels are mantled with debris.

The series of elevations which follow indicate in a general way the magnitude of the uplift which has occurred, but most importantly they demonstrate the fact that warping has been an accompanying feature of general uplift. In the table below two sets of elevations are given for each level. Those in the top line are altitudes along the sea cliff, the lower are taken on the back slope. Both sets are measured in sequence from west to east.

Terrace Elevations of Rincon Mountain

IV Terrace	900	1290	1245	1355			
	950	990	1285	1380	1410		
III Terrace	620	1080	1085	1150	1155	1180	
	640	1147	1275	1280			
II Terrace	395	490	680	705	720		
	490	500	555	800	785	805	970
I Terrace	210	380	400	445	500	555	560
	380	530	650	590	675	570	

Los Sauces Creek to Padre Juan Canyon

This sector presents a different appearance from the preceding one of Rincon Mountain. Instead of culminating inland in a single domed summit, it is divided by sharp ridges between deep valleys, two of which are antecedent to the elevation of the coast. Terrace levels, instead of forming conspicuous features of the landscape are notable for their absence.

The rocks of this coastal area are unlike the deformed Modelo shale of the western and central parts of Rincon Mountain. In the Los Sauces-Padre Juan salient the Ventura Avenue anticline reaches the sea and plunges westward beneath its surface. This fold is developed in the shales, mudstones, and sandstones of the Pico formation. The axis of the structure intersects the shoreline at the railroad station of Sea Cliff and passes through the oil field of the same name. The seaward extension is marked by the oil wells drilled on piers, one of which extends half a mile from the shore.

The dominant structure of this segment is a large anticline developed in rocks of only slight or moderate erosional resistance. The most noticeable

Figure 38

Wells drilled on piers in Seacliff field.

features of this area are the abrupt seaward slope of the coastal hills, their accordant summits, and the deep canyons cut across the axis of uplift. These deep canyons are at right angles to the trend of the Ventura Avenue anticline, and do not seem to have been influenced by its presence.

Among the antecedent streams the largest is Los Sauces Creek. It flows through a canyon with a maximum depth of 1500 feet and a length from Casitas Valley to the sea of 2.5 miles, in which distance it drops 250 feet. The canyon is narrow enough in its central part to be nearly impassable. It is only in the upper reaches, after it has crossed the Rincon-Red Mountain axis, that it widens out and branches at right angles to the lower course to form the Casitas Valley. The walls of the canyon are precipitous to a height of 1100 feet above the stream bed. From this point they widen to form a broader, mature valley, part of the Rincon Surface.

This topographic unconformity across the axis of uplift in the case of both Los Sauces, Madranio and Padre Juan Creeks, coupled with the entrenched meanders developed by each of these streams indicates their antecedent nature. Their present courses were outlined during the Rincon erosion cycle. They were rejuvenated by the late Pleistocene uplift of the coast.

The appearance of this sector is determined by the type of bed-rock on which stream erosion, wave attack, and rain wash have played their part in sculpturing the surface. In common with other areas underlain by the Pico formation, only a scanty growth of grasses, sage and wild mustard is supported. The canyons are deep, and ridge crests, though rounded, are narrow. Where the slope is oversteep, landslides, slumping, soil creep are frequent. In spite of the rapidity of erosion, the slope from the Rincon-Red Mountain Crest to the sea would be gentle if the valleys were restored to their original profile and the present sea cliff ignored.

The I is the only terrace lvel to be preserved in its full extent, and only on the ridges between Los Sauces-Madranio Canyons and Madranio-Javon Canyons. Here terrace remnants which appear to coincide with the I level of Rincon Mountain and possibly the II level are left as flat-topped ridges, covered with patches of rounded pebbles and cobbles. These levels, as would be expected, show the same increase in elevation eastward as those of Rincon Mountain and Carpinteria Plain. That is, the I level runs from 700 feet through 750-800 up to 850 feet on the west side of Padre Juan Canyon. An increase of 850 feet through westward tilting in a lateral distance of 9 miles from Carpinteria.

Higher l vels than I and II are faintly indicated on the seaward slope of ridges in this area. No patches of gravel remain, nor are any flattened surfaces which are undoubtedly terraces to be seen. The sole evidence of one of these high levels is a small deposit of shells occurring at an altitude of 1500-1540 feet on the divide between Madranio and Javon Canyons. Instead of representing a terrace horizon they may have weathered out of an isolated occurrence of the Santa Barbara formation, in a fashion similar to the exposure at the west end of Rincon Mountain.

One other noteworthy terrace is at the head of Padre Juan Creek. The surface of this level ranges from 1250 to 1500 feet in altitude, and covers an irregular area of 0.5 mile in diameter. It is cut in steeply dipping rocks of the Sespe formation and is underlain by poorly sorted and stratified, reddish boulders and stream laid gravel derived from the Sespe formation. This level forms the floor of a bowl-like valley on the south flank of Red Mountain anticline.

Although this level has been destroyed farther down Padre Creek, traces are visible as narrow benches along the canyon sides. All of these occur at the sharp break separating the Rincon Surface from the steepened walls of the rejuvenated canyon.

The Padre Juan terrace is an unconsumed remnant of a valley floor developed in the Rincon erosion cycle.

Figure 39

Isolated terrace at head of Padre Juan.

It has partially survived the rejuvenation of Padre Juan Creek, which has maintained about the same course throughout its existence.

Pitas Point to the Ventura River

The coastline between Pitas Point and the Ventura River is similar to the preceding section. There are two notable exceptions. In the first place, none of the short coastal streams cut across the divide which stands only a short distance inland. Secondly, no trace of marine terraces, save for a very few isolated patches, is to be seen except on the western margin of the Ventura River Valley. This area is underlain by the Pico formation, with the exception of a narrow triangular wedge of the San Pedro formation west of the Ventura River mouth. Both these formations have a steep seaward dip, and form the south flank of the Ventura Avenue Anticline.

The steep seaward dip in the same direction as the inclinaion of the land surface has produced a unique type of erosion. The rocks are comparatively non-resistant to erosive attack. They are silty shales and mudstones of great thickness with only comparatively thin layers of poorly cemented sandstones and conglomerates to provide rigidity.

In the rainy season the mudstones are converted to clay, the whole mass becomes lubricated and slides off the sandstone dip slopes. This process produces landslides of considerable magnitude, two of which in adjoining canyons have pushed out jumbled protrubrances of contorted clay shales as far as the railroad track.

The amphitheatre on the axis of the Ventura Avenue Anticline at the mid-point of this sector is one of the most unusual of all the coastal valleys. It widens out into a bowl-shaped basin nearly 1000 feet deep. On its precipitous walls the faulted axis of the Ventura Avenue Anticline is clearly revealed.

Most of the stream divides in this segment of the coastline are narrow ridges that descend abruptly into deep ravines on both sides. Erosion has advanced rapidly everywhere throughout this area, and all traces of marine terraces, if they existed, have been destroyed. The Rincon Surface has been obliterated as well, although an indication of it is preserved in the uniform altitude of most of the peaks and saddles.

The sole exception to the general destruction is the broad band of terraces to the west of the Ventura River at its mouth. There are three major levels which grade imperceptibly into the river series. At the coast the highest level attains a maximum altitude of 425-450 feet.

The significant fact about these coastal terraces is that they are cut across the surface of steeply dipping (35-45 degrees) marine Pleistocene conglomerates; good evidence for the recency of the deformation which has affected the Ventura Region.

Figure 40

Marine terraces transitional into the river series on the west side of the Ventura River.

East of the Ventura River

The area east of the Ventura River is difficult to interpret. The principal reason is that terraces have been cut in tilted Pleistocene sands and gravels, little more consolidated than the terrace deposits. Due to lack of coherence, these Pleistocene sediments have washed over the terrace surfaces and buried them almost completely. It is nearly impossible to distinguish between original marine Pleistocene deposits, terrace material, and reworked sediment derived from either source.

The best method is to note the attitude of the rocks exposed in the numerous road cuts and excavations. The deposits which preserve a horizontal attitude are terrace gravel, either original or reworked. Other sediments which show a steep inclination are Marine Pleistocene. This method is not completely satisfactory, for in many exposures such poor sorting shows that a determination of attitude is futile. This portion of the coast is covered with the buildings and streets of Ventura; a fact which serves to increase the difficulties of field work.

There seems to be three distinct terraces behind Ventura. The highest reaches an elevation of 500 feet and is visible on the hill summit behind the Serra Cross. The second shows clearly in the road cut north of the reservoir, and, from its silt-like covering indicates for the environment of deposition a shallow lagoon, similar to that at the mouth of the Ventura River. This sandy deposit is filled with many broken shell fragments, among which occur few complete specimens. These shells may not be contemporaneous with the terracing epoch, but have been reworked from the San Pedro. The lowest level stands at nearly the same altitude as Poli Street and the Ventura County Court House and Jail.

Other sub-levels exist in the town itself, notably along the line of Meta Street and by the old high school; and deposits on its surface are visible in the Don Jon Barranco. The low sea cliff which runs from Seaside Park by the Bathhouse and behind Pierpont Bay is treated more fully under the section on shore changes.

The principal business and residential sections of Ventura are built on an abandoned marine platform now rather deeply covered with alluvial material. That this piedmont alluvial plain is of considerable age is proved by elephant remains found in excavations for building foundations. Fossils similar to those encountered in

Ventura have been described by T. E. Bailey for some of the Pleistocene alluvial deposits at the mouth of Barlow Canyon behind the County Hospital.

THE VENTURA SHORELINE

The present shoreline of the Ventura Region is nearly straight with a northwest trend. Three unsymmetrical promontories interrupt the linear pattern, and are nearer the western than the eastern side of the area. The coastline, 18 miles long, recently emerged. It has progressed to late youth in the present cycle throughout most of the length.

In determining the outline of this coast an important factor is the direction of the prevailing wind. The afternoon sea-breeze that generally blows from west to southwest is the most persistent wind. The winds accompanying the occasional cyclonic storms of winter may shift to southwest, but more frequently come from west and northwest. Neither type of wind builds up a large sea because of the short fetch. The Channel Islands make a lee for a southwest gale, and the west-trending coast behind Santa Barbara prevents a north or northwest wind from making more than a moderate sea.

The persistent current through the Santa Barbara Channel exerts a strong influence in determining the shape of the coast. Its effect is felt most strongly in areas where the waves strike the coast obliquely, for there the littoral drift is alongshore, and the coast is retrograding. Where the wave front parallels the coast, the littoral current is negligible, and the coast is prograding.

Figure 41

Punta Gorda, showing the oblique approach of the waves on the southeast side of the point.

The relationship between wave and current direction and shoreline development is responsible for the cuspate pattern of the three principal points. The northwest side parallels the wave front and is building seaward, the southeast side makes an angle with the wave direction, and is being attacked. Two of the points are at stream mouths, and the third is a rock-defended promontory.

This shoreline has not had an identical history throughout its length. The eastern and western extremities have been downwarped, and the central part elevated during recent times. The evidence for this slight warping is treated in the sections to follow. The various features of the coast are discussed in sequence from west to east.

Carpinteria Shoreline:

This is a cliffed shoreline, except at the extreme western end of the area. The interesting feature of the sea-cliff is its progressive decrease in elevation westward. The altitude of the cliff edge at Rincon Creek is 200 feet, and it is non-existent at the Carpinteria Estero, 2 miles distant. This decline in height is caused by the westward tilting of the Carpinteria Plain, and accentuated by the greater back-cutting by the sea near Rincon Creek.

Waves are attacking the base of the sea cliff as far as 0.9 mile west of Rincon Creek. Westward to 0.5 mile beyond the Higgins' Asphalt Pit, the waves at high tide, or during storms, break at the foot of a 50 foot cliff. The rocks exposed in the cliff are contorted and faulted Vaqueros and Modelo sandstones and shales. They are finely laminated, occasionally brecciated, and the seams filled with calcite. Tar seeps from fractures in these rocks, and has stained much of the cliff face.

Figure 42

The Carpinteria sea-cliff, showing the westward decrease in elevation.

The cliff is nearly vertical, and makes a right angle with the rock bench at the base. The bench truncates the nearly vertical strata, and reveals the complexities of their structure at low tide. A thin veneer of sand is spread over the rock platform, but is usually stripped off by storm waves. Isolated rocks project above the sand and the water surface. These are remnants of an older rock platform, 3-4 feet above sea level. Whether this is a storm cut, or eustatic bench could not be determined.

The sea no longer attacks the base of the cliff between Rincon Creek and the point where the railroad reaches the terrace surface. This section of the cliff is fronted by a relatively permanent sandy shelf-beach widening towards Rincon Point.

Rincon Creek to Punta Gorda:

Rincon Creek fails to maintain an open channel to the sea. Ordinarily its water is impounded by a low barrier beach built by the waves. The river water backs up in a shallow lagoon, and escapes only by percolating through the sand. During the rainy season, the stream breaches this barrier, and sweeps a large volume of sediment into the sea. The low, rounded projection of Rincon Point has been built seaward by this accretion of flood debris. The finer material distributed by the littoral current makes

Figure 43

Mouth of Rincon Creek closed by barrier beach

the narrow beaches to leeward. The larger stream-transported boulders remaining where they were dropped, now constitute a boulder pavement protecting the point. These boulders are on both sides of the channel, cover the sea floor beyond the sand barrier, and may be traced along the lee shore for 0.1 mile. The wind has built several dunes on the west side of Rincon Creek. Most of the sand has shifted along shore from the west, and is probably derived from Carpinteria Creek.

East of Rincon Creek the coast makes a right angle bend, and trends northeast for 0.6 mile. Waves approaching from west and southwest intersect the coast at an angle. Less than 100 yards separate the base of the 300 foot sea cliff from the shoreline, and both a 4 lane highway and railroad are confined in this narrow space.

Figure 44

Seacliff bench west of Punta Gorda.

Note parallel approach of waves.

Because of the concentrated wave attack, a concave-surface concrete bulkhead was necessary to stop undermining of the highway. To protect the concrete barrier steel sheet-piling was driven parallel to the sea wall, and a series of short groins at right angles to the wall. No perma-

Figure 45

Small alluvial fan built

at foot of seacliff by narrow arroyo

nent deposition occurs in this section of the shoreline, and the material supplied by Rincon Creek is carried by. The groins were built in an attempt to stop the sediment in transit.

Deposition commences as soon as the coast resumes its southeast trend. A broad foreshore commences at the southern boundary of Rancho El Rincon, and continues 1.7 miles to Punta Gorda. This bench has a maximum width of 0.2 mile behind Punta Gorda, and slopes up to 50 feet at the base of the sea cliff. The actual beach is confined to a narrow strip between the highway and the shoreline. The wider area between the highway and the base of the 500 foot sea cliff is covered with dune sand. Small alluvial fans are built at the mouths of the larger streams which have cut small canyons through the sea cliff. None of these arroyos cross the bench and enter the sea. Their water sinks into the sand.

<u>Punta Gorda:</u>

No stream flows into the sea at Punta Gorda, as in the case of Rincon and Pitas Points. Instead, the promontory is defended by Mussel Rock. This rock is a ledge of Pico sandstone which strikes east and dips north. This stratum is on the north limb of the Ventura Avenue anticline, whose axis enters the sea 1.5 miles south of Punta Gorda. The rock standing 10 feet above sea level, is riddled with Pholad borings to the top. Their presence at this height above sea level is confirmation of the recent elevation of this section.

The coastline repeats the pattern established at Rincon Point, and turns northeast for 0.5 mile at Punta Gorda. The waves attack this shore with enough vigor that it, too, must be defended with a concrete sea

Figure 46

Punta Gorda

Note the change in the direction of wave approach.

wall. There is less space at the foot of the sea cliff than at Rincon Point. Before the modern concrete causeway was constructed the highway ran on a wooden trestle built over the surf. In even earlier times it was necessary for horse-drawn stages to wait for low tide before the passage over the rock covered beach could be attempted.

The first prograded portion of this coastal section is 0.5 mile west of Los Sauces Creek. From Los Sauces Creek to Pitas Point, a shelving bench 0.3 mile wide and rising to 100 feet protects the seaward slope of the Coastal Hills. This bench is covered with stationary dunes and resembles the coast between Rincon Point and Punta Gorda. The Seacliff oil field is between Los Sauces and Madranio Canyons on this coastal strip which will be be called the Seacliff Bench.

Exposed in roadcuts on the surface of the Seacliff Bench are lenses of flattened boulders and cobbles embedded in unconsolidated sand. These gravel concentrations underlie the dune sand, which, in turn, is overlain by alluvium at the mouth of Madranio and Javon Canyons. East of the Ventura County Park, highway roadcuts show that the boulder deposit rests on the surface of truncated, steeply dipping Pliocene strata. Many of these boulders are pierced by Pholad borings. The contact between boulders and bedrock is well-defined, and is approximately 15 feet above sea level.

Figure 47

The sea cliff bench east of Punta Gorda

The axis of the Ventura Avenue anticline disappears under the sea at the mouth of Los Sauces Creek. Between Los Sauces Creek and Pitas Point the prevailing dip of the Pico formation is seaward. North of Los Sauces Creek it is landward. The difference in the direction of dip is partially responsible for the steep sea cliff north of Los Sauces Creek, and the more gently sloping cliff south of the creek. The sea cliff on the south limb of the anticline is essentially a dip slope, and has been less recently attacked by the sea than the north side of the fold.

Pitas Point to the Ventura River:

Although Pitas Point resembles Rincon Point more than it does Punta Gorda, it differs significantly from these two. At first glance it seems to be rock defended, as a prominent headland projects almost to the point. Padre Juan Canyon is concealed within it, and its stream flows through a steep walled canyon cut through the apex of the promontory. The valley is hidden from sight until viewed directly opposite the headland.

The behavior of Padre Juan Creek is especially instructive. The stream flows in a vertical-sided, narrow trench incised in the flat canyon floor. At the canyon mouth its course is through a series of entrenched meanders in former creek deposits which consist in large part of reddish Sespe boulders. These boulders increase in size towards the base of the stream deposit, and at the bottom are 1-3 feet in diameter. They are derived from the floor of the isolated, old valley remnant at the head of Padre Juan Canyon.

Figure 48

Entrenched meanders at mouth of Padre Juan Creek

A large group of sand dunes cover the surface of the Seacliff Bench west of the mouth of Padre Juan Creek. A crescent-shaped boulder embankment parallels the curved railroad grade eastward from these dunes and around the headland. This moraine-like embankment was built from boulders deposited by Padre Juan Creek when Pitas Point was 15-20 feet lower than it is today. The sand dunes were part of the former barrier beach. The meanders were trenched through the stream gravels when Padre Juan Creek was rejuvenated by the recent slight coastal uplift.

The Seacliff bench continues eastward around Pitas Point. The highway, instead of being defended by artificial structures, crosses a broad platform in this northeast trending salient. The Seacliff bench is 1.0

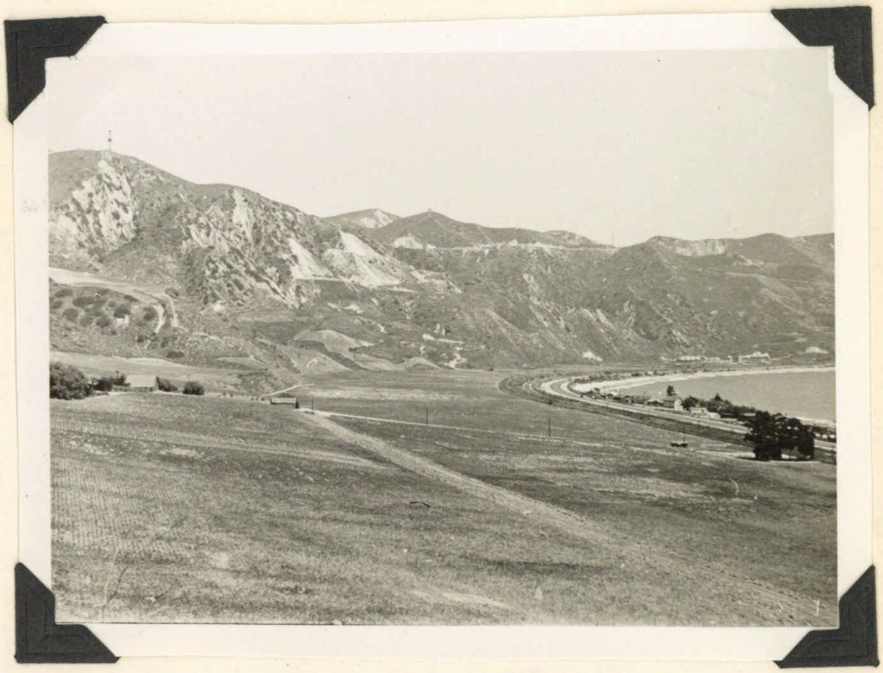


Figure 49

Sea cliff bench east of Pitas Point

mile long and 0.3 mile broad. Near the east end are several truncated alluvial fans terminated by a 50 foot cliff. This low cliff, paralleling the base of the main sea cliff from the Continental Oil Company's refinery to Pitas Point, is slightly more convex landward than is the shoreline. Should the sea once more reach the cliff base, the coastline at Pitas Point would be a replica of Punta Gorda and Rincon Points. The shoreline would be separated from the sea cliff west of the point and close to the cliff east of the point.

The Seacliff Bench east of Pitas Point is the result of recent upwarping which has elevated this section of the sea floor. The elevation was not uniform along the Ventura Coast, but reached its maximum between Padre Juan and Madranio Canyons. The northern limit is midway between Punta Gorda and Rincon Point, the southern, two miles east of Pitas Point. The uparched area has an approximate length of 8 miles, and probably results from renewed folding on the axis of the Ventura Avenue anticline.

A summary of the evidence for the recent elevation of the seacliff Bench is:

1.) Pholad borings on Mussel Rock, 10 feet above sea level.

2.) The wave cut platform exposed in roadcuts east of the Seacliff oil field.

3.) The old dunes and gravel deposits on the Seacliff Bench, especially near Pitas Point.

4.) The entrenched meanders of Padre Juan Creek.

5.) The broad platform and abandoned sea cliff east of Pitas Point.

A uniformly broad bench extending from Pitas Point to the Ventura River is the most persistent one along the coast. Its greatest breadth of 0.2 mile is in the area between the Continental oil refinery and the mouth of the stream draining the amphitheater. Although the beach retains its full width, the coastal bench narrows from the amphitheater eastward, and finally disappears 1.5 miles west of the Ventura River.

Midway between Pitas Point and the river are two large landslides in the Pico clay shales. In both cases a large, hummocky mass of shale slid down the steep sea cliff. Both masses formerly extended beyond the railroad, and were cut through when the grade was established. The contorted, jumbled structures in the interior of the slides are shown in the walls of the excavation. The western slide is the larger, and has moved 0.3 mile from the cirque-like cliff at the head. The slide is 250 feet high, and has a base approximately 1200 feet broad.

Figure 50

Non-terraced coast east of Pitas Point

The contact between the Sand Pedro and Pico formations crosses the beach at the mouth of an unnamed canyon 2 miles west of the Ventura River. The mud-pit member of the Pico formation exposed here is a finely laminated clay shale. The San Pedro formation has proved more resistant to wave attack than the Pico formation. The contact is marked on the shoreline by a small, but distinct, projection on the San Pedro side. The coastline is almost straight in the section where the San Pedro formation crops out, and projects 0.8 mile beyond the apex of the bight cut in the Pico clay shales east of Pitas Point.

One reason for the superior resistance of the unconsolidated San Pedro formation is the great number of boulders that it contains. These weather out and cover the beach where the San Pedro formation is exposed. The boulders are so abundant that they act as a pavement and prevent the shoreline from receding as rapidly as it does west of the contact.

The small point at the San Pedro-Pico contact has a strong influence on the littoral current. West of the promontory the coast trends N 35° W, east of it N 65° W. The current paralleling the coast on the west side is deflected seaward upon reaching the point. This flow of seaward moving water sets up a dangerous eddy. As a result the beach is placarded with signs of warning against the "rip-tide".

Recent Shoreline Changes

The resurvey of the Ventura shoreline by the U.S. Coast and Geodetic Survey in 1933 has made it possible to determine the amount of change in its configuration since the earlier surveys of 1855 and 1869. Photostatic copies on a scale of 1:10,000 of the 1933 and earlier surveys were obtained, and a comparison was made of the coastline in the vicinity of Carpinteria and the coastal section between the Ventura and Santa Clara rivers.

Carpinteria Shoreline:

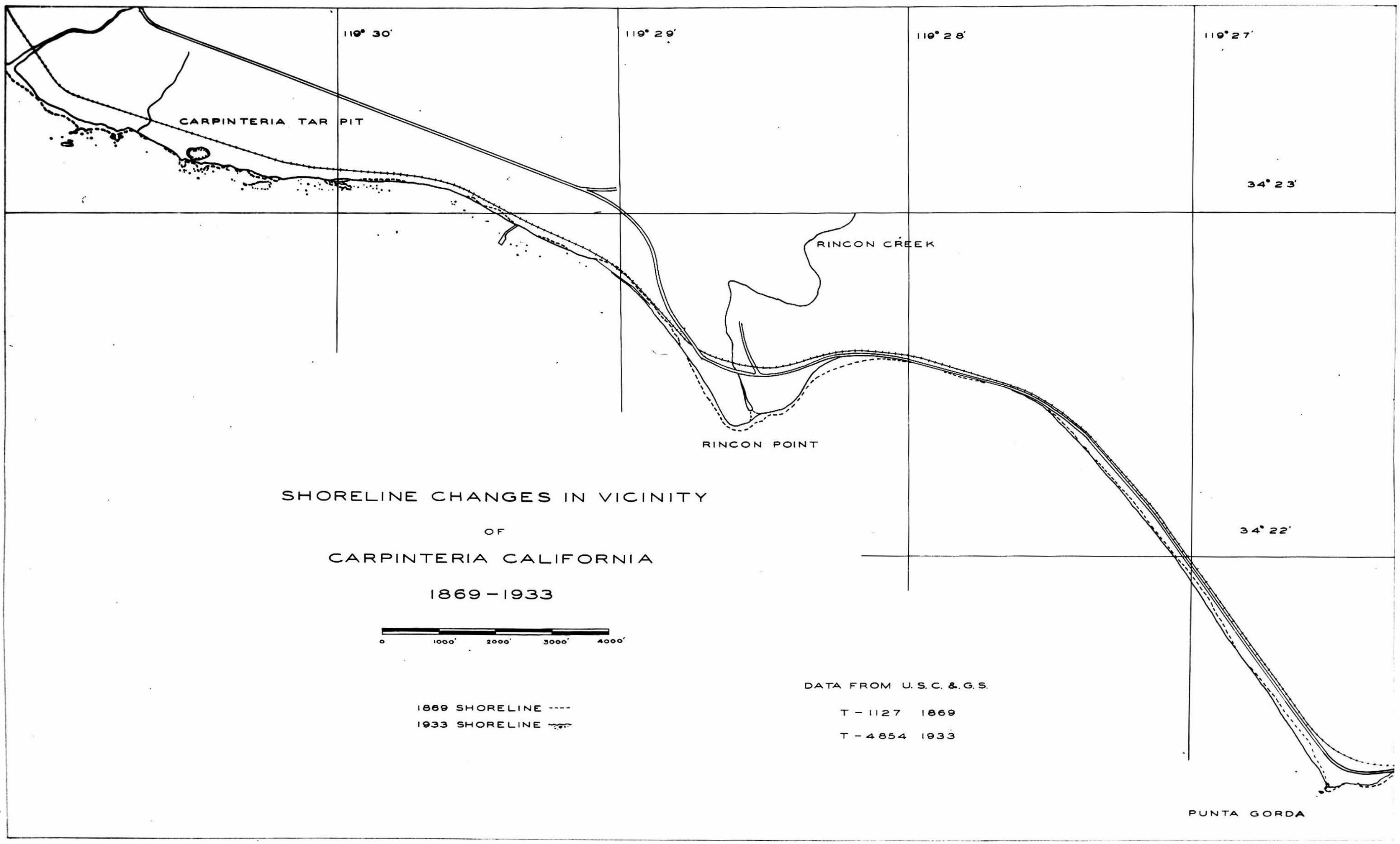
The earliest detailed survey of the coast between Carpinteria Creek and Punta Gorda was made in 1869. When the tracing for this period is compared with that for 1933, it may be seen that this coastline is essentially in equilibrium. In general, those sections which were probably retrograding in 1869 have continued to recede; the prograded portions have been built farther seaward. Two notable exceptions are Rincon Point and Punta Gorda. Both these sandy points have retreated from their 1869 position.

The shoreline near the Carpinteria tar pits has retreated slightly, but at an unequal rate. This is a

Plate XIII

Shoreline changes in vicinity of Carpinteria

California, 1869 - 1933


119° 30'
119° 29'
119° 28'
119° 27'
34° 23'
34° 22'
CARPINTERIA TAR PIT
RINCON CREEK
RINCON POINT
PUNTA GORDA
SHORELINE CHANGES IN VICINITY
OF
CARPINTERIA CALIFORNIA
1869 – 1933
0 1000' 2000' 3000' 4000'
1869 SHORELINE ----
1933 SHORELINE
DATA FROM U.S.C. & G.S.
T – 1127 1869
T – 4854 1933

cliffed coast, composed of steeply inclined, resistant, siliceous shales. Differential erosion has probably played an important role. The rate of recession was most rapid from Carpinteria Creek to a point 1700 feet east of the tar pits. This part of the cliffed coast is lower than the section to the east, less bedrock is exposed, and the shoreline has a more northwesterly trend. The maximum retreat was 80 feet, the minimum 0, and the average 20-40 feet.

Eastward, to the concrete seawall built by the Southern Pacific Railroad at a point 3400 feet west of Rincon Point, the shoreline shows no important change. At the seawall a rather curious modification has occurred. The 1869 shoreline of this cliffed coast is shown farther inland than the 1933 mean high tide line. The explanation is the construction of the railroad in the interval between the surveys. The railroad grade is carried by a large fill from near sea level at Rincon Point to the terrace surface at a height of 50 feet. The sea wall to protect the fill has built the shoreline seaward.

Rincon Point has apparently receded an average distance of 125 feet since 1869. This point is built of sediment deposited by Rincon Creek at its entrance to the sea. This shoreline section probably shows both a seasonal and cyclical variation. The actual position of the strandline is determined by the balance between the waves and currents of the sea, and the volume of detritus supplied by streams. The recent cycle of comparatively dry years, with the consequent diminished flow of Rincon Creek, may be a partial explanation for the retreat of this shoreline.

The coastline east of Rincon Point has receded 210 feet since 1869, and, because of the diminished supply of sediment, no beach is maintained. In this section where the waves approach at an oblique angle a vigorous attack occurs. The highway is protected by a concrete wall which at present faces destruction. In order to protect it a series of sheet-pile groins have been built.

The 8300 foot stretch of coast trending northwest of Punta Gorda has prograded slightly during the 64 year period, and the shoreline has advanced a maximum distance of 170 feet north of Punta Gorda. Punta Gorda has had a nearly identical history with Rincon Point. It has receded during this period most rapidly on the eastern side where the oblique approach of the waves concentrates the strongest attack.

Coastline between the Ventura and Santa Clara Rivers:

The coastline south of Ventura is of particular interest due to the considerable changes in its appearance during the historic period. It is prograding, and if it has advanced at its present rate, has built forward a maximum distance of 2500 feet since 1600 A.D. Three factors have operated in determining the appearance of this coastal section: 1.) the recent movement it has undergone is responsible for its general outline, 2.) the amount of sediment supplied by the two rivers, and 3.) the intensity of wave attack, have determined the progression or retrogression of the shoreline. For the most part this coast has been prograding, and the volume of sediment supplied by the Ventura and Santa Clara Rivers has built the shore seaward, even though the foundation on which it rests is subsiding. There are indications that this accretion has temporarily halted. The coast is being attacked at Pierpont Beach, and the waterfront of Ventura has suffered considerable damage. The removal of large quantities of water for irrigation from both rivers, combined with the aridity of the past few years, may be an explanation for the lack of sediment which ordinarily protects the beach.

Figure 51

Mouth of the Ventura River

The earliest detailed survey of the Ventura section was made in 1855, and considering its early date is quite accurate. A comparison with the 1933 survey (Plate XIV) reveals a number of distinct changes. The Ventura River, now entering the sea 250 feet west of its 1855 channel, has advanced the sand bar across its mouth 270 feet seaward.

Figure 52

Prograding shoreline between
Ventura and the Santa Clara River

The waterfront of Ventura, eastward from the river to the foot of Palm Street, is in approximate equilibrium. During the 78 year period between surveys this section of the coast advanced an average distance of 42 feet, and the shore at the foot of Figueroa Street remained unchanged. This part of the coastline is armored with cobbles and boulders carried down by the Ventura River and heaped up in steep-faced embankment. Little sand occurs, and the obliquely approaching waves carry by most of the sediment.

Figure 53

Boulder Beach at Foot of Palm Street,
Ventura, reputed to be Cabrillo's landing place
View West

and heaped up in steep-faced embankment. Little sand occurs, and the obliquely approaching waves carry by most of the sediment.

Figure 53

Boulder Beach at Foot of Palm Street, Ventura, reputed to be Cabrillo's landing place View West

Deposition commences at the foot of Palm Street and continues beyond the Santa Clara River to Point Mugu. The City Engineer's office of Ventura made a detailed survey of the city waterfront in 1930 and again in 1931. A comparison of the two surveys shows that the coast prograded 80 feet directly east of the Ventura River in this one year period, and retrograded 100 feet between Califor-

Figure 54

Boulder Beach at Foot of Palm Street,

Ventura, reputed to be Cabrillo's landing place

View East

nia and Chestnut Streets, a short distance west of the lumber wharf. This marked recession is probably to be correlated with the dry winter of 1930. The past four years have been equally dry, and at the present time the beach in front of the central part of Ventura has been almost completely stripped away.

Pierpont Bay:

From the lumber wharf eastward, the beach shows a net advance in the 78 year interval of 584 feet at Pierpont Beach and 416 feet at the mouth of the Santa Clara River. In 1855 waves broke at the base of the low alluvial cliff near Pierpont Inn. This low bluff, which continues east behind Pierpont Bay, is probably mentioned by Crespi (161):

(161) Bolton, Herbet E., "Fray Juan Crespi, Missionary Explorer of the Pacific Coast, 1669-1774," Univ. of Calif. Press., pp. 158-159, 1927.

"It (the village) is situated on a tongue or point of land running out on the same beach which stands so high that it seems to dominate the waters."

The waves of the Pacific very likely reached the foot of the bluff behind Pierpont Bay as recently as 1600

A.D.. The cliff is now 2500 feet from the shoreline, and if the coast prograded 584 feet in 78 years, it would have required 332 years to fill in the entire distance.

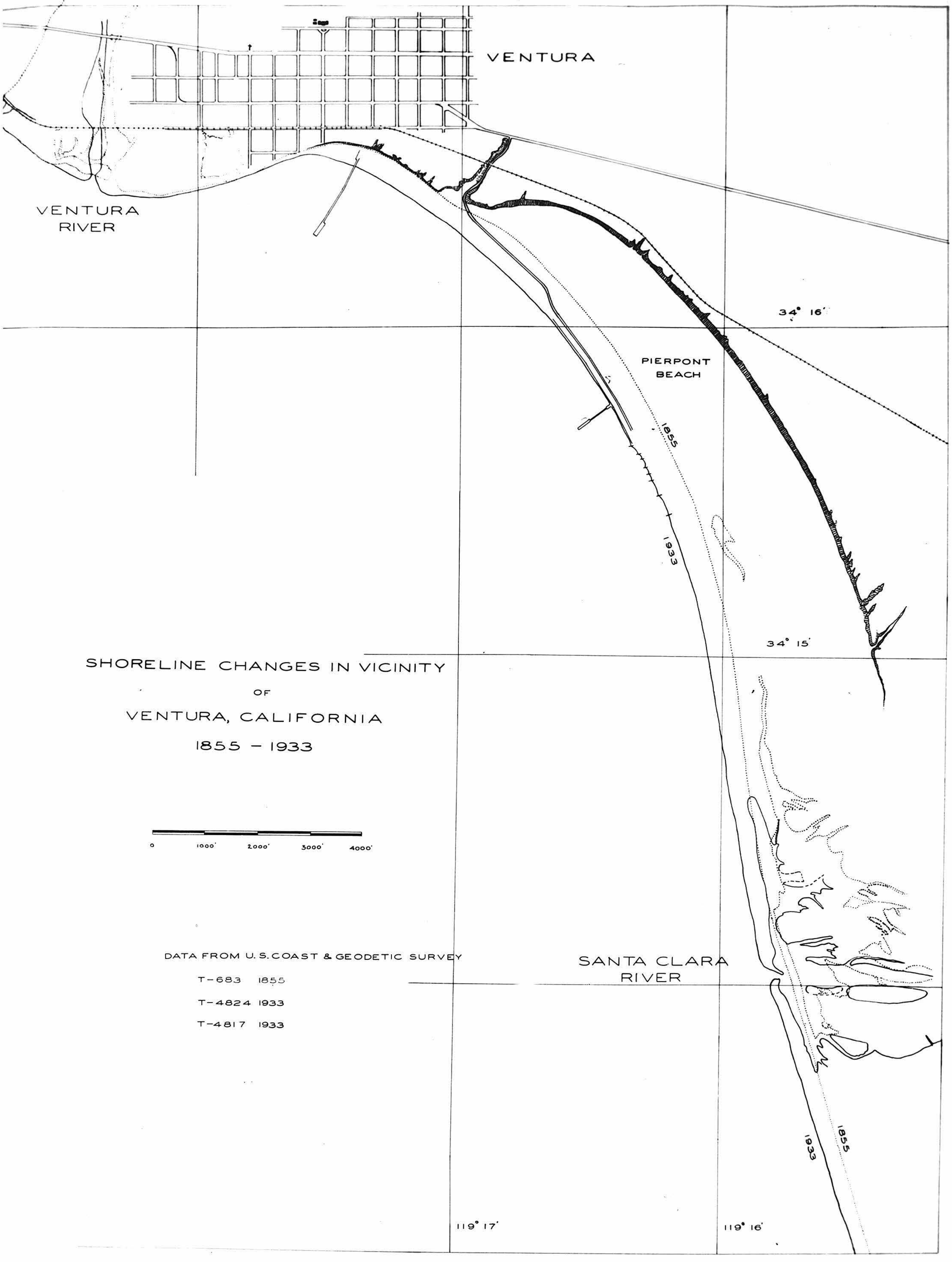
Figure 55

Low bluff behind Pierpont Beach

At present the coast is being eroded. In the winter of 1934-35 much damage occurred at Pierpont village. The concrete seawall was demolished for a distance of 1100 feet west of the pier, two houses were destroyed,

Plate XIV

Shoreline changes in vicinity of Ventura, California, 1855-1933



VENTURA
VENTURA RIVER
PIERPONT BEACH
34° 16'
34° 15'
1855
1933
SHORELINE CHANGES IN VICINITY OF VENTURA, CALIFORNIA 1855 – 1933
0
1000'
2000'
3000'
4000'
DATA FROM U.S. COAST & GEODETIC SURVEY
T-683 1855
T-4824 1933
T-4817 1933
SANTA CLARA RIVER
119° 17'
119° 16'

and the landward section of the pier was undermined.

Figure 56

Seawall destroyed in winter of 1934-35 at Pierpont Beach

The Santa Clara River has shifted its course during the period since 1855, and has built the shore outward. Its channel has moved 1250 feet northward, the lagoon has filled in a maximum distance of 1670 feet, and the shoreline has prograded 420 feet opposite the river mouth.

This entire section of coast is built of sediment brought down by the Santa Clara and Ventura Rivers and distributed by the waves and currents of the sea. The shoreline advanced or retreated according to the strength of the two processes. The net result has been a seaward advance of the land, and whether this gain will be permanent is for the future to tell. The balance appears to be disturbed today, and sections which were formerly prograding are now retreating. This is not a new phenomenon for this coast. It should be remembered that when the alluvial piedmont plain upon which Ventura stands was built, the shoreline stood farther west than it does today. It retreated as far inland as the Pierpont Bluff, and only in the past 330 years built out to its present position.

THE CYCLE OF EROSION FOR A STEEPLY SLOPING SHORELINE OF EMERGENCE

The Ventura coast is progressing through an erosion cycle unlike the one previously described for the offshore bar type of the Atlantic coast. The Ventura coast is a shoreline of emergence through most of its length, but differs from the emergent part of the Atlantic shoreline in the following respects:

1.) The water is deep close to shore; a depth of 35 feet is found one fourth mile from the coast, and 50 feet at approximately one half mile.

2.) The land has been elevated to a greater height; 1,400 feet as compared to 200-300 for the Atlantic.

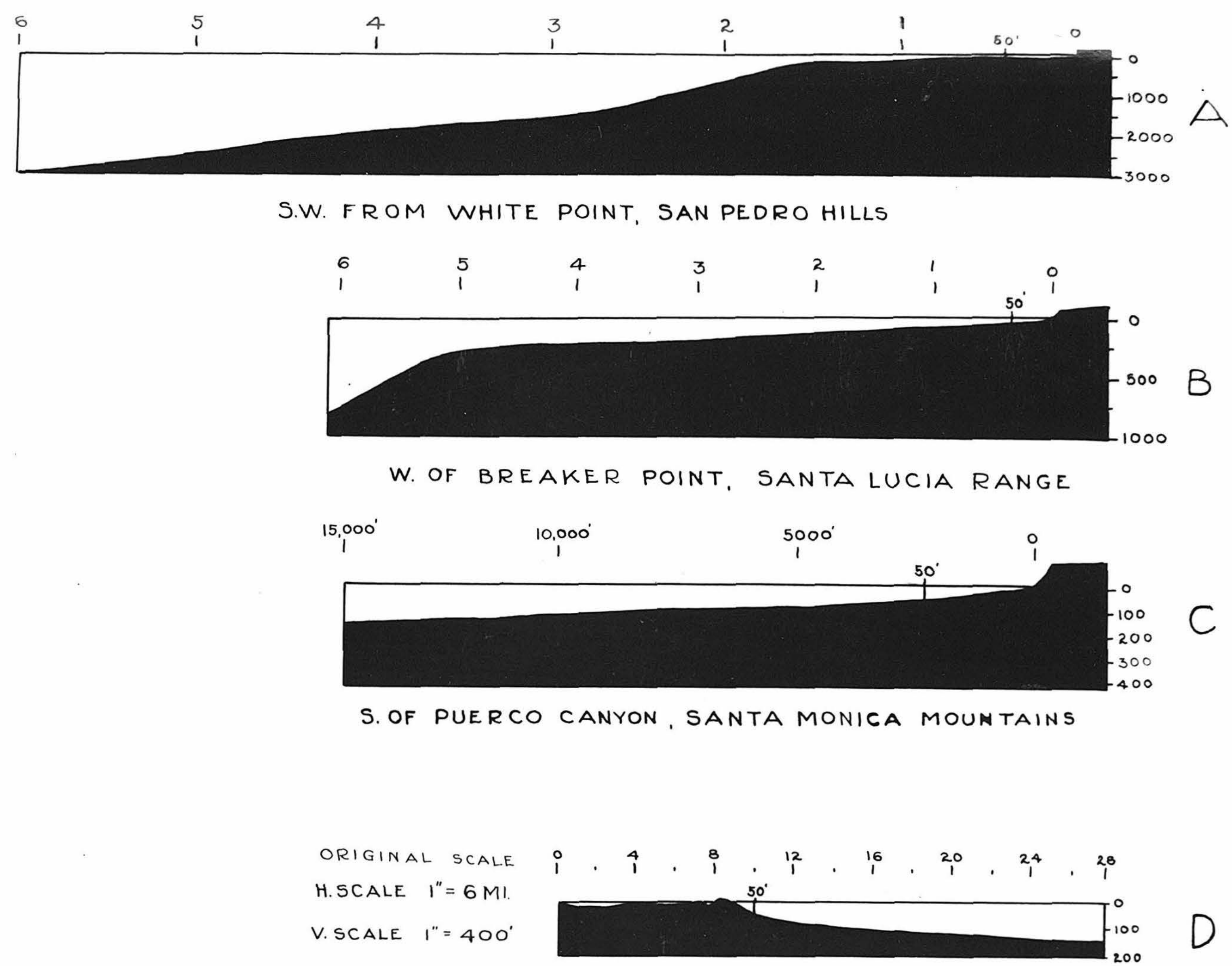
3.) This uplift has been intermittent, and is recorded by steeply sloping, shelf-like terraces.

4.) The uplift occurred within a short period of time, and is restricted to the late Pleistocene.

5.) The steep gradient of the sea floor permits direct wave attack upon the cliffed shoreline.

Plate XV

Submarine profiles of typical shorelines of emergence



PROFILE AFTER FIG. 112, PAGE 364 IN "SHORE PROCESSES AND SHORELINE DEVELOPMENT," BY D. W. JOHNSON SHOWING OFFSHORE BAR AT LAGUNA MADRE, TEXAS.

These characteristics distinguish this shore from the elevated parts of the Atlantic seaboard, and relate it to other terraced coasts throughout the world. In discussing shorelines of emergence it appears necessary to separate those with a steep sea-floor gradient from those with a gentle submarine slope. The cycle of erosion for coasts of emergence with a low gradient has been described by Johnson [162] and is the type in which an offshore bar

---

(162) Johnson, D. W., "Shore Processes and Shoreline Development," John Wiley and Sons, Chapter VII, New York, 1919.

---

forms and is gradually driven shoreward by the waves. When the bar is finally driven up on land, the lagoon which separated it from the coast disappears, and the shoreline has reached the stage of maturity.

The depth of water is the controlling factor in determining whether or not the offshore bar cycle will occur. If the submarine gradient is gentle, waves break offshore, and a bar is built. If the gradient is steep, waves break near the shoreline, which is attacked directly, and no bar is formed. The control exercised by the depth of water over the type of shoreline developed is indicated in Plate XV, in which a series of profiles taken at selected points along the California coast are compared with Profile D, a typical Atlantic coast example. The depth of 50 feet is selected as the critical point at which storm waves first seriously modify the bottom profile. It may be seen on the diagram, that this depth is usually less than one half mile from shore on the California coast, while in the Laguna Madre bar for the Atlantic, it is 9 miles from land. Cape Hatteras is a more extreme example, and it is necessary to go 36 miles offshore for a depth of 50 feet.

The recently elevated Ventura coast, with deep water close to shore illustrates the changes undergone by a steeply sloping shoreline of emergence. The course of development of a shoreline of this type is definite enough to be recognized as a cycle of erosion, comparable to the ones already described for coastlines of emergence of the offshore bar type, and of submergence.

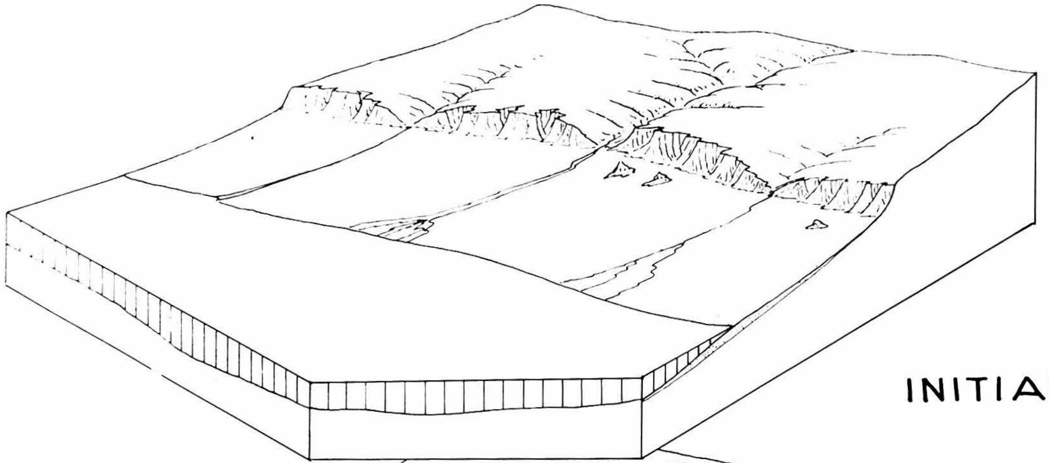
The various stages in this proposed cycle are described below, and illustrated in Plate XVI.

Initial Stage

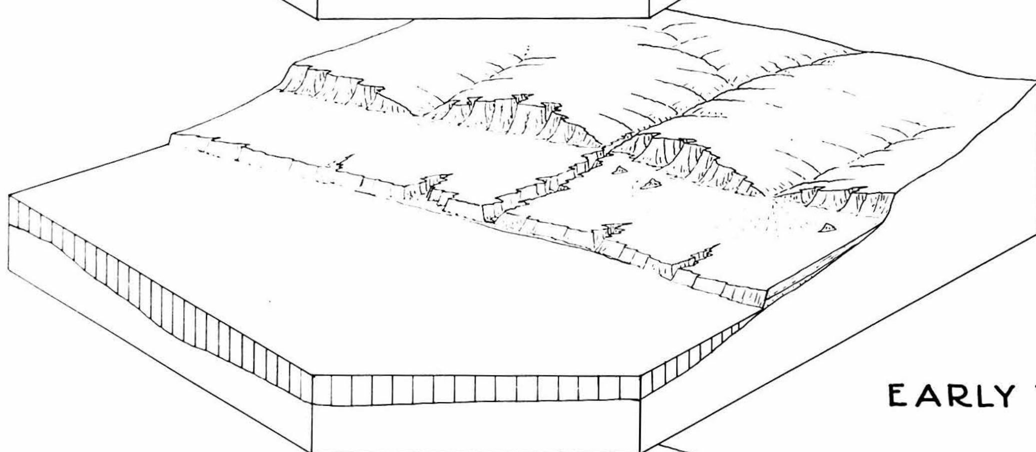
The cycle commences when the steeply sloping sea

Plate XVI

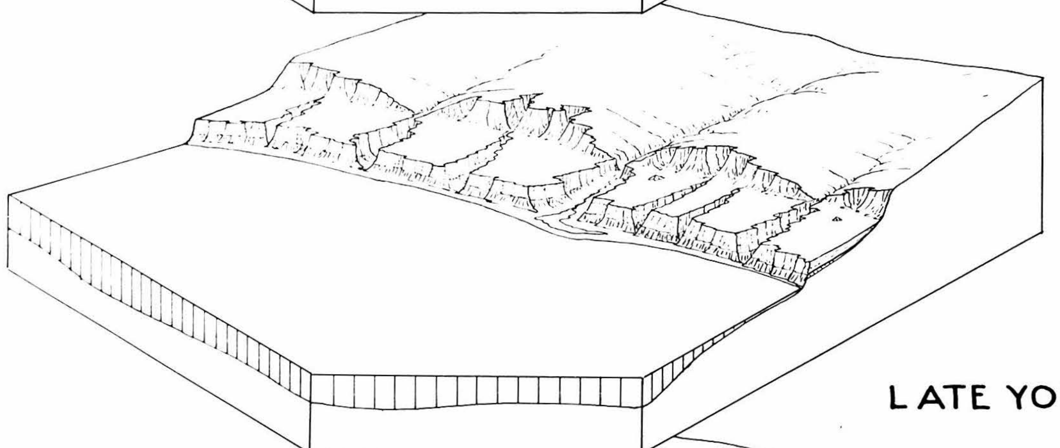
Cycle of erosion for steeply sloping shoreline of emergence



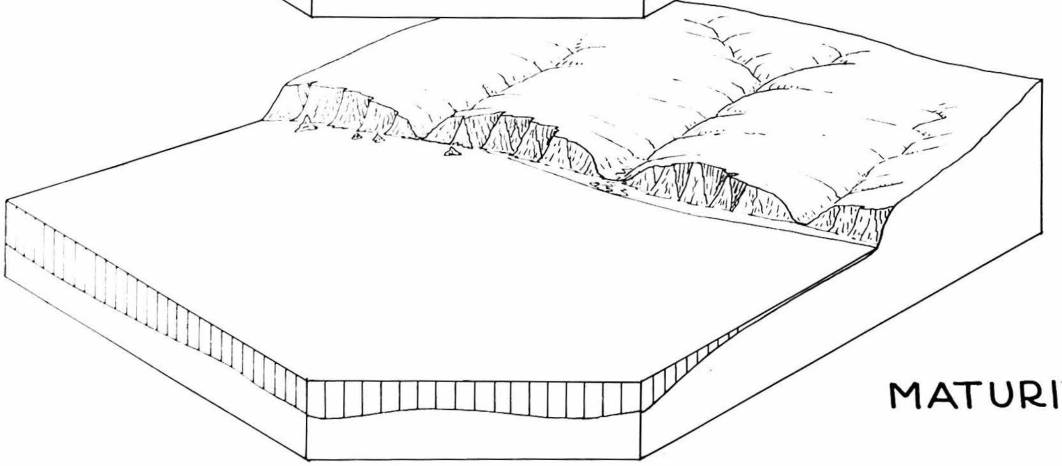
INITIAL



EARLY YOUTH



LATE YOUTH



MATURITY

floor is laid bare, either by an elevation of the land or a eustatic lowering of sea level. The initial stage begins when the sea is no longer receding, but finally halts at its new level. The submarine profile is steep enough that waves attack the shoreline directly, rather than start the construction of an offshore bar.

Early Youth

Early youth is reached when the coast shows an appreciable amount of modification from its appearance in the initial stage. The initial shoreline retrogrades, and a low sea cliff is cut. The extended consequent streams which cross the coastal plain have their length shortened as a result of this retreat. Their gradient is increased because of this shortened length, and they entrench themselves in narrow arroyos. The lesser streams, with steep courses down to the elevated shoreline, have their gradient reduced on reaching the coastal plain. They build out small alluvial fans upon the terrace surface.

Late Youth

Late youth begins when the advancing sea has consumed a significant part of its former floor. It is difficult to set an arbitrary limit, but a position for the shoreline midway between the pre-uplift and the initial shorelines, might serve to separate early from late youth. In late youth a distinct sea cliff stands behind the shoreline. The cliff height is determined by the amount of uplift, the degree of initial slope of the elevated sea floor, and the measure of shoreline retreat.

The larger streams are rejuvenated, and lower their courses to sea level. The terrace surface is dissected by numerous barrancos and arroyos. Few of these streams are able to maintain open channels at their mouths, and are checked by barrier beaches built by the more powerful waves and currents of the sea. Their water is impounded in shallow lagoons, and reaches the ocean by percolating through the sand. Seasonal floods break through the barrier and sweep sediment into the sea. Stream supplied sediment is the principal source of sand for the shelf beaches which from a narrow strip at the base of the sea cliff.

As the alluvial fans, formed in early youth, are truncated, a composite cliff develops, as described by Davis (163).

---

(163) Davis, W.M., "Glacial epochs of the Santa Monica Mountains, California," Bull. Geol. Soc. of America, Vol. 44, Fig. 5, p. 1055, October 31, 1935.

This cliff will reveal a cross section of the bedrock foundation of the original sea floor, marine deposits on its surface, and the capping of alluvial fan material.

Maturity

It is difficult to determine the point at which the stage of maturity is reached. In the submergence cycle maturity arrives when all trace of the original depression has been destroyed. In the cycle for gently sloping emergent coasts it is reached when the offshore bar is driven on land, and the indications of emergence are obliterated. By analogy, maturity in the cycle for steeply sloping shorelines should come at the moment the evidence of uplift is destroyed. This will occur when the present sea cliff reaches the foot of the cliff marking the pre-uplift shoreline. At this point, all trace of the terrace vanishes, and the height of the present sea cliff is added to the surviving remnant of its predecessor.

The difficulty of the problem becomes even greater, if there has been more than one period of uplift, as in the case of Ventura. For example, if there were two periods of uplift, and the lower terrace was destroyed, leaving only the upper, at what point would maturity occur? Would it be at the time the intermediate sea cliff disappears, or would it be delayed until the upper one is reached?

The last condition seems the most practical solution to the circumstances at Ventura.

1.) The older terrace remnants have a narrow lateral extent.
2.) They were produced within a short time limit, and are clearly related to one another.
3.) The sea cliff behind the highest one is a definite upper limit to the entire series.
4.) There is no practicable way to determine if any lower levels have not been destroyed.

The terraced part of the Ventura coast will reach maturity when all the terraces have been destroyed, and the sea has removed all trace of emergence. Should renewed uplift occur, and the sea floor be again exposed, the shoreline will be rejuvenated, and will return to early youth. As long as any terraces are present, or any former sea cliffs except the highest one, the coast is in some stage of youth.

Old Age

The appearance of the coastline in old age is determined by differences in rock hardness, and by the relief of the landmass undergoing attack. There is no difference between either of the emergent shoreline types, or a shoreline of submergence in this stage. The coastline will continue to retreat until the wave-cut platform becomes too broad for wave attack to be effective.

The part of the Ventura coast which is the seaward slope of Rincon Mountain is in late youth. When the shoreline has retreated 1.3 miles farther inland it will have reached maturity. As soon as a graded profile is developed throughout its length, and a balance is achieved between rock resistance and wave attack it will be in old age.

HISTORICAL GEOLOGY OF THE TERTIARY PERIOD

A brief section dealing with the historical background of the Ventura area during the Tertiary is included for a number of reasons:

1.) It provides a proper perspective against which the events of the Pleistocene and Recent may be seen in their true proportions.

2.) It shows the comparative quiescence of this region before the rapid changes of the Pleistocene Epoch commenced.

3.) The landscape of the past controlled the environment in which the various sedimentary formations in this area accumulated. Since the landscape of the present is largely a function of rock resistance, it is a matter of some interest to interpret the conditions under which these sediments were laid down.

The pre-Tertiary history may be ignored, as no rocks earlier than Eocene crop out in this area. The earliest record commences during the deposition of the Tejon formation in the Eocene.

TERTIARY PERIOD

The Eocene Epoch

During the Eocene the sea occupied nearly all of the Ventura and Santa Paula Quadrangles as judged by the surface outcrops of the Tejon. The coastline lay to the north and probably fronted a land of moderate relief. The sea extended southward and was shallow. Although its floor slowly subsided after the period of deposition commenced, this subsidence gradually ceased. The basin filled slowly, until at the close of the period the sea withdrew. That the transition from sea to land was gradual is shown by the imperceptible gradation between the white sandstones of the Coldwater and the buff and red of the Sespe. A further proof of the gradual shallowing in the Upper Eocene is the littoral habitat of such fossils as: Pecten Calkinsi, Venericardia hornii, and Ostrea idiraensis. The sorting shown in the sand grains of the Matilija and the Coldwater members indicates transportation of sediment for considerable distances.

The maroon color of the Cozy Dell and the intercalated shale members in the Tejon have been interpreted as an indication of quite complete weathering under conditions of greater warmth and humidity than exist today. This interpretation of a warmer climate than at present is borne out by the Ione Clays (164) of the Sacramento Valley, and by

---

(164) Allen, Victor T., "The Ione Formation of California," Univ. of Calif. Pubs., Bull. Dept. Geol. Sci., Vol. 18, no. 14, pp. 347-448, 1929.

---

the characteristics of Eocene deposits in other parts of the state. From the presence of giant Venericardia and similar fossils it is believed that the climate of the Eocene in this area was humid sub-tropical.

In the Eocene Epoch the waters of a broad and shallow sea spread inland over the area of the present Santa Ynez Mountains. It was tranquil for the most part, although occasional storms disturbed the evenly graded sediment upon the sea floor. To the north stretched a low and well watered land, whose streams carried a large volume of sediment to the sea.

The basin of deposition was either filled in as it might well be with 12,000 feet of sediment deposited on it, or it was elevated to become dry land. The water began a lingering retreat. Along the slowly receding shoreline colonies of oysters flourished for a time, but they gave way as this area became land.

The Oligocene (?) Epoch

The two greatest problems of the Oligocene Epoch are: 1.) were the sediments assigned to this epoch actually deposited then, and 2.) in what environment were they laid down.

The rocks of the Sespe formation, considered as Oligocene largely on the basis of their stratigraphic position, have alternately been assigned to the Eocene or Oligocene, or divided between the two. In this paper the red beds which lie between the buff and white sandstones of the Tejon and Vaqueros are considered as Oligocene (?), largely as a matter of convenience, but it is recognized that portions of the sequence are Miocene and Eocene.

The problem of origin is interesting. In the section on stratigraphy some of the more noteworthy features of the Sespe were pointed out, and these might profitably be reviewed:

1.) The extreme lenticularity of the strata.

2.) The coarse nature of the sandstones; many of them grade into pebble beds.

3.) The angularity of grains in the sandstones.

4.) The reddish color, which is a surficial coat on the larger grains.

5.) The cementing material in the sandstones is a ferruginous, well oxidized sandy mud.

6.) Most of the pebbles are granitic types, although in the Ojai Valley there are numerous chert concentrations.

7.) The feldspar-quartz ratio is equal.

8.) There are a number of significant minor structures: ripple-marks, cross-bedding, mud cracks, mud balls, and intraformational conglomerates.

9.) The areal distribution of the formation is significant. It occurs in isolated basin-like areas, or in long bands of variable width. To the westward, near Gaviota Pass it grades into greenish and buff sandstones containing marine fossils. Elsewhere the only fossils found are terrestrial vertebrates.

There is little doubt that during the Oligocene (?) the sea withdrew to the westward leaving as land all the Ventura area. On this land surface large streams deposited their load, and built up an extensive and gently sloping alluvial plain. Although the climate was more humid than at present, the rainfall may have been quite variable. Occasional floods brought down coarse gravels and boulders. Streams overflowed their banks to cover broad reaches with quiet water from which chocolate brown mud slowly settled.

The sea lay to the west, and into it a broad deltaic plain slowly built outward as it was supplied by sediment derived from the East. The climate, originally supposed to be arid, is now regarded by Reed as humid, warm temperate or sub-tropical. Over the surface of the broad, alluvial coastal plain browsed such creatures as Subhyracodon, Miohippus, Hypertragulus, and Protylopus.

In summary, the Sespe formation in this region was formed by coalescing fans building up a piedmont alluvial plain, by flood plain deposition, by deltas, and by shallow, intermittent lakes. All of these features existed in a climate comparable to the so-called Savanna climate of the extra-tropical parts of the world today.

The Miocene Epoch

There is little important break between the conditions of deposition during the Oligocene and lower Miocene. The land, which had been either stationary or slowly rising, reversed its direction and commenced a slow, but significant subsidence. The sea spread farther inland, until it nearly regained the ground lost during the Oligocene.

This submergence was not an overnight occurrence, but a slow supplanting of a terrestrial environment by a littoral one, and eventually by conditions typical of the neritic zone. The nature of the lower Miocene sediments bears out this supposition. The Vaqueros is essentially a buff sandstone, which includes such exotic forms as Pecten Magnolia, Turritella inezana, and Scutella fairbanksi; typical of a warm, shallow water fauna, and supposedly derived from remote regions.

With continued subsidence, as the shoreline moved further inland, the Ventura area was occupied by deep, and consequently colder, water. This is shown by the <u>Foramini-fera</u> which indicate quiet and cold water during the time that the black shales overlying the sandy facies of the Vaqueros were accumulating. These strata have been correlated with the Temblor, and to them has been assigned the name of Rincon Shales.

Little direct evidence of the mid-Miocene episode of volcanism is present in the Ventura area. Outside of the one small Vaqueros sill on South Mountain, no igneous rocks crop out. The only indications of volcanic activity are the ash beds, now altered to Bentonite, which separate the Rincon formation from the Modelo formation. They occur at an equivalent horizon with the series of interbedded and intruded volcanic rocks of Conejo Mountain and the Santa Monica Mountains, 20-30 miles south and east of here.

Overlying the black shales of the Rincon formation are the organic, siliceous, and lighter colored shales of the Modelo formation. The general concensus seems to be that the water in which these sediments were laid was shallow, and while it may not necessarily have been protected from the open sea it was quiet. The adjoining lands were low and the volume of detritus washed into the sea was comparatively slight. Therefore, these sediments represent an admixture of well sorted, land derived sediments, organic matter (principally siliceous organisms), and volcanic ash - all of which accumulated in shallow water with a moderately cool temperature.

The texture of these sediments becomes increasingly fine to the west, and the organic content is of greater importance. To the east the grain size of the sediments becomes increasingly coarse, and the proportion of clastic material increases. In the area to the east of Sespe Creek the Modelo formation consists of massive, snow white, arkosic sandstones. The shales are arenaceous, and often have a dark brown color. These sediments indicate a progressive shallowing of the Modelo basin of deposition to the east.

A picture of this region during the Miocene would show:

1.) The gradual encroaching of a warm, sub-tropical sea over the Oligocene alluvial plain during the deposition of the Vaqueros formation.

2.) Its progressive deepening as the sea spread further inland, although it remained shallow enough that bottom sediment could be shifted by occasional currents.

3.) A comparatively peaceful interlude before the Modelo formation was deposited. This followed a time of intense volcanic activity in neighboring areas, as a result of which volcanic ash was spread widely over the sea.

4.) On the floor of this belted upper Miocene sea, surrounded by low land areas, a thick accumulation of organic muds, ash, and fine grained detritus was laid down. The shoreline stood to the east of Santa Paula and from it deposits of deltaic muds and sands were built seaward.

The Pliocene Epoch

Although the contact between the Modelo and Pico formations is gradational, there is abundant evidence for a rather sharp break in sedimentation between these two units. The upper portion of the Modelo consists of siliceous shales, with only a few lenses of quartzitic sandstone. The brown shales which occur between the two formations show little difference in coarseness of texture over the uppermost Modelo formation.

The significant break in the sedimentary record occurs in the lowermost Pliocene. The Pico formation includes a large number of lenticular beds of conglomerate, which grade, both laterally and vertically, into shales and sandstones. From their areal distribution, as well as from the composition of the pebbles contained, Cartwright (165)

(165) Cartwright, Lon D., "Sedimentation of the Pico formation in the Ventura Quadrangle, California," Bull. Amer. Assoc. of Petrol. Geol., Vol. 12, no. 3, pp. 239-248, March, 1928.

infers that these lower Pico conglomerates are stream deposited. The most significant feature is the presence of a great quantity of sub-rounded fragments of Modelo shale in the conglomerate. These indicate that the area north of Ventura was being eroded during the early Pliocene.

In the early Pliocene a period of deposition was initiated during which the sea withdrew from the position it occupied during the Miocene. Not only did the sea withdraw, but the water which remained became increasingly shallow. About the northern border of this restricted Pliocene seaway, the land area was elevated, the gradient of the rivers increased, and they carried a great volume of coarse detritus into the Pliocene embayment.

The Pliocene embayment probably subsided at about the same rate that sediment was supplied to it. In the course of time the gradient of the tributary streams was reduced, and only fine sediment was supplied. It was during this epoch that the thick accumulation of mudstones and silty shales of the middle and upper Pico formation were laid down.

In spite of their fine texture, and uniformity of stratification, there is not much reason to believe that the water in which these sediments accumulated was ever deep. During the upper Pliocene the Ventura embayment was a constricted tongue of water, extending inland as far as the area near Saugus. It was bounded by low shores, and into its quiet, shallow basin the well sorted muds and silts of the upper Pico formation were swept by sluggish streams.

Conclusion

From the historical discussion of each of the epochs during the Tertiary in the Ventura area, several interesting features may be recognized. These may be summed up:

1.) There has been almost uninterrupted deposition from the Eocene through the Pliocene.

2.) The history of the Ventura area during the Tertiary has largely been the slow advances and withdrawals of the sea.

3.) There is no evidence of significant diastrophism during the Tertiary. No direct trace of the post-Topanga disturbance, so prominent in the Santa Monica Mountains, is found here.

4.) There is no indication of volcanic activity in the Ventura area, with the exception of a few altered ash beds at the top of the Rincon Shales.

5.) All of the formations, with the exception of the Sespe, are marine.

6.) In general the sea showed a retreat from its greatest extent in the Eocene to its least in the Pliocene.

7.) The chief exception to 6.) is during the Oligocene when the sea receded completely and only terrestrial deposits were laid down.

8.) Throughout the Tertiary the water covering the area of accumulation was shallow and comparatively quiet.

9.) The surrounding land masses, for the most part, were of low relief, although there were several times of comparatively greater elevation, particularly during the Oligocene, early Miocene, and early Pliocene.

10.) In general, the climate changed from warm sub-tropical in the Eocene to cold-temperate and semi-arid in the Pliocene. One of the most significant breaks in the climatic record occurred before the Upper Oligocene when the Eocene forest was supplanted by an open, Savannah country.

PLEISTOCENE HISTORY

The history of later events which affected the Ventura region is complex and is compressed within a short period. These events are interesting because they occurred during the Pleistocene epoch and provide opportunity for an effort at correlation with the glacial stages recognized in the eastern United States and western Europe. Such an attempted correlation is open to several serious objections:

1.) Glaciation has not occurred in this area, and so a direct comparison is impossible.

2.) The nearest important glaciated area is 300 miles, and nearly 2000 miles separate Ventura from the standard American section.

3.) The climatic fluctuations of the Pleistocene in Ventura may have been quite different from those in the continental interior of the United States.

4.) A correlation does not necessarily exist between climatic changes and diastrophism.

5.) The climatic significance of fossil remains has not been completely established. It may be that the ecologic factors of depth of water, salinity, currents, and distance from shore are fully as important as the climatic control, but have been overlooked.

6.) Erosion and deformation often proceed concurrently and not consecutively. This makes it difficult to sharply limit the events in the history of an area, and place them in the ordinary "pigeon-hole" type of correlation chart. This type of diagram gives the impression of a sharply limited, episodic history.

Four major events occurred in the Ventura area during the Pleistocene epoch. These are:

1.) The deposition of nearly 4000 feet of marine strata.

2.) The deformation of the rocks of the Ventura region in an orogenic episode responsible for the formation of most of the structures of the district.

3.) Erosion which produced a surface of late maturity.

4.) Regional uplift, accompanied by warping, which was responsible for the formation of the marine and river terraces.

These events are discussed in the order of their occurrence and without regard to their time significance, before an effort is made to correlate them with the glacial chronology.

Deposition

No significant interruption marks the transition from the Tertiary to the Quaternary Period in the Ventura region. Deposition continued through the Pliocene into the earlier part of the Pleistocene. The embayment in which marine deposits accumulated in the Pleistocene was more restricted than it had been in the Pliocene, and otherwise there was no important change. The early Pleistocene strata are composed of coarser sediment than the Pliocene deposits, and indicate an increase in the transporting ability of the streams supplying detritus to the Ventura basin. Not only was coarser material supplied in the Pleistocene, but it accumulated in shallower water. As described in the Stratigraphy section, there was a progressive withdrawal of the sea from the eastern to the western part of the Santa Clara Valley. At Aliso Canyon only the lower 50 to 200 feet of the San Pedro formation are marine, at Harmon Canyon the bottom 1000 feet, and at Hall Canyon the lower 1950 feet contain marine fossils.

The climatic significance of the marine fossils contained in the Pleistocene strata is hard to interpret. The fauna of the Santa Barbara formation, transitional between the Pliocene and Pleistocene epochs, is commonly regarded as indicating cool water. The San Pedro, entirely Pleistocene, is characterized by an assemblage of organisms inhabiting warm water today.

Bailey (166) has shown that east of Ventura, warm

---

(166) Bailey, T.L., "Lateral change in fauna in the lower Pleistocene," <u>Bull. Geol. Soc. of America,"</u> Vol. 46, no. 3, pp. 489-502, March 31, 1935.

---

water San Pedro forms are found in Santa Barbara strata, which should contain organisms inhabiting cool water. He believes that the shoal water of a possible protected embayment some distance from the open sea formed their habitat.

Summary:

The Ventura embayment was more constricted in the Pleistocene than it had been in the Pliocene. The land area to the north and east stood higher, streams were rejuvenated, and supplied coarse debris to the shallow basin. As the basin filled, the shoreline retreated westward, and marine deposits were supplanted by terrestrial.

The fossil organisms reflect the climatic fluctuations of the epoch. The earlier indicate cool water, the later warm. These changes have been correlated elsewhere with glacial and interglacial stages. The ecologic significance of depth of water and distance from shore has largely been ignored, but is is responsible in the eastern part of the area, for the mingling of cool and warm water forms in the same strata.

Deformation

Deposition was brought to a close by one of the most important events in the history of the California Coast Ranges. This is the episode of intense deformation responsible for the formation of the principal structures of the Coast and Transverse Ranges. Near Ventura the majority of these structures were produced in a short period near the middle of the Pleistocene. The Pleistocene age of the deformation was recognized at an early period in California geology by A. C. Lawson (167) and by Joseph

(167) Lawson, A.C., "The post-Pliocene diastrophism of the coast of Southern California," Univ. of Calif. Publ., Bull. Dept. of Geol., Vol.1, no. 4, pp. 115-160, 1893.

le Conte (168).

(168) Le Conte, J., "Critical periods in the history of the Earth", Univ. of Calif. Publ. Bull. Dept. of Geol., Vol. 1, pp. 313-336, 1895.

Most of the earlier workers in California geology placed the time of deformation near the Pliocene-Pleistocene boundary. Stille (169) believes that the deformation, to

(169) Stille, Hans, "The present tectonic state of the Earth," Bull. Amer. Assoc. of Petrol. Geol. Vol. 20, no. 7, pp. 849-880, July, 1936.

which he gives the name "Pasadenan", was accomplished within a short period, about 300,000 years ago.

The rocks of the Ventura region were deformed by forces probably directed from inland towards the coast. These are sedimentary rocks exclusively, and the chief type of deformation to affect them has been folding. Faulting is important in the areas where stress has been particularly acute and overturning of strata has occured. The most intense deformation is along the northern margin of the area, the slightest at the southern. The close relationship between the type of structure developed and the nature of the underlying bedrock was pointed out in the section on Structure.

<u>Summary</u>:

The deposition of marine strata was brought to a close in the middle Pleistocene by an orogenic period which has been termed the "Pasadenan". All the rocks of the Ventura region were affected. Folding is more widespread than faulting, and was more severe near the northern boundary of the area than the southern. This deformation was accomplished in a short period.

Erosion

The relief of the Ventura region was increased as a result of the deformation of its rocks. As a consequence of the increase in elevation, the sea receded from the Ventura embayment, and marine deposition ceased in the area once occupied by its waters. Consequent streams started the destruction of the more elevated portions of the region.

It is unlikely that any part of the district reached a high altitude as the result of deformation. The rocks involved are soft and readily eroded. It may be in the Coastal Hills, that erosion and deformation were in equilibrium, and the rocks were stripped away as rapidly as they were folded. The northern part of the area, where the rocks are more resistant, probably acquired a greater initial relief.

The region remained comparatively stable for some time after the end of the period of deformation. Erosion procéded far enough in the cycle that a surface of late maturity was developed over most of the area. It was a surface with a moderate relief, most of the valleys were broad, and the streams were at grade in the lower part of their length.

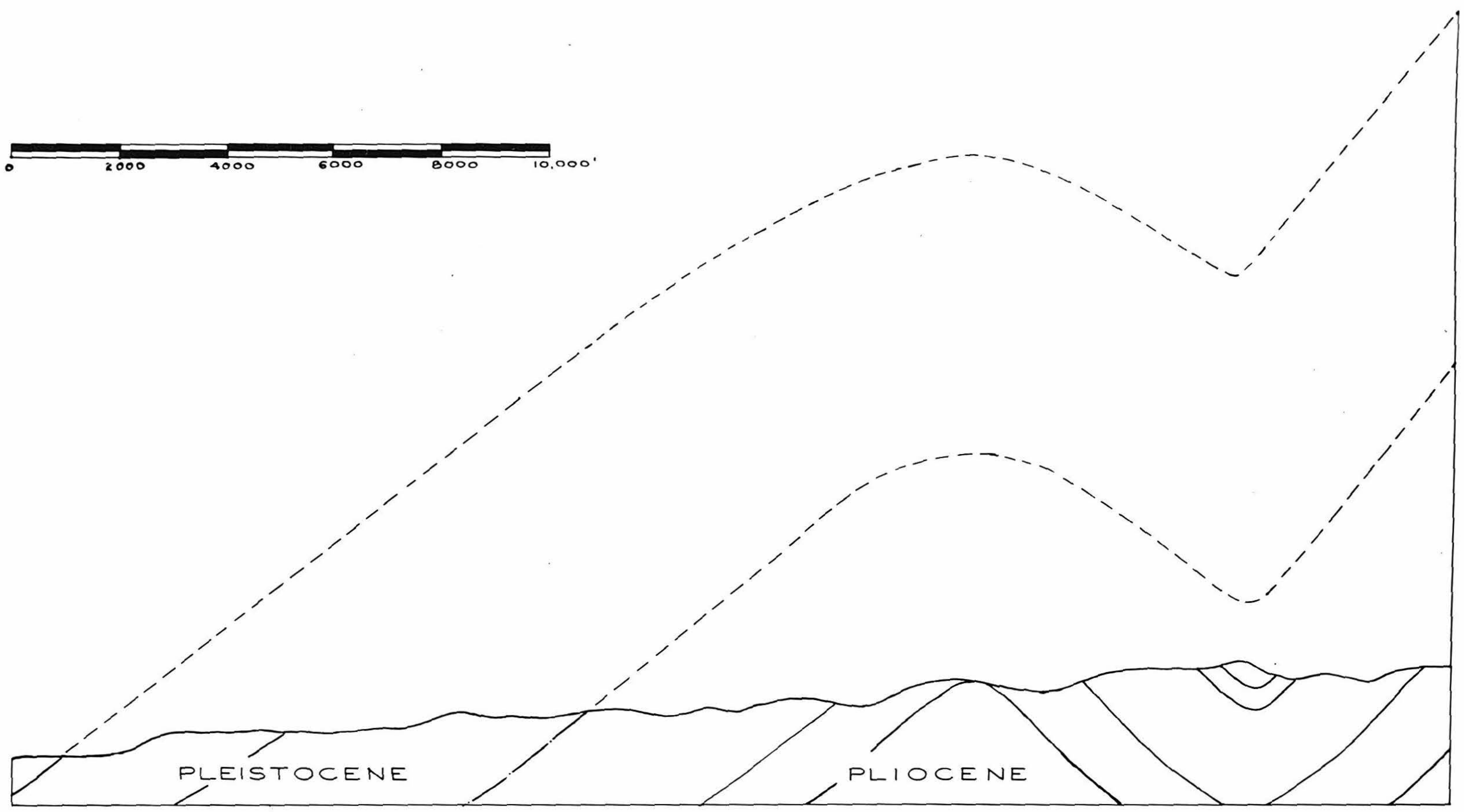
The higher mountains in the northern part of the area preserve on their summits a less well developed surface which stands 2000 feet above the lower surface in the southern section. This higher surface was formed first. The disparity in elevation may record a regional uplift before the Rincon Surface was cut at a lower elevation across the weaker rocks in the southern and central parts of the district.

The Rincon Surface had an effective relief of 1500 feet at the end of its cycle. The surface was one of late maturity, and was not a peneplain. It was interrupted, through the middle of the area, by a pronounced ridge which separated a broad central valley from the sea. A large south-flowing river, the predecessor of the Ventura, crossed the medial ridge, and connected the central lowland with the Pacific. This stream was joined by an equally large west-flowing tributary, Santa Paula River, which held a course along the northern side of the Sulphur Mountain ridge.

The coastline was straight, although interrupted by a number of blunt salients. For the most part the country inland was low, and the sea cliffs bordering the shoreline were unimpressive. The broad submarine platform was floored with sand and silt close to shore. The only moderately steep coast was in the northwestern part of the area, where the predecessor of the Santa Ynez Mountains reached the sea.

Plate XVII

Restoration of Ventura Avenue Anticline



RESTORATION OF THE VENTURA AVENUE ANTICLINE

The production of the Rincon Surface required a long period. Although the underlying rocks are relatively non-resistant, a great thickness of them has been removed. Some indication of the amount stripped off is shown in the accompanying diagram of a restoration of the Ventura Avenue anticline to its full height. Some 10,000 feet have been removed since folding commenced in the middle Pleistocene. This statement is not meant to infer that the Ventura Avenue anticline ever formed a ridge 10,000 feet high, for erosion never lagged far behind deformation. The diagram does give a quantitative picture of the amount of stripping necessary to produce one section of the Rincon Surface.

Summary:

A surface of moderate relief was produced over most of the Ventura region in the quiet period following the mid-Pleistocene orogeny. This surface reached the stage of late maturity in its erosion cycle, and possessed a maximum relief of 1500 feet. The amount of stripping necessary to develop this surface across the axis of the Ventura Avenue anticline totals 10,000 feet.

Uplift

The Ventura region was elevated in a regional uplift near the close of the Pleistocene. This uplift was pulsatory, with periods of still-stand alternating with times during which the land rose. The sea had an opportunity to cut a platform and the Ventura River to widen its valley during the quiet interludes. In the times of elevation the sea was forced to retreat, and the river to downcut in order to hold its own against the rising land. This intermittent uplift is responsible for the formation of marine and river terraces.

The terraces indicate one of the more noteworthy features of the regional uplift. Some parts of the area have risen more than others, and some, instead of sharing in the elevation, have been depressed. The terrace surfaces are not horizontal, but have been warped. This warping is well shown in the marine terraces on Rincon Mountain and the Ventura River terraces. The lower Rincon terrace disappears below sea level at Carpinteria, but rises to a maximum of 850 feet at Padre Juan Canyon 9 miles east. The Ventura River terraces are inclined against the gradient of the river north of Casitas, and with the river, but at a greater slope, south of Casitas. The area of maximum elevation coincides with the Sulphur Mountain Upland. The depressed areas are the Carpinteria Plain, the

Ojai Lowland, the Santa Clara Valley, and Oxnard Plain.

There may be uplift in progress at the present time. This is shown by the Seacliff Bench between Punta Gorda and Pitas Point, the sub-levels of the Ventura River terraces, the numerous rejuvenated streams, and faulted or warped terrace gravels and alluvial fans.

Summary:

The intermittent uplift of the Ventura region is indicated by river and marine terraces. The warping of these levels shows a differential uplift, with some areas elevated, others depressed. This diastrophism is apparently still in progress.

Chronology

The difficulty of correlating events of the Ventura Pleistocene with the glacial chronology was pointed out in the introductory part of this section. Eustatic fluctuations of sea level during the Ice Age are impossible to distinguish from crustal movements in this short length of coast. The only basis for correlation with the glacial-interglacial scheme is the supposed temperature significance of fossils found in the marine Pleistocene strata, and buried in terrace gravels. According to this evidence, at the beginning of the epoch, and before the diastrophic period, there appears to have been a time of cold temperature followed by warm temperature of sea water. That the control of ecologic conditions may have been fully as important as any temperature significance is pointed out by Woodring (170).

---

(170) Woodring, W.P., "San Pedro Hills," XVI International Geological Congress, Guidebook 15, pp. 34-40, 1932.

"Fossils from the marine Pleistocene terraces of the San Pedro Hills, California," Vol. XXIX, no. 171, pp. 292-305, March, 1935. A.J.S.

No evidence is available for correlating events in the diastrophic and erosional phases of the Ventura Pleistocene with the glacial record. It is not until the comparatevely recent Carpinteria assemblage accumulated that another common date is established. As shown in the section on Stratigraphy the Carpinteria sea cliff required approximately 20,000 years for its recession. This length of time would place the period of accumulation in the waning phase of the last glaciation.

A further difficulty in correlating Pleistocene events is the lack of unanimity among glaciologists on the number and duration of the glacial stages. There is some agreement that there has been a bipartition in the record. One of the interglacial stages lasted longer than the others, and separates an older, less well preserved from a young well preserved glacial record. This was pointed out for the Swiss Alps by Heim (171) and Penck and Brückner (172),

(171) Heim, A., "Geologie der Schweiz," Vol. 1, p. 344, 1919.

(172) Penck, A. and Brückner, E., "Die Alpen im Eiszeitalter," 3 vols., Leipzig, 1901-1909.

and in the Sierra Nevada by Matthes (173) and Blackwelder (174).

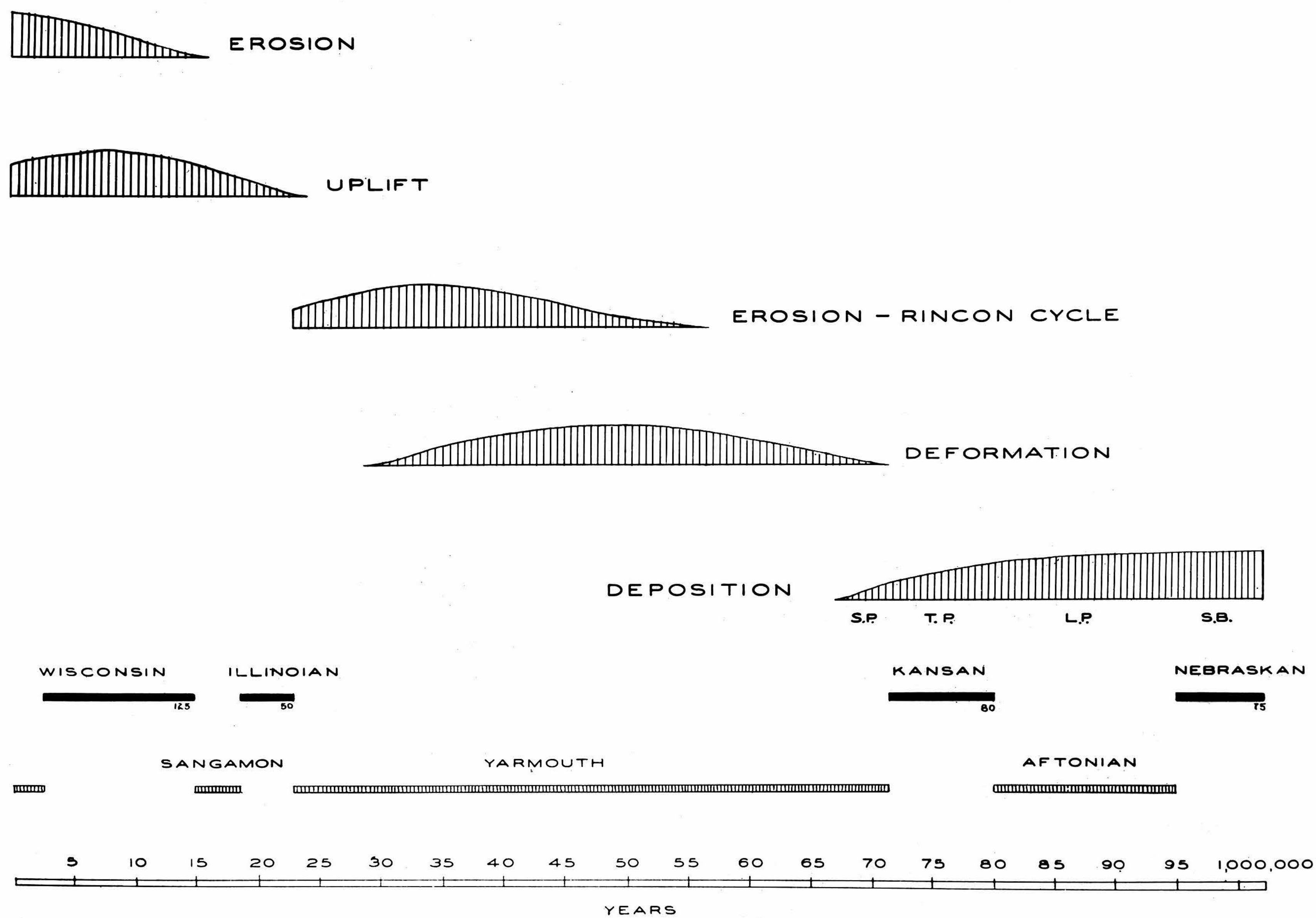
(173) Matthes, Francois, "Geologic history of the Yosemite Valley," U.S. Geological Survey, Professional Paper 160, 137 pp., 1930.

(174) Blackwelder, Eliot, "Pleistocene glaciation in the Sierra Nevada and Basin Ranges," Bull. Geol. Soc. of America, Vol. 42, no. 4, pp. 865-922, Dec. 31, 1931.

Published estimates for the duration of the Pleistocene range from 500,000 to more than 5,000,000

Plate XVIII

Pleistocene chronology of the Ventura Region



PLEISTOCENE CHRONOLOGY

years. Many authorities favor an epoch of 1,000,000 years, and 25,000 years or less for post-glacial time in the latitude of the Alps or the Sierra Nevada. In preparing the correlation chart for the Ventura region (Plate XVIII), the arbitrary figure of 1,000,000 years was selected for the length of time occupied by the glacial and interglacial stages. The purpose of the chart is to show the relative rather than the absolute durations of the various episodes in the later history of the Ventura region. Whether it will be possible to successfully correlate them with a glacial record 2000 miles away remains to be seen. The particular merit of the diagrammatic method used is that it indicates the relative duration of a number of events, and also shows that they did not commence or end in conformity with a number of arbitrary division points.

The diagram shows that deposition of the Pleistocene marine formations occurred in the first two glacial and first interglacial epochs. The Coast Range diastrophism falls in the middle Pleistocene, or during the long second interglacial stage. Erosion contemporaneous with deformation, outlasted it, and continued into the third glaciation. The post-deformation erosion cycle was ended by regional uplift which commenced in the last interglacial stage and has continued into the Recent epoch.

SUMMARY AND CONCLUSION

The Ventura region is of interest; 1.) for the great thickness of 44,000 feet of Tertiary and Quaternary sediments, and 2.) for the complex series of events which occurred in the Pleistocene. The Pleistocene history may be divided into four major episodes:

1.) The deposition of 4,700 feet of marine sediments.

2.) The deformation, by folding and faulting, of all the rocks in the region by a mid-Pleistocene orogeny.

3.) Erosion which produced a surface of late maturity followed the deformation, and was in part contemporaneous. Ten thousand feet of sediment were stripped from the axis of the Ventura Avenue anticline.

4.) Vertical uplift, averaging 1,000 feet, initiated the present erosion cycle. The intermittent uplift is recorded by terraces in the Ventura River valley, and by marine terraces along the coast.

The terraces are warped and show that uplift was not uniform over the entire area. Some parts of the region were elevated while others were depressed. The maximum elevation is found where the most intense deformation occurred, and particularly where the rocks have been anticlinally folded. The depressed areas roughly coincide with synclinal axes.

Three terraces may be recognized throughout the length of the Ventura River. They attain their greatest height near the center of the area, and slope away from this apex in both directions. North of the axis of uplift the terraces have an inclination of three degrees against the normal stream gradient. South of the axis they are inclined with the stream, but have a greater slope.

The marine terraces are best developed in the western part of the coastal section. Four levels are sufficiently well preserved that they may be mapped in detail. These terraces are inclined westward, and have a slope of 100 feet to the mile. They have been faulted, in addition to their recent warping. The evidence for these recent displacements is most apparent on the surface of the lowest marine terrace near the western border of the area where two low scarps cross the Carpinteria Plain.

The post-deformation surface of erosion is called the Rincon Surface. It had reached late maturity in its cycle, and possessed an effective relief of 1,500 feet. Differences of rock resistance and structure are clearly reflected by differences of elevation. The Ventura River followed nearly its present course across the Rincon Surface. It was joined near its mid-point by a large west-flowing tributary, known as the Santa Paula River. Near the close of the Rincon Cycle this stream was captured, and was diverted to join the Santa Clara River.

The Carpinteria fossils are found on the surface of the lowest marine terrace. From the rate of recession of the sea cliff, they appear to have accumulated approximately 30,000 years ago. A narrow coastal plain, crossed by small streams, was the environment of deposition. The vertebrate remains show few effects of transportation, and are a tar pit accumulation. The plant fossils show evidence of decay and attrition, and may have been introduced by the overflow of the small streams during occasional floods. The plants indicate a cooler, more humid climate than exists today at this latitude.

The modern shoreline is now in approximate equilibrium. The headlands are retrograding, and the sand beaches are prograding on the leeward side of the principal stream mouths. The rate of growth is correlated with the seasons, and with the intensity of storms and floods. Material carried down by streams is the chief source of sediment in the beaches.

Changes in the appearance of the Ventura shoreline during the period of uplift, and at the present time, follow a definite sequence. The recognition of this sequence as part of a cycle of erosion, applicable to steeply sloping shorelines of emergence, developed from this study. The coastline of the Ventura region is in late youth in terms of the cycle.

A possible attempt to correlate events in the Pleistocene history of the Ventura region with the standard glacial-interglacial sequence may be as follows: 1.) the deposition of the marine sediments occurred during the first glacial and interglacial epochs, 2.) the period of deformation and erosion is in the second glacial and long, second interglacial stages, 3.) the uplift took place at the time of the last, relatively short, double glaciation. This differential uplift is in operation at present, especially in the central part of the area, where the axis of the Ventura Avenue anticline enters the sea.

Fundamental Problems

Many of the problems in this study possess more than local interest, and are questions of fundamental importance in the history of the California Coast Ranges. A number of the broader problems to which this investigation contributes are indicated in the sections to follow.

1. Eustatic lowering of sea-level

Numerous papers in recent years have directed attention to the occurrence of a low bench, about 2 meters above the present sea-level, clearly abraded by the waves and occurring as a more or less continuous feature on many coasts. As a rule, this wave-cut platfoem, best seen on oceanic islands, is least apparent on continental shorelines where it has been obscured by local elevation and depression of the land. It may, also, be hidden by sediment supplied by streams and distributed by the littoral current.

In the United States the principal advocate of the post-glacial lowering of sea-level has been R. A. Daly,(175) and other writers are in essential agreement with his observations. There is little doubt of the world-wide occurrence of a low, wave-cut platform slightly above present sea-level.(176) That this platform is not the

---

(175) R. A. Daly, "A general sinking of sea-level in Recent time," Proc. Nat'l Academy of Sciences, Vol. 6, p. 246, 1920.

__________, "The Geology of American Samoa" Carnegie Institution of Washington, Publication No. 340, 1924.

__________, "The Changing World of the Ice Age," Yale University Press, New Haven, 1934.

---

(176) Baulig, Henri, "The Changing Sea-level," Inst. of British Geographers, Pub. 3, George Phillips and Son, London, 46 pp., 1935. Reviewed in The Geographical Journal, Vol. LXXXVI, No. 4, pp. 24-25, October, 1935.

L. J. Chubb, "Geology of the Marquesas Islands," Bernice P. Bishop Museum, Bull. 68, 71pp., 1930.

J. S. Gardiner, "Coral Reefs and Atolls," Bull. Museum Comp. Zool., Vol. 71, No.1, 30 pp. 1930.

D. W. Johnson, "Supposed two-meter bench of the Pacific Shores," Inter. Geog. Congr., Comptes Rendus, Tome II, fasc. 1, pp. 158-163, 1933.

J. B. Pollock, "The amount of geologically recent negative shift of strand line on Oahu," Jour. Wash. Acad. of Sci., Vol. 18, No. 3, pp. 53-59, 1928.

H. T. Stearns, "Shore benches on the island of Oahu, Hawaii," Bull. Geol. Soc. of Americ Vol. 46, pp. 1467-1482, 1935.

C. K. Wentworth and H. S. Palmer, "Eustatic bench on islands of the North Pacific," Bull. Geol. Soc. of America, Vol. 36, pp. 521-544, 1925.

Howel Williams, "Geology of Tahiti, Moorea, and Maiao," Bernice P. Bishop Museum, Bull. 105, 89 pp., 1933.

---

work of storm waves is shown by the fact that it occurs behind coral reefs, along the shores of embayments, and in other localities protected from strong wave attack.

Evidence for the presence or absence of an eustatic bench along the Ventura coast is not conclusive. The main reasons for this are the recency and character of deformation. Another process that obscures the evidence is the fact that the coastline is being prograded through much of its length, especially in the section east of the Ventura River. In spite of its inconclusive nature, the appearance of the Ventura coast favors the proposition of a recently lowered sea-level. Indications that suggest this negative shift are;

1.) Traces survive of a low bench, 4-6 feet above sea-level, in protected coves along the Carpinteria coast near the tar-pits.

2.) Partially submerged rocks off the coast are truncated at approximately the same height above sea-level.

3.) Streams entering the sea are entrenched near their mouths, even where their length is not being shortened by wave attack.

4.) Waves no longer reach the base of sea cliffs which were being vigorously attacked in comparatively recent times.

5.) Although the Sea Cliff Bench is interpreted as the product of local warping, some of its apparent elevation may be due to the lowering of sea-level.

<u>Summary</u>: The problem of an eustatic lowering of sea-level can be answered only by observations extended over a long distance on a coastline free from local deformation.

It is interesting that in the Ventura Region more evidence was found favorable to a negative shift of sea-level than opposed to it.

2.) <u>Glacial changes of sea-level</u>

The fact that removal of large quantities of sea water during the glacial stages of the Pleistocene caused a lowering of sea-level, escaped general notice for a long time. Probably the first mention of this accompaniment of glaciation was in an early review of Agassiz's glacial theory.(177) It as not until Daly advanced his

(177) C. MacLaren, "The Glacial Theory of Professor Agassiz," <u>Amer. Jour. of Science</u>, Vol. 42, pp. 346-365, 1842.

Glacial-Control Hypothesis for the origin of coral reefs that interest was aroused in the problems associated with a shifting sea-level.

Attempts have been made to correlate coastal terraces with fluctuations of sea-level during the Pleistocene. For the California coast the most significant paper is that by W. M. Davis(178) on the terraces cut on the south side of

(178) W. M. Davis, "Glacial Epochs of the Santa Monica Mountains, California," <u>Bull. Geol. Soc. of America</u>, Vol. 44, pp. 1041-1133, 1933.

the Santa Monica Mountains. Davis discounted the importance of local movements of the land and believed that the terraces were produced by alternate transgressions and regressions of the sea in harmony with ice advance and retreat in the continental interior.

This hypothesis fails to account for the great number of terraces found on other sections of the coast, and the elevations at which they stand. The complex series of events in the earlier Pleistocene is ignored in this theory of glacial control. In the Ventura region the terracing epoch occurred in the late Pleistocene. The terraces are too numerous and are too high to have been formed by the shifting strand line of an oscillating sea.

Changes did occur in the position of sea-level during the Ice Age, and some evidence should survive of its fluctuations. No indication of the lowered sea level of the first two glaciations can be expected in the landscape; for these two precede the "Pasadenan" orogeny. Furthermore, it is not possible to discriminate between the effects of the Illinoinan low-stand of the sea, and the pulsatory uplift of the land.

Some evidence should exist, on a stable coast, of changes associated with the Wisconsin lowering of sea-level. In spite of the mobility of the Ventura coast, a number of features are preserved which may be the result of the late Pleistocene swinging sea-level. Among these are the gravel-filled, former stream channels which cross the Carpinteria Plain. It is possible that they were incised during the lowered Wisconsin sea-level and filled in during the post-glacial rise.

Transverse profiles of the valleys of the Ventura and Santa Clara Rivers are significant. The walls of both valleys intersect the floor at a high angle, and appear to continue beneath the alluvial fill. The flat floors of these valleys have been built up by aggradation. The Ventura valley, 4 miles inland, is filled to a depth of 60-80 feet. The depth of fill in the Santa Clara Valley is not known to the writer, but it must be considerable. It would appear that these streams excavated their channels below their present elevation during the Wisconsin low-stand of the sea. With the rise of sea-level in the early Recent, they filled in the valley floor to its present level.

Not enough soundings have been recorded on the

Coast Survey chart of this coastal section to tell whether or not a submerged sea-cliff is present. No large submarine canyons are reported here, although one has been described at Hueneme, south of the Santa Clara River.

<u>Summary:</u> Evidence of the oscillating Pleistocene se-level has been obscured by deformation and uplift of the land. The only shift in sea-level which may be provisionally identified is the one associated with the Wisconsin glaciation. It is unlikely that it will be possible to correlate marine terraces in the Ventura area with glacial fluctuations of sea-level.

3.) <u>Relation of terraces to coastal rocks</u>.

One of the interesting problems in the study of the Ventura terraces is their relation to the underlying rocks from the standpoint of development and preservation. A study of the physiographic map (Plate VIII) shows that no terraces occur along a considerable stretch of coast, but that they reach their fullest development in a single part of the area, the western slope of Rincon Mountain.

a.) <u>Development</u>: The relation of rock resistance to terrace development was pointed out by W.S.T.

Smith[179] more than thirty years ago. Rocks of high

---

(179) W.S.T. Smith, "A topographic study of the islands of Southern California," Bull. Dept. of Geol., Univ. of Calif. Publ., Vol. 2, No. 7, pp. 179-230, 1930.

---

erosional resistance will be only slightly benched in the same time interval that rocks of moderate resistance will be truncated by a broad wave-cut terrace.

In the Ventura area, under nearly identical conditions of marine erosion, insignificant terraces in the Eocene sandstones of the Santa Ynez Mountains were cut during the same time interval as the broad Rincon series in the Miocene siliceous shales. The broadest platforms should be expected in the non-resistant mudstones of the Pico formation. Undoubtedly they did develop in the coastal area underlain by Pliocene rocks, as is suggested by the broad bench west of the Ventura River mouth, but they were destroyed in the present erosion cycle.

b.) Preservation: The problem of terrace preservation is of somewhat greater interest. The marine and river terraces are best preserved where they are underlain by siliceous Miocene shales. Examples are; the I level of the Carpinteria Plain, the west slope of Rincon Mountain, the west end of Sulphur Mountain, and the Ventura River Valley in the vicinity of Oakview and LaCrosse.

This preservation of landforms cut in these siliceous shales is not restricted to the Ventura region. Two other important terraced regions between Ventura and Los Angeles Harbor are underlain by similar rocks. These districts are the San Pedro Hills and the Santa Monica Mountains near Point Dume. The reasons for this resistance to denudation were discussed in the section describing Sulphur Mountain (pp. 189-190).

The rock structure appears to exercise little control over terrace development or preservation. The Miocene rocks which underly the best preserved terraces are among the most intensely deformed in the region. One exception to the general lack of structural control might be noted. The Pliocene deposits west of Los Sauces Creek preserve the lowermost of the Rincon terraces as well as do the Miocene shales. Here the Pico formation dips landward. South of Seacliff, where the dip is seaward, no further terraces are encountered and they are supplanted by dip slopes and extensive landslides. The single exception is the terrace series west of the Ventura River which is beyond the reach of wave erosion.

4.) <u>Local Nature of Coastal Terraces</u>.

A striking feature of the terraces of the California Coastline is their discontinuity. Long stretches of shoreline support a series of broad terraces that often rise to high altitudes. Equally long parts of the coast are devoid of any indications of terraces. This phenomenon is clearly illustrated within the limits of the Ventura region. No terraces occur south of Ventura on the hills surrounding the Oxnard Plain. In fact, the lower hill slopes on the northern side of the Santa Monica Mountains are buried by the alluvium of the plain, and appear to have been depressed below sea-level. Northwest of Carpinteria the coast also gives indications of recent submergence.

The classic example for the differential movement of the California coast is the contrast between the terraced slopes of San Clemente Island and the San Pedro Hills, and the submerged shoreline of Santa Catalina Island at a midpoint between the elevated blocks. South of the Ventura region, the western end of the Santa Monica Mountains was depressed below sea-level in late geologic time, and their seaward continuation, the Santa Barbara Islands was separated from the mainland. The islands, themselves, are girdled with terraces, and the northern shore of the Santa Barbara Channel is terraced.

Some understanding of the nature of these unlike movements, in contiguous areas, is an outgrowth of this study. The sections describing the Rincon marine and the Ventura river terraces show that these levels have been warped. The river terraces are arched upwards in a fashion similar to a broad anticline. The marine terraces are tilted, and slope westward from the point of maximum elevation down to a region where the most recent movement is that of depression.

5.) Correlation of Marine Terraces.

It would be a comparatively simple task to correlate terraces along the California coast if it could be clearly shown that they were produced by a fluctuating sea-level. Unfortunately it is impossible to reconcile thirteen terraces on the San Pedro Hills with the standard glacial-interglacial sequence. Most of the Southern California coastal terraces are the result of elevation of the land. This is a local phenomenon, while a change in sea-level is world-wide. The preceding section has indicated that the amount, as well as the nature, of the movement varies from place to place.

The correlation of terraces is not likely to be successful because of their local rather than regional character. The Rincon sequence, for example, differs from the descriptions by Davis for the Santa Monica Mountains, and by Woodring for the San Pedro Hills.

6.) Relative stability of the Coast compared to the earlier Pleistocene.

It is difficult to determine whether the California coast is more stable today than it was in the earlier stages of the Pleistocene. Deformation is active at present, but whether it is proceeding at a less rapid rate is a problem which requires further study.

In spite of this difficulty, the present appears to be a period of comparative crustal stability. Two episodes of crustal unrest occurred during the Pleistocene; first, the "Pasadenan" orogeny, and second, the uplift recorded by the terraces. In the same geologic epoch there were also two periods of stability; the depositional phase at the beginning of the Pleistocene and the Rincon erosion cycle.

The Ventura Region is, at least, as stable now as during the two quiet stages of the Pleistocene, but less so than during the times of deformation. Stille, and other geologists believe that the "Pasadenan" orogeny occupied a short interval of geologic time, and was a period of greater instability than the present.

The coast is more stable today than during the period of regional uplift. The present Rincon sea cliff is the highest of the terrace series, and indicates that the sea has been attacking the land at the present level for a long period of time.

7.) <u>Recency of later deformation</u>.

One feature of the Southern California landscape is the abundant evidence of the recency of deformation. The Ventura region is no exception, and among the indications of recent crustal unrest may be cited; the faulted surface of the Carpinteria Plain, the faulted alluvial fans at the base of Santa Paula Ridge, the low hills elevated above the Oxnard Plain near Montalvo, the warped terrace surfaces, and the recent elevation of part of the modern shoreline at Seacliff.

8.) <u>Nature of the most recent deformation</u>.

One of the more speculative of the fundamental problems raised by this investigation is the nature of the most recent deformation of the Southern Coast Ranges. Is the Ventura region now undergoing broad regional uplift, or are its rocks being folded and faulted? As pointed out in the preceding section, most of the visible deformation is faulting or warping. An important point is that the present crustal unrest is most active where the most intense deforamtion occurred in the mid-Pleistocene orogeny. In general, sections faulted, then have been revived as faults today, anticlinal axes, as the Ventura Avenue anticline, have been uparched, and synclines, as the Ojai Valley depressed.

Pasadena, California
February 1, 1937