GEOLOGY OF
SAN NICOLAS AND SANTA BARBARA ISLANDS
SOUTHERN CALIFORNIA

THESIS BY

LUIS EMMETT KEMNITZER

IN PARTIAL FULFILLMENT OF

THE REQUIREMENTS FOR THE DEGREE OF

M A S T E R   O F   S C I E N C E

CALIFORNIA INSTITUTE OF TECHNOLOGY

PASADENA, CALIFORNIA

1933

TABLE OF CONTENTS

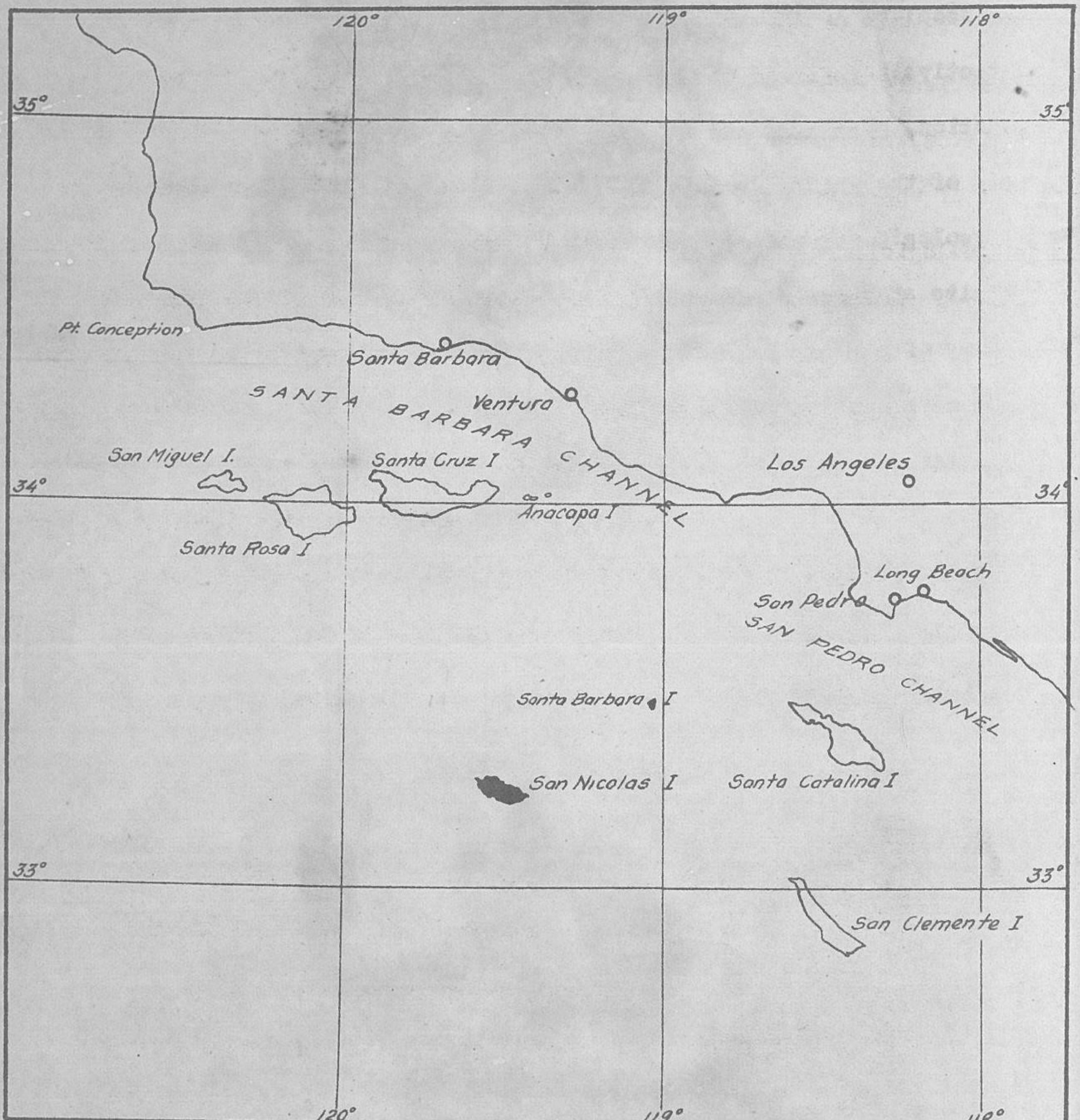
TABLE OF CONTENTS (Cont'd)

SANTA BARBARA ISLAND

List of Illustrations

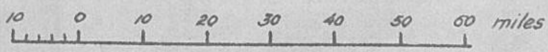
List of Illustrations (Continued)

SANTA BARBARA ISLAND



INDEX MAP
SHOWING LOCATION OF SAN NICOLAS AND SANTA BARBARA ISLANDS

Scale: 1 inch = 30 miles



FRONTISPIECE

SAN NICOLAS ISLAND, VENTURA COUNTY, CALIFORNIA

SANTA BARBARA ISLAND, LOS ANGELES COUNTY, CALIFORNIA

GEOLOGY OF SAN NICOLAS AND SANTA BARBARA ISLANDS SOUTHERN CALIFORNIA

GENERAL STATEMENT

San Nicolas and Santa Barbara islands are the loneliest and the most desolate of the islands lying off the coast of Southern California, collectively referred to as the Channel Islands. Because of their isolation, smallness and unattractiveness they probably are the least known of the entire group. The islands have been mentioned casually in the geologic literature, but there is, so far as the writer knows, no definite statements concerning the geology of either of the islands. The geology of the two islands is dissimilar and they present individual problems; although the geologic history of each island is intimately connected with that of the other Channel Islands and the nearby mainland. It is the purpose of this discussion to present the geologic features and the physiographic history of each of the two islands and to draw some conclusions regarding their part in the general development of the present coast line of Southern California.

SAN NICOLAS ISLAND

INTRODUCTION

Location and Size:- San Nicolas Island is the farthest from the mainland of any of the islands off the coast of Southern California. It is under the jurisdiction of Ventura County, on the mainland to the north, and is about seventy-five miles south from the town of Ventura. (Plate I, Index Map) The island is roughly oval shaped with its longest axis of about ten miles oriented west-northwest, while the maximum width is about three and one half miles. The total area is approximately thirty-three square miles or about twenty-one thousand five hundred acres.

Topography:- The island, which is part of an anticline in sandstones and shales, belongs to a much larger block which emerged from the sea and was reduced by erosion and abrasion to a mass with subdued relief. The mass was then submerged for a time, followed by a period of reemergence during which the eroded anticline was abraded by the sea which cut terraces and cliffs, at several different levels, some of which are preserved. The greatest elevation is 890 feet near the south central portion of the island. The southern slope is a steep highly dissected erosional escarpment while the northern slope is gradual, stepped down by several marine terraces, and cut by consequent and insequent stream channels. The watershed is nearer the south side and lies for the most part at or near to the crest of the escarpment. The prevailing storms come from the northwest, and as a consequence the western half of the island is made desolate, by the building up of sand dunes and windswept stretches, upon which the drainage channels are subdued or obscured. In the eastern half of the island intermittent stream channels have carved the surface into an assortment of coarse and fine textured topography.

Accessibility:- San Nicolas Island is not easily accessible, and the only means of transportation to the island is by government boats, especially through the courtesy of the United States Coast Guard at San Pedro, or by private boat. There are few landing points and these can be used only in fair weather. The best landing can be effected near the middle of the north side just below some ranch houses, located here because of this sheltered position. Kelp beds surround the island and are particularly thick and continuous off the northern shore, where they form a strip over a mile wide between about the five and fifteen fathom lines. Inside the five fathom line is an area of clear water. On the south and southwest sides the kelp is found only on discontinuous reefs

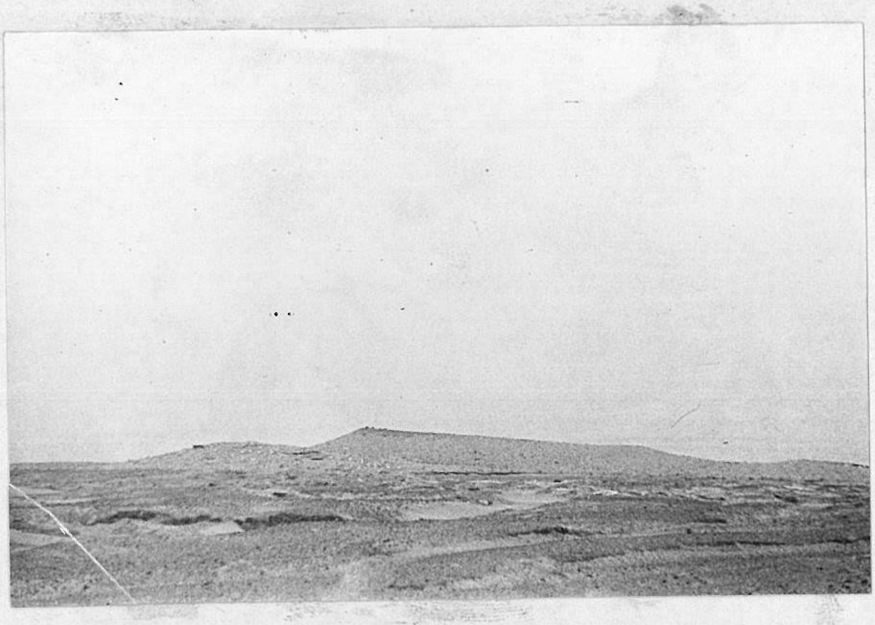


Fig. 1 A kitchen midden on one of the upper terraces. These are found practically everywhere on the island but are particularly abundant in the western end.

Fig. 2 Typical remains found in kitchen middens.

Fig. 3 One of the larger petrifactions.

Fig. 4 Evidence of former plant life near the west end. Semi-petrifactions of trunks and roots of shrubs and small trees replaced by calcite cemented sand.

and from the crest of the southern escarpment the strike of the beds can be traced for some distance out to sea by the alignments of the seaweed.

Inhabitants:- At the present time the island is inhabited by one family of sheep ranchers who graze some twelve hundred head on the rather meagre growth of grass. There is mute testimony that at one time a good sized Indian population was supported here, for there is a great number of kitchen middens as well as remains of implements andhuman skeletons. (Plate II, Figures 1 & 2).

Flora and Fauna:- Plant life is sparse, being limited to a few scattered shrubs and cactus, ice plant, and some rather large tracts of grass used for grazing, principally on the upper slopes on the eastern half of the island. There is evidence that at one time there existed a more extensive growth of shrubbery and probably small trees. Near the west end are stretches covering several acres as well as small patches, where the remains of former plant growth are found, ranging in size from a fraction of an inch to several inches in diameter. Apparently these plants were buried by dune sands, which abound on the northwestern or windward end of the island, the organic matter replaced by calcite or sand cemented by calcite, and subsequently the burying material blown away, leaving the semi-petrifactions standing. (Plate III, Figures 3 & 4). Bowers(1) observed these on San Nicolas Island in 1889 and W. S. T. Smith(2) records a similar phenomenon on San Clemente Island. Continuous pasturing of sheep for a period of over seventy years has, no doubt, been an important cause for the decrease in growth of plant life on the island.

---

(1) Bowers, Dr. Stephen; Calif. State Mining Bureaus, 9th. Ann. Rept., State Mineralogist, for 1889, p. 58-59

(2) Smith, W. S. Tangier; A Geological Sketch of San Clemente Island. U.S.G.S., 18th. Ann. Rept., 1896-97, Pat. II, p. 466.

Dr. Stephen Bowers(1) has given an account of the zoology of the island and states "The only animals found on San Nicolas are a small fox, a kangaroo mouse, and a diminutive sand lizard." He further states that as far as he was able to learn, the species of fox found is confined to the Channel Islands. (PlateIV, Figure 6) Several species of land birds are found, among which are the bald eagle, ground owl, raven, crow, and plover. Water fowl are abundant and among them are gulls, pelicans, cormorants, and sea pigeons.

Climate:- Only a sketchy and inaccurate record of the climate has been kept by one of the ranchers during the last three years. However, his log indicates a semi-arid climate with sparse rainfall mostly confined to about four winter months, frequent fogs throughout the year, and winds which blow with violence generally from the northwest. The winds blow intermittently for periods of from one to ten days throughout the year, and the strong winds have played a great part in the configuration of the island by erosion and deposition, especially in the western half.

Water:- Springs occur in various places on the island, but most of these springs are brackish and unsuited for consumption either by stock or man. While in a few places on the western half of the island the spring waters are potable, most of the water for drinking purposes is caught in cisterns at the ranch houses. The run-off of rain water is so rapid that the stream channels are dry most of the time; although on the upper terraces of the western half, wind blown sands have prevented the formation of a surface drainage system, and the meteoric waters which fall are absorbed in the porous covering of aeolian and alluvial deposits. The underground drainage is there toward the northwest along the contact

---

(1) Bowers, Dr. Stephen; Calif. State Mining Bureaus, 9th. Ann. Rept., State Mineralogist, for 1889, p. 58-59.

with the underlying older sedimentary rocks, and waters flow in this direction issuing as springs in several localities in the western part of the island. The water thus trapped is potable and the natural reservoir is of sufficient capacity to allow the springs to flow the year round. The springs which exist in the eastern half are all more or less brackish and all emerge from the older sediments. These waters are probably meteroic waters, contaminated by salts taken into solution, while percolating through portions of the older rocks.

Literature:- The only published data concerning the geology of San Nicolas Island known to the writer are a topographic reference by W. S. T. Smith[1], and some more general notes by Dr. Cooper[2] and by Dr. Stephen Bowers[3]. Mr. Smith personally stated that he had never visited the island and his statements were based on a study of the available maps. In spite of the correct reports of Cooper in 1865 and Bowers in 1889 to the effect that the island was composed of sandstones and shales, the Geologic Map of the State of California issued by the State Mining Bureau in 1916 erroneously shows the island to be composed entirely of volcanics. According to my personal observations only one small igneous dike was found, cutting the bedded rock.

Acknowledgements:- Altogether about a month was spent in the field investigation during three trips to the island. The United States Coast and Geodetic Survey was helpful not only in furnishing transportation on the first trip to the island, but in willingly permitting the use of their most recent survey results on and about the island. I wish to express my

---

(1) Smith, W. S. Tangier; A Topographic Study of the Islands of Southern California. Univ. of Calif., Bull Dept. Geol., 1900 Vol. 2, No. 7, pp. 179-230.

(2) Geol. Surv. of Calif., Geol., Vol. 1, p. 184.

(3) Bowers, Dr. Stephen; Op. Cit., pp. 57-61.

thanks to Lieutenant Robert W. Knox of the Coast Survey for his part in facilitating my field work. Captain Swainson, also of the survey, kindly procured a rock sample from Begg Rock[1]. The United States Coast Guard at San Pedro was courteous in giving transportation to and from the island on two occasions. George Richards, a recent graduate from Stanford University, accompanied me on my first trip to the island; Chester Cassel, also formerly of Stanford, made the trip on my second visit; and on the third trip Messers Nelson Nies, Jack Judson, and Donald Curry, fellow students at California Institute of Technology, went along. All of these men were good field companions and their comments and suggestions in the field are appreciated and gratefully acknowledged. The staff of the Geological Department of the California Institute of Technology has been helpful in the preparation of the paper; especially Professor W. M. Davis has encouraged me in my work and criticized the results herein recorded. I am indebted to Messers Donald Hughes and Boris Laiming of the Texas Company for the determination of certain foraminifera, and to Messers Frank Bell and Willard Finlay of the California Institute of Technology for the criticism of the determination of the age of the sediments. I am indebted to Dr. Ralph Arnold and Mr. William J. Kemnitzer, my brother, for many photographs which are acknowledged as used.

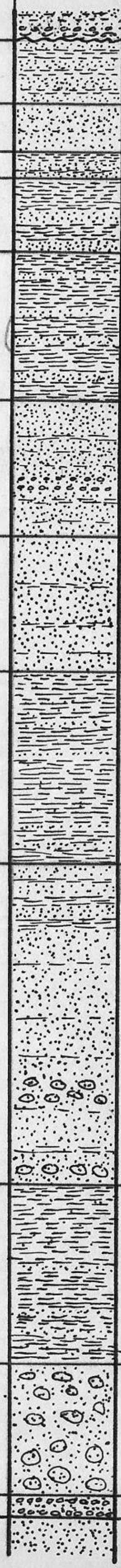
STRATIGRAPHY

The rocks forming San Nicolas Island, with the exception of the recent subaerial deposits, the Pleistocene marine terrace deposits, and

---

(1) Begg Rock which lies about five miles northwest of the west end of the island and over one and a half miles northeast of the extension of the anticlinal axis, protrudes only about fifteen feet above the sea and has an area of only about one hundred square feet. The depth of water immediately surrounding this stack is close to forty fathoms. The rock sample obtained was examined and found to be a fine grained rhyolite with vague flow structure. It is likely that Begg Rock represents the remnants of a volcanic neck.

COLUMNAR SECTION OF SAN NICOLAS ISLAND



FORMATION	ZONE	SECTION	THICKNESS IN FEET	DESCRIPTION
Recent and Pleistocene				Aluvium; dune sds & ss and silts
			0-50	Marine terrace Deposits - beach ss & grs
Unconformity				Coquina and marl
EOCENE Meganos	13		200	Coarsely bedded ss & sh. Foraminifera
	12		150	Massive buff med grd ss, thin sh partings
	11		90	Buff ss & silty sh. Foraminifera
	10		240	Laminated to paper sh. Two massive buff ss. layers. Foraminifera in top sh.
	9		500	Bl to buff sdy & silty sh, occasional ss layers. Foraminifera.
	8		450	Massively bedded buff ss separated by interbedded buff & gr ss & buff sh. Thin conglomerate in middle. Ostrea & a solitary cup coral
	7		470	Gr & buff ss, occasional dk gr sh beds.
	6		650	Bl-gr sdy & silty sh, occasional buff ss layers. Foraminifera
	5		1100	Gr to buff ss & buff sdy sh. Ss thicker & somewhat concretionary near base. Sh strat more numerous in upper half.
	4		600	Buff to bl-gr sdy sh. Thin ss layer & lense near base.
	3		450	Hd buff to gr concretionary ss. Occasional Ostrea
	2		50	Conglomerate zone, with blocky ss.
	1		100	Hd. blocky ss.

one small igneous dike, are all Tertiary non-volcanic marine sediments - Eocene in age. Other Tertiary formations are not present, although it is possible that younger rocks might be present off shore to the north-east. The shallow shelf along this side of the island is close to four miles wide; so there is adequate space for at least a partial section of younger formations to be present.

The Eocene Sediments:- There are over five thousand feet of Eocene marine sediments exposed on the island, the exposures being limited to the shore line and immediately adjacent areas, and the escarpment along the southside. There are few outcrops of these older sediments in the interior portions of the island, although they do occur in the deeper valleys. The rocks are buff and gray sandstones alternating with buff and blue-gray shales, and several comparatively thin beds of conglomerate. The sandstones only slightly predominate the shales, and there is always some intercalation of either the sandstones with the shales or the shales with the sandstones, even in those phases which appear to be purely shale or sandstone. This alternation and intercalation of sandstone and shale together with occasional conglomerate and conglomeratic beds indicates a continual change and alternation of the conditions of deposition. The Eocene section is described from top to bottom in the following outline:

Zone	Description	Thickness in feet.
13	Rather coarsely interbedded sandstones and shales. Sandstone medium grained, buff to gray, some soft and crossbedded, others hard and concretionary. Shales generally silty and fissile, gray-buff to yellow-buff, and carrying _Foraminifera_ (Plate IV Figure 5)	200

(Continued on next page)

Zone	Description (Continued)	Thickness in feet.
12	Massive buff medium grained sandstone in beds 1 to 10 feet thick separated by thin layers of silty shale 1 to 3 inches thick. (Plate IV, Figure 6)	150
11	Interbedded buff sandstone and silty shale, sandstone predominating. Shales nodular to fissile, gray buff and purplish, carry Foraminifera (Plate V, Figure 7)	90
10	Thinly laminated to paper shales. Beds of shale separated by two massively bedded buff sandstone strata 10 to 30 feet thick. Foraminifera in top of shale.	240
9	Blue to buff, sandy and silty shale with occasional thin buff sandstone layers and lenses. Foraminifera.	500
8	Massively bedded buff sandstone separated by areas of interbedded buff and gray sandstone and buff shale. Thin erratic conglomerate strata and patches of conglomeratic sandstone about the middle of this zone. Specimens of ostrea rare, and a solitary cup coral.	450
7	Interbedded gray and buff sandstone with occasional dark gray shale beds. (Plate V, Figure 8)	470
6	Blue gray sandy to silty shale with occasional buff sandstone layers and lenses. Lowermost Foraminifera zone.	650
5	Gray to buff sandstone interbedded with buff sandy shale. In the bottom half the sandstone beds are thicker and somewhat concretionary, while in the upper half the shale strata are more numerous. (Plate VI, Figure 9 & 10)	1100
4	Buff to blue-gray non-fossiliferous sandy shale interbedded with thin sandstone layers and lenses increasing in number toward the base. (Plate VI, Figure 10)	600
3	Hard buff to gray concretionary sandstone, massively bedded. Local cross bedding and local unconformities. Sandstone beds separated by thin silty shale layers, some of which carry carbonaceous material. Concretions average about 3 feet in diameter and many contain a single ostrea. (Plate VII, Figure 11)	450

(Continued on next page)

Zone	Description (Continued)	Thickness in feet.
2	Conglomerate zone. Blocky buff sandstone interbedded with conglomerate beds 2 to 6 feet thick. The Conglomerate strata thicken and thin and are sometimes lenticular. The pebbles are fairly sorted, well rounded, ranging in size from 1 to 18 inches in diameter with about 3 inches as the average. (Plate VII, Figure 12)	50
1	Hard blocky, gray and buff sandstone.	100
	Approximate Total Thickness	5050 feet.

The uppermost beds (Zone 13) exposed on the island are at U.S.C. and G. station "Knob" on the northeast side of the island about one mile west of the east end, while the base of the section (Zone 1) is found on the southwest shore a few hundred feet east of the west end of the island.

There is a paucity of megascopic fossils: Only a few specimens of nondiagnostic ostrea were found in the sandstones of zones numbers 3 and 8, a solitary cup coral was found in the sandstone zone number 8. However, microscopic fossils, in the shape of foraminifera, were collected from the buff shale of zones numbers 13, 11, and 9 near the top of the section. The localities where foraminifera samples were collected are shown on Map 1 in pocket. The determination of the forms shows that the fauna correspond most closely to those of the middle Eocene, probably Meganos formation.

The following species were found only in the upper zones 9, 11, and 13:

Bulimina cf. rostrata H. B. Brady
Gaudryina cf. indentata Cushman & Jarvis
Bathysiphon eocenica Cushman & Hanna
Bulimina cf. declivis Reuss
Bulimina aff. obtusa d'Orbigny
Rhabdammina sp.
Globulimina sp.
Guttulina sp.
Textularia sp. (Compressed)
Spirilina aff. vivpara (Ehrenberg)

Silicoigmolina cf. californica Cushman and Church

The following species were found only in the middle zone number 6:

Loxostomum applini (Plummer)
Allomorphina globulosa Plummer
Chilostomelloides eocenica Cushman
Bulimina obtusa d'Orbigny
Gaudryina aff. jacksonensis
Siphogenerina cf. eleganta Plummer
Pullenia aff. alazanensis Cushman
Nodosaria latejugata Gümbel
Ellipsopleurostomella cf. attenuata Plummer
Globorotalia sp.

The following species were common to zones 6, 9, 11, and 13:

Cibicides perlucida Nuttall
Cibicides (Planulina) alazanensis Nuttall
Eponides umbonata Reuss
Spiroplectammina cf. bentonensis Carman
Haplophramoides sp.
Globigerina
Gyroidina florealis White
Robulus (Lenticulina) cf. inornata d'Orbigny

Conditions of Deposition:- The lithology of the exposed section was not studied in sufficient detail to warrant any definite conclusions as to the conditions under which these sediments were deposited. However, it can be safely said that the series of Eocene sands, shales, and conglomerates were laid down in a marine environment. Foraminifera occur in Zones 13, 11, 9, and 6; and Ostrea are found in zones 3 and 8. Changes in the force of the transporting currents were no doubt frequent, as shown by the alternation of sandstones and shale beds, as well as by the intercalation of shale and sandstone layers in the thicker beds of either. Occasional conglomerate and conglomeratic beds and lenses occur, probably indicating shore line conditions. Minor problems of sedimentation, which make the consideration of the general conditions of deposition more complex, exist in different horizons. There is some abrupt and rather striking interfingering and lensing of the massive sandstones of zone 7, with the top of the blue shale of zone 6. This condition is excellently exposed in Big Blue on the southwest slope. Also, on the north side about a half mile east of Corral Harbor a conglomeratic lense is unexpectedly found near the middle of Zone 8. This lense is made up of soft, coarse-grained, blue-gray sandstone studded with well rounded igneous pebbles, ranging from walnut to cocoanut size which are haphazardly scattered through the sand about a foot apart. A similar lense of much harder material and with the pebbles more numerous occurs near the bottom of zone 3, on the south side not far from the west end of the island. Many other problems of sedimentation exist, but, as stated, sufficient time was not spent in the investigation of this phase to offer explanations.

The Igneous Dike:- There is only one occurrence of igneous rock on the island and that is a small, nearly vertical dike of diabase, located near the southeast flank of the island. (Plate VIII, Figures 13 and 14) It can be traced over a distance of about a mile and a half in a N 70° E direction from U.S.C. and G.S. station "Gault", cutting across the strike of the beds. (See Map in Pocket) The dike rock is dark greenish buff material which weathers easily, so that it has an appearance similar to that of the surrounding gray buff sandstone, and is, therefore, rather inconspicuous. Where the dike disappears into the sea near Station "Gault" it has a width of about six feet, but a few hundred feet northeastward from this station, the dike divides into two parallel dikes, each about three feet wide, which condition holds for a distance of a little over a mile, after which a single dike is found to resume a width of six feet. Little change can be noticed in the adjacent sandstones and shales; except for a slight baking within a foot of the dike itself. The age of the dike is post-Eocene (post-folding) and pre-Pleistocene (pre-terracing), for it cuts undisturbed across the strike of the tilted and folded sediments, and is truncated along with other rocks in the formation of an elevated sea platform. Although the strike of the dike corresponds with that of one set of faults, there is no evidence of movement having taken place in the dike fracture.

The Pleistocene and Recent Sediments:- Unconformably overlying the truncated Eocene sediments are undisturbed Pleistocene and recent deposits. (Plate IX, Figure 15) These sediments consist of beds of coquina (Plate IX, Figure 16), beach sands and gravels, dune sands, and poorly sorted debris and wash of sand and silt. These deposits are found on practically all of the elevated marine terraces and vary greatly in thickness up to about fifty feet. The greatest thicknesses are obtained in the sand dune areas on the western half of the island, and near the base of the elevated cliffs. It is difficult if not impossible to determine where the Pleistocene ends and the recent alluvium begins, because the recent deposits are in part reworked Pleistocene. Bowers[1] gave a list of fossils from a coquina bed on the lowermost terrace which he determined to be Pliocene in age, but a check of his list with the results of Grant and Gale shows the fauna to be mostly Pleistocene[2]. Considering this with the fact that the marine terraces are apparently unwarped and unfaulted their age may be placed at upper Pleistocene, presumably after the Pleistocene revolution[3].

The streams of the island are practically everywhere corrading and there is little deposition by the streams at present. However there is some deposition of material on the island by wind as well as by occasional sheet washes. The wind has spread sand and constructed sand dunes while

---

(References 1, 2, and 3 on following page)

the sheet washes have instigated small mud flows through which streams have cut.

---

(1) Bowers, Stephen op. cit. p. 58

(2) Time ranges of species given in: Bowers, Stephen; San Nicolas Island; Cal. St. Min. Bur., 9th An. Rept. St. Mineralogist, 1889, pp. 57-61, (1890); sp 58. Data taken from Grant, U. S. and Gale, H. R.: Catalogue of Marine Pliocene and Pleistocene Mollusca, etc; San Diego Soc. Nat. Hist., Memoirs, Vol. 1, 1931.

- (Table by Mr. Willard Finley) -

	PLIOCENE	PLEISTOCENE	RECENT
Acmaea mitra Esch.	------	------	------
A. patina Esch.			
A. pelta Esch.		------	------
A. spectrum Nutt.		------	------
A. scabra Nutt.		------	------
A. persona Esch.		------	------
Arionta gabbi Newc.			
Amphissa corrugata Roe.	------	------	------
Bittium asparum Leach	------	------	------
Crepidula adunca Sby.	------	------	------
Chlorostoma brunneum Phil.		------	------
Chama exogyra Con.	------	------	------
Chlorostoma pfeifferi Roe.		------	------
Calliostoma annulatum Mart.	------	------	------
Chlorostoma funebrale Ad.	------	------	------
Crepidula dorsata Brood.	------	------	------
Cumingia californica Con.		------	------
Drillia inermis Hds.		------	------
Euparypha tryoni Newc.			
Fissurella volcano Roe.		------	------
Glyphis aspera Esch.		------	------
Gadinia radiata J. G. Cooper	------	------	------
Haliotis cracherodii Leach		------	------
Hipponyx antiquatus Lin.	------	------	------
Lottia gigantea Gray			
Lacuna solidula Mont.		------	------
Lazaria subquadrata Carp.		------	------
Lunatia benisii Gld.			
Lucina californica Con.	------	------	------
Mitra maura Roe.	------	------	------
Muricidea subangulata Stearns			------
Pomaulax undosus Wood		------	------
Petricola carditoides Con.	------	------	------
Stenoradsia magdalensis Roe.			
Strongylocentrotus drobachiensis			
Serpulorbis squamigerus Carp.		------	------
Septifer befurcatus Roe.		------	------
Tapes staminea ruderata Con.			------
Tapes staminea Con.	------	------	------

(3) Grant, U. S. and Gale, H. R. op. cit. p. 57

Plate IV

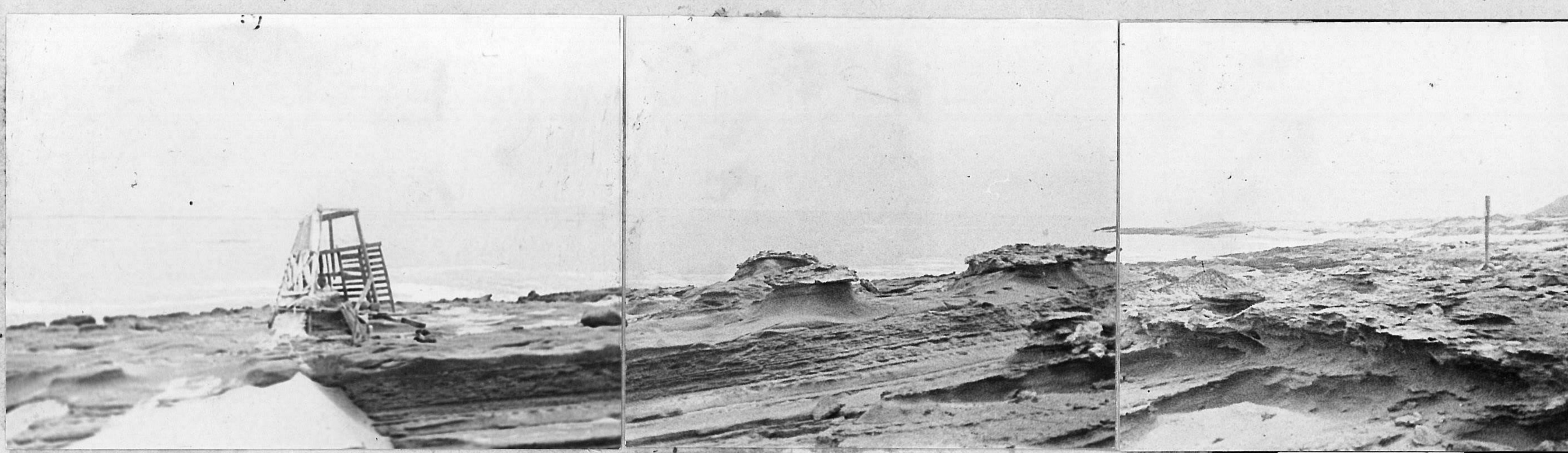


Fig. 5 Upper beds of the Eocene section exposed on the island (Zone 13). View taken on the northeast side of the island about two miles east of the ranch house.

Fig. 6 Massively bedded sandstone of Zone 12. Outcrop near beach about one and a half miles east of the ranch house. Note small fox in under ledge. (W.J.K. & R.A.)

Fig. 7 Inter bedded sandstones and shales of Zone 11. View taken on northeast side of island about one and a half miles east of ranch house. (W.J.K. & R.A.)

Fig. 8 Sandstones of Zone 7 out cropping on northwest shore, just west of the Gardens. Springs of potable water issue in the area and flow the year round. (W.J.K. & R.A.)

Fig. 9 Buff to blue gray shales (Zone 4) capped by the basal portion of the sandstone of Zone 5, on the right faulted against the interbedded sandstones and shales of zone 5. View taken about one and a half miles east of Big Sandy, on the south side.

Fig. 10 Concretionary sandstone bed near basal portion of Zone 4. (W.J.K. & R.A.)

Fig. 11 Hard buff to gray concretionary sandstone (Zone 3) near the shore line on the south side about two miles east of the west end. The plane surface at the top of the picture is part of the fifth island platform and the cliff is the present one with back-shore terrace in the foreground.

Fig. 12 Conglomerate zone (Zone 2) exposed in the present island cliff about three quarters of a mile east of the west end on the south side.

Fig. 13 Igneous dike cutting almost at right angles through tilted Eocene sandstones and shales. The comparatively even surface is the scoured and dissected platform of the fifth island stage as revealed on the south side of the island. Note the absence of in-fill.

Fig. 14 View showing two parallel dikes taken a few hundred feet northeast from the above view.

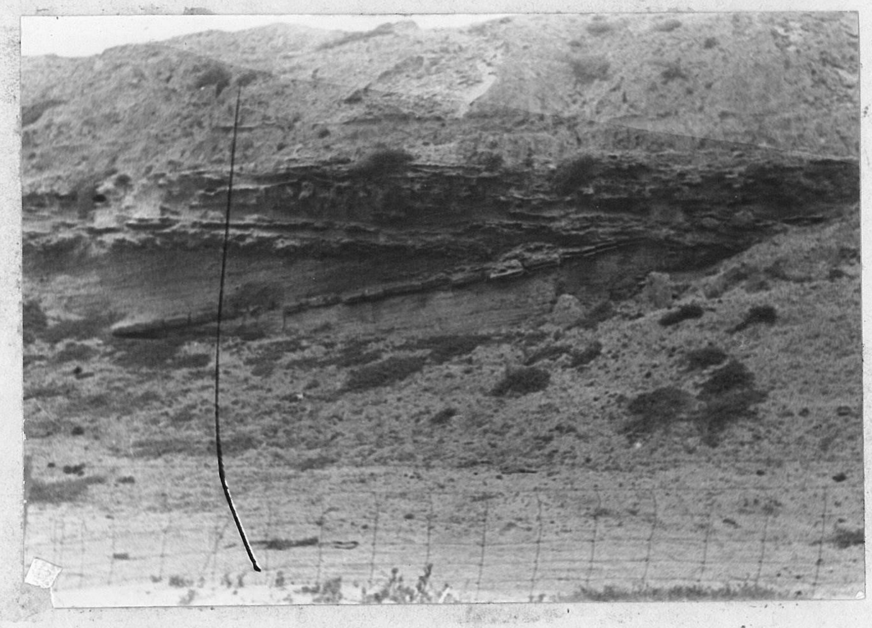


Fig. 15 Unconformity between the Pleistocene terrace deposits and the Eocene Marine sediments exposed in the present island cliff on the north side just below the ranch.

Fig. 16 Coquina bed on lower terrace. (W.J.K)

STRUCTURE

Folding:- San Nicolas Island is the emergent portion of the southeastern nose of an eroded anticline, whose axis strikes northwest-southeast and plunges gently to the southeast. The trace of the anticlinal axis runs along the southwest flank of the island about three quarters of a mile inshore, distinctly south of the island axis, in the eroded escarpment. It goes out to sea to the southeast at station "Gault", and leaves the island to the northwest at a point about one quarter of a mile west of Station "Chino". (Map I, in Pocket) The anticline is slightly asymmetrical with the southwest flank dipping about four degrees steeper than the northeast flank. The average dip of the former is about thirteen degrees northeast, while that of the latter is about seventeen degrees southeast. It happens that the asymmetry of the fold is apparently reflected by the topography of the island, as well as by the submarine contours adjacent to the island, but there appears to be no structural connection. (Plate X, Figure 17) There is a southeast closure to the fold and near the center of the southern flank of the island the beds can be followed around the nose of the anticline. The attitudes of the beds show the open side of the nose to be pointing toward the extension of the fold northwestward, with the axis continuing in a northwesterly direction toward Santa Rosa Island and through a point about one and a half miles southwest of Begg Rock. As indicated above, no northwest closure of the anticline is to be found on the island, but near the west end there is a tendency for the tilted beds to flatten and the submarine contours off the western end show a broad, relatively flat under-water surface in the direction of the extension of the anticline for a distance of about five miles, after which there is a gradual descent of the sea floor northwestward. It can be inferred from this evidence that an eroded dome may exist in this area, and that the apex likely would lie about two and a half miles northwest from the west end of the island.

Continuing northwestward the submarine contours show a notable submarine plateau with a broad rounded crest extending on the sea floor from San Nicolas Island to Santa Rosa Island, a distance of about fifty-five miles. (Map 2, in Pocket) The plateau averages about twelve miles in width between the 100 fathom lines and the soundings indicate an undulating sea bottom, which slopes gently from each island toward a transverse depression midway between the islands, about two hundred fathoms deep at its midpoint. The plateau is bounded by definite submarine escarpments along its northeast and southwest flanks. The northeast flank descends to a depth of over nine hundred fathoms from the 100 fathom line in about three miles, to an extensive deep. The southwest slope reaches over four hundred fathoms in depth in less than a mile and a half from the 100 fathom line. The submarine plateau with its broad subdued top, and its steep flanks descending to pronounced deeps can be considered an up thrust orographic block with the faults located near the declivities. It might further be inferred that the saddle near the middle of the plateau represents the location of a cross fault, but what the intimate structure of this large block might be, can only be guessed. It appears, however, that San Nicolas Island is a part of this block and that the island owes its prominence to movements of and within the block.

Judging from the presence of this broad submarine swell apparently connecting Santa Rosa Island with San Nicolas Island, it is possible that at one time there might have been a land connection between these two islands. Pleistocene vertebrate remains have been found in the terrace

Fig. 17 Panoramic view of the southern erosional escarpment looking eastward from Big Sandy. In the central part of the picture is seen the shale of Zone 6 capped by the buff sandstone of Zone 7. On the left can be seen a steep normal fault which has dropped the Sandstone of Zone 7. The anticlinal axis strikes about normal to this picture just right of the base of the cliff back of the fifth island terrace, seen in right center.

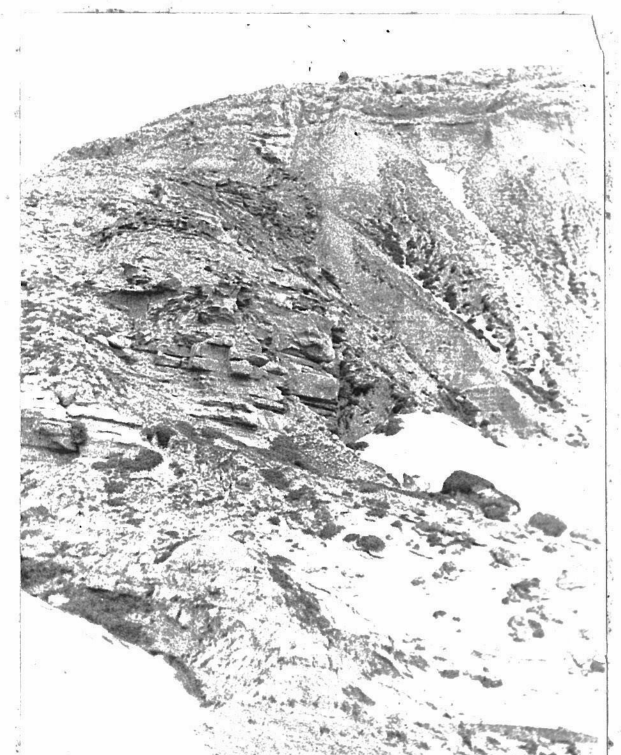


Fig. 18 Close View of the normal fault with the downthrow to the west. Zone 7 (left) if brought into fault contact with Zone 6 (right).

deposits of Santa Rosa Island(1), and San Miguel Island(2), which indicate a necessary connection with the mainland during Pleistocene time(3). The deepest water between the mainland and these channel islands in their alignment with the Santa Monica Mountains is about two hundred and fifty fathoms; so a depression of this amount would have broken such a connection. If such a movement had affected the submarine swell between Santa Rosa Island and San Nicolas Island, the latter island also might have been connected to the mainland. A concentrated effort on San Nicolas to discover some vertebrate remains yielded negative results; so this speculation is at present unsubstantiated.

Faulting:- The faults on the island were perceived from stratigraphic changes and few of the actual planes of movement could be examined, but certain pertinent data were obtained from which tentative conclusions might be drawn. Faults occur on the island in two systems, one averaging N 5-10° W and the other N 70° E. (Map 1, in Pocket) Under this condition the major fault systems make an angle of about forty-five degrees with the northwest strike of the anticlinal axis, but there are also a few faults nearly parallel to this axis, and occasional small blocks have been moved up or down a few feet. Most of the faults are apparently normal with rather steep dips, (Plate X, Figures 17 & 18), but they may be shear faults with a large part of the movement taken up in strike slip. (The vertical dis-

---

(1) Stock, Chester and Furlong, E. L.; Science, Aug. 10, 1928 Vol. LXVIII, No. 1754, pp. 140-141.

Note: Dr. Stock personally stated that certain elephant remains were also found on Santa Cruz Island, but because these were discovered in a kitchen midden it was not certain that these remains were in place or truly belonged to this island.

(2) Hay, O. P.; Carnegie Inst. Wash. Pub. 322B. pp. 42, 43, and 51, 1927

(3) Hay, O. P.; Op. cit., pp. 28 and 196.

Chaney, Ralph W., and Mason, Herbert L.; Carnegie Inst. Wash. Pub. 415, pp. 20-22.

placement nowhere has been more than five hundred feet and in most cases it is much less, although the horizontal movement in some cases may be greater. None of the faults has its expression the Pleistocene or later deposits; so there is no topographic expression of the faulting. It is then, impossible to trace faulting across the terraces, and observation of the faults is limited to the exposures near the shore line.

The few major faults observed in the western half of the island show a down throw to the west, and this movement may account in part for the southeast nose of the anticline being preserved as a high point on the rather extensive orographic block; that is, there has been a continual up-stepping of the minor blocks eastward. Most of the storms come from the northwest; so the down-thrown blocks would be more vigorously attacked and hence in a position to be more readily planed. No intersection between faults was found. Therefore no definite statement can be made as to whether one may have displaced the other. It is probable that all the faulting occurred at about the same time and that either set may have displaced the other, or that one fault might die out against another. The conjugate arrangement of the major fault systems at forty-five degrees to the anticlinal axis, the lack of any predominant fault, and the occurrence of small horsts and grabens, especially those parallel to the anticlinal axis suggests that the fracturing and movement was due to adjustment at the time of, and closely following folding.

There are no faults on the island of sufficient magnitude to be responsible for raising the island to prominence. The steep southern flank might be assumed to be an eroded fault scarp (Plate X, Figure 17), but the study of the geology on the island does not verify this assumption, for the exposed beds show regularity in their attitudes, which can be observed to extend for some distance off shore by the allignment of kelp beds growing on subaqueous ridges, seen from the heights along the south side of the island. If the south flank be an eroded fault scarp the abrasive action by the sea supplemented by stream erosion has worn back the escarpment so far from the fault itself, that there is no direct evidence of the fault perceptible. Such a fault could lie at least two miles south of the present shore line, for here there is a decided submarine declivity indicated by the bathymetric map. However, there appears to be little doubt that the elevation of an orographic block upon which the San Nicolas Anticline was a swell, accounts for the origin of the island. The location of the limits of this block can only be inferred from a study of the bathymetric chart. Such a study indicates an uplifted block between faults which appear to intersect some twenty miles east of the island. (Map 2, in pocket) One limit of the block lies from seven to thirteen miles northeast of the island and strikes northwest to form the northeast flank of the submarine plateau already referred to. The other limit lies about two and a half miles southeast of the island, and strikes a little north of west and farther along may curve to form the southwest boundary of the submarine plateau connecting San Nicolas and Santa Rosa islands.

PHYSIOGRAPHY

General Statement:- As discussed above, the rocks forming San Nicolas Island are almost wholly composed of sandstones and shales, neither of which is very resistant to weathering, although the sandstones occasionally are sufficiently more resistant than the shales to have been preserved as ridges or promontories. The only igneous rock present is a narrow dike about six feet wide on the southeast side. The dike trends in a northeast direction and is not prominent, nor is it more resistant to weathering than the other rocks of the island; so its topographic expression is slight.

Also as pointed out previously, the island is elongate, with its major axis running in a N 70° W direction. The submarine contours reflect a similar trend in a much larger mass and further indicate a rather extended uplift in a northwest direction toward Santa Rosa Island. (Map 2, in Pocket) San Nicolas is a high point on this uplift and the attitudes of the sedimentary series suggests that the island is the southeast end of an eroded and faulted anticline, with the anticlinal axis about one mile landward along the southwest shore, trending roughly northwest. The topography is in harmony with the folding, and the shape of the island is guided by the structure of the underlying sedimentary rocks.

Before the succession of emergences which brought about the cutting of the several terraces now evidenced on the island was inaugurated in the San Nicolas area, a great amount of erosion had already taken place, for the oldest marine terrace now seen on the island truncates beds well down in the folded series of sediments. It is unlikely that this erosion took place during these emergences and the evidence obliterated, for the amount of Pleistocene and recent sediments now on the island is too insignificant to include even a small fraction of the material eroded from the anticline, although such a view could be an alternative explanation. It is reasonable to believe, at least for the purpose of a physiographic study, that during and following the period of folding in post-Eocene time, probably lower Miocene, the San Nicolas swell was largely land for a period of time long enough for the warped area to be eroded to a subdued surface. This condition was followed by

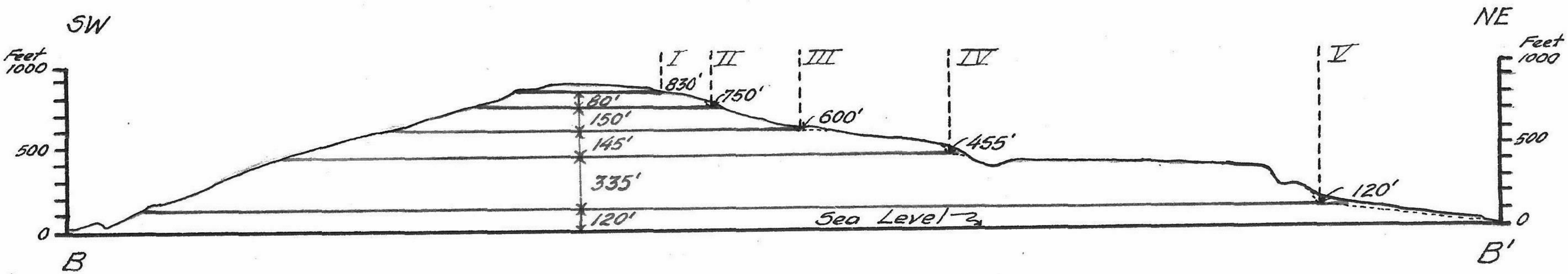


Plate XI Sketch profile through San Nicolas Island showing the relative positions of sea level during the several island stages, the amount of emergence and the present elevation of the ancient shore lines. Ancient sea levels in red. Horizontal scale one half the vertical scale.

submergence which lasted until middle Pleistocene when a reemergence of the island began, and it is from this point on in the history of the island that we find more tangible evidence of the succession of events affecting the physiographic history of the island.

Five marine terraces above the one now being abraded show successive stages in the carving of the island. (Plate XI) No doubt there are more stages in the development of the island where the emergence was more gradual, or where subaerial erosion and later abrasion might have obliterated low cliffs formed in the comparatively soft rocks, but these intermediate terraces are not clearly manifest. The five terraces which have been mapped are traceable on the north side for some distance, but even there, sometimes they are discontinuous. Along the steep south side erosion has effaced all but the very last terrace.

The folding and faulting in the Eocene rocks antedate the terracing for in every case the marine terrace cuts across the beds disregarding the underlying structure and there are no features which might be assigned to recent faulting. The terrace surfaces are not perceptibly warped and are nearly parallel to one another; so there is no conclusive evidence of folding since emergence began.

A condition suggested by Professor Davis[1] which must be borne in mind when treating with Pleistocene marine terracing, is the oscillation of sea level during glacial time. When a large area on the continents was covered with a mantle ice, there was a lowering of the sea level due to the extraction of water from the sea for the formation of the glaciers. This resulted in a consequent slight emergence of the land

---

(1) Davis, W. M.; Glacial Epochs of the Santa Monica Mountains, California, Proc. Nat. Acad. Sc., Vol. 18, No. 11, pp. 659-665, Nov. 1932.

and weakening of comtemporary abrasion. With the melting of the ice and the return of the water to the sea, the level of the sea rose, resulting in slight submergence and a more vigorous attack on the coasts by the sea. How much of the emergence and submergence of the land is due to orographic movements and how much might be due to changes in sea level during glacial and interglacial epochs is not known, for no adequate criteria for this differentiation has yet been worked out.

It might be well to recall at this point, that when the sea is forced to cease cliff cutting because of a relative uplift of the land, as the sea recedes an amount of only partially worn and poorly sorted debris accumulates at the cliff base. This debris is covered by more detritus washed from the higher ground as retrogression of the sea continues and the material is deposited in such a manner as to form a characteristic concave surface, the concavity of which broadens as the deposits thicken. Such deposits will be referred to as the in-fill. Measurement of the amount of emergence in each case is based on the differences of cliff-base elevations.

The First Island Stage (I):- The reappearance of land in the San Nicolas area was the rise of two small low islands of low relief. These small islands were located on the northeast limb of the anticline about a half mile from the crest of the anticline, and were composed of sandstone gently dipping to the northeast. No sea cliff was cut, but rather a gently sloping pebbly beach was formed. This feature is still preserved in several places at an elevation of eight hundred and thirty feet and the tracing of these pebbles together with a gentle though marked change of slope indicates the limits of these primal islets.

<u>The Second Island Stage (II)</u>:- A further emergence of twenty feet joined these two islands and a continuance of this same movement for about sixty feet more established the second island stage. The island at this stage had a maximum relief of less than two hundred feet and might be roughly estimated to be oval shaped about three miles long and one mile wide with the longest axis oriented west northwest. The shore line of the second island was cliffed to height of about twenty five feet and benched over an area more than a half mile wide. It is testified to by the clear though gentle slope of the in-fill and by actual cliff bases, which are revealed in two localities where stream channels have cut through the covering of subaerial detritus and sea floor veneer, into the bedrock. However this is true only on the north side of the island, for on the south side erosion has obliterated all evidence of this shore line. At the present time the shore line of this island stage has an elevation of about seven hundred and fifty feet.

<u>The Third Island Stage (III)</u>:- Approximately one hundred and fifty feet is the difference in elevation between the Second Island stage and the Third Island stage of emergence, and an island with a maximum relief of about three hundred feet and estimated to have been about five miles long and two miles wide with the longest axis oriented about west-northwest was formed. The outline of the island at the third stage is better preserved than that of either of the previous two, but as in the case of the second, only the northern shore can be traced through the characteristic concave slope of the in-fill in the areas between the eroded cliff base exposed in the stream channels. The cliff cut during this stage had a height of about fifty feet, while the platform still preserved varies from about a thousand feet to over a mile and a half in width.

To the south the shore of this island has been effaced by erosion, with the exception of the southwest side where the presence of the eroded cliff is seen, and a six foot coquina deposit lies on truncated older sediments. Along the western end of the third island the receding cliff appears to have consumed the cliff line of the second island. In the northwest portion there is an extensive segment of the third island platform wherein the coquina bed is, in view of action since subsequent emergence, now overlain by aeolian sands and other subaerial deposits which have been leveled and packed by the wind and percolating waters. This sector is flanked on the south and the northeast by promontories on the third island shore line, and the area between now has a drainage different from that of any other part of the island. The area is not dissected by any definite drainage system, nor are there any pronounced stream channels so characteristic elsewhere on the island, but there is a general slope toward the northwest controlled by the original inclination of the third island abrasion platform, now masked by cover. Apparently wind blown and other subaerial deposits kept ahead of any channelling activity and the material laid down by these forces is so porous that any meteoric water is rapidly absorbed and flows northwestward through underground aquifers, emerging as fresh water springs at various places along the northwest slope of the present island- notably Tule Creek, Corral Harbor, and the Gardens. (Map I in Pocket) The in-fill on the other remnants of the third island platform on the northside is largely sheet wash of alluvial material, rather than aeolian sands and silts. The in-fill is here highly dissected by insequent and consequent channels running into deep steep walled consequents which have cut back as far as, and in some cases into the limits of the second island. The present elevation of it shore features is approximately six hundred feet.

<u>The Fourth Island Stage (IV)</u>:- The fourth island was formed by a further emergence of one hundred and forty-five feet. This island was also elongate in a west-northwest direction with its longest axis about six miles and its maximum width about two miles, and had a maximum relief of about four hundred and fifty feet. As in the cases of the second and third islands the buried cliff line is indicated by the slope of the in-fill and the eroded cliff base is exposed in several of the deeper major stream channels. The abrasion platform developed at this time was also rather large varying from about a thousand feet to over a mile and a half in width, while the cliff appears to have been cut to a height of about fifty feet. The platform is shown by the broad gently sloping in-fill on the north side of the eastern half of the island, and a five foot coquina bed was deposited upon the older sediments. The outline of the island at this stage is rather clear along the north and northeast flanks, but on the northwest and west sides, sand dunes as well as wash have greatly obscured the evidence of the cliff line, and the shore of the fourth island can only be guessed in these salients. Along the south side of the island erosion has destroyed all evidence of this stage of uplift. The features of its shore line are now found at an elevation of about four hundred and fifty-five feet.

<u>The Fifth Island Stage (V)</u>:- The fifth island shows an emergence of three hundred and thirty-five feet. This island was oval shaped with its longest axis orient nearly as that of the present island, north-northwest, but only about seven and a half miles long. The width was about two and a half miles and it had a maximum relief of around eight hundred feet. In spite of this great difference in elevation this movement may not have been accomplished during one continuous period of emergence but any evidence

Fig. 19 Ancient sea cave in the cliff of the fifth island now about one hundred and fifty feet above the present level of the sea. View taken on the north east side of the island about one mile from the east end.

Fig. 20 -- View looking southwest over the sand dune area toward the west end of the island showing how drifting sands have subdued the topography. (W.J.K. & R.A.)

to the contrary is lacking. The eroded cliff of this fifth island is one of the imposing features of the island, in front of which the abraded platform, ranging in width from five hundred feet to over a half mile, forms a more or less continuous run around the island. Along the north flank of the island about one half mile inshore this steep acclivity rises about two-hundred and fifty feet, from the top of which the covered platform of the fourth island ascends gently to its cliff base. The height and steepness of this eroded cliff indicates a long period of persistent abrasion during which time evidence of any intermediate stages of emergence have been consumed. The in-fill in front of this ancient cliff is actually visible in many places along the north side of the island, and on the northeast flank near the east end, ancient sea caves are to be seen, now about one hundred and fifty feet above the present level of the sea. (Plate II, Figure 19) It is notable that this is the only case on the island of sea caves still preserved and visible in an elevated sea cliff. Along the northwest, west, and southwest, sand dunes have obscured the location of even so prominent a feature as this, and its location in these sectors can only be surmised. (Plate XII, Figure 20) However, along the south side the cliff base can rather safely, I believe, be inferred from the change of slope in the cut and scoured surfaces of the truncated older sediments, no in-fill having remained on the abraded platform along this flank. Along the north shore of the fifth island the cliff line has suffered greatly from undercutting, slumping, and landslides, presenting a very broken and rugged steep rise to the gentler terrace slopes on the top of the island. Along the northern side, however, the accumulation of debris by wash from the highlands and by landslides, has preserved the sea floor which is exposed in numerous channels and along the present sea shore where

Fig. 21 Looking west along northern shore about one mile east of ranch. Note low cliff and back shore terrace of present island. (W.J.K. & R.A.)

Fig. 22 Looking west along northern shore, about three miles east of ranch, showing north easterly dipping Eocene bed overlain unconformably by Pleistocene and recent in- fill. Note sea caves and cuspate form of recent cliff. (WJK & R.A.)

Fig. 23 View looking east taken about three and a half miles east of the west end on the south side of the island showing a portion of the platform now being abraded in the shales of Zone 4. Note cliff of the present island and the stripped platform of the fifth island in the background.

Fig. 24 View looking west taken about two miles east of the west end on the south side, showing the stripped platform of the fifth island, the present cliff line and the narrow backshore terrace in hard rocks. In the distance can be seen sand dunes which have subdued the erosional escarpment of this side of the island.

Fig. 25 Beach on southeast shore, showing low cliff and narrow sandy back-shore beach. (W.J.K. & R.A.)

Fig. 26 View looking west along north shore about two miles east of ranch. Showing low cliff and back-shore terrace cut in sandstone. White coating on the rock is birdguano. (W.J.K. & R.A.)

the most recent cliff has been cut. Apparent differences in the elevation of the sea platform exist, but these irregularities correspond to the configuration of the present shoreline; that is, in areas of soft bedrock, embayments and beaches are formed, and in areas of hard bedrock, promontories and reefs persist, producing an uneven platform surface. At the present time, the cliff base of this island stage has an average elevation of about one hundred and twenty feet.

The Sixth Island Stage (VI) The Present Island

Shoreline:- About one hundred and twenty feet is the amount of the most recent emergence which brought about the formation of the sixth or present island. All around the present island is a cliff which averages about twenty feet high, a back-shore terrace(1) about five feet high with a width varying from a few feet to hundreds of feet, and an abrasion platform some hundreds of feet in width, all giving evidence of the work of the sea since that most recent movement. (Plate XIII, Figures 21 & 22 Plate XIV, Figures 23 & 24) The cliff and back shore terrace are attacked only during periods of exceptional storms, and the width and height of the back-shore terrace very according to the exposure to the weather and to the character of the underlying bedrock. In areas of hard rock exposed to storms, the cliff line is close to the high tide shore line, and the back shore terrace is narrow and low or missing; while in areas of soft-rock in protected sectors, embayments are made with the cliff well back from the high tide shore line, and the back shore terrace is developed into a broad beach. (Plate XV, Figure 25 & 26) Along the west end of San Nicolas Island, which is unprotected from the prevailing storms coming from the northwest, there is an insignificant back-shore terrace, and the cliff itself is in many places being abraded in ordinary weather. (Plate XVI,

(1) Johnson, D. W.; Shore Processes and Shoreline Development p. 162.

Fig. 27 View of present island cliff about one mile east of the west end on the south side of the island showing tide pools in the back-shore terrace. Here exposure to the weather has brought about a decrease in the size of the back-shore terrace and the cliff is almost at high tide shore line.

Fig. 28 View of the present island cliff just below the ranch on the north side of the island. This is protected sector and the back-shore terrace is broad; so the cliff is only reached by water during exceptional storms.

Fig. 29 The extreme west end of the island exposed to the full force of the prevailing northwest storms. Here the present cliff line is attacked by the surf in ordinary weather. (W.J.K. & R.A.)

Fig. 30 Sand spit on the extreme eastern or leeward end; built by shore drift along both sides of the island. The location of this spit has shifted over a half mile to the southeast during the last fifty years. (W.J.K. & R.A.)

Figure 27) Along the northeast flank are several protected segments where the cliff line is several hundred feet from the high tide shore line, and only in exceptional storms is the entire back-shore terrace covered with water. (Plate XVI, Figure 28) There are beaches, but these are limited to areas of softer underlying bedrock. Slight embayments occur where sandstone promontories and reefs have provided a slight breakwater, but none of these is sufficiently protected to furnish shelter in all kinds of weather. A notable feature on the shore line is the sand spit on the southeastern or leeward end due to accumulation of sand and gravel brought by shore drift along both sides of the island. (Plate XVII, Figures 29 & 30) Reunion Island, a volcanic island in the southern Indian Ocean is an example of a similar occurrence. Davis[1] describes this island as being oval in outline with harborless shores. "Its exposed shore (to the southeast), where the tradewind surf strikes with full force, is slightly cut back in low and ragged cliffs apparently not yet provided with beaches"......"A detrital cuspate foreland of gravel and sand has been prograded at the northwestern or leeward end of the island; an artificial harbor, excavated in this foreland, gives the only protected landing place in the coast." The base map used was surveyed by the United States Coast and Geodetic Survey in 1879 and shows the spit of San Nicolas Island over a half mile northwest of its present position. Surveys recently made by the Coast Survey show that the spit has changed shape and position within the last few years. These surveys further indicate that the movement of the spit has been oscillatory rather than a sustained migration in a certain direction. The waters along the south side of the spit afford a good anchorage in most weather and a landing can generally be made at this

(1) Davis, W. M.; The Coral Reef Problem, Am. Geog. Soc., Spec. Pub. No. 9, 1928 p. 244

Fig. 31 Desolate aspect of the upper wind blown and wind scoured terraces in the western half of the island. Note the absence of a drainage system.

Fig. 32 A patch of sheet-like caliche in the upper terraces of the western half.

Fig. 33 Highly dissected erosional escarpment on the south side.

Fig. 34 View taken about one half mile west of the above, showing how drifting sands have subdued the aspect of this erosional escarpment.

point. The shore features on this island indicate an advanced stage of development, which means that San Nicolas Island is at the present time experiencing another period of quiescence.

Topography and Drainage:- San Nicolas Island presents a twofold expression. The western half is desolate, with its shell-sand dunes in the lower terraces, and its wind blown and wind scoured upper portions where the aeolian deposits have kept ahead of the efforts of the streams to establish any sort of drainage system. (Plate XVIII, Figure 31) The bleakness of this end of the island is intensified by tracts and patches of sheet-like chalky caliche, which protrude above the surface in violent array mixed with the above mentioned petrifactions of shrubs replaced by calcite cemented sand (Plate XVIII, Figure 32), and by immense kitchen middens with their millions of shells and vertebrate bones and here and there a weathered human skeleton exhumed from its place of burial. All these factors produce mixed impressions. Possibly not so long ago San Nicolas Island had a more favorable climate - at least it was sparsely wooded and habitable, but now it is almost destitute of vegetation and forbidding to man. The upper terraces slope gently to the northwest, and as stated above, there is no apparent drainage system, but beyond the limits of the upper bench-like area the slope increases and is cut by stream channels mostly filled by drifting sands. There is no sharp distinction between the several terrace levels in this portion of the island, but a rough irregular descent to the sea. To the southwest even the erosional escarpment which monopolizes ones attention all along the south side is subdued by drifting sands carried by the fierce winds from the northwest. (Plate XIX, Figures 33 & 34) The eastern limit of the desert portion of the island is irregular and marks the place where the wind has been forced to unload its burden.

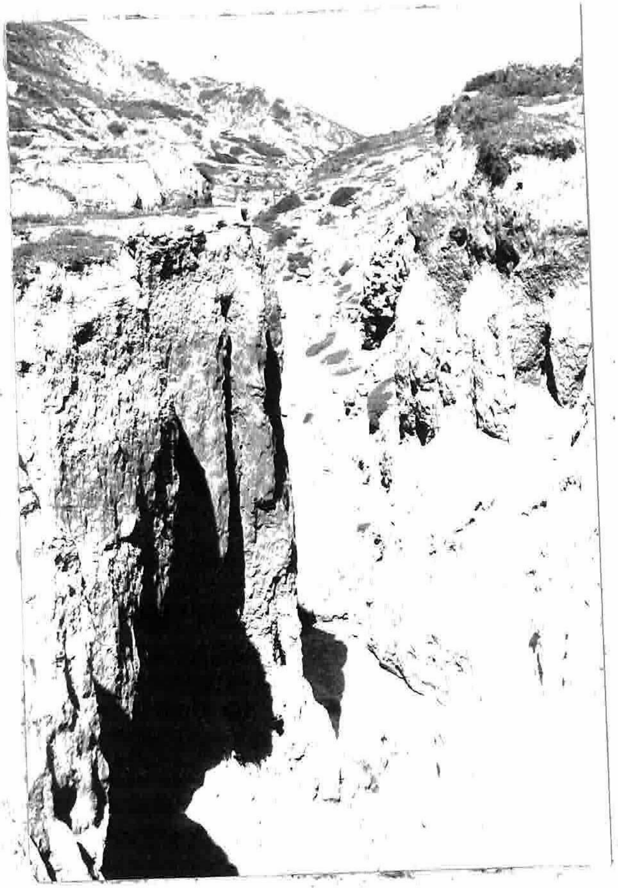


Fig. 35 Almost vertically walled stream channel cut in the in-fill on the upper terraces.

Fig. 36 Comparatively deep V-shaped canyon of one of the major stream channels where the stream has incised the two hundred and fifty foot cliff.

Fig. 37 V-shaped can you of one of the major streams cut deep into bedrock near where it emerges through the Fifth Island cliff. (W.J.K. & R.A.)

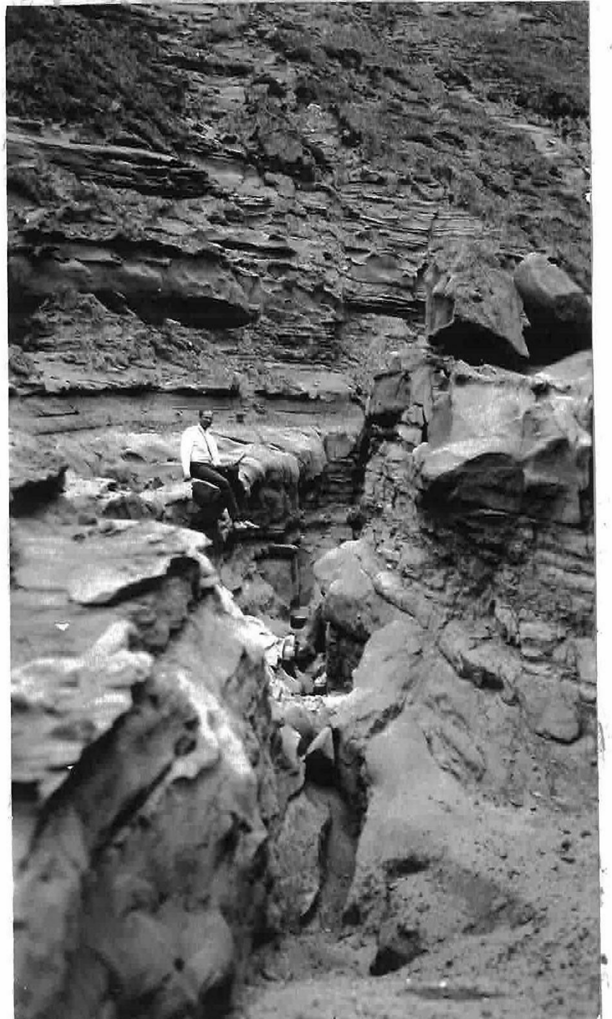


Fig. 38 Another V-shaped canyon cut deep into bedrock. (W.J.K.& R.A.)

In the eastern part of the island is observed a more striking difference in the effects of erosion between the southern and northern slopes. The northern slope is gentle and all of the marine terraces are preserved, covered by wash to thicknesses up to fifty feet. The major drainage of this portion is to the north and most of the stream channels have their sources in the upper terraces of the island. On these upper bench-like stretches the intermittent streams have cut a mass of tortuous channels, some steep walled and fairly deep, others shallow and comparatively broad. In places one finds badland topography in miniature and in others a flat surface cut abruptly by almost vertically walled channels several feet in depth, often making crossing impossible. (Plate XX, Figure 35) In this upper area many of the minor streams from a higher area are lost on the in-fill below, while others form part of a highly dendritic system of the higher reaches of the major streams. The middle segment of these major streams is marked by a sinuous course and few tributaries, with flat, grass covered intervening areas; while further toward the terrace-front the streams have cut deep V-shaped canyons which become deeper as they advance, cutting deep into the bedrock, especially near where they have incised the two-hundred and fifty foot cliff the crest of which marks the northern limit of the upper terraces. (Plate XX, Figure 36, Plate XXI, Figures 37 & 38) Where the major streams emerge onto the lowermost terrace they have cut down through the detrital covering and into bedrock, but here the channel is broad and more box-like and at the most only fifteen feet deep, finally ending at sea level. On the terrace below the two-hundred and fifty foot cliff the minor streams are initiated on the steep cliff slopes, and have eroded rapidly to form gullies in the face of the cliff, which only in a few

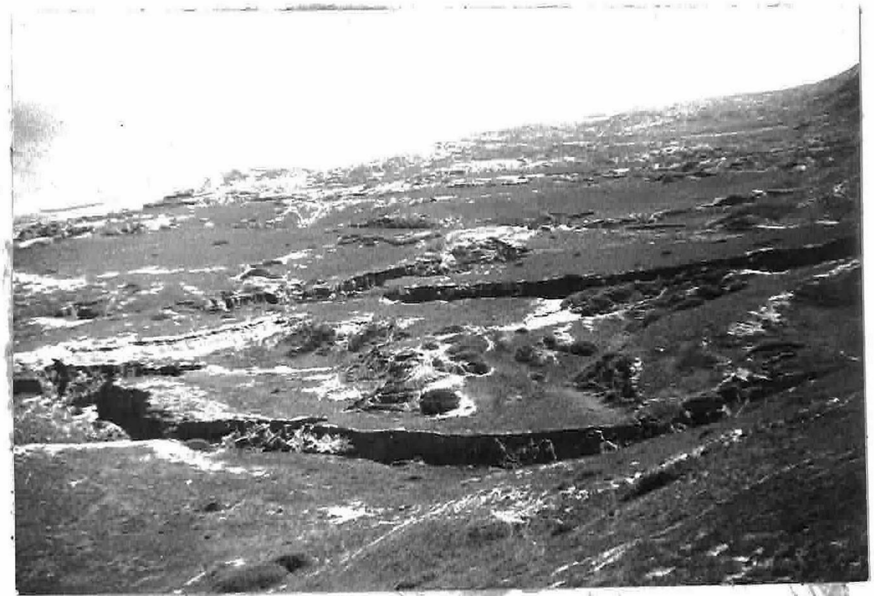


Fig. 39 Box-like channels cut in the in-fill of the Fifth Island terrace.

Fig. 40 Looking south from the Ranch. Gullies cut on the face of the Fifth Island cliff. In the center of the picture can be seen a normal fault which has brought Zone 7 (left) in contact with Zone 6 (right).

Fig. 41   Amphitheatre formed on the south side by the coalescence drainage areas.

Fig. 42   Eroded and dissected platform of Fifth Island.

cases carry on to the sea, most of them ending in small alluvial fans on the terrace. (Plate XXII, Figures 39 & 40)

As mentioned above the water shed lies near the south side about three quarters of a mile inshore, near the crest of a pronounced erosional escarpment forming the slope to the south shore. The dissection of this side of the island is almost complete. Most of the stream channels are steep and deep, and the sides of the V-shaped canyons are abrupt. A large majority of the interstream divides are sharp, and only in a few cases have the harder sandstone ledges withstood the rapid erosion to preserve broad ridges. Many of the drainages have consumed their seperating divides to such an extent that amphitheatres have developed. (Plate XXIII, Figure 41) As a consequence to the rapid erosion in this quarter all evidence of marine terracing has been effaced with the exception of that of the last terrace which is shown only by a dissected and scoured platform. (Plate XXIII, Figure 42) Faulting in the underlying beds has had little part in the control of drainage, and only in the case of some minor subsequent streams can the position of the channel be attributed to such a control.

BIBLIOGRAPHY

Bowers, Dr. Stephen - San Nicolas Island - 9th Ann. Rep., Calif. St. Mng. Bur. pp. 57-61.

Bremner, Carl. St. J., Geology of Santa Cruz Island, Santa Barbara County, California, Santa Barbara Mus. Nat. Hist., Occas. papers No. 1.

Chaney, Ralph W., and Mason, Herbert L.; A Pleistocene Flora from Santa Cruz Island, California Carnegie Inst. Wash. Pub. 415.

Cooper.,.....Geol. Sur. of Calif., Geol. Vol. 1, p. 184 (1865)

Davis, W. M. - Glacial Epocks of the Santa Monica Mountains, California, Proc. Nat. Head. Sc., Vol. 18, No. 11, pp. 659-665 (1932)

Davis, W. M.; The Coral Reef Problem; Am. Geog. Soc., Spec. Pub. No. 9 (1928)

Grant, U. S. and Gale, H. R.; Catalogue of Marine Pliocene and Pleistocene Mollusca, etc.; San Diego Soc. Nat. Hist., Vol 1, 1931.

Hay, O. P. - The Pleistocene of the Western Region of North America and its vertebrate animals. Carnegie Inst. Wash. Pub. 322B, (1927)

Hill, R. T.; Southern Calif. Geol. and Los Angeles Earthquakes, So. Calif. Acad. Sci. (1928)

Hoots, H. W. - Geology of the Eastern Part of the Santa Monica Mountains, Los Angeles County, Calif. U.S.G.S., pp. 165 c. 1930.

Johnson, D. W. - Shore Processes and Shoreline Development.

Kew, William S. S., Geological Sketch of Santa Rosa Island, Santa Barbara County, California, Bull. G.S.A. Vol. 38, pp. 645-654, (1927)

Lawson, Andrew C. - The Post-Pliocene Diastrophism of the Coast of Southern California, Univ. Calif. Pub., Bull. Dept. Geol. Vol. 1, No. 4, pp. 115-160., (1893)

Smith, W. S. Tangier - A Topographic Study of the Islands of Southern California; Univ. Calif. Pub., Bull. Dept. Geol., Vol. 2, No. 7, pp. 179-230, (1900)

Smith, W. S. Tangier - A Geological Sketch of San Clemente Island. U.S.G.S., Ann. Rep. 1896-97, Part II pp. 465-496.

Stock, Chester and Furlong, E. L.; The Pleistocene Elephants of Santa Rosa Island, California.; Science, Aug. 10, 1928, Vol. LXVIII, No. 1754, pp. 140-141.

SANTA BARBARA ISLAND

INTRODUCTION

<u>Location and Size:</u> Santa Barbara Island is a small forbidding island off the coast of Southern California belonging to Los Angeles County, lying about 50 miles southwest of San Pedro and approximately 31 miles northeast of San Nicolas Island. The island is roughly triangular with its rounded apex to the south and an indented base to the north. The total area is about 680 acres or a little over one square mile.

<u>Topography:</u> The shore line is nearly everywhere precipitous, with cliffs ranging in height from about 10 feet to over 500 feet. Two high points occur, one 547 feet high close to the almost vertical cliff about the middle of the west side, and the other 517 feet high near the middle of the steeply cliffed north side. A gentle slope connects these two hills with the saddle a little over 400 feet high. West of the saddle the slope is rather steep to an elevation of about 300 feet whence it flattens considerably to form a triangular benched area on the northwest peninsula. This peninsula also has remnants of lower terraces. East of the saddle there is a gradual slope to a zone not far from shore to an elevation of about 150 feet, from where the descent to the water's edge is very steep and there is little or no evidence of terracing. Streams have made little impression on the topography of the island and only on the eastern side have they cut straight coursed V-shaped gullies for a short distance back from the shore.

PLATE XXIV

Fig. 43 Typical shoreline; looking west along north side of the island. The whitish streaks on the face of the cliff are outcrops and slide areas of the foraminifera zone. The right side of the view shows the remnants of ancient marine terraces. On the extreme left can be seen the fault pictured in PLATE XXV, Fig. 44,

Accessibility: The trip to Santa Barbara Island can be made only by private boat or through the courtesy of government agencies, principally the Coast Guard. Only in very fair weather can a landing be effected, and then not without some risk, for even a skiff must be kept clear of the rocky and precipitous shore. About the middle of the northern half of the east side is a slight cove which is best suited for a trial at landing and for anchorage, the area being fairly well protected from storms blowing from the northwest. Lobster fishermen have constructed some frail landing gear at this point which is a considerable aid. Kelp beds are thick but discontinuous around the island.

Inhabitants: The island is uninhabited, although there is an abandoned cabin, a polluted cistern, and some scattered farm implements now ruined by exposure, all voicing a sad, hopeless effort by someone for independence. There is no evidence that the island was ever inhabited by Indians, but low down on the more gentle cliff slopes are a few small heaps of mollusc shells, probably left by travelers to or from San Nicolas Island.

Water: There are no springs on the island and any water for domestic use must be imported.

Flora and Fauna: Plant life is sparse - limited to a few types of low growing cactus, ice plant, grass, and patches Coreopsis maritima. On the flat triangular area of the northwest peninsula and on the slopes of the eastern flank are platts of once-tilled land with grain still struggling.

The only animals seen on Santa Barbara Island were a kangaroo mouse and a couple of house cats now grown wild. Several species of land birds were observed, although there were not many individuals. Water fowl are abundant.

Climate: The climate in general is similar to that of San Nicolas Island; that is, semi-arid with the rainfall confined to the four Winter months, and frequent fogs. However, there is no evidence that Santa Barbara Island is subjected to winds of the fierceness obtained on San Nicolas Island.

Acknowledgement: Five days were spent on the island in the early part of October, 1932. A United States Coast and Geogetic Survey party under Lieutenant Robert W. Knox was making soundings adjacent to the island, and it was through his courtesy that this field trip was accomplished. Mr. Lawrence W. Richards camped with me on the island during this first trip. A second trip was made about a year later in the early part of October, 1933, accompanied by George Richards, then a student of geology at Stanford University. This time we were taken out and back by the U.S. Coast Guard, remaining only one full day on the island.

I am indebted to Mr. Robert W. Kleinpell for the determination of certain foraminifera found on the island, and for the estimation of the age correlation of the zone. The staff of the geology department at the California Institute of Technology has been helpful in the preparation of this paper. Especially, the late Dr. William M. Davis encouraged and criticized me in my efforts.

Literature: The geology of Santa Barbara Island has been treated even more casually in the literature than has that of San-

Nicolas Island. W.S.T. Smith made a topographic reference to it (1)

(1)
W.S.T. Smith, "A Topographic Study of the Islands of Southern California", Univ. Cal. Bull. Dept. Geol., Vol. 2, No. 7, p 196 (1900)

and refers to Dr. Cooper as having mentioned the existence of three or four imperfect terraces and that the island is composed of volcanic rocks. (2) Smith did not visit the island but limited his work to

(2)
Calif. State Mining Bureau, 9th Ann. Rept., State Mineralogist, for 1889, p 183.

a study of the available maps. The Geological Map of California issued by the Mining Bureau in 1916 correctly shows the island to composed of volcanics.

STRATIGRAPHY

General Statement: Santa Barbara Island is composed of two types of volcanic rocks separated by a thin whitish bed of soft sandy shale composed chiefly of foraminifera, determined to be middle Miocene in age. The lowermost volcanic bed is an ellipsoidal ("pillow") basalt highly vesicular and brittle, while the rock overlying the foraminifera zone agglomerate cemented with chert and calcite.

Ellipsoidal Basalt: The greatest portion or body of the island is composed of the lower or ellipsoidal basalt. This phase outcrops all about the island except on the northeast corner where the northeasterly dip of all the beds brings the agglomerate below sea level. The imposing cliffs of the southern, Western, and northern sides are cut in the more massive volcanic rocks. The ellipsoidal character of this lower phase apparently does not hold throughout, but is characteristic of the lower portion of the member. The lower portion exposed in the inaccessible cliffs on the southwest side of the island were scanned with aid of binoculars and appears to be massive but still high vesicular. The formation is dark colored, but is blotched with irregular areas of black and reddish basalt. The thickness of this member is indterminate, but there are at least one thousand feet exposed.

Foraminifera Zone: Overlying the ellipsoidal basalt and exposed only in several of the cliff faces is a light colored very fine grained sandy shale composed chiefly of foraminifera. This thin bed of soft material shows no scorching effect either on its lower or upper surfaces in contact with the volcanic rocks. The thickness varies from several inches to several feet and the exposures on the north cliff give the impression that this bed was deposited irregularly on a slightly uneven surface of the ellipsoidal basalt. This fossil zone occurs as an irregular stripe running diagonally up from the northeat corner of the island across the northern cliff. The only other locality where this bed was encountered is on the south side of the island on the face of a cliff in a rather secluded bight difficult of access.

The foraminifera collected from this bed were determined as belonging to the middle Miocene near the base of the Modelo formation. R.M. Kleinpell states: "As to the correlation, I would be strongly inclined to place the fauna in the transitional zone, or subzone between the Baggina robusta and the Pullenia miocenica zones - in other words it is just above the Gould shale of the Valley (San Joaquin) west side section, but not quite as high as the so-called Valvulineria zone (Pullenia miocenica zone) of Chico-Martinez Creek." The following list gives the species identified by Mr. Kleinpell:

Valvulineria californica var. opressa
Valvulineria californica var. obesa
Baggina robusta
Cancris sp.
Bolivina cf. floridana

Basaltic Agglomerate: Overlying the irregular surface of the foraminifera zone is a bed of basaltic agglomerate cemented with chert and calcite. The fragments are all dark colored basalt and some of them are vesicular. They vary greatly in size and there appears to have been little sorting, although from a distance off-shore on the northeast side the agglomerate appears to be crudely bedded. This member covers the northeastern segment of the island and is exposed from the northeast corner westward to the middle of the north side and southward to about the middle of the east side. It can be studied best along the north half of the east shore.

Pleistocene and Recent Deposits: The top of the island is covered with a mantle of Pleistocene(?) marine sediments and recent alluvial detritus derived from the Pleistocene(?) deposits and the older basalts. The thicknesses of the younger covering varies greatly from place to place from a few inches up to about 40 feet. The Pleistocene(?) marine deposits carry indeterminate foraminifera, shell fragments and haliotis specimens which are found over the highest points on the island. The thickest accumulation of these later sediments is found on the large flat of the northwest segment of the island.

Conditions of Deposition: The indications are that all of the volcanic material accumulated under the sea. It is believed that the ellipsoidal structure of the lower basalt is due to submarine cooling, although the existence of the pillows does not conclusively point to subaqueous origin. However, as the soft foraminifera bed overlies the uneven but uneroded surface of the basalt and shows no signs of scorching it is highly probable that the lava was amassed under the sea. The thin foraminifera zone is marine, but the from the fauna collected were not diagnostic of a certain depth range. The agglomerate is also considered to have been accumulated under the sea, for the cementing material of chert and limestone could be of marine origin, there is a distinct though crude stratification, and the upper surface of the foraminiferal zone also shows no effects of heat.

The source of the volcanic material is unknown. Doubtless the island itself is not a volcano, for the structure is that of a homocline in pyroclastic and flow rock, rather than a radial dipping conical accumulation.

STRUCTURE

General Statement: The volcanic rocks forming the island are crudely stratified, a condition more apparent when viewed from a distance than when scrutinized at close range. This is true not only of the lower flow member, the ellipsoidal basalt, but also of the

Fig. 44 Steep fault plane on the north side of the island, striking N60°W. Note the steepness and the clean cut character of the fault. The steep face at the top of the picture is part of the fault plane and the north side of Hill 517.

pyroclastic member which more than likely accumulated under circumstances that might have resulted in more definite layers. The general structural aspect is that of a northeasterly dipping homocline with a tilt of about 20 degrees, complicated, however, by an intersecting system of faults and some minor folds.

Folds: The folds are difficult to recognize, but they are small and of little importance. Only one small anticline could be observed near the northeast corner, and even this fold was seen only in the agglomerate and mapped only at one locality. Other folds probably occur and can be inferred from differences in rather vague attitudes. Even were these folds mappable it is my belief that they could be considered as undulations in the general homocline and would doubtless have no great vertical or lateral extent. From observations of the insignificant warp on the northeast end of the island, it is difficult to picture this structure as existing also in the ellipsoidal basalt.

Faults: A system of intersecting faults occurs on the island, one set striking N 10° W and the other set striking at about N 60° E. The strikes of these faults are nearly the same as those of the faults observed on San Nicolas Island. It cannot be said which of the two sets of faults is the older, for in no locality was one fault found displacing another, but, as in the case of the San Nicolas Island faults I believe both sets to be contemporaneous each set displacing or being displaced by the other. It is difficult also to make any estimate as to the amount of movement on any of the faults or to state which set had the major amount of activity, but the character of both the northern cliffs and the western cliffs points to the inference that the faces are escarpments primarily caused by faulting. If this be true, then the major movement would have to be over 500 feet, with both sets sharing in importance. Even then this apparent displacement may not be the result of movement on just one fault but may be the result of movement and subsequent erosion of thin slices between roughly parallel faults, a situation indicated along the north side. Here four faults, striking N 50° E with just a few hundred feet between them, are mapped. The dips of the fault planes vary within themselves from about 65° to vertical with the direction of dip tending to the north. The plane of the most southerly of this group of faults is exceptionally well exposed near the edge of the cliff for about three quarters of the distance across the north side of the island, while the remaining three are identified for short distances only cutting across promontories along this side. Altogether it appears that the displacement in this region has been cumulative, although it was impossible to measure the amount of movement along any one fault. The group character of the faulting is not evident along the imposing western cliff, but it is likely that the north-south set of faults has acted in the same manner; that is, closely spaced breaks with small displacementcumulating movement until a very perceptible scarp is obtained. Fault planes of both sets in the intersecting system can observed in several places on the cliff faces about the island, and in some cases the topography of the surface can be interpreted as being under structural control, but no features conclusively due to faulting occur on the main upland. An interesting set of features surrounds the two high points of the island: the west flank of the northern eminence and the east flank of the southern hill are in alligmment with the strike of two observed fault planes, one on the north cliff and the other in a small bight near the southern tip of the island. Both fault planes agree as to attitude and enclosing rocks, and the entire set of features are in sympathy with the N 10° W set of faults. If these features represent the reflection of faulting, and I believe they do, then the island is made up of two distinct blocks which have had a rotary movement in relation with one another, with the point of rotation located near the midpoint of the island or perhaps a bit north of the midpoint. At any rate the action would be such that the eastern block was relatively depressed on the south and elevated on the north while the western block was relatively tilted down on the north and raised on the south, in consequence of which movement the two hills separated by a saddle are found as prominent topographic features. This rotational fault is displaced by or displaces at least two fractures of the east-west set, observable only on cliff faces and by slight steepening of the general upland slopes. It would be difficult to prove the rotary movement of the mid-island fault, for where the fault plane can be observed the enclosing rocks are the ellipsoidal basalt which defies zoning to any accurate degree, especially in the area of inaccessible declevities. However, as in the case of other faults of the island the movement has not been great, but is part of the general fracturing brittle rocks under pressure.

With the fault systems at about 45° to the general strike of the homoclinal beds, and with the group character of the two sets, together with the cumulative displacement rather than a large single

Fig. 45. Looking North 500 feet south of Hill 547. Comparatively gentle slope to the east with bedded marine Pleistocene or recent material overlying basalt.

Fig. 46 Looking north from the same position as Fig. 45, showing abrupt cliff of the west side of the island all in ellipsoidal basalt.

displacement, it seems rather to point to fracturing being due to the same forces causing the general tilting either at the same time or closely following. It would be impossible to accurately date the time of faulting or tilting closer than to say that both phenomena took place after middle Miocene and before Pleistocene, for the accurately dated foraminifera zone is faulted, while the Pleistocene and later marine terrace deposits are unfaulted.

PHYSIOGRAPHY

General Statement: The hard brittle volcanic rocks which make up Santa Barbara Island are not easily molded by weathering processes, especially those due to the sea and waves, and as a result the shore is very uneven, with practically no beaches, the rock surfaces which form the shore line being cavernous and jagged. Not only are caves and tunnels found at the present shore line, but like features are found above as remnant configurations along previous shore lines. There are rocky shoals about the island and stacks of volcanic rocks add to the rugged but picturesque scenery. Curiously, however, the upland surface of the island is rounded and gentle. This condition is due to the mantle of marine sediments and the recent alluvium derived from them, as well as the less violent weathering of the volcanic material. After one climbs about 150 feet up the steep cliff of the east side and then plods up the more gentle slope toward the 547 hill he is astonished at the abruptness with which the almost vertical wall along the west of the island is encountered. There is no warning of a change of slope until the edge is practically reached and the shear drop of 500 feet is viewed. The same feeling is experienced

Fig. 47 Looking north along west side to the northwest peninsula, showing remnants of the 25 foot, 75 foot, 150 foot, and 300 foot marine terraces.

Fig. 48 Looking east along the north side of the island, showing the northeasterly dip. The dark bed is agglomerate, overlying the foraminifera zone,

to a lesser degree along the north side of the island.

Stream action has been slight and only on the east side is there a few straight coursed, steep-sided, V-shaped gullies which have cut back but a few hundred feet. Elsewhere around the island the rim appears to be practically void of established channels, although steep freshet courses can be seen on the cliffs and occasional undecided shallow water paths exist in the flatter portions.

Marine Terraces: Marine terraces are present in fractions of their original extent. Four stages of cliff cutting are present above the present one at elevations of 300 feet, 150 feet, 75 feet, and 25 feet above sea level. As brought out previously a mantle of marine material covers the island, and the position of the covering which overlies the debris at the base of the 300 foot cliff indicates complete submergence after a prior island stage. The oscillatory or unstable condition is to be expected in a locality of crustal adjustment.

The 300 foot cliff base is strikingly seen in two locations, only one of which is accessible for examination, but the other can be scanned with a high degree of certainty with aid of field glasses. On the north cliff about 600 feet west of 517 hill the debris at the base of the ancient 300 foot cliff can be examined and the relationship between this feature and the overlying sea floor clearly observed. Similar conditions were observed on the face of the cliff about 1000 feet north of 547 hill, and as the islandward limits of the northwest terrace conform to an arcuate connection between these two points of observation the 300 foot marine terrace line has been

Fig. 49 Detail of 25 foot marine terrace on the northwest peninsula showing ancient cliff base, in-fill, and platform, as well as present day cliff cutting.

Fig. 50 Looking west on north side of northwest peninsula showing 25 foot marine terrace remnants. The black spot in the upper center portion of the picture is a sea cave of this period.

Fig. 51 The 300 foot cliff base and mantle of marine material exposed on the north cliff of the island. This feature is described in the last paragraph of page 43 of the text.

Fig. 52 Similar exposure seen on the west cliff.

assumed here. It is apparent that after an emergence of something over 250 feet a period of quiescense or slight submergence inaugurated cliff cutting and the formation of a broad marine platform. Some reemergence must have taken place long enough for the accumulation and induration of the in-fill, for upon complete submergence a portion of the in-fill was retained. The resubmergence must have been rapid in order to prevent obliteration of all the debris and to preclude complete leveling of the island mass. That entire submergence took place is evidenced by the mantle of sediments in which marine forms have been collected, unfortunately fragmentary and indeterminate but nevertheless definitely marine. The block rose partially, no doubt rapidly at first and then more slowly, for at an elevation of about 375 feet a second reef-like marine floor overlaps the first at an angle of from 10 to 15 degrees. The extent of these sea floors cannot be determined and they are best observed on the northwest quarter, though the first certainly covers the highest points and can be seen in place on the eastern slopes of the island.

A period of quiescence and slight resubmergence occurred when the island had an elevation of something over 400 feet, for the next cliff base and the accompanying in-fill is clearly seen at the present elevation of about 150 feet. Remnants of this feature are to be seen on the northwest corner just northwest of 216 hill, on a promontory 500 feet east of this point on the north side of the island, and on the northeast tip of the island. There is also vague indications of the 150 foot cliff base along the north half of the east side, but only a small amount of in-fill remains.

Further emergence then occurred until the island had an elevation of something over 475 feet, but this is not definitely shown for the cliff now at an elevation of 75 feet is vaguely apparent in only one locality on the northwest corner of the island.

The next emergence ceased when the island had an elevation of something over 525 feet, for a cliff base and the accompanying infill occur at various places about the island at a present elevation of around 25 feet. This feature is observable on both the southwest and the northeast sides of the northwest corner of the island, and again over a distance of about 2000 feet along the south half of the east side of the island. On the northwest corner is a sea cut cave now about 20 feet above the level of the water.

There is a complete lack of beaches and very little accumulation of debris at the base of the present imposing cliffs, showing that cliff cutting is going on at the present time. This condition together with the presence of stacks and rocky shoals about the island indicates that Santa Barbara Island is experiencing a period of cuiescence or possibly some submergence.