The U. S. Navy has recently constructed a new marine biological facility at Point Mugu, where scientists of the Naval Missile Center and the Naval Ordnance Test Station are collaborating on marine mammal studies. There are also other research programs encompassing invertebrate marine biology, and many of them are being conducted in collaboration with university scientists.

The Office of Naval Research, through its contract research program, has supported financially the research of many scientists concerned with problems in this geographic area. This is only one way in which the Office of Naval Research has tried to encourage and coordinate governmental and civilian scientific efforts in exploring the scientific potential of the Southern California Islands.

Another effort to do this, something of an innovation, was carried out by the Office of Naval Research within the last two years. We called it project ILEX for Island Expeditions. Project ILEX consisted, in part, of a series of helicopter expeditions in which marine corps or naval pilots carried scientists on flying platforms to and from and around the Southern California Islands at seasonal intervals. We took along botanists, zoologists, archaeologists, geologists, photographers, and others who were interested in specific research objectives. While botanists and geologists collected specimens, others observed and photographed the sea lions and elephant seals. We also photographed aquatic habitat groups along the shores of Santa Catalina Island and the sites where the new University of Southern California station is being built. Through the use of these flying platforms, we overcame the sea barrier to these islands and the participating scientists of project ILEX accomplished in hours and days what otherwise would have taken weeks, perhaps months. Several scientific communications have already been prepared for publication, and other findings will be discussed during this symposium. We extended the ILEX flights to Los Coronados when the California grey whales were migrating, and anticipate extending this type of expedition southward and northward. The enthusiastic response received from scientists participating in this cooperative effort is indicative of the widespread scientific interest in the California Islands.

WESTERN ANACAPIA – A SUMMARY OF THE CENOZOIC HISTORY OF THE NORTHERN CHANNEL ISLANDS

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Anacapia is a geologic province which forms the southern boundary of the Santa Barbara Embayment and the northern limits of an old, often emergent, land mass - Catalinia. It embraces San Miguel, Santa Rosa, Santa Cruz, and Anacapa islands as well as the western part of the Santa Monica Mountains (Reed and Hollister, 1936).

A study of the geology and evolution of the Northern Channel Islands, lying as they do on the southern edge of the Transverse Ranges (fig. 1) of California, has long held the interest of natural historians, both geologic and biologic. The Transverse Ranges as a whole form an anomalous feature to the general north-south trending structures of western North America. The Murray Escarpment, trending westward 1,900 miles out to sea, is believed to be a structural extension of this continental anomaly. This east-west trend terminates to the east against the great San Andreas fault system and the San Bernardino Range. Not only is it of interest for its obvious structural significance as it is related to one of the great features of the earth's crust, but this transverse feature also has strong biogeographical implications, having roots perhaps as far back as early Mesozoic time. With the progressive provincialization of marine faunas during the Cenozoic (Smith, 1919), these east-west trending mountain ranges, at times partly submerged, partly emerged, served as the limits on more than one occasion for new biogeographic provinces (Kleinpell and Weaver, 1963), some of which became distinctive and conspicuous life areas in the middle and late Cenozoic. Thus the Transverse Ranges serve as a focal point of considerable significance not only for structural but for biogeographic studies as well. In fact, these two fields, tectonics and chorology, are rather intricately interrelated, though perhaps more directly through intermediate climatological phenomena.

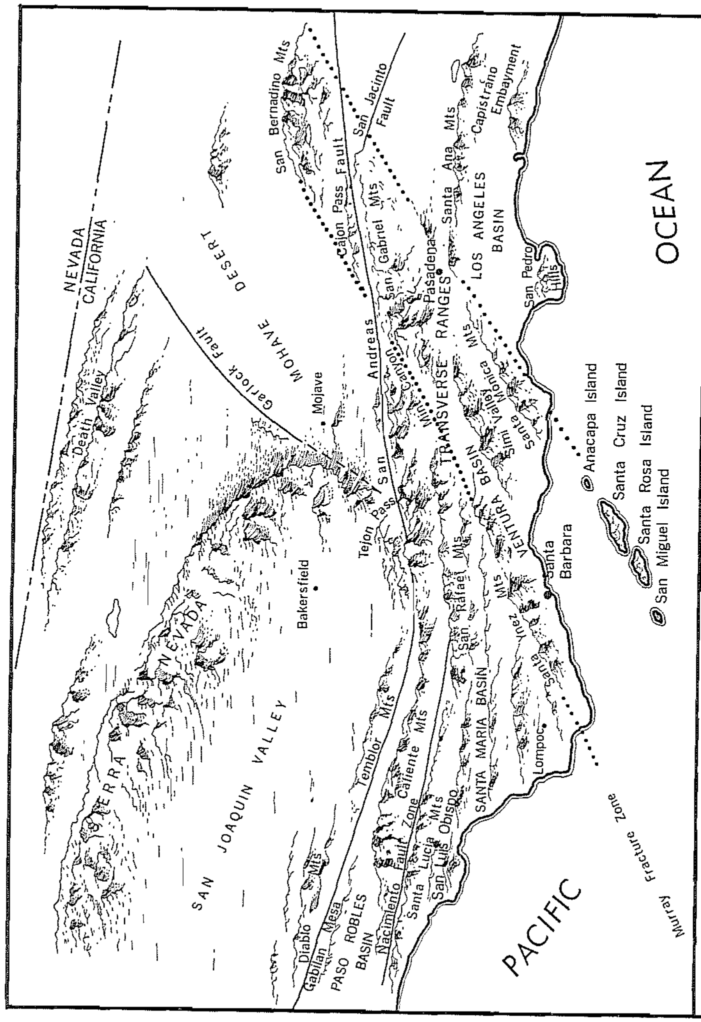

FIG. 1.– Diagrammatic relief map to show some important topographic and structural features of Southern California.
Modified from Reed & Hollister, 1936

The purpose of this paper is to summarize for the Symposium the paleogeographic implications of the available[1] geologic data for the southern fringe of the Transverse Ranges - the Northern Channel Islands. Realizing that members of the Symposium are primarily interested in Cenozoic migratory land routes to the islands, it should be stated at the outset that present-day Anacapia offers a paucity of evidence for Cenozoic connections to the mainland. In general, ancient migratory routes are best delineated by the land animals and plants of the time. With but two exceptions, the late Pleistocene to sub-Recent dwarf mammoths and the Recent biota of the Northern Channel Islands, such organisms are not known to be preserved. The Cenozoic land masses that are needed for faunal migrations to the islands are inferred from: (1) the presence of continental deposits; (2) the absence of deposits representing major intervals of time, thus permitting the inference that the land was emergent during at least part of the time represented by the hiatus; (3) the fossil and mineralogical composition, texture, and structure of the marine and non-marine sedimentary rocks, which permit ecologic inferences; and (4) the gross structural framework of the province along which any orogenic (mountain building) forces must have operated. The foregoing types of data are available from the literature cited and from recent unpublished work by the authors.

Anacapia is an east-west trending physiographic unit with much of its lower elevations flooded by the Recent seas. Its pre-Tertiary, perhaps Mesozoic, origin is faintly reflected in the metamorphic and granitoid rocks of unknown, but pre-Cenozoic, age which are exposed on Santa Cruz Island and in the Santa Monica Mountains. It is dominated by sedimentary and volcanic rocks of Cretaceous to Miocene age and capped by late Pleistocene terrace formations. Rock exposures on the islands are notable for their complete lack of Pliocene deposits. The pre-Pliocene shales, sandstones, conglomerates, and volcanics are conspicuous for their lateral variation and discontinuity. Areas of post-Eocene erosion and deposition, especially in Catalinia, appear to have been uplifted and depressed mainly by block faulting of the basin and range type, i.e., similar to the basins and ranges common in Nevada (fig. 2). Such deformation began in Oligocene time and continued intermittently through the rest of the Cenozoic Era. Many of the blocks reversed their relative vertical positions during this time (Corey, 1954; Emery, 1954).

1. More information is known than is available to the author, since much data involving the off-shore area are of an industrial and thus confidential nature.

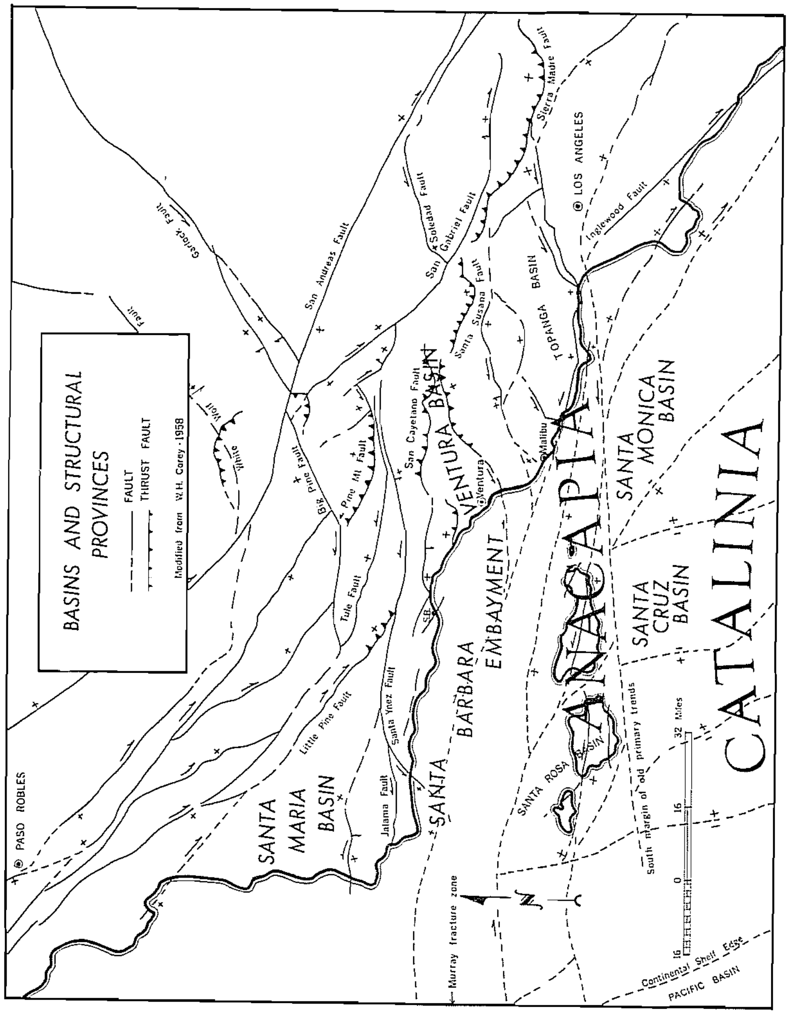

Fig. 2

The beginning of Cenozoic time saw much of western Anacapia covered by a shallow tropical sea. A sand and gravel bottom environment, rich in shallow water mollusks in the vicinity of southwestern Santa Cruz Island, gave way to the west (San Miguel Island) and north (outer Santa Barbara Channel) to deeper water rich in Paleocene plankton. Presumably the land masses lay nearby to the south and east, perhaps as near as the granitoid rocks presently exposed on Santa Cruz Island, as Paleocene strata are not known elsewhere on Santa Cruz, either on the surface or subsurface, nor on the present day islands to the south. Much of subsequent Eocene time involved what must have been a general continuation of the Paleocene scene, though with marked exceptions. Considerable finer-grained sediments were deposited at moderate depths on all three of the principal islands during Eocene time. However, middle Eocene seas, covering San Miguel in the west and Santa Cruz in the east, were receiving coarse sands and cobbles from nearby topographic highs, presumably leaving the Santa Rosa area as a submarine topographic low. The elevations necessary to provide energy for the transport of such coarse debris subsided by late Eocene time, producing a relatively low-relief shoreline, which is evident in the southwestern corner of Santa Cruz Island (Rand, 1933). Just as evident, relative to what it is today, is the prominence of an expanded Santa Barbara Embayment to the north (Kleinpell and Weaver, 1963).

The Santa Rosa basin was maintained and perhaps even became more pronounced during Oligocene time. Although continental redbed deposits occur nearby, normal marine deposition was taking place in the basin; and Santa Cruz and San Miguel highs were supplying sediments to this intermediate low. High also at this time and through much of the subsequent early Miocene was the land mass(es) to the southwest and southeast (Catalinia). Land emergence during Oligocene time was at a local maximum, and broad mainland connections to Anacapia were evident. By late Oligocene - early Miocene time there was a marine transgression upon Anacapia as was generally the scene elsewhere in California (Reed and Hollister, 1936). Much if not all of San Miguel was covered by shallow warm seas, as was the southwestern portion of Santa Cruz Island. Santa Rosa remained a relative topographic low. However, a high relief land mass and extensive volcanic activity were supplying large quantities of coarse metamorphic and volcanic debris as well as volcanic flows throughout western Anacapia, and particularly in the vicinity of San Miguel and Santa Cruz islands and points eastward. Though volcanic activity continued through much of Miocene time, it was masked by the middle Miocene transgression which drowned all but the highest elevations on Santa Cruz Island. And Anacapia as a Miocene land mass with its associated fauna and flora was essentially destroyed in the chalky and siliceous transgressive sea.

Late Miocene time saw a re-emergence of western Anacapia, though the Santa Rosa basin was still evident as a marine trough. However, by Pliocene time even this long persistent topographic low had filled or was uplifted; and emergence was again, as in Oligocene time, general and at a maximum throughout Anacapia. Major basins to the south, undergoing embryonic development between the fault scarps (fig. 2) during Miocene time or earlier, persisted throughout the Pliocene and into the Recent (viz., the Santa Cruz, Santa Monica, and other basins; see fig. 2). The extent of the Pliocene land mass of western Anacapia with its undoubted connections to the mainland must surely have produced a rich land biota. However, no Pliocene marine or non-marine strata are known from any of the Northern Channel Islands; and therefore, no record of the Pliocene life in western Anacapia is preserved. Any deposits that did accumulate were eroded away in the subsequent land environment that persisted along the east-west trending backbone of Anacapia.

Pleistocene and Recent times saw great fluctuations in the sea level; and these, coupled with movements along the established fault systems (fig. 2), all but drowned western Anacapia. Only in late Pleistocene and sub-Recent times did mainland connections sufficiently, although briefly, re-establish themselves to permit a Pleistocene mammalian fauna to reach as far west as San Miguel Island.[2]

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2. In addition to the well known mammoths on Santa Rosa Island, recent work has redocumented the presence of these Pleistocene and sub-Recent dwarfs on San Miguel and Santa Cruz islands. It is also worthy to note that not only did these proboscidians not reach western Anacapia before late Pleistocene because of the lack of an adequate peninsular migration route, but that the elephants as a group did not arrive in the new world until mid-Pleistocene time; and therefore, could not have existed in Anacapia before that time and probably not until post-late Pleistocene terracing, i.e., the sub-Recent or Holocene. The question arises whether sufficient time was then available for dwarfing of the stock. In this connection, it is of considerable interest to note the rate of dwarfism in other mammalian groups as, for example, the dwarfing of Recent horses isolated in the Grand Canyon since their reintroduction by Europeans following the late Pleistocene extinction of *Equus* in North America.

In summary, it can be said that connections during the Cenozoic Era between Anacapia and the mainland were general for the first time in Oligocene time and reached a maximum during the Pliocene and late Pleistocene or sub-Recent, but that the general emergences were in each case separated by an interval of submergence sufficient to all but destroy the biota of the time. Indeed, the middle Miocene transgression is believed by most workers to have completely drowned western Anacapia. Recent studies on Santa Cruz Island, however, suggest that localized remnants of this early Miocene center of volcanic activity may have remained as a vestige of the earlier peninsula. A comparable scene must have existed during Pleistocene time, for marine terraces cover all but the top of Green Mountain on San Miguel and occurred possibly as high as 1,800 feet on the north side of Santa Cruz.

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LATE CENOZOIC HISTORY OF THE SOUTHERN CALIFORNIA ISLANDS[1]

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INTRODUCTION

The floor of the ocean off southern California consists of a series of low depressions and basins separated by high ridges, some of which protrude above sea level to form the Southern California Islands. The basins and many of their intervening sills are at depths that are much greater than usual for the continental shelf. This peculiar region of complicated topography has been called the "continental borderland" by Shepard and Emery (1941). It lies offshore from the continental shelf of the mainland but inshore of the continental slope which extends down to regions of oceanic depths and structures.

The basins and ridges are somewhat elongated, and most are aligned in a northwest-southeast direction, parallel to the major structural features of the mainland; a few of these ridges bear islands which are also elongated along a northwest-southeast trend (fig. 1). However, in the north there is a transverse ridge, locally rising above sea level to form an east-west chain of islands. This ridge is separated by the transverse Santa Barbara Basin from the east-west mainland coast formed along the flanks of the Santa Ynez Mountains. For convenience, the islands will be grouped here as Northern Channel Islands (Anacapa, Santa Cruz, Santa Rosa, and San Miguel, from east to west) and Southern Channel Islands (Santa Catalina, San Clemente, Santa Barbara, and San Nicolas).

The bedrock geology of the Northern Channel Islands indicates that they represent a westward extension of the general geologic and structural style of the Santa Monica Mountains, with a granitic core (exposed on Santa Cruz Island) intruded into what are

1. Submitted after the symposium as an elaboration of a discussion presented by J. H. Lipps.