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PRELIMINARY REPORT ON THE GEOLOGY OF THE CONTINENTAL BORDERLAND OF SOUTHERN CALIFORNIA

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INTRODUCTION

Appraisal of the mineral resource potential and assessment of environmental problems of any specific area require an understanding of the regional geology. The geology of the coastal zone and offshore islands from Point Conception to the Mexican boundary serves as a frame of reference from which rock units and structures can be extrapolated into submerged parts of the borderland (sheet 1). Such extrapolations should be used with caution, for the tectonic evolution and depositional history of parts of the borderland may not have paralleled those of the mainland. On shore, rocks and structures can be observed directly with supplemental aid from deep drill holes; but in areas covered by deep water, only indirect techniques such as geophysical methods and shallow coring provide information from which geologic interpretations can be made.

For many years the California Continental Borderland has been envisioned as a region of high petroleum potential, and exploration in the Santa Barbara Channel has partly substantiated this premise. Early in 1974, the Bureau of Land Management released a map (sheet 2) showing the proposed area for nomination of future lease tracts. Inasmuch as a possible lease sale is scheduled for the late spring of 1975, publication of this preliminary report is intended to afford a geologic base from which additional appraisals can be made.

The principal sources used in preparation of this report are published papers and unpublished data in the files of universities and government agencies. Many new subbottom profiles, gravity and magnetic traverses, and seafloor samples, gathered mainly during recent cruises by the U.S. Geological Survey research vessels KELEZ and LEE, are incorporated to supplement the information in previously available reports.

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SUMMARY OF THE REGIONAL GEOLOGY OF THE MAINLAND AND ISLANDS

Basement rocks

Basement rocks on the mainland coast and on the islands (sheets 3 and 4) consist of several distinct types, some of which may be closely related genetically, and all of which are believed to be pre-Late Cretaceous in age. In the Santa Ynez Mountains north of the borderland, fault slivers along the Santa Ynez fault zone are composed of Franciscan rocks including severely deformed graywacke, shale, and chert bodies that are intruded by serpentine and greenstone (Dibblee, 1966; Vedder and others, 1969). Within a predominantly fault-bounded belt on Santa Cruz Island, chloritic schist formed chiefly from volcanic rocks is intruded by dioritic and gabbroic rocks, which are in part of Late Jurassic age (Weaver and others, 1969; Hill, 1974; D. G. Howell, oral commun., 1974). In the eastern Santa Monica Mountains, a metamorphosed shale and graywacke unit, some of which is Late Jurassic in age (Imlay, 1963), is intruded by granodiorite, quartz monzonite, and quartz diorite of early Late Cretaceous age (Jennings and Strand, 1969). In the northern Peninsular Ranges, Late Cretaceous batholithic rocks that range in composition from quartz monzonite to gabbro intrude both volcanic rocks of Late Jurassic(?) to Early Cretaceous(?) age and underlying argillite and graywacke which are of Late Jurassic age in part (Yerkes and others, 1965; Baird and others, 1974). Distinctive metamorphic rocks containing a blueschist-facies mineral assemblage unlike that of schistose basement rocks in the eastern Transverse Ranges and Peninsular Ranges are exposed in the Palos Verdes Hills and on Santa Catalina Island (Woodford, 1924; Woodring and others, 1946). In addition to the blueschist facies, rocks of the greenschist facies as well as amphibolite, serpentinite, saussuritized gabbro, and younger intrusive dioritic rocks have been reported on the same island (Platt, 1972; Platt and Stuart, 1974). Both facies have been described from the subsurface section in the western Los Angeles basin near the Newport-Inglewood fault zone (Schoellhamer and Woodford, 1951; Yeats, 1973, 1974). The areal distribution of these various basement rocks and the location of their boundaries beneath the borderland and the Ventura and Los Angeles basins are uncertain, but it seems likely that metamorphic rocks related to those exposed on Santa Catalina Island underlie large segments of the offshore region (sheet 3).

Basement rocks are buried by exceptionally thick sequences of sedimentary and volcanic rocks in the coastal basins and in some of the borderland basins. For example, depths to basement rocks are estimated to be as much as 50,000 ft (15,200 m) in the Ventura basin (Curran and others, 1971), more than 30,000 ft (9,150 m) in the Los Angeles basin (Yerkes and others, 1965), and at least 12,000 ft (3,700 m) subsea in the San Nicolas Basin.

Upper Cretaceous rocks

On the mainland coast, thick successions of Upper Cretaceous sedimentary rocks are exposed in the Santa Ynez Mountains and Santa Monica Mountains, but their areal extent is relatively small. In the northwestern Santa Ana Mountains, strata of Turonian to late Campanian age form a nearly continuous belt for about 40 mi (64 km) and locally are more than 5,000 ft (1,520 m) thick. South of Oceanside, partly equivalent and slightly younger outcropping sequences are much thinner: near Carlsbad, less than 100 ft (31 m), at La Jolla, about 850 ft (260 m) and at Point Loma, about 500 ft (160 m) (Sliter, 1968; Kennedy and Moore, 1971). The subsurface section near San Diego locally may be as much as 2,175 ft thick (Hertlein and Grant, 1944). In the Channel Islands, the only known exposures of Upper Cretaceous strata are on the west end of San Miguel Island; there the sequence may be as much as 10,000 ft (3,050 m) thick (Kennett, in Redwine, 1952), and possibly correlative strata occur in a small fault wedge on Santa Rosa Island. Upper Cretaceous sedimentary sequences have been penetrated by wells on Santa Cruz Island, beneath the shelf north of San Miguel Island, and beneath the east-central Santa Barbara Channel (Weaver and others, 1969; Vedder and others, 1969; U.S. Geological Survey, 1974). Structure sections compiled by Curran and others (1971, figs. 7, 8) show Cretaceous rocks under all parts of the Santa Barbara Channel, in places as much as 12,000 ft (3,660 m) thick. Upper Cretaceous strata have not been reported from any of the islands south of the northern group, but they may be present in the subsurface section beneath San Nicolas Island.

Most of the Upper Cretaceous sequences in southern California consist of interbedded marine conglomerate, sandstone, and mudstone beds that were deposited in a broad range of sedimentary environments, but the paleogeography of the region is poorly understood. In general, Upper Cretaceous strata in the central and eastern Santa Ynez Mountains and on San Miguel Island represent lower slope and deep-sea fan deposits, whereas equivalent strata in the western part of the range probably are of shallow-water origin. In the Santa Monica Mountains, Santa Ana Mountains, and in the San Diego district they are chiefly upper slope and shelf deposits that locally include nonmarine conglomerate beds at the base.

Paleocene and Eocene rocks

Lower Tertiary marine strata, primarily Eocene in age, are widely distributed in the Santa Ynez Mountains where they consist in large part of lenticular sandstone and shale units that may be in excess of 20,000 ft (6,100 m) thick (sheet 4). Although most of the Eocene strata in this area were deposited as upper continental slope sediments, locally they suggest shallow marine and lagoonal conditions. Both Paleocene and Eocene rocks are present beneath the Oxnard Plain and the westernmost Santa Monica Mountains and are exposed in the central and eastern Santa Monica Mountains, where shallow marine deposition is suggested by sedimentary structures and fossil content.

In the northwestern Santa Ana Mountains, shallow-marine and nonmarine sandstone and conglomerate beds of Paleocene and Eocene age total about 4,000 ft (1,220 m) in thickness, and a partly equivalent section in the San Joaquin Hills (sheet 4) probably is less than 3,000 ft (910 m) thick (Yerkes and others, 1965). Paleocene rocks are not known to occur in the San Diego district. Eocene shelf and slope sandstone and shale beds, including nonmarine conglomerate lenses, are about 3,000 ft (910 m) thick (Kennedy and Moore, 1971).

On San Miguel Island, Paleocene sandstone, shale, and conglomerate beds may be as much as 1,500 ft (460 m) thick and probably represent outer shelf and upper slope conditions of deposition. Less than 300 ft (90 m) of correlative deposits are exposed on Santa Cruz Island (sheet 4). Marine beds of Eocene age that have a composite thickness of more than 4,000 ft (1,220 m) are present on and beneath San Miguel, Santa Rosa, and Santa Cruz Islands (Weaver and others, 1969). These strata are predominantly coarse-grained slope deposits that suggest gradually deepening conditions progressively upward through the sequence. In the subsurface section beneath the Santa Barbara Channel, Curran and others (1971, figs. 7, 8) infer that the Eocene strata are thick, widespread, and probably continuous between the outcrops on the Channel Islands and those on the mainland coast to the north. Farther to the south, on San Nicolas Island, the stratigraphic sequence consists of interlayered deep-water sandstone, shale, and conglomerate beds that are chiefly middle and late(?) Eocene in age (Ulatisian and Narizian). The outcrop thickness there is about 3,500 ft (1,070 m), but the base and top of the succession are not exposed (Vedder and Norris, 1963).

Oligocene rocks

Throughout the mainland of southern California, strata of Oligocene age (Refugian and lower Zemorrian) are predominantly nonmarine. Only in the western Santa Ynez Mountains (Dibblee, 1950) does this red-bed sequence tongue into a marine succession. There the marine sandstone and shale section is about 1,000 ft (300 m) thick (sheet 4), but its nonmarine sandstone, conglomerate, and mudstone counterparts thicken eastward from a thin wedge in the vicinity of Gaviota to as much as 8,000 ft (2,440 m) a few miles east of Ventura, where the section includes late Eocene and early Miocene beds (Vedder and others, 1969). About 1,250 ft (380 m) of equivalent red beds are exposed on Santa Rosa Island, and similar rocks possibly occur on San Miguel Island and in the subsurface section beneath the eastern part of Santa Cruz Island (Weaver and others, 1969). In the Santa Monica Mountains, partly correlative nonmarine sandstone, conglomerate, and mudstone beds have an aggregate thickness of as much as 4,000 ft (1,220 m) (sheet 4), and similar strata in the San Joaquin Hills are about 2,500 ft (760 m) thick (Yerkes and others, 1965). The name Sespe Formation generally is applied to the nonmarine part of the section in both the Transverse Ranges and Peninsular Ranges. Southeast of the town of San Clemente these strata do not occur in either surface or subsurface sections. Neither Oligocene nor older nonmarine Tertiary rocks have been reported from the southern group of islands.

Miocene rocks

Sedimentary and igneous rocks of Miocene age are widely distributed in coastal southern California, and at many places surpass the early Tertiary rocks in areal extent and thickness (sheets 3, 4). Along the mainland coast, marine sedimentary rocks of Miocene age are divided arbitrarily into lower, middle, and upper parts for convenience of description. As used herein, the lower part includes the upper Zemorrian and lower Saucesian Stages; the middle part, upper Saucesian through Luisian; and the upper part, Mohnian and Delmontian. Volcanic and shallow intrusive igneous rocks of the same age are discussed under a separate heading.

Lower Miocene strata.--A persistent narrow belt of lenticular transgressive marine sandstone (Vaqueros Formation) as much as 600 ft (180 m) thick forms the basal unit of the Miocene succession along the south flank of the Santa Ynez Mountains and is disconformable on the underlying red beds. These sandstone beds are conformably overlain by a fine-grained sequence of claystone, mudstone, and siltstone beds (Rincon Mudstone) that locally are interstratified with thin zones of bentonitic clay (Dibblee, 1950, 1966). This fine-grained unit is as much as 2,500 ft (760 m) thick near Ventura. A similar succession is exposed on southern Santa Rosa Island (3,200 ft ± [970 m ±] thick) and on San Miguel Island (1,500 ft ± [460 m ±] thick) (sheet 4), but the basal sandstones are missing on San Miguel and the entire section is coarser grained on Santa Rosa (Weaver and others, 1969). Equivalent strata are increasingly coarser on Santa Cruz Island and are about 1,000 ft (300 m) thick. In the central and western Santa Monica Mountains, interbedded marine sandstone and siltstone beds about 3,500 ft (1,068 m) thick in the lower part of the Miocene section are intertongued at the base with nonmarine red beds, and the composite section thins eastward and lenses out. In the Santa Ana Mountains, on the east side of the Los Angeles basin, marine strata of early Miocene age interdigitate with nonmarine beds; in the San Joaquin Hills nearer the coast, they rest gradationally on red beds and are increasingly finer grained as the section thickens southward (Yerkes and others, 1965). Lower Miocene rocks are not known to be present in the area between the southeastern San Joaquin Hills and the Mexican border.

Middle Miocene strata.--Sedimentary rocks of middle Miocene age in coastal southern California are characterized by three contrasting facies: an organic siliceous shale (Monterey Shale), a feldspathic sandstone (Topanga Formation), and a blueschist breccia and conglomerate (San Onofre Breccia). The siliceous shale and related fine-grained rocks form one of the most widely distributed and distinctive units along the coast; they are absent only in the area from Oceanside to San Diego, at Santa Catalina Island, south of the median fault on Santa Cruz Island, and on San Nicolas Island. The sandstone unit, which generally is slightly older than the shale unit, is not present at the surface along the mainland coast between Point Conception and Point Mugu but is exposed north of the Santa Ynez fault and may occur locally beneath the Santa Barbara Channel. The feldspathic sandstone facies forms a major stratigraphic unit in the central Santa Monica Mountains, where it is as much as 4,000 ft (1,220 m) thick, and along the southeast side of the Los Angeles basin where it is about 3,500 ft (1,020 m) thick in outcrop (sheet 4); it probably is absent on the mainland southeast of the San Joaquin Hills. The blueschist breccia and associated conglomerate and sandstone constitute a distinctive lenticular unit that is discontinuously distributed along the coastal zone from the Santa Monica Mountains to Oceanside (Woodford, 1925; Woodford and Bailey, 1928; Stuart, 1973); it also occurs on Santa Rosa, Santa Cruz, and Anacapa Islands and the adjacent seafloor (Scholl, 1960; Weaver and others, 1969; Yeats, 1970). Similar breccia is reported from Santa Catalina Island (Howell and others, 1974) and forms part of the section on Islas Los Coronados and the mainland just south of the Mexican border (Minch, 1967; Lamb, 1972; Stuart, 1973). On Santa Cruz Island south of the median fault, volcaniclastic rocks composed primarily of agglomerate gradationally overlie the schist-detritus unit and themselves contain schist fragments in the lower part (Weaver and others, 1969).

Upper Miocene strata.--Marine sedimentary rocks from the upper part of the Miocene succession have varied compositions and range from diatomaceous claystone to conglomeratic sandstone. Where present along the mainland coast of the Santa Barbara Channel, most of the upper Miocene section is composed of diatomaceous mudstone and claystone beds that contain increasing amounts of sandstone both higher in the section and eastward in the Ventura basin. A possibly equivalent sequence may occur in a fault block at the top of the exposed section on the southeast side of Santa Rosa Island, where the middle and lower parts of the section consist of lenticular beds of middle Miocene tuffaceous sandstone and volcanic agglomerate (Weaver and others, 1969). Upper Miocene strata total 1,700 to 2,200 ft (520 to 670 m) in thickness along the anticlinal trend near the mainland coast of the Santa Barbara Channel west of Ventura but thin to about 1,000 ft (300 m) beneath the Oxnard Plain. In the north-central Santa Monica Mountains, the upper Miocene section (Modelo Formation) is about 2,000 ft (910 m) thick and is composed chiefly of interlayered siltstone, shale, and sandstone; in the Palos Verdes Hills, it is dominantly mudstone (Malaga Mudstone Member of the Monterey Shale) that attains a thickness of about 1,100 ft (330 m) (sheet 4). Outcrops near the coast in the southeastern part of the Los Angeles basin include a mudstone unit (Capistrano Formation, lower part) similar to that in the Palos Verdes Hills. Farther northwest in the Los Angeles basin, the surface and subsurface sections (Puente Formation) consist mainly of turbidite units composed of interlayered sandstone and clayey siltstone that have a total thickness of as much as 13,400 ft (4,087 m) (Yerkes and others, 1965). Southeast of the town of San Clemente, upper Miocene strata strike seaward, and a possibly correlative section south of San Diego is only 115 to 165 ft (35 to 50 m) thick (Artim and Pinckney, 1973). A little more than 100 ft (30+ m) of tuffaceous conglomerate and diatomite of possible late Miocene age overlies dacitic flows near the isthmus on Santa Catalina Island (Forman and others, 1972).

Miocene volcanic rocks.--Volcanic rocks of Miocene age are distributed over a large part of coastal southern California and are useful for regional correlations and tectonic reconstructions. Extrusive and intrusive igneous rocks that range in composition from basalt to rhyolite form parts of the northern Channel Islands and the western Santa Monica Mountains. Similar rocks, chiefly andesitic, encircle the Los Angeles basin, both at the surface and at depth (Eaton, 1958), but are not present in the coastal zone southeast of the San Joaquin Hills. Although some of these igneous rocks are late Miocene in age (Yerkes and others, 1965), the bulk are middle Miocene (Yeats, 1969a, fig. 1; Turner, 1970). On the southern group of islands, volcanic rocks of probable middle Miocene age form most of the Santa Barbara (Emery, 1960) and San Clemente Islands (Olmsted, 1958), but constitute less than one third of the area of Santa Catalina Island (Bailey, 1941) and occur only as minor intrusions on San Nicolas Island (Vedder and Norris, 1963) and at Begg Rock. On San Clemente Island the flow sequence probably is more than 1,500 ft (450 m) thick (Olmsted, 1958; Merifield and others, 1971) and at the top is intercalated with and overlain by diatomaceous shale beds that are middle Miocene in age. South of the international boundary, basalt flows and tuffaceous rocks form most of the Miocene part of the stratigraphic column (Minch, 1967; Hawkins, 1970).

Pliocene rocks

Marine strata of Pliocene age generally are restricted to existing deep depositional basins and their closely adjacent margins. In the vicinity of Ventura, the Pliocene section (rocks commonly called Repetto and Pico Formations) is 15,000 ft (4,575 m) or more thick and may be more than 14,000 ft (4,270 m) thick in the central Los Angeles basin (Fernando Formation). In both basins, strata of this age consist primarily of repetitously interbedded mudstone and sandstone with minor amounts of conglomerate. Transport of sand- and gravel-size components to the central parts of the basins is generally attributed to turbidity current action. Thin beds of volcanic ash locally are present in the lower part of the succession in the Los Angeles basin and in the upper part in the Ventura basin. In the San Diego district, the Pliocene section has a maximum thickness of about 1,000 ft (300 m) and is composed primarily of fine-grained sandstone with minor amounts of coarse-grained sandstone and conglomerate, most of which represents shelf deposition.

Pleistocene and Holocene deposits

Thick accumulations of marine and nonmarine deposits of Pleistocene and Holocene age are preserved at places along the coastal plain and in the interior basins and are as much as 6,000 ft (1,830 m) thick east of Ventura (Yerkes and others, 1965; Vedder and others, 1969). These deposits generally consist of poorly consolidated sediments that range from clayey mudstone to boulder conglomerate and represent diverse depositional environments that include outer shelf, littoral, estuarine, eolian, flood-plain, and stream-bed conditions. On the islands, Quaternary strata are limited chiefly to marine terrace deposits of late Pleistocene age and dune and slope-wash cover of Holocene age.

Regional structure

West-trending structures typify the Transverse Ranges province and are expressed by alined topographic elements such as the Santa Ynez Mountains, northern Channel Islands, Santa Monica Mountains, and Ventura basin. The structure of the Peninsular Ranges province is reflected by a northwest topographic grain, and a similar structural grain is shown by most of the submarine ridges and elongate basins of the continental borderland south of the northern group of Channel Islands (sheet 3).

Faults.--In the westernmost Transverse Ranges, the major faults have sinuous traces but trend generally westward (Dibblee, 1950, 1966; Vedder and others, 1969; Lee and Vedder, 1973; U.S. Geological Survey, 1974). Both active faults (less than 500,000 years old) and older, dormant faults, which probably have histories of recurrent movement, transect much of the coastal zone from Point Conception to San Diego (Ziony and others, 1974). Various amounts of reverse, dip-slip, oblique-slip, or strike-slip separations are demonstrable, but the most recent dominant pattern suggests regional north-south compression with development of opposing reverse faults such as the San Cayetano and Oak Ridge faults on the margins of the Ventura basin (Bailey and Jahns, 1954). The longest continuously mappable fault in the western Transverse Ranges is the Santa Ynez, which extends for 90 mi (140 km) along the north edge of the Santa Ynez Mountains (Dibblee, 1950, 1966; Ziony and others, 1974). Near its western end, a southwest-trending branch shows evidence of late Quaternary movement, and several faults in the vicinity of Santa Barbara and Ventura suggest Holocene activity (Ziony and others, 1974).

On the northern Channel Islands, faults with a west or northwest trend are the dominant structural features (Weaver and others, 1969). Both Santa Rosa and Santa Cruz Islands are cut by large median faults, each of which seems to be a major structure with left-lateral separation that has been estimated to be as much as

10 mi (16 km) (Weaver and others, 1969). Late Tertiary and Quaternary movements have offset rock units and terrace deposits in a left-lateral sense along both of these median faults, although Howell and others (1974) postulate substantial mid-Tertiary right slip along the Santa Cruz Island fault. Inferred faults beneath the Santa Barbara Channel generally have east-west trends; some of these are active (Curran and others, 1971; Lee and Vedder, 1973; U.S. Geological Survey, 1974), but the direction of movement is uncertain.

The structure of the Santa Monica Mountains is extremely complex, as indicated by the irregular fault pattern (sheet 3). This pattern has resulted from folding and faulting of large detachment thrust sheets by later strike-slip and reverse displacement along the Malibu Coast fault (Campbell and others, 1966). The Malibu Coast fault, which lies along the coastal flank of the mountains, probably was the fault on which major left-lateral slip took place in pre-late Miocene time (Yerkes and Campbell, 1971; Sage, 1973). At present, the Malibu Coast fault is regarded as a northern branch of the Santa Monica fault system, a zone of north-dipping reverse faults that forms the southern boundary of the east-west structural trends of the Transverse Ranges province, the seaward (westward) extension of which may be the locus of recent seismic activity at depth (Ellsworth and others, 1973).

In contract to the faults of the Transverse Ranges, those in the Peninsular Ranges province have dominant northwest trends, and young reverse faults apparently are uncommon. Some are similar to the Transverse Ranges faults in that they have complex histories of movement. Aside from the San Andreas and related faults, the Elsinore fault system is one of the largest in the northern Peninsular Ranges. It extends for more than 140 mi (225 km) along the northeast side of the Laguna Mountains and Santa Ana Mountains and apparently splays and dies out in the northwestern Los Angeles basin along the subsurface continuation of the Whittier fault. A well-defined zone of discontinuous faults more than 130 mi (210 km) long trends northwest from the San Diego area onto the nearshore shelf from La Jolla to Newport Beach and thence back on shore into the Los Angeles basin (sheet 3) (Ziony and others, 1974). This zone includes the Rose Canyon fault, 25 mi (40 km) long, at the south (Moore, 1972) and the Newport-Inglewood fault zone, 40 mi (65 km) long, at the north (Harding, 1973; Yeats, 1973). Late Cenozoic right-lateral strike-slip separation is attributed to both the Elsinore and Newport-Inglewood fault zones. Faults in Tertiary rocks on the southern group of islands are oriented north to northwest in general, and most seem to have relatively small amounts of dip slip or oblique slip.

<u>Folds</u>.--The normal trends of major folds in the Transverse and Peninsular Ranges provinces are west and northwest respectively, and tend to parallel the major fault systems. The folds in both provinces are arranged en echelon and, in contrast to the large fault zones, rarely are more than 10 to 15 mi (16 to 24 km) long. Fold axes along some of the through-going fault systems such as the Newport-Inglewood zone are oblique to the trends of the fault zones and probably are genetically related to wrench-style deformation.

In the central and eastern Santa Ynez Mountains, many folds along the south flank of the range are asymmetric, the south limbs of anticlines being steep or overturned. In the central part of the Ventura basin, other folds, such as those at South Mountain and Oak Ridge, have north limbs that are steep or overturned to the north. Episodes of folding or regional uplift have been recurrent on the margins of both the Ventura and Los Angeles basins during much of post-middle Miocene time, and local warping apparently is continuing at present at the edges of both basins. On the northern group of islands, northwest-trending en echelon folds are oblique with respect to the main fault system (Weaver and others, 1969). West-trending metamorphic structures in the basement rocks of the Santa Monica Mountains predate Late Cretaceous and Paleogene deposition, and folds with similar trends have formed since middle Miocene time (R. H. Campbell, written commun., 1974). Nearly continuous folding and uplift apparently persisted through late Cenozoic time along the southern margin of the Transverse Ranges province (Bailey and Jahns, 1954; Winterer and Durham, 1962; Campbell and others, 1966; Yerkes and Campbell, 1971).

Northwest-trending folds prevail throughout the Los Angeles basin region, where deformation has been recurrent since the beginning of middle Miocene time (Yerkes and others, 1965; Yeats, 1973). Strongly warped beds as young as late Pleistocene attest to the recency of folding around the margins of the basin. In the coastal area from Oceanside to San Diego, the degree of tectonism has been less intense, as the Upper Cretaceous and Eocene strata there are only moderately deformed except in places that are adjacent to young faults.

A single broad, faulted anticline underlies each of the islands of San Clemente (Olmsted, 1958) and San Nicolas (Vedder and Norris, 1963), but the age limits of the folding can be placed only between pre-late Pleistocene and post-middle Miocene time. On the mainland and islands, Pleistocene terraces indicate late stages of uplift that may be in progress at present (Davis, 1933; Vedder and Norris, 1963; Birkeland, 1972).

GEOLOGY OF THE SUBMERGENT PART OF THE CONTINENTAL BORDERLAND

Status of knowledge

Published information on the bedrock geology of the continental borderland exclusive of the islands is sparse and is based primarily on scattered bottom samples and reconnaissance geophysical investigations. A large amount of data has been gathered by oil companies since the 1950's, but most of it is proprietary. There is little doubt that the gross structure and late Tertiary stratigraphy resemble those of the adjoining mainland coast, but the relatively simple geologic patterns (sheet 3) that result from recent interpretations of available offshore data contrast strikingly with the complex relations that have been deciphered on shore, where outcrop and subsurface studies have been in progress for more than 50 years. Emery's (1954) cautionary advice on interpreting this seafloor region still holds:

> * * *"here the unknown geology far exceeds the known. Because of the relative inaccessibility of the submarine area, each new fact gained is expensive in terms of both time and effort, and thus it receives more attention and interpretation than an equivalent new fact of land geology. Care must constantly be exerted to avoid over-exploitation of the facts, and this can be done mainly by judging what is reasonable in terms of knowledge borrowed from the geology of the adjacent land."

The geologic map (sheet 3) was constructed using data from surface samples and sparker profiles. Because of the wide separation of these data on the outer part of the borderland, the exact location of contacts is uncertain except where sparker profiles cross the contacts; in many places, the contacts were projected on the basis of the bathymetry. Recognition of geologic horizons on the sparker profiles used in compilation of sheets 3, 5, and 6 is based on (1) down-dip and lateral extension from surface samples, (2) record characteristics, and (3) superpositions relative to unconformities, which are correlated by inference with similar relations on adjoining land. Bedded sedimentary sequences show well-defined continuous internal reflections. Miocene and post-Miocene sedimentary units generally appear on seismic profiles as closely spaced acoustic reflections. Where both units are present on a single profile, they commonly are separated by an unconformity on the flanks of the basins, and the contacts can be projected into the basin. Miocene sequences show greater small-scale internal deformation than younger units. Where either of the units occur as an isolated patch, correlation is difficult and may be in error at places. Pre-Miocene strata (probably mostly Eocene in age) show fainter, widely separated bedded reflections. Both Miocene volcanic rocks and basement rocks generally show no bedded reflections or only discontinuous, weak, internal ones and cannot be differentiated. However, in some seismic profiles the nonbedded characteristics of Miocene volcanic rocks grade laterally into well bedded Miocene sedimentary units. In these areas the Miocene volcanic rocks can be distinguished from basement rocks.

Predicted thicknesses of the sedimentary section in this subsea region are questionable because data on sound velocities through the various rock units are inadequate. Inasmuch as subbottom acoustic reflection profiling is the primary tool for constructing offshore structure sections, these velocities are critical for accurate interpretations. It is noted above that several rock units show no internal reflectors and resemble the pre-Late Cretaceous basement rocks on acoustic profiling records. Examples include the relatively widely distributed Miocene volcanic rocks and the schist-breccia and conglomerate units of middle Miocene age. On the other hand, some of the Franciscan-like rocks show intermittent internal reflectors but rarely are mistaken for younger strata.

A constant velocity of 2,000 m/sec is used for computing thicknesses of the entire sequence of post-Miocene strata (sheets 5, 7) except for Santa Monica and San Pedro Basins, where a more accurate velocity distribution was obtained by use of the formula: 1,500 m/sec + 0.5Z (Z = depth to reflection horizon below seafloor). The value of 2,000 m/sec undoubtedly is too high for the upper horizons and results in thickness figures that are too large for post-Miocene isopachs, but the error is small for thin intervals. All velocities are based on general experience and may be in error by as much as 20 to 25 percent. Large lateral variations in velocity are known to occur in California Tertiary basins.

The faults shown on sheets 3, 5, and 6 are based on sparker profiles, most of which were located by precise navigation systems. Where faults cut low-dipping well-bedded strata, location of faults is reliable, and vertical components of slip as small as 25 ft (8 m) may be recognized. Where the profiles show no bedded reflections, faults cannot be interpreted; in structurally complex sections, identification of faults is difficult.

Attempts to recover samples of pre-Quaternary rocks generally have been limited to the ridge crests, banks, knolls, and steep slopes with the result that many areas remain unsampled. The only precise method for determining thickness, age, and rock composition is shallow core drilling (500 ± ft) or deep well tests, but relatively little has been done because of the high cost.

Geomorphic features of the borderland

The California Continental Borderland (Shepard and Emery, 1941; Moore, 1969) is typified by elongate, northwest- and west-trending seafloor ridges and basins. On the northwest, the borderland is bounded by Point Arguello and Arguello Canyon; on the southeast, by Bahia Sebastian Vizcaino and Isla de Cedros. Its western edge is marked by the Patton Escarpment at the north and the Cedros Deep at the south (Moore, 1969, plate 1). It differs from a typical continental shelf in that it encompasses large depressions as deep as 6,912 ft (2,107 m) below sea level and island ridges as high as 2,450 ft (747 m) above sea level. Topographic relief within a single ridge-basin pair is as much as 8,900 ft (2,713 m) from the top of Santa Cruz Island to the bottom of Santa Cruz Basin. North of a seaward projection of the California-Baja California boundary, eight islands and several isolated rocks protrude above the sea surface (sheet 1). According to Emery (1960), the part of the borderland that lies north of lat 31°30'N. covers an area of more than 30,000 mi^2 (about 80,000 km^2), and about 85 percent of this area is in water deeper than 660 ft (200 m).

One of the conspicuous ridges of the northern part of the borderland is the west-trending insular platform that extends 80 mi (129 km) from Hueneme Canyon to the slope west of San Miguel Island and includes the northern group of Channel Islands. The most persistent geomorphic feature on the borderland east of the Patton Escarpment is the Santa Rosa-Cortes Ridge (sheet 1). The ridge extends uninterrupted for approximately 130 mi (210 km) southeast from Santa Rosa Island to the southeast end of Cortes Bank and lies between 60 mi (100 km) and 90 mi (145 km) off the mainland coast. It is flat-topped and slightly asymmetric in that the east-facing slopes adjoining the Santa Cruz and San Nicolas Basins are gentler than those to the west. Along the northern half of the ridge, the crest is broad and less than 660 ft (200 m) deep, although a broad, shallow saddle more than 1,150 ft (350 m) deep transects it at about the midpoint. San Nicolas Island, which forms the highest point on the ridge at 907 ft altitude (277 m), is on an east-trending salient. At the southeast end, Tanner and Cortes Banks form a shallow, double protuberance that culminates in Bishop Rock, a rocky reef on Cortes Bank less than 15 ft (4 m) deep. Another prominent ridge that locally projects above the 100-m isobath bifurcates southeastward from Santa Cruz Island to form the Santa Barbara and Santa Catalina Island platforms and extends beyond Santa Barbara Island to San Clemente Island.

Patton Ridge (Moore, 1969), which forms a relatively shallow area just east of the northern part of the Patton Escarpment and west of northern Tanner Basin, trends northwest in its southern part but is oriented nearly due north in its narrow northern part. This broad, curving ridge is nearly 70 mi (110 km) long and has banks as shallow as 715 ft (218 m) in its east-central part. Another irregular, Y-shaped ridge system, which reaches a depth of only 318 ft (97 m) at its south end on Sixtymile Bank, separates San Clemente and East Cortes Basins.

North of an arbitrary line from San Diego to Northeast Bank, there are four deep silled basins, the floors of which are more than 3,000 ft (1,000 m) below sea level. These are: Santa Cruz Basin (maximum depth 6,450 ft [1,966 m]), Catalina Basin (maximum depth 4,429 ft [1,350 m]), San Nicolas Basin (maximum depth 5,994 ft [1,827 m]), and Tanner Basin (maximum depth 5,082 ft [1,549 m]). Part of a fifth basin, San Clemente Basin (maximum depth 6,913 ft [2,107 m]), extends into the area from the southeast, and a deep, open-ended depression, the San Diego Trough, slopes toward the international boundary and is 4,131 ft (1,253 m) deep west of Coronado Bank. Santa Monica and San Pedro Basins have much shallower floors that generally are about 2,500 ft (750 ± m) deep, although the deepest point in the Santa Monica Basin is 3,110 ft (948 m) below sea level. The west-trending Santa Barbara Basin is shallower than the others with a maximum depth of 2,050 ft (600 m). Several of these elongate basins are roughly rhomboid in outline, but both Santa Cruz and San Nicolas Basins taper to the southeast, and San Clemente Basin is irregular and poorly defined topographically. The long axes of all but Santa Barbara Basin are oriented approximately N. 45° W.

San Nicolas and Santa Cruz Basins at sill depth cover about 1,027 mi^2 (2,660 km^2) and 687 mi^2 (1,779 km^2), respectively. For comparison, the relatively flat part of the filled Los Angeles basin extends over approximately 980 mi^2 (2,538 km^2) (Emery, 1960).

Offshore basement rocks

R.D. Reed (1933) postulates that all of the basement rocks on the California Continental Borderland are related to the Franciscan and that granitic rocks are limited to areas east of the coastal zone. Yeats (1968b) and Winterer and others (1969) suggest the presence of three northwest-trending, subparallel belts of Franciscan-like basement rocks representing increasingly higher grades of metamorphism from the

Patton Escarpment eastward into the San Gabrial Mountains. In succession from west to east, these zones are envisioned as consisting of (1) altered sedimentary rocks of the zeolite facies along the escarpment and outer ridges, (2) blueschist facies and related rocks in the central and inner parts of the borderland, and (3) greenschist facies on the mainland to the northeast. Recent work partly substantiates that of earlier workers, but there are some important differences. Investigations on Santa Catalina Island (Platt, 1972; Platt and Stuart, 1974) show that some of these diverse facies occur there in close association with one another. Seafloor samples collected by the U.S. Geological Survey have genetic affinities to those of the Franciscan Formation but also contain a variety of metamorphic rocks. Sampling to date indicates a complex distribution of many types from which no well-defined pattern emerges (table 1 and sheet 9). Furthermore, the relation of these rocks to the metamorphic rocks on Santa Cruz Island remains unexplained. Silicic plutonic rocks similar to those that occur on the mainland, as well as the Miocene quartz diorite porphyry on Santa Catalina Island and the tonalite on Santa Cruz Island, have not been reported from any part of the borderland south of the Transverse Ranges except as erratic boulders or as transported material.

High pressure-low temperature rocks of the "blue amphibole" facies recently have been sampled from seafloor outcrops as far south as the seaknoll east of Sixtymile Bank and as far north as the low ridge 4.8 nmi (nautical miles) (9 km) northwest of Santa Rosa Island (table 1) and possibly are in place as far west as the Patton Escarpment. These rocks are similar to those referred to as the "glaucophane-lawsonite" or Catalina metamorphic suite exposed on and around Santa Catalina Island and in the Palos Verdes Hills. A possibly related chlorite-albite schist with a high quartz content occurs at Sixtymile Bank, and Emery (1960) reports the same rock type from a knoll 17 nmi (32 km) to the north.

Metamorphosed basic igneous rocks similar to those exposed on Santa Catalina Island have been recovered from the Patton Escarpment, along Patton Ridge, and from the saddle on the ridge between Santa Barbara Island and San Clemente Island. These are chiefly amphibolite and pyroxenite, many with a high percentage of epidote, and some saussuritized gabbro. In several localities along Patton Ridge and the Patton Escarpment, serpentinite is common, as are other chloritized basic to ultrabasic volcanic rocks. Preliminary studies of the petrology of coarse-grained late Cenozoic sediments throughout the borderland indicate that the same basement rock types locally are a major constituent of these sands. At places, basic igneous volcanic rocks, some of which are probably in the ultrabasic range, have been sampled at the same site or at adjacent stations. These volcanic rocks are altered but not metamorphosed, and their age and relations with the serpentinites and other metamorphics are uncertain.

Rocks similar to Franciscan rock types from the Coast Ranges recently were dredged 8 nmi (14.8 km) southeast of San Nicolas Island, from a knoll 10 nmi (18.6 km) west of the deep part of Tanner Basin, and from the northernmost and central parts of Patton Ridge (table 1 and sheet 9). These are large angular fragments of lithic wacke and argillite, densely welded with negligible porosity. The composition ranges from clasts rich in volcanic material with a chlorite matrix, to poorly sorted feldspar-rich sandstone with a high percentage of chert, metamorphic grains, and small percentages of volcanic rocks and chlorite. Some of the sandstone samples contain leonhardite, a variety of laumontite. Dredge hauls on Patton Ridge containing these Franciscan-like metasedimentary rocks are near hauls of serpentinite, suggesting an association of the two similar to that in the Coast Ranges. However, the marked compositional variation of the grains in these dense sandstones suggests that they may be atypical Franciscan rocks.

Offshore Upper Cretaceous and lower Tertiary rocks

Outcrops of Upper Cretaceous rocks presumably are present on the shelf close to the west and southwest sides of San Miguel Island; they also form the walls of submarine canyons just offshore from La Jolla and crop out on the ocean bottom west and south of Point Loma. Curran and others (1971, figs. 7, 8) indicate that Cretaceous rocks underlie the Santa Barbara Channel and may be as much as 12,000 ft (3,660 m) thick, but this section may include strata older than Late Cretaceous. Parker (1971, fig. 6) infers less than 2,000 ft (610 m) of Cretaceous strata beneath Santa Rosa-Cortes Ridge and Santa Cruz Basin and shows none directly east of the basin.

South of the northern group of Channel Islands, large seafloor outcrops of Cretaceous strata are not known with certainty, and Lower Cretaceous samples have not been reported. An isolated occurrence of Cretaceous rocks on a seaknoll about 13 nmi (24 km) west of San Nicolas Island (Jennings, 1962) is supported by a nearby sample of siltstone recently identified as Late Cretaceous in age (table 2, KZ 73-1-30). Inasmuch as Upper Cretaceous rocks were penetrated in wells on Cruz Island, they probably are present in the subsurface section immediately south of the island. Redeposited Cretaceous nannofossils in Miocene strata on the northern part of the Santa Rosa-Cortes Ridge, about 13 nmi (24 km) southeast of Santa Rosa Island, support the inference that Cretaceous strata were subjected to erosion in Miocene time in that area. It seems likely that an Upper Cretaceous sedimentary section underlies the San Nicolas Island platform and may extend southeast beneath the Santa Rosa-Cortes Ridge as far as Cortes Bank, but its thickness and composition are unknown. Although equivalent rocks possibly are exposed along parts of the Patton Ridge, their presence there has not been documented by our sampling. No Upper Cretaceous sedimentary rocks have been reported in the region between the mainland shelf break and a straight line connecting the east end of Santa Cruz Island with Sixtymile Bank.

Lower Tertiary rocks are rather sparsely distributed as seafloor outcrops on the borderland. Paleocene strata have not been reported but possibly underlie younger beds on the northwesternmost part of the Santa Rosa-Cortes Ridge and may be exposed on the shelf west of San Miguel Island. In the subsurface section beneath the Santa Barbara Channel, Eocene strata may be as much as 10,000 ft (3,050 m) thick if they are continuous with outcrops in the Santa Ynez Mountains as inferred by Curran and others (1971, figs. 7, 8). However, other interpretations (U.S. Geological Survey, 1974) suggest that a thickness of about 5,000 ft (1,500 m) may be more likely for the Eocene section beneath the east-central part of the channel. Beds of Eocene sandstone and claystone are present on the platform west of San Miguel Island, and the broad shelf around San Nicolas Island exposes interbedded sandstone and siltstone of Eocene age that extend northwest beyond Begg Rock (sheet 3; table 2). Correlative strata undoubtedly constitute a thick subsurface section southward from Santa Rosa Island. Seafloor outcrops of Eocene strata are noted by Strand (1962) in La Jolla Canyon and along the shelf edge west of Point Loma, but they probably are very thin in these places.

The distribution of Eocene rocks in the subsurface section of the outer part of the borderland is not known with certainty, but we infer that strata of this age underlie younger rocks beneath most of the Santa Rosa-Cortes Ridge northwest of San Nicolas Island, where they may range in thickness from 4,000 to 7,000 ft (1,200 to 2,100 m) (sheet 5), and they may extend under much of the same ridge southeast of the island. Our sparker profiles suggest that equivalent rocks underlie both Santa Cruz and San Nicolas Basins and that the unit thins eastward and wedges out or is faulted near the east edges of these basins. Even though they have been sampled as far south as Cortes Bank, it seems unlikely that Eocene strata are thick or extensive east and southeast of that area because wedgeouts, pre-Miocene erosion, and fault truncation may have occurred between the shallow part of the bank and the knolls north of Sixtymile Bank, where basement rocks are exposed. The possibility that an Eocene section exists beneath Patton Ridge cannot be discounted, but our sparse sampling there has revealed only basement and younger Tertiary rocks. Early Tertiary strata have not been reported from the ridge system that extends southeastward from Santa Cruz Island to Sixtymile Bank or from the basins and banks directly east of it.

Offshore Oligocene rocks

Nonmarine sedimentary rocks of presumed Oligocene age lie within the subsurface section beneath the central and eastern Santa Barbara Channel, where they may be as much as 5,000 ft (1,520 m) thick at places (Curran and others, 1971, figs. 7 and 8). Redbeds of the same age possibly occur beneath outcropping Miocene and Pliocene rocks along the mainland shelf between San Clemente and Oceanside. Even though they are present on and beneath Santa Rosa and Santa Cruz Islands and possibly beneath the northwesternmost part of the Santa Rosa-Cortes Ridge, nonmarine strata equivalent to the Refugian and lower Zemorrian Stages seem to have very restricted distribution seaward of the islands. Marine beds representing these stages undoubtedly extend seaward beneath the western part of the Santa Barbara Channel but have not been reported from the shelf around or on San Miguel Island. Far to the southeast, marine siltstone and claystone samples from the northwestern part of Cortes Bank have yielded microfossils of Oligocene age (table 2, LCB 130). Similar, but unfossiliferous samples from sites farther northwest along the Santa Rosa-Cortes Ridge may be correlatives, and it seems likely that equivalent beds may occur at places along what is now mapped as an Eocene-Miocene contact (sheet 3) north and east of San Nicolas Island. Angular blocks of siltstone dredged from the south side of a knoll on Patton Ridge about 40 nmi (85 km) west-southwest of San Nicolas Island contain lower Zemorrian foraminifers, but it is uncertain whether the samples were in place or were transported.

Offshore Miocene rocks

Miocene rocks, including both volcanic and sedimentary types, form most of the high-standing topography of the submerged part of the continental borderland. Although sedimentary rocks seem to predominate, seafloor exposures of both kinds of rocks are widely distributed along ridges and on knolls but ordinarily are covered by a thin veneer of Pleistocene or Holocene sediment. Presumably both the volcanic and sedimentary types extend beneath all of the major basins, but locally the stratal successions, even though thick, seem to be interrupted by unconformities. The volcanic rocks are believed to include thick flow sequences in some areas, particularly near Santa Barbara and San Clemente Islands, but in other places may represent local intrusions or thin flows of limited extent.

Miocene sedimentary rocks.--Paleontologically dated samples suggest that much of the crest of the Santa Rosa-Cortes Ridge for a distance of 20 nmi (37 km) southward from Santa Rosa Island and for 8 nmi (15 km) northward from Begg Rock is composed of silty claystone of early Miocene age (upper Zemorrian and lower Saucesian). Strata of the same age and similar composition are present on the shelf west of San Miguel Island and in the vicinity of Tanner and Cortes Banks. One occurrence on the ridge northwest of Santa Barbara Island is noted by Jennings (1962), but elsewhere on the seaward part of the borderland the distribution of lower Miocene rocks is uncertain. Correlative sedimentary rocks presumably underlie most of the Santa Rosa-Cortes Ridge, both northwest and southeast of the San Nicolas Island salient, and the Patton Ridge and intervening basins. Nearer the mainland, siltstone from the lower part of the Miocene succession occurs on the northern flank of the Santa Monica Basin (Jennings and Strand, 1969).

Fine-grained strata of middle Miocene age (upper Saucesian through Luisian), predominantly shale and claystone, compose large tracts of the Santa Rosa-Cortes Ridge for a distance of nearly 35 nmi (65 km) southeast of Santa Rosa Island and parts of the same ridge between San Nicolas Island and its southeast end. Shaly beds of the same age occur on the shelf west and northwest of San Miguel Island, on the knolls north and south of East Cortes Basin, and on the two small, en echelon ridges west of the south end of Tanner Basin. Diatomaceous shale of the same age is locally present on and around San Clemente Island (Olmsted, 1958; Mitchell and Lipps, 1965; Ridlon, 1972), in the vicinity of Santa Barbara Island (Jennings, 1962; table 2), and around Santa Catalina Island. With the exception of pumiceous and schist-bearing sandstone samples recovered from ridges and slopes south of Santa Cruz and Anacapa Islands and scattered samples of lithic wackes from the Patton Ridge, coarse-grained sedimentary rocks of middle Miocene age seem to be sparse seaward of the mainland and northern island shelves. Blueschist and other Catalina-like metamorphic rock fragments from the unnamed banks west and north of Sixtymile Bank are commonly associated with volcanic fragments in some samples of this age (table 2, Area V).

Strata of late Miocene age (Mohnian and Delmontian), chiefly diatomaceous mudstone, have approximately the same distribution along the outer ridges as the middle Miocene shale and are inferred to drape the slopes and pass beneath younger sediments that floor the outer basins.

Thicknesses of these sedimentary sequences may range from less than 1,000 ft (300 m) for the entire Miocene succession on the ridges to as much as 3,500 ft (1,000 + m) in some of the large outer basins. Some of the thinnest sections of Miocene strata are believed to be in the region of Thirtymile and Fortymile Banks, where volcanic and basement rocks are inferred to be close to the surface on the basis of sparse sparker profiles. Along the northeast slope of the Santa Monica Basin, Miocene sedimentary rocks may be as much as 2,600 ft (800 m) thick and on the southwest flank of the basin, 1,300 to 1,600 ft (400 to 500 m) thick. On the north edge of the San Pedro basin, they are estimated to be 3,000 ft (900 m) thick but seem to wedge out toward the center of the basin. In the Santa Barbara Channel, the Miocene section is thicker; Curran and others (1971) show about 6,500 ft (2,000 m) beneath the deep part of the channel, and the U.S. Geological Survey (1974) estimates a thickness of about 9,000 ft (2,700 m) in the eastern part.

The high porosity and very low density of some of the Miocene strata on the outer ridges suggest that velocity inferences used for thickness calculations are too high. Thus, it follows that thickness estimates for the Miocene section in some of the outer basins may be as much as 1.25 times the actual thicknesses.

Recently collected samples of the fine-grained Miocene sedimentary rocks from the Santa Rosa-Cortes and Patton Ridges range from rare concretionary dolomitic claystone to common diatomaceous and foraminiferal mudstone or marlstone, which has very low density and high porosity. Presumably these low-density rocks have never been subjected to deep burial. At the time of deposition, most of these clayey calcareous strata were laid down in water deeper than the shelf and upper slope, and the fossils in some suggest lower bathyal depths. Several samples from both ridges are crosscut with fractures that are filled with "dead" oil.

Miocene volcanic rocks.--One of the commonest rock types sampled from the borderland is volcanic rock, most of which is believed to be middle Miocene in age. Because these igneous rocks represent diverse conditions of emplacement ranging from aquagene tuffs and thick, extensive flows to local narrow, near-vertical intrusions and sill-like bodies, it is difficult to predict their volume and distribution either on the basis of seismic interpretations or on scattered samples.

Rocks that range in composition from basalt to rhyodacite, in which andesitic types seem to predominate, form nearly continuous exposures along the ridge from the east end of Santa Cruz Island southeastward to Santa Catalina Island. North of Santa Cruz and Anacapa Islands, these volcanic rocks thin toward the mainland and probably do not continue beyond the central part of the Santa Barbara Channel. Andesitic and rhyolitic rocks may form much of Emery Seaknoll northeast of San Clemente Island (Garrison and Takahasi, 1950). Farther to the southeast, on Fortymile and Thirtymile Banks, olivine basalt and hornblende andesite occur as more isolated exposures. Volcanic rocks also occur on isolated knolls south-southeast from Thirtymile Bank, and the most southerly of those sampled is entirely capped by hornblende andesitic and dacitic rocks. Alkali basalt and diabase occur on Cortes and Tanner Banks and characteristically contain augite, olivine and ilmenite, and similar basaltic rock has been dredged from Northeast Bank where some of the extrusive rocks are younger than Miocene (Hawkins and others, 1971).

Along Patton Ridge, volcanic rocks recently have been sampled at several localities (table 1) and some Pleistocene and Holocene sands there are composed entirely of volcanic debris containing angular clasts that indicate a nearby source. These relatively unaltered rocks are especially noteworthy, for some are the most basic of those examined to date. They have been recovered from the Patton Escarpment, on two knolls on Patton Ridge 35 and 32 nmi (65 and 60 km) west of San Nicolas Island, and as far south as the crest of a knoll about 20 nmi (40 km) north of the high point on Northeast Bank. Their age is unknown, but their relatively unaltered nature suggests that they are late Cenozoic rather than pre-Late Cretaceous. They may in fact represent eruptions that occurred throughout late Tertiary and Quaternary time similar to those on the mainland at Mesa de Colorado-Redonda Mesa in the northern Peninsular Ranges (Rogers, 1965) and at Bahia San Quintin in northern Baja California (Woodford, 1928; Gorsline, 1962). On the borderland south of the region mapped (sheet 3), basalt apparently is one of the dominant rock types (Krause, 1965).

Offshore Pliocene rocks

Exposures of Pliocene sedimentary rocks are much less common than Miocene strata on the outer borderland shelves and slopes and are restricted primarily to the mainland shelf at San Pedro Bay and Santa Monica Bay, and southeast of Dana Point. Other scattered occurrences are on the ridge northwest of Santa Barbara Island, on the slopes northeast and south of San Clemente Island, on both slopes of the Santa Rosa-Cortes Ridge, and on Lasuen Seaknoll (Emery, 1960; Jennings, 1962; Moore, 1969). Our subbottom acoustic profiles indicate that Pliocene sediment has accumulated on many of the lower slopes and in all of the basins of the borderland. Outcrops representing significantly thick sections are not known from the ridge crests, although authigenic deposits there contain a meager Pliocene faunal element (Emery, 1960). Seaward of the islands, Pliocene strata have been recorded at only a few places in water less than 1,500 ft (450 m) deep. Pliocene sample sites from deeper water are reported from near the southeast end of San Nicolas Basin, on the flanks of Santa Catalina and Santa Cruz Basins, and on the northern Patton Escarpment. Extrusive volcanic rocks that have been dated as Pliocene are present on Northeast Bank (Hawkins and others, 1971). Thick successions of Pliocene strata are estimated for the Santa Barbara Channel area, about 5,000 ft (1,500 m) beneath the central deep and as much as 10,000 ft (3,000 m) in the subsurface section of the eastern shelf (U.S. Geological Survey, 1974). In Santa Monica Basin, the Pliocene section may have a maximum thickness of about 8,400 ft (2,500 m), although this section may include some beds as old as late Miocene. An equivalent succession in the central part of the San Pedro Basin is estimated to have a maximum thickness of 7,000 ft (2,100 m). Estimates of thickness range from close to 2,000 ft (610 m) in the central parts of Santa Cruz and San Nicolas Basins to less than 500 ft (150 m) on the flanks. Maximum thickness in the Catalina Basin apparently is less than 1,000 ft (300 m) in contrast to an estimated 3,000 ft (900 m) of section in a partly filled basin 30 nmi (56 km) west-northwest of San Nicolas Island.

The predominant rock types among the newly acquired Pliocene samples are semiconsolidated mudstone and unconsolidated mud. Sandstone of Pliocene age has not been reported from the outer borderland basins, but several new samples of undated semiconsolidated sand may be Pliocene. Redeposited sediment in the form of slumped material or turbidite derived from adjoining ridges, banks, and islands probably is present in the Pliocene sections of many of the basins.

Offshore Pleistocene and Holocene deposits

Shelves and slopes near the mainland coast are extensively covered by relatively thick deposits of unconsolidated sand and mud that are Pleistocene and Holocene in age. The nearshore basins are floored chiefly by deposits of Holocene mud except near submarine canyon mouths, where sand has been transported downslope. Curran and others (1971, fig. 7) show about 4,000 ft (1,200 m) of Quaternary beds in the eastern part of the Santa Barbara Channel. A structure section across the deep western part of this channel (U.S. Geological Survey, 1974) indicates a thickness of about 1,600 ft (490 m) of Quaternary deposits. As much as 1,100 ft (330 m) of correlative deposits is present in the Santa Monica and San Pedro Basins.

Thin veneers or pockets of authigenic, biogenic, and relict sand and mud on the outer ridges and hemipelagic mud on the slopes and floors of the intervening basins are the dominant surficial sediments. Authigenic materials in these deposits are composed largely of pelletal and nodular phosphorite and glauconite, some of which has been redeposited from older rocks containing similar materials. Turbiditelike sand is interbedded with the mud beneath the basin floors. According to Gorsline and others (1968) in their study of Tanner Basin, thicknesses are irregular rather than uniform because deposition of Holocene material results from lateral transport of detritus, and its distribution is controlled by bathymetry rather than a rain of particles. A probable maximum thickness for supposed Pleistocene and Holocene deposits in the outer basins is estimated to be about 550 ft (165 m) in the central Santa Cruz Basin.

Authigenic deposits of questionable age

As Emery (1960) has noted, sampling on the borderland has revealed high concentrations of authigenic materials, typically enclosing faunal assemblages that range in age from middle Miocene to Holocene. Glauconite and phosphorite are two of the most common constituents and commonly occur together on the ridges and banks where conditions for their development are optimum. Manganese dioxide commonly forms thin films or crusts on rocks exposed on the slopes throughout the borderland. Recent dredge hauls have recovered blocks and slabs of rock with thick ferromanganese coatings and suggest that local concentrations may be substantial. On the slopes of Northeast Bank, volcanic blocks of probable Pliocene age are coated with manganese crusts as much as 1 cm thick (Hawkins and others, 1971). The U.S. Geological Survey has dredged manganese-rich slabs and nodules more than 5 cm in diameter from the west slopes of the seaknoll 19 nmi east (35 km) of Sixtymile Bank, where the manganese also encloses large blue amphibole schist fragments (table 1, Area V, LCB 25).

Barite has been described from steep basin slopes east of San Clemente Island (Emery, 1960) and has recently been dredged from two widely spaced localities, one (KSB 25) 16 nmi (30 km) southwest of San Nicolas Island and the other (LCB 20) on the steep southwest slope of Cortes Bank. The barite southwest of Cortes Bank was dredged as freshly broken blocks as much as 12 inches (30 cm) across. Most blocks are composed of a porous mesh of crystals with veinlets and concretionary growths of dense barite. In others the barite cements glauconitic and foraminiferal sand, in which some fossil assemblages are as old as middle Miocene. The barium sulfate solutions may have originated from volcanic magma as suggested by high barium concentrations in nearby late Tertiary volcanic rocks (Hawkins, 1970) or from the interstitial solutions in deep-sea sediments (Church and Wolgemuth, 1972). In either case, the solutions probably have been expelled and precipitated along fault zones, similar to the emplacement of a barite vein 1 m thick along a fault on the south side of the Palos Verdes Hills (Emery, 1960).

Offshore structure

A structural relief of about 20,000 ft (6,100 m) on the basement surface between the axial part of San Nicolas Basin and Santa Catalina Island is judged by Parker (1971) to be a maximum for the northern part of the borderland (excluding the Santa Barbara Channel), although there seems to be a nearly equal amount of relief between the trough of Santa Cruz Basin and the top of Santa Cruz Island. These estimates for basins that are nearly free of post-Miocene strata do not approach those for the Ventura and Los Angeles basins, where structural relief is postulated to be, respectively, as much as 60,000 ft (18,000 m) and more than 40,000 ft (12,000 m) (Vedder and others, 1969; Yerkes and others, 1965). On the Patton Escarpment there may be a difference in elevation of nearly 12,000 ft (3,700 m) between the basement surface on Patton Ridge and the acoustic basement that lies beneath the base of the continental slope. This does not account for possible relief not now apparent because of erosion on bedrock highs. For example, Platt and Stuart (1974) estimate that the formation of the Catalina metamorphic facies occurred under pressure of about 8 kb. This inferred sequential compression, uplift, and stripping are presumed to have occurred between Late Jurassic and middle Miocene time and would amount to vertical transport at least equal to the structural relief in the Ventura and Los Angeles basins.

Faults.--Faults shown on the borderland by Corey (1954), Emery (1960), Moore (1969), and Parker (1971) do not agree in detail but are similar in general trend and density of distribution. Some of these faults are well documented by our seismic profiling; however, others that are inferred from seafloor topography (Emery, 1960) and regional geologic relations (Howell and others, 1974) are not evident from our data. Seaward of the islands the predominant fault trend is believed to be northwest, but a few east-trending cross faults are depicted by most published sources.

Previous workers have inferred that the northwest-oriented fault zones with the greatest length are those that form, from west to east (1) the Patton Escarpment, (2) the west edge of the Santa Rosa-Cortes Ridge, (3) the east margin of the Santa Cruz and San Nicolas Basins, and (4) the San Clemente Island Escarpment-northeast margin of the San Clemente Basin. Our data indicate that some of the postulated flanking faults, such as those along the southwest edges of Santa Cruz and San Nicolas Basins, may be erroneous, for acoustic profiles indicate unbroken east-dipping Miocene and older strata. South of the Santa Monica fault zone the largest cross fault presumably is the one that marks the north edge of the San Nicolas Basin. Southeast of San Nicolas Island, probable pre-Tertiary rocks are displaced along this fault relatively upward on the north side with respect to Miocene sedimentary rocks on the south side.

According to Parker (1971, figs. 6, 7) dip-slip separations on most of the large faults are less than 2,000 ft (610 m) but may be 5,000 ft (1,500 m) or more on both the Patton Escarpment and Catalina Escarpment. Our interpretations suggest that dip slip of this magnitude is much less along both features, although large dislocation may be present at depth seaward of the Patton Escarpment. Strike-slip separations of about 25 mi (40 km) were suggested by Shepard and Emery (1941) for apparent topographic offsets on the San Clemente fault and the fault northeast of Thirtymile Bank. Howell and others (1974) include the San Clemente fault in their East Santa Cruz Basin fault system. Our subbottom acoustic profiles, however, indicate that these are not single throughgoing faults in post-Miocene rocks. In addition to the shorter fault segments illustrated in the aforementioned references and on the geologic map (sheet 3), there probably are many undetected small faults along the ridges that are similar to those on San Clemente Island (Olmsted, 1958) and on San Nicolas Island (Vedder and Norris, 1963).

Strike-slip movement accompanied by a vertical component of offset has been attributed to some of the large faults (Corey, 1954; Emery, 1960), whereas some intersecting sets imply block faulting (Corey, 1954). Yeats (1968b) called upon extensional tectonics to account for the borderland structure. Complex fault mechanisms including both transform and dip slip are proposed by Crowell (1973) to explain the configuration of the basin margins, and Howell and others (1974) point out that large-scale strike-slip offsets along a middle or late Miocene fault system could account for apparent regional dislocation of older Tertiary units.

The amount of relief on the basement rock surface suggests that vertical components of movement on faults have been significant at times (sheet 5). Many offshore faults undoubtedly have undergone recurrent late Cenozoic episodes of activity in a manner similar to that of their counterparts on the mainland. It also seems likely that the kinematic behavior of some may have changed through time in response to changing tectonic stress. The timing of movement is also variable. Some fault traces are deeply buried by late Miocene and Pliocene deposits, yet a few show topographic expression on the seafloor indicating probable late Pleistocene or Holocene movement (sheets 3, 5, and 6). Earthquake epicenters of the borderland (Hileman and others, 1973; U.S. Geological Survey, 1974), although poorly located and less densely distributed than on the mainland, suggest recent activity associated with some offshore faults, particularly along the San Clemente-Agua Blanca fault system (Allen and others, 1960) and in the Santa Barbara Channel (Lee and Vedder, 1973).

Folds.--Offshore, folds have been identified chiefly from acoustic profiling records. On the few available tectonic maps that show folds on the borderland (Moore, 1969; Weaver and others, 1969; Wilkinson, 1972), the gross patterns are roughly the same, but the positions, lengths, and number depicted show little consistency presumably because of generalizations and lack of detailed information. One map, for example, illustrates an unbroken anticlinal "trend" nearly 90 mi (145 km) long on the northern part of the Santa Rosa-Cortes Ridge (Weaver and others, 1969), whereas another source shows three en echelon anticlines, each less than 20 mi (32 km) long, within a 50 mi (80 km) long segment of the same part of the ridge (Moore, 1969). The fold pattern is far more complex than these maps indicate; not only are there greater numbers of folds, but also the structures have more diverse orientations (for example, see Ziony and others, 1974; U.S. Geological Survey, 1974). Because evaluation of our data is incomplete, folds recognized on subbottom acoustic profiles have not been depicted on the geologic map (sheet 3) but are briefly discussed in the following paragraphs.

Our highly interpretive structure sections (sheet 5) suggest that the major folds on the outer part of the borderland are very broad and nearly symmetrical in contrast to typical structures in the Ventura and Los Angeles basins, where tight, steep-limbed, asymmetric, en echelon folds are commonplace. Acoustic profiling records recently made across the northern part of the Santa Rosa-Cortes Ridge confirm the presence of a large anticlinal structure that is steeper on its western flank, but superimposed on it are numerous discontinuous folds with much smaller amplitudes and wavelengths. The exposed faulted anticline at San Nicolas Island (Vedder and Norris, 1963) probably is representative of many of the folds along the ridge. Relatively large anticlinal structures underlie the southeast end of the same ridge system at Tanner and Cortes Banks (sheet 5). In fact, many topographic highs on the borderland seem to reflect underlying anticlinal structure. Thirtymile and Fortymile Banks have a set of regular folds, probably similar to those of other bank areas, in which the wavelength is about 5 nmi (10 km) and the amplitude about 6,500 ft (2,000 m). Other areas that seem to have local folds are Patton Ridge and the ridge between Osborn Bank and Santa Cruz Island. More complex folds are common along the axial parts of the nearshore basins and in some places deform Quaternary strata. In the Santa Barbara Channel, for example, small en echelon folds near the mainland coast tend to be asymmetric, whereas other larger folds near midchannel are nearly symmetrical.

Broad structural lows form both Santa Cruz Basin, which is about 25 mi (40 km) wide and 45 mi (72 km) long, and San Nicolas Basin, which is nearly 30 mi (48 km) wide and 50 mi (80 km) long (sheet 5). Santa Cruz Basin is nearly symmetrical in both transverse and longitudinal seismic profile records, but acoustic basement in the San Nicolas Basin is much shallower at the southeast end than at the northwest. Both basins are flanked on their east and west margins by small northwest-trending low-amplitude folds that tend to die out basinward, although an upwarp is present in the central part of San Nicolas Basin. Santa Monica Basin apparently is a fairly symmetrical late Miocene structural low that was faulted on the north edge and on which smaller folds were superimposed in post-Miocene time (sheet 6). Tight folds and faults complicate the structural pattern on the east and west ends of the basin. San Pedro Basin is more complex and seems to have undergone two discrete phases of evolution in late Miocene time followed by post-Miocene downfaulting at the northwest end and folding throughout.

The age of the small folds along all the major ridge crests and their flanks probably is restricted primarily to post-late Miocene to pre-late Pleistocene time, and regional warping and block faulting resulting from crustal dilation probably developed throughout the entire borderland during Miocene time. Some of the major basins and anticlinal ridge systems may have begun to form as early as Oligocene and early Miocene time and since then have developed almost continuously through late Cenozoic time.

FREE-AIR GRAVITY MAP

The first-order anomalies of the free-air gravity map (sheet 7) reflect the depth of the sea floor because free-air gravity, unlike Bouguer gravity, is not adjusted to minimize the effects of variations in water depth. As a consequence, free-air gravity usually is lower over deep water and higher over shallow water. This relation is clearly evident where pronounced free-air gravity lows occur over the large basins and relatively high free-air gravity occurs over banks and ridges and near islands. A regional gravity gradient caused by variations in the density of deep crust or upper mantle across the continental margin also is present in the free-air gravity. Because the regional gradient is believed to be of significant magnitude and probably is variable over the borderland (Harrison and others, 1966), individual free-air anomalies must be referenced to a virtually unknown and possibly nonuniform datum surface. Thus, maximum or minimum values of individual anomalies from widely separated areas of the borderland cannot be compared quantitatively, and some anomalies may be displaced or distorted. An additional effect that detracts from the ready interpretation of the free-air gravity map results from seafloor topography, which can significantly distort anomalies related to or near major features of relief.

In spite of these shortcomings, the effects of variations in the density of rocks beneath the sea floor can overshadow the influence of variable water depth on free-air gravity. Thus, useful geologic information can be obtained in a qualitative way, if the effects of variations in water depth are disregarded. Although water depth in Santa Cruz Basin is more than twice that in Santa Monica Basin, gravity is lower over Santa Monica Basin, where, among other controlling factors, a substantially greater thickness of less dense sedimentary rocks is present. The large gravity low southwest of San Miguel Island is independent of bathymetry and must reflect relatively low density rocks at depth in this area. The gravity lows in Santa Cruz and San Nicolas Basins are situated northwest of the respective bathymetric lows of these basins and probably reflect the locations of greatest accumulation of relatively low density rocks. The gravity lows in these basins extend northwestward onto the Santa Rosa-Cortes Ridge suggesting greater thicknesses of lower density rocks at these locations. The isopach map of post-Miocene sediments (sheet 6) supports this conclusion for the area just south of San Nicolas Island.

Many additional gravity anomalies are either partly or totally unrelated to seafloor topography and are expressions of rock density distributions. Examples of gravity lows are:

1) offshore from La Jolla and Laguna Beach,
2) in San Pedro, Santa Monica, Santa Barbara and Catalina Basins,
3) in San Diego Trough, southern San Clemente Basin, west and southwest of San Clemente Island,
4) in Arguello Canyon,
5) near the base of the Patton Escarpment.

Examples of gravity highs are:

1) offshore from Point Loma and Del Mar,
2) northwest and southeast of the Palos Verdes Hills and in the outer San Pedro Bay,
3) south and west of San Miguel Island and immediately south of Santa Cruz Island.

RESIDUAL MAGNETIC MAP

In a qualitative sense, four anomaly patterns characterize the residual magnetic map that was compiled for this study (sheet 8). Each pattern is distinguishable on a relative scale by the average map dimension, range of amplitude, and trend of the individual anomalies within it. One pattern characterizes the region west of the Patton Escarpment, and three typify the borderland.

In the deep-sea region west of the Patton Escarpment, magnetic anomalies trend north and northwest in a fashion that is typical of the magnetic fabric for much of the northeastern Pacific Ocean near California. The trend of these anomalies is parallel or nearly parallel to the Patton Escarpment and appears to be disrupted by an east-west trend through San Juan Seamount. Magnetic maps and magnetic anomaly patterns for larger areas west of the California continental slope are discussed by Mason and Raff (1961) and Theberge (1971).

Within the borderland, one magnetic pattern consists of dimensionally small, moderate- to high-amplitude anomalies with variable trends. An example of this pattern is the set north of Santa Barbara Island, north of Santa Cruz Island and eastward through Anacapa Island to the mainland south of Oxnard. These anomalies are caused by rock units that are dimensionally small on a relative scale, that have moderate- to high-magnetic susceptibilities, and that are located at very shallow depth. The proximity of this magnetic pattern to known island and offshore exposures of Miocene volcanic rocks suggests that it is related to the distribution of these rocks (compare sheets 3 and 8).

Medium-wavelength, moderate- to high-amplitude anomalies with variable trends occur in the vicinity of East Cortes Basin and Sixtymile Bank, southwest of San Clemente Island, west-southwest of San Nicolas Island, west of Osborn Bank, west of San Diego, south of Santa Cruz Island, and southwest of Santa Rosa Island. These anomalies are associated with rocks that have relatively high magnetic susceptibilities, such as mafic intrusive rocks, and diverse types of extrusive igneous and metamorphic rocks. The sources responsible for these anomalies probably have abrupt and relatively large changes in susceptibility at their boundaries, which may be structurally controlled, or they may be related to abrupt changes in rock type such as occur at intrusive contacts and within some metamorphic sequences. Many of these anomalies coincide with areas that are interpreted to be underlain by Miocene volcanic rocks or pre-Miocene extrusive, intrusive or metamorphic rocks (compare sheets 3 and 8). In some places, magnetic anomalies occur where no seismic data or bottom samples are available. Most notable of these is the cluster of anomalies west of Northeast Bank, where they may be caused by Miocene and younger volcanic rocks resembling those exposed on Northeast Bank. Similar inferences are plausible for the origin of magnetic anomalies immediately west and northwest of San Diego, west of San Clemente Island, south of Santa Cruz Island, and southwest of Santa Rosa Island.

Within the borderland, very broad, low-amplitude anomalies and open magnetic contours with variable trends occur over much of the area from Santa Cruz and San Nicolas Basins westward to the Patton Escarpment, over the region west and southwest of Point Conception, and over parts of Santa Barbara, Santa Monica and San Clemente Basins and the Gulf of Santa Catalina. This magnetic pattern implies great depth to volcanic or basement rocks or rocks of relatively low and uniform magnetic susceptibilities.

CONCLUSION

In summary, the regional geologic framework of the California Continental Borderland includes a few features that are fairly well understood, but many problems remain unsolved. For a full appraisal of the significant geologic factors that govern resource estimates and environmental analyses, one cannot rely completely on knowledge of doubtfully analogous regions onshore. With the exception of areas of the borderland that are contiguous with onshore basins, such as Santa Barbara Channel, Santa Monica Bay, and San Pedro Bay, much needs to be learned before accurate resource evaluations can be made in this frontier area. The remainder of the borderland, which constitutes by far the largest part of this region, differs in many respects from the major oil-producing basins onshore. How these differences will influence a conclusive petroleum-resource evaluation of the borderland cannot yet be determined. Questions that normally are considered before any reasonable appraisal is offered are beyond the scope of this preliminary report, and many data need to be gathered, analyzed, and correlated with existing information before these questions can be answered. Obviously our understanding of the regional geology of the borderland is limited but we hope that the background furnished here will focus future offshore research and guide efforts to appraise meaningfully the area's resources and assess properly any potential environmental problems.

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TABLE 1

DESCRIPTION OF SELECTED VOLCANIC, BASEMENT AND PROBABLE PRE-TERTIARY ROCK SAMPLES

Sample locations are grouped into five major areas within which the samples are systematically listed from north to south. All listed sample locations are plotted on sheet 9. Only dredge and dart samples that are inferred to be from or near outcrops are included. Descriptions are based on thin-section examination supported by X-ray diffraction analysis on some samples. Rock color is noted in the code of Goddard and others (1948).

AREA I. PATTON ESCARPMENT AND PATTON RIDGE TO NORTHEAST BANK

N lat	W long	Depth (metres)	Description	Sample and thin section designation (dart core unless noted)
33°38.3'	120°53.9'	3250±	Augite olivine basalt, porphyritic, N2; plagioclase phenocrysts to 15 mm; abundant magnetite, altered olivine	Bart 5B (dredge)
33°38.3'	120°53.9'	3250±	Augite basalt, N4	Bart 5C (dredge)
33°36.8'	120°15.9'	570	Serpentinite, 5Y7/2 to 5Y5/6; orthoantigorite	LCB 3-7 (T-254)
33°36.6'	120°16.1'	558	Amphibolite(?); actinolite, albite, calcite	LCB 3-6
33°36.4'	120°40.1'	1000±	Serpentinite, spotted, 5GY6/2; antigorite	Bart 6-2A (dredge)
33°36.3'	120°16.2'	590	Amphibolite(?); fibrous actinolite	LCB 3-5
33°29.4'	120°16.5'	1100±	Lithic sandstone, 5G3/1; intense welding and diagenesis of matrix; clasts of chert, quartz-rich muscovite-epidote-chlorite schist, volcanic rocks	KSB 29A (dredge)
33°29.4'	120°16.5'	1100±	Argillite, N3; bedded, fractured	KSB 29B (dredge)
33°22.7'	120°40.2'	1750±	Serpentinite, 5YR8/1; altered to sepiolite	LCB 6 (dredge) (T-281 B,C)
33°22.9'	120°17.0'	530	Volcanic wacke, 5G5/1; grains to 0.2 mm in chlorite (and zeolite?) matrix; mostly plagioclase and altered ultramafic(?) volcanic rocks and epidote	LCB 114-10 (T-266)
33°21.3'	120°17.0'	458	Lithic wacke, N4; coarse grained, tightly packed; chlorite matrix; clasts of volcanic rocks, chert, epidote-rich metamorphic rocks, serpentinite, pyroxenite, amphibolite; less than 5 percent quartz grains	LCB 114-7 (T-248A,B)
33°20.1'	120°17.1'	458	Augite andesite, 10YR5/4; flow banded, vesicular; hypersthene	LCB 114-5B (T-249)
33°19.2'	120°16.6'	478	Albite-epidote metavolcanic rock, 5GY4/1; radiating plagioclase laths, intergranular epidote; sphene, chlorite, calcite	LCB 114-3 (T-250)
33°18.7'	120°16.3'	474	Chlorite pyroxenite, 10YR5/2	LCB 114-2B (T-251)
33°17.3'	120°38.0'	2950± to 1800±	Ultramafic rock, schistose, 5G2/1; crossite, pyroxene, blue and green chlorite. Crossite schist, spotted, 5B4/1; porphyroblasts of augite in groundmass of crossite; chlorite, minor lawsonite, sphene, quartz, and albite. Schist, spotted, 5B4/1; porphyroblasts and matrix a mixture of albite, epidote, chlorite, blue amphibole, pumpellyite(?), lawsonite(?)	KSB 28B,C,D (dredge)*

*Outcrop or nearby outcrop uncertain; diverse rock types in haul.

TABLE 1 - Continued

N lat	W long	Depth (metres)	Description	Sample and thin section designation (dart core unless noted)
33°09.2'	120°11.1'	950±	Lithic sandstone, feldspathic 5GY4/1; moderately sorted, medium grained; tightly welded with minor chlorite matrix; minor leonhardite veinlets; clasts of chert, quartz-rich metamorphic rocks, epidote and muscovite schist, metavolcanic rocks; grains of twinned and unzoned plagioclase, quartz, biotite, epidote, chlorite; rare garnet and tourmaline	LCB 14 (dredge) (T-246A,B,C)
32°55.5'	119°56.2'	900±	Lithic sandstone; 5G4/1; poorly sorted; intense welding and diagenesis in matrix, minor chlorite cement; clasts of chert, muscovite-epidote schist, silicic plutonic rocks, and volcanic rocks	KSB 26A (dredge)
32°55.5'	119°56.2'	900±	Argillite, silty, pebbly; 5G3/1; contains rounded clasts of argillite siltier than matrix	KSB 26B (dredge)
32°34.3'	119°41.6'	265	Olivine(?) diabase, porphyritic; 5Y5/4; altered, subophitic texture, intercrystalline augite	LCB 122-5B (T-259)

AREA II. SAN MIGUEL-SANTA ROSA ISLANDS-AND SANTA ROSA-CORTES RIDGE TO CORTES BANK

N lat	W long	Depth (metres)	Description	Sample and thin section designation (dart core unless noted)
33°51.0'	120°12.0'	500±	Epidote-glaucophane schist; 5PB5/2; chlorite, sphene, lawsonite, minor albite	KSB 17A (dredge)
33°51.0'	120°12.0'	500±	Metavolcanic rocks, sheared; 5GY5/2; chlorite and augite with minor sphene, epidote	KSB 17B (dredge)
33°50.3'	120°11.8'	350±	Lithic wacke, feldspathic; 5Y5/2; chert and volcanic rock clasts; chlorite in matrix; lawsonite in grains and matrix	KSB 18A (dredge)
33°50.3'	120°11.8'	350±	Schist, banded; 5GY6/1 and N3; quartz, chlorite, epidote, calcite, actinolite, sphene	KSB 18B (dredge)
33°50.3'	120°11.8'	350±	Phyllite, chloritic; N3; bedded and schistose	KSB 18C,D (dredge)
33°49.5'	120°11.3'	350±	Albite-glaucophane schist; 5B4/1; chlorite, stilpnomelane, epidote, lawsonite. Quartz-albite-glaucophane schist; 5B4/1; sphene, muscovite, chlorite garnet, and calcite. Muscovite-epidote schist; 5G4/1; sphene, chlorite, actinolite, garnet	KSB 19A,B,C (dredge)
33°49.0'	120°10.7'	400±	Quartz-crossite schist; 5B5/1; albite, garnet, chlorite, muscovite, hornblende with thick reaction rims of crossite. Muscovite-hornblende schist; 5GY4/1; albite, chlorite, epidote, sphene, calcite, rare glaucophane	KSB 20B,E (dredge)
33°49.0'	120°10.7'	400±	Albite amphibolite, spotted; 5G3/1; apatite, prehnite, epidote, sphene, garnet	KSB 20D (dredge)
33°11.0'	119°16.6'	1500±	Lithic wacke; 5GY5/1 to N4; very fine-to medium-grained; moderately sorted; tightly welded, recrystallized matrix with chlorite and sericite(?); micaceous; abundant chert and volcanic rock fragments, common metamorphic rock fragments	KSB 24A,B, (dredge)
32°55.4'	119°23.5'	150	Lithic sandstone; 10Y6/4; fine-to very coarse-grained; altered matrix; secondary calcite and zeolite; volcanic rock grains	KZ 73-3-12 (T-216)

TABLE 1 - Continued

N lat	W long	Depth (metres)	Description	Sample and thin section designation (dart core unless noted)
32°55.0'	119°24.6'	190	Olivine diabase; 10R5/2; fresh augite, altered olivine	KZ 73-3-10 (T-217)
32°54.5'	119°26.4'	105	Basalt, glassy, vesicular; 5GY4/1; few crystals of plagioclase and pyroxene, slightly devitrified	LCB 126-13 (T-279)
32°44.3'	119°11.2'	83	Andesite, porphyritic, vesicular; 5GY4/1 (wet); altered mafic minerals; ilmenite	KZ 73-5-7 (T-226)
32°43.1'	119°12.2'	80	Olivine diabase; 5Y3/2; titaniferous augite, ilmenite, apatite	KZ 73-5-10 (T-222)
32°36.2'	119°18.0'	107	Olivine basalt; N5; titaniferous augite, altered olivine	KZ 73-5-27 (T-208)
32°35.9'	119°18.4'	105	Basalt, vesicular; 10YR5/2	KZ 73-5-28 (T-218)
32°35.5'	119°18.7'	112	Olivine diabase, porphyritic; N3; titaniferous augite, rare brown hornblende, ilmenite, apatite	KZ 73-5-29B (T-204)
32°35.5'	119°18.7'	112	Olivine basalt; 5R4/2; vesicular and amygdaloidal	KZ 73-5-29A (T-210)
32°35.1'	119°19.1'	82	Basalt, vesicular; 5GY3/1; altered olivine, abundant ilmenite	KZ 73-5-30 (T-212)
32°34.3'	119°19.8'	75	Olivine diabase; 10YR4/4; titaniferous augite, altered olivine, ilmenite, apatite	KZ 73-5-32 (T-207)
32°28.3'	119°15.0'	104	Olivine diabase, porphyritic; 10YR4/2; titaniferous augite, ilmenite, apatite	KZ 73-6-35 (T-223)
32°27.3'	119°09.0'	56	Olivine diabase, porphyritic; 10R5/2; altered olivine, ilmenite	KZ 73-7-35 (T-221)

AREA III. SANTA CRUZ ISLAND SOUTHEAST TO SANTA CATALINA AND SAN CLEMENTE ISLANDS

N lat	W long	Depth (metres)	Description	Sample and thin section designation (dart core unless noted)
33°38.1'	119°07.5'	158	Augite basalt; 5GY6/1; weathered(?); altered olivine	KSB 906-3 (T-274)
33°37.7'	119°07.7'	145	Olivine basalt; 5GY3/1; altered olivine; fresh augite	KSB 906-4 (T-269)
33°37.1'	119°05.4'	157	Andesite, porphyritic; N3; enstatite, pyroxene	LCB 108-2B (T-268A,B)
33°30.4'	118°48.0'	567	Pyroxene and oxyhornblende andesite; 10YR5/2; altered glassy groundmass	LCB Hill 310-1 (T-261)
33°29.6'	118°54.4'	1000±	Basalt, porphyritic; N5; fresh augite; large altered phenocrysts of olivine(?)	KSB 21A (dredge)
33°29.6'	118°54.4'	1000±	Pyroxene andesite; N6; glassy groundmass; oxyhornblende	KSB 21B (dredge)
33°29.6'	118°54.4'	1000±	Volcanic agglomerate; N6; clasts of andesite and basalt, minor siltstone; volcanic matrix incorporates glauconite, carbonate	KSB 21F (dredge)
33°22.7'	118°18.0'	348	Quartz keratophyre; N8; plagioclase albitized; sericite and chlorite, sphene	VA 70-6 (T-270)
33°16.7'	118°55.4'	1350± to 850±	Actinolite epidotite, porphyritic; 10GY5/2; euhedral actinolite pseudomorphs after pyroxene; groundmass of equidimensional epidote pseudomorphs after large plagioclase crystals; original rock possibly a pyroxene anorthosite	KSB 23A (dredge)
33°16.7'	118°55.4'	1350± to 850±	Saussurite gabbro; 5B5/1; subophitic texture; saussuritized plagioclase; actinolite pseudomorphs after pyroxene	KSB 23B (dredge)

TABLE 1 - Continued

N lat	W long	Depth (metres)	Description	Sample and thin section designation (dart core unless noted)
33°14.6'	118°52.5'	750± to 490±	Saussurite diabase; 5G3/1; actinolite, some pseudomorphs after pyroxene; plagioclase and groundmass saussuritized	KSB 33A (dredge)
32°43.1'	118°24.1'	185	Olivine diabase; 10R4/2; altered; ilmenite and apatite	KZ 73-9-5 (T-205)

N lat	W long	Depth (meters)	Description	Sample and thin section designation (dart core unless noted)
32°38.9'	117°58.6'	142	Andesite; 5Y7/2; flow-banded; rare pyroxene and plagioclase phenocrysts	KZ 73-10-30 (T-219)
32°16.3'	117°33.0'	722	Hornblende andesite; 5Y8/7; weathered, flow-banded, fractured; glassy groundmass	LCB 138-5 (T-234)

AREA IV. THIRTYMILE AND FORTYMILE BANKS AND VICINITY

N lat	W long	Depth (metres)	Description	Sample and thin section designation (dart core unless noted)
32°51.2'	117°50.9'	308	Glaucophane schist, spotted; 5B5/1; porphyroblasts of albite, epidote, glaucophane; groundmass with chlorite, sphene, actinolite	KZ 73-10-2 (T-203A,B)
32°49.3'	117°48.5'	250± to 150±	Reibeckite schist, quartz-rich; 5B6/1; muscovite, chlorite, stilpnomelane	VO 12016-A (dredge)
32°49.3'	117°48.5'	250± to 150±	Albite-chlorite schist; 5B5/1; epidote, sphene, glaucophane, lawsonite(?)	VO 12016-B (dredge)
32°44.8'	117°49.1'	300	Hornblende andesite; 10YR4/2	LCB 143-9 (T-228)
32°44.8'	117°51.1	548	Schist, spotted; 5Y5/2; epidote-albite-muscovite porphyroblasts; chlorite-actinolite matrix	LCB 143-12 (T-230)
32°44.7'	117°47.8'	273	Olivine basalt, porphyritic; 5GY5/1; rare hornblende	LCB 143-7 (T-227)
32°41.6'	117°42.3'	358	Hornblende-hypersthene andesite; N7; altered glassy groundmass	LCB 142-2 (T-231)

AREA V. SIXTYMILE BANK AND VICINITY

N lat	W long	Depth (metres)	Description	Sample and thin section designation (dart core unless noted)
32°35.5'	117°52.0'	1750± to 1300±	Albite-epidote-amphibole schist; 5B5/1; sphene, blue amphibole. Chlorite schist; 5G5/1; blue amphibole, sphene, lawsonite(?)	LCB 25 (dredge) (T-283A,B)
32°01.1'	118°13.3'	350± to 120±	Muscovite schist, quartz-rich; 5RP5/2; garnet. Albite-epidote-chlorite schist; 10Y5/2; actinolite. Muscovite-chlorite schist, quartz rich; 5B5/1; garnet, sphene, epidote. Quartz-muscovite-epidote schist; 5B7/1; sphene, lawsonite(?)	VO 12021-A,B,C,D (dredge)

TABLE 2

PRELIMINARY DESCRIPTION OF SELECTED DART CORE SAMPLES OF PRE-LATE PLIOCENE AGE

Sample locations are grouped into five major areas within which the samples are systematically listed from north to south. All listed sample locations are plotted on sheet 9. Rock descriptions are based chiefly on megascopic inspection supported by microscopic examination of some samples. Sample splits for paleontologic study were taken from the bottom of the cores. Fossils were identified by R. E. Arnal (foraminifers) and D. Bukry (nanno-fossils), and their stage and age correlations are based on Kleinpell (1938), Mallory (1959) and Bukry (1973) with some modifications. Colors are coded after Goddard and others (1948) and apply to dried samples unless otherwise noted.

AREA I. PATTON ESCARPMENT AND PATTON RIDGE TO NORTHEAST BANK

N lat	W long	Depth (metres)	Description	Fossils	Sample and thin section designation
33°36.0'	120°16.4'	625	Siltstone, calcareous; 5Y6/1 and 5Y4/1; faintly laminated; 10°± dip, moderately indurated	--	LCB 3-4
33°35.5'	120°16.7'	838	Claystone, diatomaceous; 5Y6/1; faintly laminated in part, deformed, moderately indurated, low density	Middle Miocene coccoliths	LCB 3-2
33°35.2'	120°16.8'	1015±	Claystone, silty, micaceous; 5Y6/1; massive, fractured, moderately indurated, low density	Middle Miocene coccoliths	LCB 3-1
33°30.9'	120°45.1'	1750±	Mudstone, diatomaceous, tuffaceous; 5Y7/2; moderately indurated, burrowed	Late Miocene radiolarians and silico-flagellates	LCB 6 (dredge)
33°09.1'	120°11.2'	405	Sandstone, lithic; 5Y5/6; clasts of glassy and altered volcanic rocks	--	LCB 116-1 (T-260, T-260A)
33°08.5'	120°12.3'	385	Claystone, highly organic, tar-saturated, pyritiferous; N2 and 5Y4/1; laminated; 5°± dip; poorly indurated; low density	Middle or late Miocene coccoliths; middle Miocene foraminifers	LCB 116-3B
33°08.0'	120°13.2'	480	Claystone, diatomaceous; 5Y6/1; and siltstone, clayey, micaceous, phos-phatic, pyritiferous; 5Y6/1 to 5Y2/1; mottled; possible dip <5°	Upper Luisian or lower Mohnian foraminifers	LCB 116-5B
33°04.6'	120°9.7'	495	Claystone, silty, highly organic; mottled 5Y6/1 and 5Y4/1; massive, low density	Middle Miocene coccoliths; upper Relizian or lower Luisian foraminifers	LCB 117-5B
33°04.0'	120°9.2'	470	Claystone, silty, diatomaceous; mottled, 5Y8/1 and 5Y6/1; nearly vertical parting; low density	Middle Miocene coccoliths; upper Relizian or lower Luisian foraminifers	LCB 117-4
33°03.5'	120°8.7'	470	Mudstone, silty, organic, micaceous; 5Y4/1; fractured, poorly indurated, low density	Middle Miocene coccoliths; probable lower Luisian foraminifers	LCB 117-3
33°03.1'	120°8.7'	520	Mudstone, diatomaceous, quartzose; 5Y4/1; massive, poorly indurated	Middle Miocene coccoliths; Relizian or lower Luisian foraminifers	LCB 117-2
32°45.3'	119°56.1'	475	Diatomite; 5Y8/1 and 5Y6/1; mottled; shattered and deformed, very low density	Early Miocene coccoliths, and silicoflagellates; upper Relizian or lower Luisian foraminifers	LCB 120-5
32°44.2'	119°54.8'	534	Claystone, diatomaceous, highly organic, pumiceous(?); 5Y4/1; poorly indurated	Early Miocene coccoliths, and silicoflagellates; Luisian foraminifers	LCB 120-2

TABLE 2 - Continued

N lat	W long	Depth (metres)	Description	Fossils	Sample and thin section designation
32°43.8'	119°54.3'	660	Claystone, silty, micaceous; 5GY6/1; massive, moderately indurated	Early Miocene coccoliths; Luisian foraminifers	LCB 120-1
32°41.5'	119°51.9'	660	Claystone, diatomaceous; 5Y4/1 and 5GY6/1; streaked, moderately indurated	Early Miocene coccoliths; upper Relizian or lower Luisian foraminifers	LCB 121-2
32°41.5'	119°33.1'	280	Claystone, silty; 10YR2/2 (wet)	Late Miocene coccoliths; middle Miocene foraminifers	KZ 73-8-2
32°41.0'	119°51.7'	680	Diatomite, clayey; 5Y6/1; massive, fractured, very low density	Early Miocene coccoliths, and silicoflagellates; upper Relizian or upper Luisian foraminifers	LCB 121-1B
32°40.6'	119°36.0'	135	Sandstone, lithic, medium- to coarse-grained; 5GY8/1; massive, indurated; clasts chiefly basic and ultra-mafic rocks; partly cemented by zeolite	--	LCB 123-7 (T-255)
32°40.5'	119°35.4'	143	Siltstone; 5Y4/1; massive poorly indurated; contains dark mineral grains and volcanic rock fragments	Early or middle Miocene coccoliths; possible Luisian foraminifers	LCB 123-6 (T-273)
32°40.4'	119°34.2'	155	Claystone, silty, highly organic; 5Y4/1 massive, moderately indurated, low density	Middle Miocene coccoliths; Luisian foraminifers	LCB 123-4
32°40.3'	119°32.9'	215	Siltstone, clayey, micaceous; 5GY6/1; massive, fractured, poorly indurated, low-density	--	LCB 123-2B
32°40.3'	119°32.1'	550	Claystone, highly organic, mottled; 5Y6/1 and 5Y4/1; massive, deformed, moderately indurated, low-density	Late(?) Miocene coccoliths; upper Mohnian foraminifers	LCB 123-1
32°40.1'	118°35.7'	130	Sandstone; 5Y5/1 (wet); coarse-grained, indurated; contains clasts of volcanic rocks	--	KZ 73-8-7
32°39.3'	119°37.2'	770	Claystone, silty; 5YR2/1 (wet); contains chips of phosphorite	Early middle Miocene coccoliths; probable lower Luisian foraminifers	KZ 73-8-10

AREA II. SAN MIGUEL-SANTA ROSA ISLANDS AND SANTA ROSA-CORTES RIDGE TO CORTES BANK

N lat	W long	Depth (metres)	Description	Fossils	Sample and thin section designation
34°10.9'	120°31.1'	128	Claystone, diatomaceous; 5Y6/1; faintly laminated, poorly indurated, low-density; probable 5° dip, fractured	Middle Miocene coccoliths; Luisian foraminifers	KSB 709-4
34°10.6'	120°31.7'	127	Claystone, diatomaceous; 5Y6/1 to 5Y4/1; massive, poorly indurated, low-density; shattered	Early middle Miocene coccoliths; possible middle Miocene foraminifers	KSB 709A-6
34°10.6'	120°25.0'	132	Claystone, diatomaceous, N3 to 5Y2/1; mottled, poorly indurated, low-density; contains phosphorite blebs; sheared	Middle to late Miocene diatoms	KSB 697-22
34°10.3'	120°32.0'	130	Claystone, diatomaceous; N8 and 5Y6/1; pumiceous; laminated, poorly indurated, low-density; 30° dip	Probable late Miocene coccoliths; upper Mohnian foraminifers	KSB 709A-7
34°09.8'	120°36.0'	152	Shale, diatomaceous, tuffaceous(?); N8 to 5Y8/1; poorly indurated, very low-density; 25° dip	Middle Miocene silicoflagellates and coccoliths	KSB 717A-2

TABLE 2 - Continued

N lat	W long	Depth (metres)	Description	Fossils	Sample and thin section designation
34°09.7'	120°32.4'	128	Claystone, diatomaceous, 5Y6/1; massive, poorly indurated, low-density	Late late Miocene silicoflagellates and diatoms; lower Mohnian foraminifers	KSB 709A-8
34°09.7'	120°25.6'	113	Claystone, diatomaceous; 5Y6/1; massive, poorly indurated, low-density; fractured	Early Miocene to middle Miocene coccoliths; probable lower Relizian foraminifers	KSB 697-20
34°09.4'	120°32.6'	115	Claystone, pumiceous; 5Y6/1; faintly laminated, poorly indurated, low density; ±20° dip	Early middle Miocene coccoliths	KSB 709A-9
34°09.4'	120°25.9'	106	Claystone, silty; 5YR5/2; massive, moderately indurated	Middle Miocene to early Pliocene coccoliths; probable middle Miocene foraminifers	KSB 697-19
34°09.2'	120°36.5'	122	Sandstone, feldspathic, silty, fine- to medium-grained; 5GY6/1; indurated; contains sporadic coarse- to very coarse grained rock fragments	--	KSB 717A-1(3)
34°08.9'	120°33.0'	113	Claystone, diatomaceous; 5Y6/1; contains crystal tuff; N8; laminated, poorly indurated, very low density; dip 15 to 30°	Early or middle Miocene diatoms; possible middle Miocene foraminifers	KSB 709A-10
34°08.9'	120°26.2'	88	Shale, silty; 5Y4/1; mottled and streaked, laminated, poorly indurated; possible 10° dip	--	KSB 697-18
34°08.7'	120°36.8'	122	Siltstone, sandy, and sandstone, feldspathic, micaceous, very fine grained; 5GY6/1; moderately indurated; possible 10° dip	--	KSB 717A-4
34°08.5'	120°33.3'	96	Claystone, silty, micaceous; 5Y6/1 to 5Y4/1; massive, moderately indurated; fractured	Late early or early middle Miocene coccoliths	KSB 709A-11
34°08.0'	120°26.7'	81	Siltstone fragments, clayey, micaceous; 5GY6/1; indurated	--	KSB 697-16
34°07.6'	120°33.9'	85	Sandstone, feldspathic, micaceous; very fine to medium grained; 5Y8/1; massive, poorly sorted	--	KSB 709A-13
34°07.3'	120°34.2'	103	Claystone, foraminiferal; 5Y6/1 to 5Y4/1; massive, moderately indurated	Neogene coccoliths	KSB 709A-14
34°06.8'	120°34.5'	105	Claystone, silty, micaceous; 5Y6/1; massive, moderately indurated, low-density	Middle Miocene to early Plio-cene coccoliths; probable Luisian foraminifers	KSB 709A-15
34°06.8'	120°27.7'	70	Claystone, silty, micaceous, N7 to 5GY6/1; massive, moderately indurated; apparent dip greater than 45°	Early to middle Eocene coccoliths	KSB 697-13
34°05.9'	120°35.2'	135	Siltstone and sandstone, very fine grained; 5Y5/2; massive, indurated; contains angular fragments	--	KSB 709A-17
34°05.9'	120°21.8'	53	Shale, siliceous; 10YR6/2; platy, indurated, low-density; dip 25°+; contains bentonitic(?) layer	--	LCB 101-4B

TABLE 2 - Continued

N lat	W long	Depth (metres)	Description	Fossils	Sample and thin section designation
34°04.7'	120°29.4'	56	Sandstone, feldspathic, silty, micaceous; 5Y7/2; moderately indurated; includes 3-cm long clasts of micaceous clayey siltstone, N5 (dry)	--	KSB 697-8
34°04.4'	120°22.6'	41	Siltstone, clayey, micaceous; 5B7/1; massive, indurated	--	LCB 101-2B
34°04.3'	120°29.7'	59	Sandstone, feldspathic, clayey, micaceous; N7 to 5GY6/1; fine- to coarse-grained, poorly indurated, contains dark-colored rock fragments	--	KSB 697-7
34°03.9'	120°37.3'	450±	Claystone, foraminiferal, diatomaceous, tuffaceous; N8 to 5Y4/1; laminated, poorly indurated; dip less than 5°	Late Miocene, Mohnian foraminifers	KSB 709A-22
34°02.7'	120°31.1'	95	Siltstone, clayey, and sandstone, very fine grained micaceous; 5Y5/2; massive, poorly indurated	Probable middle Miocene foraminifers	KSB 697-3
34°02.1'	120°31.9'	121	Claystone, silty, diatomaceous, micaceous; 5Y6/1; mottled, poorly indurated; possible 20-30° dip	Late Miocene silicoflagellates and coccoliths; probable lower Mohnian foraminifers	KSB 697-1
33°56.0'	119°52.9'	183	Claystone, diatomaceous, pumiceous; 5Y4/1; mottled, poorly indurated; contains sporadic phosphorite blebs; possible 15-20° dip	Middle Miocene coccoliths; Relizian foraminifers	KSB 795-14
33°55.7'	119°53.2'	203	Claystone, diatomaceous; 5Y6/1 to 5Y4/1; poorly indurated, low density; possible 5° dip	Middle Miocene coccoliths; Relizian and Saucesian foraminifers	KSB 795-13
33°55.4'	119°45.6'	345	Sandstone, volcanic; N4; bedded, and mudstone, tuffaceous; 5Y5/2	--	LCB 107A-5B (T-280A, B)
33°55.3'	120°00.2'	25	Siltstone, clayey, micaceous; 5GY6/1 and 5Y6/4; fractured massive, indurated	--	LCB 105-1
33°54.8'	120°11.1'	31	Siltstone, clayey, highly micaceous; N7; platy in part, dip 50°±, indurated	--	LCB 103-2
33°53.9'	120°00.9'	32	Siltstone, clayey, micaceous, pyritiferous; 5GY6/1; massive, indurated	--	LCB 105-4
33°53.8'	120°12.8'	153	Shale, silty; 5Y6/1; thinly laminated, 40°± dip, poorly indurated, very low density	Middle Miocene silicoflagellates; Luisian foraminifers	LCB 103-5
33°52.3'	119°57.1'	77	Sandstone, micaceous; N7; medium- to coarse grained, poorly sorted, friable; may be pyroclastic in part	--	KSB 795-8
33°52.2'	120°03.0'	62	Claystone; 5Y4/1; freshly broken fragment; faint laminae, moderately indurated; contains small nodule of phosphorite	Probable Saucesian foraminifers	KSB 768-7
33°51.6'	119°58.0'	82	Claystone, micaceous, platy; 5Y6/1 to 5Y4/1; moderately indurated; contains small pumice? fragments	Early Miocene coccoliths; middle or late Miocene foraminifers	KSB 795-6
33°51.5'	120°03.2'	77	Claystone, silty; 10YR4/2 and 5Y7/2; angular fragments, faint laminae, well indurated, carbonate cement	Early to middle Miocene coccoliths	KSB 768-10
33°51.3'	120°01.9'	78	Claystone; 5Y5/2; massive indurated	--	LCB 105-9

TABLE 2 - Continued

N lat	W long	Depth (metres)	Description	Fossils	Sample and thin section designation
33°50.7'	119°58.7'	90	Siltstone, clayey, micaceous; N7 and 5GY6/1; massive, moderately indurated	--	KSB 795-4
33°50.6'	119°59.2'	92	Mudstone, pumiceous; 5Y6/1; massive, poorly indurated; contains blueschist fragments	--	KSB 795-3
33°50.5'	120°03.5'	92	Claystone, silty, micaceous 5GY6/1; mottled, faintly laminated, moderately indurated, contains black carboniferous material; flat dip	Early to middle Miocene coccoliths	KSB 768-14
33°50.5'	119°59.5'	92	Sandstone, arkosic; 5Y6/1; massive, poorly indurated; carbonate cement in part	--	KSB 795-2
33°50.2'	120°00.2'	93	Claystone, silty, micaceous; 5Y6/1 and 5Y4/1; massive, moderately indurated; possible parting at 15 to 20°	Possible middle Miocene foraminifers	KSB 795-1
33°49.7'	120°02.6'	98	Claystone, silty, pumiceous(?); faintly laminated, fractured, indurated	Early or middle Miocene	LCB 105-12
33°49.2'	120°02.8'	107	Claystone, silty, diatomaceous; 5Y4/1 and 5Y6/1; laminated, dip 45±°; indurated, low density	Middle(?) Miocene silicoflagellates	LCB 105-13
33°47.1'	120°04.0'	233	Siltstone, clayey, tuffaceous, organic; 5Y3/2; massive, moderately indurated, low density	Middle or late Miocene coccoliths and silicoflagellates	LCB 105-17
33°45.5'	120°01.7'	123	Claystone, silty, tuffaceous(?); 5Y6/1; massive, fractured, low-density	Early Miocene coccoliths and silicoflagellates; Miocene foraminifers	LCB 106-19
33°45.5'	120°01.0'	112	Vitric tuff; 5B7/1; and claystone, diatomaceous; 5Y6/1; deformed, moderately indurated	Middle Miocene silicoflagellates; upper Mohnian or lower Delmontian foraminifers	LCB 106-18
33°45.5'	120°00.4'	112	Mudstone, micaceous; 5Y6/1; bioturbated, fractured	Miocene(?) silicoflagellates	LCB 106-17
33°45.5'	119°51.0'	137	Claystone, silty, calcareous(?); 5Y7/2; thin laminae of lithic tuff(?), faintly bedded, low density	Early Miocene coccoliths	LCB 106-3
33°45.4'	119°59.7'	125	Claystone, diatomaceous; 5Y7/2; massive, fractured	Early or middle Miocene silicoflagellates	LCB 106-16
33°45.4'	119°52.0'	127	Claystone, silty, diatomaceous; 5Y5/2; massive, moderately indurated	Early Miocene coccoliths, reworked Cretaceous and Eocene; possible Relizian foraminifers	LCB 106-5
33°45.3'	119°52.6'	129	Claystone, silty, micaceous; pyritiferous(?); 5Y6/1; massive, moderately indurated	Early Miocene silicoflagellates	LCB 106-6
33°45.3'	119°51.3'	127	Siltstone, clayey, diatomaceous, calcareous, massive, moderately indurated	Early Miocene coccoliths; upper Relizian or lower Luisian foraminifers	LCB 106-4
33°45.3'	119°49.1'	230	Claystone, silty, highly organic, phosphatic; 5Y3/2; faintly laminated to mottled, fractured, low density	Late(?) Miocene coccoliths and silicoflagellates; upper Mohnian foraminifers	LCB 106-1
33°45.2'	120°04.5'	173	Claystone, silty, pumiceous(?); 5Y5/2; massive, moderately indurated, low density	Late Miocene silicoflagellates; Mohnian foraminifers	LCB 105-21

TABLE 2 - Continued

N lat	W long	Depth (metres)	Description	Fossils	Sample and thin section designation
33°42.7'	119°58.6'	124	Claystone, diatomaceous, micaceous; 5Y6/1 to N8; massive, poorly indurated; includes thin laminae of tuffaceous siltstone and very fine grained sandstone	Early to middle Miocene and redeposited Cretaceous coccoliths; probable Saucesian foraminifers	KSB 783-12
33°42.7'	119°58.0'	117	Claystone, silty, micaceous; 5GY6/1; massive, moderately indurated; fractured; pyritiferous	--	KSB 783-11
33°42.6'	119°57.3'	126	Claystone, micaceous; 5Y6/1 to 5GY4/1; bedded, moderately indurated; dip less than 5°	--	KSB 783-10
33°42.6'	119°56.7'	134	Siltstone, sandy, and sandstone, very fine to fine grained, micaceous, tuffaceous?; N7; poorly indurated; fractured	Lower Saucesian foraminifers	KSB 783-9
33°42.6'	119°55.9'	134	Claystone, diatomaceous, 5Y6/1; faintly laminated, poorly indurated, low-density; dip ±5°	Late(?) Miocene silicoflagellates and diatoms; Saucesian or Relizian foraminifers	KSB 783-8
33°42.6'	119°54.9'	137	Claystone, silty, micaceous, 5Y6/1 to 5Y4/1; faintly laminated; poorly indurated; low-density; possible 5-15° dip	Lower Saucesian foraminifers	KSB 783-7
33°42.6'	119°54.2'	137	Claystone, silty, or mudstone; 5Y4/1 massive, moderately indurated, low-density	Early to middle Miocene coccoliths; Relizian foraminifers	KSB 783-6
33°42.6'	119°53.6'	135	Claystone, diatomaceous, micaceous; 5Y6/1; massive, poorly indurated; phosphorite nodules at top of core; low-density	Early Miocene coccoliths; upper Saucesian or Relizian (bottom), Relizian (top) foraminifers	KSB 783-5
33°42.6'	119°53.2'	132	Claystone, silty, micaceous, diatomaceous; 5Y6/1; massive; poorly indurated; contains thin white tuff(?) lens; fractured	Early to middle Miocene coccoliths; probable Mohnian (top), probable upper Relizian (bottom) foraminifers	KSB 783-4
33°42.6'	119°52.6'	130	Claystone; 5Y6/1; faintly laminated, poorly indurated, low-density; dip ±10°	Early middle Miocene coccoliths; upper Relizian or lower Luisian foraminifers	KSB 783-3
33°42.5'	120°02.0'	101	Sandstone, clayey, micaceous; 5GY6/1 to 5GY4/1; very fine to fine grained; massive, poorly indurated	--	KSB 783-18
33°42.0'	120°2.4'	145	Claystone, diatomaceous, pumiceous(?); 5Y8/1 to 5Y4/1; laminated; 25°± dip, moderately indurated, low density; saturated with tar(?)	Late Miocene silicoflagellates	LCB 4-4B
33°41.1'	120°2.8'	365	Claystone, diatomaceous; mottled, 5Y6/1 and 5GY6/1; indistinctly laminated, deformed, low-density	Late Miocene or early Pliocene coccoliths and diatoms	LCB 4-2B
33°29.1'	119°11.9'	350	Sandstone, very fine grained, silty; 5Y5/2; massive, poorly indurated	Late(?) Miocene coccoliths and silicoflagellates; upper Mohnian foraminifers	LCB 109-1
33°27.9'	119°47.6'	111	Claystone, diatomaceous, highly organic; 5Y5/2; moderately indurated, low-density	Early Miocene coccoliths and silicoflagellates; Saucesian foraminifers	LCB 110-20
33°27.4'	119°47.4'	113	Claystone, silty, pumiceous; 5Y6/1; massive, moderately indurated	Middle(?) Miocene coccoliths, Zemorrian foraminifers	LCB 110-19

TABLE 2 - Continued

N lat	W long	Depth (metres)	Description	Fossils	Sample and thin section designation
33°25.9'	119°44.8'	115	Claystone, silty, diatomaceous, pumiceous; 5Y5/2; massive, moderately indurated, low-density	Early(?) Miocene coccoliths; Saucesian foraminifers	LCB 111-1
33°25.7'	119°45.3'	118	Claystone, silty, diatomaceous; 5Y5/2; massive, moderately indurated	Early(?) Miocene coccoliths and silico-flagellates; probable lower Saucesian foraminifers	LCB 111-2
33°24.7'	119°47.4'	103	Claystone, silty, micaceous; 5Y6/1; well developed parting, and sandstone, fine grained, feldspathic, micaceous	Middle Eocene coccoliths; Ulatisian or Narizian foraminifers	LCB 111-6
33°24.5'	119°48.0'	103	Siltstone, clayey, micaceous; 5Y6/1; poorly developed parting; massive; indurated	Early Eocene coccoliths; Ulatisian or lower Narizian foraminifers	LCB 111-7
33°24.3'	119°48.6'	110	Claystone; 5Y6/1; massive fractured, indurated	Early Eocene coccoliths	LCB 111-8
33°24.3'	119°46.1'	105	Siltstone, micaceous; 5Y6/1; and mudstone, mottled, pyritiferous; N6; dip <5°, indurated	Eocene(?) coccoliths	LCB 110-13
33°24.2'	119°49.4'	105	Siltstone, clayey, micaceous; 5Y4/1; poorly developed parting, indurated, burrowed	Eocene foraminifers	LCB 111-9
33°24.0'	119°50.0'	123	Claystone, silty, micaceous; 5Y6/1; fractured, indurated	Early Eocene coccoliths; probable Ulatisian foraminifers	LCB 111-10
33°23.3'	119°30.1'	430	Claystone, diatomaceous; 5Y2/1 with streaks of 5Y6/1 (wet); faintly laminated, poorly indurated, porous, very low density	Late Miocene(?) coccoliths; probable upper Mohnian foraminifers	KZ 73-1-1
33°22.8'	119°45.5'	97	Siltstone, clayey, micaceous; 5Y6/1; mottled; fractured, indurated	Early or middle Eocene coccoliths; Ulatisian foraminifers	LCB 110-10
33°22.4'	119°32.1'	117	Claystone, silty; 5Y4/1 (wet); laminated; indurated	Late Miocene(?) coccoliths; Mohnian foraminifers	KZ 73-1-5
33°22.3'	119°45.2'	95	Claystone, silty, micaceous; 5GY8/1; burrowed, fractured, indurated	Early Eocene coccoliths; Ulatisian foraminifers	LCB 110-9
33°22.2'	119°32.6'	116	Siltstone, sandy; 5Y4/1 (wet); semiconsolidated	Early middle Miocene silicoflagellates	KZ 73-1-6
33°22.1'	119°33.2'	105	Siltstone, sandy; 5Y4/1 (wet); indurated	Early middle Miocene coccoliths; Luisian or lower Mohnian foraminifers	KZ 73-1-7
33°21.8'	119°45.0'	95	Claystone, silty, micaceous, pyritiferous; 5Y6/1; mottled; bioturbated, indurated	Early Eocene coccoliths; probable Ulatisian foraminifers	LCB 110-8
33°21.7'	119°33.6'	100	Siltstone; 5Y3/2 (wet); indurated	Middle Miocene coccoliths	KZ 73-1-8
33°21.2'	119°44.8'	88	Siltstone, clayey, micaceous; 5Y6/1; poorly developed parting, indurated	Early Eocene coccoliths; probable Ulatisian foraminifers	LCB 110-7

TABLE 2 - Continued

N lat	W long	Depth (metres)	Description	Fossils	Sample and thin section designation
33°20.8	119°35.8'	85	Sandstone, micaceous; 5Y5/1 (wet); medium-grained, clasts include silicic plutonic rocks and muscovite schist, calcite cemented	--	KZ 73-1-12 (T-215)
33°20.7'	119°44.5'	93	Siltstone, clayey, micaceous; 5Y6/1; poorly developed parting, indurated	Early Eocene coccoliths	LCB 110-6
33°20.2'	119°44.3'	95	Siltstone, clayey, micaceous; N7; interlayered with mudstone; N6; possible dip <5°	Probable Ulatisian foraminifers	LCB 110-5
33°19.7'	119°44.1'	97	Claystone, silty, micaceous; 5Y6/1; well developed parting, indurated	Early Eocene coccoliths; upper Ulatisian foraminifers	LCB 110-4
33°19.6'	119°39.0'	76	Siltstone; N4 (wet); layered	Early middle Eocene coccoliths; probable Ulatisian foraminifers	KZ 73-1-18
33°19.2'	119°40.0'	75	Siltstone; 5Y4/1 (wet); contains scattered rock fragments	Middle Eocene coccoliths; probable Ulatisian foraminifers	KZ 73-1-20
33°18.7'	119°43.8'	87	Sandstone, feldspathic, very fine to fine grained, micaceous; N7; massive, indurated	Narizian foraminifers	LCB 110-2
33°18.7'	119°41.1'	70	Siltstone; 5Y4/1 (wet); indurated. Sandstone micaceous; 5Y5/1 (wet); fine grained, indurated	Early Eocene coccoliths; Ulatisian foraminifers	KZ 73-1-22 (T-211)
33°18.5'	119°41.6'	75	Siltstone, micaceous; 5GY4/1 (wet); indurated	Early Eocene coccoliths; Ulatisian foraminifers	KZ 73-1-23
33°18.3'	119°43.6'	88	Siltstone, clayey, micaceous; 5Y7/2; massive, fractured, indurated	Ulatisian or lower Narizian foraminifers	LCB 110-1
33°18.3'	119°42.1'	76	Sandstone, very fine to fine-grained; 5Y4/1 (wet)	Early Eocene coccoliths; Eocene foraminifers	KZ 73-1-24
33°18.2'	119°50.6'	450	Claystone, silty, diatomaceous; 5Y5/2; faintly laminated, dip 45±°, moderately indurated	Middle or late Miocene coccoliths and silico-flagellates; Mohnian foraminifers	LCB 112-1
33°18.1'	119°42.7'	85	Siltstone, clayey, micaceous, mottled; N4 (wet); moderately indurated	Early Eocene coccoliths; Ulatisian foraminifers	KZ 73-1-25
33°17.9'	119°43.2'	80	Siltstone and claystone, silty, micaceous; 5GY4/1 (wet); moderately indurated	Early Eocene coccoliths	KZ 73-1-26
33°17.7'	119°43.7'	94	Siltstone, sandy; N4 (wet); indurated	Early middle Eocene coccoliths; Ulatisian? foraminifers	KZ 73-1-27
33°17.5'	119°51.5'	115	Claystone, silty, micaceous; 5Y5/2; massive, fractured	Middle Miocene coccoliths; Mohnian foraminifers	LCB 112-3
33°17.5'	119°44.3'	100	Sandstone, micaceous, very fine to fine-grained; 5PB5/2 (wet)	Early or middle Eocene coccoliths; Eocene foraminifers	KZ 73-1-28
33°17.1'	119°51.9'	100	Siltstone, clayey, micaceous; 5Y6/1; minutely bioturbated, fractured, indurated	--	LCB 112-4
33°16.6'	119°52.3'	155	Siltstone, clayey, tuffaceous; 5Y6/1, composed primarily of glass shards	Late Miocene coccoliths	LCB 112-5

TABLE 2 - Continued

N lat	W long	Depth (metres)	Description	Fossils	Sample and thin section designation
33°16.3'	119°52.8'	±200	Claystone, silty, highly organic; 5Y4/1; deformed; low-density	Middle Miocene coccoliths	LCB 112-6
33°15.9'	119°47.9'	275	Siltstone, sandy; 5Y3/2 (wet); moderately indurated	Late middle or late Miocene coccoliths; Mohnian foraminifers	KZ 73-1-35
33°15.7'	119°48.5'	120	Sandstone, very fine to coarse-grained, micaceous; N7 (dry), N4 (wet); poorly sorted, medium-density, moderately indurated; contains beds of siltstone, N4 (wet); dip 18°	Early middle Eocene coccoliths	KZ 73-1-36
33°15.4'	119°21.4'	53	Marlstone; 5Y7/1 (wet); porous, low-density	--	KZ 73-2-8 (T-220)
33°15.1'	119°50.0'	85	Siltstone; 5GY4/1 (wet); moderately indurated	Late Cretaceous foraminifers	KZ 73-1-39
33°14.9'	119°50.6'	112	Sandstone, feldspathic, medium-grained; 5Y4/1 (wet); indurated	--	KZ 73-1-40 (T-206)
33°14.3'	119°48.1'	105	Siltstone, micaceous, clayey; 5Y6/1; fractured, indurated	Probable Ulatisian or lower Narizian foraminifers	LCB 113-3
33°12.4'	119°26.2'	37	Sandstone, lithic, micaceous; 10YR5/4 (wet); medium-grained, clasts include silicic plutonic rocks and quartz-rich schistose rocks	--	KZ 73-2-18 (T-213)
33°11.0'	119°28.6'	400	Siltstone, sandy; 5Y2/1 (wet); indurated	Eocene (?) to Miocene (?) coccoliths; Saucesian to Luisian foraminifers	KZ 73-2-23
33°06.7'	119°35.7'	300	Siltstone, sandy; 5YR2/1 (wet); poorly indurated	Middle Miocene(?) coccoliths	KZ 73-2-38
33°05.9'	119°36.5'	292	Sandstone, fine-grained, silty; 5Y3/2 (wet); bedded	Middle Miocene to early Pliocene coccoliths; upper Mohnian foraminifers	KZ 73-2-40
33°04.6'	119°38.1'	285	Siltstone, clayey; 5Y2/1 (wet), 5Y3/2; moderately indurated, low-density	Middle Miocene to early Pliocene coccoliths; Luisian or Mohnian foraminifers	KZ 73-2-44
33°03.5'	119°33.0'	346	Claystone, silty, micaceous; 5Y6/1; fractured, moderately indurated	--	LCB 125-1
33°02.9'	119°34.8'	283	Claystone, silty, diatomaceous; 5Y6/1; massive, low-density	Late Miocene coccoliths	LCB 125-4
32°54.5'	119°26.2'	122	Claystone, silty; N5; pyritiferous; indurated, shattered	--	KZ 73-3-7
32°54.1'	119°27.3	113	Siltstone, clayey; N4; pyritiferous; indurated, brittle	--	KZ 73-3-5
32°54.0'	119°26.1'	130	Claystone, silty, highly organic; 5Y6/1 and 5Y4/1, faintly laminated, 15±° dip	Late Miocene coccoliths	LCB 126-12
32°53.9'	119°27.9'	144	Siltstone, sandy; 5Y2/1 (wet)	Middle Miocene, possible Relizian foraminifers	KZ 73-3-4
32°53.4'	119°29.4'	465	Claystone, micaceous, sandy; 5Y6/1 to 5Y4/1 (wet); moderately indurated; low-density	Middle Miocene coccoliths	KZ 73-3-1
32°53.1'	119°25.3'	125	Claystone, silty, tuffaceous; 5Y6/1; massive, deformed, low-density	Late Miocene coccoliths	LCB 126-10

TABLE 2 - Continued

N lat	W long	Depth (metres)	Description	Fossils	Sample and thin section designation
32°52.7'	119°24.7'	117	Siltstone, sandy, micaceous; 5GY6/1; poorly indurated	Miocene(?) diatoms and silicoflagellates	LCB 126-9
32°52.3'	119°24.3'	120	Claystone, silty, highly organic; 5Y6/1; moderately indurated, low-density	Middle Miocene coccoliths	LCB 126-8
32°52.3'	119°17.3'	517	Siltstone, sandy; 5Y3/1 (wet)	Early or early middle Miocene coccoliths; lower Relizian foraminifers	KZ 73-4-1
32°51.8'	119°18.2'	492	Siltstone, sandy; 5Y3/2 (wet); moderately indurated, laminated; contains phosphorite nodule(?)	Middle Miocene to early Pliocene coccoliths; upper Mohnian foraminifers	KZ 73-4-3
32°51.7'	119°18.9'	440	Siltstone, sandy; 5Y3/2 (wet); indurated	Early middle Miocene coccoliths; lower Luisian foraminifers	KZ 73-4-4
32°50.2'	119°22.3'	141	Claystone, silty, micaceous, highly organic; 5Y5/2; fractured, laminated	Early Miocene coccoliths	LCB 126-3
32°50.1'	119°23.2'	150	Siltstone, sandy; 5Y2/1 (wet)	Late Miocene coccoliths; upper Mohnian foraminifers	KZ 73-4-12
32°49.8'	119°22.0'	158	Claystone, silty, highly organic; 5Y6/1; sheared, moderately indurated	Middle Miocene coccoliths	LCB 126-2
32°49.3'	119°25.3'	475	Siltstone, sandy; 5GY4/1 (wet)	Late Miocene(?) coccoliths; upper Mohnian foraminifers	KZ 73-4-16
32°46.3'	119°09.5'	430	Claystone, silty; 5Y2/1 (wet)	Upper Miocene, Mohnian foraminifers	KZ 73-5-2
32°45.9'	119°09.7'	315	Siltstone, diatomaceous; 5Y2/1 (wet); laminated, poorly indurated, low-density	Late Miocene silicoflagellates and coccoliths; upper Mohnian foraminifers	KZ 73-5-3
32°45.2'	119°13.4'	125	Diatomite, clayey; 5Y8/1 to 5Y6/1; massive, fractured, moderately indurated, very low density	Early or middle Miocene coccoliths Relizian foraminifers	LCB 127-7
32°45.1'	119°10.6'	110	Claystone, micaceous, silty, massive; 5Y4/1 (wet); poorly indurated, low density	Middle Miocene to early Pliocene coccoliths; Luisian foraminifers	KZ 73-5-5
32°44.8'	119°13.6'	108	Mudstone, micaceous; 5GY6/1; massive, indurated	--	LCB 127-6
32°44.6'	119°10.9'	100	Siltstone; 5GY4/1 (wet)	Probable Miocene foraminifers	KZ 73-5-6
32°44.3'	119°14.1'	111	Claystone, silty, micaceous; 5GY6/1; massive, moderately indurated	--	LCB 127-5
32°43.9'	119°14.5'	107	Siltstone, clayey, micaceous, burrowed; 5GY/6; massive, indurated	--	LCB 127-4B
32°43.5'	119°11.8'	82	Siltstone, micaceous, sandy; 10YR4/2 (wet); moderately indurated, medium density	Eocene(?) or Oligocene(?) coccoliths	KZ 73-5-9
32°43.4'	119°14.7'	106	Sandstone, feldspathic, fine- to coarse-grained, N6 to N7; massive; calcareous cement	--	LCB 127-3 (T-276)
32°42.8'	119°15.0'	125	Claystone, highly organic, tuffaceous; 5Y4/1; fractured, moderately indurated, low density	Middle Miocene coccoliths; probable Saucesian foraminifers	LCB 127-2

TABLE 2 - Continued

N lat	W long	Depth (metres)	Description	Fossils	Sample and thin section designation
32°41.4'	119°04.4'	89	Siltstone, sandy; 5Y2/1 (wet); indurated	Neogene coccoliths; probable Relizian foraminifers	KZ 73-6-3
32°40.6'	119°15.8'	130	Claystone, highly organic; 5Y6/1 and 5Y6/1; tar-filled fractures	Middle or late Miocene coccoliths; Mohnian foraminifers	LCB 128-7
32°40.3'	119°15.3'	135	Claystone, diatomaceous; N7 to 5Y6/1; laminated, 20°± dip; tar-filled fractures	Middle Miocene coccoliths; Mohnian foraminifers	LCB 128-6
32°39.8'	119°05.6'	94	Siltstone; 5PB5/2 (wet)	Middle Miocene coccoliths	KZ 73-6-7
32°39.8'	118°54.4'	710	Claystone, silty; 5Y2/1 (wet)	Middle Miocene silicoflagellates; Mohnian(?) foraminifers	KZ 73-7-1
32°39.5'	118°54.8'	655	Claystone, silty; 5YR2/1 (wet); phosphorite nodule(?)	Middle Miocene coccoliths; middle Miocene foraminifers	KZ 73-7-2
32°39.0'	119°13.9'	171	Claystone, organic; 5Y7/2; and 5Y4/1; fractured	Middle Miocene coccoliths; probable lower Mohnian foraminifers	LCB 128-3
32°38.8'	118°55.7'	637	Siltstone, sandy, diatomaceous; 5YR2/1; (wet)	Early middle Miocene coccoliths	KZ 73-7-4
32°38.7'	119°16.0'	203	Claystone, silty; 5Y2/1 (wet); 5YR2/1 (wet); with phosphorite	Late middle Miocene coccoliths; upper Mohnian foraminifers	KZ 73-5-21
32°38.6'	119°06.7'	102	Siltstone, sandy; 5Y2/1 (wet)	Early middle Miocene silico-flagellates and coccoliths; lower Mohnian foraminifers	KZ 73-6-10
32°38.3'	118°56.0'	687	Siltstone; 5GY3/2 (wet); bedded, indurated	Late Miocene coccoliths; upper Delmontian foraminifers	KZ 73-7-5
32°38.1'	119°13.3'	195	Claystone, highly organic, bentonitic; 5Y2/1 and 5Y4/1; faintly laminated, moderately indurated	Middle Miocene coccoliths; Relizian or lower Luisian foraminifers	LCB 128-1
32°37.6'	118°56.9'	699	Siltstone, sandy; 5Y2/1 (wet); indurated	Lower Repettian(?) foraminifers	KZ 73-7-7
32°35.9'	119°11.6'	163	Claystone, organic, 5Y4/1; tar(?)-saturated	Late Miocene coccoliths; upper Mohnian foraminifers	LCB 129-6B
32°35.3'	119°11.6'	153	Claystone, highly organic, tarry; N2; fractured, moderately indurated, low density	Probable Mohnian foraminifers	LCB 129-5B
32°34.3'	119°18.0'	88	Claystone, silty, micaceous; 5GY6/1; massive, moderately indurated	Probable late Eocene and early Oligocene coccoliths; Refugian foraminifers	LCB 130-8B
32°34.3'	119°17.4'	89	Siltstone, clayey, micaceous; 5GY6/1; fractured, moderately indurated	Middle Eocene to late Oligocene coccoliths; Refugian foraminifers	LCB 130-7
32°34.2'	119°19.2'	90	Claystone, silty micaceous; 5Y6/1; massive, indurated	Late Eocene or early Oligocene coccoliths; Refugian foraminifers	LCB 130-10B
32°34.1'	119°20.4'	108	Sandstone, tuffaceous, very fine to coarse-grained, 5Y7/2; angular to subrounded grains; indurated; weathered	--	LCB 130-12B

TABLE 2 - Continued

N lat	W long	Depth (metres)	Description	Fossils	Sample and thin section designation
32°34.1'	119°10.9'	142	Claystone, highly organic; N5; deformed; poorly indurated, low density	Late Miocene coccoliths; upper Mohnian foraminifers	LCB 129-3
32°34.0'	119°21.1'	129	Mudstone, phosphatic; mottled; 5Y6/1 and 5Y2/1; deformed, poorly indurated low density, tar-saturated(?)	Late Miocene coccoliths; upper Mohnian foraminifers	LCB 130-13B
32°31.2'	118°39.3'	930	Claystone; diatomaceous; 5Y6/1; massive, moderately indurated	Middle Miocene coccoliths	LCB 133-9
32°30.4'	119°19.3'	300	Claystone, diatomaceous, highly organic; 5Y6/1 to 5Y4/1; laminated, 5°± dip, moderately indurated	Late Miocene coccoliths; lower Mohnian foraminifers	LCB 131-3
32°30.4'	118°40.3'	660	Claystone, silty, micaceous, organic; 5Y6/1; fractured, moderately indurated, low-density	Middle Miocene coccoliths and silicoflagellates	LCB 133-7
32°30.2'	118°40.9'	605	Claystone, silty, micaceous; 5Y6/1; massive, moderately indurated, low-density	Early Miocene coccoliths and silicoflagellates	LCB 133-6
32°30.1'	118°41.5'	535	Claystone, diatomaceous; 5Y6/1; faintly laminated, possible 5°± dip; moderately indurated, low-density	Middle Miocene silicoflagellates and coccoliths	LCB 133-5
32°30.1'	118°39.8'	720	Diatomite, clayey; 5Y8/1; massive, moderately indurated; very low-density	Middle Miocene coccoliths and silicoflagellates	LCB 133-8
32°30.0'	119°19.8'	510	Claystone, silty, diatomaceous, micaceous; 5Y6/1 and 5Y5/2; faintly laminated, 10°± dip, moderately indurated, low-density	Early Miocene silicoflagellates and diatoms	LCB 131-4
32°29.8'	118°42.1'	505	Claystone, diatomaceous; 5Y6/1; massive, moderately indurated, low-density	Middle Miocene coccoliths	LCB 133-4
32°29.5'	118°42.6'	535	Claystone, silty, diatomaceous; 5Y6/1 and 5Y4/1; faintly laminated, dip <5°, low density	Middle Miocene coccoliths; probable Luisian foraminifers	LCB 133-3
32°29.2'	118°43.1'	655	Claystone, diatomaceous, pumiceous(?); mottled, N8 to 5Y6/1; moderately indurated, very low density	Middle Miocene coccoliths	LCB 133-2
32°28.9'	118°43.6'	750	Siltstone, clayey, glauconitic; 5YR4/1 to 5Y4/1; poorly indurated	Middle Miocene coccoliths	LCB 133-1
32°24.5'	119°4.0'	87	Siltstone, clayey, tuffaceous(?), calcareous; 5Y4/1 to 5Y6/1; porous, indurated	--	LCB 132-3B
32°22.9'	119°16.3'	1000±	Sandstone, barite cemented, glauconitic; 5Y7/2 to 5Y6/1; matrix of dense to porous intergrowths of tabular crystals with laminated veinlets and concentric growths	Middle Miocene Luisian foraminifera	LCB 20 (dredge) (T-252A,B,C)

AREA III. SANTA CRUZ ISLAND SOUTHEAST TO SANTA CATALINA AND SAN CLEMENTE ISLANDS

N lat	W long	Depth (metres)	Description	Fossils	Sample and thin-section designation
33°55.4'	119°45.6'	345	Sandstone, fine- to medium-grained, feldspathic, tuffaceous, N6, poorly bedded; contains volcanic rock fragments; 15°± dip; friable; overlain by laminated diatomaceous claystone, 5Y4/1 to 5Y8/1	Late Miocene diatoms	LCB 107A-5B (T-280B)
33°54.2'	119°46.4'	760	Conglomerate, pebble, 5GY6/1; angular clasts of silty claystone, vitric tuff in mudstone matrix; poorly indurated	Early or middle Miocene coccoliths, diatoms, silicoflagellates; probable Relizian foraminifers	LCB 107A-2

TABLE 2 - Continued

N lat	W long	Depth (metres)	Description	Fossils	Sample and thin section designation
33°41.5'	119°14.3'	259	Claystone, 5Y6/1 to 5Y4/1 (dry); tuffaceous laminae, N7 to N8; poorly indurated; very low density; dip less than 5°	Late early Miocene silicoflagellates and coccoliths; probable upper Relizian foraminifers	KSB 905-9
33°37.4'	118°56.9'	351	Claystone, diatomaceous; 5Y6/1, massive, poorly indurated, low density, shattered	Probable upper Luisian foraminifers	KSB 907-1A
33°36.1'	119°08.5'	185	Claystone, tuffaceous?, 5Y4/1 to 5Y6/1, laminated, poorly indurated, low density; dip 0-5°	Relizian foraminifers	KSB 906-7
33°35.1'	119°09.0'	465	Claystone and siltstone, thin bedded, sandy, micaceous, 5Y6/1, poorly indurated, very low density; dip ±5°	Middle Miocene to middle Pliocene coccoliths; upper Mohnian foraminifers	KSB 906-9
33°32.1'	119°11.1'	315	Claystone, diatomaceous, 5Y4/1, massive, fractured, moderately indurated, low-density	Middle Miocene coccoliths and silicoflagellates; probable Delmontian foraminifers	LCB 108-10
33°31.9'	119°11.5'	345	Crystal tuff; N8; and claystone, organic, pumiceous, 5Y6/1, deformed, low-density	Middle Miocene coccoliths and diatoms; probable Delmontian foraminifers	LCB 108-11
33°31.5'	119°11.6'	425	Sandstone, very fine grained, silty, glauconitic, 5Y4/1, massive, friable	Late Miocene or early Pliocene? coccoliths	LCB 108-12B
33°29.8'	119°13.1'	350	Claystone, diatomaceous, 5Y8/1 to 5Y4/1, laminated, deformed, low-density	Middle Miocene, coccoliths and silicoflagellates; Luisian foraminifers	LCB 109-4B
33°29.6'	118°54.4'	1000±	Breccia, tar saturated; composed of clasts of calcareous and siliceous mudstone and volcanic rocks	Late Miocene(?) clasts, diatoms, rare radiolarians and silicoflagellates	KSB 21E (dredge)
33°29.5'	119°12.8'	296	Diatomite, clayey, 5Y8/1 to 5Y6/1, massive, fractured, very low density	Middle Miocene coccoliths and silicoflagellates; upper Mohnian or Delmontian foraminifers	LCB 109-3
33°29.1'	119°12.5'	260	Claystone, diatomaceous, pumiceous(?), 5Y4/1, mottled, poorly indurated, low-density	Late Miocene or Pliocene silicoflagellates and diatoms	LCB 109-2B
33°29.1'	119°11.9'	350	Sandstone, very fine grained, silty, 5Y5/2, massive, poorly indurated	Late(?) Miocene coccoliths and silicoflagellates; upper Mohnian foraminifers	LCB 109-1
33°28.5'	119°12.1'	260	Claystone, diatomaceous, pumiceous(?), 5Y6/1, faintly laminated, poorly indurated, very low density	Late Miocene or Pliocene silicoflagellates and diatoms	LCB 109-1B
33°23.8'	118°13.6'	503	Sandstone, fine-grained, 10YR2/2 (wet), indurated	--	VA 70-8
33°23.7'	119°02.5'	200	Claystone, benthonitic?, 5GY8/1, massive, poorly indurated, low-density, shattered	Late early Miocene coccoliths; probable lower Luisian foraminifers	KSB 908-2
33°23.3'	119°02.7'	254	Claystone, diatomaceous, 5Y6/1 to 5Y4/1, laminated, poorly indurated, low-density	Late early Miocene coccoliths; probable lower Luisian foraminifers	KSB 908-3
33°15.1'	118°8.7'	678	Siltstone, clayey, micaceous, pumiceous(?), 5GY6/1, massive, moderately indurated	--	LCB 146-1
33°14.6'	118°9.8'	410	Claystone, diatomaceous, 5GY6/1, highly deformed seamed with calcite(?) veins	Middle or late Miocene? coccoliths, diatoms and silicoflagellates; possible Relizian foraminifers	LCB 146-3

TABLE 2 - Continued

N lat	W long	Depth (metres)	Description	Fossils	Sample and thin section designation
33°04.6'	118°35.4'	450	Siltstone, micaceous, 5Y3/2 (wet), moderately to poorly indurated; contains thin fine-grained sandstone lenses	Late Miocene coccoliths	KZ 73-14-3
33°03.9'	119°29.4'	530	Siltstone, sandy, 5Y3/2 (wet)	Late Miocene silicoflagellates; upper Mohnian foraminifers	KZ 73-2-46
33°03.9'	118°37.1'	89	Volcanic sandstone, coarse-grained, N6; angular clasts, calcite cement	--	KZ 73-14-6 (T-214)
33°02.0'	118°41.4'	465	Siltstone, 5YB4/1 (wet)	Late middle or late Miocene coccoliths; lower Mohnian foraminifers	KZ 73-14-14
32°43.2'	118°21.5'	540	Siltstone, 5YR2/1 (wet)	Middle or late Miocene foraminifers	KZ 73-9-1
32°43.0'	118°22.8'	317	Siltstone, 5Y2/1 (wet)	Middle Miocene coccoliths; upper Luisian to lower Mohnian foraminifers	KZ 73-9-3
32°42.5'	118°27.4'	320	Claystone, silty, 5Y2/2 (wet)	Early middle Miocene coccoliths	KZ 73-9-11
32°42.5'	118°27.0'	270	Siltstone, sandy, 10YR4/2 (wet), poorly indurated	Early middle Miocene coccoliths; Luisian foraminifers	KZ 73-9-10
32°42.4'	118°28.5'	586	Claystone, silty, 5Y2/2 (wet)	Late Miocene? coccoliths	KZ 73-9-13
32°42.3'	118°27.9'	538	Claystone, silty, diatomaceous, 5Y2/2 (wet)	Middle Miocene to early Pliocene coccoliths; Luisian foraminifers	KZ 73-9-12
32°42.0'	118°30.3'	860	Claystone, silty, 5Y3/3 (wet)	Middle Miocene silicoflagellates and diatoms; Repettian foraminifers	KZ 73-9-16
32°41.2'	118°35.1'	870	Siltstone, sandy, 5Y2/1 (wet)	Late Miocene coccoliths; Repettian foraminifers	KZ 73-9-25
32°41.0'	118°36.4'	746	Siltstone, sandy, 5Y4/1 (wet), contains subangular quartzite and greenschist fragments	Middle Miocene coccoliths	KZ 73-9-27
32°40.9'	118°37.0'	740	Siltstone, sandy, 5Y4/1 (wet)	Middle Miocene coccoliths; Repettian foraminifers	KZ 73-9-28
32°40.7'	118°37.6'	794	Siltstone, clayey, 5Y2/1 (wet)	Early middle Miocene silico-flagellates	KZ 73-9-29

AREA IV. THIRTYMILE AND FORTYMILE BANKS AND VICINITY

N lat	W long	Depth (metres)	Description	Fossils	Sample and thin section designation
33°58.8'	119°00.5'	292	Siltstone, 5Y2/1 (wet), friable; Dolomitic siltstone; 5Y2/1 (wet), contains calcite veins	Late Miocene or early Pliocene coccoliths	VO-13951
33°39.2'	118°18.4'	595	Siltstone, 5Y2/1 (wet)	--	VA 70-4
33°39.0'	118°17.0'	311	Claystone, sandy, 5Y3/1 (wet)	Middle Pliocene coccoliths	VA 70-3
32°44.8'	117°48.5'	282	Tuff, altered, N8, and claystone, mottled, 10YR4/2, fractured, deformed	--	LCB 143-8
32°44.7'	117°47.2'	285	Claystone, silty, micaceous, tuffaceous, 10YR4/2, massive, deformed, moderately indurated	Early or middle Miocene foraminifers	LCB 143-6

N lat	W long	Depth (metres)	Description	Fossils	Sample and thin section designation
32°41.5'	117°44.2'	403	Claystone, silty, diatomaceous, tuffaceous(?), 5Y7/2, mottled, massive, low-density	Middle(?) Miocene silicoflagellates	LCB 142-5 (T-238)
32°40.3'	117°57.8'	225	Siltstone, sandy, 5Y2/1 (wet) Phosphorite breccia; 5Y2/1 (wet), contains oolites and quartz sand grains	Miocene(?) silicoflagellates	KZ 73-10-27
32°36.8'	117°56.2'	175	Siltstone, 5Y5/2	Late Miocene coccoliths	LCB 141-7
32°36.4'	117°55.9'	190	Claystone, highly organic, 5Y5/2, deformed	Late Miocene coccoliths; upper Mohnian foraminifers	LCB 141-6
32°36.2'	117°25.7'	280	Siltstone, sandy, micaceous, 5YR2/1 (wet), laminated, poorly indurated; possible 10° dip	Late middle Miocene silicoflagellates	KZ 73-11-2
32°35.9'	117°55.7'	245	Claystone, silty, micaceous, highly organic, 5Y5/2, massive, poorly indurated, very low density	Late Miocene foraminifers	LCB 141-5
32°34.9'	117°54.9'	345	Siltstone, 5Y5/2, scrapings from core barrel	Probable upper Mohnian foraminifers	LCB 141-3
32°34.5'	117°54.5'	395	Claystone, highly organic, silty, mottled, 5Y4/1; massive, low-density	Probable lower Mohnian foraminifers	LCB 141-2
32°34.0'	117°54.2'	456	Siltstone, 5Y5/2, scrapings from core barrel	Late Miocene coccoliths	LCB 141-1
32°26.5'	117°34.9'	580	Siltstone, pebbly, 5Y3/2, contains angular clasts of altered andesite	--	LCB 139-4 (T-237A,B)
32°26.0'	117°36.0'	790	Siltstone, 5Y5/2, scrapings from core barrel	Upper Mohnian foraminifers	LCB 139-6

AREA V. SIXTYMILE BANK AND VICINITY

N lat	W long	Depth (metres)	Description	Fossils	Sample and thin section designation
32°22.6'	118°28.1'	292	Siltstone, 10YR2/2 (wet)	Early middle Miocene coccoliths; probable Luisian foraminifers	KZ 73-13-3
32°22.4'	118°15.3'	545	Sandstone, silty, 5Y2/1 (wet), medium-grained	Middle Miocene coccoliths; Luisian foraminifers	KZ 73-12-2
32°22.1'	118°29.0'	415	Siltstone, sandy, 10YR2/2 (wet)	Early middle Miocene coccoliths; upper Relizian or Luisian foraminifers	KZ 73-13-5
32°21.6'	118°30.1'	510	Siltstone, clayey, diatomaceous, 5YR2/1 (wet), contains phosphorite fragments	Early middle Miocene silicoflagellates	KZ 73-13-7
32°11.7'	118°26.1'	705	Siltstone, 5Y5/2	Middle Miocene coccoliths	LCB 134-1
32°11.1'	118°26.6'	654	Siltstone, clayey, diatomaceous, micaceous, 5Y5/2, massive, moderately indurated, low-density	Middle Miocene coccoliths; Repettian foraminifers	LCB 134-2
32°10.2'	118°23.5'	630	Siltstone, clayey, diatomaceous, 5Y5/2, massive, low density	Middle Miocene coccoliths; probable Relizian foraminifers	LCB 135-3
32°08.6'	118°26.8'	378	Marlstone, porous, silty 5Y6/2, massive, moderately indurated, low-density; contains blue amphibole detritus	Middle Miocene foraminifers	LCB 134-6 (T-247)
32°08.6'	118°24.5'	530	Claystone, silty, diatomaceous, 5Y6/1, massive, moderately indurated	Middle Miocene silicoflagellates	LCB 135-5

TABLE 2 - Continued

N lat	W long	Depth (metres)	Description	Fossils	Sample and thin section designation
32°07.8'	118°25.0'	493	Marlstone, pebbly, 5Y5/1; massive; contains blue amphibole detritus	Middle Miocene coccoliths, Saucesian or Relizian foraminifers	LCB 135-6 (T-241A)
32°07.3'	118°29.8'	364	Claystone, silty, micaceous; 5Y6/1, moderately indurated	--	LCB 134-8
32°07.0'	118°25.5'	501	Siltstone; 5Y6/1	Middle Miocene coccoliths	LCB 135-7
32°06.3'	118°26.0'	527	Marlstone, sandy, diatomaceous, 5Y6/1, moderately indurated; contains glaucophane detritus	Lower or middle Miocene coccoliths and silicoflagellates; possible Relizian foraminifers	LCB 135-8 (T-242)
32°06.0'	118°30.9'	488	Marlstone, sandy, pumiceous, 5Y7/2; contains blue amphibole detritus	Possible Relizian foraminifers	LCB 134-10B (T-240)
32°05.5'	118°26.5'	546	Siltstone, 5Y6/1	Middle Miocene foraminifers	LCB 135-9 (T-239)
32°04.8'	118°31.9'	400	Siltstone, clayey, micaceous, 5Y6/1, massive, moderately indurated, low-density	Middle Miocene silicoflagellates	LCB 134-12
32°04.1'	118°32.5'	460	Siltstone, clayey, micaceous, 5Y6/1, massive, low-density	Middle Miocene silicoflagellates	LCB 134-13
32°03.9'	118°27.5'	545	Claystone, silty, micaceous, 5Y6/1, massive, moderately indurated	Probable Delmontian foraminifers	LCB 135-11
32°03.5'	118°33.0'	473	Siltstone, clayey, micaceous, 5Y5/2; contains blueschist detritus in coarser layers	Middle Miocene coccoliths and silicoflagellates; probable Relizian foraminifers	LCB 134-14 (T-272)
32°03.1'	118°27.5'	601	Siltstone, 5Y6/1; scrapings from core barrel	Middle Miocene coccoliths	LCB 135-12
32°02.9'	118°33.5'	528	Siltstone, clayey, calcareous, 5Y5/2, massive, fractured, low-density	--	LCB 134-15
32°02.3'	118°34.1'	682	Claystone, silty, micaceous, 5Y6/1, moderately indurated, low-density	Middle Miocene coccoliths; probable Delmontian foraminifers	LCB 134-16
32°02.3'	118°28.5'	774	Claystone, diatomaceous, 5Y6/1, massive, moderately indurated, low-density	Middle Miocene coccoliths; Repettian foraminifers	LCB 135-13

*GPO 691-095