UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

INVESTIGATION OF THE HOSGRI FAULT OFFSHORE SOUTHERN CALIFORNIA POINT SAL TO POINT CONCEPTION

By

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**Part II Contains the complete seismic reflection profiles (SONIA) made during the investigation. A paper copy of 79-1199 Part II sells for $13.75, microfiche sells for $.50 and may be obtained from: Open-File Services Section, USGS, Box 25425, Federal Center, Denver, CO 80225

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ABSTRACT

A high-resolution seismic reflection survey of the inner continental shelf between Point Sal and Point Conception has revealed faults that displace post-Wisconsin strata (less than 17,000-20,000 years). These faults are the Hosgri fault, the Offshore Lompoc fault, and smaller unnamed faults. Faults trending offshore from the adjacent shoreline such as the Pezzoni, Lions Head, Honda, and Pacifico faults, do not show post-Wisconsin activity.

The Hosgri fault trends directly toward the coastline between Purisima Point and Point Arguello where it appears to merge with folds and smaller faults in the western Transverse Ranges. This trend of offshore structures toward the Point Arguello-Point Conception area is consistent with a hypothesis that the regional structural fabric of the southern California Coast Ranges and its adjacent offshore area merge with the Transverse Ranges.

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INTRODUCTION AND SUMMARY OF RESULTS

In May and June 1978, Fugro, Inc. conducted an offshore geophysical survey between Point Sal and Point Conception, California, (Fig. 1) utilizing the 3.0 kHz SONIA profiling system. The purpose of the study was to investigate the location and nature of the Hosgri fault south of Point Sal and to evaluate its regional tectonic implications. The investigation was performed under the U.S. Geological Survey's Earthquake Hazards Reduction Program (Contract 16820). The specific objectives of the Hosgri fault investigation were:

1. To define the southerly location and extent (horizontal and vertical) of the Hosgri fault using a minimum of 300-line kilometers of high-resolution, seismic-reflection profiling.

2. To attempt to delineate any displacements across the fault in shallow subbottom deposits and on the seafloor, or any other fault characteristics which could be significant in fault risk analysis.

3. To integrate the proposed investigation data with presently available information and determine the tectonic implications of the Hosgri fault within the context of the regional structural framework.

4. To determine whether the Hosgri fault can be associated with other geologic structures, and specifically, its relationship to structures in the Transverse Ranges.

To fulfill the objectives of the investigation, 39 seismic-reflection profiles totaling about 425 km were run in a zig-zag pattern generally perpendicular to the coastline and reaching as far as 25 km offshore (Plate 1). Immediately upon completion of the Hosgri fault investigation, an additional 60 km of profile (Plate 1) were run over the adjacent Offshore Lompoc fault zone; results from this separately funded study were used to augment the Hosgri fault study at no cost to the U.S.G.S.

The SONIA system penetrated up to about 100 m of the seafloor sediment and underlying rock formations. These sediments were comprised of flat-lying unlithified strata overlying faulted and folded, Miocene- and Pliocene-age marine sedimentary rocks. The flat-lying strata, which are post-Wisconsin (younger than 17,000-20,000 years) in age, are faulted where they overlie the Hosgri fault zone between Point Sal and Purisima Point signifying late Pleistocene to Holocene fault activity.

The SONIA profiles were integrated with the deeper penetration, seismic-reflection data collected during previous U.S.G.S. cruises, and to profiles obtained during investigations by private firms in conjunction with siting of Diablo Canyon Nuclear Power Plant. In many cases this integration of data allowed correlation of shallow structural features to regional structural trends.

In addition to showing that the Hosgri fault in the Point Sal area has been active in late Quaternary time, the study has also shown that the fault extends south to about the latitude of Purisima Point. The fault's projection along this trend aligns with mapped northwest-southeast trending onshore and nearshore faults and folds between Purisima Point and Point Arguello as interpreted from deep-penetration, seismic-reflection profiles. These relationships suggest that the Hosgri fault may merge with folds and smaller faults within the western Transverse Ranges, and that the fault probably does not extend south of the latitude of Point Arguello (Plate 1).

GEOLOGIC SETTING

The area of the Hosgri fault investigation is over the continental shelf between Point Sal and Point Conception (Fig. 1). This region is at the southern end of the offshore Santa Maria basin which extends from Point Sur in northern California to Point Arguello where it continues onshore (Hoskins and Griffiths, 1971).

The Santa Maria Basin is an elongate post-middle Miocene synclinal basin with a predominant northwest-southeast structural grain. Major faults bound both the west and east sides of the Santa Maria Basin. The eastern boundary is the Hosgri fault which extends some 145 km from Cape San Martin south to Point Sal. The western boundary is formed by Santa Lucia Bank, a faulted anticlinal upwarp which forms a relatively shallow bathymetric high. The Franciscan Formation (Jurassic-Cretaceous) constitutes the basement of the basin as it does in the nearby onshore area. The stratigraphic section above the basement is comprised of Eocene through Holocene strata with marked angular unconformities above the basement, between Eocene and lower Miocene, between lower and middle Miocene, and between upper Miocene and lower Pliocene (Hoskins and Griffiths, 1971).

Features such as Santa Lucia Bank and the smaller faulted and folded uplifts within the basin lend a "continental borderland" aspect to the offshore area somewhat similar,but much less developed, to the Southern California Continental Borderland lying to the south of Point Conception. This northern "continental borderland" appears to terminate in the southern part of the study area where structural trends converge toward the Point Arguello-Point Conception area.

The onshore region adjacent to the study area (the Santa Maria Oil Province; Crawford, 1971) forms a triangular area bounded by the California Coast Ranges on the northeast and the Transverse Ranges on the south (Fig. 1). The Province is comprised of a series of Tertiary basins between the anticlinorial upwarps reflected by promontories along the coastline at Point Arguello, Purisima Point, Point Sal, and Point Buchon. The basement consists of igneous and metamorphic rocks of the Franciscan Formation and sedimentary rocks of the Knoxville Formation. The Tertiary stratigraphic section is comprised of predominantly fine-grained, sedimentary rock formations. Exposures along the coastline consist primarily of the Monterey and Sisquoc Formations overlain by Quaternary marine and continental terrace deposits (Plate 1).

As shown on Figure 1, the geologic structures within the study area and in the region surrounding the study area have two dominant trends. The structure of the Coast Ranges and the offshore Santa Maria Basin trend northwest-southeast. The structures of the Transverse Ranges (which includes the Santa Barbara Channel and Channel Islands) trend predominantly east-west but they bend slightly to the northwest at their western end. The trend of structures in the Santa Maria Province is intermediate to the Coast Ranges and Transverse Ranges trends and seems to gradually change from east-west on the south to northwest-southeast on the north (Fig. 1). The lack of mapped geologic structures in the area between the offshore Santa Maria Basin and the Santa Barbara Channel-Channel Islands region partially may be a result of lack of study.

Regional gravity trends (Pacific Gas and Electric Co., 1974; Beyer and others, 1974) are highly consistent with the mapped geologic trends and show the same strong northwest-southeast trend of the California Coast Ranges gradually changing to the east-west trend of the Transverse Ranges. Negative free-air anomalies form a trend around Point Arguello and Point Conception suggesting continuity of the Santa Maria Basin with the Santa Barbara Basin.

Aeromagnetic maps (Pisciotto and others, 1974; McCulloch and Chapman, 1977) show strong northwest-southeast trending alignments offshore of the Coast Ranges and east-west alignments in the Santa Barbara Channel-Channel Islands region but do not show any strong connection between the two trends. The dominantly negative residuals of the Santa Barbara Channel and the Santa Maria Basin are interrupted by positive anomalies at the western sill of the Santa Barbara Channel and at a bathymetric high in the southern Santa Maria Basin. These two positive residuals are separated by a negative trough in the Arguello Canyon region.

The seismicity in the region surrounding the study area is characterized by low-magnitude, randomly dispersed earthquakes. Due to a large azimuthal gap in seismograph coverage and to a paucity of local stations, the earthquake catalogue is probably not complete with respect to lower magnitude events. The earthquakes recorded during the interval 1932 through 1977 generally fall in the 3 to 4.5 magnitude range. They show no preferred orientations or alignments except for events in 1969 clustering near faults on the continental slope west of Santa Lucia Bank (see Gawthrop, 1975). Despite the relatively low rate of activity suggested by the instrumental data, large and destructive earthquakes have occurred in this region. The major earthquakes were the 1902 and 1915 events in the vicinity of Los Alamos and a 1927 event offshore. The 1927 earthquake is the largest known (M=7.3) in this region and was originally located about 70 km west of Point Arguello (Byerly, 1930) in the same area as the 1969 sequence. Using teleseismic data, Gawthrop (1975) relocated the 1927 earthquake to the northern part of the study area. Uncertainty in the relocation accuracy could be as large as 20 to 25 km thus the event could have been associated with any of the faults in the area. Hanks (1978, in press), using local data, concludes that the data are not consistent with a rupture on the Hosgri fault and places the epicenter at a location more consistent with Byerly (1930).

Focal mechanism solutions (Gawthrop, 1975) in the region surrounding the northern study area show a predominance of strike-slip motions with smaller components of vertical movement. The tectonic regime suggested by these mechanisms is consistent with that shown by geologic data such as the northwest-southeast trending faults and folds in the Coast Ranges. Focal mechanisms and geologic data from the Transverse Ranges generally indicate left-lateral reverse and thrust movements (Lee and Vedder, 1973; C. Johnson, personal commun., 1978, regarding the August 1978 Santa Barbara earthquake).

PREVIOUS INTERPRETATIONS ON THE NATURE AND SIGNIFICANCE OF THE HOSGRI FAULT

Since discovery of the Hosgri fault (Hoskins and Griffiths, 1971), numerous offshore geophysical surveys have been conducted in the region. Most investigators agree that the Hosgri fault is composed of a series of subparallel, discontinuous northwest-trending segments roughly paralleling the California coastline (see, for example Fig. 1). These investigators are in general agreement that the fault zone extends at least from Cape San Martin to about Point Sal, a distance of approximately 145 km. Interpretations and postulations on which there may be less than complete accord are:

1. Wagner (1974) postulated that even though the Hosgri fault displays several thousand feet of vertical displacement of the pre-Tertiary horizons, the more recent movement is right-lateral strike slip similar to most other California coastal faults. Wagner also postulated post-Wisconsin displacements (younger than 20,000 years) in scattered localities along the Hosgri fault between Point Piedras Blancas and Point Buchon.

2. The geologic investigation for the Diablo Canyon Nuclear Power Plant (Pacific Gas and Electric Co., 1974) concluded that the Hosgri fault bends between the latitudes of Point Sal and Purisima Point and trends toward the shoreline between those two points.

3. Hall (1975) suggested that the Hosgri fault merges with the onshore San Simeon fault in the vicinity of San Simeon Point to the north of the study area.

4. Silver (1977) suggested a connection between the Hosgri fault and the San Gregorio fault, and a merging of the system with the San Andreas fault system near the mouth of San Francisco Bay. The total length of Silver's Hosgri-San Gregorio system is in excess of 220 km.

5. Graham and Dickinson (1978) consider the Hosgri fault to be part of the San Andreas fault system and view it as the principal structural boundary between the southern Coast Ranges and the offshore basins. They accept Hall's (1975) connection with the San Simeon fault and postulate as much as 115 km of post-early-Miocene, right-lateral, strike-slip movement.

SEISMIC REFLECTION SURVEY METHODS AND EQUIPMENT

The Hosgri fault seismic-reflection survey was conducted between May 19 and June 3, 1978 aboard the Emerald, a 75-foot-long vessel stationed in Santa Barbara. The SONIA transducer was mounted on the side of the ship in outrigger fashion by specially fabricated mounting devices. Specifications and capabilities of the SONIA system are described in Appendix A.

Prior to beginning work at sea, approximately 300 km of profile lines were plotted on an arc plot with the aid of Fugro's navigational computer programs. Adjustments in line locations at sea were made, as needed, with an onboard computer. Navigation of the vessel was accomplished with a Del Norte trisponder navigation system. This range-range microwave navigation system employed four stations located on high points along the coast. The system provided coverage of the study area with an estimated accuracy of approximately 3 m at 37 km.

A zig-zag, survey-line pattern (Plate 1), generally perpendicular to the coastline, was considered optimal to obtain the proposed amount of seismic profile within the budgeted time frame. Lines were also run parallel to the coast line to enable correlation between offshore and onshore structures.

The survey was begun in the north to obtain acoustic signatures typical of the Hosgri fault zone where the fault is well documented by others (Plate 1). The first few profiles indicated that the orientation of the pre-plotted track lines were highly satisfactory to traverse the Hosgri fault perpendicular to its trend. Major geological features were plotted by geologists at sea on an arc plot to ensure that the survey instruments were recording pertinent and accurate data. As structural and stratigraphic features were recorded they were analyzed and compared with features recorded by previous boomer and sparker surveys.

SONIA SURVEY RESULTS

Introduction

On completion of the ocean survey, interpretation of the SONIA records were made independently by the Principal Investigator and the geologists who were onboard the Emerald. The composite map of geologic features is shown on Plate 1 (in pocket). During the final interpretation process, deep-penetration sparker and boomer records of the U.S.G.S. Bartlett and Polaris cruises plus selected profiles from the Kelez cruise and the Diablo Canyon Nuclear Power Plant investigation aided in interpreting the features seen on the shallow-penetration SONIA data. SONIA results were in this way integrated with existing data. In many cases a correlation between the shallow SONIA data and pre-existing deep data was possible where the two were recorded over the same area.

General Nature of the Seafloor

The Hosgri fault study area lies on the coastal shelf between the offshore Santa Maria Basin and the California coastline. This coastal shelf has low relief with a relatively constant gradient sloping slightly seaward. The gradient varies from a maximum of about 25 m/km in the Point Conception area to about 5.5 m/km near Purisima Point. The edge of the coastal shelf lies between about 100 and 140 m depth. The shelf has a maximum width of about 18 km offshore of San Antonio Terrace and a minimum width of about 5 km near Point Conception (Plate 1).

Rock crops out on the seafloor near shore causing an irregular relief compared to the seafloor surface farther seaward (Plate 1, Figs. 2 and 3). These outcrops appear barren of sediment cover except for scattered local pockets.

Except for the predominantly bare rock in the surf zone, there is very little evidence of erosion, and the study area appears to be in a depositional regime. Only at the southern end of the study area is there any sign of active erosion; there, several tributaries of Arguello Canyon dissect the strata at the edge of the shelf.

Acoustic Stratigraphic Units

General Characteristics: The acoustic properties of the seafloor and subbottom sediments vary considerably throughout the area. Generally, in nearshore areas where water depths are less than 20 m, penetration was minimal presumably due either to signal absorption by coarse-grained seafloor sediments (sand and gravel) or to the nature of the rock on the seafloor near shore. As water depth increased, energy penetration generally increased. Along most survey lines in the northern part of the study area, the near-horizontal surficial strata were penetrated allowing SONIA to record more highly deformed strata lying below. Between Purisma Point and Point Arguello, where the post-Wisconsin stratigraphic sequence is thickest, SONIA did not record the underlying deformed unit and this resulted in poor correlations between profiles. South of Point Arguello, recognition of geologic structures and their correlation was hampered by discontinuous reflectors, high-amplitude water waves, and bedding dips that closely parallel the dip of the inner slope. Two acoustic sratigraphic units are recognized for the purposes of this study:

Unit A: Unit A consists of the unlithified, flat-lying, modern marine sediment. The unit is well bedded, dips very gently seaward, and lies unconformably over relatively highly deformed strata of Unit B. Based on a velocity of 1,585 m/sec (Wagner, 1974), typical thicknesses of Unit A are approximately 20 to 25 m in the mid shelf areas and about 10 m near the shelf edge. Maximum thickness is about 36 m in the area between Purisima Point and Point Arguello; this greater thickness is probably due to sediment influx from the Santa Ynez River. These sediment thicknesses yield depositional rates ranging from 5 mm/yr to 18 mm/yr over a 20,000 year interval. Based on the general nature of seafloor sediments in this region as seen from previous studies and on the nature of the reflectors seen on the SONIA profiles, Unit A is believed to consist of interbedded sands, silts, clays, and minor gravel lenses. A fairly common characteristic of Unit A is an acoustically transparent lower layer which is probably mostly sand. This relatively transparent layer comprises up to about half of the thickness of Unit A nearer shore but gradually thins seaward (Fig. 4) and generally pinches out near the edge of the shelf (Fig. 12). Structural deformation of Unit A consists of slight warping (Fig. 4), tilting, and minor scattered faulting (Figs. 6-8).

Unit A deposits form an onlapping relationship with the underlying beveled rock surface and thus appear to be a result of deposition during a sea level transgression. The onlap sequence is locally overlain by "deltaic" sediments near shore (foreset bedding). Deposition of these "deltaic" sediments as well as migration and reworking of sediments by longshore currents, density currents, and storm waves has probably modified some of the original sedimentary materials and structures but there is no evidence of extensive reworking or erosion within Unit A. This continuous record of sedimentation suggests that the deposits were laid down during the last sea-level transgression which began about 17,000 to 20,000 years ago. The age of the unit then is less than about 17,000-20,000 years.

Unit B: Unit B comprises the strata below the beveled late Wisconsin surface. Unit B is distinguished from Unit A by its greater amount of folding and faulting and by its angular unconformity with the overlying Unit A strata (see, for example, Fig. 6). In many cases, however, Unit B is recognized only by the presence of a faint reflector assumed to represent the late Wisconsin beveled surface (for example, Fig. 7). The beveled surface is generally very flat but becomes irregular near shore where its slope increases relatively abruptly. This change in slope is not believed to be a result of faulting because it exists in areas where neither the deep nor shallow seismic reflectors indicate faults. Upwarping immediately prior to or during the last sea-level transgression could have been partially responsible for this rise, or it simply may be a result of the nearshore area having experienced a shorter interval of erosion owing to the relatively recent transgression of the sea into the nearshore area.

No attempt has been made to subdivide Unit B into geologic formations because of the paucity of offshore borehole data and distinctive marker horizons. Unit B strata are assumed to be correlative predominantly to the Miocene to Pliocene Monterey, Sisquoc, and Foxen formations, but in some areas, such as near Point Sal, the Knoxville-Franciscan melange probably is also present. In addition to the Tertiary and Mesozoic strata, some lower to upper Pleistocene strata may be included in Unit B (Figs. 5 and 12). Correlations to the above formations are based on several factors;

1) lithologic and geophysical data from the Oceano No. 1 well in the northern part of the study area (Plate 1) which revealed an offshore stratigraphy similar to that onshore,

2) previous interpretations based on seismic reflection studies just north of the study area (Hoskins and Griffiths, 1971; Wagner, 1974; Pacific Gas and Electric Company, 1974),

3) previous surficial geologic field studies by Fugro in the onshore region which reveal that these formations crop out along the coast, and trend into the offshore region,

4) previous onshore subsurface studies (Department of Water Resources, 1970; proprietary oil company data) which show that these formations occur at depth near the shoreline and thus indicate that these formations probably extend offshore for some distance.

Unit B has been assigned a velocity of 2,439 m/sec based on previous studies (Wagner, 1974). However, the younger rocks, which are generally shales, siltstones, and mudstones, probably have a lower velocity than the older rocks which are commonly well indurated igneous rocks or compacted sedimentary rocks (Hoskins and Griffiths, 1971).

Age of Unit B Surface

The beveled, late-Tertiary strata (Unit B) underlying the modern modern marine sediment (Unit A) are considered to have been eroded by the last major eustatic sea-level cycle which commenced with a regression approximately 30,000 to 40,000 years B.P. The Unit A sediments overlying the beveled erosional surface are assumed to have been deposited during the last sea-level transgression beginning about 17,000-20,000 years ago.

The background behind these age assignments is as follows:

1) Uranium-series and amino acid dates from the lowest marine terraces along the central and southern California coast yield ages ranging from about 80,000 to 200,000 years old (Veeh and Valentine, 1967; Wehmiller and others, 1974; Ku and Kern, 1974; Lajoie, personal commun., 1978). These dates are roughly equivalent to the "Sangamon interglacial stage" of the mid-continent region of North America. Most dates, however, fall in the 80,000-130,000 range indicative of a "late Sangamon" high stand of sea level correlative with stage 5 of the standard O^{18}/O^{16} sea level (see, for example Emiliani, 1966; Shackleton and Opdyke, 1973). Aerial photograph and geomorphic field analyses of the terraces and their associated deposits in the Point Sal-Point Arguello area by Fugro (unpub. data) also suggest a Sangamon age for these terraces.

   Correlation of the terraces between Cayucos and Santa Barbara is often tenuous owing to differential uplift, folding, and faulting. However, there does not appear to have been any major tectonic subsidence in the study area within the last 80,000 years, thus the lowest prominent emergent terrace along the coast of the study area is assumed to be late Sangamon and the eroded surface on Unit B is younger than late Sangamon (Stage 5a).

2) Onshore, along the flanks of the Casmalia Hills the late Pleistocene Orcutt Formation is locally tilted as much as

12 degrees (Woodring and Bramlette, 1950). Correlative marine sediments, if present, at the western offshore extension of the Casmalia Hills structure should also show deformation. Unit A strata lapping onto this uplift are not deformed and therefore must be younger than the Orcutt Formation.

3) The mid-Wisconsin high stand of sea level occurred about 30,000 to 40,000 years ago (Stage 3) when sea level transgressed to within about 20 m below present mean sea level (MSL). The late Wisconsin low stand (Stage 2) of this sea occurred about 17,000-20,000 years ago with sea level lowering to about 120 to 130 m below MSL. At that time the shoreline was probably near the edge of the present coastal shelf which is about 110 m to 140 m below MSL. This emergence of the shelf allowed subaerial erosion of Unit B strata and any overlying Pleistocene sediments.

   The post-glacial rise in sea level, occurring about 17,000 to 5,000 years ago, apparently resulted in beveling of bedrock and removal of most, if not all, of the post-late Sangamon continental deposits. The lack of erosion and unconformities within Unit A suggests that deposition of this unit was not interrupted by major uplift, warping, or rising and falling sea levels. This suggests that they were deposited during only one transgression and this must have been the most recent one beginning about 17,000 to 20,000 years ago. Much of Unit A may have been laid down in the last 5,000-6,000 years when sea level reached approximately its present position and submarine sedimentation began prograding seaward across the modern continental shelf.

Geologic Structure

General: Alternating synclines and anticlines, mapped from SONIA records, are generally symmetrical, of small amplitude, and relatively gently folded. Folds are short (about 3 to 4 km long) and discontinuous. Correlation of folds between profile lines was difficult due to the large distance between lines compared to the lengths of the features. Line 10 (Fig. 3) between Purisima Point and Point Sal, shows folds which are interpreted to trend east-west to west-northwest. This fold orientation would suggest compressional forces predominantly from the south and southwest. Based on comparison to sparker and boomer profiles (Polaris cruise), these folds appear to be minor features superimposed over larger folds at depth. The folds on Figure 3, for example, may be minor folds in a larger synclinorium which appears to extend onshore beneath San Antonio Terrace.

The locations of the fault traces mapped with sparker and boomer systems prior to this study (Hoskins and Griffiths, 1971; Wagner, 1974; Pacific Gas and Electric Company, 1974) were interpretive and often conjectural due to the low resolution inherent in the geophysical tools used. With the high resolution of the SONIA system, portions of the Hosgri, Offshore Lompoc, and a few other unnamed faults could be identified within the shallow subbottom sediment (Unit A) and located more pecisely. Others, such as the Purisima fault are questionable at least within the shallow subbottom.

Although the lines ESA 1-9 (Plate 1) are proprietary and not submitted with this report they provided valuable information on structural trends farther offshore. Specifically, lines ESA 7, 8, and 9 showed subtle similarities in stratigraphy and subbottom morphology which seem to indicate that the structural trends are merging toward Point Arguello.

The following paragraphs summarize significant observations made from SONIA profiles at specific localities along specific lines. Interpreted SONIA records are shown on Figures 3 through 16. A geologic map (Plate 1) showing the distribution of these features is in a pocket in the back of this report.

Hosgri Fault: The Hosgri fault was observed along lines 101, 41, 39, 118, 35, 33, and 29 (Figs. 4 through 10). No bathymetric expression of the fault was noted, however, post-Wisconsin age sediments (Unit A) clearly have been displaced along lines 118 and 35 (Figs. 7 and 8). The signature of reflectors on line 35 (Fig. 8) suggests that fault displacement is very young and that only the uppermost reflector is not affected. Along lines 101, 41, and 39 (Figs. 4 through 6) Unit B sediments are disrupted and/or have evidence of subbottom displacement. Apparent displacements do not exceed about 2.5 m vertically. Lateral displacement could not be measured, however, some evidence of lateral movement may be suggested from the variable thickness of beds on opposite sides of fault planes (Figs. 5 and 8), and from warping (drag?) of beds near the fault plane(s) (Fig. 5) which suggests compressional forces.

The fault planes are rarely obvious on the profiles but where observed they appear to be high angle with dips ranging between vertical and 45 degrees. Where vertical displacement is evident, the east block is generally up with respect to the west block. The fault varies from a single break (Fig. 8) to several breaks over a zone about 2,000 m wide (Fig. 6). Some features, such as observed on line 33 (Fig. 9), are only irregularities (rock highs) in the Unit B surface and do not necessarily denote fault displacement. However, alignment of such features along the projection of the Hosgri fault trace between definite post-Wisconsin displacements suggests that these irregular features may be related to faulting.

The Hosgri fault was not observed south of line 29; the possible explanations for this are that the fault: 1) terminates at this point; 2) is transformed into folded structures;

3) cuts back across the structural fabric and continues southward in the offshore area without post-Wisconsin displacement, or 4) continues along its projected alignment towards land without post-Wisconsin displacement (if the fault is projected along its trend it would have a landfall between Purisima Point and Point Arguello). Geologic maps and aerial photographs on land do not indicate a major onshore active fault in this area and there is no strong evidence in either the deep-penetration or the SONIA profiles of a major southerly or southwesterly trending offshore fault, thus it seems that the Hosgri fault may terminate in this region. Projection of the Hosgri fault shows an alignment with northwest-southeast trending small faults and folds in the Point Arguello area suggesting that the termination may be involved with folding in the western Transverse Ranges.

Offshore Purisima Fault: The Offshore Purisima fault was originally described as "possibly two intersecting faults" (Pacific Gas and Electric Company, 1975). The southern portion was inferred to exist on the basis of discordant dips across the line of inflection of a large upwarp. SONIA records do show folding but only inconclusive evidence for faulting. The northern section of the fault projects to the western end of line 39 where there is a seafloor anomaly, but whether this anomaly represents fault displacement or merely erosion of sediments over the bedrock upwarp could not be determined with great confidence.

Offshore Lompoc Fault: Upon completion of the Hosgri fault investigation, nine additional lines were run over the area of the Offshore Lompoc fault (Plate 1). These lines were run for private groups (Pacific Gas and Electric Company and Earth Science Associates) at no cost to the U.S. Government, and thus the original profiles are not submitted with this report. However, permission has been granted to utilize these profiles in our evaluation.

The Offshore Lompoc fault is the informal name applied by Pacific Gas and Electric Company (1974) to a pair of prominent subparallel faults located approximately 17 km west of Purisima Point. The westernmost fault is an eastward dipping reverse fault which parallels the western flank of a large anticline. Figures 13, 14, and 15 are examples of profiles transecting features believed to be associated with the Offshore Lompoc fault. The major feature is an anticlinal upwarp of Unit B strata which rises about 30 m above the general level of the seafloor (Fig. 15). The feature is the strongest seafloor irregularity encountered in the study area, and coincides with a strong positive magnetic residual (Pisciotto and others, 1974). The upwarp is marked by erosional channels on both its eastern and western flanks. The western channel may show evidence of being fault controlled on Figure 15, but not on Figure 13. The area farther to the west of the anticline shows several features of possible fault origin. This area to the west of the anticline is a broad zone of chaotic reflectors, many of which are probably slumps. The fault zone as indicated on Plate 1 is quite wide because, in addition to several suspected faults,it includes features which may represent seismically induced slumps. The major seafloor disruptions suggestive of faults are marked by a line within the shaded zone. The total length of the fault zone is about 20 km; the exposed bedrock upwarp is about 10 km long (Plate 1). In addition to faults, there are numerous local unconformities on both the east and west limbs of the anticline suggesting that it has experienced episodic uplift during late Pliocene up to at least late Pleistocene time.

Other Faults: The offshore projections of the Pezzoni, Lions Head, Honda, and Pacifico faults were crossed with SONIA profiles at least once but no bathymetric disruptions or displacement of Unit A or B sediments were observed. Several small faults in Unit B were detected on lines 33 and 35 (Plate 1); one of these (SP 90-91, line 33) appears to displace the seafloor.

Linear Seafloor Rock Outcrops (Hogbacks): Several seafloor rock outcrops or hogbacks identified on SONIA records between Point Arguello and Point Conception were important in establishing structural trends because of the lack of other correlatable features (Plate 1). These bedrock protrusions extend above the general level of the beveled Unit B surface and in some cases extend above the seafloor as outcrops. Where bedding is conspicuous the ridges dip in the same direction as the subbottom strata. The ridges are of low relief, averaging 1 to 3 m in height, and probably consist of well indurated, erosion resistant beds. Correlation of these rock outcrops (seen on lines 11, 5, 7, and 111) suggests a northwest-southeast structural trend south of Point Arguello which nearly parallels the coastline. This trend is considerably more northwesterly than the structural trend north of Point Arguello.

Submarine Landslides: Submarine landslides were observed along Lines 102 and 45 (Plate 1; Fig. 16). These rotational slump features extend 20 m into the subbottom strata, may be as much as 1,000 m in length, and occur on about 2 degree slopes. The disruption of the seafloor suggests that these slumps occurred in late Holocene time.

Subbottom Angular Unconformity

A well defined group of angular unconformities at the edge of the inner shelf (Fig. 12) can be observed extending from line 39 in the north to line 118 on the south, a distance of about 7 km (Plate 1). In addition to the angular discordance between Unit A and B, there are up to four or five intermediate units which represent several episodes of deposition separated by episodes of local uplift and folding. These units probably are Pleistocene in age and perhaps even late Pliocene. The position of these angular unconformities is believed to approximate the point of maxium withdrawal of the last Wisconsin sea level. Deposits west of about shotpoints 54 and 55 (Fig. 12) then would represent near-shore marine sediments deposited during the latest Wisconsin interval (30,000-40,000 to 17,000-20,0000 years B.P.

CONCLUSIONS

The Hosgri fault was noted along seven SONIA profile lines, with evidence of displaced Unit A sediments on five of the lines in the area between Point Sal and Purisima Point. The fault zone is as much as 2 km wide in Unit B but in most cases only a single trace could be identified in Unit A. The displacements of Unit A indicate that the Hosgri fault has been active in latest Pleistocene and perhaps Holocene times (less than 17,000-20,000 years). The lack of seafloor displacements, although not conclusive, does not favor speculations that the 1927 Point Arguello earthquake occurred on the Hosgri fault.

Upper post-Wisconsin beds are continuous south of line 29 suggesting that the Hosgri fault terminates in this area or is too deep to be picked up by the SONIA system. Based on onshore geologic field data and both deep- and shallow-penetration geophysical data offshore we conclude that the fault probably terminates at about the latitude of Purisima Point, and that the regional stress is probably absorbed by folds or smaller faults with western Transverse Range orientations. The termination of the Hosgri fault in this manner is in accord with the general merging of structural trends of the offshore area with trends of the western Transverse Ranges.

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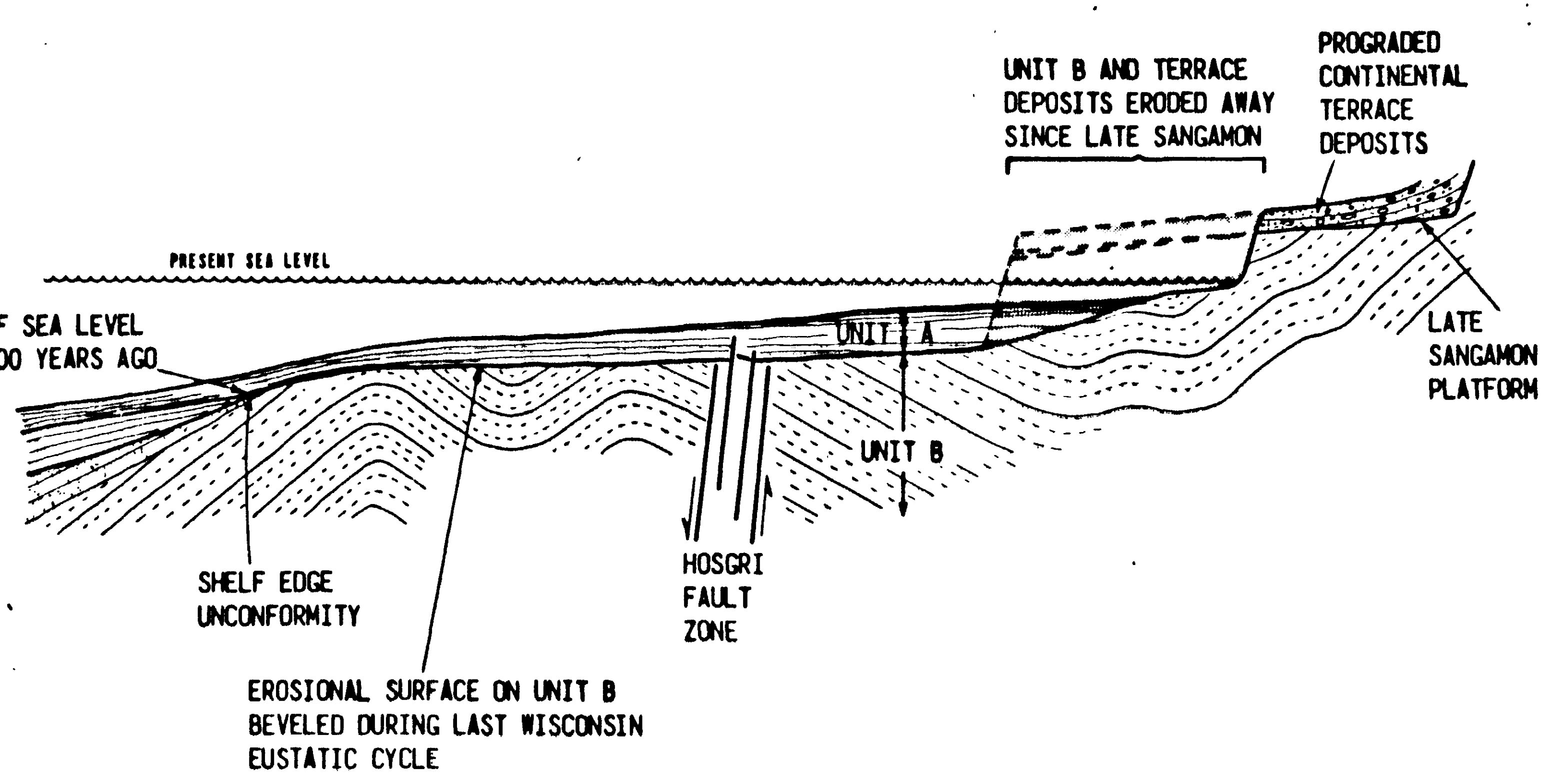


FUGRO

PROJECT NO.: 78-157

USGS HOSGRI FAULT INVESTIGATION

DIAGRAMMATIC GEOLOGIC CROSS SECTION,
INNER CONTINENTAL SHELF;
POINT SAL-POINT ARGUELLO AREA

11-78

FIGURE 2

APPENDIX A

THE SONIA SYSTEM

The SONIA subbottom profiling system (Fig. A-1) was designed specifically for geotechnical evaluation of shallow subbottom conditions. The high resolution and illustrative records of the SONIA system are unique and eliminate much of the interpretation required with conventional seismic reflection systems.

The SONIA (Table A-1) has a versatile, state-of-the-art electronic amplifying and recording package, but the transducer sets it apart from other high resolution systems. The principal advantages provided by the transducer are its short pulse length, its narrow beam width, and its large acoustic power. Additionally, it is very stable (highly repeatable), and doesn't ring.

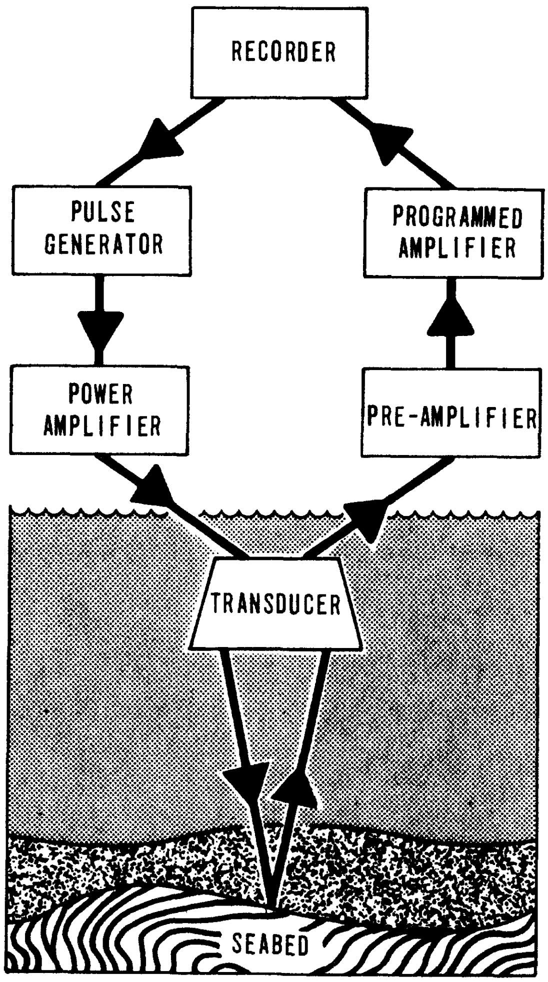
The limit of discrimination of successive reflections, or the ability to detect thin layers, is mainly determined by the length (time) of the acoustic pulse. If the acoustic pulse is long, the reflection will be long, as well, thereby masking any subsequent reflections which might arrive shortly after the onset of the previous reflection. To detect thin layers, short acoustic pulses must be used. The SONIA pulse length is 1/3 millisecond when operating at 3 kiloHertz (kHz). These pulses are approximately half (or less) of those achieved by other high-resolution systems.

The recording system is equipped with band-pass filters, time-varied gain adjustable for maximum gain (between 0 and 100 db) and rate of change (0 - 20,000 db/sec). The time at which the time-varied gain is triggered is also adjustable. It can be set manually according to time, or it can be set to trigger automatically from either the transmitted pulse or the bottom reflection.

TABLE A-1

SONIA TECHNICAL DATA

- Large transducer (38" diameter), mounted over the side of the vessel. Directional characteristics of transducer similar to transmitting characteristics.
- Directed sound beam. Directional characteristics depend on frequency used.
- Sound frequency 3 kHz.
- Power. Maximum electric power is 10 kw. Maximum acoustic power is 7.5 kw. Variable in steps.
- Electric pulse length 1/6 - 5-1/3 msec., variable in steps. Acoustic pulse length 1/3 - 5-1/3 msec.
- Pulse repetition rate 32, 64, 128 or 256 msec. with line adjustment of 20% around these values.
- Pulse stabilization.
- Programmed amplifier.
- Variable gain.
- Time varied gain with time varied start and with possibility to treigger T.V.G. by the reflection of the sea-floor.
- Variable dynamics.
- Matched filter.
- 3 kHz band pass filter.
- Electro-chemical precision graphic recorder.
- Gain of power amplifier variable in steps.
- Width of paper 19".
- Vertical scale of recording (sound velocity 1500 m/sec.) continuously variable.
- Full-wave rectification or half-wave rectification before recording of signal.
- Precision power supply (stability better than 0.0005%).
- Back line indication for marking position fixes and particular events.



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THE SONIA SYSTEM

FIGURE A-1