

The same devices for definition of sea floor boundaries—the “transponder” geodetic bench marks—could be used for FAA type monitoring of surface or submerged vehicle movements first at ports, and then throughout coastlines and into the deep ocean waters.

The state of the art of technology with both battery powered transponders (for temporary fixes and short life) and atomic powered transponders (for long-life and long-range capability) makes the installation economical and reasonable at this time.

Areas such as the North Sea, the Black Sea, the Red Sea, the Adriatic, the Gulf of Aqaba, and others could be surveyed and temporarily zoned in a technically accurate manner. A plan for five or six such pilot surveys will be proposed to the United Nations.

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WHAT'S AHEAD ON O.C.S. IN PACIFIC

(No abstract submitted)

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Glomar Challenger and DEEP-SEA DRILLING PROGRAM

Glomar Challenger has been engaged in its unique assignment of investigating the character of deep-ocean-floor sediments since August, 1968 and at year end was well into the third of four Atlantic Ocean segments. The very comprehensive documentation of this effort includes the film that is presented with this paper, which was taken during the sea trials and first leg of the voyage.

A geologic summary of the status and goals of the program and some of the findings developed during the *Challenger's* initial efforts is presented by courtesy of Scripps Institution of Oceanography, operators for the program. Both the technical and academic results of the coring program have been very gratifying to date.

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ADAK “PALEOZOIC” SITE, ALEUTIANS—IN FACT OF EOCENE AGE¹

In 1946 several specimens of the plant genus *Annularia* [cf. *A. stellata* (Schlotheim) Wood], a primitive horsetail of Pennsylvanian or Permian age, were found by Robert R. Coats of the U.S. Geological Survey in tuffaceous sandstone exposed near Andrew Lake, northern Adak Island, Alaska. Because of the geographic position of these upper Paleozoic fossils near the middle of the Aleutian insular chain, it has been a challenging if not a vexing problem to fit the enclosing rocks into a structural scheme for the development of the Aleutian ridge. In view of this, the enigmatic upper Paleozoic section was restudied during

¹ Publication authorized by the Director, U.S. Geological Survey.

July 1968 to enlarge the fossil collection and to determine its depositional environment and stratigraphic setting.

The *Annularia*-bearing beds are associated with a sequence of sedimentary rocks that is more than 850 m thick, and that consists mainly of northwest dipping tuffaceous sandstone, siltstone, and shale, and siliceous and calcareous siltstone and shale interbedded with basaltic flows and/or penecontemporaneous sills a few tens of meters thick. Specimens of *Annularia* have been found only within the basal 5–10 m of this section, which lies with apparent depositional contact on the massive and intensely altered andesitic and basaltic flows and pyroclastic rocks of the Finger Bay Volcanics that form most of Atak Island. The top of the section is not exposed. The section is uncomplicated structurally and dips homoclinally northwestward between 40° and 65°; it is exposed across an area of about 2.5 km² (approximately 1 sq mi).

Mollusks, Foraminifera, sponge spicules, fish scales, and skeletal remains were found by the writers in the lower 350 m of the section just above the basal *Annularia*-bearing beds. Included in this fauna is the mud pecten *Propeamossium* [cf. *P. stanfordensis* (Arnold)], indicating a probable Eocene age; the associated foraminiferal fauna is of definite Eocene (most likely late Eocene) age, and the fish scales are similar to those found in the Refugian and Narizian (Eocene-Oligocene) of California. The microfossils imply a paleobathymetry of 1000 meters or deeper. In consideration of these new findings, the rock matrix surrounding specimens of *Annularia* was searched for microfossils. A substantial dinoflagellate flora was found—establishing that the *Annularia*-bearing beds are themselves marine units of early Tertiary age. The paleontologic and stratigraphic significance of *Annularia* is now being reevaluated.

The Adak findings clearly establish that at least a portion of the structural framework of the Aleutian Ridge was in existence by early Tertiary time.

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AIR FORCE WESTERN TEST RANGE OPERATIONS

(No abstract submitted)

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RAPID CHANGES IN HEAD OF RÍO BALSAS SUBMARINE CANYON, MEXICO

The Río Balsas submarine canyon heads in or near the surf zone of Mexico's Pacific coast, 280 km northwest of Acapulco. One of its tributaries is related directly to the main distributary of a large river of the same name. Seaward, the canyon terminates in the Middle America Trench.

The intricately bifurcated heads of the tributaries were investigated by divers. They are cut into poorly consolidated deltaic sediments. The walls commonly slope more than 30°, and are vertical to overhanging where sedimentary strata are exposed. The tributaries apparently are not controlled tectonically.

Shifts in river discharge cause formation of new tributaries and filling of old ones. The easternmost tributary heads in an embayment formerly associated with the main river discharge. Sediments exposed in three

overhanging banks, at depths of 7.5, 17, and 32 m, were deposited less than 185 years ago according to C^{14} dates. Historic records indicate that the major river discharge shifted away from this tributary about 100 years ago. Thus the canyon apparently was deepened by at least 25 m in 100 years.

It is concluded that canyon cutting can progress at rapid rates, that submarine processes can form tributaries, and that, therefore, a dendritic canyon pattern is not necessarily indicative of subaerial erosion.

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SUMMARY REPORT ON RECENT DEVELOPMENTS, SANTA BARBARA CHANNEL, CALIFORNIA

The Santa Barbara Channel is between the Oxnard plain in Ventura County on the east and Point Conception in Santa Barbara County on the west. It is approximately 75 mi long and 22 mi wide, and encompasses an area of about 1,650 sq mi. It is bounded on the north and east by the Santa Barbara County-Ventura County coastline and on the south by the westward-trending Channel Islands chain. Maximum water depth is 2,050 ft. The areal extent of federal acreage in the channel is approximately 1,250 sq mi.

Geologically, the area comprises the western half of the prolific oil-producing Ventura basin. More than \$100 million has been spent on channel exploration during the past 20 years and has indicated substantial oil-producing potential.

On February 6, 1968, 165 bids totaling \$1,293,601,113.26 were submitted on 75 of the 110 tracts offered for lease by the U.S. government. These covered the most promising of the known geologic structures within the federal channel area. Bids ranged from a high of \$61,418,000 (\$11,373.70 per acre) to a low of \$92,736 (16.10 per acre). Four bids were rejected as too low for the tracts offered. The amount overbid by successful bidders totaled nearly \$273 million. Exploratory drilling commenced immediately after the awarding of leases. All available drilling vessels and platforms are being utilized and activity has proceeded continuously.

Statistics covering exploration and development activity during the first year of channel operations under federal leases have been compiled.

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ANACAPA RIFT, CALIFORNIA

The Channel Islands, like the Salinian block, have been explained as a granitic spur projecting westward into the Franciscan realm of coastal and offshore California. According to Ralph Reed, this spur was the autochthonous Anacapa, but according to P. B. King, the spur was an allochthonous sliver derived by lateral fault movement.

Both interpretations require a boundary fault south of the Channel Islands; actually, the fault picture is more complex. The Malibu Coast fault, arcuate and convex southward in plan, appears to extend from Beverly Hills across the Mugu-Hueneme submarine fan into the eastern Santa Barbara Channel north of Anacapa Island. The Santa Cruz Island fault, also convex southward, continues south of Anacapa.

San Onofre Breccia flanks both faults. San Onofre paleocurrent indicators on Santa Cruz Island and limited San Onofre outcrops on the northern tip of Santa

Rose Island indicate the blueschist basement source was northeast of the Santa Cruz Island fault, thereby invalidating the Anacapa spur-silver concept. Instead, Anacapa is a microcontinent of granite with a Cretaceous-Eocene sedimentary veneer. The granite tectonically overlies Franciscan and is separated from the mainland by a rift bounded by the Malibu Coast and Santa Cruz Island faults.

The pre-Mohanian terrane in the rift is mainly volcanic, and presumably overlies Franciscan basement. This basement was exposed during Miocene time, when the Channel Islands raft drifted westward from the Santa Monica Mountains. At first, the ductile Franciscan welled up in the rift as a tectonic ridge, shedding San Onofre talus on either side. Subsequently, the ridge in the rift sank, and gravity tectonics were produced in the Santa Monica Mountains.

Palinspastic restoration of the 80-km lateral offset and the 20-km rift extension brings together similar Cretaceous-Eocene sequences of the Channel Islands and Santa Monica Mountains, and connects Poway Conglomerate clast assemblages of the islands with their mainland source.

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MIOCENE VOLCANIC ROCKS OF NORTHERN CHANNEL ISLANDS, CALIFORNIA

(No abstract submitted)

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MIOCENE VOLCANICS OF WESTERN SANTA MONICA MOUNTAINS, CALIFORNIA

In the western Santa Monica Mountains the Miocene volcanics consist of olivine basalt, basalt, andesite and dacite flows, breccias, pyroclastic rocks, volcanic-derived epiclastic rocks, and associated intrusive bodies of related compositions. Pillow breccias are abundant in some areas, almost everywhere near the base of the volcanic sequence. True pillow lavas are scarce. Chemical analysis of these rocks show them to be low in FeO, Fe₂O₃, and MgO, and very low in K₂O. Silica content ranges from 45.31 to 66.12 percent.

The more basic rocks generally are present in the lower half of the volcanic sequence and the less basic are present in the upper third of the sequence. However, there is no consistent variation trend and the tendencies are of limited usefulness for purposes of stratigraphic correlation. Some tentative statement about a rock's probable stratigraphic position can be made if it contains olivine or is largely a pillow breccia (low in sequence), or if it contains primary quartz with or without oxyhornblende (high in sequence).

A comparison of the volcanic rocks near the eastern end of their continuous outcrop area with those near the western end shows the latter to be of similar petrographic types but much more extensively altered. Toward the western end, fresh ferromagnesian rock types are scarce, the minerals having been replaced in part or completely by bowlingite, iddingsite, etc. The plagioclase is commonly affected and partly replaced by kaolinite or carbonate and commonly partly albitized. The glass has devitrified or has been replaced.

The dominant structure of the volcanics in the mountains is that of a north-dipping homocline broken by steep east-west or east-northeast to west-northwest faults. Broad east-west folding also is recognized at several places.