CENE-OLIGOCENE, SANTA YNEZ MOUNTAINS, CALIFORNIA

Facies relations between deep and shallow-marine to continental deposits in the Eocene-Oligocene sequence of the Santa Ynez Mountains, California, have been studied in detail. The rocks studied include the Anita, Sierra Blanca, Juncal (with Camino Cielo Member), Matilija, Cozy Dell, and "Coldwater" formations. The topmost unit of the Eocene-Oligocene sequence, the nonmarine Sespe Formation, was not included in this study.

In landward sequence, the facies recognized include turbidites and marine lutites, proximal turbidites, shallow-marine, coastal, and continental facies. These are present in 2 major regressive sequences. In the first, the Juncal-Matilija sequence, thin-bedded turbidites and marine lutites are overlain by, and are laterally equivalent to, very thick proximal turbidites which pass upward into shallow-marine and coastal sands. The major sand accumulations are in the basin-margin shallow-marine, coastal, and proximal-turbidite facies. The second regression, the Cozy Dell-Sespe sequence, lacks significant proximal-turbidite deposits, but has extensive shallow-marine and coastal deposits. Facies distribution and stratigraphic sequence are explained as responses to the interplay of depositional and structural processes.

Detailed stratigraphic mapping has clarified correlation in the Eocene sequence of the Santa Ynez Mountains. Micropaleontology is used in support of correlations and bathymetric interpretations. Stratigraphic and paleontologic data resolve a biofacies problem in the lower to upper Narizian interval and clarify definition of the Eocene-Cretaceous boundary. Bathymetric interpretations based on comparison of fossil assemblages with modern Gulf of Mexico fauna are in better agreement with depths of deposition interpreted from lithologic data than interpretations based on comparison with modern assemblages in the Pacific Ocean off California.

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SEISMIC EXPLORATION IN CANADIAN ARCTIC

No abstract available.

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SEDIMENT DISTRIBUTION IN SOUTHWESTERN INDIAN OCEAN

Sediment distribution patterns in the southern Mozambique Channel and adjacent southwest Indian Ocean were investigated from short gravity cores and surface bottom samples. These shelves are covered by terrigenous sediments of varying grain sizes, chiefly silty, and upper slopes by hemipelagic calcareous mud. Areas of nondeposition on parts of the African shelf and upper slope reflect the winnowing action of the Mozambique-Agulhas Current. Relict foraminiferal faunas and exposed beachrock on the African shelf indicate a former lowered sea level. Lower continental slopes (below 1,500 m), continental rises, and plateaus are covered by foraminiferal marl and chalk oozes whose distribution correlates in part with the grain-size distribution. A size analysis of planktonic Foraminifera indicates that concentrations of small and large tests in some oozes are due to sorting. Manganese nodules are abundant on the Mozambique Plateau, which is swept by an eddy of Antarctic Intermediate Water. Natal basin sediments include turbidites, derived from neritic and bathyal depths, which are dispersed from northwest to southeast. Surficial turbidite layers did not reach the southern part of the basin floor, which is covered by pelagic clay and manganese nodules.

Average sedimentation rates of sediments younger than approximately 4,000-6,000 years range from 1 to 9 cm/1,000 years, depending on topographic position and distance from land. The average rate of accumulation for undisturbed deep-sea ooze during the entire late Quaternary is 1.5-2.5 cm/1,000 years.

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TRANSPORT PROCESSES FOR LOWER PALEOZOIC RESEDIMENTED CONGLOMERATES OF APPALACHIANS

Three fining-upward sequences of resedimented conglomerate, totaling about 40 m in thickness, are present in the lower Paleozoic Cap Enragé Formation of Gaspé, Quebec. Boulders, dominantly of shelf-type carbonate rocks, are up to 3 m in diameter, but average about 10-50 cm. Individual beds are more commonly massive than normally graded, although inverse grading occurs at the base of many beds. Stratification, delineated by alternations of grain size, is common.

At the base of each fining-upward sequence, beds tend to be poorly sorted, and contain very large boulders. At the top of the sequences, well sorted conglomerates, with pebbles normally less than 5 cm, are interbedded with sandstones. Deep scouring is uncommon.

The best clue to the transport process which resedimented the conglomerates into the Appalachian geosyncline is the well-defined pebble fabric. Most beds show a strong preferred southwest orientation of *a*-axes in plan view. In vertical cross section, most beds show a well-developed pebble imbrication. The *a*-axes of the pebbles dip upstream (rather than lying horizontal, transverse to flow) and indicate flow toward the southwest, parallel with the present tectonic strike. This type of fabric is very rare in deposits where pebbles rolled as bed load, because such movement develops a transverse *a*-axis fabric. Bed load transport was minimal to nonexistent for these conglomerates. Alternative mechanisms include some form of mass flow for each bed, or movement of pebbles in suspension. Mass flow is unlikely because of the well-developed imbrication and stratification, and hence it is suggested that the pebbles fell onto the bed out of fluid suspension, and were not subsequently moved. The outstanding problem is how the boulders were maintained in fluid suspension.

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CAMBRIAN OF THE GRAND CANYON—A REEVALUATION

The Grand Canyon Cambrian, previously thought to represent a subtidal transgressive-regressive sequence recording deepening offshore accumulations of marine sandstone, shale, and limestone, is reinterpreted to record shallow-marine, tidal-flat, and fluvial sedimentation on the landward part of a vast cratonic platform marginal to the Cordilleran miogeosyncline

The basal Tapeats Sandstone is dominantly trough-crossbedded, contains no record of organic activity or marine-tracer grains, and displays a low-variance, unimodal paleocurrent trend down the paleoslope. This part of the Tapeats Sandstone records prevegetation, bed-load fluvial sedimentation.

Shallow-marine "lagoonal" deposits dominate the rest of the sequence: burrowed, very thinly interbedded fine sandstones and shales (Bright Angel Shale) and arenaceous or soft-pellet limestones and dolomitic siltstones (Muav Limestone).

Within the Bright Angel Shale, many 1-6 m thick units of burrowed, cross-laminated sandstone and glauconitic sandstone record shoaling sedimentation. These sandstones locally are succeeded by hematitic oolite beds which were exposure surfaces. Unburrowed, channeled, flaser-bedded sandstones form an extensive 20 m thick tidal-flat sequence in the western Grand Canyon.

Within the Muav Limestone, 1-8 m thick units of dolomitized eocrinoidal biocalcarenite and algal-ball limestone, flat-pebble intraclast beds, and a few stromatolites emphasize the shoaling nature of the carbonate platform. A 20 m thick, dolo-

laminite, tidal-flat unit locally interrupts the marine limestone sequence at the western (more offshore) end of the Grand Canyon.

The 250-500 m Cambrian sequence appears to consist of more than 30 laterally persistent sedimentation cycles that are grouped into 5 grand cycles. The basal Tapeats Sandstone and the clastic and carbonate tidal flats are not cyclic.

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MICROSTYLOLITES, BEDDING, AND DOLOMITIZATION

Microstylolites are fine dissolution surfaces, with a relief of only 20-40 microns, on which a thin film of silicic-clastic clay and platy silt is concentrated. They commonly form in slightly shaly limestone during secondary (overburden) compaction. Two causes appear to inhibit microstylolite growth: the film concentrate of clay and silt chokes the dissolution surface as a pathway for fluid migration, and acts as a glide plane to relieve stress along the surface.

Microstylolites can accentuate or distort primary sedimentary structures and appear to control the pattern of dolomitization. 1. They commonly accentuate stromatolitic or ripple laminations and outline limestone intraclasts. 2. Thinly-bedded, knobbly, nodular, lumpy, braided or boudinage limestones, characteristic of Paleozoic platform carbonates, appear to result from a microstylolitic induced distortion of originally thin, continuous beds of slightly shaly, pelleted lime muds interbedded with limy (now dolomitic) shale. "Swarms" of subhorizontal, interconnected microstylolites are present throughout both the dolomitic shale interbeds and the dolomitic areas between limestone knobbles. Thin swarms penetrate the sides of limestone knobbles, cutting off clots of limestone. The areas between adjacent knobbles have undergone 20-80% solution thinning, with tension fracturing of the brittle limestone knobbles and flowage along microstylolite surfaces into the area between knobbles. Overburden compaction with microstylolitic dissolution and flowage explains the knobbly bedding. 3. Zoned dolomite rhombs (less than 60 microns) are present in intimate association with microstylolites. In knobbly limestones these rhombs are much coarser than unzoned rhombs scattered throughout the limestone, and are so abundant that they cannot be explained as a simple stylolite solution concentration. Rather, some attribute of the microstylolites, *i.e.*, permeability-controlled fluid migration, composition of concentrate, or differential pressure, provided preferential conditions for dolomitization. Much of the fine-scale, primary or stratigraphic dolomite appears to be a product of preferential dolomitization along microstylolites.

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ABYSSAL SEDIMENT BURROWERS—TRACE FOSSILS IN CARIBBEAN CHALKS AND MARLS, DEEP-SEA DRILLING PROJECT CORES

Cores recovered in the Caribbean Sea on JOIDES Leg 15 exhibit a superb assemblage of biogenic sedimentary structures. They are identified as distinctive trace fossils (ichnogenera) similar to those well-known from land-based stratigraphic sections. They represent the burrowing behavior of benthic animals living contemporaneously with sedimentation.

Some of the best examples are at sites 146 and 149 in the Venezuelan basin. These adjoining sites were drilled in abyssal depths of 3,949 and 3,472 m, respectively, and provide a complete section from Coniacian to Pleistocene. Faunal and sedimentologic evidence from the cores suggests that deposition was abyssal.

The most distinctive biogenic structures are *Zoophycus* (a spiral web), *Teichichnus* (a laminated trough), and *Chondrites* (a regularly branched system). These represent the deep-water trace fossil assemblage of Seilacher, which has been documented in rocks of various ages deposited in bathyal and abyssal frameworks from widespread geographic areas.

Because similar trace fossils are present throughout the Phanerozoic, it is disappointing that they are not recognized in modern deep-sea sediments, and the animals responsible for them have not been identified. One reason is that the traces are accentuated only with time. Our material shows a progressive enhancement of biogenic structures, from vague outlines in the softer Tertiary sediments to increasingly marked contrast and detail downward in the cores. Furthermore, little knowledge exists about modern abyssal burrowers and their burrows, and few cores have been taken for the identification of potential fossil traces.

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ULTRAMORPHOLOGY OF CARBONATE AND SILICATE PHASES ASSOCIATED WITH DEEP-SEA CHERT

Deep-sea diagenesis resulting in chert-nodule formation has been studied by scanning electron microscopy, light microscopy, X-ray diffraction, and electron microprobe analysis of core material recovered by the Deep-Sea Drilling Project (DSDP). Nodules in Tertiary chalk are generally cristobalite-rich, except where metastable silica has converted to quartz. At high magnification, fractures through nodules appear smooth, with little indication of intergranular pore space. Several transition zones may separate chert nodules from unsilicified host rock. For example, in DSDP sample 7/64.1/11/CC, a nodule is surrounded by a weakly silicified chalk zone several centimeters wide, in which interstices are partly filled with 10-micron-diameter cristobalite microspherulites (lepispheres). In a high-silica zone directly adjacent to the nodule, lepispheres are more numerous and exhibit hollow centers. At the chalk-chert boundary, the chalk groundmass has been largely replaced by isotrophic silica, which occludes pore openings but not the hollow centers of the lepispheres. These can be traced for several millimeters into the nodule. Chalcedony within foraminiferal chambers is present in cherts and silicified chalks, but is more common toward the centers of nodules. Fracture surfaces, however, reveal no differences in ultramorphology between groundmasses composed of isotropic silica and those of chalcedonic quartz.

Growth of chert nodules causes dissolution and displacement of most (but not all) of the organic calcite which forms the chalk. Some displaced carbonate in reprecipitated as ultra-fine, euhedral calcite grains within chalk interstices adjacent to nodules. These are probably the supposed calcium-silicate intermediary mineral grains, which some investigators have reported at chert-chalk boundaries. Calcite also may be precipitated as secondary overgrowths on radial prisms of some planktonic foraminiferal tests. This produces characteristic euhedral terminations on inner and outer chamber surfaces.

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SEDIMENTATION ON BALEARIC RISE, A FOUNDERED BLOCK IN WESTERN MEDITERRANEAN

The fan-shaped Balearic rise, southeast of the islands of Mallorca and Menorca, lies at the base of the Emile Baudot escarpment at a depth of 1,600-2,600 m. A sparker, 3.5 Khz profiler, and coring survey reveals that the rise, unlike most deep-sea fans, is almost entirely tectonic in origin. It is a post-Miocene, block-faulted terrane with a thin sediment cover. A large valley, heading between Mallorca and Menorca, follows