through submarine canyons incised in the shelf margin, and (3) redeposited carbonate sediment derived from shelf-margin buildups.

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Sea Gullies and Development of Linear Conglomeratic Units

Sea gullies are localized dissections of California borderland upper basin slopes; the gullies form groups, covering distances of 10 to 16 km off points and narrow shelves. Gullies have youthful "V" cross-sectional profiles and relief of less than 100 m; they may extend to basin floors, creating small, coalescing submarine cones.

Gully development is attributed to subaerial stream erosion during eustatic sea-level lowering and outer-shelf exposure. Also, during rapid regional uplift, shelves become narrower and short, steep streams characteristic of immature drainage patterns prograde across shelves, depositing unstable coarse debris near the shelf break. Differential relief, overburden instability, and earthquakes trigger subaqueous mass flows, creating gullies by headward sapping; and at the base of slope, linear aprons of coarse conglomeratic debris accumulate.

Four stages of nearshore basin deposition are recognized in the lower Capistrano Formation (upper Miocene, Mohnian) at Dana Point, California. Basal deposits of fine siltstones, sandstones, and diatomite represent abyssal deposits. These are overlain abruptly by conglomerates interbedded with structureless coarse sandstones, superseded by graded sandstones and siltstones interpreted as mid-submarine-fan deposits.

Basin subsidence, tectonic activity, and increased erosion climaxed during the late Miocene. Conglomeratic debris flows are also associated with sinistral-coiled *Globigerina pachyderma,* indicating the late Miocene N-17 period of glaciation and possible sea-level lowering. Coarse debris accumulated near the shelf break, and gullied submarine slopes developed. Undermining through liquefaction caused debris flow down these gullies; the flows "froze" at the abrupt slope/basin junction, forming linear, composite conglomerate units. Overlying fan sequences reflect basin maturity dominated by canyon point sources.

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Shallow-Water Carbonate and Evaporite Sedimentation Patterns in Lower and Middle Jurassic Rocks of Southern Tunisia

The Lower and Middle Jurassic rocks in southern Tunisia can be divided on the basis of lithology into two distinct regions, the central and northern provinces.

Outcrops in the central province extend in a continuous escarpment south from the Wadi Tatahouine and display a variety of carbonate and sulfate rock types representing very shallow-water deposition. The Lower Jurassic and lower Middle Jurassic Mestaoua Formation is a largely gypsiferous sequence representing deposition in lagoons and on hypersaline shotts. The overlying Bathonian Krachoua Formation displays a range of carbonate lithologies, representing shoreline and tidal-flat environments, and sulfate units, again indicative of gypsiferous lagoons and shotts.

These formations pass northwestward into massive and laminated carbonate strata indicative of deposition on extensive wind-tidal flats. This is the northern province. The lower part of the sequence, the Semoumenia Breccias, is composed of breccias believed to have resulted from evaporite-solution processes. This sequence passes into clastic facies, the Sidi Stout Sandstones (an accumulation of wind-blown sand dunes), toward the Permian outlier of Djebel Tebaga.

Paleogeographic reconstructions show that the area preserves part of the carbonate shoreline sequence which acted as the sill separating a true marine area on the northeast, Tethys, and the Algerian-Tunisian salt basin on the southwest. Periodic marine incursions into the margin of this salt basin are suggested by the presence of extensive storm deposits.

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Devonian Organic-Rich Black Shales in Subsurface Pennsylvania—Stratigraphy and Natural Gas Production

The basal sediments of the Devonian clastic wedge in Pennsylvania consist of a series of black, radioactive, organic-rich shales interbedded with non-black shales and siltstones. Three major black shales are present in the subsurface as indicated by stratigraphic cross sections. These units are the Middle Devonian Marcellus shale facies, and the Upper Devonian Rhinestreet, and Dunkirk shale facies. Mapping of these facies indicates that they are distributed in three generally overlapping belts paralleling the regional strike. The Marcellus facies attains its maximum development in the eastern Appalachian Plateau. This unit, the oldest and deepest of the Devonian black shales, has had numerous shows of gas in wells drilled through it. However, gas has not been produced from it in commercial quantities. The Rhinestreet facies is best developed in the northwest. It is younger and shallower than the Marcellus and has produced commercially from wells in Beaver County. The Dunkirk facies is restricted to the northwestern part of the state where it reaches its greatest accumulation along the margin of Lake Erie. This youngest and shallowest of the major black shale facies has produced commercially since the early 1800s. All three facies have the potential to produce natural gas in commercial quantities. However, owing to drilling economics, the Dunkirk facies appears to have the most immediate potential because of its shallower depths and production history. The Rhinestreet facies is also considered to have immediate potential. The Marcellus facies does not appear to be an attractive primary target at this time because of its great depth, but it could be a good secondary drilling objective.

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Anatomy and Growth History of Holocene Ooid Shoal

Facies anatomy of the Joulters ooid shoal is strikingly

similar to many Jurassic oolite reservoirs of the Gulf Coast. Extensive coring of the shoal, lying north of Andros Island on the margin of Great Bahama Bank, has documented six subsurface facies: (1) skeletal grainstone; (2) ooid grainstone; (3) ooid packstone; (4) fine-peloid packstone; (5) pellet wackestone; and (6) lithoclast packstone. The relief of the shoal over the surrounding seafloor is the result of contributions by these different facies in differing amounts throughout the area, but in broadest terms the relief is a result of ooid sands in one facies or another. Basically, the facies anatomy consists of a fringe of ooid grainstone bordering a much wider shoal composed of two opposing sand wedges—an upper bankward-thinning wedge of ooid packstone overlying a muddier seaward-thinning wedge of fine-peloid packstone.

During sea-level rise in the last 5,000 years, topography of the underlying Pleistocene limestone has affected shoal growth by initially localizing ooid formation and structuring the shoal's bankward-curving trend. Growth of the shoal occurred in three stages: (1) bank flooding, from 4,000 to 5,000 years B.P., when fine-peloid and pellet muddy sands were deposited in platform interior; (2) shoal formation, from 3,000 to 4,000 years B.P., the beginning of ooid accumulation along the platform margin; and (3) shoal development, during the last 3,000 years, when growth of a marine sand belt established size and physiography of the shoal and changed platform sediments from muddy sands to ooid sands. This change was a result of increased agitation produced by a combination of topographic buildup and rising sea level.

The anatomy and growth history of the Joulters ooid shoal suggest that present patterns in surface sediments are a product of changing subenvironments throughout the late Holocene. The development of the shoal provides one possible scenario for the evolution of a common facies package—a narrow belt of ooid grainstone bordering a much wider belt of ooid packstone that becomes increasingly muddy with depth.

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Key Largo—Subsurface Core Study

The islands of the Florida Keys are often viewed as an exploration model of stratigraphic traps which may form, during very high stands of sea level, several kilometers landward of shelf margins. A detailed study of one of these islands—Key Largo—has been undertaken utilizing cores from 10 boreholes drilled to depths of 7 to 21 m. The stratigraphic section cored is of late Pleistocene age and represents a linear accumulation of reefs enclosed by extensive, generally burrowed deposits of skeletal sand. Reef facies contain approximately 20 to 30% of the relatively large corals, predominantly *Montastrea annularis, Diploria* sp., *Porites astreoides,* and *Porites porites.* Skeletal-sand facies (packstones to grainstones) vary in detail but are characterized by pellets, *Halimeda* sp., mollusk, coralline algae, and foram debris, and are associated with both the reef facies and with finer grained, mollusk-bearing wackestones. Mudstones per se are scarce.

The stratigraphic succession is interrupted in the upper 10 m by two major discontinuities formed as the result of subaerial diagenesis during low stands of sea level. Evidence includes caliche crusts, angular substrate fragments, root casts, and pockets of reddish soil. The shallowest and commonly more subtle of these two breaks is generally developed within 2 to 3 m of the modern surface, whereas the deeper and more conspicuous discontinuity lies at a minimum depth of 7 to 8 m. This latter break represents a prolonged period of exposure and is overlain by a burrowed to locally cross-bedded zone of quartz sand containing varied amounts of coarse skeletal debris.

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Paleoecologic Interpretation of Environmental Stability—A Different Approach

Evolutionary patterns, taxonomic diversity, and genetic variability commonly have been used to interpret environmental stability in ancient communities. Paleoecologists have lamented the imprecision of these interpretations. Much of the imprecision was due to inadequately defined species distribution within units. The problem here is that adult organisms, particularly marine benthos, occur in isolated patches. By contrast, larval and juvenile forms, commonly ignored in paleoecologic studies, are more widely distributed and much greater in number. They also are more sensitive to subtle environmental fluctuations. This greater distribution and larger population size of younger organisms is well exemplified by the fossils recovered from acid residues of limestone units from the 240-ft (72 m) thick Kope Formation (Cincinnatian Series). In each of the five sections studied, at least half of the individual layers contained large populations of larval and juvenile organisms. Adults of the same species of these varied taxa are comparatively rare, however. Taxa represented include gastropods, pelecypods, and brachiopods. Any paleoecologic interpretations based on adult forms only would be drawn from much more restricted information than one drawn from all stages of the life cycle represented in these samples. It is suggested that much more precise interpretations of environmental factors such as stability and diversity can be drawn from analyzing remains of the entire life cycle, rather than just adult forms.

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Drainage Anomalies in Gulf Coast Tertiary Sandstones

Unanticipated drainage patterns or drainage anomalies are common phenomena in Gulf Coast Tertiary sandstones. Drainage anomalies can occur in reservoirs that were deposited in a single depositional environment or in several environments. They can be recognized by an analysis of the production data, from pulsed neutron logs, or from logs in new wells drilled later in the life of the field. One of the best ways to locate drainage anomalies is by undertaking comprehensive subsurface engineering reviews which incorporate all geologic, petrophysical, production, and reservoir engineering data from the field—the synergistic