(Amposta Marino), found by a consortium led by Shell, is scheduled to produce 40,000 BOPD by October 1972. Oil reserves are estimated at ½ billion bbl. Oil is 19° API with 5% sulfur and a pour point of 75°F. The field appears commercial and will help to reduce Spain's daily import of 410,000 bbl. Amposta Marino produces from porous, fractured dolomites of late Mesozoic age (Neocomian-Aptian) which are capped by the probable source beds of Miocene clays. The Miocene itself tested subcommercial(?) gas from several shallow sandstones and 37° API oil and gas from a basal carbonate which becomes biogenic on the flanks of tilted fault blocks. The field is on a relatively stable marine platform (not in a delta model) which accumulated thick (10,000 ft) Mesozoic carbonates. The early Tertiary was a period of emergence during which the easternmost fault blocks were stripped down to the Paleozoic rocks. In Miocene time, the area sank and marine clays, as well as evaporites of the Mio-Pliocene, were deposited in a basin between the mainland and the Balearic Islands. As exploration continues, the Tertiary and not the Mesozoic is postulated to become the main target. A drifting away of the Balearic Islands from the Spanish mainland is proposed by some to accommodate the geologic history.

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Grand Canyon Bight—Significant Tectonic Feature of the Southwest

A bight, by definition, is a curve in a coastline, or a bend, angle, or corner in any configuration. This seems to be descriptive of the dominant tectonic feature of southwestern Utah, northwestern Arizona, and a small adjacent tract of Nevada. The Grand Canyon is the best-known local geographic feature of the region, hence the name Grand Canyon bight.

The Grand Canyon bight is the somewhat drawn out and distorted southwest corner of the Colorado Plateau; more importantly, it is a region of relatively simple structure between the converging Wasatch line on the north and the Central Arizona uplift (Mogollon rim?) on the south. These great structural trends approach each other but, due chiefly to the change of direction of the Wasatch line from southerly to westerly and the dying out of the Central Arizona uplift, they do not merge and there is a space of relatively simple structure between them.

The bounding tectonic features came into topographic prominence when the Mesocordilleran highland was elevated in Middle Triassic time. Subsequent sedimentary deposits, especially the marine and fluvial formations, are strongly influenced by the bight. Cretaceous shorelines and isopachs show this influence particularly well. The river system which deposited the Salt Wash Sandstone Member of the Morrison Formation entered the region of the Colorado Plateau through the Grand Canyon bight; the present Colorado River leaves the bight in a reverse direction. Other geologic references also are simplified by recognition of the Grand Canyon bight as a tectonic entity.

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Stratigraphy and Exploration of Lower Cretaceous Muddy Formation, Northern Powder River Basin, Wyoming and Montana

The Lower Cretaceous Muddy Formation in the northern Powder River basin of Wyoming and Montana was deposited during a marine transgression across a stream-dissected surface of the underlying Skull Creek Shale. The transgression occurred over most of the area, but was limited on the northeast by a prograding delta, which supplied most of the sand.

The Muddy Formation is divided into lower and upper units. The lower Muddy was restricted to a system of dendritic channels incised into the Skull Creek Shale during a period of emergence. The sands from the delta source were transported south by longshore currents. They were deposited principally in a transitional marine and estuarine environment, and are composed of fine-grained, moderately well-sorted, partially clay-filled quartzose grains.

By the time of deposition of the upper Muddy, the incised depressions in the Skull Creek topography had largely been filled. The upper Muddy sands were deposited in a complex marine shoreline environment, which resulted in offshore bars, barrier islands, beaches, and tidal deposits. Several shoreline trends are recognizable in the upper Muddy. They are progressively younger eastward and reflect the overall west to east transgression. These trends were controlled by the remnant Skull Creek topography and changing conditions of sediment supply.

Production from the Muddy Formation is principally from stratigraphic traps; however, structure has been important in localizing some of the oil and gas accumulations.

Lower Muddy pools are restricted to updip channel boundaries and are localized by structural noses and updip channel reentrants. Upper Muddy production is controlled chiefly by porosity development and lateral facies changes.

Exploration for Muddy sandstone reservoirs is aided by the use of an isopach map of the total Muddy Formation. This map shows the configuration of the Skull Creek channels and, therefore, the distribution of the lower Muddy sandstone. It also is helpful in predicting the orientation of the upper Muddy shoreline trends where they were related to remnant Skull Creek highs, and in showing an increased Muddy thickness due to sand buildups in nonchannel areas. Electric log maps, combined with zonal sandstone isopachs, provide a means of visualizing the rapid changes in sandstone geometry and also aid in the interpretation of depositional environments.

Exploration must be focused on the location of primary stratigraphic traps which have not been strongly altered by later structural movements. The widespread clay-filled porosity has resulted in large areas being nonproductive. It is believed that the clay fill is largely diagenetic and occurred subsequent to accumulation of primary oil. The lower percentage of clay fill in the oil-filled primary traps suggests that the presence of the oil inhibited clay diagenesis.

In the last 3 years, nearly 3,000 wells have been drilled in the study area in the search for Muddy oil. Every year new fields of significant size are discovered. Detailed stratigraphic work is called for as well as courage to use the drill as an exploration tool.

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Lithologic Associations and Sandstone Provinces

A limited number of clastic lithologic associations support the widely accepted view that tectonism and source-rock type exert the dominant control on sandstone composition. Because various kinds of tectonic provinces exist, corresponding sandstone provinces such as cratonic-sandstone provinces, fault-block basin sandstone provinces, and others also exist. However, within these provinces anomalous sandstone compositions occur (*e.g.*, quartz arenite in a fault-block basin), because other processes such as recycling, transportation, deposition, and diagenesis obliterate or mask the effects of tectonism. Although it normally is possible to recognize the anomalies, it is difficult to determine which processes have caused the anomaly and is almost impossible to measure the individual effect of each. Thus attempts to reconstruct the paleogeography of sandstone provinces and to compare and contrast the significance of sandstone provinces in various tectonic settings are hampered.

Compositional norms for recent sand derived from a variety of source rocks, in a variety of tectonic settings, and deposited in a variety of environments are needed before the process variables that have influenced the compositions of ancient sands can be identified and measured. New and improved studies of the relative destructibility of mineral types and rock fragments also are required before reliable semi-quantitative provenance interpretation within a sandstone province is possible.

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Provincial Aspects of Some Neogene Ostracoda of United States

Marine Neogene fossil ostracod assemblages that show some degree of provinciality include those from the Louisiana subsurface, the Florida panhandle, North and South Carolina, Virginia, Maryland, and southern California. Nonmarine Pleistocene fossil ostracod assemblages from Illinois, Ohio, Kansas, Minnesota, Utah, Idaho, and Nevada, and Miocene and Pliocene assemblages from Nevada and Idaho also are represented to some extent by restricted species.

One of the main problems in the analysis of the assemblages is determination of the limiting effects of environmental factors on the species having restricted distribution versus other less tangible limiting factors. Comparisons of the fossil distributions with those of living representatives are helpful.

As an example of provincial restriction of marine Neogene Ostracoda not obviously controlled by facies, the Atlantic Coast of the United States is typified by certain species of *Murrayina* and *Hulingsina,* whereas rocks of similar age are typified (1) in the Caribbean by *Ambocythere,* (2) in east Africa and the Mediterranean by *Chrysocythere,* and (3) in Germany perhaps by *Urocythereis* and *Kuiperiana.*

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Provincialism Exhibited by Ordovician Conodont Faunas

Throughout the Ordovician, 2 well-distinguished provinces were delineated by distribution of conodonts in the northern hemisphere. One, the North Atlantic province, includes all of northwest Europe, the British Isles, and a tract in the eastern Appalachians that stretches from Newfoundland on the north to Georgia and Alabama on the south. A second, the North American Mid-Continent province, embraces all of interior North America, the western belts of the Appalachians, and at least part of the Canadian Arctic Archipelago. Although there was limited and episodic exchange between North Atlantic and North American Mid-Continent conodont faunas, and vicarism is evident between some elements, the two were strikingly different and apparently largely unrelated.

Limited information suggests that Mid-Continent faunas were also characteristic of at least parts of the Siberian platform, and elements of these faunas are known also from the Ordovician of New Zealand and Australia. Paleogeographic, paleotectonic, and paleomagnetic considerations suggest that the Mid-Continent fauna developed at low latitudes, perhaps astride the Ordovician equator, and that the North Atlantic fauna was characteristic of higher latitudes. This suggestion is reinforced by the presence of mixed or modified North Atlantic and Mid-Continent faunas in rocks that accumulated at relatively more deeply submerged sites in the Mid-Continent or Cordilleran areas. Water temperature was probably the most important factor in defining boundaries between the 2 recognizable provincial faunas.

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Natural Hydrocarbon Seepage in Marine Environment

Evidence of hydrocarbon seepage in the marine environment has been documented back to prehistoric times. Hydrocarbons are held in structural and stratigraphic traps by overlying, impervious layers, and they can escape only if the capping layer is destroyed. Escape channels through the capping layer are formed primarily by faulting, which may be essentially due to tectonic forces, as in the Santa Barbara Channel area, or may be due to diapiric uplift as in the Gulf of Mexico.

Unconsolidated sediments of varying thickness overlie consolidated sediments and bedrock in most marine environments. Because of the incompetency of these sediments, fault traces usually are not transmitted to the surface as open fractures. Hydrocarbons are forced to flow or bubble up through these sediments in a manner that may be analagous to diapirism. The more viscous the hydrocarbon the more probable it is that traces will remain in the sediment. Traces have been found at various locations in the Gulf of Mexico and off the California coast.

Seepage is intermittent and aperiodic with unpredictable rates. Viscosity and the passage up through the sediments may be the controlling factor in the intermittent flow. Tidal effects may be significant.

Hydrocarbons have a specific gravity lower than that of seawater. There is no evidence that floating oil or tar through self distillation will increase enough in specific gravity to sink. It has been suggested that accretion of sediment particles could cause floating tar to sink. This could occur only along the surf zone, or at the mouths of heavily laden streams if at all.

It is, therefore, almost axiomatic that tar or tarry residues found in marine sediments originated from a natural seep. No oil from pumped bilges or ruptured fuel tanks ever sank to the bottom.