fine-grained sediments infilling the channels may have acted as a seal, entrapping the oil or gas in the reservoir rocks through which the canyons cut.

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Namorado Field, Major Oil Discovery in Campos Basin, Brazil

The Campos basin is located offshore the State of Rio de Janeiro, between parallels 21 and 23°S. In 1974, while drilling the ninth wildcat in the basin, Petrobras discovered the Garoupa oil field. This field was the first in a new and important oil province in one of the little explored Atlantic-type basins. Between 1974 and 1978, 10 other significant oil discoveries have been made, but most of these new fields are still in the process of either delimitation or early development. At present only the 20-sq km Namorado oil field has proved reserves (recoverable oil volume) of 250 million bbl.

The Namorado oil field was discovered in 1975 by the 1-RJS-19 wildcat (22°27'S, 40°25'W) in 166 m of water. The prospect was located on a seismic structural high associated with an amplitude anomaly at the level of the Macae Formation (Albian carbonate rocks). In the interval between 2,980 and 3,080 m, the wildcat penetrated thick, oil-bearing sandstones interbedded with calcilutites in the upper part of the Macae Formation. In this well, an oil flow of about 6,000 bbl/day from the high-porosity (30%) and high-permeability (1 darcy) sandstone was estimated.

From sedimentologic analysis, the reservoirs were classified as deep-water marine deposits (turbidites) associated with the first major transgression over the Albian carbonate shelf. From this model, the first assumption was of variable sand distribution and strong stratigraphic control of the oil accumulation, which is now confirmed.

Today, six wells have been drilled in the field, some of them located by detailed interpretation of specially processed seismic data, such as synthetic acoustic impedance sections. This method proved to be very useful and accurate in mapping reservoir extension.

The reservoir rock, the Namorado Sandstone, was the result of coalescent deep-water channels and fans over a rough depositional surface when the area was a relative low containing several turbidite layers. In some places, there are continuous clean sandstone bodies 100 m thick. As a result of active faulting during the Late Cretaceous and because of different compaction over the reservoir, the relative low became an elongate dome-shaped high, partly limited by faults.

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Oil Exploration in Campos Basin, Brazil; Model for Exploration in Atlantic-Type Basins

Petrobrás drilling activities for oil exploration in Campos Basin, offshore Rio de Janeiro state, were initiated in 1971. Up to October 1978, 70 exploratory wells have been drilled and an estimated recoverable petroleum volume of 1 billion bbl has been discovered.

The structural style and lithologic characteristics of the stratigraphic column disclosed by seismic and drilling investigations reflect several stages of tectonic basinal evolution, as follows. (1) An Early Cretaceous intracratonic rift-valley stage is recorded by syntectonic terrigenous sediments, commonly underlain by or interbedded with basaltic lava flows; this section contains good oil-source beds but, up to now, only fair reservoirs have been found. (2) A transitional phase, still of Early Cretaceous age, characterized by evaporites, dolomites, and carbonate rocks, marks the transition from continental to marine conditions. (3) An Albian shallow-water marine phase is represented by thick carbonate deposition where oil entrapment is related to porosity variations. (4) A deep-water phase characterizes the younger part of the section; the sedimentation of this phase, begun in the Late Cretaceous with the deposition of a transgressive shale section with good source potential, was interrupted during the Paleocene and early Eocene with deposition of a thick turbidite section, which provided excellent reservoirs.

The Lower Cretaceous section exhibits rifting and fault blocks bounded by normal faults. Important halokinesis occurred in the Late Cretaceous and affected the sediments that underlie the depositional hiatus at the base of the Tertiary. As a result of salt extrusion and dissolution, salt scars, collapsed structures, sliding faults, and other types of holakinetic structures are common, and are of paramount importance in reservoir distribution and oil entrapment in the Albian-Eocene section.

The main oil fields in the basin have been found in combination traps, provided by turbidite sandstone lenses or porosity variations in carbonate rocks, mostly associated with collapse faulting. Minor oil fields, structurally controlled by block faulting, have also been found. These modes of oil occurrence seem to be good exploration models for oil prospecting in analogous Atlantic-type basins.

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Computer-Compatible Handling of Geologic Data

Results in hydrocarbon exploration will be improved if all available information is readily accessible to the explorationist. The great amount of data on geology, geochemistry, seismic, etc, now available to the interpreter, can no longer be handled efficiently by conventional methods alone. Bottlenecks owing to nonstandard data capture, time-consuming preparation of graphic displays, and integration of old and new data can be solved by the computer.

However, other constraints will be encountered unless standardized and disciplined data handling is ensured. (1) Data from different disciplines may be stored separately, but mechanical integration within a three-dimensional grid (x, y, z) must be ascertained. (2) Factual data (observation) and interpretation (subject to change) should be clearly distinguished. (3) Interpretations should be recorded by the geologist himself to increase file reliability.

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Are Pennsylvanian "Freshwater" Limestones Actually Intertidal and Supratidal Deposits?

Previously, Upper Pennsylvanian carbonate rocks and associated strata in southeastern Ohio were interpreted as freshwater deposits. Detailed examination of these units has led to the recognition of depositional environments which include marine, intertidal, and supratidal.

Upper Conemaugh units contain an abundant marine fauna and grade upward into lower Monongahela sandstone, shale, and coal. Monongahela sandstones occur as elongate, lenticular bodies. Thin sandstone beds which extend from the lenticular sandstone and interfinger with green shale contain rip-up limestone fragments, stromatolites, and mudcracks. Middle Monongahela limestones and dolomitic limestones overlie these sandstones and shales and are interbedded with green shale. The carbonate rocks contain a sparse fauna of ostracods, gastropods, pelecypods and, locally, fish teeth and scales. Carbonate rocks are thick-bedded, brecciated micrites which contain bird's-eye structures, gypsum crystal molds, and stromatolites. Red-mottled claystones dominate the upper part of the sequence and are interbedded with thin, nodular, conglomeratic algal limestones.

Upper Conemaugh strata represent shallow-marine deposition offshore from a shifting Monongahela barrier-bar system. Behind these barrier bars, coal swamps developed which evolved into tidal flats on which dolomitic carbonate muds and clay muds were deposited. As tidal flats became more extensive, supratidal conditions developed, ranging from hypersaline to fresh water and subaerial, and clay and carbonate muds were deposited.

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Sverdrup Basin Response to Cratonic Events

Sverdrup basin is large (~520,000 sq km) and deep (~13 km), and was long lived (Early Carboniferous to latest Cretaceous). It belongs to a distinctive class of cratonic basins because it received great volumes of terrigenous clastic sediments, but never had a contemporaneous adjacent orogenic belt. Therefore, its stratigraphic record portrays responses to cratonic epeirogenesis unmasked by eccentricities of local orogeny.

Initial subsidence of the basin (Early Carboniferous) was along a system of grabens. During Carboniferous and Permian times, the axial region was relatively starved, whereas thick carbonate deposits and sandstones accumulated on the margins. In the Triassic the axial region received great thicknesses of fine-grained terrigenous clastics but basin-margin successions were thinner and coarser grained. Jurassic and early Neocomian deposits accumulated slowly. Aptian and later Cretaceous marine and nonmarine clastic deposits transgressed widely cratonward over the formerly well-defined basinal margins, and the structural basin lost identity in a broad continental-shelf and coastal-plain complex that existed until the area was fragmented in latest Cretaceous and early Tertiary time.

Mafic volcanism in the Carboniferous, Permian, Early and Late Cretaceous, and gabbro intrusion in the Jurassic and Cretaceous, indicate that crustal fracturing, accompanied by tapping of upper mantle fluids fashioned primary basin subsidence. Sedimentation in phases of accelerated subsidence appears to be dictated by the availability of detritus and the prevailing erosional gradient on the adjacent craton. The basin was relatively starved in the Carboniferous and Permian and relatively "stuffed" in the Triassic. Thick, widely distributed sandstones indicate vigorous erosion of the craton in the intervals late Norian to Sinemurian, late Valanginian to early Aptian, late Albian to Cenomanian, and late Campanian to early Tertiary. In contrast, black, laminated, marine shales mark early phases of marine transgression onto the craton in Leonardian, Griesbachian, Oxfordian, Valanginian, middle Albian, and Cenomanian-Turonian times.

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Cenozoic Clay-Mineral Stratigraphy in South Philippine Sea, DSDP Legs 59 and 60

On DSDP Legs 59 and 60, sites were drilled in the South Philippine Sea along an east-west transect at 17°N lat. Clay minerals from Cenozoic samples at DSDP sites 447A, 449, 450, 452, 453, and 454A were analyzed by X-ray diffraction methods. A semiquantitative determination of the percentages of clay minerals was made for each sample. In addition, illite crystallinities and relative iron contents in illites and chlorites were analyzed using X-ray diffraction data.

At site 447A, on the western flank of the Palau-Kyushu Ridge, the drill penetrated an undated surficial clay zone into underlying early Miocene pelagic clay. The clay is smectite-rich (averaging 95% smectite). The remaining percentage is almost evenly divided between crystalline illite, relatively low-iron chlorite, and kaolinite, all of which reflect detrital input from the Chinese mainland.

Site 449, on the eastern ridge flank, yielded a thick pelagic clay sequence ranging from an undated cover down through middle Miocene to upper Oligocene clays. An increase in smectite content during the late middle Miocene resulted from ash deposition due to volcanism on the West Mariana Ridge. Below this zone, in older middle Miocene clays, the content of chlorite, illite, and kaolinite increases considerably relative to smectite. The mineralogic change is associated with radiolarian-rich deposits of the same age. This change could mark a northward shift in the equatorial countercurrent associated with increased boundary-current circulation that occurred at this time.

Pelagic clays from the other sites in the Parece Vela Basin, Mariana Trough, and Mariana Trench are smectite-rich owing to the ash content of the sediment. However, stratigraphic interpretation of the Mariana Trough