representing the intrusive mass. The surrounding beds dip away from the central depression, often very steeply, to form a series of cuestas. In contrast, the Iza diapir is a buried wall or ridge of plastic rock at least five kilometers (three miles) long by less than 1.5 kilometers (one mile) wide intruded into a sedimentary section over 4,410 meters (14,470 feet) thick. Only the uppermost tip is exposed at the surface in a belt of indistinct outcrops up to 30 meters (98 feet) wide. One of the wells drilled on the structure encountered an inverted block of Upper Cretaceous sandstone above Paleocene carbonates, apparently incorporated into the diapir.

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Salt Deposits and Structure of the Maritime Provinces of Canada

Aeromagnetic, gravity, and seismic surveys in the Maritime Provinces of Canada have provided extensive new information bearing on (1) the geometry of the depositional basins, (2) the distribution and shape of the major salt masses, and (3) the sub-salt structure.

The basins and uplifts exhibit a striking geometrical relationship of east- and northeast-trending elements that strongly suggest a shear pattern. This pattern was developed during the Acadian and possibly earlier orogenies. Large crustal blocks, bounded by faults, appear to have tilted and shifted, with rapid erosion and deposition during Mississippian and Pennsylvanian times creating large prisms of sediments which differ greatly in shape, size, and sedimentary facies.

Widespread deposits of rock salt, gypsum, and anhydrite exist in the Windsor Group (Upper Mississippian) in all the Maritime basins. The saline facies is interbedded and interfingered with thin limestones, red and grey shale, and coarse red clastics, and in a few places lies directly on the basement rocks. In the anticlines, notably those of northern Nova Scotia, western Cape Breton, and southern New Brunswick, the rock salt thickened greatly in the axial region of the folds and in places pushed through the overlying rocks to the surface. This sequence of thickening of the salt within the folds followed by diapirism is similar to that of the salt anticlines of the Paradox Basin and South Persia. Little is known about the original depositional thicknesses of the saline facies, but gravity data indicate wide differences in the amount of rock salt along the axes of the major anticlines. This may indicate the original pattern of salt deposition.

A thick section of sandstone and shale, plentiful oil shows, a basin-wide seal afforded by the evaporite section, and the large structural traps provided by the major anticlines combine to make the sub-salt Horton Group (Lower Mississippian) rocks a prime target for oil and gas exploration in these largely untested basins.

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Geosynclinal Filling: Some Stratigraphic-Structural Relationships

A geosyncline does not develop by mere crustal sag but rather by movement along faults. Contemporaneous faults are known to have been active during development of the large Ouachita and Gulf Coast geosynclines and development of the small but active Los Angeles, Hanna, and Ardmore basins, which are tectonically similar.

The sedimentary fill of tectonically similar geosynclines, however, may be quite different. The Los Angeles Basin along the continental margin received thick turbidite deposits before it was filled to shelf depths. During its rapid subsidence, the Hanna Basin within the landlocked western interior filled with alluvial deposits. The Ardmore Basin during the late Paleozoic received shallow marine and coastal (paralic) sediments. Disharmonic folds involving the thick, ductile Springer-Goddard Shale indicate the influence of rock type in forming local structural features.

While the Springer Shale was being deposited in the Ardmore Basin, turbidites were being deposited along the length of the Ouachita geosyncline. After water depths shoaled, shallow marine beds of the Atokan were deposited. The over-all regressive sequence of the Tertiary in the Gulf Coast geosyncline has resulted in paralic sediments overlying ductile, offshore, and "deep-water" shales. This relation may have been the cause of structures formed independently of salt tectonics. Such features are thought to be analogous to those failures recognized causing failures in foundation engineering and to the Recent mudlumps of the Mississippi River.

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Some Oil Occurrences in the Tar Springs (Mississippian) Delta, Illinois

The Tar Springs Sandstone along the southwestern flank of the Illinois basin is one of a series of Mississippian Chester clastic formations comprising a major deltaic complex. The Tar Springs was deposited in a slowly subsiding, intracratonic basin by a major river system, the Michigan River system of D. H. Swann.

The Tar Springs deltaic deposits are the principal reservoir in the 9-mile-long, 1–3-mile-wide producing trend formed by the Benton, Orient, and West Frankfort fields in south-central Franklin County. In this north-south oriented trend, the Tar Springs Sandstone is at an average depth of 2,050 feet and lies between two widespread, shallow marine, impermeable limestones. The reservoir is made up of very fine-grained to fine-grained sandstone laid down in overlapping and coalescing fan-shaped buildups and in lenticular bodies. Individual sand buildups are partially separated vertically and laterally from one another by impermeable siltstone and shale. The sandstone was probably deposited by shifting distributary channels. The siltstone and shale are probably quiet water, interdistributary deposits.

Oil accumulations in the Benton-Orient-West Frankfort trend are primarily structurally controlled; however, stratigraphic variations influence the over-all distribution of hydrocarbons. All the Tar Springs accumulations lie on a broad, north-south trending anticline of moderate closure. Local folding and warping of the anticline combined with lateral and vertical facies change from sandstone to shale determine the size, shape, and position of the oil pools.

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Distribution of Hydrocarbons in South Louisiana by Types of Traps

Hydrocarbons in Frio and younger sediments in South Louisiana, both onshore and offshore, are associated with six types of structural or combination structural-stratigraphic traps: salt domes; circular or elongate domes (which are probably deep-seated salt domes); anticlinal closures associated with regional syn-depositional faults; fault closures; and stratigraphic traps on the flanks of structural noses or closures where no hydrocarbons are trapped on the apex of the structure.

The total estimated ultimate recovery of 691 fields in the area is 9,057,003,000 barrels of oil, 2,223,215,000 barrels of condensate, and 85,688,836,000,000 cubic feet of gas. Using an economic value of one barrel of oil equals 15,000 cubic feet of gas, the total ultimate recovery of hydrocarbons is equivalent to 16,959,196,000 barrels of oil.

Salt domes account for 17.9% of the number of producing fields, 61.09% of the ultimate oil, 18.48% of the ultimate condensate, and 19.48% of the ultimate gas recovery. *Circular* or *elongate domes* account for 20.98% of the producing fields, 18.96% of the ultimate oil, 47.94% of the ultimate condensate, and 47.15% of the ultimate gas recovery. *Anticlinal closures associated with regional syndepositional faults* account for 20.41% of the producing fields, 12.63% of the ultimate oil, 21.88% of the ultimate condensate, and 22.09% of the ultimate gas recovery. *Fault closures* account for 31.74% of the producing fields, 6.43% of the ultimate oil, 9.61% of the ultimate condensate, and 9.04% of the ultimate gas recovery. *Closures on regional noses* account for 3.91% of the producing fields, .56% of the ultimate oil, 1.13% of the ultimate condensate, and 1.29% of the ultimate gas recovery. *Stratigraphic traps* on flanks of structural noses or closures account for 5.06% of the producing fields, .36% of the ultimate oil, .86% of the ultimate condensate, and .95% of the ultimate gas recovery.

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LOCATING THE SOURCE OF SANDS IN FLYSCH TROUGHS

Field characteristics of sand units are stressed in most flysch studies. Megascopic properties of lithology, stratification, and sedimentary structures are essential for interpretation of depositional environments and directions of sediment transport within mobile belts. Problems related to the *source* of sands, however, cannot be solved by field work alone.

In certain studies, two of the most important questions concerning source remain unanswered:

(a) What was the nature of the parent-rocks exposed in the source area?
(b) Where was the source area with respect to the site of flysch accumulation?

Petrographic examination of sands on a regional scale is required to help solve these fundamental problems. Heavy mineral studies are particularly useful in providing paleogeographic information. Heavy mineral assemblages display a lack of diversity (small number of mineral species) in almost all flysch formations where they have been examined. These assemblages are invariably mature to supermature (high percentages of resistant minerals). Sands containing assemblages of this type were probably derived from terrains already lacking a diversity of minerals. Thus, sands in many flysch troughs were largely derived from older clastic formations (re-sedimentation or "cannibalization" process) exposed within or adjacent to the mobile belt.

Furthermore, the distribution patterns of light and heavy mineral fractions vary laterally in these formations indicating the presence of local sediment sources along mobile belts. Petrography serves as a check on the relative importance of lateral versus longitudinal transportation of sands in flysch troughs.

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DIRECTION OF CRUSTAL MOVEMENTS INDICATED BY EARTHQUAKE DATA

Two factors make desirable a re-evaluation of the inferences, drawn from seismic data, concerning the direction of crustal movements: 1) the revision of published fault plane solutions, occasioned by questions of the reliability of the solutions and by the recognition of bias in favor of strike-slip faulting; 2) the development of other methods, including the use of S waves and the application of surface waves in determining the directivity, dimensions, and initial phase of the source.

The most extensive seismic data pertinent to crustal movements are associated with the borders of the northern Pacific Ocean. Data from the smaller earthquakes (magnitude $6\frac{3}{4}$–$7\frac{1}{4}$) indicate predominantly reverse or thrust faulting along fractures parallel to (e.g. Kamchatka-Kurile Island arc) or oblique to (e.g. Aleutian Islands) the trend of the tectonic features, with a lesser transcurrent component of motion. The principal compressive stress is nearly horizontal and is directed normal to the trend of the arc. The major earthquakes, on the other hand, especially as inferred from the data of surface waves, are predominantly strike slip. Fracturing extends for hundreds of kilometers and parallels oceanic deeps.

Examination of other regions, especially South America and regions of the southwest Pacific, permit inferences related directly to the underlying causes of crustal movement.

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LOCAL VARIATIONS IN EARTH TIDES

Observations in various parts of the world show marked inconsistencies in the apparent deformations produced by earth-tides; such variations may in large part result from errors of measurement. However, horizontal variations in crustal composition must produce effects of this kind, and accordingly an attempt has been made to estimate the order of magnitude of such anomalies. The very complicated elastic problem could be solved numerically if we had any idea of the changes of composition involved. In default of such information, a two-dimensional model has been investigated, using a method of successive approximation. Two cases are of special interest—(1) where changes of elastic constants are appreciable within a small fraction of the circumference of the Earth, and (2) where the wave-length is one-half of the Earth's circumference.

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AGE OF SOME CALIFORNIA COAST RANGE LOWER TERTIARY MARINE RED BEDS

Microfossils, including benthonic and planktonic foraminifera as well as coccolithophorids and related nannoplankton, are abundant in the marine red beds of the California Coast Ranges. These have usually been assigned a middle Eocene age. Comparative studies of the foraminifera and nannoplankton in these red beds have revealed two of these microfossil assemblages (from San Miguel Island, Santa Barbara, and the Oakland hills) to be of Campanian, Upper Cretaceous age; two others (from the lower red bed, type Anite Shale