shot the first seismic survey the same year. These data were adequate to confirm a thick sedimentary section, and they contained sufficient structural indications to select the initial drill site. By 1974, four different seismic surveys had been conducted. More and more faulting became apparent with improving data quality. To resolve the structural pattern, a high-resolution seismic survey was conducted in 1976. These data first demonstrated the very complicated fault patterns now known to exist. Additionally, processing of this survey proved that migration is essential for fault definition, although dips are relatively shallow. Paradoxically, it was observed that the best seismic correlations across the many faults were predominantly low frequency. Consequently, a "low-frequency" seismic survey was initiated in 1979. Interpretation of this survey made it possible to correlate gross sedimentary units over large areas of the structure. These correlations were consistent with well control. In 1979, development plans were completed and a 3-D seismic survey was conducted prior to installation of permanent production facilities. This survey comprised 5,000 line-km of data with subsurface coverage of 25 m in the dip direction and 75 m along strike. Nonstandard processing techniques are being tested, both for Erawan field data and other structures in the Gulf of Thailand. Wavelet processing, utilizing a recorded far-field signature, has shown significant improvement in some cases. Migration before stack has significantly enhanced the data by better fault definition and improved correlations across the faults. Development plan for Erawan field consists of five platforms with 12 well slots per platform. Gas will be transported by pipeline to Bangkok and condensate will be separated and offloaded via a single point mooring system. Gas production of 250,000 mcf is planned with first production in the fall of 1981. The development program will continue to be heavily dependent upon detailed analysis of 3-D and other seismic reflection data for optimum positioning of boreholes in both horizontal and vertical dimensions.

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Depositional History and Dolomitization, Kirkuk Oil Field Host Rocks, Iraq

The modified lithostratigraphic framework of the Kirkuk (northern Iraq) carbonates shows that the Paleocene shoal/shelf facies graded northward into the nearshore dolostones and southward into the offshore (basinal) limestones. During Eocene time the shoal deposition covered the whole shelf area, with basinal equivalents present in the southwest. In contrast, the two major cycles of Oligocene sedimentation were controlled by shelf-edge bioherms (in-situ mechanical pilings of skeletal grains). In the Baba-Tarjil area, the bioherms grade laterally into mud flat (NW to NE) and basinal (SE to SW) facies.

Subaerial exposure caused cementation, dolomitization, and dissolution; moldic porosity being the dominant factor controlling the porosity development in the Kirkuk oil reservoir. The associated fine-grained dolostones of the Paleocene time show petrographic, chemical, and isotopic characteristics of the hypersaline (sabkha) type, whereas their coarse-grained Eocene and Oligocene counterparts resemble the diagenetic (Dorag) type dolostones.

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Present Thermal State of Western Canada Sedimentary Basin

The regional geothermal pattern of Western Canada sedimentary basin was studied using available temperature data from shut-in wells. Average heat conductivity was estimated with net-rock data from Canadian Stratigraphic Services. These data allow heat-flow estimations.

The geothermal gradient and heat-flow values for the basin are exceptionally high in comparison with the other Precambrian platform areas, especially in the northwestern part of the Prairies basin in Alberta, British Columbia, and most of southern Saskatchewan. Low-gradient areas are found close to the eastern limit of the Disturbed belt of Alberta and British Columbia. Neither the analysis of regional conductivity nor heat generation of the basement rocks based on U, Th, and K data after Burwash (1979) explains the heat-flow patterns. Certain hydrogeological phenomena do suggest the significant influence of fluid flow on geothermal features. Low geothermal gradient areas coincide with water recharge and high hydraulic head regions.

The phenomenon of upward water movement in the deep strata and downward fluid flow through much of the Cenozoic and Mesozoic strata seems to be the main influence on heat distribution in the basin. Analyses of coal metamorphism in the upper and middle Mesozoic formations of the Foothills belt and in the central Prairies basin suggest that pre-Laramide heat-flow distribution was different from the present. It is probable that the Foothills belt had a higher geothermal gradient than the central part of the Prairies basin, opposite to the present relationship.

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Hydrodynamic and Geologic Significance of Upper Jurassic Smackover Marine Oncolites—Evidence for Penecontemporaneous Lithification

Smackover oncolites from the Chalybeat Springs field, Columbia County, Arkansas, exhibit evidence for penecontemporaneous cementation. "Flower spar" cement, previously reported only in caliche and vadose pisoliths, has been found as thin ribbons within the oncolites. Bivalve and polychaete borings penetrate both the concentric algal laminations and the bioclastic nuclei of the nodules. Boreholes are found around the entire periphery of the nodules indicating that the oncolites were mobile at the time boring occurred. Some borings have their openings capped by subsequent layers of algally bound material, implying that the oncolites were periodically lithifying while still accreting. Foraminifera, serpulids, and bryozoans are seen to encrust the oncolites suggesting that the nodules were indurated at the time of encrustation.

Smackover oncolites are characterized by micritic and pelletal laminations and contain blue-green algal filaments attributed to *Girvanella*. Thus, they closely resemble modern marine oncolites with the exception that modern forms are unlithified. Recent lithifying blue-green algae are known only from freshwater and hypersaline environments.

The density of these large (5 to 35 mm), hard, cemented grains would be considerably higher than that of modern marine oncolites. If the cemented oncolites are assumed to have the same specific gravity as recent freshwater oncolites, current velocities exceeding 100 cm/sec would be required to initiate movement.

A survey of ancient oncolites suggests that virtually all Mesozoic oncolites show evidence of penecontemporaneous cementation.

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Stratigraphy and Hydrocarbon Potential of Upper Jurassic Formations in Northeastern Gulf of Mexico Area

Upper Jurassic Norphlet, Smackover, and Haynesville deposition in Mississippi, Alabama, and Florida was controlled by the Mississippi Interior Salt Basin (MISB) and the Manila and Conecuh Embayments. Salt movement produced local variations in sediment distribution, and pre-Jurassic paleo-highs modified sedimentation. Norphlet lithofacies include eolian quartzose sandstone, alluvial-fluvial red-bed sandstone, alluvial conglomeratic sandstone, and bay black shale. The eolian lithofacies is best developed in the MISB area. The Conecuh Embayment and northern parts of the MISB and Manila Embayment are characterized by red-bed deposits, whereas the conglomerate lithofacies occurs in the updip parts of the study area. The shale lithofacies is present in the MISB and the Conecuh Embayment areas. In the tristate region, the Smackover Formation consists of a lower intertidal to subtidal, laminated mudstone lithofacies that overlies the Norphlet and an upper subtidal to intertidal lithofacies sequence dominated by grain-supported textures. The upper subtidal oolitic grainstone lithofacies is best developed in the MISB area. The Conecuh Embayment is characterized by subtidal peloidal packstone and intertidal laminated mudstone. Peritidal dolostone is the dominant lithology in the Manila Embayment area. The Buckner Anhydrite Member of the Haynesville Formation usually overlies the Smackover. This evaporite lithofacies is well developed in the southeastern part of the MISB, but thins eastward into the Conecuh Embayment. Upper Haynesville lithofacies change from alluvial-fluvial red bed dominated lithologies in the northern parts of the study area to supratidal-intertidal evaporite, limestone, and shale to the south. Over 100 oil and gas fields have been discovered in the tristate area with Smackover carbonate and Norphlet sandstone the primary reservoirs. Petroleum traps are combination traps involving favorable stratigraphy and salt features. Smackover algal mudstone is probably the source rock for the Jurassic oil.

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Use of Dolostone Rhythmite Stratigraphy to Interpret Origin of Cross-Cutting and Manto Breccias Hosting a Lead-Zinc Deposit at Robb Lake, Northeastern British Columbia

The Robb lake lead-zinc deposit occurs within a brecciated Silurian-Devonian dolostone succession of transgressive-progradational sabkha rhythmites. The rhythmites are characterized by light gray color, white sparry dolomite cemented bird's-eyes, dolomite pseudomorphs of gypsum, and zebroid textures, which are diagnostic evaporitic cementation structures. The rhythmites were identified by logging color and lithologic variations observed in diamond drill core. The light gray tops of rhythmites are attributed to penecontemporaneous oxidation during sabkha progradation; the darker gray bases of rhythmites are attributed to penecontemporaneous reduction during marine transgression. Recording the color variation encountered in drill cores, even of highly brecciated intervals, permits stratigraphic correlation based on key beds and rhythmites. Relative sag of groups of rhythmites from the brecciated areas demonstrates the origin of breccias by collapse. Correlation also suggests that manto-like breccias formed after gentle tilting of the host succession. Tilting probably resulted from differential consolidation of an underlying shale-carbonate facies front. The orientation of the manto-like breccias is interpreted to have been controlled by infiltration of migrating formational fluids along horizontal planes within the tilted evaporitic succession.

Well-defined rhythmites in the upper half of the succession average 2.8 m in thickness with a standard deviation of 1.8 m (N = 1,295). Poorly defined rhythmites in the highly brecciated lower half of the succession have an average thickness of 4.4 m with a standard deviation of 3.7 m (N = 791) proving that even monotonously repetitive and brecciated strata can be differentiated by careful attention to thickness data.

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Jurassic Subcrop and Its Effect on Sedimentation, West-Central Alberta

In eastern and central Alberta, topography on the Pre-Cretaceous surface reflects the presence of a northwest-trending drainage system which intermittently carved into older Paleozoic rocks from Late Mississippian until earliest Cretaceous time. Lower Cretaceous sedimentary rocks mapped across the area fill and cover the valley and ridge system. To the west, successively younger units subcrop at the Pre-Cretaceous surface. As a result, unconformity bounded Jurassic quartz sandstones are present beneath Cretaceous sandstones and, in the absence of paleontologic control (usual situation), can only be distinguished with difficulty. The tendency has been to include these sands in the Lower Cretaceous "Basal Quartz," masking the unconformity surface. Subsequent interpretation of Lower Cretaceous sedimentation patterns is seriously affected.

Mineralogically pure, fine-grained quartz sandstones of the Rock Creek Member (Middle Jurassic) in west-central Alberta are distinct from quartz sandstones of Early Cretaceous age, which have greater grain-size variation and significantly higher percentages of unweathered chert grains. The resulting Jurassic subcrop pattern reveals cuestas of resistant Rock Creek sandstone, similar to those composed of Mississippian carbonates farther east.

Erosional lows on the surface of the Rock Creek Member are commonly filled by estuarine and nearshore sediments of the Ellerslie Member, reflecting invasion of the Early Cretaceous sea into the area.

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Diagenesis and Evolution of Secondary Porosity, Minnelusa Formation, Powder River Basin, Wyoming

The upper member of the Minnelusa Formation in the Raven Creek and Reel oil fields of the Powder River basin consists of a sequence of interbedded sandstones, dolomites, and anhydrites of Early Permian age. This sequence represents depositional environments ranging from sabkha type to a coastal eolian dune complex. The sandstones of the Minnelusa Formation are predominantly moderate to well-sorted, fine to very fine-grained quartzarenites.

Silica overgrowth and anhydrite cement represent an early stage of diagenesis. Dissolution of anhydrite cement was the major process in the development of secondary porosity in the Minnelusa reservoir. Pore-filling dolomite and dolomite replacing anhydrite are late stage diagenetic products. The euhedral dolomite rhombs are ferroan in composition. Authigenic illite-smectite mixed-layered clays are formed contemporaneously with the diagenetic dolomite. Dissolution of anhydrites, formation of secondary porosity, and hydrocarbon accumulation may have occurred during Late Jurassic and terminated during Laramide orogeny.

An analysis of the subsurface formation waters from the Powder River basin was made using WATEQF computer programs. Results indicate that waters are supersaturated with respect to anhydrite and dolomite. The saturation indices of anhydrite and dolomite in the subsurface waters are plotted on maps. A