Cardium Formation at Seebe, Alberta—Storm-Transported Sandstones and Conglomerates

The Upper Cretaceous (Turonian) Cardium Formation is one of the most productive oil-bearing formations in Alberta. As a result of detailed mapping of two outcrops near Seebe, Alberta, we have defined five coarsening-upward sequences within this formation. The sequences begin with bioturbated mudstones and coarsen into sandstones, commonly with conglomeratic veneers on top. In sequence 2, a 20-cm thick conglomerate has been molded into symmetrical gravel waves.

The sandstones are dominated by hummocky cross-stratification, occurring in the upper parts of sequences 1, 2, 3, and 5. The implication is that these sequences terminate in water deeper than fair-weather wave base (10 to 15 m). The trace-fossil assemblage, dominated by abundant *Zoophycos* and long horizontal *Rhizocorallium,* suggests similar depths. Foraminifera recovered from sequences 3 and 4 comprise a highly diverse assemblage of agglutinated species, also supporting deposition below fair-weather wave base.

In view of the physical and biologic evidence for deposition in a few tens of meters of water, and the total absence of medium-scale cross-bedding, we suggest that the entire Cardium Formation at Seebe was deposited below fair-weather wave base. The sandstones were emplaced by storm-generated density currents, the same storm both generating the flow and imprinting hummocky cross-stratification on the deposit. Finally, we suggest that the conglomerates were also moved rapidly seaward by density currents, there being no evidence for the traditional beach or transgressive lag interpretation of these rocks.

WRIGHT, V. PAUL, Open Univ., Milton Keynes, United Kingdom

Paleokarsts at Unconformities

The awareness of the importance of subaerial exposure in the diagenesis of limestones has led to the recognition of a variety of subaerial phenomena in carbonate sequences such as vadose cements and calcrete crusts. Other such phenomena include paleokarsts, of which there are surprisingly few detailed descriptions.

One problem in recognizing paleokarst is to differentiate it from both Holocene and ancient interstratal (or subadjacent) karst. This is a post-burial effect which can create subsurface karstic surfaces along unconformities or bedding surfaces. The unconformity between the Lower and Upper Carboniferous in South Wales displays karstic features which have formed interstratally and have overprinted and were controlled by the original erosional relief along the unconformity. Interstratal karst can be differentiated from true paleokarstic surfaces by simple stratigraphic criteria.

Paleokarsts are common in the Mississippian limestones of Britain, and three types can be recognized in the shelf sequences in South Wales. First, there are large clay-filled hollows interpreted as solution dolines; second, there are mammillated karstic surfaces overlain by paleosols and calcrete crusts with abundant alveolar fabrics (rootlet tubules), interpreted as a type of deckenkarren analogous to Holocene South African Makondo karsts. Third, there are unusual paleokarstic zones consisting of bands of rubbly limestones containing large, irregular fluted blocks surrounded by clay-filled solution pipes and fissures and analogous to Holocene Kavornossen karren, Puerto Rico.

The paleokarsts provide information on the paleoclimate, paleohydrology, and the vegetation cover existing at the time of their formation and are useful paleoenvironmental indicators. They are the raw material for paleogeomorphology and obviously can provide excellent sites for hydrocarbon accumulation.

WYATT, DANNY J., Mobil Oil Corp., Denver, CO

Preliminary Analysis of Depositional Environments of Tar Sand Host Rocks, Uinta Basin, Eastern Utah

Four major tar sand bodies in the Uinta basin were examined in terms of their depositional environments: (1) the Duchesne River and Mesaverde Formations at the Asphalt Ridge deposit near Vernal, Utah; (2) the Wasatch and Green River Formations at the Sunnyside deposit near Sunnyside, Utah; (3) the Green River Formation of the Hill Creek deposit in the southern Uinta basin; and (4) the Green River Formation in the P.R. Spring deposit of the southeastern Book Cliffs.

The Mesaverde Formation at Vernal is interpreted as a fluvial deposit, based on the discontinuous geometry, and the presence of large-scale trough cross-beds which grade vertically into smaller trough cross-beds and tabular foreset beds. The lower Duchesne River Formation was deposited in distributary channels, based on the discontinuous geometry, large-scale trough cross-beds, contorted bedding, and clay-chip zones. This facies is overlain by a meandering flood-plain sequence of sandstones and red shales.

The Wasatch Formation in the Sunnyside area is comprised of stream-mouth bars, point bars, and both active and partial abandonment channel fill. The Green River Formation at Sunnyside was deposited in distributary channels as evidenced by a scoured contact, calcareous clay clasts, large-scale convoluted bedding, and the geometry. This facies grades to the southeast into more laterally continuous sands in the P.R. Springs area. These sands reflect delta front deposition.

YOUASH, YOUNATHAN Y., and AMITABHA MUKHOPADHYAY, Kuwait Inst. Scientific Research, Safat, Kuwait

Geology of Minagish Oil Field, Kuwait

The Minagish oil field is located in southern Kuwait. To date, 23 wells have been drilled in this field. The discovery well, MN-1, was drilled to explore a seismic prospect in this area and was completed in May 1959. The primary aim of this wildcat well was to test all the potentially oil-bearing formations down to and including the Jurassic Arab Zone equivalent. The well established the first commercial accumulation of oil in the Minagish Oolite Formation of Early Cretaceous age. The well found oil prospects in the middle Cretaceous Wara, Mauddud, and Burgan Formations. The Minagish oolitic limestone of Early Cretaceous age is the main oil-bearing reservoir in the Minagish field. The Mishrif Limestone Formation of uppermost Middle Cretaceous has also been found productive in two of the Minagish wells. The quantitative evaluation of well logs indicate that the Upper Cretaceous Tayarat Formation and the Paleocene-lower Eocene Radhuma Formation may also be prospective in this field.

The well evidence suggests that the field is located on a north-south-trending anticlinal structure which has been cut across by a few faults. The structure is oriented north-south. It is 8 km (5 mi) wide and 14 km (9 mi) long. The structural closure is about 200 m (650 ft). The thickness, porosity, and shaliness variation of Ratawi Limestone suggest that, in all probability, the structure was existing in an incipient form at the time of the deposition of this formation. Maps of gross thickness and average effective porosity as derived from the quantitative log evaluation have been prepared for the formations of interest. The reservoir parameters show an overall conformance with the structure.

YOUN, SUNG H., Univ. Calgary, Calgary, Alberta, Canada

Depositional Model of Falher Conglomerates, Elmworth Area, Alberta

A detailed sedimentological study has been conducted on cores from the subsurface Elmworth area, Alberta. Characteristic vertical sequences of the Falher A and B units show coarsening-upward sandstone to conglomerate sequences. Ideal cycle is a shallow-marine to beach progradation. The major sedimentary environments recognized in the Elmworth area are wave-dominated coastal environments which prograded to the north. Falher sediments are interpreted to have been deposited in beach, nearshore, shallow-marine, and coastal-plain environments. On the basis of the interpretation of depositional environments, a depositional model is proposed to explain the sedimentary motifs of Falher sediments. The model consists of shingle ridges, spits, lagoon, coastal plain, and fluvial channels. In this study, most Falher sediments, conglomerates in particular, are interpreted to be transported southeastward by longshore currents and deposited along shoreline in the Elmworth area. These shingle ridges prograded to the north and some spits were developed. Even though some channels were recognized in the study area, the local drainage system during Falher deposition seems to have been poorly developed. It is very unlikely that this system could transport the great amounts of sediments, particularly conglomerates. In considering the distribution and volume of Falher sediments, these channels might contribute part of sands, but not the large amounts of pebbles that are present in the Elmworth area.

ZEIN EL-DIN, M. Y., Univ. Qatar, Doha, Qatar, and E. M. SHALTOUT, Central Laboratories, Cairo, Egypt

Geochemical Correlation of Crude Oils, Gulf of Suez Region, Egypt

A chemical correlation has been made for oils produced from strata ranging in age from Carboniferous to middle Miocene. The correlation parameters used are carbon isotope ratios of $C_{15}+$ fractions, difference between carbon isotope ratios of $C_{15}+$ saturates and aromatic fractions, and the ratios of pristane/phytane, pristane/normal heptadecane, phytane/normal octadecane, and (pristane + normal heptadecane)/(phytane + normal octadecane).

The values of (pristane + normal heptadecane)/(phytane + normal octadecane) and carbon isotope ratios of $C_{15}+$ fractions are found to be the most useful in oil-oil correlation. However, the difference between carbon isotope ratios of $C_{15}+$ saturates and aromatic fractions can be used to differentiate the different producing strata. The other parameters are affected in different magnitudes by depth and age of the producing formation.

It was found that the analyzed oils most likely have stemmed from a common or very similar source rock of marine origin.

ZIELINSKI, GARY W., Gulf Research & Development Co., Harmarville, PA, and PETER M. BRUCHHAUSEN, Lamont-Doherty Geol. Observatory, Palisades, NY

Shallow Thermal Anomaly Over San Sebastian Oil and Gas Field, Eastern Tierra del Fuego

Low thermal diffusivity of peat and soils overlying parts of the oil and gas province of the eastern Magellan basin has resulted in a small number of unusually shallow (<2 m) relative heat-flow determinations. The values are in agreement with the single published heat-flow value for Tierra del Fuego of 2.3 HFU and with deep bottom-hole temperature measurements located in coincidence with the shallow determinations. They are furthermore consistent with local surface air-temperature measurements obtained for a period of 1 year prior to the field work. Compared with that for similar tectonic provinces (post-Precambrian, nonorogenic), the heat flow in eastern Tierra del Fuego appears to be about 0.5 HFU greater than might be expected. Maturation level estimates based on burial history of sediments in the area suggest considerable lateral migration (>100 km) of hydrocarbons from deeper in the Magellan basin. A model is explored whereby the same mechanisn for transport of the hydrocarbons, namely, deep ground-water movement can also explain the heat-flow results. The dramatic 10-HFU decrease in relative surface heat flow observed across the southwestern edge of the San Sebastian oil and gas field is of similar magnitude as other thermal anomalies reported to be in close association with hydrocarbon accumulations.

ZIERENBERG, R. A., AND W. C. SHANKS, III, Univ. Wisconsin, Madison, WI

Depositional and Diagenetic Model for Brine Related Stratiform Mineralization: Atlantis II Deep, Red Sea

Genetic models of many massive sulfide deposits postulate deposition of metalliferous sediment by venting of high-salinity hydrothermal fluids onto the sea floor. The Atlantis II deep, Red Sea, is a currently active modern example of such a process. Areal extent of the brine pool in the Atlantis II deep exerts primary control on the distribution of metalliferous sediment. The presence of a density-stratified brine pool allows dispersion of undiluted metal-rich brine to all parts of the deep. Currently, brine vents in the Southwest basin, advects vertically to the density interface between the brine pool and overlying sea water, and then flows laterally along the interface. The lower brine mass is isolated from oxygenated sea water, allowing base metal sulfides to precipitate in areas distal from the site of venting. The metalliferous sediments are extremely fine grained with interstitial water contents in the uppermost sediments of greater than 98% by weight. Sedimentation rates inside the brine pool are in excess of 100 cm/1,000 years. High salinity, high temperature, and high trace-metal content of the brine produce a toxic environment which ensures that the finely laminated sediments are not disturbed by bioturbation. However, metalliferous sediment deposited in the area of active brine venting is highly disturbed, with common features of soft sediment deformation. Heterolithic and homolithic breccias occur, some of which are metalliferous turbidites dislodged, by tectonic activity, from steep graben walls flanking the deep. Influx of new brine causes further disruption and deposition of epigenetic minerals in veins which cut unlithified metalliferous sediment.

ZOLLNAI, GREGORY, Aquitaine Co. Canada, Calgary, Alberta, Canada

Late Mississippian–Pennsylvanian Orogenic Movements of West Canadian Platform and Adjacent Areas—Their Role in Sedimentation and Hydrocarbon Accumulation

Important, though not too evident, structural changes took place near the end of the Paleozoic Era along the western edge of the North American craton. They roughly correspond to the orogenic phases in geosynclinal areas all around the continent: "Appalachian orogeny," "Antler orogeny," "Cariboo orogeny." The style was block-faulting (with predominantly normal faults) forming platform edges and grabens, surrounded by shallower troughs. The result is a network of rift valleys along the