

HURST, D. J., and J. R. STEIDTMANN, Univ. Wyoming, Laramie, WY

#### Early Eocene Tectonics and Sedimentation in Northern Fossil Basin, Wyoming Overthrust Belt

The Tump Member of the early Eocene Wasatch Formation in southwestern Wyoming was shed from rising thrust sheets as debris flows containing abundant, very poorly sorted to unsorted, coarse clastic material in a mudstone matrix. Deposition occurred on the margins of the northern Fossil basin as coalesced alluvial fans and fan deltas. Small braided streams traversed the surface of these fans and reworked debris flow material, but the resultant fluvial deposits are volumetrically minor.

Tump Member deposits are preserved in three north-south-trending belts around the periphery of the northern Fossil basin. Each belt had a separate source in discrete highlands created by early Eocene motion on the Absaroka, Tump, and Crawford thrust faults. These thrusts possessed unique characteristics of uplift style, provenance, and duration of in-situ weathering that are reflected by differences in clast lithology, size and rounding, as well as thickness and areal extent of the deposits resulting from each thrust.

The results of this study have several important implications about thrust belt development: (1) passive rotation of older thrusts by younger ones can provide an uplifted source for syntectonic sediments, (2) the tenet that major thrusts young in the direction of tectonic transport may be violated by the Tump and Crawford thrusts in the Fossil basin area, and (3) those heretofore faults (i.e., Tump and Crawford) possess a similar geometry that is distinct from other thrust faults in the area.

ISBY, JOHN S., and M. DANE PICARD, Univ. Utah, Salt Lake City, UT

#### Tectonic Significance of Currant Creek Formation, North-Central Utah

The Currant Creek Formation is composed of conglomerate, sandstone, and fine-grained clastic rocks that crop out along the northwestern margin of the Uinta basin in north-central Utah. Lateral gradations in grain size define proximal, medial, and distal parts of coalescing alluvial-fan deposits that prograded eastward from the active Sevier-Laramide orogenic belt during Maestrichtian through Paleocene(?) time.

Paleocurrent directions indicate a dominant southerly transport direction and a minor easterly component. Strong east and southeasterly directions, measured in imbricated clasts and in sand lenses in conglomerate, indicate multiple source areas for the detritus. Source of the coarse-grained detritus in the Currant Creek Formation was the Charleston thrust sheet. Conglomeratic clasts are composed of Precambrian and Cambrian quartzite, chert derived from Cambrian and Mississippian carbonate beds, and Pennsylvanian sandstone. These rocks are exposed in the upper plate of the Charleston thrust near Deer Creek Reservoir, Mount Timpanogos, and Strawberry Reservoir. At Big and Little Cottonwood Canyons, the same rocks are exposed in the lower plate.

A large basement-cored east-verging anticline that is refolded around the Uinta Mountain structure is present in the Cottonwood region. By the time of its final emplacement, the "Cottonwood fold" likely formed a small mountain range. Erosional dissection was well under way and Carboniferous, Cambrian, and Precambrian beds were exposed.

The Charleston-Absaroka thrust rises in the stratigraphic section farther east, displacing Mesozoic rocks. Reworking of Cretaceous sandstone and shale flanking the newly uplifted western end of the Uinta arch also contributed sediment to southward-flowing streams.

JENSON, JOHN, Brigham Young Univ., Provo, UT

#### Stratigraphy and Facies Analysis of Upper Kaibab and Lower Moenkopi Formations in Southwest Washington County, Utah

Pre-Moenkopi karst topography formed on the nonresistant gypsum beds of the Harrisburg Member in the Beaver Dam Mountains of southwestern Utah. Local relief on the erosional surface may be more than 140 m (450 ft), forming potential unconformity traps with substantial closure.

Upper Permian and Lower Triassic rocks in the Beaver Dam Mountains accumulated on a gently westward-sloping continental shelf as both

carbonate and clastic tidal-flat environments. Facies analysis shows seven lithofacies, including gypsum, dolomitic and calcareous mudstone, dolomitic and calcareous siltstone, dolomite, silty wackestone, fossiliferous packstone, and pelloidal-oidal grainstone to packstone. Gypsum and dolomite facies formed mainly on supratidal flats. Packstone and grainstone rocks formed mainly on shoals, bars, and banks in the intertidal zone of a carbonate tidal flat. Mudstone and siltstone units formed mainly on muddy tidal flats.

High-displacement Basin and Range normal faults have uplifted the rocks, forming good exposures of the Permian and Triassic strata in the Beaver Dam Mountains and perhaps forming structural traps to the east. Stratigraphic traps may also occur throughout the Harrisburg and Shnabkaib members. Thick anhydrite beds form the cap. Grainstone, packstone, and dolomite units may be effective reservoir rocks. Source rocks include algal-rich wackestone and dolomite beds, fossiliferous units, including the underlying Fossil Mountain Member, and organic-rich mudstone units. Though trapping mechanisms are abundant in the Beaver Dam Mountains, oil exploration has not been very successful to date; this may be due, in part, to the difficulty of locating suitable traps.

KOPANIA, ANDREW A., Champlin Petroleum Co., Englewood, CO

#### Deformation Consequences of Impingement of Foreland and Northern Thrust Belt (Palisades-Jackson Hole Area), Eastern Idaho and Western Wyoming

Structural studies in the Wyoming-Idaho segment of the Cordilleran thrust belt have provided insight into the nature and origin of the broad, east-facing salient west and southwest of Jackson, Wyoming. Changes in the orientation of regional fracture patterns and compression directions determined by dynamic analysis of calcite twins both indicate that the thrust sheets rotated into the salient in a counterclockwise direction. Furthermore, both field observations and calcite twin data show that there has been a large amount of subhorizontal, strike-normal deformation in the Prospect thrust sheet in the Teton Pass area, where the Prospect and Cache Creek thrusts are in direct contact. Subsurface evidence from Teton valley and the Hoback basin dates the Cache Creek thrust as older than the Prospect, Darby, and Absaroka thrusts.

Balanced cross sections drawn along deformation paths through the area show that movement on the Prospect thrust increases from less than 11 km (7 mi) near Victor, Idaho, to more than 37 km (23 mi) south of Jackson Hole. The fracture pattern and calcite twin data also show that the thrust sheets have rotated by as much as 40°. Palinspastic maps made by the sequential restoration of the cross sections show that prior to movement on the Prospect thrust, both the Darby and Absaroka thrusts curved gently to the northwest. As the Prospect sheet moved, it began to impinge upon the previously emplaced Teton-Gros Ventre uplift. The result was the rotation of the Prospect and piggyback Darby and Absaroka thrust sheets. The deformation due to this bending was taken up primarily by differential rotation of imbricate and main thrust sheets. An accurate understanding of the timing of these structural events relative to the timing of hydrocarbon generation and migration should be an essential factor in any exploration model of the area.

KRINSLEY, DAVID, Arizona State Univ., Tempe, AZ, and KENNETH PYE, Univ. Cambridge, Cambridge, England

#### Examination of Lower Jurassic Mudrocks Using Backscattered Electron Microscopy

The small size of many of the particles in mudrocks makes it almost impossible to image and identify them individually and in situ, using conventional light microscopy. Since the average mudrock contains about 60% clay minerals, an understanding of the physical and chemical characteristics of these minerals is central to the question of burial diagenesis and hydrocarbon generation. Much of the existing evidence concerning burial diagenesis relies on x-ray diffraction data (XRD), particularly with respect to the clay-sized (< 2  $\mu\text{m}$ ) fraction of mudrocks. Backscattered electron techniques (BSE) in scanning electron microscopy (SEM) together with energy-dispersive x-ray microanalysis (EDX), XRD, and electron microprobe analysis, indicate that Lower Jurassic mudrocks from the North Sea basin contain many clay mineral stacks up to 150  $\mu\text{m}$  long.

By studying polished mudrock sections with BSE and EDX, the sizes, shape, orientation, textural relations and internal compositional variation of the clay minerals can be observed *in situ*. Preliminary evidence suggests that the clay stacks are authigenic and may have formed at shallow burial depths during early diagenesis. In addition, sand- and silt-sized clay pellets (glauconite) composed chiefly of iron-bearing dioctahedral mica were observed in the sediment. The irregular shapes and textural intergrowths of many pellets suggest that active outward growth occurred, probably by a combination of displacement and replacement in the surrounding matrix material.

LAW, B. E., and WARREN W. DICKINSON, U.S. Geol. Survey, Denver, CO

#### Conceptual Model of Gas-Seal Development, Green River Basin, Wyoming

Previous work in the Green River basin of Wyoming indicates that overpressuring is the result of gas generation in low-permeability rock sequences. We concur, but suggest that an equally important aspect of overpressuring is the development of an effective seal.

Most porosity in these tight reservoirs results from dissolution of mineral grains and cements. The effectiveness of this porosity-enhancing process is dependent, in part, on the ability of pore fluids to transport dissolved products away from the sites of dissolution. We suggest that, in low-permeability rocks, at depths beginning at subsurface temperatures of 190°-200°F (88°-93°C), rates of thermogenic gas generation exceed gas loss, causing fluid pressure to increase. In the larger pores, free water is forced upward into zones of lower pressure. As a result, a water block is formed, with water-bearing reservoirs updip and gas-bearing reservoirs downdip. In the active gas-generating zone, the remaining water is irreducible. This water is immobile and incapable of removing dissolution products. Thus, while other porosity-reducing processes continue, porosity-enhancing processes become ineffective, resulting in a pore network with very low porosity and permeability.

The initial stages of our model take place in a subsiding basin where subsurface temperatures are at equilibrium with organic matter metamorphism. However, most basins currently are not at equilibrium, and the relationships of organic maturation, temperature, and overpressuring are obscured due to local or regional uplift and temporal variations of paleotemperature. Despite these modifications, the seal, as proposed here, is retained. We suggest that the San Juan basin of New Mexico and Colorado is a postequilibrium example of our model. This basin has progressed through the overpressured equilibrium stage and is now abnormally low pressured due to cooling and gas-volume contraction accompanying regional uplift. However, the gas seal developed during the overpressured stage is present as a low-permeability updip water block.

LAW, B. E., U.S. Geol. Survey, Denver, CO

#### Relationships of Source Rock, Thermal Maturity, and Overpressuring to Gas Generation and Occurrence in Low-Permeability Upper Cretaceous and Lower Tertiary Rocks, Greater Green River Basin, Wyoming, Colorado, and Utah

Most hydrocarbon production from low-permeability Upper Cretaceous and lower Tertiary reservoirs in the Greater Green River basin of Wyoming, Colorado, and Utah is gas. The most likely sources of the gas are the interbedded coal beds and other carbonaceous lithologies. A source-rock evaluation of these rocks indicates predominantly humic, type III organic matter capable of generating mainly gas.

The relatively closed nature of these low-permeability rocks facilitates examination of the geologic processes involved in gas generation and occurrence. All gas accumulations are associated with overpressuring. Thermal generation of gas is the main cause of overpressuring and is directly related to organic richness, level of organic maturation, and temperature. Distances of gas migration, in most areas, do not exceed a few hundred feet. Consequently, the temporal relationships of gas generation

and migration with respect to the development of structural and stratigraphic traps are not as important as in more conventional reservoirs. On the basis of the premise of minimal gas migration, the initiation, or threshold of significantly large volumes of thermogenic gas occurs at a temperature of about 190°-200°F (88°-93°C) and a vitrinite reflectance of about 0.80  $R_o$ .

LAW, BEN E., U.S. Geol. Survey, Denver, CO

#### Biogenic Gas Accumulations in Large-Scale Compaction Structures, Powder River Basin, Wyoming and Montana

The coal-bearing lower Tertiary Fort Union and Wasatch Formations in the Powder River basin of Wyoming and Montana are potentially important sources of biogenic gas. The presence of gas seeps, flowing gas wells, and gas shows in shallow drill holes indicates that these rocks contain economically recoverable methane resources. Chemical and isotopic analyses of coal-derived gas and gas produced from sandstone reservoirs in these rocks indicate that the gases are basically identical and are biogenic ( $\delta^{13}C$  values range from -53.59 to -60.85 ‰ and  $C_1-C_{1.5}$  values range from 0.97 to 0.99).

The search for shallow biogenic gas accumulations may be facilitated by the recognition of the significance of compaction anticlinal folds. The development of compaction structures occurs penecontemporaneously in response to abrupt lithofacies changes associated with specific environments of deposition. Measured relief of these anticlines is as much as 250 ft (76 m).

Compaction folds may provide early formed structural traps in cases where the overlying folded strata contain suitable sandstone reservoirs. In other cases, compaction folds may reflect the presence of stratigraphic traps in the structural core of the fold. For example, the compaction contrasts inherent in a fluvial system of lenticular channel sandstones and fine-grained overbank deposits may be the eventual site of compaction folding. In either case, compaction folds may indicate the presence of very early formed structural and/or stratigraphic traps, and these folds can be mapped on the surface and in the subsurface. They are in stratigraphic proximity to excellent gas source rock (coal), providing optimal conditions for early entrapment of biogenic gas.

LEFEVER, JULIE A., North Dakota Geol. Survey, Grand Forks, ND, RICHARD D. LEFEVER, Univ. North Dakota, Grand Forks, ND, and SIDNEY B. ANDERSON, North Dakota Geol. Survey, Grand Forks, ND

#### Mississippian Frobisher-Alida-Kisbey Sandstone, North-Central North Dakota

Argillaceous and arenaceous marker beds and lenses are common in the Frobisher-Alida interval of the Mississippian Madison. These markers are used to define "pay" zones in Bottineau, Renville, and Burke Counties. One of these regional markers is the Kisbey sandstone, also referred to as the MC-4 bed or the K-2 marker. The Kisbey sandstone has a characteristic log pattern and can be traced from southeastern Saskatchewan into north-central North Dakota. It occupies a specific stratigraphic position between the "Mohall" and "Glenburn" porosity zones and averages 15 ft (4.5 m) thick. Lithologically similar to other arenaceous units locally present within the Frobisher-Alida, the Kisbey generally is a gray to buff, medium to fine-grained, well-sorted, subangular to rounded, quartzose sandstone. Primary structures include lenticular bedding, ripple marks, and small-scale cross-bedding. Dolomite or anhydrite cement are also present locally.

The ability of the Kisbey to act as a reservoir rock is demonstrated by several fields in southeastern Saskatchewan and by the North Haas field in Bottineau County, North Dakota. Nineteen wells in the North Haas field produce or have produced from the Kisbey sandstone. Oil migrating through the "Glenburn" porosity in the Haas field has charged the porous and permeable Kisbey sandstone. Updip, the "Mohall" and "Glenburn" zones become progressively more anhydritic until the Kisbey is bounded above and below by anhydrite. An updip porosity loss acts as the final trapping mechanism.

The principal factor which determines the reservoir quality of the Kisbey sandstone is the presence or absence of cement or argillaceous material.