fields that fit historical field-size patterns similar to those established in both plays during the past 10 years.

PRATT, RICHARD M., Consultant, Littleton, CO

Relationship of Cretaceous Synorogenic Conglomerate in Central Utah to Sevier Thrust Events

A boulder conglomerate facies is found almost continuously along the western edge of the Cretaceous seaway in central and southern Utah. At the present time, north-south continuity of the facies is disrupted by Tertiary volcanic cover and basin and range-type faulting, making the original distribution of conglomerate difficult to follow.

Careful physical comparison of good conglomerate exposures and developing palynologic control in fine-grained equivalent sediments to the east allows some correlation of the facies trend and indicates a close time relationship with Sevier thrust events. Silicic and carbonate boulder conglomerates were limited to a relatively narrow east-west zone directly in front of the leading thrust edge. Rapid eastward transition to well-sorted sand and coastal marine conditions suggests deposition relatively close to base level.

Major unconformities within the conglomerate sequence and the upper and lower limits of coarse clastic sedimentation define several depositional episodes. It appears that the conglomerate packages are related to specific Sevier orogenic events.

PRATT, RICHARD M., Consultant, Littleton, CO

Changing Exploration Concepts in Arapien Basin, Central Hinge Line, Utah

The Arapien basin is situated along the hinge line in central Utah between the Wasatch Plateau to the east and the Canyon and Pavant Ranges to the west. The basin was initially described from the extensive exposure of Jurassic shale and evaporites in the Arapien Valley. Subsequent drilling and seismic profiling revealed thick zones of structurally complex strata beneath the ranges and great depths of sediment fill in the central valleys.

The concept of the Arapien basin and consequent exploration strategies are dependent on how the sequence and importance of structural events in central Utah are envisioned. New ideas include: (1) the concept of stratigraphic thickening from shelf to miogeosyncline across the hinge line includes the Arapien basin as a partially enclosed, graben-type basin subject to desiccation and evaporative deposition, (2) the concept of salt diapirism and salt solution collapse, which has figured prominently in the thinking of some recent workers, (3) the full acceptance of Sevier thrusting, which brings into focus the uniform timing of compressional events in central Utah and thickening of strata by tectonic duplication, and (4) the concept of basin and range extension which is now accepted by many geologists. The reality of listric block faulting and back sliding explains the tilted Tertiary strata on the ranges and the anomalously thick strata in the valleys.

Sorting out the sequence of structural events in the Central Utah hinge line is clearly needed to formulate exploration strategies in the Arapien basin. The abundance of shows in the Wasatch Plateau and the projected extension of overthrust structures south into the area warrant continued interest.

PRZYBYLO, ROBERT A., SALLY K. ODLAND, and WILLIAM L. THOEN, RPI/Colorado, Boulder, CO

Generation of Depositional Facies Maps Using Microcomputers and Lithocrossplot Data, Minnelusa Formation, Powder River Basin

A series of depositional facies maps for units within the upper member of the Permo-Pennsylvanian Minnelusa Formation was generated using data from core descriptions and geophysical logs in combination with regional isopach maps. Over 1,300 ft (396 m) of described core from 22 wells was used to "calibrate" log readings to the four principal lithologies: anhydrite, dolomite, cross-bedded sandstone, and wavy-bedded sandstone. Log cutoff values for each lithology were derived from core through graphic and statistical analysis routines using standard crossplots. Over 24,000 ft (7,315 m) of "synthetic" core was generated for 121 uncored wells. Data were analyzed with microcomputers using common software such as LOTUS 1-2-3 and dBASEII. Clastic and carbonate percent maps were made using all 143 control points. Lithofacies work maps were then constructed by overlaying clastic and carbonate percent maps with regional isopachs. Facies interpretations, based on sedimentary features observed in core, were extrapolated to the lithologic sequences in the "synthetic" cores. These interpretations served as environmental constraints in the construction of the final facies maps.

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Seismic Exploration for Oil and Gas Traps in Wind River Basin: a Laramide Example

The Wind River basin in central Wyoming is typical of the large sedimentary and structural basins that formed in the Rocky Mountain region during Laramide deformation in latest Cretaceous and early Tertiary times. Northeast-southwest-oriented seismic profiles across the Wind River basin and flanking Owl Creek and Bighorn Mountains illustrate the structural configuration and correspondent stratigraphic development of a typical Laramide intermontane basin. Understanding the geometry of the basin margin and the timing of structural movement aids in prospecting for mountain-front subthrust structures, like Tepee Flats field, and stratigraphic traps, like Haybarn field, in fluvial and lacustrine basin-fill sequences.

The Wind River basin is structurally asymmetric with the basin axis close to the Owl Creek Mountains and Casper Arch thrusts, which form the north and east basin boundaries. Major Laramide deformation began in latest Cretaceous time (beginning of Lance Formation deposition) with pronounced downwarping of the basin trough and broad doming of parts of the peripheral areas. The intensity of movement increased through the Paleocene and culminated in early Eocene time as high mountains were uplifted along thrust faults. Clastic debris, stripped from the surrounding rising mountain arches, was shed basinward, resulting in a pronounced wedge-shaped accumulation of fluvial and lacustrine sediments now representing the Lance, Fort Union, Indian Meadows, and Wind River Formations.

REEL, CHRISTOPHER L., JOHN C. HORNE, and ANNE O. KELLY, RPI/Colorado, Boulder, CO

Comparison of Hydrocarbon Production Trends in Middle and Upper Members of Minnelusa Formation

The main reservoir rocks in the upper and middle members of the Minnelusa Formation consist of windblown dunal sands in the area surrounding the Lusk embayment. Changes in the local depositional setting, tectonic framework, and eustatic sea level controlled the distribution and reservoir quality of these sandstones. An understanding of the lateral and vertical variations within and between these members explains the different production trends and may be utilized to formulate predictive models to aid in the development of future exploration programs.

The middle member exhibits two production trends. Age-equivalent Tensleep rocks deposited along the western margin of the embayment produce from sandstones accumulated in a sand sea paleoenvironment. Structure is necessary for trapping owing to permeability continuity. Along the eastern margin of the embayment, production comes from isolated accumulations of sandstone deposited as dunes on broad coastal sabkhas. Fields in these sandstones define a linear trend due to the coast-parallel alignment of these dunes.

Production from the upper member defines four major trends. Upper member sandstones in the southern part of the basin, similar to "Leo" reservoirs, produce from sediments deposited as coast-parallel dunes in a northwest-southeast alignment. In the northern portion of the basin, production is from sandstones deposited in broad, flat eolian sand seas. Because of the permeability continuity of these sandstones, structural closure is necessary for trapping hydrocarbons.

Upper member production has been influenced by the unconformity developed at the top of the Minnelusa. Movement along the Rosebud arch resulted in a southwest-northeast production trend apparent in each sandstone unit reflecting their northwestward erosional limits. The last, and most apparent, production trend, results from the Opeche Shale infilling of northwest-southeast-oriented stream valleys. Most production to date has been from sandstones following this alignment juxtaposed downdip of these impermeable shales.

RICE, DUDLEY D., CHARLES N. THRELKELD, and APRIL VULETICH, U.S. Geol. Survey, Denver, CO

Origin and Significance of Surface Occurrences of Natural Gas, Northern Denver Basin, Colorado

Natural gas commonly occurs in ground water and has been venting to the surface from abandoned water wells in the northern part of the Denver basin near urban areas of LaSalle and Greeley. Because these gases pose an explosion and fire hazard, our studies are aimed at determining their origin and source in an effort to help prevent these dangers.

Two types of gases have been distinguished on the basis of chemical and isotopic composition. Some of the gases are chemically dry ($C_1/C_{1\text{-}5}$ >0.99) and enriched in the light isotope ^{12}C ($\delta^{13}C$ values range from -73 to -67 ppt). These gases are interpreted to be of biogenic origin; they are being, or have been, generated in an anoxic, sulfate-free environment by decomposition of organic matter within Upper Cretaceous Laramie-Fox Hills aquifer.

Other gases contain significant amounts of heavier hydrocarbons ($C_1/C_{1\text{-}5}$ values range from 0.76 to 0.88) and are isotopically heavier ($\delta^{13}C_1$ values range from -49 to -44 ppt). The chemical and isotopic compositions of these gases suggest that they are of thermogenic origin and were generated during intermediate stages of thermal maturity in the deeper part of the Denver basin. In addition, these thermogenic gases are almost identical in both chemical and isotopic composition to those produced from the underlying Cretaceous "J" sandstone and Codell Sandstone Member of the Carlile Shale at depths ranging from about 2,100 to 2,300 m (6,888 to 7,544 ft). The surface gases of thermogenic origin have probably migrated from these deeper reservoirs, and this migration may be related to recent drilling activity in the area.

ROBINSON, LAURA N., and BRUCE E. BARNUM, U.S. Geol. Survey, Denver, CO

Evidence for Extension of Lake Basin Fault Zone from Coal Bed Correlations in South-Central Montana and Implications for Hydrocarbon Exploration

The Lake Basin fault zone is a structural lineament that extends west-northwest across central Montana. The lineament consists mainly of en echelon northeast-striking normal faults that are surface expressions of left-lateral movement along a basement wrench fault. Information gathered from the recent field mapping of coal beds and from shallow, closely spaced drill holes in the northwest part of the Powder River basin, Montana, permit detailed coal bed correlations, which revealed another linear zone of en echelon faulting directly on the extended trend of the Lake Basin fault zone. The faulted area, herein named the Sarpy Creek area, is located 48 km (30 mi) east of Hardin, Montana. It is about 13 km (8 mi) long and 10 km (6 mi) wide and contains 20 en echelon normal faults that have an average strike of N65°E. The Lake Basin fault zone is therefore extended 32 km (20 mi) farther southeast than previously mapped to include the Sarpy Creek area.

The Lake Basin oil field, Montana, and the Ash Creek oil field, Montana and Wyoming, produce from faulted anticlinal structures that have been interpreted to be genetically related to primary wrench-fault systems—the Lake Basin fault zone and Nye-Bowler fault zone, respectively. Therefore, the faulted area of Sarpy Creek (as yet unexplored), and areas southeastward from there along the trend of the Lake Basin fault zone are possible sites for hydrocarbon accumulation.

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High-Resolution Stratigraphic Correlations and Geochemical Analyses, Cretaceous Niobrara Formation, Northwestern Denver-Julesburg Basin

The middle Santonian–lower Campanian part of the Smoky Hill Member of the Niobrara Formation represents a fourth-order regressive-transgressive cyclothem. Studies of this interval have improved our understanding of the influence of depositional environments and structural setting on distributions of organic matter in epicontinental marine strata. Geochemical analyses of fresh quarried sections at Lyons and LaPorte, Colorado, show that, in general, C_{org} (organic carbon) levels are highest between mid-regression and mid-transgression. Rhythmic fluctuations of C_{carb} (carbonate carbon) and C_{org} correspond to limestone-marlstone bedding couplets at a scale of 15-20 cm (6-8 in.). Pronounced lateral variations between Lyons and LaPorte exist in C_{org}, HI (pyrolytic hydrogen index), sediment accumulation rates, and T_{max} (temperature of maximum pyrolytic yield). Comparisons of geochemical averages at Lyons (C_{org} = 2.5%, C_{carb} = 9%, HI = 100, T_{max} = 445°C) and LaPorte (C_{org} = 4%, C_{carb} = 9.5%, HI = 450, T_{max} = 422°C) indicate an elevated thermal maturity at Lyons and depositional conditions more favorable for preservation of marine organic matter at LaPorte. In both sections, C_{org} and C_{carb} show strong negative correlations, possibly reflecting cyclic climatic controls on the development of bedding couplets. High-resolution stratigraphic correlations of 100,000-year or smaller intervals between Boulder and Owl Canyon, Colorado, based on widespread bentonites and bedding couplets, reveal a paleostructural high near Lyons. Shallow-water conditions and increased turbulence over this high are reflected in sediment accumulation rates only 60% of those at LaPorte. Increased amounts and hydrogen richness of organic matter at LaPorte may reflect a deeper water, more quiescent depositional setting.

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Structural Development and Oil Occurrence on Northeast Flank of Uinta Mountains near Irish Canyon, Northwestern Colorado

The study area is located along Vermillion Creek, 1-3 mi (1.6-5 km) east of Irish Canyon, in northwestern Colorado. The exposed stratigraphic section consists of steeply dipping to vertical Upper Cretaceous Almond Formation, Ericson Sandstone, and Mancos Shale along the toe of the Sparks Ranch thrust fault, and of lesser dipping older Mesozoic and Paleozoic formations in distant parts of the thrust plate. In most places, the Almond Formation is in contact across the thrust fault with the Eocene Wasatch and Green River Formations, and all of these formations are unconformably overlain by the Oligocene Bishop Conglomerate and the Miocene Browns Park Formation. The structural development of the area has involved three major events: (1) Late Cretaceous uplift of the Uinta Mountains; (2) Paleocene and Eocene thrust movements of the Sparks Ranch fault; and (3) late Tertiary normal faulting associated with a collapse of the eastern Uinta Mountains. Oil-saturated sandstones are present in outcrops of 10 Paleozoic, Mesozoic, and Tertiary formations adjacent to several of the late Tertiary normal faults. Oil is escaping to the surface along these faults, probably from a large, deep-seated reservoir located below the Sparks Ranch thrust fault.

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Solution of Devonian Prairie Formation Salts: Implication, Seismic Recognition, and Interpretation

Evaporite deposits of the Devonian Prairie Formation in the Williston basin have undergone episodic dissolution, creating many types of hydrocarbon traps. Removal of the salt has resulted in collapse breccias, drape structures, local thickening of potential reservoir rock by sink infill, and enhanced migration paths. Recognition of the presence and absence of the salt section assists an interpreter in avoiding the pitfall, of salt-related velocity phenomena. Keys to recognizing salt solution on seismic data include abrupt terminations of salt reflectors, rootless structures, and isochron thickening and thinning. Comparisons of sets of isochron maps, to identify areas of superimposed thicks and thins, help determine the timing of solution.

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Paleozoic Paleotectonics and Sedimentation in Southern Rocky Mountain Region

During the Paleozoic, the southern Rocky Mountain region included most of New Mexico and Arizona and at least the northern parts of adjacent Chihuahua and Sonora. It was particularly stable part of the North American craton during the Cambrian through Middle Devonian. Slow