apart basin nucleated and subsequently developed throughout Middle Pennsylvanian time. Smaller subbasins developed by orthogonal spreading along intersecting northeast-trending transform faults, where the rate of basin-floor subsidence was related to combinations of normal and strike-slip faulting. The greater Paradox basin was episodically deepened during Middle Pennsylvanian time by rejuvenated extensional basement faulting. Vertical displacement was greatest along the Uncompahgre front, which caused tilting of the basin and deposition of an asymmetrically thick sedimentary sequence.

By mid-Desmoinesian time, the rate of divergent strike-slip faulting slowed considerably. Folds caused by minor wrench movements provided shoaling conditions along the southwest shallow carbonate shelf where porous algal mounds developed. Meanwhile, continued tectonic movement and space-reduction of the basin floor may have triggered salt flowage and diapirism in the deep eastern pull-apart trough. As wrench tectonism diminished from late Desmoinesian through Early Permian time, the eastern portion of the basin continued to subside and was filled with marine and continental sediments.

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Geologic Interpretation of a Seismic Profile Across Oregon Basin Thrust, West Flank of Big Horn Basin, Wyoming

A seismic profile across the central western rim of the Big Horn basin, Wyoming, provides evidence of major flank thrusting beneath the Oregon Basin anticline. Vertical separation at the Precambrian basement level on this westerly dipping thrust zone is at least 6 km (20,500 ft), as verified by a deep footwall test of a spurious subthrust structural closure. The displacement on the Oregon Basin thrust is the same order of magnitude as that measured on the Casper Arch thrust and about half of that on the Wind River thrust. Actual fault plane dip cannot be accurately determined on the seismic profile because of poor seismic returns from the subthrust block, but based on data from other seismic line crossings of the thrust it appears that the fault plane dips west at about 45°. Under this assumption the amount of overhang at the Precambrian-sediment contact is at least 3 mi (4.8 km), and could be as much as 5 mi (8.0 km) if the fault plane is listric. Forward seismic modeling has helped in the selection of the most likely fault-plane solution and in understanding the attenuation of footwall seismic data.

The seismic profile traverses three major thrust-fold trends in the hanging-wall block (all with westerly asymmetry), each of which contains an important oil accumulation. From east to west, these are: Oregon Basin, Horse Center, and Half Moon.

In the footwall block of the thrust, Mesozoic and Paleozoic rocks beneath the Tertiary unconformity dip uniformly west at low angles, and this regional homoclinal dip continues for about 30 mi (48 km) across the Big Horn basin to the first line of thrust-folding (e.g., Garland trend) on the eastern basin flank.

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Pre-Laramide Tectonics—Possible Control on Locus of Turonian-Coniacian Paralic Coal Basins, West-Central New Mexico

Published evidence indicates that Late Cretaceous shorelines trended northwest through west-central New Mexico and adjacent Arizona. Our investigations delineate these shorelines through time and relate them to the prominent northwest-trending monoclinal flexures in the Zuni and southwestern San Juan basins. We related the transgressive (T)-regressive (R) marine cycles (T2-R2, T3-R3, T4-R4) of C. M. Molenaar to deep-rooted monoclinal or asymmetric anticlinal structures. The T2-R2 turnaround is coincident with the Pinon Springs anticline in the northern part of the Zuni basin and appears to be controlled by the Atarque and Gallestina monoclines in the southern part of this basin. Shoreline configurations during the T3 and T4 transgressive maximums coincide with the axis of the Nutria monocline and relate to some subtle pre-Laramide movements along this structure. The R2 regression is unique to New Mexico, suggesting local tectonic control on the configuration of the seaway. The subsequent T3 transgression, which was a major widespread event elsewhere in the Western Interior, was abbreviated in west-central New Mexico near the location of the Nutria monocline.

The T2-R2 through T4-R4 shoreline turnarounds produced numerous paralic basins favorable for the accumulation of organic detritus. A turnaround probably represents a period of slow rates of shoreline migration which allowed a thicker, more extensive accumulation of plant material and hence thicker coals. The present and most of the past coal production in the Zuni and southwestern San Juan basins is from coals formed in paralic basins just landward of the turnarounds caused by pre-Laramide tectonics.

SUMMERS, W. K., W. K. Summers and Assoc., Inc., Socorro, NM

Continental-Scale Ground-Water Flow Systems and Occurrence of Oil and Gas

Physical processes in continental-scale ground-water flow systems account for the migration and accumulation of oil and gas. Conceptualized discharge areas correlate well with existing fields, and flow-system dynamics offer explanations for discrepancies in physical and chemical properties of hydrocarbons for the observed pressure-temperature regimes.

Quantification of continental-scale ground-water systems demands that we apply Darcy's law and fluid-continuum mechanics to all rocks regardless of geologic and petrologic character. However, difficulties arise in quantifying continental flow systems because data have not been generalized for the purpose. For example, a lot of potentially useful data contain transient components which diminish their utility. In-situ data for rocks with low intrinsic permeabilities are virtually nonexistent.

Slice or slab maps offer a partial solution to overcoming the most difficult problem: how to represent three-dimensional (time-dependent) phenomena adequately using maps and cross sections.

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Time-Temperature Reconstructions of Diagenetic Systems

Predicting the distribution of porosity and permeability enhancement in hydrocarbon reservoirs can be achieved by integrating the generation of carboxylic acids, phenols, mineral oxidants, and liquid hydrocarbons in time-temperature space. Such predictive models can be constructed by linking data from oil-field water chemistry, source rock geochemistry, clay mineralogy, clastic diagenesis, thermal modeling and basin analysis.

The detailed organic and inorganic geochemistry and the thermal scenarios used in the time-temperature analysis must be basin specific. Predictive time-temperature models using kerogen-specific kinetic parameters have been developed for two tectonic settings: rift or "pull-apart" basins, and intermontane or "Laramide" basins. From these integrated reconstructions, the optimum conditions and capacity for porosity and permeability enhancement can be predicted.

The optimum conditions for porosity and/or permeability enhancement are: (1) short migration distances, (2) rapid evolution from organic solvent generation to the liquid hydrocarbon window (thermal environments associated with crustal attenuation or overpressuring could cause such perturbations), (3) adequate fluid flux (organic acids are highly water soluble), and (4) available conduits in potential reservoir rocks (fractures, unconformities, or preserved original porosity).

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Echo Springs Upper Almond Field, Washakie Basin: Study of a Successful Tight Gas Reservoir

The Echo Springs (upper Almond) field is an economically successful tight gas reservoir. A study of the upper Almond reservoir petrophysics and performance was undertaken to explain reservoir and production anomalies between the upper Almond "sweetspot" and "non-sweetspot" areas of the field, and to develop a geologic and economic model of the field that could be used to evaluate other areas for tight gas potential. Well performance in the upper Almond is a unique function of depth of burial and reservoir overpressuring, pore size and pore throat radius, and connate water saturation. The sweetspot and non-sweetspot production profiles correspond to two distinct upper Almond rock types. Variations in porosity and permeability between the two rock types appear to be related solely to a unique set of diagenetic conditions. The two rock types can be defined by log analysis, hydrocarbon pore volume calculations, and permeability-thickness data.

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Paleotectonic Influence of Precambrian Wyoming Province and Adjacent Terranes on Phanerozoic Sedimentation on Western Cratonic Shelf

The Archean Precambrian Wyoming province is bounded on the north and south by regionally extensive early Proterozoic mobile belts. Archean rocks have been remobilized by early Proterozoic tectonic events in the northern belt, but the southern belt does not appear to contain rocks as old as Archean. On the east, an early Proterozoic suture belt separates the province from the Archean Superior province. The western margin lies under the western Overthrust belt. The paleotectonic articulation among these anisotropic Precambrian lithostructural terranes, in response to cratonic and continental margin vertical and horizontal forces, influenced the distribution of many Phanerozoic stratigraphic facies. An analysis of the major unconformities in the stratigraphic record in light of the Precambrian lithostructural history of the western shelf discloses new observations concerning the petroleum source rock and reservoir rock stratigraphy of the northern Rocky Mountain region. A correlation between these tectonic terranes and the localization of regional hydrocarbon accumulations has been observed and has been useful in basin analyses for exploration.

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Age Correlation and Tectonic Significance of Wildcat Peak Formation, Northern Toquima Range, Nevada

The Wildcat Peak Formation is exposed only in the northern part of the Toquima Range, Nye County, Nevada. It lies on western siliceous assemblage rocks (Ordovician Vinini Formation) and eastern carbonate assemblage rocks (Ordovician Pogonip Group and Silurian Roberts Mountains Formation), which were juxtaposed by thrusting during the Antler orogeny. The Wildcat Peak consists of three datable marine tongues separated by intervals of coarse clastic deposits. The coarse clastic intervals resulted from truncation following sporadic and cyclic uplifting that continued after the emplacement of the Roberts Mountains allochthon.

In the literature, age assignments for the formation range from Early Pennsylvanian (Atokan) to Early Permian (Wolfcampian). These age assignments are correct, but they only represent the middle and upper parts of the formation. Microfossil analysis has now established that the lower part of the Wildcat Peak is mid-Mississippian (Meramec). All microfossil dates are from material collected from transgressive limestones.

The new information indicates that major Antler thrusting ceased prior to mid-Mississippian time in the Toquima Range. This restricts the length of time of the Antler orogeny from Late Devonian to pre-middle Mississippian (Meramec) instead of Late Devonian to mid-Pennsylvanian. Such an interpretation is consistent with recently published data from the Pinyon Range area, Nevada.

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Thrusting and Synorogenic Sedimentation in Central Utah

The thrust belt in central Utah can be divided geometrically into four major thrust systems, from west to east: the Canyon Range, the Pavant, the Gunnison, and the Wasatch thrust systems, Biostratigraphic correlations together with constraints imposed by the geometry indicate the following ages for thrusting events: late Albian for the Pavant 1 thrust, late Santonian–early Campanian for the Pavant 2 thrust, middle to late Campanian for the late Canyon Range thrust, late Maestrichtian for the Gunnison thrust system, and late Paleocene for the Wasatch thrust system.

In the hinterland, a combination of structural, stratigraphic, and chronologic evidence indicates that shortening was accommodated by the development of a backbreaking (overstep) thrust sequence: Pavant 1 thrust, Pavant 2 thrust, (late) Canyon thrust. This led to the formation of successive overlapping unconformities of late Cenomanian, early-middle Campanian, and late Campanian age. In the foreland, the Gunnison thrust system has a ramp-flat geometry; a series of blind, splay, imbricate faults are associated with a major ramp beneath Sevier and Sanpete Valleys. Late Cretaceous and Paleocene unconformities coincide with the development of an imbricate fan, which was subsequently deformed during the late Paleocene by formation of a deeper duplex structure within the Wasatch thrust system. Associated back thrusts accommodated shortening toward the surface at the west side of the Wasatch Plateau.

The times of superimposed thrusting phases, when compared with eustatic episodes recorded in the Cretaceous seaway, indicate that episodes of continental tectonism were approximately synchronous with eustatic rises in central Utah.

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Pennsylvanian-Permian Block Faulting in Subsurface of Piceance Basin, Colorado

Pennsylvanian-Permian age block faulting has been identified on two regional seismic lines in the Piceance basin. At the south end of a north-south line along the west side of the basin, the Mesozoic section unconformably overlies the Precambrian. Five miles (8 km) to the north, reflectors of the Mississippian Madison Limestone appear in a series of fault blocks downthrown to the north. These faults generally do not displace overlying Mesozoic rocks. In the vicinity of Douglas Creek field, this block faulting created a large horst block on which Madison Limestone is faulted step-wise up the flanks of the structure. The overlying Pennsylvanian Maroon Formation is 50% thinner over the crest of this structure than it is 10 mi (16 km) to the north. Similar features can be seen on a second seismic line running east-northeast through the central portion of the basin between DeBeque field and the Grand Hogback. Coming off the ancestral Uncompahgre highland, Madison reflectors appear near the southwest end of the line in a series of fault blocks downdropped to the northeast. Near Rulison field, a large Pennsylvanian-age horst block is present that may have Madison Limestone stripped from its crest. Near the Grand Hogback, Madison Limestone is faulted up to the east to form a Pennsylvanian-age basement high between the Piceance basin and the Eagle basin to the east.

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Oil and Gas Potential of Idaho Thrust Belt North of Snake River Plain

The thrust belt north of the Snake River plain in south-central Idaho has the elements necessary for major oil and gas accumulations: large traps, thick reservoir rocks, top seals, rich oil-source rocks, and in at least parts of the area, a favorable temperature history. Only drilling is lacking.

The Utah-Wyoming Sevier thrusting extended north of the Snake River plain into southwestern Montana and south-central Idaho. Styles of thrusting and resulting traps are similar to the Utah-Wyoming portion of the thrust belt. After thrusting, large listric normal faults formed northwesterly trending valleys that were filled with Tertiary sediments. Some companies are looking for traps in thrusted Paleozoic rocks; others are exploring the valleys looking for stratigraphically trapped oil generated from deeply buried Tertiary sediments.

Paleozoic strata thicken westward from a normal cratonic sequence consisting of about 5,000 ft (1,524 m) of chiefly carbonate rocks in the east to more than 30,000 ft (9,144 m) of sandstones, conglomerates, shales, and carbonates in the west. Of particular importance as a hydrocarbon source rock was the accumulation of about 3,000 ft (914 m) of organic-rich Mississippian McGowan Creek Shale in a starved basin between the Antler uplift on the west and the craton on the east. Outcrop samples of this shale contain from 0.8-6.3% total organic carbon.

Paleotemperatures in much of the area were too hot for preservation of oil according to alteration of conodonts. At least two important exceptions to the generally high paleotemperatures exist. The Tendoy thrust plate in the eastern part of the area has a conodont alteration index of 1,