field. This understanding of facies-controlled porosity development has application both in regional exploration and in field development.

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Seismic Line Across Wind River Thrust Fault, Wyoming

A seismic line was acquired by ARCO Exploration Company in 1977 in southern Freemont County and extends northeast from the deepest part of the Green River basin across the Wind River thrust onto crystalline basement rocks of the Wind River Mountains. A COCORP line across the area has been discussed previously, but the ARCO line shows more detailed information beneath the thrust.

The seismic line is significant because it shows a strong reflection at the base of the Precambrian granite, which overlies sedimentary rocks of the northern Green River basin. It also illustrates an apparent anticline beneath the thrust fault which is the result of lateral velocity variation caused by a shallow wedge of low-velocity Miocene sediments superimposed on a velocity pull-up related to the high-velocity Precambrian granite. The effects of the velocity variations can be analyzed by ray tracing and by studying the near offset and far offset stacks of the seismic data. A post-thrusting normal fault, the Continental fault, appears to extend downward and causes diffraction energy and time offset on the seismic section. Proper field technique, appropriate processing, and ray tracing interpretation are all necessary in areas of granite overthrusts.

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Stratigraphic Reconstruction Using Digitized Well Logs: Lewis Shale, South-Central Wyoming

Advances in manipulating and displaying log data and improved methods of well-log digitizing have greatly enhanced explorationists' ability to incorporate large volumes of well data into basin-wide stratigraphic reconstructions. Computer manipulation of digital traces expedites construction of cross sections, generation of log-derived lithologic columns, normalization of log response, and updating of regional studies. The ease and speed with which cross sections can be changed and printed allow use of numerous datums to test correlations and permits construction of paleoslope configurations. Additionally, the ability to reduce a large cross section to a single field of view, without loss of definition, produces enhanced basin-side perspective and reveals stratigraphic relationships not apparent at larger scales.

The approach proved critical in depositional reconstruction of the Maestrichtian-aged Lewis Shale in the Washakie and Red Desert basins, Wyoming. Deep-water sandstones within the Lewis are hydrocarbon reservoirs at Wamsutter and Hay Reservoir fields. Core data, cross section thickness patterns, and lithology computed from logs show the Lewis to consist of a thin transgressive shale overlain by progradational sequences. Progradation occurred as deltas entered the basin initially from the northeast and later from the south. Correlation of log response indicative of volcanically derived clay-rich layers results in stratigraphic patterns on log cross sections similar to patterns on seismic sections. The transgressive shale onlaps the Almond Sandstone; progradational sequences are depicted as irregular, sigmoidal clinoforms. Patterns indicate high sediment input and very rapid basin subsidence.

BLACK, BRUCE A., Black Oil, Inc., Farmington, NM

Anatomy of a Regional Play in Rio Grande Rift Basins of New Mexico and Colorado

The integration of regional Cretaceous stratigraphy, surface mapping of different structural styles, seismic data, and accumulating subsurface well control has blended over the past 16 years into a regional Cretaceous play encompassing many of the subbasins of the Rio Grande rift from Texas, north through New Mexico, and into the San Luis basin of southern Colorado.

Different structural styles, as well as changing stratigraphy, can make exploration in one of the subbasins a very different problem from exploration in another. Remnant structures of pre-rifting tectonics vary radically along the course of the rift from north to south, and are present and preserved beneath the subsequent rift-valley fill. Although the same basic tectonic causes for the rift are common throughout its length, this later Tertiary tensional event was imposed across all previous structural grains from Precambrian to Laramide.

In areas such as the northern Albuquerque basin, which was relatively undisturbed by Laramide thrusts, the predominant structural style is listric faulting caused by the rift. However, areas such as the Espanola basin show strong evidence of pre-rift thrusting during the Laramide orogeny. This structural style is still quite evident, and in places is the predominant style preserved beneath Tertiary valley fill.

In other areas, such as the San Luis basin, the rift has superimposed itself across earlier block faulting that occurred during the Precambrian and late Paleozoic and was modified by Laramide thrusts. The area was then covered by Oligocene-Miocene volcanics and rift-valley fill.

Such complex tectonic history makes exploration in the various subbasins of the rift extremely difficult. It also presents rare opportunities for hydrocarbon exploration in potential new provinces where abundant stratigraphic and structural trap potential is combined with adequate source rocks and a favorable maturation history.

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Hydrocarbons in Northern Basin and Range, Nevada and Utah

Occurrences of surface and subsurface hydrocarbons in the northern Basin and Range province indicate that oil and gas have been generated in several areas in this province. Documented surface occurrences include: (1) oil in ammonites found in Triassic shales in the Augusta Mountains northeast of Dixie Valley, (2) the Bruffey oil and gas seeps and asphaltite dikes in Pine Valley, (3) Diana's Punch Bowl (probable gas seep) in Monitor Valley, (4) droplets of oil in goniatites of the Mississippian Chainman Shale and oil staining at one locality of the Sheep Pass Formation in the ranges surrounding Railroad and White River valleys, (5) oil shale in the Tertiary Elko Formation near Elko and the Ordovician Vinini Formation in the Roberts Mountains, and (6) numerous outcrops with petroliferous odor and a few with oil staining.

Subsurface oil and gas shows are more widespread, but most have been found in the same general area as the surface shows. However, there are some important exceptions.

To date, all commercial and noncommercial oil and gas fields in the northern Basin and Range are located near the sites of the surface hydrocarbons. This relationship emphasizes the importance of source rock studies to exploration in this province. Prospective areas that lack surface hydrocarbons might be delineated by source rock studies.

Eleven oil and gas fields have been discovered in this province of which only three or four can be classified as commercial fields. All of these fields are located in Neogene basins--no fields have been found in an exposed mountain range. The significant fields have some additional common characteristics: (1) the traps are associated with a Tertiary unconformity, (2) the reservoirs have a relatively thick oil column, and (3) fractures usually enhance the reservoir quality. Fields in Railroad Valley and the Great Salt Lake illustrate these and other characteristics.

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Red Wing Creek Field, North Dakota: Growth-Faulted or Meteoritic-Impact Structure?

During the early stages of development at Red Wing Creek field, meteoritic impact was the accepted explanation for structure. Spectacular structure that apparently did not persist below the Mississippian Madison Group and the presence of shatter cones, which were thought to be indisputable proof of shock metamorphism from impact, were the primary points of evidence.

More subsurface information from new wells, and more careful correlation, subsurface mapping, and cross sections appear to indicate that there are two interpenetrating systems of fault slivers that persist down through the Ordovician Red River Formation. These fault slivers seem most likely to be torn from northeast- and northwest-trending, reactivated lineaments at their intersection. This deep structure, which is offset from the central high, supports the concept of at least 100 m.y. of progressive structural growth at Red Wing Creek field.

In 1978, the presence of shatter cones was documented at the intersection of two major regional faults in the Canadian Slate Islands of Lake Superior. Thus it can no longer be concluded that shatter cones indicate shock metamorphism from meteorite impact exclusively.

These stratigraphic anomalies also support long-term structural growth at Red Wing Creek field. In the three highest wells, the Mississippian Charles Formation has no salt, which indicates that this 100-ac area was positive during deposition. Progressive, orderly absence of Mississippian and Pennsylvanian formations toward the central high of the pre-Amsden subcrop further substantiates major, late Paleozoic structural growth. Lack of breccia or meteoritic material in the Permian-Triassic Spearfish Formation and Jurassic Piper Formation ring-depression fill appears to rule out any explosive event. Instead of the normal gray Piper shales, there is much red shale within the Piper Formation at Red Wine Creek. This implies long-term, continued uplift rather than instantaneous impact and rebound.

BRITTENHAM, MARVIN D., Snyder Oil Co., Denver, CO, and BRUCE H. TADEWALD, Consulting Geophysicist, Eagle, CO

Seismic Definition of Detachment and Basement-Involved Structures Beneath Absaroka Range, Western Big Horn Basin, Wyoming

The subsurface structure of the western margin of the Big Horn basin is obscured by the Absaroka Volcanic Supergroup (Eocene). This volcanic-volcaniclastic sequence, in many places more than 5,000 ft (1,500 m) thick, is dissected into an extremely rugged terrain. This steep terrain and presence of surface volcanic rocks had in the past discouraged petroleum exploration. Recent seismic data, as represented by two lines, have extended the known western limits of the basin far under the volcanic-volcaniclastic rocks of the Absaroka Range.

The Cody platform, an uplifted and eastward-tilted platform containing surface anticlines and associated oil fields such as Oregon Basin, Grass Creek, Little Buffalo Basin, and Hamilton Dome, extends under the eastern third of the range where other similar anticlines have been defined. As shown by an east-west seismic line traversing the North Fork Shoshone River, the northern area of the platform is dominated by structures radiating from the giant Sunlight volcanic center. This line shows that prospective sedimentary rocks and potential structural traps exist as far west as Yellowstone National Park.

New evidence relating to detachment faulting in Mesozoic rocks is illustrated by a north-south portable seismic line through the South Fork Shoshone River valley and Carter Mountain. This line demonstrates that thrust faults exposed on either side of the valley are not traces of the same fault or a window in the "South Fork thrust fault." The new term "Carter Mountain fault" is proposed for the southern fault trace and "South Fork fault" is retained for the northern fault trace.

The seismic data presented show excellent quality in spite of difficult portable operations and complex velocity problems. The area shows promise for future discovery of giant oil fields characteristic of the Big Horn basin.

BROADHEAD, RONALD F., New Mexico Bur. Mines and Mineral Resources, Socorro, NM

Petroleum Geology of Santa Rosa Sandstone (Triassic), Northeastern New Mexico

The Santa Rosa Sandstone (Triassic) occurs at depths of less than 2,000 ft (610 km) over most of northeastern New Mexico. Two major, presently unproductive heavy oil accumulations are known to exist in the Santa Rosa Sandstone in New Mexico: the Santa Rosa tar sands near the town of Santa Rosa in central Guadalupe County and a subsurface accumulation near the town of Newkirk in northeast Guadalupe County.

The Santa Rosa Sandstone is 67-350 ft (20-107 m) thick in northeastern New Mexico. It overlies the Artesia Group (Permian) with regional angular unconformity and is subdivided into three regionally recognizable units: a lower sandstone unit 18-140 ft (5-43 m) thick, a middle mudstone unit 0-144 ft (0-44 m) thick, and an upper sandstone unit 7-150 ft (2-46 m) thick. The lower and upper units are blanket deposits of braided streams and consist mostly of fine to medium-grained porous sandstones and minor red mudstones. The middle unit is lacustrine, consisting chiefly of red mudstones and minor sandstones.

Structures on the Santa Rosa Sandstone are mostly northwest to northeast-trending gentle folds superimposed on a southeast regional dip of 0.4°.

The two heavy oil accumulations occur in the upper sandstone unit. Shows of asphaltic hydrocarbons occur in the lower unit. Stratigraphic and petrographic studies indicate that good reservoirs are widespread in the lower and upper sandstone units in northeastern New Mexico. The blanket geometry of the lower and upper sandstone units indicates that structure should play an important or even dominant role in the trapping of undiscovered hydrocarbons in the Santa Rosa Sandstone.

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Deadwood Formation and Winnipeg Group Stratigraphy of Williston Basin

The Deadwood Formation thins southward and eastward from about 850 ft (259 m) in western North Dakota to an erosional edge in eastern North Dakota and central South Dakota. Thickness variations reflect pre-Middle Ordovician erosion, preexisting topography of the Precambrian surface, and depositional thinning eastward. The lower Deadwood consists of a clean, quartzose basal sandstone overlain by glauconitic carbonates and sandstones with minor shales. The upper Deadwood consists of less glauconitic to nonglauconitic sandstones and carbonates.

The Winnipeg Group consists of the Black Island and Ice Box Formations and Roughlock Sandstone. The Black Island Formation is composed of a lower red-brown and green sandstone and shale unit with a maximum thickness of about 100 ft (30 m) that is confined to the central basin area. The upper Black Island is primarily a quartzose sandstone with a maximum thickness of about 160 ft (49 m) in the central basin area. It thins to less than 20 ft (6 m) in eastern North Dakota and pinches out southward in southern North Dakota. The Ice Box Formation consists primarily of greenish-gray, noncalcareous shale with a thickness of 110-130 ft (34-40 m) in most areas of North Dakota; it thins southward to about 40 ft in the northern Black Hills outcrops and thins northward as it intertongues with the Black Island sandstone in Canada. The Roughlock Sandstone consists of greenish-gray calcareous shale grading upward into interbedded calcareous shale and argillaceous limestone in eastern North Dakota. It grades into a calcareous siltstone and fine-grained sandstone in south-central North Dakota and extends through north-central South Dakota to the outcrops in the northern Black Hills.

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Mustang Flat—Significant New Paradox Basin Field

The Mustang Flat oil and gas field in T36S, R23E, Utah, was discovered by Texas Eastern Skyline Oil through the integration of regional geologic concepts and seismic stratigraphic techniques.

Mustang Flat currently is capable of production from five wells in the Ismay (Des Moines) Member of the Hermosa Formation. The reservoir is developed from limestones and dolomites associated with the deposition of algal (*Ivanovia*) mounds. The porous section ranges from 30 to 104 ft (9 to 32 m) thick, using a 7% porosity cutoff (as indicated on a compensated neutron log). A hydrocarbon column of at least 180 ft (55 m) has been established; a water contact has not been encountered. Developmental drilling is continuing. Two wells are capable of production from the Desert Creek.

The Patterson field in T37S, R24E, served as a model for exploration. Regional seismic and subsurface studies revealed the Patterson field to be associated with a break in the slope of a postulated paleoshelf. In addition, modeling indicated that porosity within the Ismay could be recognized from seismic data. From regional seismic control, the paleoshelf break was traced to the northwest into T36S, R23E. Seismic data revealed a broad northeast-southwest-trending nose that intersected the paleoshelf break, and porosity indicators were noted. Seismic and leasing programs were subsequently begun. Portable shothole seismic equipment was used because of terrain considerations. High-resolution acquisition and processing techniques were utilized. Careful analysis of isochron and time structure maps, and use of porosity indicators resulted in the Mustang 1 discovery location. Subsequent drilling and seismic work have revealed pitfalls of which the seismic interpreter should be aware.