In the fall of 1981, Northwest Exploration Co. drilled the discovery well for Haybarn field. The field is located in the Wind River basin of Wyoming and produces stratigraphically trapped 43° API gravity, 80°F pour point oil and associated gas from the Paleocene upper Fort Union Formation; these rocks are thought of generally as poor exploration targets and gas-prone at best. The reservoir is an arkosic sandstone deposited along the front of a lacustrine delta system. Clays in the reservoir are almost entirely secondary. Despite the precipitation of diagenetic kaolinite and chlorite, the reservoir capacity has remained high with porosities ranging from 18 to 26% and averaging about 20%. Reservoir permeabilities average about 7 md. Transmissibility has been enhanced in some zones by natural vertical fractures. The fractures also provide an avenue for water from lower water sands. The resistivities of the formation waters are variable, making electric log calculations difficult. The R_w of the productive sand tongue in the discovery well ranges from 0.35 ohm-meters at the top to 1.40 at the base, over a vertical distance of 75 ft (23 m). Oil production is limited to the upper, more saline portion. Both the petroleum source and the trapping mechanism for the field appear to be the lacustrine Waltman Shale. The depositional system responsible for Haybarn field is not unique. Similar oil fields remain to be found in other parts of the Wind River basin.

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Three-Dimensional Seismic Survey Applied to Field Development in Williston Basin

The Medicine Lake field of Sheridan County, Montana, was discovered in March 1979 by the drilling of a seismic anomaly. Production is obtained from Paleozoic carbonate reservoirs ranging in age from Ordovician to Mississippian. Cumulative production from the field, as of March 1982, is 1.2 million bbl.

A mini-3D seismic survey was acquired in October 1981 to facilitate development drilling. The survey covered 2.4 mi^2 (6.2 km^2), encompassing the field's seven producing wells and two dry holes. The purpose of this survey was to provide an accurate image of the subsurface structure and delineate the extent of the producing formations.

The areal coverage and improved subsurface imaging of the 3D survey provided a detailed view of the Medicine Lake anomaly. The seismic data reveals that the structure results from a local basement (Precambrian) high. Mapping of the Ordovician Winnipeg Formation revealed a domal structure covering approximately 0.6 mi^2 (1.5 km^2) with closure in excess of 180 ft (55 m).

Although all producing wells are located on the Medicine Lake structure, stratigraphic variations within the reservoirs may localize production within structural closure. Porosity in several producing formations is diagenetic; prediction of reservoir trends from well data alone is difficult. Inversion and interactive modeling were used to study these stratigraphic variations. A correlation between relative acoustic impedance and porosity was established for several formations. Vertical and horizontal relative acoustic impedance sections were then employed to locate zones of possible porosity. This information, combined with the improved structural data, should aid in further development of the Medicine Lake field.

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Lemhi Arch

The Lemhi arch was a northwest-trending landmass that controlled marine depositional patterns in southwest Montana and east-central Idaho during the late Proterozoic and early Paleozoic, and provided a source for early Paleozoic clastic sediments. The arch persisted as a landmass until Late Devonian, when it was finally covered by marine sediments.

The arch first formed in the late middle Proterozoic, when middle Proterozoic miogeoclinal sedimentary rocks, the Lemhi Group and Swauger and Lawson Creek Formations were arched into an elongate dome. It was deeply eroded in late Proterozoic, and as much as 5,000 m (16,400 ft) of clastic rocks were stripped away. The eroded edges of the middle Proterozoic rocks on the west flank of the arch were partly covered in late Proterozoic(?) and Early Cambrian by the onlapping Wilbert Formation and Tyler Peak Formation of McCandless, but sedimentation apparently did not continue into the later Cambrian. On the east flank of the arch, marine sedimentation began with deposition of the Middle Cambrian Flathead Formation, and continued through the Late Cambrian, leaving a westward-thinning wedge of marine rocks against this flank.

During the Ordovician and Silurian, the east flank of the arch was emergent. The west flank was partly submerged in the Early Ordovician, and the onlapping nearshore clastic and carbonate rocks of the Summerhouse Formation were deposited. These rocks are successively overlain by the eastward-thinning marine rocks of the Kinnikinic Quartzite (Middle Ordovician) and the Saturday Mountain Formation (later Ordovician and Silurian?). The west flank of the arch was briefly exposed to erosion after deposition of the Saturday Mountain Formation, but was again partly submerged in Middle and Late Silurian, when the eastward-thinning Laketown Dolomite was deposited.

Both flanks of the arch were exposed in Early Devonian, but in Middle Devonian, deposition was renewed on the west flank as fresh- and brackish-water sandstone was deposited in channels cut deeply in the Ordovician rocks. Later Middle and Upper Devonian sandstone, algal dolomite, and sedimentary carbonate breccia indicate eastward, onlapping deposition in a nearshore environment, and these are succeeded by Upper Devonian marine dolomite and limestone; all of these rocks above the channel sandstone are included in the Jefferson Formation. The east flank of the arch was exposed through much of the Devonian, but late in the period a thin sequence of marine carbonate rocks of the Jefferson Formation was deposited across the top of the arch, and marine sedimentation in this region was continuous from the miogeocline far onto the craton for the first time since uplift of the cratonic region early in the Middle Proterozoic.

The Lemhi arch continued to influence marine deposition even after it was submerged, separating the region of shelf deposition in southwest Montana and east-central Idaho from the region of miogeoclinal deposition in central Idaho. The arch apparently was a landmass again through much of the Mesozoic; it was overridden by the Medicine Lodge thrust plate, which is composed of miogeoclinal sedimentary rocks, in late Early and Late Cretaceous.

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Seismic Interpretation of Basement Block Faults and Associated Deformation in Rocky Mountains Foreland

The reflection seismic method is the most effective technique for the interpretation of buried block fault/forced fold structures. Recent advances in seismic acquisition and processing have improved the interpreter's ability to define fold and fault geometry but limitations still exist. Two major problems involve lateral velocity changes and complicated raypath geometry. It is, therefore, desirable to study surface exposures to use as a guide for mapping buried features. The block fault/forced fold concept has been used effectively to provide models for analyzing foreland structures as demonstrated by seismic lines from several Wyoming basins.

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Foreland Deformation—A Critique of Cause

The cause of foreland deformation has been argued for nearly 100 years, and despite definitive stratigraphy, superb exposure, and extensive seismic and well data, the mechanism and geometry remain elusive. It is necessary to separate arguments for cause from arguments that only support a particular geometric interpretation.

The following statements are presented for discussion and are not advanced as "the answer."

(1) Foreland deformation is caused by end-load buckling in a plate tectonic setting driven by abnormally shallow subduction. (2) The crust is the active (competent) unit, and the plastic subcrust is a passive cushion allowing the great vertical component, though a slight slope forced on it by the subducting slab may have aided telescoping of the crust above. (3) No strictly vertical cause can allow the basins to go down as much as they did, and active (causal) intrusion under uplifts only is not likely. (4) While reverse faults and modest shortening predominate, fault attitudes can