SEISMIC INTERPRETATION OF THE CASPER ARCH THRUST, TEPEE FLATS FIELD, WYOMING

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INTRODUCTION

A northeast-southwest oriented seismic line across the northeastern Wind River Basin and flanking Casper Arch illustrates the structural geometry of mountain front thrusts in the Rocky Mountain foreland province. The line crosses the Tepee Flats Field which produces gas from the Cretaceous Frontier Formation beneath a plateau of Precambrian granite.

The steep structural dip at the leading edge of the thrust, in combination with dramatic lateral velocity variations created by juxtaposing high velocity Precambrian rocks and lower velocity basin sedimentary rocks, create unique seismic interpretation problems. Refining seismic migration procedures and velocities are critical for an accurate interpretation.

Location

The seismic line is a 15 mi long, structural dip-oriented profile in Natrona County, Wyoming (Fig. 1). The southwest end of the line begins in the eastern trough of the Wind River Basin and traverses northeastward across the Casper Arch. The line cuts the steeply dipping rocks on the edge of the arch and then passes over the Tepee Flats Field (lying the discovery well, the Monctief 16-1 Tepee Flats [Fig. 2]). The line continues northeastward across Nortchen Anticline, a southeast plunging structural nose on the arch.

REGIONAL GEOLOGY

Tectonic Setting

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. The basin is surrounded by mountains and structural uplifts including the Granite Mountains on the south, the Wind River Mountains on the west, the Big Horn, Owl Creek, and Bighorn mountains on the north, and the Casper Arch on the east. During late Cretaceous through early Eocene time, the basin was the site of accumulation of a sequence of alluvial, fluvial, and lacustrine sediments which attained a maximum thickness of nearly 20,000 ft.

Surface mapping of the near-vertical dipping Upper Cretaceous and lower Tertiary rocks along the west flank of the Casper Arch, and well control along the basin margin, indicated the Casper Arch was uplifted along a reverse fault (Koehler, 1970). The fault was thought to be a moderate- to high-angle reverse fault. New vintage seismic data and new well data clearly indicate the Casper Arch Thrust is a low-angle reverse fault with the sedimentary section of the eastern Wind River Basin continuing northeast under it for 5 to 15 mi (Skeen and Ray, 1983).

History of Petroleum Exploration

Early hydrocarbon exploration was concentrated in the shallow section above Precambrian rocks on the Casper Arch. Numerous structurally-controlled fields, gas productive from the Cretaceous Frontier Formation or oil productive from the Pennsylvaniaian Tensleep Sandstone, were discovered. Many early discoveries were based on mapping surface structure.

From 1977 to 1979, CIGL Exploration drilled the No. 1-63-96 Bullfrog Unit well east of the arch in the deep Wind River Basin. The borehole cut reverse faults in the shallow section on the flank of the Casper Arch and established production in the basin from sandstones in the Jurassic Sundance and Morrison formations and the Cretaceous Lakota and Muddy formations (Sprague, 1983). The W.A. Monctief No. 16-1 Tepee Flats well, spudked in October 1979, drilled through 8835 ft of Precambrian granite before perforating the thrust and drilling into overturned Triassic beds at 15,032 ft. The well bore penetrated overturned Triassic rocks through Cretaceous Frontier Formation sedimentary section before crossing a second fault at 17,395 ft and drilling a normal section of Cretaceous Nokomis through Jurassic Morrison formations. The well was completed in the southfluent Frontier Formation section some 8 ft from 18,453 to 18,463 ft establishing the first major gas discovery beneath Precambrian rocks (Gries, 1983). Subsequent drilling by both W.A. Monctief and Conoco Oil & Gas have indicated that the Tepee Flats field and Bullfrog field are on the same large anticlinal structure which continues under the Casper Arch (Skeen and Ray, 1983, Sprague, 1983).

Sprague's geologic cross section (1983) roughly parallels the seismic line (Fig. 3). The cross section shows the relatively steep dip of the thrust at its leading edge and the thrust appears to flatten out with depth to about 30 degrees. The large thickness variation in the recurrent Oliver Mesozoic and Paleozoic rocks is also shown, however, it is not known whether the fault-doler continues all the way along the thrust fault as shown.

SEISMIC INTERPRETATION

Excellent quality 24-fold depth data reveals structural and stratigraphic information about the Casper Arch thrust fault. Numerous seismic reflections can be carried in the sedimentary section of the Wind River Basin including top of Precambrian, Phosphoria Formation, Cloverly Formation, Frontier Formation, Cody Shale, Mowry Formation, Lance Formation, Lower Fort Union Member, and top of the Fort Union Formation (Ray and Keffet, 1965).

At the southwest end of the seismic line, the thick sedimentary section of the basin is arched up into a structural fold by a reverse fault as the Precambrian basement (Figs. 4 and 5). This fault, named the Bullfrog Fault, trends north-northeast (Fig. 2) and forms the west boundary of the Tepee Flats Bullfrog anticline (Sprague, 1983). It appears to have over 2000 ft of vertical relief at the basement level but dies out upward in the lowermost Cretaceous formations.

Reflections in the basin sedimentary section clearly continue under the wedge of overthrust Precambrian granite. A series of subparallel reflections indicates the zone of discontinuity between the Precambrian granite and sub thrust sedimentary section. A synthetic seismogram generated for the W.A. Monctief Tepee Flats No. 16-1 well (Fig. 6) begins at the top of the overthrust Precambrian granite and shows the character tie to the seismic data. Interestingly, the largest velocity contrasts and therefore the strongest reflections are created by fault zones in the very uniform