Tectonic Framework and Gas-Filled Structures of the Bearpaw Mountains, North-Central Montana

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ABSTRACT

Regional tectonic patterns in north-central Montana are the result of at least two periods of quasi-flat-slab subduction. The Eocene-age Bearpaw Mountains are situated on a northeast-trending Precambrian suture zone between two Archean-age microplates. This zone, known as the Great Falls Tectonic Zone (GFTZ), was the collision zone between the Medicine Hat Block of the Hearne Province to the northwest, and the Wyoming Province to the southeast. A COCORP seismic profile across the south flank of the Bearpaw Mountains shows the internal structure of the GFTZ with steeply-dipping Wyoming Province descending northwestward under the Medicine Hat Block. We consider the collision to have occurred about 2.7 Ga during the Archean, with reactivation about 1.8-1.7 Ga during the Proterozoic.

During the Trans-Hudson Orogeny about 1.8-1.7 Ga, the Dakota Plate was subducted westward under most of Montana in a manner similar to India being subducted under the Himalayas. Some of the effects that can be attributed to this event include a doubling of the thickness of the lithosphere, potassic metasomatism of the upper mantle, underplating of the base of the crust with more than 10 km of magma, pervasive deformation and metamorphism of crustal rocks, and uplift with erosion of perhaps 10-to-15 km of crust before the transgression of Belt sediments about 1.58 Ga.

The Laramide structure and volcanism of the Bearpaw Mountains resulted from the flat-slab configuration of the subducted oceanic Farallon Plate beneath Montana. The Bearpaw Mountains are an elliptical dome formed by uplifted basement rock. The dome is the northernmost of a series of Laramide uplifts that include the Little Belt, Big Snowy, Beartooth, and Bighorn mountains. The GFTZ may have provided paths of easy migration for mantle-derived phonolite lava flows and shonkinite intrusions present in the overlying Bearpaw Mountains.

Pervasive gravity sliding on the flanks of the Bearpaw Mountains occurred on two bentonite beds in the Marias River Formation (Upper Cretaceous Colorado Group). The gravity sliding coincided with rapid loading as a thick pile of volcanics accumulated on the uplifted dome. The best explanation for blocks of strata gliding down slopes less than 3 degrees is the overpressure that developed in the bentonite layers due to a transformation of smectite (montmorillonite) to illite, which created superior seals and released structurally-bound water. Above the detachment zone, strata include the Eagle Formation, a wide-spread shoreface sandstone unit 200–250 ft (60–75 m) thick, and the overlying Claggett Shale, 400–550 ft (120–170 m) thick. Sandwiched between source rocks, the very porous and permeable Eagle Sandstone is a prolific reservoir for shallow biogenic gas trapped in structures 500-2500 ft (150–750 m) deep.

The ubiquitous gravity sliding broke the overlying strata into a myriad of structural traps that pervade the Bearpaw Mountains and their perimeter, continuing outward more than 50 km. Slide-induced faulting produced pull-apart structures at the "heads" of the gravity slides

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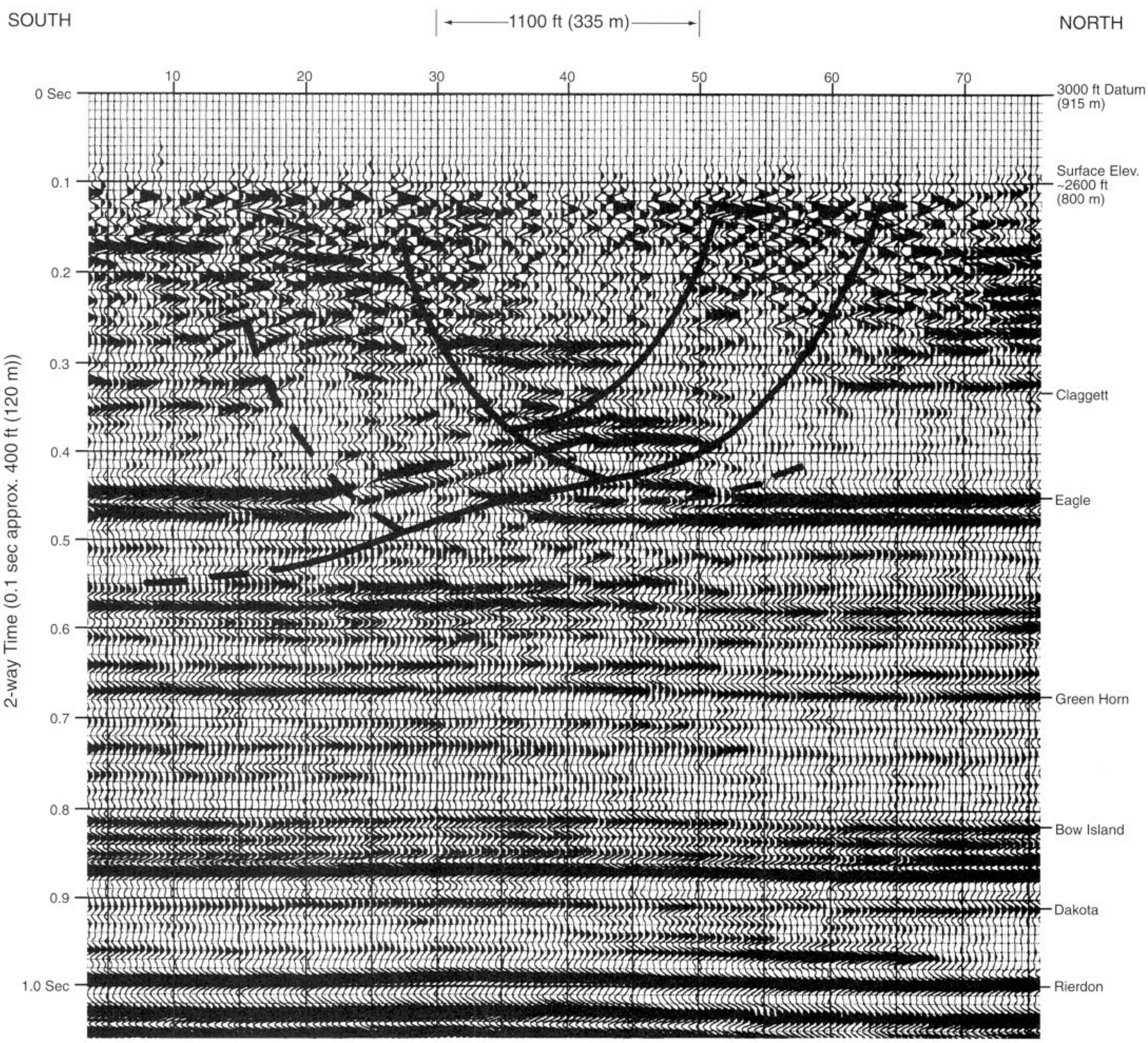
and compressional "pop-up" structures, containing imbricated Eagle strata, in the "toes" of the slides. Fault displacements are erratic and can vary from 30–1300 ft (10–400 m) between adjacent blocks of strata. While the gravity slide structures were generally evident from early surface geology and drilling, recent seismic data have provided clearer images and a better understanding of the structural form of the gas traps.



An example of a slide-induced structure about 20 miles (32 km) north of the Bearpaw Mountains. Note that the Eagle Sandstone (strong reflection) is repeated 3 times below shotpoint 40 and that deeper strata are not involved in the structuring (see Baker and Johnson, Volume 1).