Oblique-slip on this ramp probably resulted in about 20 km (12 mi) of crustal shortening perpendicular to the trend of the mountains.

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Dissolution of Permian Salt and Mesozoic Depositional Trends, Powder River Basin, Wyoming

Salt deposits in the Powder River basin of Wyoming occur in the Late Permian Ervay Member of the Goose Egg Formation which was deposited in a redbed-evaporite trend extending from the Williston basin of North Dakota to the Alliance basin of Nebraska and Wyoming. However, only remnants of the once extensive Ervay salt remain in the Powder River basin, with major salt dissolution events occurring during Late Jurassic and Early Cretaceous. Subsidence and deposition at the surface were contemporaneous with subsurface salt dissolution except in areas where uplift and erosion were occurring. The presence or absence of Ervay salt and the relationship to overlying syndepositional strata can be seen readily and mapped using borehole logs or seismic data.

Earliest dissolution of the Ervay salt occurred in the Jurassic, during regional uplift and erosion of the overlying Triassic Chugwater Formation in the present Hartville uplift and southeastern Powder River basin areas. Thickness variations of the Canyon Springs and Stockade Beaver members of the early Late Jurassic Sundance Formation, which unconformably overlie the deeply eroded Chugwater Formation, may be related in part to dissolution of the Ervay salt. Extensive salt dissolution, synsubsidence, and syndeposition occurred throughout most of the Powder River basin during latest Jurassic and Early Cretaceous. Evidence of this is seen in thick trends of the Morrison, Lakota, Dakota, or Muddy formations overlying areas of Ervay salt collapse. One area escaping extensive dissolution in the Early Cretaceous was the eastern Belle Fourche arch, which trends northeast across the middle of the Power River basin. Here the Lakota, Dakota, and Muddy formations are thin over areas with underlying Ervay salt, but thicken rapidly in areas of salt collapse.

Many producing fields from the Mowry, Muddy, and Dakota formations exhibit either rapid stratigraphic changes syndepositional to salt collapse or fracture-enhanced reservoir quality due to postdepositional salt collapse. Major Muddy accumulations occurring in areas of local Ervay salt collapse include Kitty, Hilight, Fiddler Creek, and Clareton which have produced jointly over 172 million bbl of oil. The relationship of Ervay salt dissolution to Lower Cretaceous deposition can be exploited as an effective exploration tool.

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Structural and Depositional History, Jefferson and Madison Basins, Southwestern Montana

Recent seismic and gravity data from the Cenozoic Jefferson and Madison basins provide new information concerning their structural and depositional histories. Both basins are north-south elongated structural basins formed as a result of horizontal extension after Laramide horizontal thrusting. Each basin is bounded on the east side by a sinuous faulted steep mountain front, and large west-sloping alluvial fans extend almost completely across both basins.

Gravity data show that each basin in the subsurface is asymmetric with a large steep west-dipping fault on the east flank, and one or more east-dipping fault(s) of smaller magnitude on the west flank. The deep axis of each basin runs parallel to the east mountain front and lies east of the surface geographic central axis. Jefferson basin has two deep, closed, structural lows (one east of Silver Star and one east of Twin Bridges), which are separated by a structural arch. Sediment depth on the arch exceeds 3,000 m (10,000 ft). Madison basin is shallow on its north end (approximately 2,100 m, 7,100 ft) where it is terminated by the prominent northwest-southeast Spanish Peaks structural trend, and progressively becomes deeper (4,500 m, 5,000 ft or more) south of Ennis, Montana.

Seismic data confirm or support the gravity data. Seismic also shows the folded and thrusted rocks of the east mountain footwall block dipping steeply westward to where they gradually disappear beneath the thick Tertiary sediments. Tertiary strata lying directly against the large west-dipping basin fault show dip reversal caused by drag-folding during basin subsidence. Downthrown "rollover" type anticlines are thus present on the east side of the basins. Numerous small faults, many antithetic, cut the deeper strata and diminish in throw upward.

Strata seen in the seismic sections can be subdivided into a lower set which forms the bulk of the basin fill (possibly equivalent to the Renova Formation, late Eocene to early Miocene); a thinner middle set unconformably overlying the lower set (equivalent to the Sixmile Creek Formation, Miocene and Pliocene); and an upper set composed of west-dipping Quaternary alluvial fan deposits. Each set thickens toward the east basin-bounding fault. In the lower "Renova" set, lacustrine intervals are indicated by their consistent lateral seismic character, whereas fluvial intervals appear to terminate abruptly.

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Example of Inner-Shelf Sand Ridges from Upper Cretaceous Eagle Sandstone, Central Montana Uplift

The Upper Cretaceous Eagle Sandstone of central Montana was deposited during a general eastward progradation of the western shoreline of the narrow, north-south-trending Western Interior epicontinental seaway. Cordilleran highlands to the west were episodically uplifted, and provided the main source for sediments deposited in the seaway.

On the Central Montana uplift, the lower member of the Eagle consists predominantly of very fine-grained sandstone, which is exposed as a thick (average 100 ft, 30 m), continuous topographic rim. This sandstone gradationally overlies shales of the Telegraph Creek Formation. Within the rim, resistant beds and concretions of calcite-cemented sandstone define several smaller units, which can be traced laterally over distances of several miles. These units maintain fairly uniform thicknesses from north to south. However, in an east-west direction, the units thin, are imbricated, and become younger to the west. Excellent exposures of these imbricated lenses occur along a rim that extends 12 mi (19 km) southwest from the town of Winnett.

Although the sandstone of the lower member is very fine-grained throughout the rim, systematic changes occur within a single lens. These changes include: (1) thinning and grading into shale and siltstone to the southwest: (2) bioturbation decreasing upward and to the northeast; (3) oblique *Asterosoma* burrows predominating in the lower part of each lens and to the southwest, with horizontal *Ophiomorpha* burrows being more common in the middle part of each lens and to the northeast; (4) parallel bedding and hummocky cross-stratification successively occurring in the upper part of each lens and to the northeast; and (5) relatively straight-crested symmetrical ripples generally capping each lens. The sedimentary structures within each lens indicate increasing energy and shoaling upward, but do not indicate subaerial exposure.

The lenses in the lower member are interpreted as landward-prograding (westward) sand ridges that were deposited on the inner shelf at distances of tens of miles from the shoreline. Laterally equivalent coastal sandstones of the Virgelle Sandstone Member prograded seaward (eastward) at this same time. The lenses are elongated in a north-south direction, generally parallel to the coast. However, the exact geometry of individual ridges is unknown. After bypassing the shoreface zone, the sand probably was transported parallel to the shoreline by geostrophic currents driven by wind-forcing. Storm waves reworked the upper, seaward-facing slopes of the ridges, whereas landward-facing parts of the ridges were more protected and subjected to bioturbation.

Ridges that occur on the Central Montana uplift are comparable in many aspects to sand ridges on the modern Atlantic inner shelf. However, the modern sand ridges differ from those of the Eagle in two ways: (1) they occur at angles oblique to the shoreline, and (2) they resulted from "shoreface detachment" during the Holocene transgression.

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Haybarn Field, Fremont County, Wyoming, an Upper Fort Union (Paleocene) Stratigraphic Trap