northeastern part of the state (Williston basin). The ratio of sodium plus potassium plus chloride to dissolved-solids concentration is greatest in northeastern Montana where the Madison contains salt beds, and decreases toward recharge areas. The ratio of sulfate to total anions is greatest in north-central and southeastern Montana where anhydrite probably is the source of the sulfate. The ratio is smallest in northeastern and northwestern Montana; however, the concentration of sulfate, in milligrams per liter, can be greater in northeastern Montana than in other areas because of the greater concentration of all dissolved solids.

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Depositional Framework for Lower Member of Metaline Formation (Cambrian), Northeastern Washington

The Metaline Formation is a Cambrian unit that crops out in Stevens and Pend Oreille Counties, northeastern Washington. The 985 to 1,250-m (3,200 to 4,100-ft) thick formation has been divided into lower, middle, and upper members, although structural complications and numerous covered intervals have made measurement of complete stratigraphic sections impossible. Based mainly on trilobite studies, early workers assigned a Middle Cambrian age to the 120 to 290-m (390 to 950-ft) thick lower member. The present study divides the lower member into the following five lithofacies: (1) gray mudstone, (2) ooid-arenite, (3) gray packstone-wackestone, (4) black packstone-wackestone, and (5) black mudstone facies.

The gray mudstone facies grades upward from underlying fine-grained siliciclastics, and it is composed of bioturbated lime mudstones with a small admixture of thin-shelled trilobite fragments, chitinophosphatic inarticulate brachiopods, and disarticulate echnioderms. The ooid-arenite facies occurs as pods within the gray mudstone facies, and is composed of spherical quartz grains and ooids developed around quartz cores in a neomorphic spar matrix. The facies is extremely well-sorted. The gray packstone-wackestone facies is composed of ooid-oncoid packstones alternating with argillaceous, fossiliferous wackestones. Rounded intraclasts and peloids are secondary components. Fossil allochems include robust trilobite fragments, echinoderm plates, and rare (?) *Epiphyton* algae. The black packstone-wackestone facies contains the same components as underlying rocks but is characterized by an increase in carbonaceous material and pyrite causing the black color. Fossils are less robust than in the underlying facies. The black mudstone facies is characterized by bioturbated lime mudstones with rare fossil fragments. The top of the member is marked by a red-stained, well-cemented zone below a disconformable contact with the middle member.

The lower member of the Metaline Formation represents the first carbonates deposited on a ramp-type shelf margin during a major Middle Cambrian transgression. The observed lithologies suggest deposition under conditions of changing water depth, agitation, and oxygenation in the shallow subtidal zone. The mudstones and wackestones in all facies were deposited under low-energy conditions. Shallowing allowed increased agitation, and oxygenation suitable for the local development of ooids and oncoids. Periodic storms produced high-energy packstone deposits composed of concentrations of the components found in the typically low-energy subtidal zone.

Along with the transgression of marine environments, oxygen-starved waters migrated shoreward from an offshore, lower shelf basin. This transgression of the pycnocline caused dysaerobic and anaerobic conditions in shallow subtidal waters of the upper shelf. Aerobic and dysaerobic conditions produced gray rocks, and anaerobic conditions produced black rocks rich in organic material. Biofacies were also affected by the low oxygen levels. Thin-shelled and chitinophosphatic forms dominated the epifauna when dysaerobic conditions occurred. With decreasing oxygen content, the epifauna was progressively excluded from the shallow subtidal zone. The result of maximum anoxia was the cessation of carbonate sedimentation and the formation of a submarine hardground at the end of "lower Metaline deposition."

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Origins of Oil in Railroad Valley, Nye County, Nevada

Trap Spring field was discovered in 1976, becoming the second commercial oil field in Nevada. The first, Eagle Springs, was discovered in 1955 and is about 6 mi east of Trap Spring. Currant, a third, noncommercial, one-well field, was found in 1978 and is about 7 mi north of Eagle Springs. Trap Spring field is productive from Oligocene welded ash-flow tuffs, and Currant produced from the Eocene Sheep Pass Formation. Production at Eagle Springs is from both of these units plus some production from the Ely Limestone (Pennsylvanian). Possible sources of oil for these fields are beds within the nonmarine Sheep Pass Formation and the marine black shales of the Chainman Formation (Mississippian). Prior to discovery of Currant field, the origin of the Eagle Springs and Trap Spring oils was problematical, and a wide range of source rock and post-generation alteration possibilities were considered. The n-C_{15+} chromatograph of the Currant oil shows unusually high peaks of pristane and phytane and a slight even-carbon preference in the n-C_{18} to n-C_{26} range. These factors are indicative of a recently generated oil from a source rock in a carbonate-evaporative sequence. The geochemical data and geologic conditions support the hypothesis that the oil produced at the Currant well was generated in the Sheep Pass Formation. The n-C_{15+} distribution of Trap Spring oil differs significantly from that of the Currant oil and is more typical of oil generated in source rock deposited in a marine environment. The most likely source of this oil is the Chainman Formation. The origin of the oil from Eagle Springs remains unclear as it has chemical affinities to both Trap Spring and Currant oils. It is possible that the Eagle Springs oil is a mixture of oil generated in the Sheep Pass Formation and Chainman Shale.

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Differential Vertical Tectonics: Insights from Models Composed of Sandstone and Limestone Deformed at Confining Pressure

Rock models (12 × 3 × 3 cm, 4 × 1 × 1 in.) composed of a precut forcing block of sandstone beneath a 1-cm thick, multilithologic layered veneer of sandstone and limestone or of uncemented sand, have been deformed room-dry, at 100-MPa confining pressure, room temperature, and a strain rate of 10^{-4} sec^{-1}. Upon frictional sliding along the lubricated precut (inclined at 30° to 90° to the intact veneer) the forcing blocks deform the layered veneer into a faulted drape fold. Thin sections cut parallel to the dip and to the strike of the precut and major fault in the veneer are studied to provide detailed maps of the induced deformation (microfractures, faults, intragranular strains, "bedding" thickness changes, brittle versus ductile behavior, and nature of the folding and hinge formation). In addition, dynamic fabric analyses of faults, microfractures, and calcite twin lamellae yield stress trajectory diagrams that serve to test the applicability of corresponding numerical or analytical solutions.

Insights gained from the models primarily deal with (a) brittle or ductile behavior of the limestone depending upon location within the faulted drape fold; (b) nature of the deformation concentrated in the leading edge of the "upthrown" forcing block; (c) configuration and sequence of faulting associated with the major "upthrust" in the veneer; (d) location and significance of associated precursive microfracturing; (e) cataclastic thinning of veneers to the point where discrete layers are "tectonically eliminated" in the major fault zones; (f) hinge formation within the veneer; and (g) the role of "bedding-plane slip" in the folding process.

Deformation features in these models are used to interpret the geometry and genesis of the large scale structures at the Clark's Fork Corner of the Beartooth Block and at Rattlesnake Mountain near Cody, Wyoming; at Colorado National Monument near Grand Junction, Colorado; at the Yampa drape fold, Dinosaur National Monument; and in the subsurface along the Oak Ridge fault, Ventura basin, California. Collectively, these features are criteria for, and hence help define, the differential-vertical-tectonic style.

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Paleotectonic Implications of Arkose Beds in Park Shale (Middle Cambrian), Bridger Range, South-Central Montana

The Cambrian System in the Bridger Range of south-central Montana is part of a 450 to 500-m (1,475 to 1,640-ft) thick transgressive-regressive sequence of fine-grained clastic and carbonate rocks. Above the Flathead