Pennsylvanian in age, and thus precipitated at temperatures around 25°C (77°F); they are interpreted as meteoric phreatic cements. The youngest cement, zone 5, is interpreted as a pre-Permian burial cement precipitated at temperatures less than about 80°C (176°F) and at burial depths less than about 1 km (3,300 ft).

Originally defined on the basis of luminescence and staining, each zone has a distinctive assemblage of C^{13}, O^{18}, Mg, Mn, and Fe contents. The low MgO contents (less than 0.25 wt. %) in all zones indicates that sea water was insignificant in their precipitational waters over most of the region. Their FeO and MnO contents are compatible with their subsurface interpretations.

The isotopically most positive values from bioherm muds and synsedimentary former high-Mg calcite cements (+4.5‰ δC^{13}, −1.5‰ δO^{18} PDB) are interpreted as marine values, and offer a baseline with which to compare isotope values of non-marine cements.

The pre-Pennsylvanian cements, zones 1, 2, 3, are markedly different from one another and show a progressive decrease in δC^{13} and δO^{18} with decrease age (δC^{13} = +3.7, +2.4, −0.8‰ PDB, respectively; δO^{18} = −1.3, −2.8, −3.7‰ PDB, respectively). This decrease in δC^{13} is interpreted to reflect increased contribution from soil or atmospheric CO_2 carbon. The decrease in δO^{18} is interpreted to reflect a decrease in O^{18} content of precipitational waters rather than an increase in temperature. The δC^{13} of all three zones is less than the interpreted marine values, which reinforces their fresh-water interpretation. The δO^{18} of zone 1 is greater and the δO^{18} of zones 2 and 3 is less than the interpreted marine values.

We propose a model in which zones 1, 2, and 3 precipitated in fresh phreatic groundwaters largely uncontaminated by sea water. Their chemistries reflect progressive stages in the chemical evolution of the water-rock system. This evolution resulted from either a progressive change from a rock-dominated to a water-dominated system, or may have involved a progressive climatic change from arid (zone 1) to wetter and more seasonal (zone 3). The carbon for these cements derived from Mississippian skeletal and lime mud components plus contributions of light organic carbon. Crinoids, the main skeletal component, could have been major sources only for zone 3 if they had C^{13} contents comparable to modern crinoids. More likely, they had C^{13} contents comparable to Mississippian marine values and were major sources of carbon for all three zones via pressure solution and dissolution at the pre-Pennsylvanian unconformity.

The post-Mississippian zone 5 has a wide range of δO^{18} values (mean = −7.4‰ PDB), all less than those of the pre-Pennsylvanian zones. This light δO^{18} reflects elevated temperatures in the 40 to 60°C (104 to 140°F) range. Zone 5 has intermediate δC^{13} values which reflect complex, predominantly rock carbon sources, many of which were extraformational.

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Tectonic Control of Pennsylvanian Fan Delta Deposition, Southwestern Colorado

Cyclical deposits within the Lower Member of the Honaker Trail Formation (Desmoinesian), between Durango and Silverton, Colorado, have been studied in detail and indicate tectonically controlled sedimentation along the western flank of the Uncompahgre uplift. These cycles were previously considered the result of eustatic sea level fluctuation. Fan delta deposits form a thick wedge of coarse clastics and are interbedded with thin carbonates and siliciclastic shelf-bar systems. Significant lateral variation in depositional style and stratigraphic succession occurs along the strike of this faulted basin margin.

Two major types of cyclic sequences are recognized. Clastics found in the northern and southern portion of the study area near Molas Lake and Engineer Mountain are dominantly thin (10 to 15 m, 33 to 50 ft), sheet-like, rapidly shifting fan delta complexes. Three subfacies within these fan deltas can be distinguished. (1) The bottomset beds, (2.5 to 8 m, 8 to 26 ft, thick) are parallel-laminated and rippled, moderately sorted, micaceous, fine (0.125 mm) to medium-fine (0.25 mm) sandstones. Large plant fragments, as well as mascerated plant debris and bioturbation are common. (2) Forsets (2.5 to 4.5 m, 8 to 15 ft thick) are characterized by small to medium-scale trough cross strata and abundant soft sediment deformation in poorly sorted, arkosic, medium (0.25 mm) to coarse (0.71 mm) sandstones. (3) Topset beds (1.5 to 2.5 m, 5 to 8 ft thick) form a capping unit of very poorly sorted, arkosic, very coarse sandstones (2 mm) to conglomerates (4 mm +). Climbing units of topset beds are characterized by medium scale trough cross strata with occasional ripple stratification.

In association with these fan delta units are thin carbonates (0.5 to 2 m, 1.6 to 6 ft of wackestones/packstones) and nonmigrating shelf sands (0.25 to 2 m, 10 in. to 6 ft) with subparallel laminations and ripple stratification. The carbonates apparently do not cap the deltaic sequences but are more closely associated with the shelf sands. These fan deltas are fluvially-dominated with little or no evidence of reworking by marine processes.

The central region of the study area near Coal Bank Pass is characterized by marine-influenced high energy fan deltas (9 to 16 m, 30 to 52 ft) as evidenced by the abundance of hummocky cross strata at the base of the fan delta sequences and flanking shelf-bar systems. The topsets and forsets are similar in scale and in sequences of sedimentary structures and textures to those previously discussed. The bottomsets, however, are finer (0.17 mm), better sorted, and not as micaceous as those in lower energy areas.

Closely associated with these delta complexes are flat-bottomed, lense-shaped shelf sand-bars. These coarsening-upward, laterally migrating bars are the cleanest, most well-sorted, and finest (0.06 to 0.125 mm) sandstones. Oscillation ripple stratification subparallel laminations with both broad synforms and antiforms are the dominant sedimentary structures indicative of the marine reworking of fan delta sediments.

Variation in stratigraphic successions in adjacent areas and the areal distribution of fan delta types suggests major strike-slip motion along the bounding faults responsible for the development of upthrown and downthrown wedge-shaped blocks within the border fault zone.

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Petroleum Resource Assessment of Wilderness Lands

The U.S. Geological Survey is conducting an investigation of the oil and gas potential of the existing and proposed wilderness areas for the western United States. These current assessments are based upon a Wilderness System containing approximately 105 million acres (42 million ha.) of land (80 million acres [32 million ha.] in existing wilderness; about 16 million acres [6.5 million ha.] in proposed wilderness; and another 9 million acres [3.5 million ha.] potential wilderness lands under study).

It is necessary to consider the uncertainty in the estimates of petroleum resources in the wilderness tracts due to the limited data and lack of detailed geologic information available for many of the areas. In light of these limitations, maps were compiled on a state-by-state basis which delineate: (1) the boundaries of the wilderness land categories for the Forest Service, National Park Service, Fish and Wildlife Service, and Bureau of Land