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Tectonic Significance of Microstructures in Idaho-Wyoming Thrust Belt and Hinterland

Mechanics of foreland thrust belt development can be explained using paleostress orientations from dynamic analyses of microstructures in quartz, calcite, and dolomite. Deformation in the hinterland must also be considered since the two basic models—gravity spreading and lateral tectonic compression—predict substantially different stress fields in this region.

Petrofabric studies in the Meade plate show that compression was dominantly layer-parallel, trending approximately east-west. On overturned fold limbs, compression at 50–80° to bedding suggests a locking angle which agrees well with existing theoretical and experimental analyses of kink-folding. Observed kink-fold geometries may be a necessary result of ramp configurations in the decollement thrust surface. These data are in accord with either of the two principal models.

Dynamic analyses at scattered localities in the southern Idaho hinterland show primarily layer parallel or subparallel, east-west compression in all demonstrably allochthonous rocks at all structural levels. Fold vergence and local overturning indicate eastward translation along the undated, but probably Mesozoic, younger-over-older thrusts characteristic of this region. Near metamorphic core complexes, Tertiary thermal events may have affected preservation of older microstructures. Parautochthonous Precambrian metasediments between foreland and hinterland record compression at high angles to bedding. The age and origin of these microstructures are unknown at present.

These studies indicate that maximum compression was nearly horizontal and oriented approximately east-west throughout southeastern Idaho during thrust belt activity. Therefore, the lateral tectonic compression model is favored.

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Coarsening-Upward Shelf Sequences in Aphebian Wishart Quartzite, Knob Lake Area, Quebec and Newfoundland

The Wishart Quartzite of the Aphebian Labrador Trough contains coarsening-upward sequences about 10 to 20 m thick consisting of three successive subfacies: (A) basal centimeter-scale beds of ripple cross-laminated, very fine to fine sandstone separated by shaly partings, (B) decimeter-scale beds of fine to medium sandstone with thin lamination and hummocky cross-bedding, and (C) medium to coarse sandstone with herringbone trough cross-bedding. The top and bottom contacts of the sequences are sharp, the transition from A to B is completely gradational, and the transition from B to C is abrupt but still gradational. Scattered slabs of syndepositionally cemented sandstone cap most of the sequences. The upsection changes in primary sedimentary structures and mean grain size both indicate a temporal progression from distal, low-energy to proximal, high-energy shelf deposition. The sandstone slabs

are interpreted as lag gravels deposited during erosional hiatuses. Individual coarsening-upward sequences could have formed either by coastal progradation coupled with erosional truncation of the tops of the sequences (e.g., ravinement) or by aggradation on the offshore shelf. An offshore shelf origin is preferred for three reasons: (1) no sedimentary structures requiring subaerial exposure are recognized in any of the sequences, (2) very similar coarsening-upward sequences in Cretaceous strata of the western United States have been interpreted as offshore shelf deposits on firm stratigraphic grounds, and (3) although no known Holocene offshore shelf deposit is entirely analogous, all of the sedimentary structures in the Wishart sequences have been observed in cores from one or more Holocene shelf environments.

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Drill as Tool for Studying Mineral Deposits and Hydrothermal Systems

During 6,000 years of mining, many different kinds of mineral deposits have been found and much has been learned about their formative processes. In no example can we explain completely why a deposit formed where and when it did. Mining focuses on the deposit itself and leaves untested the much larger volumes of rock that were also involved in the formative processes. One major objective of a continental scientific drilling program will be to fill that gap.

The program will select several areas where extensively studied mineral deposits are known to be the result of old hydrothermal convection systems. Drilling will explore regions far below and beyond the known limits of mineralization to determine the extent and chemistry of the old system. Proposed sites are: Tonopah, Nevada; Tintic, Utah; Butte, Montana; and Santa Rita, New Mexico. Modern hydrothermal systems would also be drilled to study the hydrology and chemistry of present-day equivalents of the fossil ore-forming systems. Examples are the geothermal systems at the Geysers and the Salton Sea, California, and Yellowstone National Park, Montana. The metal-rich formation waters discovered in the Mississippi embayment and believed to be precursors of Mississippi Valley-type deposits would also be studied in situ.

Finally, it is proposed that a deep-drilling program be used to fill in gaps in our knowledge regarding the chemical heterogeneity of the crust. We must determine whether the heterogeneities control the observed distribution of mineral deposits or whether the chemistry and the deposits are both manifestations of larger scale processes.

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Upper Paleozoic Paleogeography of Idaho

In south-central Idaho, Mississippian rocks were deposited in flysch-trough and carbonate-bank environments. Lower Mississippian detritus shed from the Antler highland accumulated to a thickness of more than 3,000 m in an adjacent elongate flysch-trough and

spread eastward to the inner craton margin. In southeastern Idaho, less detritus was available from the Antler highland in Early Mississippian time, and a starved basin developed between the foreland basin on the west and the inner craton margin on the east. Carbonate-bank deposition followed on both sides of the Snake River plain in Late Mississippian time, as the northern flysch basin ceased subsidence.

By Middle Pennsylvanian time, the flysch deposits rose to form a highland from which coarse detritus was shed west, east, and south to interfinger with the fine-grained craton-derived, in part subarkosic, sands of the Wood River and Sublett basins, which gradually deepened through Late Pennsylvanian into Early Permian (pre-Phosphoria) time. Carbonate-bank deposition continued into Early Permian time east of the Copper Basin highland.

The Lower and Upper(?) Permian Phosphoria Formation is recognized throughout southeastern Idaho and in south-central Idaho as far west as the Lemhi Range. West of the Lemhi Range, mollusk-rich fine-grained Phosphoria-equivalent rocks are known from one locality in the White Knob Mountains and from two localities in the Pioneer Mountains. Fine-grained, banded and graded siltites of Phosphoria age, which resemble continental-rise contourites, are present in the Boulder Mountains. Phosphoria-equivalent andesitic and dacitic volcanic rocks in western Idaho record a contemporaneous volcanic arc west of the continent.

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Basins, Basement, and the Drill

Subcircular to broadly elliptical sedimentary basins of cratonic interiors remain among the more enigmatic elements of continental geology. Such basins may be characterized by significant, preserved sediment thicknesses (approaching 4 km); long subsidence history ($>100 \times 10^6$ year); non-systematic but, commonly, globally synchronous variation in subsidence rates; and obscure relation to anomalies of the magnetic or gravity fields or of crustal thickness. Mechanisms involving thermal contraction and/or loading of the crust appear inadequate to explain subsidence history and amplitude. Lacking new, critical data, progress toward rational concepts is slow.

Deep drilling of basement rocks of sedimentary basins, including adequate sample recovery and measurement of thermal, magnetic, density, and stress parameters, holds the exciting promise of providing essential information for testing concepts. It is held, for example, that basins lie along ancient continental margins or at the triple junction of sutures. Remanent magnetism and petrologic and structural data from oriented cores could be definitive.

The basement rocks of the continent hold the keys to many fundamental earth science problems. The early history of the planet, the mechanisms of continental development, the nature and timing of pre-Mesozoic global tectonics, and the sources of many materials essential to society, are examples. The drill can probe the

third dimension of the basement, interpolate through cover between surface exposures, extend basement data to outer continental margins, and target critical features. Measurements of the dynamic state of the crystalline crust can provide insights to seismic hazards, geothermal energy potential, hydrothermal ore-forming processes, and possible suitable settings for long-term toxic waste disposal.

A feasible basement drilling program, integrated with appropriate surface studies designed to achieve maximum scientific yield, can probe one of the great frontiers in the earth sciences.

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Cretaceous Niobrara Gas Play

The Upper Cretaceous Niobrara Formation has yielded natural gas of biogenic origin from structural closures on the gently dipping east flank of the Denver-Julesburg basin and the northern plunge of the Las Animas arch. Present production is from the Smoky Hill Member of the Niobrara Formation. The majority of fields located to date are in Colorado and Kansas; however, several new fields have been discovered in the Nebraska part of the basin. Potential for significant Niobrara gas production exists in the Kennedy and Salina basins of Nebraska, and from parts of South Dakota, North Dakota, Montana, and Canada. The formation has high porosity and low permeability and requires hydraulic fracture stimulation for economic production. Production depths range from 1,000 to 3,200 ft (305 to 975 m).

The chalk beds of the Niobrara were deposited in the deep, quiet water of the Cretaceous interior seaway.

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Geophysical Exploration for Precambrian-Related Uranium Deposits

Genetic models for uranium mineralization found at Proterozoic unconformities between fluvial sandstones and crystalline lithologies include three general geologic features: (1) structural relief at the unconformity; (2) permeable zones controlled by lithology and faulting; and (3) graphitic and sulfide-bearing zones commonly associated with mantled gneiss domes. Though radiometric surveys have been successfully used where the fluvial rocks are thin or eroded away, non-radiometric geophysical methods are commonly used in the interior parts of the sedimentary basins to detect one or more of the above geologic features to define favorable areas for uranium. In the Athabasca basin of Canada, airborne and ground electromagnetic (EM) methods as currently used are thought to have a depth of exploration of 200 m. Application of these non-radiometric geophysical methods to Precambrian sedimentary basins in the United States is not likely to produce as great a depth of exploration because the fluvial cover rocks are not as geophysically transparent as the Athabasca sandstone. We suggest that two approaches be used to improve the