compressive deformation and the second vertical, or nearly vertical tectonics, as the principal deformation mechanism. The main battleground involves the "Wyoming province" floored by Archean crystalline rocks. This province includes much of southwestern Montana, west of commonly recognized limits of Laramide foreland deformation and south of the Helena salient of the Cordilleran overthrust belt.

In this area, west-northwest of Yellowstone National Park, thrust faults and other structural features indicative of compressive deformation are widespread and have been mapped in the Snowcrest Range by M. R. Klepper and in the Greenhorn Range by J. B. Hadley. These two ranges expose the Snowcrest structural terrane: the complexly deformed steeper limb of the asymmetric Laramide Blacktail-Snowcrest massif. This massif, like the Madison-Gallatin "uplift" farther east, has been broken and stretched by Tertiary extension faults, principally subparallel and behind the major range-front thrusts and probably listric to these thrusts. Current geologic and gravity studies in the southwestern part of the Snowcrest structural terrane extend the zone of Laramide foreland thrust faulting into the southwest Montana reentrant of the overthrust belt. Here foreland thrust faulting is chiefly Late Cretaceous in age, and thrust faulting occurs along the Greenhorn lineament, a zone of crustal weakness active since Paleozoic time within the northwestern part of the Wyoming province. The presence of foreland thrust faulting has broad implications for oil and gas potential of the southwestern Montana and adjacent foreland.

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Illite/Smectite Diagenesis: Relation to Coal Rank in Tertiary Sediments of Pacific Northwest

Bentonite partings formed by alteration of air-fall tephra interbedded with coal in three Eocene coal basins (Tulameen, British Columbia; Chuckanut and Centralia, Washington) record the nature of arc volcanism and subsequent diagenesis and metamorphism. Euhedral feldspar phenocrysts, embayed quartz, and relict glass shards demonstrate volcanic provenance, whereas the absence of muscovite, microcline, and other nonvolcanic minerals indicates lack of epiclastic detritus. At Tulameen, abundant sanidine and biotite indicate rhyolitic tephra; at Centralia, plagioclase and absence of quartz and K-spar indicate dacite. Absence of K-spar from Chuckanut deposits may be due to its destruction by metamorphism, since quartz phenocrysts are present, suggesting rhyolite.

Alteration of glassy tephra to bentonite has taken place in two or three steps. (1) Leaching (weathering) in the swamp may have formed allophane or halloysite, but much glass remained unaltered. (2) Early diagenesis at temperatures below 60°C (suggested by vitrinite $R_o = 0.40\%$) formed, by reaction of nonphenocrystic components with pore fluids within individual partings, one of five assemblages depending on degree of prior leaching: zeolite-smectite-crystobalite, smectite-cristobalite, smectite, smectite-kaolinite, kaolinite. Na-smectite at Centralia inherited interlayer Na from original glass. Delicate vermicular kaolinite may also have formed during this stage. (3) Thermal metamorphism has transformed smectite in some Tulameen and all Chuckanut partings to regularly interlayered illite/smectite (I/S). At Tulameen ($R = 1$ ordered I/S with 55% I + kaolinite), the source of potassium for the reaction was solution of phenocrystic sanidine and mica; $R_o = 0.9\%$ suggests 130 to 200°C. The Chuckanut bentonites ($R = 1$ and $R = 3$ ordered with 65 to 90% I + chlorite) show $R_o = 3\%$ suggesting temperatures exceeded 300°C; some potassium may have been derived from outside the parting, and more complete illitization may have been inhibited by lack of potassium and by calcium released during albitization of plagioclase.

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Observations Concerning Benthic Foraminiferal Genus *Melonis*

For many years, the benthic foraminifer *Melonis pompilioides* has been used as an important deep-water index species indicating deposition in abyssal environments. However, uncertainties about the character and importance of its morphological features have caused problems in species identification, which in turn have produced paleobathymetric interpretations that differ from those based on seismic, sedimentary, and stratigraphic data. Incorrect identifications of *Melonis pompilioides* and the probably automatic assignment of an abyssal environment to sections containing this species have led to controversy and, at times, to serious questions regarding the reliability of this genus for paleoenvironmental interpretations.

An attempt has been made to rectify the problems of identification of *Melonis pompilioides* and related forms so that micropaleontologists can accurately and consistently identify specimens from the *Melonis* species complex and can recognize misidentifications by others. Characteristics such as pores, umbilical size, sutures, apertures, and height/width ratios were studied and evaluated.

Other studies have shown that depth of water may not be the single or dominant factor controlling the distribution of this species and that discretion should be used in establishing a paleoenvironmental determination.

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Ichnology of Trenton Group Between Montreal and Quebec City, Eastern Canada

Despite lateral thickness variations and lithostratigraphic complexities, a coherent depositional model can be recognized for carbonates of the upper Middle Ordovician Trenton Group between Montreal and Quebec City in the St. Lawrence lowland of eastern Canada. Between Montreal and Quebec City, the Group was deposited initially on a confined and irregular shallow shelf and latterly on a broader and essentially flatter shelf, whereas northeast the onshore-to-offshore profile was steeper and rapid submergence promoted the early development of deeper shelf and slope-and-basin sediments.

Within the area between Montreal and Quebec City, the Trenton Group contains an abundant but generally poorly preserved assemblage of biogenic structures, the majority of which can only be identified (sometimes only questionably, at a general level). These genera represent a variety of behavioral groups and include *Arenicolites?, Calycraterion?, Chondrites, Circulichnis, Cruziana?, Diplichnites?,* cf. *Furculosus, Helminthopsis, Isopodichnus, Oichnus, Palaeophycus, Plagiogmus?, Planolites, Rosselia, Scalarituba?, Teichichnus, Trichichnus, Trypanites,* and cf. *Zoophycos*, as well as unclassified pronged, looped, oblique, and vertical burrows.

The spatial and temporal distribution and abundance of these traces are examined in context of the environmental model and related depositional patterns. Because limestones show a great susceptibility to early and late diagenesis, trace fossils in skeletal shoal sediments (lower Trenton Group) were preserved through toponomic processes, whereas those in lagoonal (basal Trenton Group) and offshore (middle and upper Trenton Group) sediments were preserved through diagenetic processes (diagenesis also obliterated morphological details resulting in a bias towards simple forms). These processes resulted in ichnocoenoses restricted respectively to surface crawling traces for the former and infaunal dwelling and feeding traces for the latter. It is suggested that substrate consistency and rates of deposition were the most important controlling parameters.

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Carbonate-Clastic Facies Changes, Pennsylvanian-Early Permian, Northwest Arizona-Southern Nevada

Successive facies changes in Chesterian through Wolfcampian strata illustrate five distinct carbonate to clastic transitions. These result from differing combinations of depositional environment, climate, sea level changes, and differential subsidence. Comparative stratigraphy of successive facies change across the craton-miogeosyncline boundary, combined with analysis of sedimentary structures and lithology, enhances interpretation of the causes of these facies changes.

A Chesterian to Morrowan transgressive facies change illustrates a carbonate to clastic transition resulting from shallow marine to subaerial environments, wherein the climate was tropical and marine current energy was low. A Morrowan to Atokan regressive facies change closely resembled the underlying transgressive facies change and results from similar circumstances, except that this transition has the addition of eolian quartz silt units and diagenetic overprints resulting from periodic emergence during the regression.

A subsequent Atokan transgression illustrates a contrasting facies change. Sandstones change to carbonates more gradually. Rocks containing equal amounts of carbonate and quartz sand occur commonly. Fewer varieties of carbonate texture and fossil species occur in corresponding facies than in the Morrowan transition. Cross-bedding of similar style occurs in sandstones as well as in carbonates. The facies change results from a broad shallow marine environment in which there was an eastern detrital source in the eastern Grand Canyon region. These environments existed in conditions resulting from more open marine conditions and/or greater aridity than during the Morrowan sequence.

The distribution of Desmoinesian strata is more easily explained by reciprocal sedimentation rather than by facies. Virgilian facies appear to result from a combination of the factors involved in the Morrowan and Atokan strata. Beginning in Wolfcampian time faulting and attendant differential subsidence control the distribution of clastic and carbonate facies.

Carbonate buildups along the upthrown side of faults serve as clastic sediment traps. Also erosion may occur on the upthrown side of faults. Both of these result in abrupt facies changes in Wolfcampian sequences.

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Distribution and Preservation of Carbonate Cements in Pleistocene Limestones of Hogsty Reef Atoll, Southeast Bahamas

Four shallow cores taken in Hogsty Reef Atoll, southeast Bahamas, reached the early Pleistocene at a depth of 30 m (98 ft) (below sea level). Unlike other banks of the Bahamas, Hogsty Reef Limestone consists of carbonate grains and cements that have maintained their original mineralogy. Five types of cements were found in the Pleistocene limestones of Hogsty Reef: (1) micritic magnesian calcite which predominates in all four cores; (2) bladed magnesian calcite which occurs in several thin (< 1 m) intervals, where it is associated with (3) fibrous aragonite, which also is found in Holocene cemented crust; (4) blocky low magnesian calcite, which occurs in several thin intervals underlying subaerial exposure horizons; and (5) an unusual type of blocky magnesian calcite cement, which consists of clear anhedral crystals, 25 to 100 microns in size, which contain less than 10% $MgCO_3$. This cement is found together with bladed magnesian calcite and aragonite.

Preservations of the cements and grains original mineralogy may be attributed to a minor influence of fresh water resulting from the semi-arid climate of the southeastern Bahamas and the unlikely formation of a permanent freshwater lens during periods of emergence.

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A Basin Plain Sand-Layer Geometry Classification: A Predictive Tool

The areal distribution of sand layers in the basin plains of 13 modern deep ocean basins has been studied. Fundamentally, sand-layer distribution is controlled by the volume of sand input in single events relative to the basin plain size and by the areal distribution of basin entry points on the ocean basin floor. Although tectonic setting and sea level position may play a role in rate of basin infilling, these factors are relatively unimportant in the control of sand-layer geometry. A basin plain sand-layer classification has been devised. The classification is comprised of a hierarchy with three ranks or categories. The first category describes the distribution of basin entry points as being one of the following; radial, semiradial, longitudinal, or lateral. The second category separates basin plains with similar entry point distributions on the basis of the extent of sand coverage on the flat basin floor. Sand coverage is classified as either overall or partial. The final category further separates basin plains according to the general shape of sand bodies on the basin floor—either wedge, sheet, or axial. The classification has application to the study of both modern and ancient deposits. If the distribution of sand layer characteristics is known, it may be possible to locate probable basin entry points and to predict the size of the drainage area relative to the size of the flat basin floor. Alternatively, if the approximate size of the drainage area relative to the basin plain area and the distribution of basin entry points are known, it may be possible to predict the nature of the sand distribution on the basin plain.

Inherent in each basin plain type is a specific distinctive areal distribution of sand layer characteristics and particular manifestations of proximal/distal relations. For example, a basin with sand layer geometry classified as radial fill, overall coverage, and wedge-shaped (the Hispaniola-Caicos plain) would have its thickest sand and lutite (or shale) layers located around the periphery of the basin plain. The highest frequency of sand layers would probably be found in the basin plain center and the ratio of drainage area to basin plain area would be relatively large (greater than 3).