have greater diversity than in the thin-skinned regime because the plastic substratum allows easy vertical motion; nearly vertical faults are allowable. (5) The basement does fold, but with difficulty and in broad wavelength. (6) Because of the broad arching, a "neutral surface" exists well within basement over uplifts, allowing high-level features, such as Rattlesnake Mountain, to be bounded by high-angle normal faults. (7) This same neutral surface forces out-of-the-basin crowding, causing the steep flanks of most basin folds to face toward the adjacent uplift.

(8) The "Hafner approach" illustrates the diversity of curved faults that can be generated in a vertically sinusoidally loaded beam, and which can be generated equally well in an end-loaded sinusoidally buckled beam, as long as it sits on a passive plastic substratum. (9) The Sanford model is excellent for depicting the fault configuration generated in sediments above a high-angle fault. (10) Faults such as Dinosaur Monument can be seen to steepen downward, but my models suggest that they go listric at their lower transition with the plastic substratum. (11) The COCORP trace of the Wind River fault indicating a nearly planar 35° dipping fault most of the way through the crust is probably real; arguments that you cannot see a fault of "granite" against "granite" do not apply. (12) Gravity highs over uplifts, models, and later collapsed uplifts speak for a flexed and jostled slab configuration and against a buoyant root configuration.

(13) Thrusting from several different directions appears not to be a problem when viewed in the context of "jostled slabs." (14) Blocky corners do place limits on amount of thrust and strike-slip translation. (15) The argument for pure verticality to solve a presumed "space problem" in the Piney Creek structure loses validity as soon as the bounding tears are allowed to stray from a perfectly vertical dip. (16) The argument at Elk Mountain that the dip of the bounding structure must be at least as low-angle as the degree of overturning of sedimentary panels is wrong (proven by Five Springs).

(17) Sales' eastward crowding of the Colorado Plateau and development of a "Wyoming couple" north of it still seems cogent. (18) The Chapin and Cather, and Gries subdivision into movement phase also appears to be correct. (19) If horizontal compression is a reality, Stone must be correct in principle; there have to be logical connecting structures. (20) The crust can transmit stress over great distances because it is weak enough; southeast Asia tectonics require greater distances of stress transmittal than Laramide foreland tectonics.

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Horizontal Compression and a Mechanical Interpretation of Wyoming Foreland Deformation

If the basement fault-controlled style of deformation in the Wyoming foreland is dominated by elastic response of the upper lithosphere, and the deformation in the foreland is genetically linked to the horizontal compression characteristic of the thin-skinned thrust belt to the west, then concepts of continuum mechanics can be combined with results of experimental rock mechanics to suggest the following.

(1) Basement faults initiate at the basement surface, propagate downward at an approximate 35° dip, and die at a depth dependent upon the magnitude of elastic shortening. Displacement on these faults necessarily decreases with depth. The faults are not expected to be appreciably curved in cross section.

(2) Foreland structures develop early as fault-cored folds of small amplitude (< 1,500 m, 4,900 ft), with selected ones developing to large amplitudes (up to 13,000 m, 43,000 ft). Regions where the entire lithosphere has not "failed" (early stage) show only small-scale structures (e.g., Colorado Plateau), whereas regions where the lithosphere has experienced through-going failure will show small intra-basinal structures (early) isolated by more widely spaced large basin-margin structures (late). This bimodal size distribution of structures is present in the Wyoming foreland.

In this study, horizontal compression as a sole causal mechanism can be combined with accepted mechanical concepts to produce a plausible model which adequately explains the regional features of Wyoming foreland deformation.

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New Sources of Gold in the West

Records show discovery of, perhaps, 40,000 gold and silver deposits in western United States. Mine descriptions give dates of operation and allow correlations with history. These mine histories commonly indicate that the properties have further potential. Many of the prospects left 50, 75, and even 100 years ago are of interest today because of new geological concepts. Simple veins of yesterday may be the exposed parts of larger entities. The old ore controls, structures, or zones may be tied to larger lineaments, elements, or zones. In younger deposits, corollaries are often made with geothermal fields. Lineations and cross lineations require further consideration. Connections with plate tectonics come easily.

As an example of the increase in size of useful parameters, the line of segmentation portrayed in coast ranges of northern California and Oregon might be looked upon as lines marking transverse zones of extension. Better known zones of extension are parts of the very large fault network centering around the San Andreas and Garlock faults, and parts of the Imperial Valley region south of the Salton Sea, a well known geothermal area. Corollaries with such areas are sought, for example, along lines marked by the Antler and Sevier tectonic belts in Nevada.

In other western areas, pillow lavas occur in close proximity with gold occurrences which stimulates thinking along lines of spreading centers and submarine springs.

The old gold and silver deposits appear to fit readily into a framework, in which treatment of prospects as segments within a geothermal model is helpful. Conversely, with the growth of geothermal development, the view of activity will be incomplete without consideration of the potential by-products, precious metals.

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Synorogenic Sedimentation Associated with Development of Paris-Willard Thrust System, Wyoming-Idaho-Utah Thrust Belt

Depositional environments, facies distribution, and provenance analyses of Upper Jurassic through lowermost Upper Cretaceous strata in western Wyoming, eastern Idaho, and northeastern Utah suggest that episodic tectonic activity along the Paris-Willard thrust system strongly influenced deposition during early development of the Wyoming-Idaho-Utah thrust belt and associated foreland basin. Synorogenic conglomerates present at various stratigraphic levels in these strata reveal periods of rapid uplift. In general, the synorogenic units contain proximal cobble-boulder conglomerates (braided stream) which grade downslope into distal pebble conglomerates and coarse-grained sandstones (meandering stream). Periods of relative tectonic quiescence and/or less rapid uplift and erosion are represented by interbedded finer grained fluvial, lacustrine, and marine deposits.

During the Late Jurassic, erosion of incipient highlands prior to thrusting resulted in eastward progradation of beach/barrier sandstones represented by the Stump Formation. Initial intensive thrusting followed in the latest Jurassic and earliest Cretaceous, with the newly formed highlands shedding proximal braided stream cobble-boulder conglomerates and more distal meandering stream pebble conglomerates and sandstones of the Ephraim Formation into the subsiding foreland basin. Continued subsidence coupled with a decrease in clastic input due to subdued uplift, resulted in establishment of extensive lacustrine systems and deposition of the Peterson Limestone. Renewed movement on the Paris-Willard thrust system then gave rise to the proximal conglomerates and distal sandstones and mudstones of the Bechler Formation. The overlying lacustrine Draney Limestone and marginal lacustrine Smoot Formation represent another period of continued basin subsidence with little or no uplift.

The Wayan and laterally equivalent Bear River Formations represent, respectively, near-source fluvial and shallow beach-marine deposition following Smoot/Draney accumulation. Wayan strata were deposited on a meandering stream flood plain and are indicative of slow uplift and erosion in the source area. Bear River strata consist of a beach sandstone unit underlain and overlain by transgressive marine shales. Alternate deposition of transgressive and regressive facies resulted from either eustatic changes in sea level or differential uplift and erosion of the Paris-Willard highlands.

Bear River marine shales grade upward into marine shales of the Aspen Formation, deposited when the Mowry sea transgressed across the thrust belt region. Lack of significant tectonic activity during this time is suggested by the paucity of sand in the Aspen Formation.

Aspen strata pass upward through marginal marine strata into a thick sequence of meandering stream deposits of the Frontier Formation that were derived from erosion of subdued Paris-Willard highlands. Subsequent transgression of the Greenhorn sea westward covered the entire region, producing extensive Frontier marginal marine sandstones and marine shales. Renewed intensive uplift in the source area caused rapid eastward progradation of the Greenhorn sea shoreline and concurrently deposited cobble conglomerates in northeastern Utah. Coarse detritus was deposited in eastward-flowing braided streams near the source area (northeastern Utah) and in meandering stream channels farther eastward (western Wyoming). The Niobrara sea subsequently covered much of the region, and synorogenic sedimentation related to the Paris-Willard thrust system was thus completed.

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Trace Fossils as Environment Indicators in the Rocky Mountains

Ichnology is the study of the traces ancient organisms have left in or on the substrate. These traces, or lebensspuren, are in the form of tracks, burrows, trails, or borings, and are important clues in determining ancient rock environments.

Throughout time, organisms have left various types of traces while engaged in different activities. The two major types of lebensspuren were made by suspension feeders found in turbulent water where organic matter is held in suspension, and by deposit feeders whose habitat is found in quiet, deeper waters where large quantities of organic matter settle from suspension.

The different activities which occur in these two environments are the cause of the traces found in sediments. These include escape structures resulting from degradation or aggradation of sediments, feeding structures, dwelling structures, grazing traces, crawling traces, and resting traces.

The use of trace fossils in hydrocarbon exploration is especially helpful in the Cretaceous sandstones of the Rocky Mountains because of the relative abundance of outcrops and the scarcity of body fossils. By combining the interpretation of physical processes with the biological traces, one more tool is made available in the determination of rock environments as an aid in hydrocarbon exploration.

Materials exhibited include 8 × 10 color prints of different Cretaceous lebensspuren, hand-drawn "cartoons" of the six different trace activities, and a regional cross section of the Eagle sandstone illustrated by photographs of different traces near each location, as well as a variety of rock samples.

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Color Infrared Imagery as an Aid to Regional Geological Mapping

Frontier areas, particularly, lend themselves to initial phase study via remote sensing imagery. The many types of satellite imagery have the advantage that large areas of the earth's surface may be studied quickly, cheaply, and thoroughly enough to lead directly into more detailed photogeology and/or surface mapping. Imagery can be acquired in various spectra, the most useful of which are normal color, normal black and white, color infrared, black and white infrared, and side-looking radar. Perhaps the best single imagery for most geological mapping is the band 7 "False Color" infrared, at the scale of 1:250,000. Each photo measures approximately 29 in.^{2} (187 cm^2) and covers 115 mi (185 km) on a side; the cost in 1982 was $80 per photo.

Using the 1:250,000 band 7 color infrared images, good sharpness and color contrast are retained, yet enough magnification is present to allow visual recognition of roads, small towns, smaller lakes and streams, railroads, and agricultural features. Recognition of such physical features is necessary for satisfactory ground control.

Geologic and geomorphic features such as tonal, color, and drainage anomalies, linears, and more direct features such as actual geologic structures, faults, and regional structural dip directions often may be recognized. In areas of sparse well control and/or limited geophysical data, recognition of such features and geological data is of extreme importance and is a good beginning step in studying remote areas.

I have selected two 1:250,000 band 7 color infrared images from central and north-central Montana to display the variety of geologic, geomorphologic, and physical features that may be determined. Easily denoted features include regional dip; domal and anticlinal structures; tonal, drainage, and color anomalies; regional lineations; fault traces, and igneous activity. Subtle features are shown such as noses, subtle anticlines, and radial and concentric fracture patterns associated with the Bearpaw and Little Rockies uplifts. Follow-up work was performed using 1:20,000 stereo pairs, and several examples are available for inspection. In many situations, the leads from color infrared imagery subsequently proved to be bonafide geologic features.

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Landsat Linear Features in Montana Plains

Multispectral scanner images obtained from satellites provide a unique regional perspective of geologic features on the earth's surface. Linear features observed on Landsat images are particularly conspicuous and can be mapped easily. In Montana, east of long. 110°W and in adjoining parts of Canada, the Dakotas, and Wyoming, linear features have been mapped on 14 images. Black and white film products in bands 5 and 7 at a scale of 1:1,000,000 were employed. Specific linear features observed on both bands were compiled on a mosaic covering more than 90,000 mi^2 (233,000 km^2). Trends to the northwest and northeast are most common, but north-south and east-west linear features are also observed.

Four separate tectonic regions of the Montana plains seem to be characterized by different populations of linear features. In an area 100 mi (160 km) wide along the Canadian border, linear features trending northwest are common, and only a few local structures, such as Poplar and Bowdoin domes, are present. In the vicinity of the Central Montana uplift, east-west linear features are associated with features trending northwest and northeast. An area 80 mi (129 km) wide along the Wyoming border has linear features which trend dominantly north-south and east-west, although northeast and northwest trends are also present. This part of southern Montana includes the northern flanks of the Big Horn uplift, Powder River basin, and Black Hills uplift. In eastern Montana the western margin of the Williston basin has linear features which trend mainly northeast and northwest; north-south and east-west trends are rare.

Published syntheses of geophysical, structural, and stratigraphic data can be used to establish the geologic significance of specific linear features. Magnetic, gravity, and seismic data suggest that linear features may reflect basement structural elements such as fault-bounded blocks. Some specific geologic structures shown on structure contour maps are marked by linear features. Examples include Bowdoin dome, portions of Cat Creek, Lake basin, and Nye-Bowler fault zones, Cedar Creek anticline, and the Brockton-Froid fault zone. Paleotectonic features interpreted from stratigraphic maps have surface expression on Landsat that have not been recognized previously. For example, the southern margin of the Alberta shelf (Mississippian) appears to correspond with a zone of concentrated east-west linear features in north-central Montana.

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Late Cretaceous marine deposition in the western interior of the United States occurred in an epicontinental seaway elongate in a north-south direction. In central Montana, the western side of the seaway was characterized by a broad, tectonically active shelf. In eastern Montana and the western Dakotas, an actively subsiding basin was located in the central part of the seaway. In western and central South Dakota, the eastern side of the seaway was a more stable west-sloping ramp. Distinctive facies belts in the Eagle Sandstone and equivalent rocks are found in each of these tectonic settings, and some specific tectonic features have expression in the facies patterns. However, paleotectonism was even more important than suggested by these regional patterns. Selected study areas