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Compiled by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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REGIONS OF FELDSPAR PRECIPITATION AND DISSOLUTION IN THE LAMOTTE SANDSTONE, MISSOURI--IMPLICATIONS FOR MVT ORE GENESIS

DIEHL, S.F., U.S. Geological Survey, Box 25046, MS 966, Denver Federal Center, Denver, CO 80225; GOLDHABER, M.B., and MOSIER, E.L., U.S. Geological Survey, Box 25046, MS 973, Denver Federal Center, Denver, CO 80225

The Upper Cambrian Lamotte sandstone is considered to be a major aquifer for warm basinal brines which formed the Mississippi Valley-type (MVT) mineral deposits in Missouri. Petrographic studies of authigenic K-feldspar in the Lamotte constrain the geochemistry of the ore fluids. This mineral phase is important because (1) it has been dated as late Paleozoic in age, which broadly coincides with the inferred time of ore genesis, (2) previous petrographic studies constrain the relative timing of dissolution of authigenic feldspar with deposition of the ore, and (3) MVT ore fluids are typically anomalously rich in K^+.

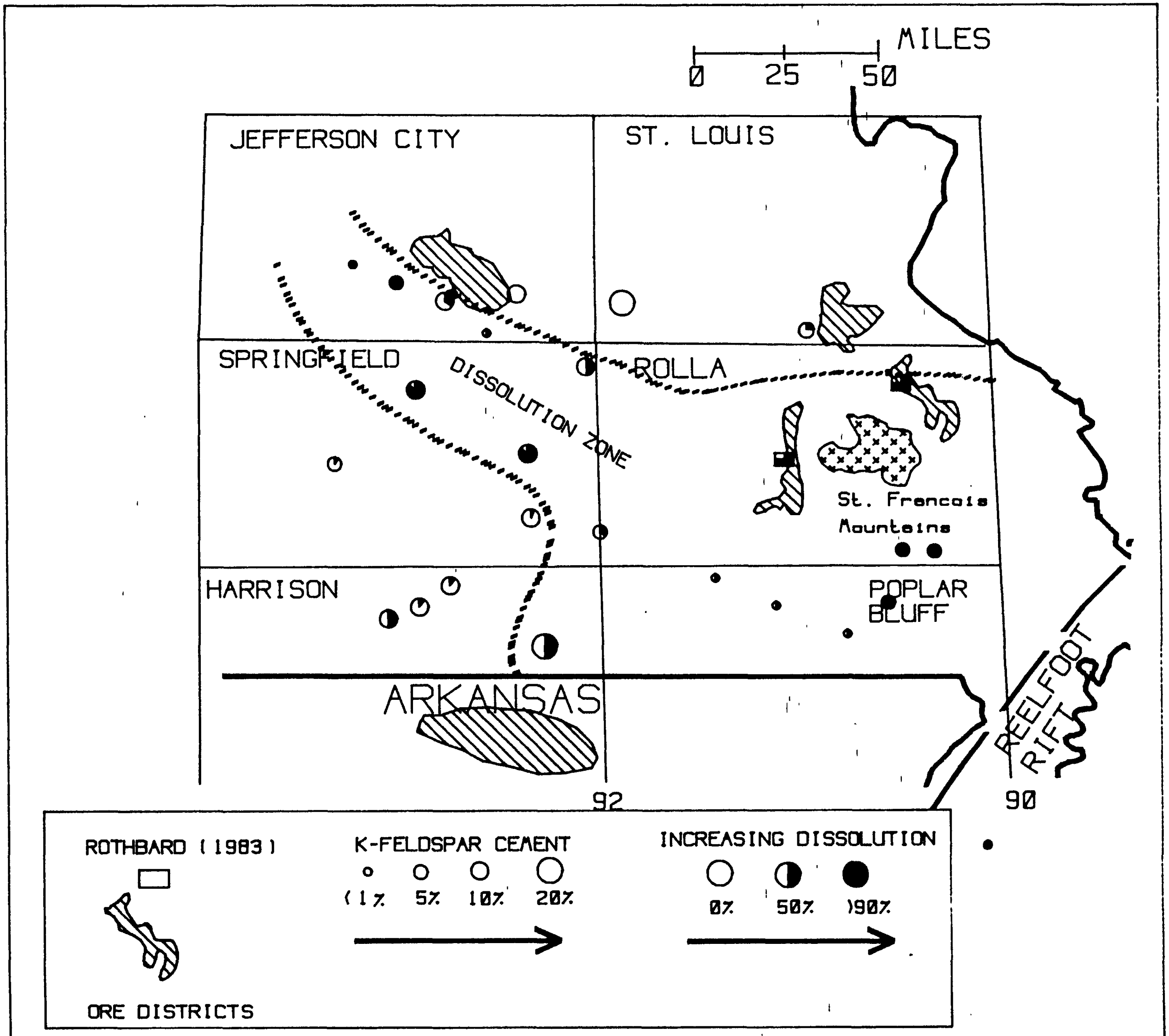
Petrographic studies of samples from central and southeastern Missouri show trends in the precipitation and dissolution of K-feldspar overgrowths that are related to sample location and sample depth (fig. 1). Northwest and southwest of the St. Francois Mountains, authigenic K-feldspar is volumetrically important, comprising up to 18 percent of the cement in feldspar-rich layers. The overgrowths occur in porous arkosic arenites, in which a later clay phase coated grains, inhibiting quartz overgrowths. The K-feldspar overgrowths are adularia-like in habit, inclusion-free, and rarely twinned, and completely surround detrital feldspar cores, indicating precipitation in a loosely-packed porous environment. Authigenic K-feldspar in samples from lower in the Lamotte section have undergone partial to total dissolution. However, higher in the Lamotte section near the transition zone, K-feldspar overgrowths are unaffected by acidic, dissolving solutions. More complete dissolution of K-feldspar overgrowths occurs within a northwest-trending corridor encompassing the St. Francois Mountains (fig. 1).

Two episodes of K-feldspar precipitation are indicated by partial dissolution of early overgrowths, which are surrounded by later well-formed rhombic overgrowths. However, only one authigenic K-feldspar generation is evident to the southeast of the St. Francois Mountains and within the Reelfoot Rift. Authigenic albite cement is common only in samples from the Rift, in which it commonly replaces K-feldspar overgrowths and their detrital cores.

Published petrographic studies of Lamotte-hosted mineralization in southeast Missouri demonstrate that the first episode of authigenic K-feldspar formation predated mineralization, and that dissolution of the overgrowths accompanied ore formation (Rothbard, 1983). Our data show that this ore-stage dissolution event was regionally extensive and was most intense along a northwest-trending corridor that includes the lead belts and the St. Francois Mountains. Fluid inclusion data from southeast Missouri shows very high K^+ concentrations during ore deposition. K-feldspar should be stable in a high K^+ environment: however, our data suggest that the ore fluid was acidic in order to both dissolve K-feldspar overgrowths and carry metals and H_2S in solution. The broad dissolution zone in the southeast part of the state suggests that this acid fluid originated in the Reelfoot Rift.

Diehl, S.F., Goldhaber, M.B., and Moiser, E.L., 1989,
Regions of feldspar precipitation and dissolution in the Lamotte Sandstone, Missouri--Implications for MVT ore genesis, in Pratt, W.P. and Goldhaber, M.B., eds., U.S. Geological Survey--Missouri Geological Survey Symposium: Mineral-Resource Potential of the Midcontinent, Program and Abstracts, St. Louis, Missouri, April 11-12, 1989, p.5-7.

Figure 1.--Distribution map showing abundance and percent of dissolution of K-feldspar cement.



Mineral Resource Assessment of the Butte 1° x 2° Quadrangle Using Geographic Information System Technology

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The mineral resource potential of the Butte 1° x 2° quadrangle has been assessed under the auspices of the U.S. Geological Survey's CUSMAP (Conterminous United States Mineral Assessment Program) project. By using geographic information system (GIS) technology, the following deposit types were assessed: vein and replacement, base- and precious-metal, porphyry-stockwork copper and molybdenum, skarn gold-silver-copper-tungsten, stockwork-disseminated gold-silver, and placer gold deposits. The steps followed in this method of assessment were (1) data acquisition, (2) data compilation and entry into the GIS, and (3) mineral resource assessment. The GIS used for the assessment consists of three main subsystems (vector, raster, and tabular) for processing diverse types of geographically referenced data. The mineral resource assessment procedure involved (1) developing descriptive mineral deposit models and recognition criteria for each of these models, (2) using GIS techniques to develop images that are based on recognition criteria for each descriptive model, and (3) using GIS technology to combine these images into a final image or map.

New data were acquired through geologic mapping, geochemical and geophysical surveys, remote sensing and geochronologic studies, and examination of mines and prospects. The acquired data were combined with previously published and unpublished data and compiled either as tables or as maps at a scale of 1:250,000. Maps, including a generalized geologic map, a map of mining district and area boundaries, an interpretive geophysical map, a map showing limonitic alteration, and a map showing domains of linear features, were digitized by using the vector subsystem. After editing, these maps were converted to a raster format for entry into the raster subsystem. Analytical data from geochemical surveys were entered into the tabular subsystem. By using a minimum-curvature surface-generation algorithm, the analytical data were combined with sample locations to produce a raster map for each required element. Other data entered and converted to raster files included the digital elevation model, as gridded data, and previously digitized linear feature data.

The final resource assessment maps show areas of low, moderate, high, and, for some deposit types, very high resource potential for each type of deposit. These maps indicate that much of the Butte quadrangle is favorable for the occurrence of one or more of the assessed deposit types. Although most of the areas of high or very high potential are within or adjacent to known mining districts, some areas of high and very high potential occur in parts of the quadrangle that have few or no known mines and prospects. These areas are geologically favorable for mineral exploration.

REFLECTANCE OF ORE MINERALS--A SEARCH-AND-MATCH IDENTIFICATION SYSTEM FOR IBM AND COMPATIBLE MICROCOMPUTERS USING THE IMA/COM QUANTITATIVE DATA FILE FOR ORE MINERALS, SECOND ISSUE

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Reflectance spectra are measurable, reproducible, and distinctive properties of ore minerals; they provide useful and objective criteria for mineral identification with the microscope, and the measurement technique is easily learned. Reference spectra for 420 minerals have been published in the Quantitative Data File for Ore Minerals (QDF) of the Commission on Ore Microscopy of the International Mineralogical Association (IMA/COM) (Criddle and Stanley, 1986), the most extensive source of quantitative reference data currently available for ore minerals. In addition, computer-assisted microscope-photometers that can measure reflectance in the 400-700-nanometer (nm) range of the spectrum in a few minutes are now available. With these tools, preliminary identification of a mineral is possible in a fraction of the time it would take for analysis with the electron microprobe or other sophisticated techniques.

To further assist geologists in the identification of ore minerals by reflectance measurements, we have designed a computer database system that compares reflectance measurements on unknown minerals with QDF measurements of reflectance in air. Features of the system include a search-and-match routine, reflectance-curve plotting capability, and a user-created database in which to store new reflectance data. The system has been published as QDF Database System, Version 1.0, U.S. Geological Survey Open-File Report 89-306A through E.

The search-and-match routine is based on the indexing scheme of Leonard (1979). When a reflectance value measured for an unknown mineral at 546 nm is entered, this initiates the retrieval of minerals that have reflectances at 546 nm of plus or minus 10 percent of the unknown mineral's reflectance. The listing includes bireflectance at 546 nm, partial dispersion of reflectance for three wavelength pairs (470-546 nm, 546-589 nm, and 589-650 nm), and a reference to the page number of each retrieved mineral in QDF.

Database users can obtain additional information from the QDF database for minerals of interest by entering QDF page numbers as search keys. Vickers hardness number (VHN) can be retrieved to complement the search-and-match list. Color values (trichromatic coefficients, luminance, dominant wavelength, and excitation purity) can also be retrieved for comparison with quantitative color data derived from measurements of the unknown mineral's reflectance. Data measured at 20-nm intervals from 400 to 700 nm can be used to plot reflectance curves; the shapes of these curves are more diagnostic for ore minerals than are the characteristically variable reflectance values. The curves can be displayed on the screen or plotted by a Hewlett-Packard or Hewlett-Packard-compatible plotter.

Reflectance data measured on unknown ore minerals can be entered into a separate database that can be updated as required and that can be used with the search-and-match and curve-plotting routines.

REFERENCES

Criddle, A.J., and Stanley, C.J., eds., 1986, The quantitative data file for ore minerals of the Commission on Ore Microscopy of the International Mineralogical Association (second issue): London, British Museum (Natural History), 470 p.

Leonard, B.F., 1979, Index to the reflectance and microindentation hardness of ore minerals in the IMA/COM Quantitative Data File (first issue, 1977): U.S. Geological Survey Open-File Report 79-658, 52 p.

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Gerlitz, C.N., Leonard, B.F., and Criddle, A.J., 1989, Reflectance of ore minerals: Search-and-match identification system for IBM PC's using IMA/COM Quantitative Data File for Ore Minerals, Second Issue [abs.]: 28th International Geological Congress, Washington, D.C., 1989, Abstracts, vol. 1, p. 544.

STRATIGRAPHY AND FACIES IN THE MIDDLE ORDOVICIAN SIMPSON GROUP, SOUTHWESTERN KANSAS AND WESTERN OKLAHOMA

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The Middle Ordovician Simpson Group in southwestern Kansas and western Oklahoma consists of a complex series of sandstones, green sandy shales, and sandy carbonate rocks. Within this area, the Simpson lies entirely in the subsurface. Borehole logs, interpreted sample logs, and cores were used to study the lithofacies and their relationships to the conventional stratigraphic nomenclature established from outcrops in the Arbuckle Mountains.

In south-central Kansas, in Kiowa and adjoining counties, the Simpson can be subdivided into six informal stratigraphic units. The lowermost two, a sandstone and a green sandy shale, correlate with the McLish Formation. The upper four--a sandstone, a sandy cherty dolomite, a green sandy shale, and a thin sandy limestone--correlate with the Bromide Formation.

To the south, in western Oklahoma, the Simpson becomes thicker and more of its formations can be distinguished as the southern Oklahoma aulacogen is approached. Where fully developed, the Simpson is divided into (ascending): the Joins, Oil Creek, McLish, Tulip Creek, and Bromide Formations. The Oil Creek Formation extends north approximately to the Kansas State line, but the Joins and Tulip Creek Formations are found only further south.

A notable feature within the Bromide Formation is a well-defined area of carbonate rocks approximately 50 miles east-west and 150 miles north-south in dimensions, half of which is in Kansas and half in Oklahoma. The carbonate facies is primarily a sandy, cherty dolomite averaging about 35 feet thick. The boundaries of this facies are very sharp, and its thickness can increase from 0 to 25 feet within a mile.

In southwestern and west-central Kansas, the Simpson is considerably thinner and the informal six-unit stratigraphy cannot be correlated into this area. Toward the northwest, the Simpson tends to be reduced to a thin sandy dolomite.

Charpentier, R. R., and Doveton, J. H., 1990, Stratigraphy and facies in the Middle Ordovician Simpson Group, southwestern Kansas and western Oklahoma [abs.]: Oklahoma Geological Survey Circular [in press].

New Interpretations of Pennsylvanian and Permian stratigraphy, San Juan Basin and southeast Paradox Basin

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Surface and subsurface lithostratigraphic studies support significant revisions in Pennsylvanian and Permian correlations in the San Juan Basin. Subsurface data provide a framework to correlate different stratigraphic units around the basin margins. Colorado Plateau nomenclature is extended into the basin from the northwest and applied as far southeastward as the correlations allow.

The Honaker Trail, Paradox, and Pinkerton Trail Formations of the Hermosa Group are recognized throughout most of the San Juan Basin. The Paradox Formation is extended southeastward beyond the limits of its evaporite facies into the basin, where it consists of thick shelf-carbonate rocks and thin black shale, sandstone, and siltstone interbeds. Where the Hermosa Group thins onto the marginal uplifts, the Paradox loses the thick carbonate rocks and becomes indistinguishable from the rest of the Hermosa. The Hermosa is correlated in the subsurface with the Madera and Sandia Formations to the southeast. The transitional Rico Formation, between the marine Hermosa Group and the continental Cutler Formation, is identified throughout the subsurface of the San Juan Basin and correlated with similar deposits outcropping along the northern and eastern margins.

The Cutler Formation includes the Organ Rock, Cedar Mesa, and Halgaito Members throughout most of the basin. In the vicinity of the Hogback monocline the Cedar Mesa Member undergoes a gradational eastward facies change from cyclic evaporite and sandstone to thick-bedded sandstone. The subsurface Cedar Mesa is correlated in part with similar rocks in the outcropping Abo and Supai Formations.

Huffman, A.C., Jr., and Condon, S.M., 1989, New Interpretations of Pennsylvanian and Permian stratigraphy, San Juan Basin and southeast Paradox basin: American Association of Petroleum Geologists Bulletin, v. 73, no. 9, p. 1161.

STRATIGRAPHIC CROSS SECTIONS OF UPPER CRETACEOUS ROCKS ACROSS THE SAN JUAN BASIN, NORTHWESTERN NEW MEXICO AND SOUTHWESTERN COLORADO

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Upper Cretaceous rocks of the San Juan basin, which are as much as 6,500 ft (1980 m) thick, comprise a classic sequence of intertonguing marine and nonmarine facies. Geophysical logs from closely spaced drill holes throughout most of the basin provide data for detailed correlations of the rock units which can be made by using numerous time marker beds within the marine shale sections. These marker beds provide a time framework for construction of cross sections that show (1) diachronism and stratigraphic rise of shoreface sandstone bodies associated with the four major transgressions and regressions of the Western Interior seaway within the basin, (2) shelf to very low angle slope (<0.25°) to basinal topography, (3) the Coniacian (basal Niobrara) unconformity, (4) low-amplitude paleostructural features, and (5) low-relief differential compaction features associated with lateral heterogeneities in sand-shale sections.

Molenaar, C.M., and Baird, J.K., 1989, Stratigraphic cross sections of Upper Cretaceous rocks across the San Juan basin, northwestern New Mexico and southwestern Colorado [abs.]: American Association of Petroleum Geologists Bulletin, v. 73, no. 9, p. 1167.

Stratigraphy and Correlation of Middle Cretaceous Rocks Around Uinta Basin, Northeastern Utah and Northwestern Colorado.

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On the north side of the Uinta basin, the nonmarine Dakota Sandstone is conformably overlain by the Mowry Shale. The unconformably overlying Turonian Frontier Formation consists of a basal transgressive sandstone and marine shale member that onlaps the Mowry Shale from west to east, and an overlying southeasterly prograding wedge of coastal sandstone and delta-plain deposits. The unconformity between the Frontier and Mowry represents as much as 6 m.y.

On the south side of the Uinta basin, the upper Cenomanian-Turonian Tununk Member of the Mancos Shale is separated from the underlying Aptian-Albian Cedar Mountain Formation by a 4 m.y. unconformity. The Cenomanian Dakota Sandstone, not everywhere present, onlaps the unconformity surface from both east and west. The middle Turonian Ferron Sandstone Member of the Mancos gradationally overlies the Tununk Member on the west and grades into siltstone of the Tununk eastward. These units are overlain by the deeper water upper Turonian Juana Lopez Member of the Mancos, which has been mapped as Ferron Sandstone Member on the south side of the basin.

Drill-hole log correlations across the east side of the basin indicate that (1) the Albian Mowry Shale on the north side of the basin grades southward into the Dakota Sandstone a few miles south of Rangely, Colo., (2) farther south this Dakota in turn grades into the upper part of the Cedar Mountain Formation, and (3) the unconformity between the Mowry and Frontier on the north side is the same as the unconformity between the Cedar Mountain Formation and the Tununk Member (or the Dakota, where present) on the south side. Thus, the Albian-Aptian? Dakota on the north side is an older unit that is separated from the younger Cenomanian Dakota on the south side by an unconformity. Further correlations indicate that (1) the lower half of the Tununk (upper Cenomanian to lower part of the middle Turonian) onlaps the unconformity surface from south to north, and (2) the Juana Lopez Member grades into the upper part of the Frontier.

Molenaar, C.M., 1989, Stratigraphy and correlation of middle Cretaceous rocks around Uinta basin, northeastern Utah and northwestern Colorado [abs.]: American Association of Petroleum Geologists Bulletin, v. 73, no. 9, p. 1167.

THE PRECAMBRIAN OF THE UNITED STATES

by

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Precambrian rocks underlie about 60 percent of the U.S., but are exposed in less than 10 percent. Archean rocks constitute the southern part of the Superior craton of the Canadian Shield, and the Wyoming craton in Wyoming and Montana. The Superior craton is composed of belts of metavolcanic and metasedimentary rocks (greenstone belts) surrounded and separated by plutons of tonalite and granodiorite. Both the volcanic rocks and the plutons have ages in the range 2800-2600 Ma. Archean gneisses that were partially reworked during the Early Proterozoic abut the Superior craton on the south, in Minnesota and Michigan. This terrane consists of Early Archean gneisses as old as 3600 Ma and some volcanic and sedimentary rocks deposited between 2750 and 2600 Ma.

Rocks of the Wyoming craton are exposed in uplifts in Wyoming and Montana, and extend northward in the subsurface into Canada. The gneisses have ages of 3200-2700 Ma, and some volcanic rocks are as young 2640 Ma. A few granitic plutons are as old as 2850 Ma, but many have ages of 2600-2430 Ma. Early Proterozoic epicratonic successions overlie Archean basement along the margins of the cratonic nucleii. These include the Marquette Range Supergroup and its correlatives along the southern margin of the Superior craton and the Snowy Pass Supergroup along the southern margin of the Wyoming craton.

Wide belts of deformed Early Proterozoic rocks separate the two Archean cratons and flank them on the south. The Penokean orogen represents an oceanic magmatic arc that was accreted to the southern margin of the Archean continent in the Lake Superior region at about 1850 Ma, deforming both the Archean rocks of the foreland and their epicratonic cover. The Trans-Hudson orogen resulted from closure of an ocean between the Wyoming and Superior cratons shortly before 1800 Ma.

Slightly younger Early Proterozoic rocks constitute the Central Plains orogen in the Midcontinent and its westward extension through Colorado and Arizona to southeasten California. Rocks in this belt are products of terrane accretion, arc magmatism, and related sedimentation along a convergent margin at the southern edge of the composite Wyoming and Superior cratons. Metavolcanic rocks in the northern part of the belt have ages of 1790-1710 Ma, and most associated plutons are dated between 1780 and 1670 Ma. Plutons and volcanic rocks in the southern part of the belt are dated at 1700-1630 Ma. This broad orogenic belt represents addition of as much as $2X10^6$ km^2 of juvenile material to the continent in less than 250 m.y. During this interval mature quartzites were being deposited on the already stabilized rocks of the Penokean orogen.

In the Midcontinent region, the Early Proterozoic mobile belts are overlain by Middle Proterozoic tuffs and felsic volcanics. Granitic plutons invaded both the volcanic sequences and the flanking Early Proterozoic rocks in a broad belt extending from Wisconsin to Arizona. Plutonic and volcanic rocks have ages of 1450-1510 Ma in the east and 1340-1400 Ma in the west. These anorogenic igneous rocks may have developed in response to incipient rifting, perhaps related to extension that began along the western margin of the continent at about the same time.

The Grenville province and its southwestern extension, the Llano province, constitute a major Middle Proterozoic orogenic belt. Grenville rocks exposed in the Adirondack uplift include metasedimentary and metavolcanic rocks, granulite-facies gneisses, and voluminous plutons of anorthosite and related rocks. The plutons and high-grade gneisses have ages of 1110-1070 Ma; the supracrustal rocks probably accumulated between 1400 and 1250 Ma. The northwest boundary of the orogen, the Grenville front, is not exposed in the U.S., but in Canada it is marked by an abrupt southeastward increase in metamorphic grade and by zones of cataclastic rocks rocks related to northwest-directed thrusting. The Grenville orogen could be the result of major continent-continent collision, but details are obscure. The nearly contemporaneous Midcontinent rift system is widely exposed around Lake Superior. It contains more than 20 km of interlayered mafic lavas and clastic sedimentary rocks of the Keweenawan Supergroup. The rift may be a pre-Grenville aulocogen, a flaw formed during the Grenville orogeny, or an unrelated feature.

Reworked Grenville gneisses exposed in the Appalachian orogen are conformably overlain by thick sequences of Late Proterozoic sedimentary and volcanic rocks accumulated during the early stage of rifting along the eastern margin of the continent between 820 and 650 Ma. Several rifts within the craton, including the Oklahoma aulocogen and the New Madrid rift, may have formed during this same episode.

Analogous but in part older sequences accumulated on the western edge of the craton during rifting that began at about 1500 Ma. Oldest of these are dominantly clastic sediments and intercalated mafic sills and basalt flows that accumulated in deep local basins; younger sequences form extensive westward-thickening wedges, some of which pass upward into Cambrian rocks without obvious stratigraphic breaks.

Precambrian rocks were added to continental North America as parts of terranes accreted during the Phanerozoic. In the east these terranes include extensive belts of Precambrian rocks accreted during the mid-Paleozoic. In the western conterminous U.S., Precambrian rocks are rare or absent in accreted terranes, but are known in some accreted terranes in Alaska. These rocks are poorly dated, and a coherent picture of the sources and histories has not yet been documented.

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Reed, J.C., Jr., Sims, P.K., Harrison, J.E., and Peterman, Z.E., 1989, The Precambrian of the United States: 28th International Geological Congress Abstracts, v. 2, p. 683-684.

Fluvial Sandstone Beds in the Petrified Forest Member of the Upper Triassic Chinle Formation, northwest New Mexico and northeast Arizona

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Distribution, lithology, and fluvial style of sandstone and conglomerate beds in the upper part of the Petrified Forest Member of the Chinle Formation provide new interpretations of Chinle stratigraphy and environments of deposition. Newly described sandstone beds near Taaiylone, Mitchell Draw, and Crazy Woman Canyon in the Grants-Gallup region lie, respectively, 60, 110, and 180 m stratigraphically above the top of the widespread Sonsela Sandstone Bed. The Correo Sandstone Bed, exposed on the south flank of Mesa Gigante, 75 km east-southeast of Grants, has been miscorrelated with the sandstone at Mitchell Draw. Subsurface data indicate that the Correo occurs stratigraphically above the other sandstone beds, near the top of the Petrified Forest Member.

As seen in well logs, the sandstone beds, including the Sonsela, pass laterally into mudstone eastward from Grants. Similarly, the Agua Zarca and Poleo Sandstones of the Nacimiento Mountains to the east grade westward into mudstone. Fining of units from both east and west, accompanied by thickening of the Chinle to 600 m, identifies a deepening of the Triassic basin near Laguna and Mesa Gigante. Because separate east and southwest source areas are indicated for the fluvial deposits, the Sonsela Sandstone Bed is clearly not correlative with the Poleo Sandstone, as previously suggested.

Sandstone beds of the Petrified Forest Member, lithologically immature, commonly consist of stacked, coarse, channel deposits overlain abruptly by fine grained, thin, horizontally bedded and tabular-planar crossbedded deposits. Except for some meander deposits in the Sonsela, the sandstone beds were deposited primarily by braided streams dominated by flash floods and high flow regimes, in a tropical climate that fluctuated between monsoon rains and hot dry seasons.

Robertson, J.F., 1989, Fluvial Sandstone Beds in the Petrified Forest Member of the Upper Triassic Chinle Formation, northwest New Mexico and northeast Arizona (abs.): American Association of Petroleum Geologists Bulletin, v. 73, no. 9, p. 1172.

The Durango Delta: Complications on a San Juan Basin Cretaceous Linear Strandline Theme

The Upper Cretaceous Point Lookout Sandstone generally conforms to a predictable cyclic shoreface model in which prograding linear strandline lithosomes dominate formation architecture. Multiple transgressive-regressive cycles resulted in systematically repetative lithologies formed in beach to inner-shelf environments. Deposits of approximately five cycles are locally grouped into bundles. Such bundles extend at least 20 km along depositional strike and change from foreshore sandstone to offshore, time-equivalent Mancos mudrock in a downdip distance of 17-20 km. Excellent hydrocarbon reservoirs exist where well-sorted shoreface sandstone bundles stack and the formation thickens. This depositonal model breaks down in the vicinity of Durango, Colorado, where a fluvial-dominated delta 'front and associated large distributary channel deposits characterize the Point Lookout Sandstone and overlying Menefee Formation. Lateral sandstone discontinuity, pervasive mudrock interbeds, and local slump features characterize the deltaic strata. Abundant current ripples in the distal delta front deposits imply NE (offshore) and SE (along shore) transport. Subsurface models in the Durango area should consider local dip-aligned distributary axes, strike-aligned reservoir discontinuity, and possible clastic shelf plumes originating from the deltaic headland.

ZECH, Robert S. and Wright-Dunbar, Robyn, 1989, The Durango Delta: Complications on a San Juan Basin Cretaceous Linear Strandline Theme: Americian Association of Petroleum Geologists Rocky Mountain Section, Abstracts with Programs Vol.73, no 9, p.1179

ORIGIN OF CLAY MINERALS IN SANDSTONE-HOSTED VANADIUM-URANIUM DEPOSITS: EVIDENCE FOR ALTERATION AFTER METAL ACCUMULATION

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Genetic models of tabular, sandstone-hosted vanadium-uranium (V-U) deposits propose that vanadium-rich clays within them formed when V and U accumulated. Steep geochemical gradients that caused V and U to precipitate in selected volumes of sandstone are also favored to explain the increased abundance of clay minerals in the deposits. However, a study of illitic material in and near V-U deposits hosted by the Jurassic Entrada Sandstone in southwestern Colorado has determined that roscoelite (V-rich illite) was a product of alteration that affected both mineralized and barren sandstones after the metals accumulated.

Petrographic, chemical, mineralogic, and Rb/Sr age-determination techniques were used to characterize illitic material from V-U ore, bleached sandstone near ore, and red sandstone distant from ore in the eolian Entrada Sandstone. All samples contain well-crystallized (Kubler index $<1.2° 2\theta$) aluminous illitic material with fewer than 8% expandable layers. Although similar to illitic material in barren sandstone, roscoelite is distinguished by its composition, abundance, larger particle size, and smaller Kubler index. Rb/Sr age determination yielded model ages ranging from 35 to 50 Ma for all samples. The differences between roscoelite and barren illite are probably explained by high concentrations of dissolved vanadium during alteration of unknown pre-existing vanadium minerals in the V-U deposits. Their age and other data suggest that both roscoelite and barren illite in the Entrada formed during relatively uniform, pervasive alteration. Solutions that formed them were either brines formed by evaporite dissolution or magmatogenic hydrothermal solutions. This study shows that genetic models of V-U deposits should consider the origin of the present ore mineralogy separate from processes proposed to explain metal accumulation, unless cogenesis is demonstrated.

Breit, G.N., 1989, Origin of clay minerals in sandstone-hosted vanadium-uranium deposits: evidence for alteration after metal accumulation: Geological Society of America Abstracts with Program, v. 21, no. 6.

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Petrology of Tullock Member, Fort Union Formation, Wyoming and Montana: Evidence for early Paleocene uplift of the Bighorn Mountains

New petrologic data collected from sandstones in the Paleocene Tullock Member of the Fort Union Formation above the Cretaceous/Tertiary boundary in the Powder River Basin (PRB) and from the lowermost Paleocene in the Bighorn Basin, Wyoming and Montana, compel reevaluation of the timing of the Bighorn uplift, formerly thought to be middle Paleocene. The Cretaceous/Tertiary boundary is identified by regionally valid palynological and trace element geochemical criteria. Basinwide outcrop and subsurface studies of the Tullock Member indicate deposition on a low-gradient alluvial plain extending toward the retreating Cannonball sea. Eastward-flowing, low sinuosity paleostreams containing small, sandy, stable channels characterized the fluvial systems.

Petrologic analyses reveal that all sandstones are angular to subangular, chert-rich litharenites. Lower Paleocene sandstones deposited on a proximal alluvial plain in the Bighorn Basin contain plutonic igneous rock fragments, chert, and minor metamorphic and volcanic fragments. In contrast, sandstones from the Tullock deposited on a medial and distal alluvial plain in the PRB contain locally abundant carbonate (micritic limestone, and ferroan and nonferroan dolomite) and metamorphic rock fragments (chlorite schist) in addition to plutonic rock fragments and chert.

Uplift of the northern end of the Bighorn Mountains accompanied by unroofing of Paleozoic rocks commenced in early Tullock time, as shown by carbonate clasts in the lower Tullock in the northwest PRB. Uplift of the southern end of the Bighorn Mountains did not occur until the end of Tullock time, as indicated by absence of carbonate clasts in the lower Tullock in the southeast PRB.

American Association of Petroleum Geologists Bulletin, v. 73, no. 9, p. 1149.

DIAGENETIC ALTERATION IN "BEDDED TUFFS", YUCCA MOUNTAIN, NEVADA: EFFECTS ON POROSITY AND PERMEABILITY

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The general term "bedded tuffs" includes pyroclastic fall, pyroclastic surge, nonwelded pyroclastic flow, and the weathered surfaces of these deposits. Macroscopic, petrographic, and scanning electron microscope criteria of shard and vesicle morphology can be used to subdivide the bedded tuffs with respect to their depositional origin. Knowledge of bedded tuff morphlogical characteristics and their resultant physical properties is important for the development of hydrologic-flow models for the unsaturated as well as saturated zones at Yucca Mountain.

Physical properties of each bedded-tuff type are a result of their unique megascopic and microscopic morphological characteristics. Deposits that have undergone alteration retain morphological characteristics of their original nature, but physical properties, such as porosity and bulk density, are significantly affected by the diagenetic history of the deposit. Density and porosity values of pyroclastic-fall and nonwelded pyroclastic-flow deposits are similar, but permeability values in pyroclastic-fall are several orders of magnitude higher than in pyroclastic-flow deposits.

A general diagenetic sequence in both the unsaturated and saturated zones is: (1) Precipitation of a smectitic rind-forming clay, (2) dissolution of the volcanic glass, (3) precipitation of zeolites, (4) precipitation of another generation of smectitic clay, then (5) precipitation of potassium feldspar. Although many of the same diagenetic minerals are found in both zones, the unsaturated zone tends to retain its vitric nature, whereas, the saturated zone contains high temperature and pressure zeolites and quartz products.

Lateral flow of pore water has been inferred to occur at boundaries between fine- and coarse-grained material, where capillary barriers inhibit the vertical movement of water. In addition, lateral flow or perched water conditions may also occur at: (1) Boundaries with clay-rich weathered zones, (2) zeolitic or devitrification boundaries that cross stratigraphic boundaries, or (3) boundaries with vesicle-poor pyroclastic-surge deposits.

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PETROGENETIC IMPLICATIONS OF RB-SR AND SM-ND ISOTOPES RELATED TO POST-CALDERA VOLCANISM IN THE WESTERN MOGOLLON-DATIL VOLCANIC FIELD, NEW MEXICO

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Two distinct groups of post-caldera volcanic rocks have been identified in the western part of the Mogollon-Datil volcanic field (M-D) on the basis of age, volume, major/trace element and isotope geochemistry, and structural setting. Both groups largely postdate the ~36-28 Ma voluminous (on the order of 1000 km^3) silicic ignimbrites and lavas that dominate M-D.

Group I comprises hypersthene normative andesites (23-27 Ma) with an original volume on the order of 100 km^3. These were erupted from structurally controlled, regional dike systems and from small (1-10 km^3) shield volcanoes. Samples for analysis were collected from one set of shield volcanoes, aligned along the ENE Morenci lineament (ML). Sr initial ratios of Group I andesites range from 0.7062 to 0.7098 and ε_{Nd} values, from -5.3 to -7.5, which suggests assimilation of crustal material by the magma. Sr initial ratios of three volcanic vents decrease from NE to SW along the ML with little change in ε_{Nd}. A change in source is suggested by those samples on the ML near its intersection with the NNE Morenci-Reserve fault zone (MRFZ) that have Sr and Nd isotope values that trend towards the Group II isotope characteristics.

The less voluminous Group II rocks (21-<1 Ma) are essentially bimodal basalt and rhyolite. Eruptive centers in the western M-D are mainly within the NNE MRFZ. The basaltic rocks of Group II on the MRFZ have a range of Sr initial ratios from 0.7031 to 0.7052 and ε_{Nd} values from +9.2 to +1.7. The spread in Sr and Nd isotopic ratios suggests crustal contamination of a magma derived from a depleted mantle reservoir. Group II lavas, derived from vents that are localized along a major fault zone between the Colorado Plateau and the Mogollon plateau, show less contamination by upper crustal materials than the Group I lavas. This may indicate that the fault zone facilitated ascent of the magma with less opportunity for assimilation.

Several samples, placed in Group II on the basis of age, have characteristics that are transitional between Groups I and II. They are located between Groups I and II and are intermediate in Rb-Sr and Sm-Nd isotope data. These samples may represent different degrees of crustal contamination between Groups I and II magmas as extension continued in this transition area between the Rio Grande rift and the Colorado Plateau.

Futa, Kiyoto, and Ratté, J.C., 1989, Petrogenetic implications of Rb-Sr and SM-ND isotopes related to post-caldera volcanism in the Western Mogollon-Datil volcanic field, New Mexico, *in* Continental magmatism abstracts, International Association of Volcanology and Chemistry of the Earth's Interior, General Assembly, Santa Fe, New Mexico, New Mexico Bureau of Mines and Mineral Resources Bulletin 131, p. 100.

UTILITY OF SAN JUAN BASIN SILCRETES

Silcretes are silicified paleosols that formed as part of deep-weathering profiles during depositional hiatuses, under humid climatic regimes. They provide chronostratigraphic support for hypotheses regarding local and regional tectonic and surface events. Silcrete occurs in the San Juan Basin (SJB), near the top of the Kirtland Shale (Cretaceous), in the Ojo Alamo Sandstone (Paleocene), and in the Nacimiento Formation (Paleocene). These occurrences mark the southern limit of a 1000-mile-long, discontinuous outcrop of silcrete discovered during reconnaissance of 16 Western Interior Basins. These silcretes, common in Upper Cretaceous to middle Paleocene rocks, are rare in older and younger rocks.

Local differences in SJB silcretes may prove useful in understanding the regional environment. 1. The lowest silcrete crops out 140 ft below the top of the Kirtland Shale and within the zone involved in the controversy over placement of the Cretaceous-Tertiary (K-T) boundary. Elsewhere, that hiatus (a) has not yet been dated (Cedar Creek anticline, Williston Basin), (b) occurred during an extended period (Uinta Basin), or (c) occurred during intermittent periods of uplift (Red Desert Basin). 2. The silcretes exhibit minor kaolinite development, as opposed to well-developed B-horizons found in some other basins. 3. The Nacimiento contains numerous soil profiles of the highest silcretes in badland topography, providing excellent three-dimensional exposures, which have not been found in highest silcretes elsewhere.

Recognition of silcrete occurrences may prove useful to field geologists where other chronostratigraphic information is absent. For example, geologists searching for the K-T boundary could use the lowest silcrete as a starting point.

GASSAWAY, J.S., 1989, Utility of San Juan Basin silcretes (abs.): American Association of Petroleum Geologists Bulletin, v. 73, no. 9, pp.1156-1157

MAFIC INTRUSIVES IN PRECAMBRIAN ROCKS OF THE WYOMING PROVINCE AND BELT BASIN

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Precambrian mafic and ultramafic intrusives occur in nearly all the fault-block mountain ranges of the Archean Wyoming Province. They range from large, complex layered intrusives to simple dikes and sills in swarms that inflate the country rock from 5 to 30 percent. Although most individual tabular intrusives are only meters wide and one to several km long, at least one dike is mappable for 130 km. Most mountain ranges and the adjacent Belt basin contain intrusives of three or more ages; some, but never all, times of intrusion are repeated from range to range. Times of least intrusive activity are about 1.0, 1.6, and 2.3 Ga throughout the Wyoming Province as well as the Canadian shield. Archean and Early Proterozoic intrusives, most of which are metamorphosed, trend mainly northeasterly parallel to the edge of the Wyoming Province in the southeastern half of the province; orientations are more diverse in the northwestern half. Middle and Late Proterozoic intrusives, most of which are not metamorphosed, trend northwesterly along the southeastern and northwestern margins of the Wyoming Province but are unrecognized in the interior.

Precambrian mafic magmas generated mostly Proterozoic clinopyroxene-dominant tholeiites with lesser plagioclase-phyric ("leopard rock") diabases, orthopyroxene-dominant norites, or olivine-dominant troctolites. The immobile-element chemistry of a majority of these rocks in southeastern Wyoming is consistent with an island arc environment. The generally Archean ultramafic rocks, which occur in much smaller quantities, have been postulated to have been emplaced as extrusive oceanic basement, as entire liquid or semisolid intrusives, or as cumulate portions of other intrusives. Mafic and ultramafic magmas derived from different mantle sources succeeded each other, either as crosscutting components of sheeted swarms or as successive liquid components of large inhomogeneous plutons. Middle and Late Proterozoic intrusives include differentiated varieties such as quartz dolerites, alkalic olivine dolerites, or even quartz porphyry rhyolites. Recently studied intrusive sequences from southeastern Wyoming include many of the above compositions in complex field relationships.

International Association of Volcanology and chemistry of the Earth's Interior, General Assembly, Santa Fe, New Mexico, USA, June 25-July 1, 1989; Continental Magmatism, Program and Directory, p. 23, Poster Session, #24, for Symposium III: Extensional volcanism: MAFIC MAGMATISM ASSOCIATED WITH PROTEROZOIC RIFTING (IGCP 257 SYMPOSIUM).

REGIONAL DEPOSITIONAL TRENDS AND ORGANIC-CARBON CONTENT OF THE WOODFORD SHALE, ANADARKO BASIN, OKLAHOMA, BASED ON GAMMA-RAY, DENSITY, AND RESISTIVITY LOGS

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The organic-rich, highly compacted Woodford Shale of Late Devonian and Early Mississippian age is widely regarded as a major hydrocarbon source rock in the Anadarko basin of Oklahoma. The Woodford is divided here into three informal units -- the upper, middle, and lower members of the Woodford Shale -- on the basis of log character. Higher kerogen content of the middle member is the likely physical basis for this subdivision.

Isopachs of the Woodford Shale and its three members reveal a positive structural feature that divided the Woodford into northeast and southwest depocenters. This feature, which is parallel to and about 120 km north of the Wichita Mountains front, was a hinge line separating areas of regional basement flexure during Woodford time. Lower and middle members of the Woodford thicken to the southwest into the now-eroded central trough of the southern Oklahoma aulacogen. The upper member thickens to the northeast reflecting initial development of the Sedgwick basin of south-central Kansas.

Total organic carbon (TOC, wt%) is calculated here from log-derived formation density (P_b, g/cm^3) using the equation $TOC=(156.956/P_b)-58.272$. TOC of the upper, middle, and lower members of the Woodford Shale averages 2.7, 5.5, and 3.2 wt%, respectively. TOC does not correlate with formation thickness, but does decrease with increasing thermal maturity in response to the progressive generation and expulsion of hydrocarbons.

Hester, T.C., Schmoker, J.W., and Sahl, H.L., 1989, Regional depositional trends and organic-carbon content of the Woodford Shale, Anadarko basin, Oklahoma, based on gamma-ray, density, and resistivity logs: Geological Society of America South-Central Section Meeting, Abstracts with Programs, p. 14.

COALS OF BANGLADESH

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Coal has been known to be present in Bangladesh for many years; however, there has been no significant utilization of this coal. Coals of Permian age are present in at least three areas in northwestern Bangladesh, and coals of early Tertiary and Pleistocene age are present in northeastern and eastern Bangladesh.

In terms of known resource potential, the coals in the Permian Gondwana sequence of northwestern Bangladesh are of principle exploration importance. The Gondwana sequence is present as structurally preserved blocks on top of the Precambrian basement complex which underlies thick, poorly indurated and permeable Tertiary and Quaternary rocks. Exploration in the region is by geologic inference, geophysical interpretation, and exploratory drilling. The three known areas of Gondwana coal range in areal extent from 10 to more than 40 square kilometers. The coal occurs at depths that range from less than 150 meters to more than 2,700 meters. The coals have apparent ranks of high-volatile A to high-volatile C bituminous and commonly have medium to high ash contents and low to medium sulfur contents.

Considerable exploration will be required before the coal resource potential of Bangladesh can be realistically evaluated. The existing information, however, indicates that coal could become an important alternative energy source in the energy future of the nation.

Landis, E.R., 1989, Coals of Bangladesh, in Geol. Soc. America, Abstracts with Programs, v. 21, no. 6.

Structural Fabric in a Great Plains Setting, North Dakota and South Dakota.

Edwin K. Maughan, and Bonnie L. Crysdale,

Structural features on the southeast flank of the Williston basin in Corson County, South Dakota, and Sioux County, North Dakota, are oriented north-northwest (about N.30°W.), east-northeast (about N.60°E.), and roughly east-west (about N.75°W.). Details of the structural fabric have been determined by field reconnaissance and by computer contouring. The location and altitude of exposures of key beds were plotted on 1:24,000 scale topographic maps and were entered into the computer for manipulation and structural contouring. Key beds range between strata exposed at the top of the Upper Cretaceous Pierre Shale in the southeastern part of the study area to the top of the Paleocene Cannonball Member of the Fort Union Formation in the northeastern part. Most north-northwest oriented structures are faults with negligible to as much as 30 m (100 ft) of vertical offset. Included in the north-northwest features is a shallow graben about 25 km across that is coincident with the Pierre lineament. East-northeast oriented faults and folds(?) occur locally, but are much less evident than the conjugate north-northwest set. Broad, east-west anticlinal and synclinal folds comprise the principal elements of another system, which possibly includes an inferred conjugate north-south set of folds. Drainages seem to be structurally controlled. The courses of the minor streams are mostly northwest-southeast, parallel or coincident with the N.30°W. structures. Major stream courses follow the roughly east-west (N.75°W.) synclines; and the master stream, the Missouri River, flows approximately north-south along the inferred, conjugate structural set.

Maughan, Edwin K., and Crysdale, Bonnie L., 1989, Structural fabric in a Great Plains setting, North Dakota and South Dakota [Abstract]: Geological Society of America Abstracts with programs, v. 21, no. 6, p. A337-338.

MULTIPLE STREAM PIRACIES OF THE RED FORK POWDER RIVER, WYOMING

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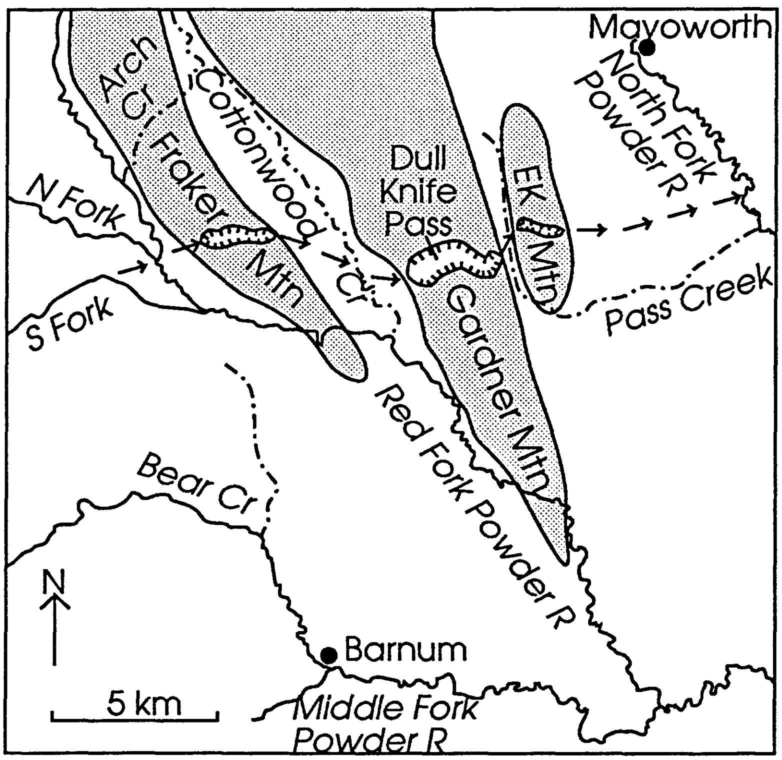
Multiple changes in the position of the Red Fork Powder River during the Quaternary are evidenced by a series of prominent abandoned canyons and isolated terrace deposits along the southeastern flank of the Bighorn Mountains. The east-flowing ancestral Red Fork (shown on the figure by arrows) was apparently superposed from a higher Tertiary surface across three northwest-trending anticlinal structures that form Fraker, Gardner, and EK Mountains. Headward erosion by streams that flowed southeast in the less resistant Triassic and younger rocks between the anticlines progressively captured segments of the ancestral Red Fork. The relative elevations of the abandoned canyons and the location of terrace deposits indicate that the eastern-most segment across EK Mountain was abandoned first when Pass Creek captured the stream flow. The captured Red Fork flowed in the valley between Gardner and EK Mountains and subsequently became superposed across the south end of EK Mountain, leaving a sequence of isolated terrace remnants along its course. The westernmost segment across Fraker Mountain was probably abandoned next through capture by a stream that followed the present course of upper Red Fork. The abandonment of the Dull Knife Pass segment may be related to other drainage changes along Arch and Cottonwood Creeks.



Gravel deposits adjacent to the abandoned canyons contain clasts of Cambrian flat-pebble limestone conglomerate that could not have been derived locally, as the canyons cut only as deep as Mississippian and Pennsylvanian limestones and sandstones. Small clasts of Precambrian crystalline rocks are present on several high, gravel benches (180–220 m above the modern drainage) adjacent to Fraker Pass and on the divide between the South and North Forks of the Red Fork. Precambrian rocks do not crop out in the present Red Fork drainage basin; hence, the presence of these clasts in the gravels indicates that the headwaters of the ancestral Red Fork reached Precambrian source terranes to the north or west.

Agard, S.S., and Sutherland, W.M., 1989, Multiple stream piracies of the Red Fork Powder River, Wyoming: Geological Society of America Abtracts with Programs, v.21, no. 5, p. 49-50.