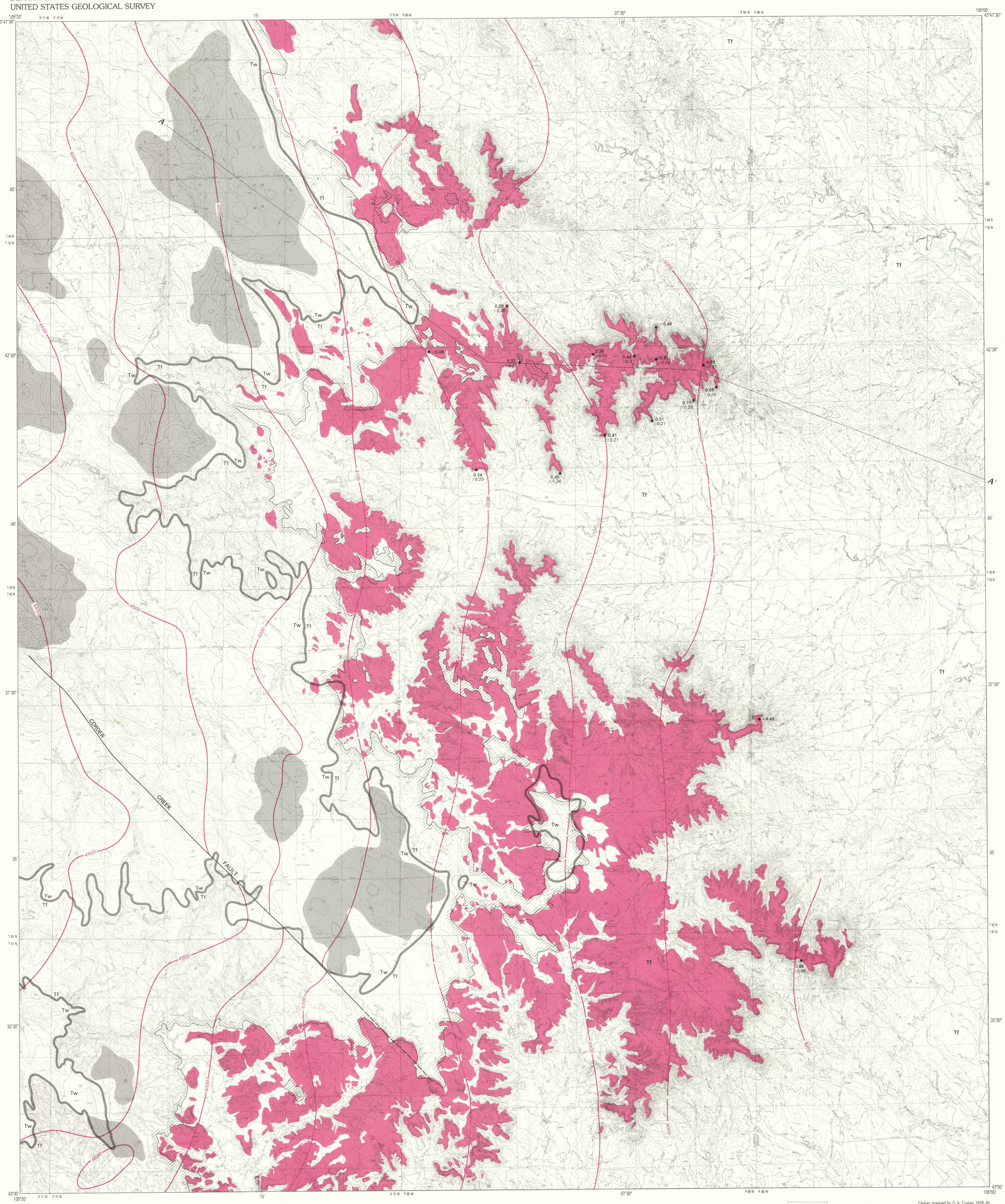


Base from U.S. Geological Survey, 1:24 000, 1971
Hilight, Open A Ranch, Buck Creek, Reno Reservoir,
Piney Canyon NW, Piney Canyon NE, Teckla,
Piney Canyon SW, Piney Canyon SE
Projection and 10,000-foot grid ticks: Wyoming coordinate system, east zone (transverse Mercator) 1000-meter Universal Transverse Mercator grid ticks, zone 13. 1927 North American datum

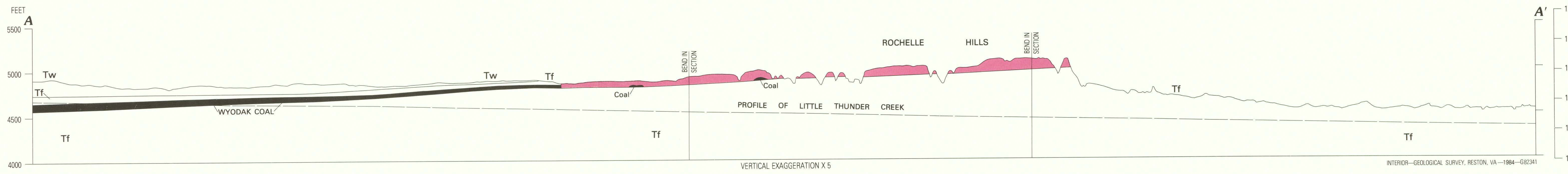
APPROXIMATE MEAN DECLINATION, 1984

SCALE 1:50 000

CONTOUR INTERVAL 10 AND 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

AREA OF MAP

Clinker mapped by D. A. Coates, 1976–81



VERTICAL EXAGGERATION X 5

EXPLANATION

CLINKER (HOLOCENE AND PLEISTOCENE)—Baked shale, siltstone, and sandstone, mostly of the Fort Union Formation, produced by burning of the Wyodak coal in the Fort Union. Mostly brick-red to orange, but locally white, gray, green, or black. In some places rock has melted, forming black or dark-green scoriaceous rocks having flow structures. Thickness 8–35 m

Tw — WASATCH FORMATION (EOCENE)—Drab-brown and gray claystone, siltstone, and fine-grained sandstone containing thick lenses of coarse-grained, crossbedded arkosic sandstone; generally poorly cemented but contains some well-cemented resistant sandstone beds and lenses. Thin beds of coal and carbonaceous shale common locally

Tf — FORT UNION FORMATION (PALEOCENE)—Light-brown and gray, soft, interbedded sandstone, silty shale, carbonaceous shale, clay, and thick to thin coal beds; commonly poorly consolidated or unconsolidated. Locally contains ironstone concretions. Wyodak coal is near the top of the formation. Top of the formation is an unconformity having several tens of meters of relief

4500 — STRUCTURE CONTOUR—Drawn on base of Wyodak coal and base of Wyodak clinker. Dashed where approximately located. Contour interval 100 feet. Contours on base of Wyodak coal from Denson and others (1980)

FAULT—Dashed where approximately located. From Denson and others (1980)

0.68 ±0.29 — LOCALITY OF DATED SAMPLE, SHOWING FISSION-TRACK AGE OF CLINKER IN MILLIONS OF YEARS—Age in millions of years plus or minus two standard deviations

APPROXIMATE EDGE OF WYODAK COAL IN THE FORT UNION FORMATION—Line pattern on coal. From Coal Resource Occurrence and Coal Development Potential maps (see "Sources of map information")

CONTACT BETWEEN WASATCH AND FORT UNION FORMATIONS—From N. M. Denson, written commun., 1978, and Denson and others (1980)

SIGNIFICANT AREA OF INTERIOR DRAINAGE

DISCUSSION

The natural burning of coal beds in the coal basins of the American West has baked extensive areas of rocks to shades of red, yellow, orange, and black. These colorful rocks, known collectively as clinker, commonly cap hills, mesas, and ridges. Although clinker is continuous for miles in parts of this map area, as well as in other areas, considerations of landscape development and fission-track ages of the clinker show that the rocks were baked by many small fires rather than a few large fires. This map shows topography, the distribution of clinker produced by burning of one major coal bed, and, in selected places, the age of the burning.

Where coal is exposed by erosion, it commonly catches fire either from an external source such as prairie fire or lightning, or internally by spontaneous combustion. The fire may then burn laterally beneath the overlying rock (overburden) and bake this rock, firing it like brick so that it is harder and more resistant to erosion than before baking. The baked areas, over time, are etched out by erosion and remain as the highest parts of the landscape. In many areas where major coal beds are being progressively exposed and burned during downwasting, this interaction between burning and erosion largely determines the shape of the landscape.

The distribution of clinker shown on this map is taken largely from maps of surficial geology (see "Sources of map information"). The distribution of coal is taken from Coal Resource Occurrence and Coal Development Potential (CROCDP) maps, which were prepared by contractors and were reviewed and published by the U.S. Geological Survey (see Intrasearch, Inc., 1979a–e). Standard methods in the CROCDP mapping program incorporated published sources and natural-color aerial photography but included little field mapping or exploratory drilling. These maps, which were made to evaluate the coal resource, may be conservative in some places in showing details of the edge of the coal, where a surface cover of sheetwash alluvium or windblown material intervenes between outcrops of coal or unbaked overburden and an exposure of clinker, the actual position of the contact between clinker and unburned coal is not evident from the surface. In such cases the CROCDP maps show the edge of the coal where coal can last be confidently inferred. Clinker was mapped on the surficial geologic maps to the extent that it shows on the surface. Conservative mapping of coal and clinker separately has resulted in small areas that surely are underlain by one or the other being mapped as neither; for example as in sec. 17, T. 42 N., R. 69 W.

In other places, although part of the thick Wyodak coal bed has burned, a significant amount of coal remains; for example, the long patch of clinker in sec. 15, T. 43 N., R. 70 W. is underlain by sufficient coal that the Kerr McGee Jacobs Ranch Mine operation is removing the clinker in order to mine the coal beneath. Here, as in some other places, there is no inconsistency in both coal and clinker being mapped at the same spot.

The structure contours show a consistent gentle westward dip of the Fort Union Formation and consistent relations between the structure and topography and drainage. In the areas having coal, structure contours were constructed by using logs from oil and gas wells and published field observations (Denson and others, 1980). In areas of clinker, the contours were drawn using the base of the clinker as published on the surficial geological maps of the area (see "Sources of map information"). Because we estimate point elevations of the base of the clinker on those maps to be accurate to only plus or minus 25 ft, we have smoothed the contours in clinker areas.

FISSION-TRACK DATING

Because clinker is a dominant component in the development of the landscape of eastern Wyoming, dating of the production of the clinker allows an estimate of the rates of erosion that have occurred during the past several hundred thousand years. Where the time of burning can be determined, rates of geomorphic processes can be estimated. At present the most accurate method of determining time of burning is fission-track dating of detrital zircons in sandstones within the clinker that were baked as the underlying coal burned.

The fundamental assumption in dating zircons from clinker is that the sandstone above the coal reached a high enough temperature during burning to completely anneal any fission tracks that were present in the zircons before heating. A temperature of 700°C sustained for one hour is sufficient to completely anneal tracks present in a zircon (Fleischer and others, 1969). Upon cooling, tracks again begin to accumulate. The Fort Union Formation is Paleocene in age; therefore all detrital zircons present in it should have a fission-track age of at least 55 m.y. if annealing had not taken place. In fact, the source area of the upper Fort Union sediments in the Rochelle Hills is thought to have been to the southwest, south, and southeast, primarily in the Laramie Mountains and the Hartville uplift (Galloway, 1979), both of which contain many Precambrian rocks. The zircons from the clinker all have fission-track ages less than 1.0 m.y., which indicates extensive annealing during the Quaternary.

Zircons were extracted from samples of baked sandstone by using conventional separation methods and were dated by external-detector method (Naeser, 1979). Zircon crystals were mounted in teflon (FEP), polished, and etched in a eutectic melt of the NaOH and KOH (7.2 g and 10 g respectively) for times as long as 50 hours at 220°C (Gleadow and others, 1976). They were irradiated in the TRIGA reactor at the U.S. Geological Survey in Denver, Colo. The dosimetry was determined by using the National Bureau of Standards glass SRM 962 with muscovite detector.

THE LANDSCAPE

Three distinct types of landscape occur in the map area. The western part of the map area is gently rolling and punctuated by only a few steep hills, and drainage is poorly developed resulting in large areas without mappable stream channels. Numerous small depressions collect local runoff. Maximum relief is developed in the central part of the map area where the steep, dissected, east-facing Rochelle Hills escarpment of Fort Union Formation is protected by the clinker of the Wyodak coal (see map and cross section). East of the escarpment a completely integrated and moderately dense stream network drains an area of low rounded ridges underlain by Fort Union.

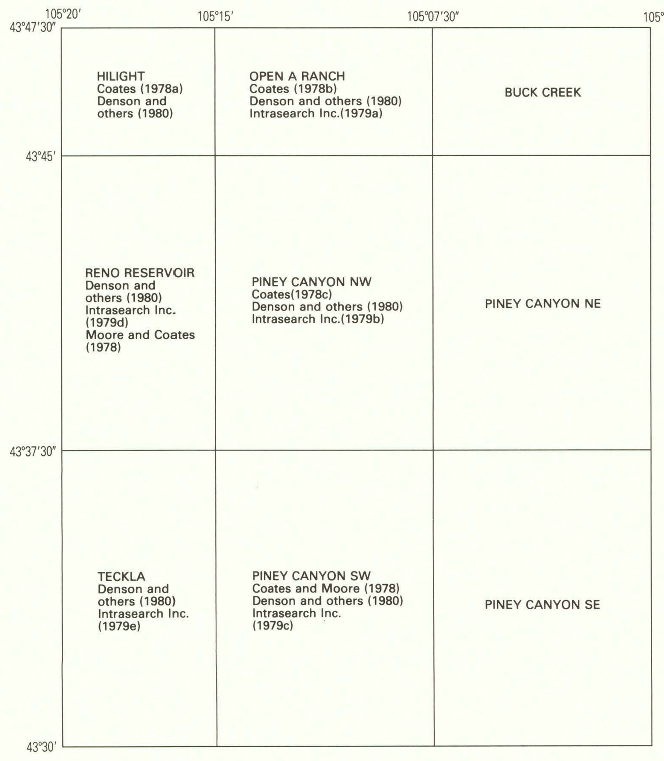
The western part of the map area is underlain by the Wasatch Formation, which contains substantial amounts of fine-grained sandstone that weathers largely to fine sand and coarse silt. These products form a mantle of residual soil, sheetwash alluvium, and windblown sand and silt that is sufficiently permeable to absorb most precipitation [14 in. (36 cm) per year; Toy and Munson, 1978]. Consequently, much of the area has little surface runoff, resulting in a loosely knit and poorly integrated drainage network. Because the sand and silt are susceptible to wind erosion during dry periods, deflation has created areas of interior drainage. Although the present natural vegetation is capable of protecting the soil where the land is managed properly, extensive areas of thin windblown deposits and large blowouts, now occupied by ephemeral lakes, show that wind has been a major influence in shaping this landscape.

The central part of the area is dominated by three major landforms. The highest parts of the Rochelle Hills are the nearly flat to gently rolling uplands that are underlain mostly by clinker. These areas have little through drainage and minimal surface erosion because the highly fractured clinker absorbs water quickly. In most places clinker is underlain by impermeable clay and shale of the Fort Union Formation, which block downward migration of groundwater and force the development of springs at the base of the clinker. Most of the clinker is structurally stronger and more resistant than unbaked rocks so that it maintains steeper slopes. Through weathering, clinker breaks down into flakes or irregular pieces as large as several centimeters in maximum dimension that are not readily moved by sheetwash.

Below the clinker tops are steep slopes of less resistant Fort Union Formation that are protected by the overlying clinker and in places by an armor of clinker fragments. These slopes are higher toward the east, where the clinker is higher above the drainage (see map and cross section). Below the steep slopes the terrain levels off abruptly to substantially lower slopes—in some areas pediments or pediment-like surfaces—which descend to the major stream.

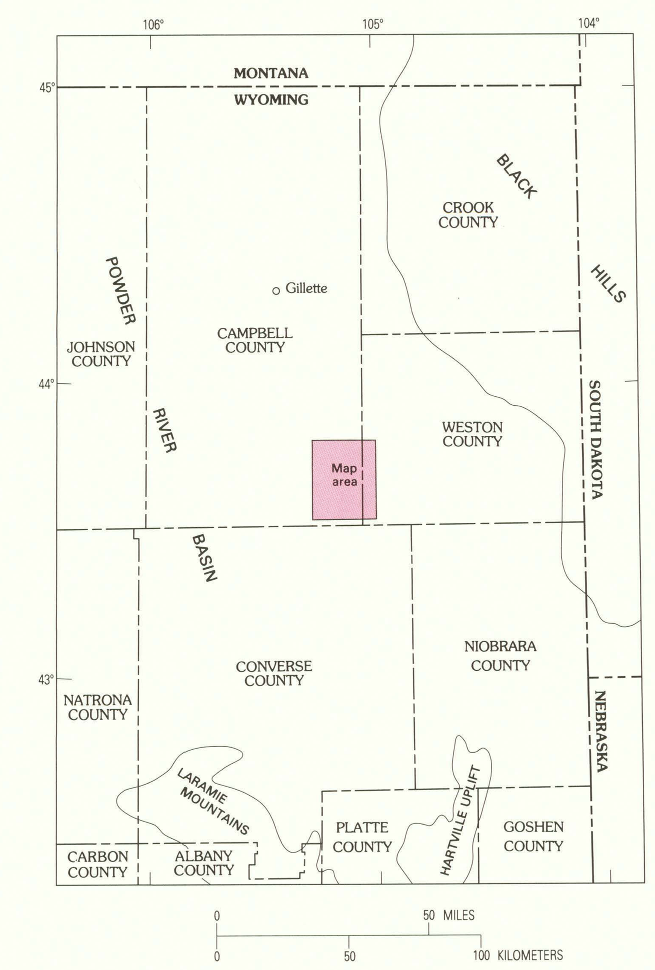
In the eastern part of the map area, which is underlain entirely by Fort Union Formation, the drainage is completely integrated and considerably closer spaced than it is to the west on the Wasatch Formation; the Fort Union, with its higher content of clay, is less permeable than the Wasatch so that more water runs off. Where unbaked, most of the Fort Union is poorly consolidated and weathers to its constituent silt, clay, and fine sand, which are easily removed by sheetwash erosion, resulting in the landscape of low relief seen in the areas of Fort Union in the eastern parts of the map area.

As regional downwasting proceeds, the Rochelle Hills escarpment maintains its identity, being held up by resistant clinker. As erosion progresses, the escarpment migrates downdip, westward; new clinker is created by periodic fires along the downdip side of the Rochelle Hills, and the eastern high escarpment progressively retreats by backwasting. The fission-track dates presently available suggest that burning on the headland north of Little Thunder Creek has progressed westward some 8 km in about the last 700,000 years, which would correspond to a total regional downwasting of 40–70 m during that period or an average rate of 6–10 cm/thousand years.



SOURCES OF MAP INFORMATION

Index shows location and names of 1:24,000-scale U.S. Geological Survey topographic quadrangles. References within quadrangles are listed in "References cited."



INDEX SHOWING LOCATION OF MAP AREA

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MAP SHOWING FISSION-TRACK AGES OF CLINKER IN THE ROCHELLE HILLS, SOUTHERN CAMPBELL AND WESTON COUNTIES, WYOMING

By
Donald A. Coates and Charles W. Naeser

1984

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