Surficial Geology of the Sheridan 30′ × 60′ Quadrangle, Wyoming and Montana

U.S. GEOLOGICAL SURVEY BULLETIN 1816

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By E. NEAL HINRICHS

Surficial deposits provide clues to the evolution of the Powder River Basin as well as support a large part of the economy of the basin

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Surficial Geology of the Sheridan 30′ × 60′ Quadrangle, Wyoming and Montana

By E. Neal Hinrichs

Abstract

The surficial deposits in the Sheridan 30′x60′ quadrangle of Wyoming and Montana include valuable mineral resources—soils that are the foundation of agriculture, and deposits of sand and gravel, the raw materials for construction. In addition to modern soils, the alluvium contains paleosols, the ages of which range from 30 to 100 thousand years dated by the uranium-trend method. These ages are younger than but generally consistent with the ages of calcretes in the terrace gravels, 124 and about 160 thousand years, dated by the uranium-thorium method. The terrace gravels are probably younger than the pediment gravels that are very likely of Pliocene age. The radiometric ages of the surficial deposits suggest that the drainage system began to form in the middle Pleistocene.

Numerous landslides have modified the landscape during most of the Quaternary. Recent movements on landslides have posed hazards to roads, utilities, buildings, and livestock, especially in the western, more populated and irrigated part of the quadrangle.

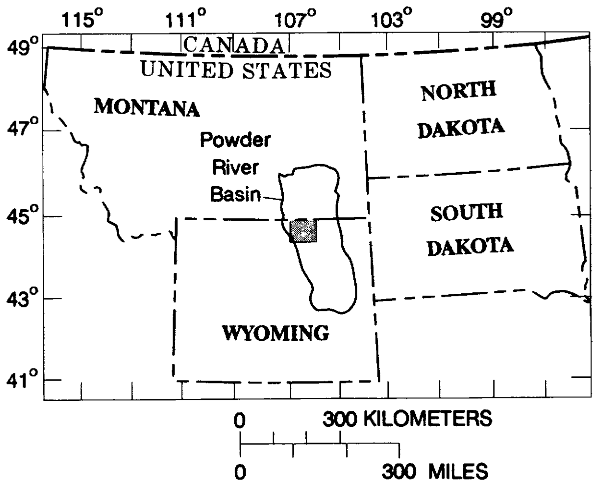

Figure 1. Location of the Powder River Basin in Montana and Wyoming. Sheridan 30′x60′ quadrangle shaded.

INTRODUCTION

The surficial geology of the Sheridan 30′ × 60′ quadrangle, which is in the west-central part of the Powder River Basin (fig. 1), merits investigation for both scientific and economic reasons. The surficial deposits, chiefly unconsolidated sediments of alluvial origin, contain clues to latest events in the evolution of the Powder River Basin, such as changes in climate, erosion, and drainage patterns. These deposits consist of sand, gravel, silt, clay, soils, and broken and disaggregated bedrock. Deposits in the study area are chiefly Quaternary in age, but some are perhaps as old as Pliocene.

Surficial deposits support a large part of the economy of the Powder River Basin. Soils are the base of agriculture and stock raising. Sand and gravel, the main raw materials of the construction industry, are used in building roads, dams, irrigation canals, as well as houses, and in reclamation of open-pit coal mines.

The Sheridan 30′ × 60′ quadrangle covers an area of 4,412 km^2. Topographic relief on 90 percent of the quadrangle ranges from 100 to 200 m. The highest point (2,635 m) is in the southwest corner; the lowest point (1,050 m) is along the Powder River at the northeastern edge of the quadrangle (pl. 1). Mean annual precipitation varies with altitude, ranging from about 31 cm to 34 cm/yr in the middle and eastern parts of the quadrangle (Toy and Munson, 1978). An estimated maximum of 50 cm/yr falls on the southwestern hills.

The Tongue River and tributaries drain the northwestern half of the quadrangle; the Powder River and tributaries drain the southeastern half. Both rivers flow northeastward across the Montana–Wyoming State line and into the Yellowstone River. The most prominent drainage pattern is the northwest parallelism of intermittent creeks and intervening ridges of bedrock. The northwest lineation is not controlled by attitude of the beds. Joints in sandstone are the structures most likely to control the parallel arrangement of drainages. The sandstone beds, however, are thin, discontinuous, and separated by thick beds of shale, siltstone, and coal. Orientations of major sets of fractures and cleat in coal-bearing rocks of the Sheridan coal field are N. 45° W., N. 37° E., and N. 13° E. (Lee and others, 1976, p. 9).

Wind erosion has been suggested as the mechanism for development of the drainage patterns. The areas of parallel drainages have been interpreted by some geologists as yardangs, erosional features characteristic of deserts (R.B. Colton, oral commun., 1983). Although the direction of the prevailing wind during the winter is from the northwest, the direction during Pleistocene and late Tertiary times has not been determined. Because no evidence has been found that this area was a desert, the yardang explanation seems improbable.

The present economy of the region is based mainly on agriculture and coal. Raising livestock, growing grain, and mining coal are the major businesses. Water, the all-important ingredient in western agriculture, flows in many irrigation ditches in the major valleys. Several of the larger ranches on the Powder River and Clear Creek irrigate from wells through large rotating sprinkler systems. Coal mining in the area began in 1892 from underground mines along Goose Creek and the Tongue River (Kuzara, 1977, p. 55). Although the mines produced fuel for the steam locomotives on the early railroad and brought prosperity to the Sheridan area, they also posed hazards from accidents, explosions, fires, and subsidence (Dunrud and Osterwald, 1980). The last underground mine was closed in 1953, about 6 years after the first open-pit mine was dug (F.W. Osterwald, oral commun., 1977).

Information about the surficial geology of the quadrangle has been published mostly in the form of maps (Hinrichs, 1979, 1983b, 1984). The surficial deposits in the southern part are described in a report on the geology and coal resources of the Buffalo–Lake DeSmet area (Mapel, 1959). A report on alluvial valleys in Wyoming includes some stratigraphic sections in the area, but no map (Leopold and Miller, 1954). Several open-file reports deal with landslides in this area (Chleborad and others, 1976; Chleborad, 1980).

ACKNOWLEDGMENTS

Fieldwork on the surficial geology amounted to 6 man-months during the summers of 1981 and 1982. David W. Rodgers assisted in reconnaissance mapping, measuring stratigraphic sections, and collecting samples. I thank John Bennetti for giving me a bird's eye view of the quadrangle from his high-wing monoplane. The local residents were generous in allowing me to go on their land. Several ranchers showed me that the best way to travel over wet fields without damaging the sod is on a 3-wheeler or all-terrain vehicle. Paleosols were sampled for radiometric age dating, size analysis, and composition. Calcretes in terrace gravels were sampled for radiometric age dating..

BEDROCK AND STRUCTURE

The bedrock exposed in the quadrangle is divided into two map units shown on plate 1: sedimentary rocks ranging in age from Cambrian to Tertiary and igneous and metamorphic rocks of Archean age. The sedimentary rocks consist of sandstone, shale, siltstone, limestone, dolomite, and conglomerate. The stratigraphic column of these rocks is shown in table 1. Tertiary sedimentary rocks make up the predominant part (about 98 percent) of the exposed bedrock. Distribution of the Fort Union and Wasatch Formations and correlation of the enclosed coal beds in the

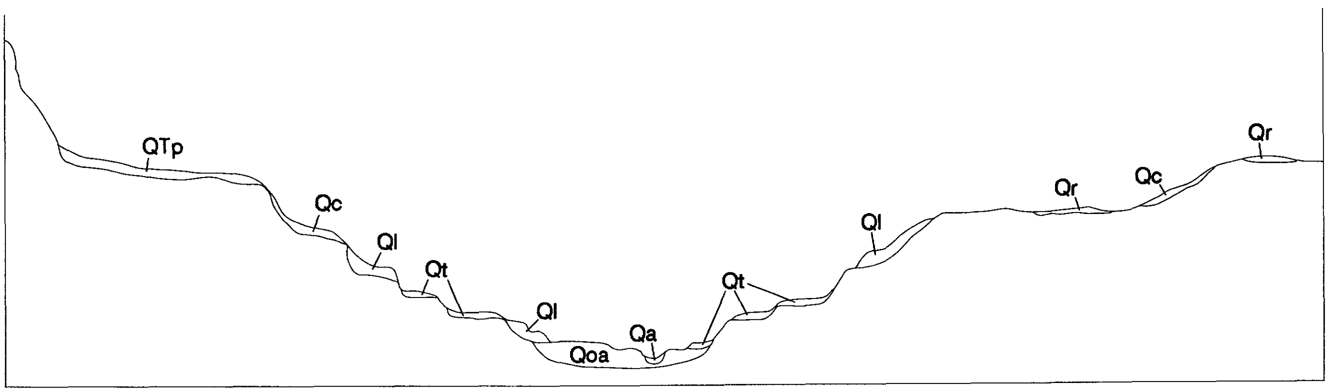

Figure 2. Diagrammatic section across a hypothetical river valley showing height relationships among Quaternary surficial deposits. Qa, stream alluvium; Qoa, older alluvium; Qt, terrace gravel; Ql, landslide debris; Qc, colluvium; QTp, pediment gravel (age possibly in part Tertiary); Qr, residuum.

Table 1. Stratigraphic column of sedimentary rocks exposed in the quadrangle

Formation	Rock type	Thickness (m)	Age
Wasatch	Sandstone, shale, siltstone.	305	Eocene.
Moncrief Member	Conglomerate, sandstone	275	Do.
Kingsbury Conglomerate Member.	do	30	Do.
Fort Union	Sandstone, shale, conglomerate.	60	Paleocene.
Chugwater	Silty sandstone	120	Triassic.
Goose Egg	Limestone, sandstone, siltstone.	90	Permian and Triassic.
Tensleep Sandstone	Calcareous sandstone	90–120	Pennsylvanian.
Amsden	Dolomite, limestone, chert, siltstone, sandstone.	75	Mississippian and Pennsylvanian.
Madison Limestone	Limestone, dolomite	185	Mississippian.
Bighorn Dolomite	Dolomite, sandstone	105	Ordovician.
Gallatin and Gros Ventre.	Shale, limestone, sandstone, siltstone, conglomerate.	135–200	Cambrian.
Flathead Sandstone	Sandstone, shale, siltstone.	135–215	Do.

northeastern quarter of the quadrangle have recently been published on a USGS coal map at a scale of 1:50,000 (Molnia and Orrell, 1988).

The igneous rocks comprise quartz diorite, quartz monzonite, and dikes and small plugs of diabase and metabasalt. A few xenoliths of mica schist, granitic gneiss, and quartzite are exposed in the granite (Hinrichs, 1983a).

The quadrangle is on the western edge of the Powder River Basin where most of the rocks dip gently and trend generally eastward. An exception to the gentle dips is in the southwestern corner where steeply dipping rocks of early Mesozoic age and older have been thrust faulted against gently dipping rocks of Eocene age and cut by strike-slip and normal faults. The faults in this locality are nearly all covered by surficial deposits. Along the northern border of the quadrangle and west of the Tongue River is a group of northeast-trending normal faults (not shown on pl. 1). They are right-stepping, en echelon, and probably represent the southeastern end of the Nye–Bowler fault zone (Law and Barnum, 1979).

SURFICIAL DEPOSITS

The surficial deposits of the Sheridan $30' \times 60'$ quadrangle have been mapped in seven units at a scale of 1:100,000 (Hinrichs, 1984). These map units, the major features of which are listed in table 2, reflect their alluvial, colluvial, and landslide origins. The topographic relations of the deposits to each other and to bedrock are shown on plate 1 and on a diagrammatic cross section (fig. 2). The surficial deposits that were formed by stream action lie in a sequence of altitudes that in general correlate with age. In other words, the older the deposit, the higher its position on the valley side.

Pediment Gravels

The coarsest and probably the oldest of all the surficial deposits are pediment gravels that lie on beveled erosion surfaces. The largest mass of pediment gravel is near Sheridan, west of Little Goose Creek. Other, smaller outcrops of gravel are erosional remnants that cap hills and small mesas in an arcuate band around Moncrief Ridge. The unconformable contact characteristic of pediment gravels, although not exposed within the quadrangle, is visible on the west bank of Little Goose Creek about 7 km southwest of the town of Big Horn.

The pediment gravels consist of pebbles and cobbles of resistant sedimentary, igneous, and metamorphic rocks, the relative percentages of each varying with locality. In the area west of Goose Creek, the predominant rock types in the clasts are quartzite, limestone, dolomite, and chert. In the area around Moncrief Ridge, the most common rock types are granite, diabase, gneiss, and metabasalt. The matrix of

Table 2. Major characteristics of the surficial deposits

Deposit	Shape	Height above drainage (m)	Estimated maximum thickness (m)	Composition	Agent of deposition	Disposition
Landslides, soil flows (Ql).	Spoon, sheet, wedge; upper surfaces hummocky.	0–200	9	Surficial material and weathered bedrock.	Gravity............	Moderate to steep slopes chiefly north- and east-facing.
Residuum (Qr)	Thin lenses, layers.	80–240	3	Sand, silt, clay	Product of weathering in place.	Flats and small closed basins on interfluves and benches.
Colluvium (Qc).	Wedge, spoon, sheet, irregular.	20–100	3	Poorly sorted and irregularly bedded sand, silt, clay, and gravel.	Slope wash, gravity.	Gentle slopes underlain by fine-grained rocks; moderate slopes by coarse.
Younger alluvium (Qa).	Ribbon, branching, meandering.	0–5	15	Sorted and bedded sand, silt, clay, and gravel.	Creeks and rivers.	Lower inner parts of valleys.
Older alluvium (Qoa).	Similar to valleys, branching, straight, curved, incised.	3–60	28	Sorted and bedded sand, silt, clay, gravel, buried soils (paleosols).	.........do.........	Outer and higher parts of valleys.
Terrace gravels (Qt).	Tabular remnants.	10–120	5	Pebbles, sand, cobbles.	.........do.........	Remnants at outer edges of valleys.
Pediment gravels (QTp).	Tabular, wedge-shaped.	20–185	15	Cobbles, pebbles, sand.	.........do.........	Remnants of highest gravel sheets sloping from hills in western part of quadrangle.

the gravels is chiefly coarse, poorly sorted sand with a minor amount of silt and clay. The gravels have a rusty appearance in areas where they have been wet for a long time.

Bedding in the pediment gravels is concealed nearly everywhere by talus and colluvium. A road cut or landslide scarp occasionally reveals lenticular beds as much as 1 m thick and sparse, thin intercalated beds of sand, silt, and clay. A few of the sand beds near the bottom of the gravel are cemented locally with calcium carbonate.

The age of the pediment gravels in the Powder River Basin can only be estimated because datable materials such as index fossils and beds of volcanic ash have not yet been found in them. A few rodent teeth, bone fragments, and some pulmonate gastropods were found in a pediment gravel on Elgin Creek about 34 km south of the quadrangle. The age of the gastropods ranges from Pliocene to Holocene (J.H. Hanley, written commun., 1985). West of the quadrangle, about 5 km west of the town of Big Horn, pediment gravels in which bones of a Pleistocene bison have been found lie about 112 m above Jackson Creek alluvium. This difference in elevation suggests that the pediment gravels formed during a long period of erosion that may have begun in the Pliocene.

Ultimate source rocks of the conglomerates of early Paleocene and Eocene age and of the younger pediment gravels are the resistant sedimentary, metamorphic, and igneous rocks of the Bighorn Mountains. The clasts of igneous and metamorphic rocks in pediment gravels around Moncrief Ridge undoubtedly came from the ridge after which a member of the Wasatch Formation was named. These gravels cap remnants of a former continuous apron that curved around the north, east, and south sides of Moncrief Ridge. Subsequent erosion left some of these remnants as much as 185 m above the present creeks.

Pediments common in the semi-arid and arid valleys of the West were formed, probably as a result of a balance between lateral and downward erosion. The pedimentation process in southern Utah has been well described by Williams (1984, p. 461-462):

> Pediments are formed in the Kaiparowits area where small streams and sheet flow, loaded with clasts of relatively hard, cohesive rock, discharge onto soft, less-cohesive rock. Where rapid downcutting is prevented by a threshold of resistant rock or a major stream nearby, lateral planation of the soft rock becomes the dominant process, and smooth, generally fan-shaped pediment surfaces are beveled on the soft rock. The width to which such pediments develop is determined by an equilibrium relationship between rate of lateral planation of the soft rock and the rate of lowering of the local base level, either by vertical erosion of the resistant rock threshold or entrenchment of the nearby major stream.

Terrace Gravels

Terrace gravels cap flattop ridges and small hills on the sides of valleys 5–130 m above the creeks and rivers. Some of the valleys lack terrace gravels—for instance, the valley of Buffalo Creek, which drains an area of only fine-grained Tertiary rocks. Terrace gravels are commonest in the western part of the quadrangle on the western and northern sides of the valleys near the source areas. The terrace gravels stand highest above valley bottoms in two localities, one on the south side of Piney Creek and west of Double Crossing Creek, the other on the west side of the Powder River on top of the L Quarter Circle Hills.

The composition of the terrace gravels varies widely depending on their source. In the western part of the quadrangle and in the major valleys draining eastward, the pebbles and cobbles are of resistant igneous, metamorphic, and sedimentary rocks from the Bighorn Mountains. Probable sources of the greater part of the terrace gravels are the conglomerates in the upper part of the Fort Union Formation and the Kingsbury Conglomerate and Moncrief Members of the Wasatch Formation. The conglomerates in the Fort Union Formation and in the Kingsbury Conglomerate Member of the Wasatch contain pebbles and cobbles chiefly of quartzite, chert, dolomite, and limestone, whereas the conglomerate in the Moncrief Member consists of cobbles, boulders, and pebbles chiefly of igneous and metamorphic rocks. In the central and eastern parts of the quadrangle not drained by the major creeks, locally derived rocks predominate in the terrace gravels—pebbles and sparse cobbles of fine-grained sandstone, ironstone, and clinker. The matrix of the gravels is sand and silt, cemented loosely in most places with clay and iron oxides. At a few localities, however, the matrix is cemented firmly with pale-brown, finely crystalline calcite, forming calcretes, the ages of which have been measured radiometrically (fig. 3).

Figure 3. Terrace gravel (Qt) on bedrock, west bank of Dutch Creek. Locality C4. Hammer, 30 cm long, lies on contact of terrace gravel and bedrock (T€s).

Table 3. Ages and locations of sampled paleosols, calcretes, and buried wood

Material	Surficial deposit	Height above drainage (m)	Locality Name	Sec.	T. N.	R. W.	Sample or locality No.	Age (ka)	Analyst	Method
Cottonwood root.	Younger alluvium (Qa).	5	Powder River.	8	47	76	W–5312	0.890±.1	Meyer Rubin.	^{14}C.
Paleosol	Older alluvium (Qoa).	3	Arkansas Creek.	15	55	81	P5–7	30±30	J.N. Rosholt.	U trend.
Do.........	.....do.......	2	.....do.......	15	55	81	P1–4	47±12	.....do.......	U trend.
Do.........	.....do.......	15	Piney Creek.	22	53	82	P16–19	90±45	.....do.......	U trend.
Do.........	.....do.......	5	Coutant Creek.	7	57	82	P8–11	100±60	.....do.......	U trend.
Do.........	.....do.......	2	Clear Creek	9	53	80	P12–15		Not analyzed.	
Do.........	.....do.......	70	Powder River.	8	57	76	P20–22	([1])		
Do.........	.....do.......	3	Dow Prong	8	55	82	Loc. D6		Not analyzed.	
Do.........	.....do.......	3	.....do.......	12	54	82	Loc. D9		Not sampled.	
Do.........	.....do.......	24	.....do.......	29	55	82	Loc. D7		Not analyzed.	
Calcrete	Terrace gravel (Qt).	27	.....do.......	27	55	82	C1	124±11	B.J. Szabo	U/Th.
Do.........	.....do.......	34	Dutch Creek.	3	56	83	C4	about 160	.....do.......	U/Th.
Paleosol	Older alluvium (Qoa).	5	Bull Creek	2	52	77	Not sampled.			

[1]Insufficient isotopes for age.

The ages of two samples of calcrete from terrace gravels measured by the uranium-thorium method (Szabo and others, 1981) are 124±11 ka and about 160 ka (table 3). The younger calcrete cements a terrace gravel that lies about 24 m above the East Fork of Dow Prong (locality C1, pl. 1); the older calcrete is from a gravel about 30 m above Prairie Dog Creek near the confluence with Dutch Creek (locality C4, pl. 1). These ages are considered approximate minimum ages of the gravel because the calcrete cement formed later than the gravel.

Older Alluvium and Paleosols

The thickest and most extensive of all the surficial deposits is older alluvium. It covers valley floors in almost all drainages, extending from the creeks or edges of younger alluvium outward to bedrock. The older alluvium includes a minor amount of colluvium deposited on it from the valley sides. A good example of older alluvium is in the valley of Coutant Creek, a tributary to Prairie Dog Creek in the northwest part of the quadrangle (fig. 4). The older alluvium of Coutant Creek and of five other creeks and rivers is known to contain buried fossil soils or paleosols, four of which have been dated radiometrically. In addition to paleosols, the older alluvium supports modern soils, which constitute the major resources in the area. Older alluvium is the principal surficial deposit in alluvial valley floors, the legal entity that is protected from disturbance of coal mining through the Surface Mining Control and Reclamation Act of 1977. This act defines (p. 72) an alluvial valley floor as

> * * * the unconsolidated stream-laid deposits holding streams with water availability sufficient for subirrigation or flood irrigation agricultural activities, but does not include upland areas which are generally overlain by a thin veneer of colluvial deposits composed chiefly of debris from sheet erosion, deposits formed by unconcentrated runoff or slope wash, together with talus, or other mass-movement accumulations and windblown deposits.

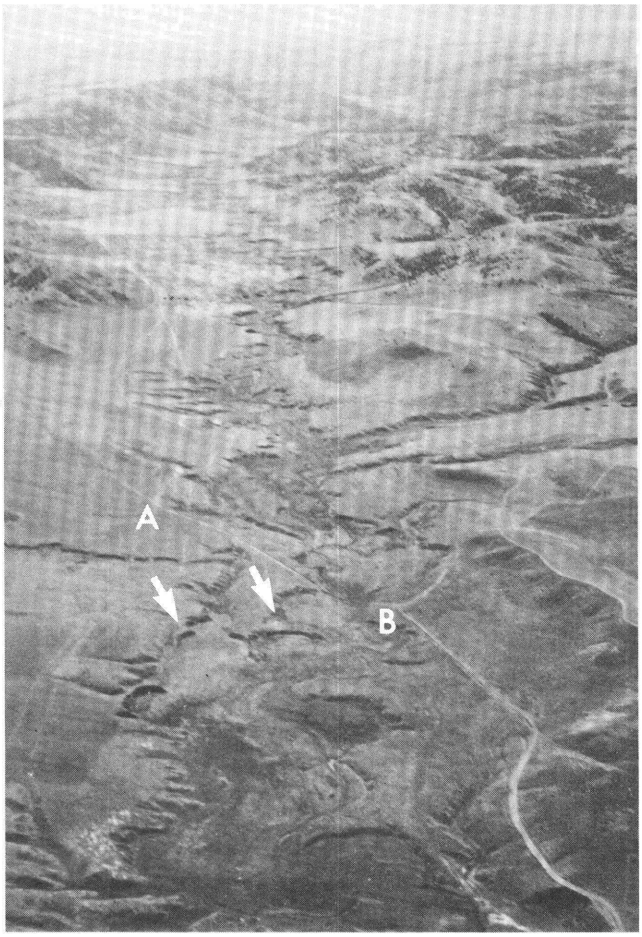

Figure 4. High-angle oblique photograph of Coutant Creek showing by arrows two terraces in older alluvium (Qoa). Distance A-B is about 500 m. View upstream.

The overall pattern of the valleys that contain older alluvium varies from dendritic and meandering to parallel. Perhaps the most striking trend is shown by the parallel valleys draining southeast into Clear and Buffalo Creeks and the Powder River (pl. 1). These valleys are probably joint controlled. The upper surfaces of the older alluvium are terraced, and the lower contact with bedrock varies from place to place with relief estimated at as much as 10 m. Thicker sections are found generally at confluences; for example, the thickest exposed section, 26 m thick, is at Waisner Draw on the west bank of the Powder River (fig. 5). The thickest section described in a published report, 27.3 m, is in the valley of Dutch Creek (Lowry and Cummings, 1966, p. 50). Two terrace levels are common, but locally three levels are preserved in the valleys of the Tongue and Powder Rivers and along the middle reaches of Clear Creek. Terrace levels and their relation to stratigraphy in regional correlation are discussed at the end of the section on older alluvium.

The older alluvium consists of the following sediments in estimated decreasing order of abundance—sand, silt, clay, and gravel, plus a minor percentage of carbonaceous material. The young material is Holocene organic matter in the soils (topsoils and paleosols); the older material, reworked Tertiary carbonaceous shale and coal, makes up thin laminae and lenses in the sediments. The bulk of older alluvium is chiefly silty and clayey sand in tabular and lenticular beds of widely varying thickness and extent. Scattered pebbles and thin lenses of gravel are common. Cementing materials are chiefly clay minerals, calcium carbonate, and gypsum. At a few localities, for example, the exposures on the west bank of Coutant Creek (fig. 6), the calcareous, older alluvium stands in vertical banks shaped by prismatic joints.

Locally, the bottom 1–3 m of the exposed section is a rusty gravel, such as on the west bank of Goose Creek north of Sheridan (fig. 7). About 1.5 km downstream at the I-90 overpass, a channel sample of older alluvium taken for size analysis contained 39 percent cobbles, 47 percent pebbles, 3 percent granules, 6.5 percent sand, and 4.5 percent silt and clay.

Two distinctly different kinds of older alluvium, banded and nonbanded, are exposed on the east bank of Dutch Creek across from the landing strip in sec. 11, T. 56 N., R. 40 E. (fig. 8). The valley is about 2 km wide there, and the total thickness of the alluvium is about 27.5 m. The banded older alluvium consists of alternating layers, 15–70 cm thick, of medium-gray to moderate-brown clayey silt in sharp contact with yellowish-gray sandy silt. Dark particles in the clayey silt are carbonaceous shale and coal. Size analyses of six channel samples 1–2 m long containing both types of alluvium show that the banded is somewhat finer and better sorted than the nonbanded (fig. 9). The banded alluvium is uncommon, found only at the Dutch Creek locality just described. It probably was deposited by small creeks and rivulets that drained the coal-bearing rocks of the Wasatch Formation on the east side of Dutch Creek. The common nonbanded alluvium, on the other hand, was probably deposited by Dutch Creek with much mixing of alluvium from many localities.

Ten paleosols were found in older alluvium at nine sites during 1981 and 1982 (table 3). Six paleosols crop out in the area drained by the Tongue River and tributaries. The paleosols are buried fossil soils, thin and immature, that are bounded by sharp disconformities above and gradational contacts below. Nine of the paleosols conform with beds and stratification surfaces in older alluvium; one, in the valley of Bull Creek in the southeastern part of the quadrangle, cuts across beds totalling about 1.5 m in thickness. Each of the paleosols consists of two zones, an upper darker zone (the A horizon of pedologists) that contains most of the organic matter, and a lower paler zone (B horizon) that is thicker and contains more calcium carbonate and gypsum. Channel samples 6–8 cm wide, 3–4 cm deep, and 10–40 cm long were chiseled from fresh vertical faces for analyses of organic matter, calcium

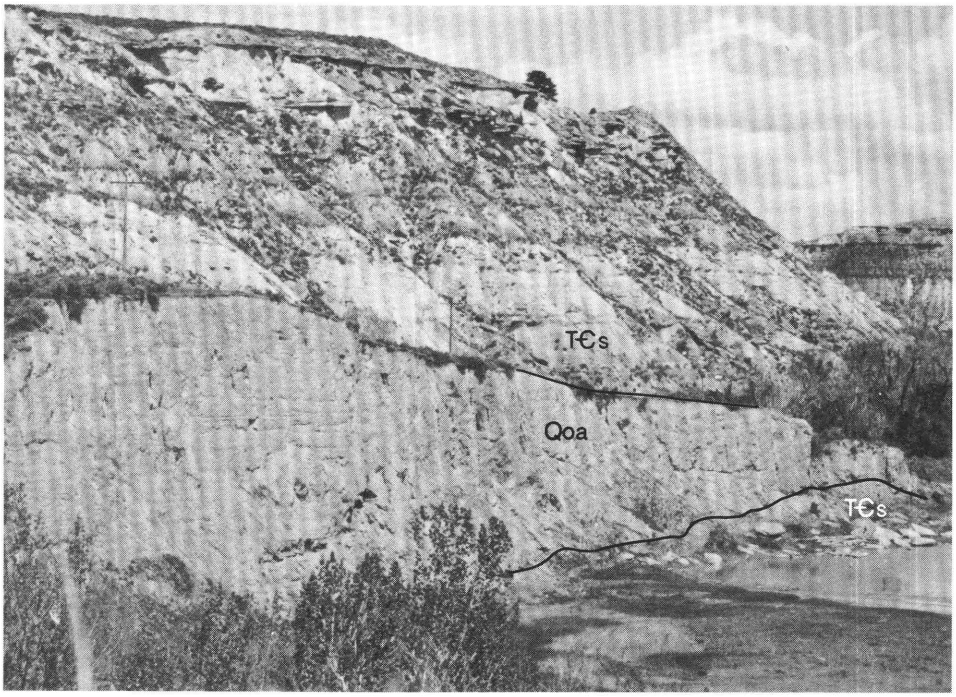

Figure 5. Older alluvium (Qoa) and bedrock (T€s) on west bank of the Powder River at Waisner Draw. Power pole 7.6 m tall.

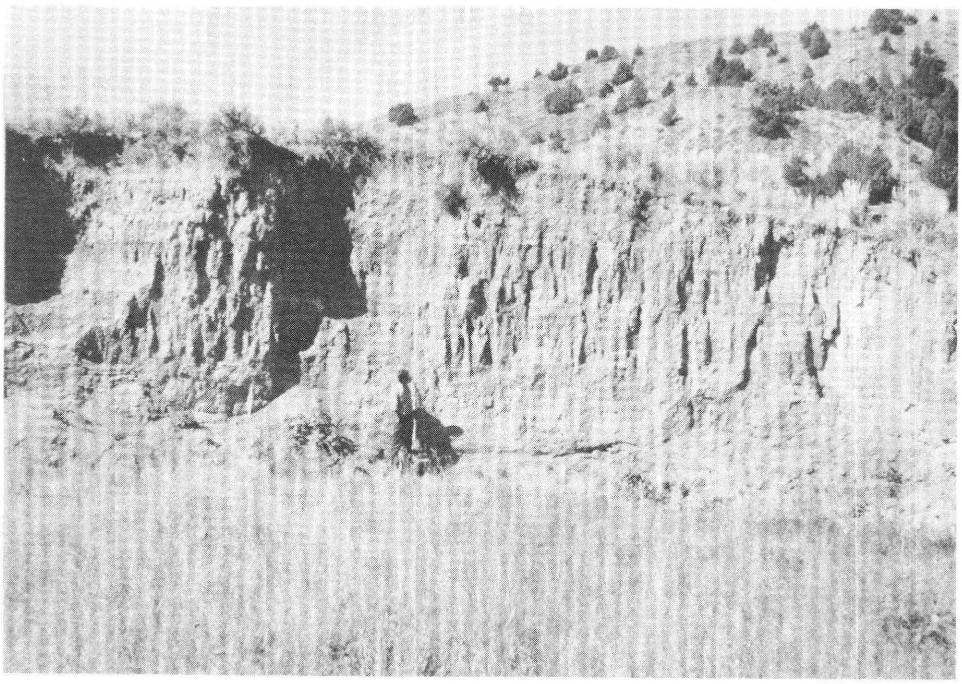

Figure 6. Prismatic joints in older alluvium (Qoa), Coutant Creek. Geologist is 1.83 m tall.

carbonate, particle-size distribution, and age (table 4). A discussion of uranium-trend dating, and of the precision and significance of the ages obtained by the method, follows descriptions of the paleosols, which are arranged by drainage basin.

One of the older paleosols crops out on the west bank of Coutant Creek, a tributary of Prairie Dog Creek (fig. 10). The lower zone, about 48 cm thick, contains a yellowish-gray to pale-greenish-gray calcareous clayey silt that commonly is mottled with stringers and irregular masses of

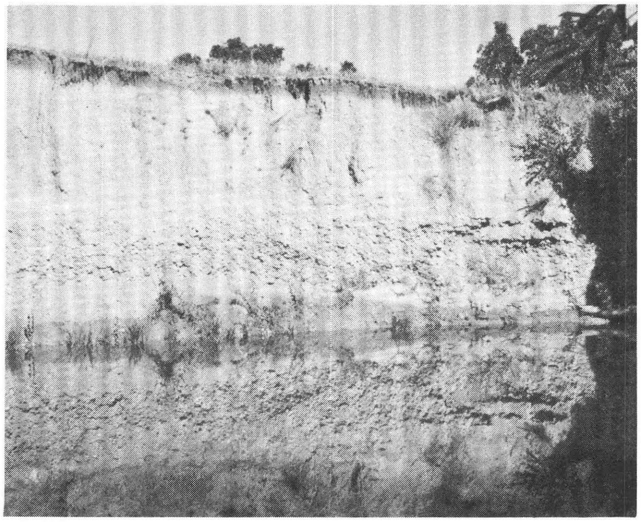

Figure 7. Older alluvium on west bank of Goose Creek, north side of Sheridan; 1.8 m of exposed gravel is overlain by 2 m of finer alluvium.

white powdery gypsum. Overlying the lower zone is a zone, 80 cm thick, that consists of moderate-grayish-brown clayey silt with some yellowish brown at the top. Particle size distribution of four samples shows clayey and sandy silts (fig. 11). The uranium-trend age of the paleosol in Coutant Creek, 100±60 ka, suggests that it might be the oldest paleosol in the area. However, the large range leaves room for overlap with the age of the paleosol on Piney Creek.

Two distinct, moderately developed paleosols and one poorly developed paleosol crop out on the Middle Fork of Arkansas Creek, a tributary to Dutch Creek (fig. 12). These paleosols are composed of typical clayey and sandy silt. The paler gray, lower zones grade upward into the brownish upper zones that have sharp disconformities at the top. The sediments are calcareous, but not gypsiferous. Pebbles of orange-pink clinker and yellowish-gray sandstone are distributed randomly throughout the section. Comparison of the particle-size distribution graphs shows that the older of the two paleosols is slightly finer and better sorted, particularly in the sand sizes (figs. 13 and 14). The uranium-trend dating of the two paleosols gives ages of 47±12 ka and 30±30 ka.

A paleosol is exposed on the southeast side of Piney Creek at the Sheridan–Johnson County line. The base of the lower zone, about 55 cm thick, stands 15 m above the creek. The yellowish-brown, clayey and sandy, calcareous silt contains very sparse small pebbles of orange-pink, red, and black clinker. In the top 3–4 cm, it grades into the upper zone, about 45 cm thick, that consists of moderate-gray and brown, slightly to very calcareous silt. Particle-size distribution curves converge in a tight group in the clay and silt sizes and diverge only slightly in the sand sizes (fig. 15). The paleosol on Piney Creek is better sorted and not so skewed toward the coarser sizes as are other paleosols. The uranium-trend age of the paleosol at Piney Creek is 90±45 ka.

Figure 8. Banded alluvium on right and nonbanded alluvium on left side of east bank, Dutch Creek.

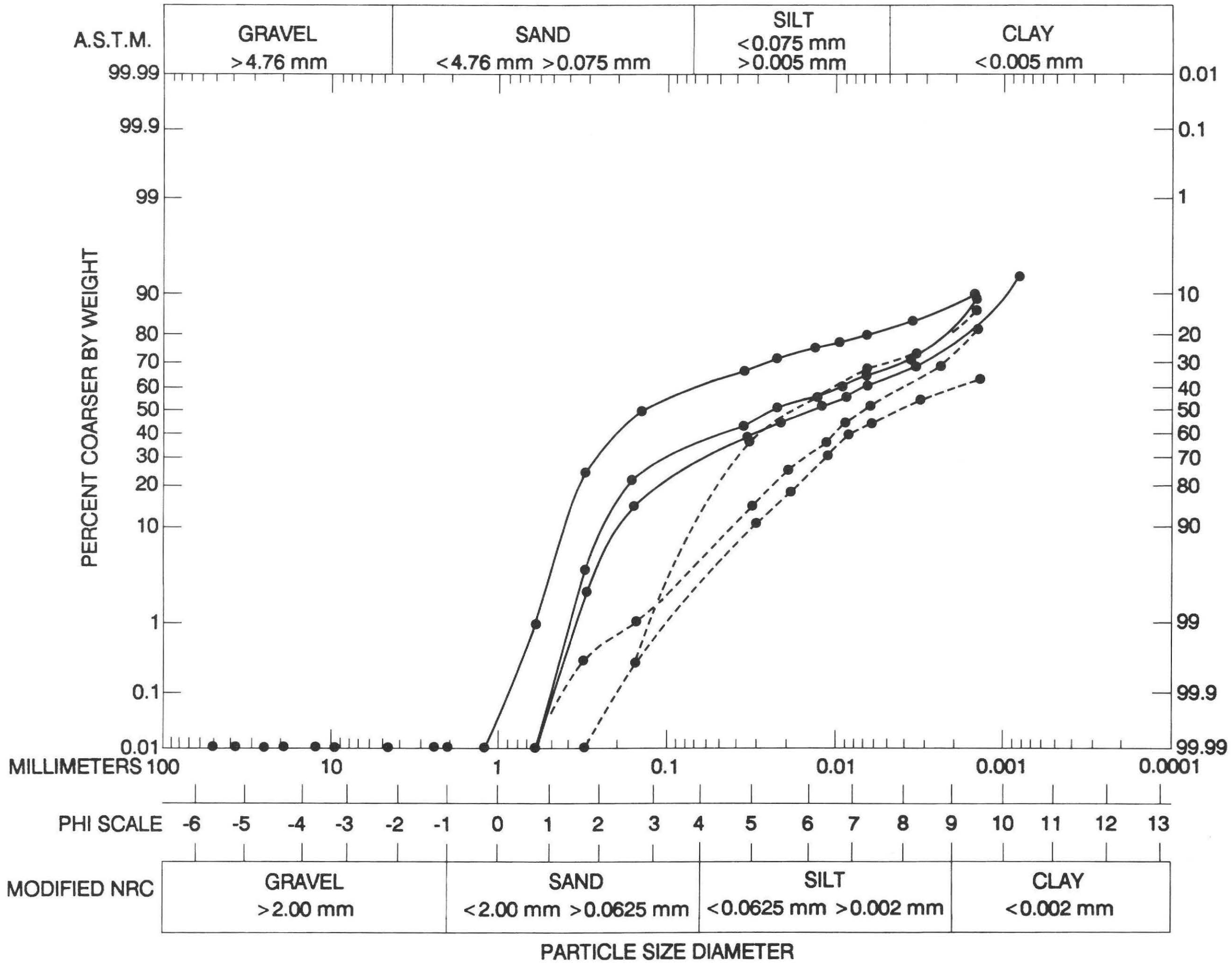

Figure 9. Particle-size distribution curves of older alluvium (Qoa), Dutch Creek. Solid curve, nonbanded alluvium; dashed curve, banded alluvium. D.M. Cheney, analyst.

A paleosol was found on the south bank of Clear Creek at the mouth of Big Corral Draw about 2.5 km southwest of Leiter. The lower zone consists of about 55 cm of yellowish-gray calcareous siltstone that contains sparse pods of white powdery gypsum as much as 5 mm long. The upper zone, about 25 cm thick, is a moderate-gray clayey silt that is slightly calcareous. Distribution of particle sizes shows spread of the curves in the sand sizes (fig. 16). This paleosol was not dated radiometrically.

A thin, immature paleosol is exposed in a gulch about 1 km north of the Powder River and 1 km west of the Sheridan–Campbell County line. The upper darker zone, 12 cm thick, consists of moderate-grayish-brown, clayey and sandy, calcareous and gypsiferous silt. It contains very sparse, small flakes of gray shale. Particle-size distribution was not measured. Samples submitted for measurement of age by the uranium-trend method contained insufficient amounts of isotopes to establish a trend (J.N. Rosholt, written commun., 1983).

Thin paleosols crop out at three localities on Dow Prong, but they were not analyzed for particle-size distribution or age.

Younger Alluvium

The younger alluvium, including sands, silts, clays, and gravels, comprises the sediments that are being moved or have recently been moved by streams. The thickest sections, estimated at 5 m, stand in banks near the creeks. The average thickness is probably much less than 5 m, because bedrock crops out many places in the creek bottoms, as in Clear Creek about 2 km upstream from Clearmont.

Composition of the younger alluvium varies greatly because of the multiple sources and constant reworking. The commonest source is older alluvium, but bedrock, pediment and terrace gravels, landslide debris, and colluvium are also sources. Some of the alluvium deposited by the Powder River is fine and medium sand in alternating tabular beds

Figure 10. Paleosol in older alluvium (Qoa), west bank, Coutant Creek. Locality of samples P8–P11 at right (downstream side of exposure). Estimated height of bank 6 m.

and crossbeds (fig. 17). Distribution of the younger alluvium reflects the meander and braid patterns of the creeks and rivers within the broader outcrops of older alluvium. Several adjacent creeks tributary to the Tongue River are now flowing on the southwest sides of their valleys—Prairie Dog Creek near Sheridan, Wildcat Creek, Coutant Creek, and Badger Creek. Uplift of the Badger Hills is a possible cause for these shifts in creek positions.

Age of the younger alluvium probably ranges over several thousand years. A few materials have been found that are useful in determining age; among them wood from the root of a cottonwood tree buried in growth position (fig. 18). The ^{14}C age of the wood is 890±100 yr (Meyer Rubin, written commun., 1984). The relatively young age of the cottonwood and enclosing alluvium contrasts with the older alluvium in the valleys of smaller creeks. One explanation for this is the larger, more constant flow of the Powder River in comparison with the mostly intermittent flow of smaller creeks. The Powder River has deposited much more alluvium in a shorter time than have the smaller creeks and has reworked it a great deal more. The radiometric ages of all the alluvial deposits, determined by three different methods, are compatible.

One unusual deposit associated with younger alluvial deposits is a yellow and black tufa in small springs and seeps in the valley of Clear Creek. At the bend in the highway 1.8 km west of Leiter are three small cold springs in the older alluvium. In and near the springs, moss grows in round clumps on tufa, a porous, crumbly calcium carbonate. The black material in the tufa is probably composed of manganese and iron compounds rather than organic matter, as prolonged heating of a sample in a bunsen burner did not decrease the weight or change the color. The source of the manganese and iron is unknown.

Age of the Alluvial Deposits

The uranium-trend method of measuring age is useful in dating deposits that range in age from 5 ka to 800 ka. Uranium-trend analysis is an open-system technique that consists of determining a linear trend from analyses of four to ten channel samples collected at different depths in a given depositional unit or the soil horizons formed in the depositional unit. The concentrations of ^{238}U, ^{234}U, ^{230}Th, and ^{232}Th are accurately determined for each sample. Analyses are made on subsamples of the less-than-2-mm-size fraction. Isotopic concentrations are determined by alpha spectrometry utilizing radioisotope dilution techniques. The results of these analyses are plotted as ratios of $(^{238}U-^{230}Th)/^{238}U$ versus $(^{234}U-^{238}U)/^{238}U$. Ideally, these data points yield a linear array in which the slope of the line of best fit changes predictably for increasingly older deposits. The rate of change of slope is determined by the half-period of uranium flux, F(O). An empirical model compensates for differing values of F(O) in response to climate and other local and regional environmental factors. Analyses of deposits of known ages are required to calibrate the empirical model;

Table 4. Organic material, calcium carbonate, and ages of six paleosols

[Samples numbered in stratigraphic order at each locality]

Locality	Channel sample No.	Thickness (cm)	Weight percent organic material[1]	[2]Weight percent $CaCO_3$	Age (ka)
1. Arkansas Creek	7 (top)	30	1.35	1.06	
	6	20	.81	9.14	30±30
	5	11	.72	17.92	
2. Arkansas Creek	4	23	.55	4.81	
	3	20	.93	10.15	47±12
	2	15	.69	5.85	
	1 (bottom)	25	([3])	6.85	
3. Piney Creek	19	16	1.11	2.33	
	18	15	1.23	.79	90±45
	17	13	.98	.66	
	16	10	.83	.80	
4. Coutant Creek	11	40	1.68	1.68	
	10	40	1.08	2.10	100±60
	9	28	.95	12.01	
	8	20	1.77	7.61	
5. Clear Creek	15	19	1.57	1.53	
	14	25	2.47	1.61	([4])
	13	25	2.17	1.73	
	12	30	.88	3.72	
6. Powder River	22	17	([3])	1.31	
	21	12	([3])	.22	([5])
	20	15	([3])	5.17	

[1]Percent organic material through Walkey–Black $K_2Cr_2O_7$ titration.
[2]Percent $CaCO_3$ by Chittick determination.
[3]Not analyzed.
[4]Not measured.
[5]Insufficient isotopes.

calibrations were provided by correlations with deposits dated by the radiocarbon and K-Ar methods * * *. The estimated potential least accuracy is about 10 percent for deposits older than 100,000 years. Percentage errors in the ages are not symmetric throughout the range; they are greater both for young (60,000 years) and old (600,000 years) deposits (Rosholt and others, 1985, p. 1).

The uranium-trend ages of the paleosols do not appear precise because of the large positive and negative numbers. However, they do correlate with stratigraphic position and relative size of the valleys in which they were found. Valleys of the major rivers, Tongue and Powder, are considered first-order valleys. Tributaries to the major rivers flow in second-order valleys, and so forth. The two superposed paleosols on Arkansas Creek that have uranium-trend ages of 30±30 ka and 47±12 ka, respectively, are in a fourth-order valley. The slightly older paleosol on Coutant Creek (100±60 ka) has an age consistent with ages of paleosols on Arkansas Creek in view of the fact that Coutant Creek flows in a third-order valley. The Piney Creek paleosol, age 90±45 ka, developed in a third-order valley. Correlations of ages of the paleosols with other features such as height above drainage are not evident. The uranium-trend ages of the paleosols are consistent with the uranium/thorium ages of the terrace gravels, 124±11 ka and about 160 ka, which correlate with height above drainage.

The older alluvium (Qoa) is equivalent to the Pleistocene Arvada and Ucross Formations, and to the Holocene Kaycee Formation of Leopold and Miller (1954). Early in this investigation, attempts were made to map subdivisions of the older alluvium, but identification and correlation difficulties from the Tongue River drainage to the Powder River drainage made such mapping impractical. Problems of rock-stratigraphic terminology as applied to Holocene terrace deposits in the Powder River Basin were outlined by D.S. Fullerton (written commun., 1977). He believed the stratigraphy and morphology to be more complicated than as visualized by Leopold and Miller.

Colluvium

Colluvium is the material that results from mass wasting, slope wash, ravelling, and talus accumulation. It

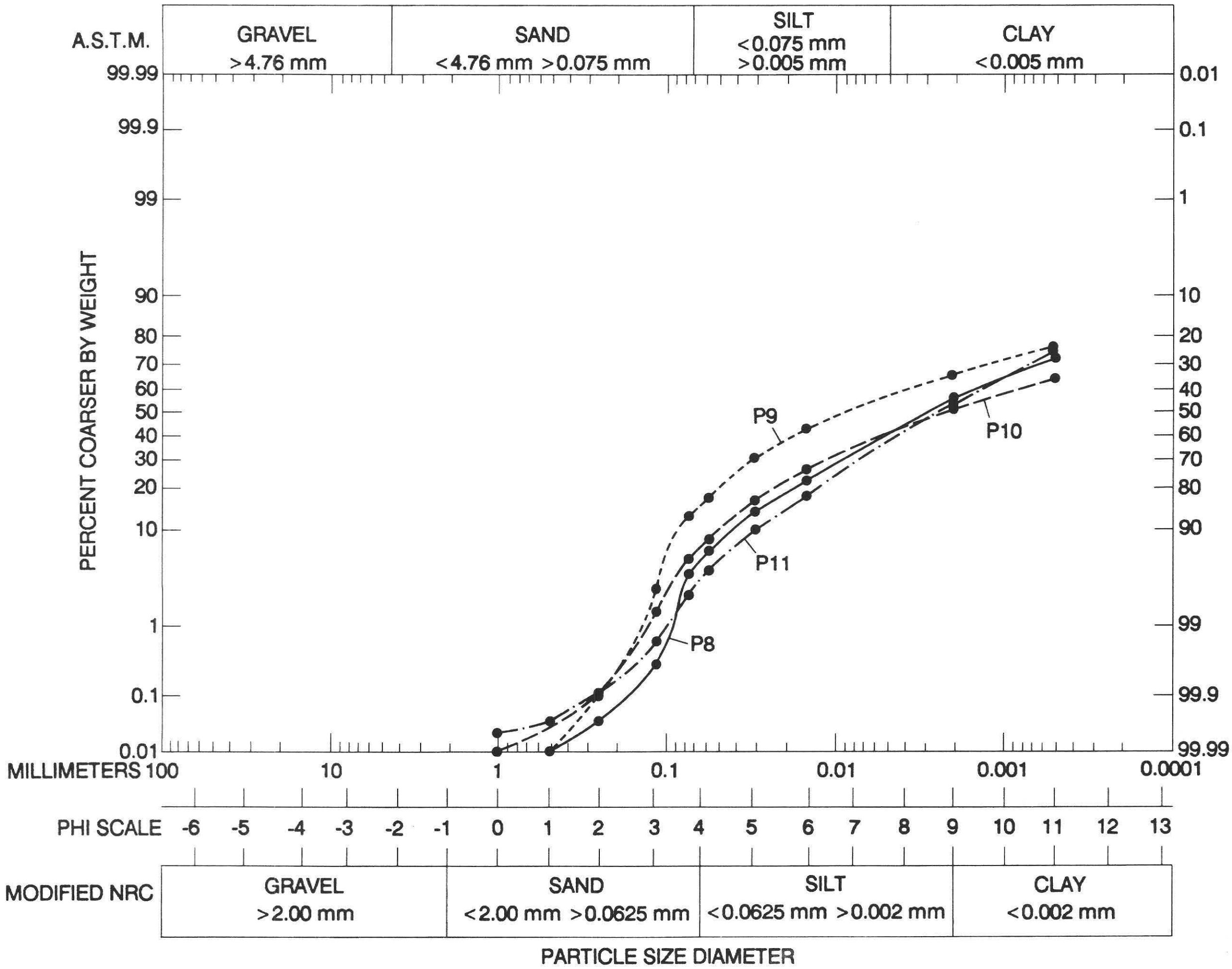

Figure 11. Particle-size distribution curves of paleosol, Coutant Creek. Samples P8–P11. D.M. Cheney, analyst.

lies on gentle to moderate slopes that have weathered from nonresistant rocks of Tertiary age. Most of it is sand, silt, clay, and gravel, but some consists of fragments of older, more indurated rocks. The estimated maximum thickness of the colluvium is 3 m. Many of the upland grain fields and pastures away from creeks are underlain by colluvium, especially in the area east of Sheridan.

Residuum

Residuum is the fine sediment, mostly silt, clay, and fine sand, that accumulated in high closed basins or on isolated flats. It is the product of weathering in place of nonresistant rocks involving little or no movement by water but probably involving movement by wind. Undoubtedly, some soils have developed on residuum, but they are probably thin and immature, chiefly because of lack of water. The estimated maximum thickness of residuum is 3 m.

Landslide Debris

Included in the term landslide debris are a wide variety of surficial materials and rocks that have moved downslope en masse. Most of the debris is in the form of slumps, translational slides, liquefaction slides, and mudflows, but there are also rockfalls and block glides. Only avalanches and debris flows are missing from all the materials in an inclusive definition of landslides (Varnes, 1978).

The largest and probably one of the oldest and most stable landslides covers a north-facing hillside on JA Creek in the southwestern part of the quadrangle. The surface of the slide is hummocky and dotted with boulders and cobbles of granite. Rainwater collects in a few small sag puddles. Exposures in gullies show much gravel of sedimentary rocks derived from adjacent outcrops of the Moncrief and Kingsbury Members of the Wasatch Formation. This slide is relatively stable, probably because it is composed of coarse material and because it does not remain wet for prolonged periods of time.

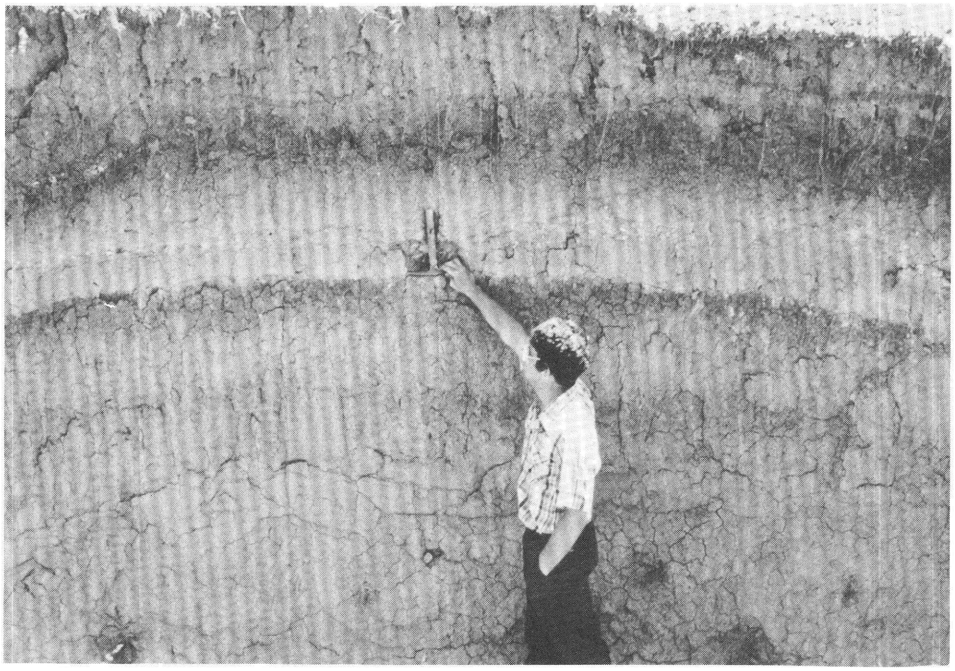

Figure 12. Two paleosols exposed in a bank of older alluvium (Qoa), Middle Fork, Arkansas Creek. Locality of samples P1–P7. David W. Rodgers holds hammer at sharp upper contact of lower paleosol, the bottom of sample P3. Note pebble line between paleosols, and faint indication of a third paleosol below the others (about shoulder level).

Debris in the vast majority of landslides consists of partly disaggregated fine-grained clastic rocks that are continually wetted by ground water and (or) leaking irrigation ditches. Landslides in the Sheridan–Big Horn area pose hazards to roads, buildings, underground utility lines, and livestock. Many of the slides have been inventoried (Chleborad and others, 1976) and mapped (Hinrichs, 1983a and 1983b; Ebaugh, 1976). Several of the slides can be seen from the highways; for instance, the slide under U.S. 87 near Massacre Hill, south of the town of Banner. This slide is moving and fracturing the blacktop at a rate that requires road repairs every year or two. An unlined irrigation ditch runs across the top of the slide.

Many slumps and earthflows are visible from I-90. The most graphic of these are on the west side of the Interstate north of Meade Creek (fig. 19). Farther north along I-90 near the western edge of the quadrangle, a slump in the east embankment reveals fill of coal mine spoil and shale (fig. 20).

A landslide on the Springer Ranch has been investigated in detail through engineering geologic methods (Chleborad, 1980) and by seismic methods (Miller and others, 1980). This slide is on the southeast side of a hill between I-90 and U.S. 87, north of State road 342.

Ages of the landslides vary widely. Determining the ages of the oldest movements is difficult. The few slides in Precambrian rocks are on steep sides of valleys probably cut during the Pleistocene. The youngest slides are mostly along perennial streams where the moving water is wearing away the toe; for instance, on the west bank of the Powder River 13 km north of U.S. 14 and U.S. 16.

GEOLOGIC HISTORY OF THE SURFICIAL DEPOSITS

Pliocene Epoch

Renewed uplift of the Bighorn Mountains in relation to the Powder River Basin created conditions favorable for the deposition of pediment gravels, notably the increased gradient of streams, exposure of source rocks, and increased streamflow from meltwater. After the gravel caps had been deposited on the beveled bedrock surfaces along the mountain front, erosion removed much of the surficial material. The pediments, protected by the gravel caps, withstood the erosion and were left at elevations above the eroded bedrock and the younger deposits.

Volcanoes in the area now known as Yellowstone Park erupted voluminous ash into the atmosphere that drifted southeastward downwind toward the high plains. Fallout from these ash clouds was deposited over a large part of central and eastern Wyoming and adjacent States

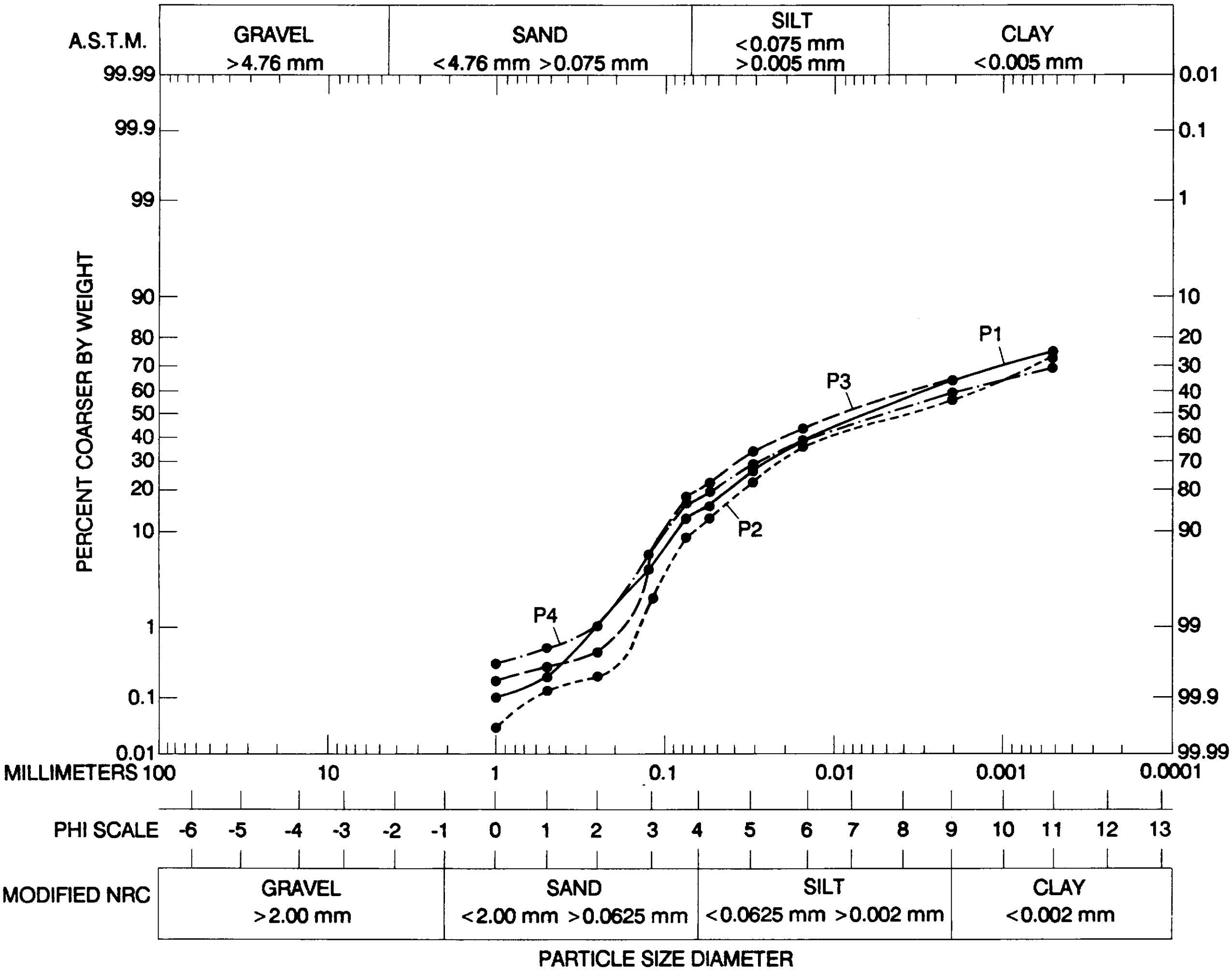

Figure 13. Particle-size distribution of older paleosol, Arkansas Creek. Samples P1–P4. D.M. Cheney, analyst.

(Izett and Wilcox, 1982). Although outcrops of volcanic ash have been found on the west flank of the Bighorn Mountains and on the north, east, and south sides of the Powder River Basin, none have been identified in the basin itself. The pale-gray ash is easily masked by caliche and gypsum.

Pleistocene Epoch

The sedimentation prevalent during the Pliocene continued at a reduced rate into the Pleistocene. Mountain streams deposited terrace gravels beginning in the Illinoian age and extending into the Sangamon (restricted) age of D.S. Fullerton (fig. 21). By this time, a drainage pattern had begun to form that has persisted to the present day. Remnants of terrace gravels lie mostly on bedrock at the edges of the valleys, especially on the western and northern edges of Piney and Prairie Dog Creeks. As erosion uncovered successively deeper beds in the Wasatch Formation, coal was exposed and burned to form clinker, some of which was incorporated into terrace deposits and alluvium.

During the Eo-Wisconsin age, most of the moisture on the basin fell in the form of summer rains that facilitated the development of alluvium and soils. The thickest alluvium formed in the valleys tributary to the Tongue River, mainly in those valleys cut into the fine-grained facies of the Wasatch Formation. The alluvium supported grasses on which abundant hoofed animals fed: many bones of ungulates have been found in older alluvium throughout the quadrangle. By the beginning of the Wisconsin age, the snowpack in the Bighorn Mountains increased enough to form glaciers. Although no glacial deposits are in the Sheridan 30′ × 60′ quadrangle, two sets of moraines have been identified in the valleys of Goose and South Piney Creeks, not far to the west (Salisbury and Blackwelder, 1903). The sand and gravel in these glacial deposits have been the source of sediments in many of the younger surficial deposits.

Holocene Epoch

During the Holocene age, downcutting has apparently been dominant. Creeks and rivers cut gullies and arroyos

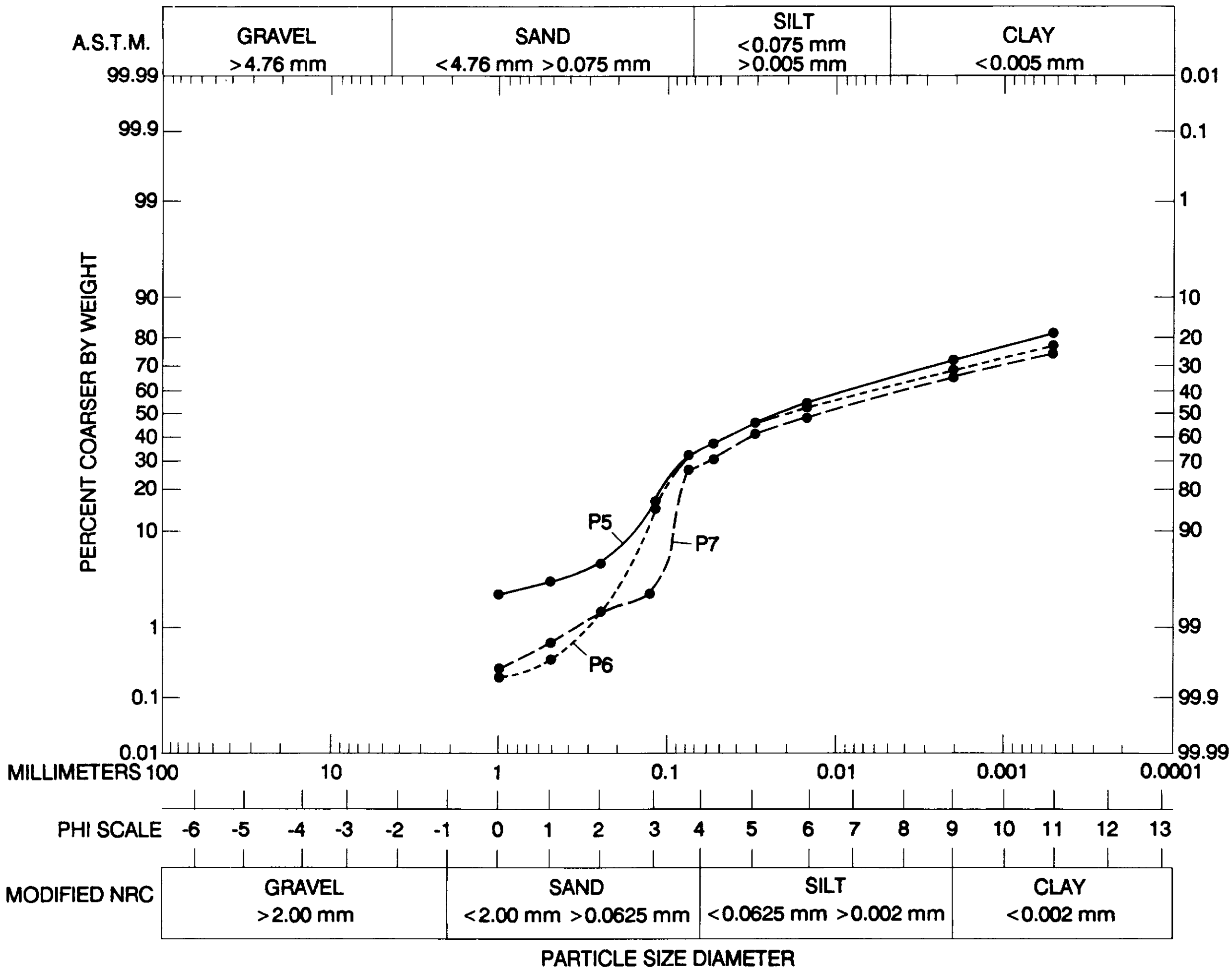

Figure 14. Particle-size distribution of younger paleosol, Arkansas Creek. Samples P5–P7. D.M. Cheney, analyst.

into the older alluvium, supplying sediment for the younger alluvium. The causes of the arroyo cutting are probably climatic. The climate likely became warmer and drier, causing reduced but more variable precipitation. A change in stream base level through basin rebound might also be involved. Evidence for rebound can be seen in the expansion of deeply buried shales in drill cores that have been brought to the surface. Laboratory tests confirm the visual evidence that the shales are overconsolidated or, in other words, that the shales were compressed by a much thicker section of rock than now overlies them.

Since man has lived in the region of the quadrangle, noticeable changes in landscape have occurred, most of them brought about by coal mining and agriculture. Coal was mined first by deep mining methods and later by open-pit methods. Methane was encountered in the deep coal mines, creating hazards from explosion and fire. Fires in the abandoned mines have not only caused air and water pollution, but also have aggravated subsidence into old mine workings (Dunrud and Osterwald, 1980). The newer open-pit methods of coal mining reduce fire hazards. However, sites of open-pit mines, if not properly reclaimed, cannot support grazing for many years. On the other hand, poor grazing land in the eastern part of the quadrangle that is underlain by thick beds of coal at shallow depths could be improved by prudent reclamation after removal of the coal.

Irrigation by ditches from the mountain streams has greatly increased the production of hay and grains. Most of the ditches are unlined, and consequently they leak. Such leakage poses no problems except in landslide areas, particularly where roads and houses are being built, as in parts of the city of Sheridan (Hinrichs, 1983b). An increasing amount of irrigation by rotating sprinklers is fed from pumped wells. Many of the valleys far from irrigation ditches contain fertile alluvium that needs only water to become suitable for grazing or growing grain.

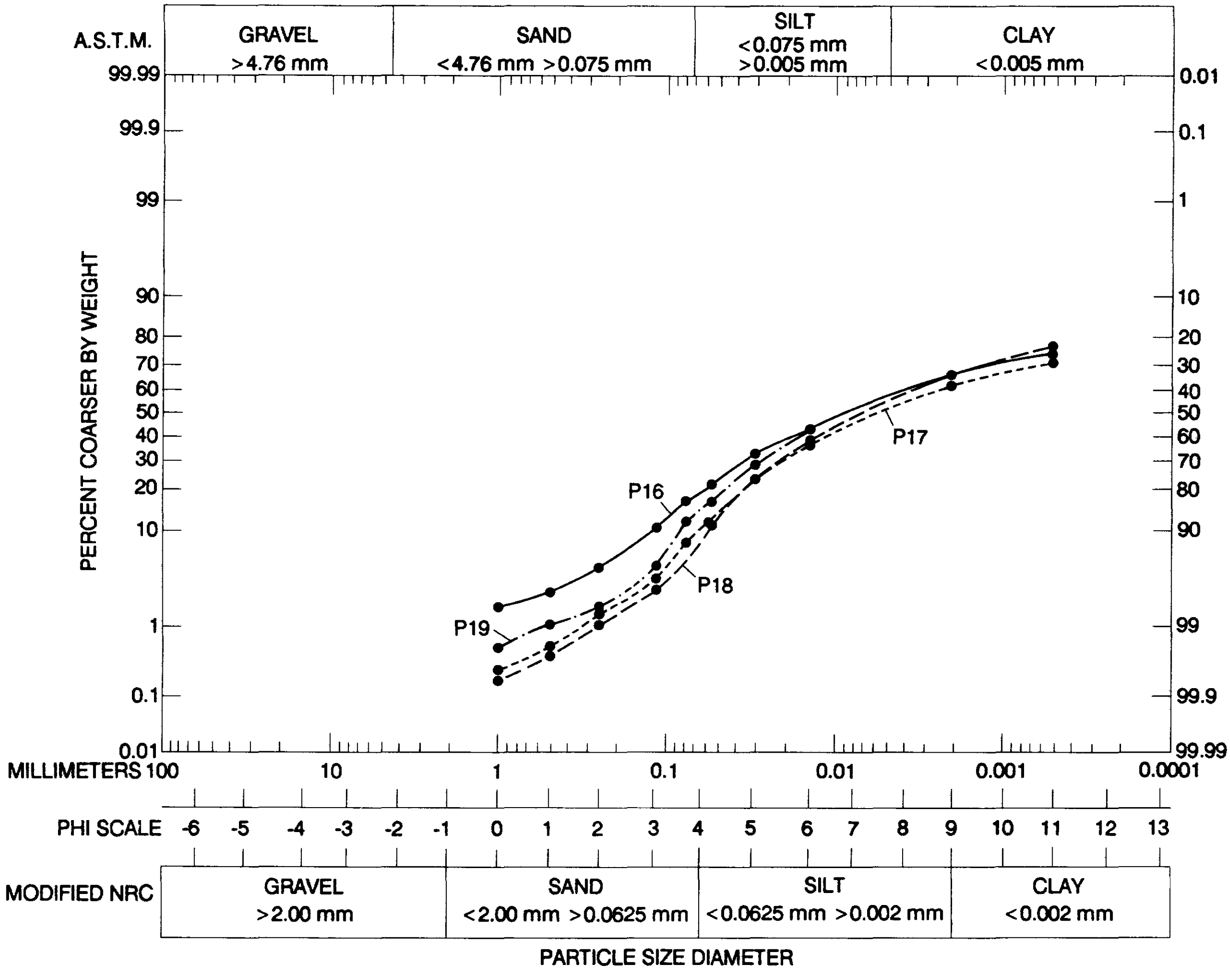

Figure 15. Particle-size distribution of paleosol, Piney Creek. Samples P16–P19. D.M. Cheney, analyst.

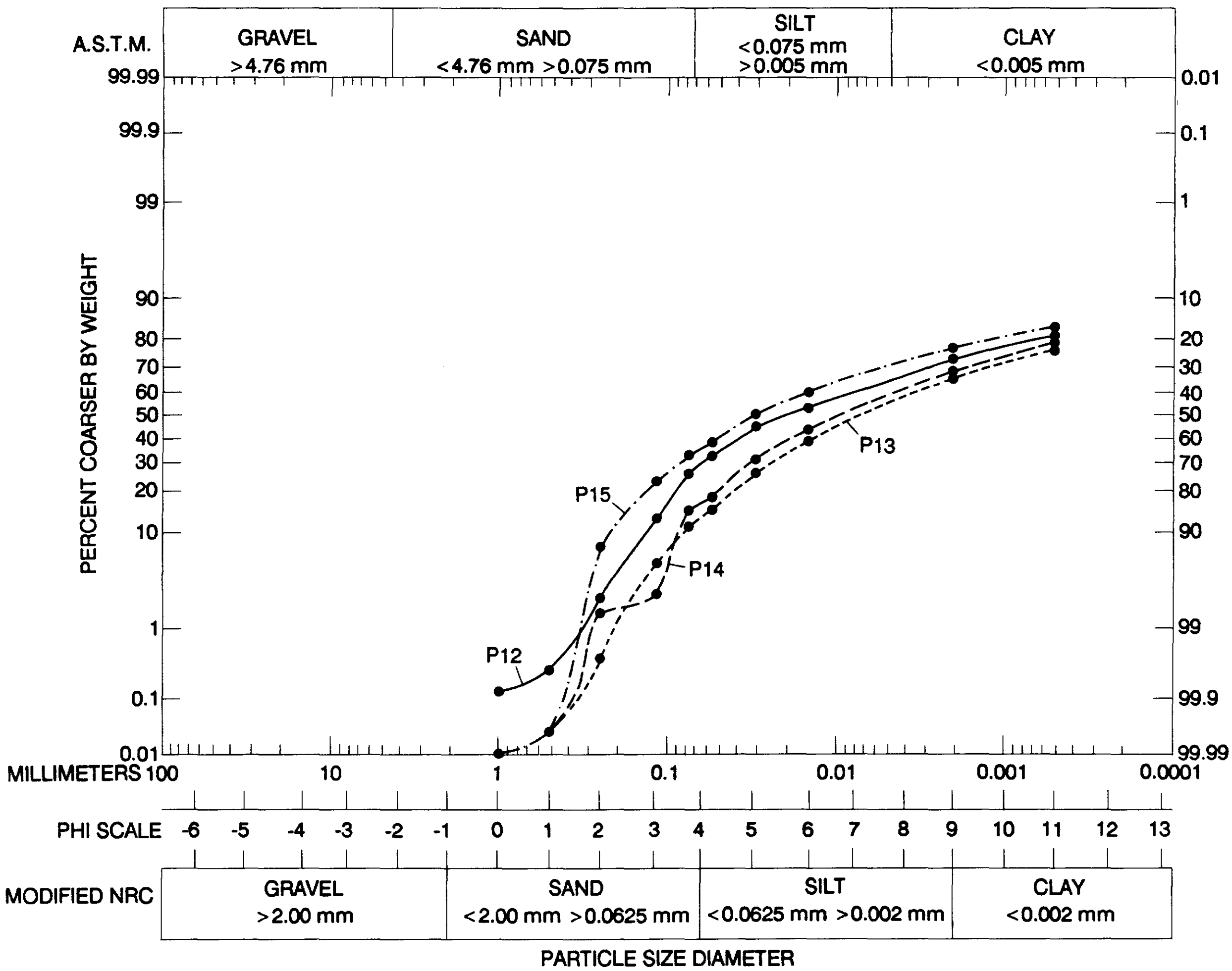

Figure 16. Particle-size distribution of paleosol, Clear Creek. Samples P12–P15. D.M. Cheney, analyst.

Figure 17. Planar and cross-stratified younger alluvium, east bank of Powder River near confluence with Spotted Horse Creek. Dark layer contains abundant granules of coal. Pen 16 cm long.

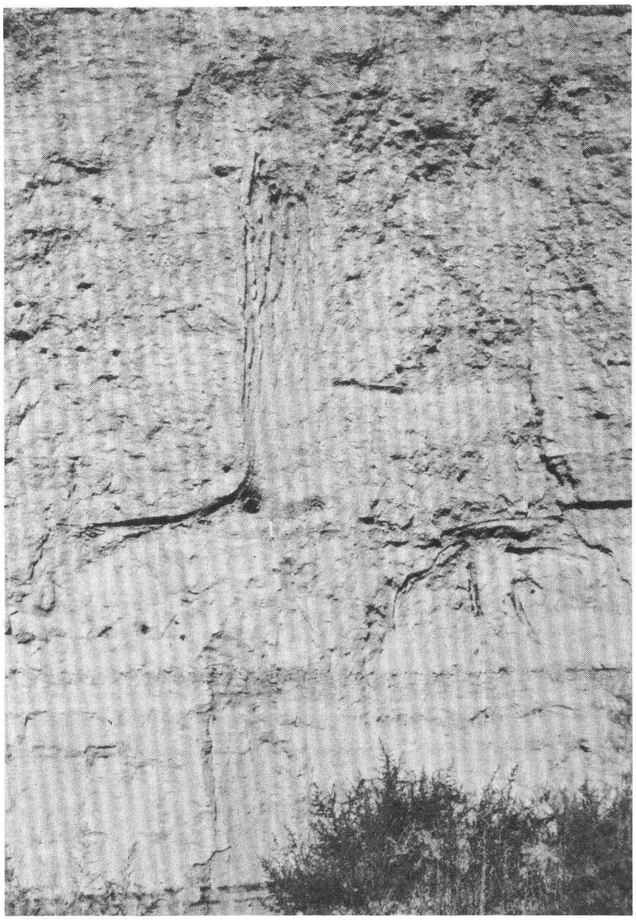

Figure 18. Cast of cottonwood tree buried in growth position in younger alluvium, east bank of Powder River. Sample W-5312 taken from roots at right. Pen at base of trunk is 16 cm long.

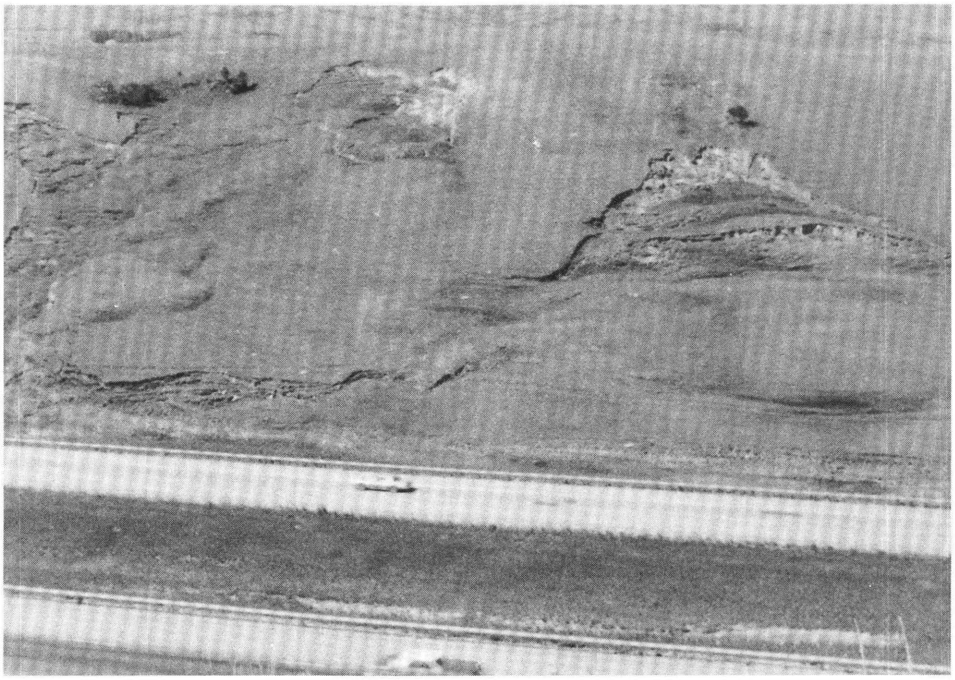

Figure 19. Earthflows in a sheep pasture, west side of I-90, north of Meade Creek.

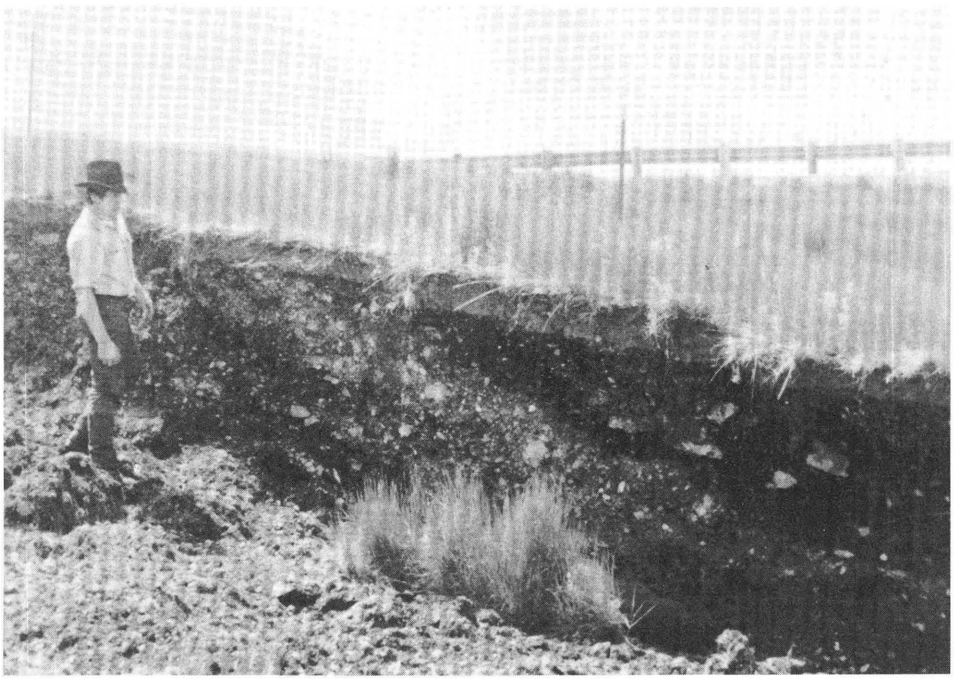

Figure 20. Slumped road embankment, east side of I–90. Coal mine spoil and shale are exposed in scarp.

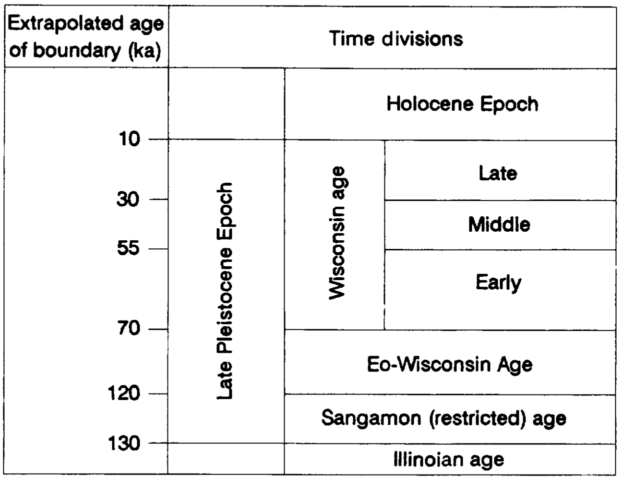

Figure 21. Time divisions of the late Pleistocene. From D.S. Fullerton (written commun., 1982).

REFERENCES CITED

Chleborad, A.F., 1980, Investigation of a natural slope failure in weathered Tertiary deposits, western Powder River Basin, Wyoming: U.S. Geological Survey Open-File Report 80–673, 66 p.

Chleborad, A.F., Nichols, T.C., Jr., and Ebaugh, W.F., 1976, A preliminary inventory, description, and statistical evaluation of landslides in a region of projected urban development, Sheridan, Wyoming: U.S. Geological Survey Open-File Report 76–571, 105 p.

Dunrud, C.R., and Osterwald, F.W., 1980, Effects of coal mine subsidence in the Sheridan, Wyoming, area: U.S. Geological Survey Professional Paper 1164, 49 p.

Ebaugh, W.F., 1976, Preliminary surficial and bedrock geologic map of the Big Horn quadrangle, Sheridan County, Wyoming: U.S. Geological Survey Miscellaneous Field Studies map MF–801, scale 1:24,000.

Hinrichs, E.N., 1979, Preliminary geologic map of the Beaver Creek Hills quadrangle, Sheridan County, Wyoming: U.S. Geological Survey Miscellaneous Field Studies Map MF–1084, scale 1:24,000.

______ 1983a, Preliminary geologic map of the Story quadrangle, Sheridan and Johnson Counties, Wyoming: U.S. Geological Survey Miscellaneous Field Studies Map MF–1512, scale 1:24,000.

______ 1983b, Engineering geologic map of the Sheridan 7 ½ ′ quadrangle, Sheridan County, Wyoming: U.S. Geological Survey Miscellaneous Investigations Series Map I–1449, scale 1:24,000.

______ 1984, Surficial geologic map of the Sheridan 30′×60′ quadrangle, Wyoming and Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF–1693, scale 1:100,000.

Izett, G.A., and Wilcox, R.E., 1982, Map showing localities and inferred distributions of the Huckleberry Ridge, Mesa Falls, and Lava Creek ash beds (Pearlette family ash beds) of Pliocene and Pleistocene age in the western United States and southern Canada: U.S. Geological Survey Miscellaneous Investigations Series Map I–1325, scales 1:4,000,000 and 1:16,000,000.

Kuzara, S.A., 1977, Black diamonds of Sheridan: Cheyenne, Wyo., Pioneer Printing and Stationery Co., 227 p.

Law, B.E., and Barnum, B.E., 1979, Wrench faulting and hydrocarbon occurrences in the northwestern Powder River Basin, Montana and Wyoming [abs.]: American Association of Petroleum Geologists Bulletin, v. 63, no. 5, p. 833–834.

Lee, F.T., Smith, W.K., and Savage, W.Z., 1976, Stability of highwalls in surface coal mines, western Powder River Basin, Wyoming and Montana: U.S. Geological Survey Open-File Report 76-846, 52 p.

Leopold, L.B., and Miller, J.P., 1954, A postglacial chronology of some alluvial valleys in Wyoming: U.S. Geological Survey Water Supply Paper 1261, 90 p.

Lowry, M.E., and Cummings, R.T., 1966, Ground-water resources of Sheridan County, Wyoming: U.S. Geological Survey Water Supply paper 1807, 77 p.

Mapel, W.J., 1959 (1961), Geology and coal resources of the Buffalo–Lake DeSmet area, Johnson and Sheridan Counties, Wyoming: U.S. Geological Survey Bulletin 1078, 148 p.

Miller, C.H., Ramirez, A.L., and Bullard, R.F., 1980, Seismic properties investigation of the Springer Ranch landslide, Powder River Basin, Wyoming: U.S. Geological Survey Professional Paper 1170–C, 7 p.

Molnia, C.L., and Orrell, S.A., 1988, Map showing principal coal beds and bedrock geology of the Buffalo Creek–Clear Creek area, central Powder River Basin, Wyoming and Montana: U.S. Geological Survey Coal Investigations Map C–114, scale 1:50,000.

Rosholt, J.N., Bush, C.A., Shroba, R.R., Pierce, K.L., and Richmond, G.M., 1985, Uranium trend dating and calibrations for Quaternary sediments: U.S. Geological Survey Open-File Report 85–299, 48 p.

Salisbury, R.D., and Blackwelder, Elliott, 1903, Glaciation in the Bighorn Mountains: Journal of Geology, v. 11, p. 216–223.

Surface Mining Control and Reclamation Act, 1977, 30 U.S. Code 1201.

Szabo, B.J., Carr, W.J., and Gottschall, W.C., 1981, Uranium-thorium dating of Quaternary carbonate accumulations in the Nevada Test Site region, southern Nevada: U.S. Geological Survey Open-File Report 81–119, 35 p.

Toy, T.J., and Munson, B.E., 1978, Climate appraisal maps of the rehabilitation potential of strippable coal lands in the Powder River Basin, Wyoming and Montana: U.S. Geological Survey Miscellaneous Field Studies Map MF–932, scale 1:1,000,000.

Varnes, D.J., 1978, Slope movement and types and processes, *in* Landslides—Analysis and control: Transportation Research Board, National Academy of Sciences Special Report 176, p. 11–33.

Williams, V.S., 1984, Pedimentation versus debris-flow origin of plateau-side desert terraces in southern Utah: Journal of Geology, v. 92, p. 457–468.

★ U.S. GPO: 1989 673-047/86031