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Characteristics, Age Relationships, and Regional Importance of Some Cenozoic Paleovalleys, Southern Nebraska Panhandle

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Few workers have reported previously on features of ancient valleys in western Nebraska. Six sites in the southern Nebraska Panhandle, ranging in age from Oligocene to Middle to Late Pleistocene, illustrate the characteristics and variability of Cenozoic paleovalleys. The dimensions of these paleovalleys vary from less than 0.1 km to more than 1.0 km in width and from less than 1.0 km to more than 100 km in length. Relief is as much as 35 m in outcrop. Four of the examples have valley sides that are nearly vertical. Potholes and other scour features occur at one site. Remnants of tributaries are present at a second site. A third locality has bedrock-incised channels that are similar to features produced experimentally in flumes.

The fills in these paleovalleys include colluviumlike sediments along valley sides and flood plain and channel silts, sands, and gravels derived from local and distant sources. Locally derived boulders more than 1 m in diameter occur in fills close to the sides of some of these valleys.

† † †

INTRODUCTION

Shepherd and Schumm (1974:257) and Schumm (1977: 180-182) pointed out that little is known about bedrock surfaces of valley floors because alluvium usually covers the erosional surfaces of both Recent and ancient bedrock valley floors. Geologists often have to infer the nature of these surfaces and the processes that produced them from studies of the development of model channel and valley forms combined with information from studies at dam sites and other localities where valley fills have been removed so that the surface configuration of bedrock can be studied. These facts certainly seem true when the descriptions of Cenozoic paleovalleys in western Nebraska are examined. Various types of reconstructions have been attempted for Quaternary, Miocene, and Oligocene drainages in parts of the southern Nebraska Panhandle by Lugn and Lugn (1956); Aadland (1959); Vondra (1963); Vondra, Schultz, and Stout (1969); Smith (1969); DeGraw (1971); Smith and Souders (1971, 1975); Stanley and Wayne (1972); Bart (1974); Blodgett (1974); Breyer (1974, 1975); Stanley (1976); Swinehart (1979); Swisher (1982); and Diffendal (1982), but only a few of these works include details on either the bedrock cross sections of paleovalleys or the nature of alluvium deposited close to the bedrock surface. In other parts of Nebraska, however, Galusha (1975), Skinner et al. (1977), and Yatkola (1978) included such details in their work.

Further impetus for study of Cenozoic paleovalleys in the region came from the University of Nebraska State Museum explorations of western Nebraska from the 1930s to the present. The purposes of this paper are to report the nature of cross sections of the floors and sides of some Cenozoic paleovalleys in the southern Nebraska Panhandle for the first time and to describe briefly the deposits that accumulated in these paleovalleys. A general geologic chronology for each site will be presented as well.

THE PRESENT VALLEY SYSTEMS

The major streams in the southern Nebraska Panhandle are the North Platte River, its principal tributary in the area, Pumpkin Creek, and Lodgepole Creek, a tributary of the South Platte River (Fig. 1). Of these, only the North Platte River is perennial along its entire length in the study area. Heavy thunderstorms, rapid snow melt, and/or releases from reservoirs produce local high discharges and flooding.

In Nebraska, these streams and tributaries drain an area underlain primarily by sediments ranging from Oligocene through Quaternary age. Pliocene and Quaternary deposits include windblown loess and sand; alluvial silts, sands, and gravels; colluvium; lacustrine diatomaceous and calcareous silts; and volcanic ash. The Ogallala Group (Miocene) includes indurated equivalents of all of the types of materials found in the Quaternary. The Arikaree Group (Miocene/Oligocene) consists primarily of eolian and fluvial volcaniclastic fine-grained sandstones and siltstones (Stanley, 1976). Exposures of the White River Group (Oligocene) are principally of eolian

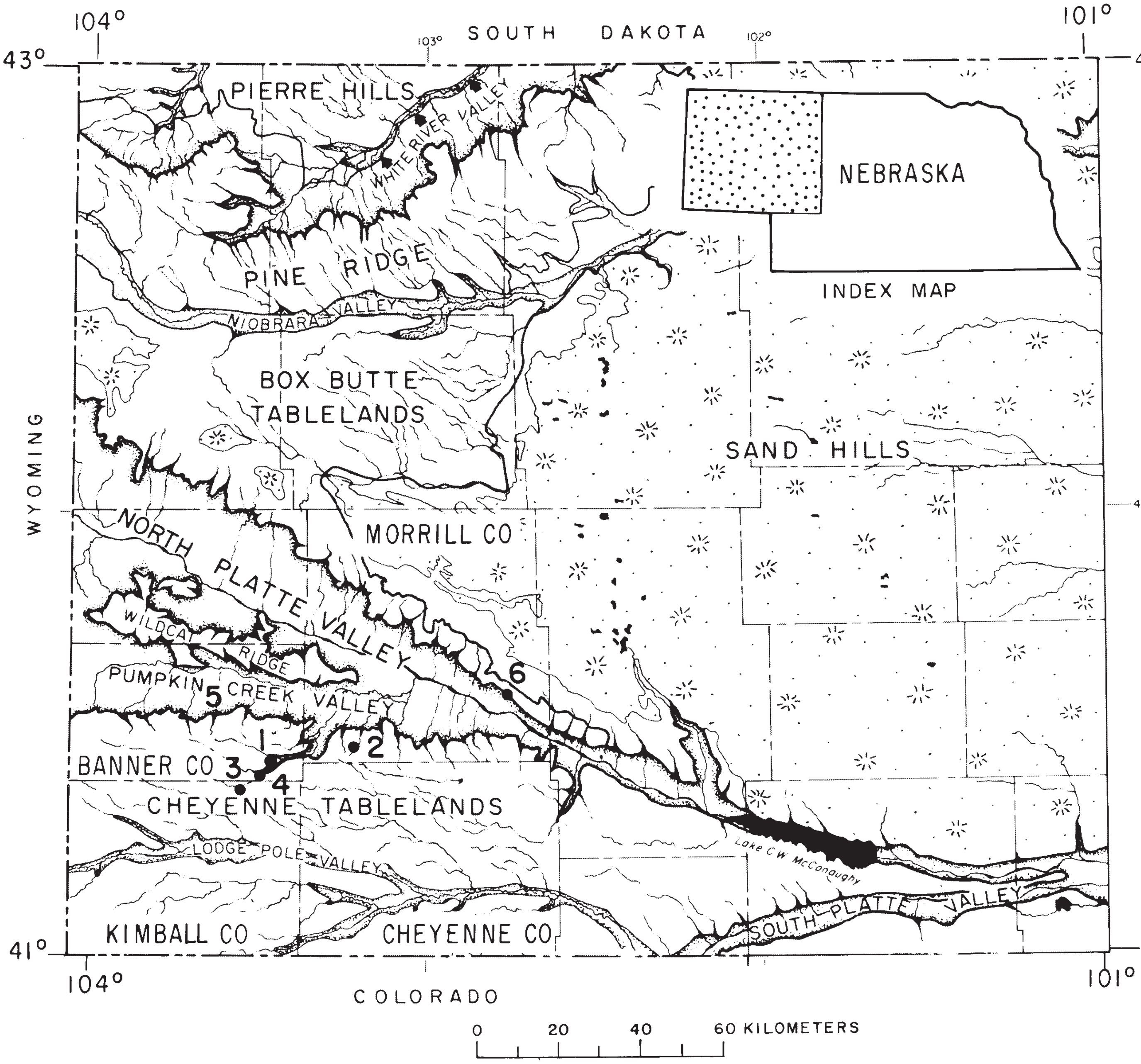

FIGURE 1. Study area, study sites, and principal geographic features. [Base *after* DeGraw (1971).]

volcaniclastic siltstones belonging to the Brule Formation. As a general rule, Quaternary through Ogallala rocks are coarser grained than are Arikaree and White River rocks.

The present valleys which are cut into these rock units vary in shape depending on the nature and amount of induration of the materials eroded, the nature of the eroding stream, the original and present slopes of the land surface, and the amount of vegetative cover [all variables touched upon by Schumm (1977, 1981)]. Valley sides are generally less steeply sloping when developed on Quaternary (excluding loess) and Ogallala deposits than when they are eroded from the Arikaree or White River groups. The Brule Formation of the White River Group is indurated enough to maintain local side slopes steepened beyond vertical at some sites (Fig. 2). Along its length, a tributary valley may be broad with moderately sloping sides where it heads in older Quaternary deposits, may narrow and have more steeply sloping sides where it is carved into the underlying Arikaree and/or White River beds, and may once again broaden and have gentle slopes where it crosses younger Quaternary alluvium and eolian deposits near its junction with a major trunk stream such as the North Platte River. Recent gully floors formed on the Brule Formation contain scour holes and potholes (e.g., Devil's Washbasin southwest of Oshkosh, Nebraska).

Valleys vary in size and gradient from small, high gradient tributary gullies to large, broad, low gradient river valleys. For example, an unnamed tributary of Pumpkin Creek in Banner County has a width of about 0.1 km, a depth of about 30 m, and a gradient of as much as 100 m/km. The North Platte Valley west of Bridgeport, Nebraska, is about 25 km wide, at least 0.16 km deep, and has a gradient of about 1 m/km.

FIGURE 2. Recent branching gully cut into Brule Formation siltstones, Garden County, Nebraska.

ANCIENT VALLEYS AND GULLIES

Given the variety of present valley morphologies, can similar complexity be documented for ancient systems in the southern Nebraska Panhandle? Swinehart (1979), Diffendal (1982), and others presented evidence supporting the concepts of deep cutting of stream valleys and multiple valley cutting and filling during the Late Cenozoic. But what were the valleys like, and what was the nature of the sediments that filled them? Six sites (Fig. 1; Table I) provide some answers to these questions.

TABLE I. Location of study sites.

Site Number	Survey Location	Nebraska County
1.	NE¼ SE¼ SW¼ Sec. 16, T. 17 N., R. 53 W.	Banner
2.	SE¼ NE¼ Sec. 36, T. 18 N., R. 52 W.	Morrill
3.	SE¼ NE¼ Sec. 5, T. 16 N., R. 54 W.	Kimball
4.	NE¼ NW¼ Sec. 36, T. 17 N., R. 54 W.	Banner
5.	T. 18 N., R. 55 W.; T. 18 N., R. 56 W.; T. 19 N., R. 55 W.; T. 19 N., R. 56 W.	Banner
6.	Sections 33 and 34, T. 19 N., R. 47 W.	Morrill

Site 1

Diffendal (1982) noted that gully development along paleovalley sides occurs in the Cenozoic geologic sequences of western Nebraska. At site 1, for example, a steep-sided gully was cut into the Brule Formation and later was filled with a complex sequence of sediments belonging to the Gering Formation of the Arikaree Group (Fig. 3). The gully is about 25 m wide at its top and more than 10 m deep. Sediments filling the gully include deposits resembling the jumbled blocks subfacies of Vicars and Breyer (1981), interbedded with horizontal to steeply inclined wedge-shaped masses of locally derived gravels, and cross stratified channel sands (Fig. 4). During aggradation of this paleogully, individual channels ranged in width from a maximum of about 10 m to as little as 2 m.

Site 2

At this site, a steep-sided tributary gully at least 3 m deep and more than 10 m wide was carved into the Brule Formation and was later filled with sediments belonging to the Ogallala Group (Fig. 5). The oldest Ogallala deposit in the fill is a massive, wedge-shaped mass of probable colluvium with individual clasts ranging in size from silt to gravel. The "colluvium" is covered by a younger mass of volcanic ash that fills the rest of the gully. A younger Ogallala channel, filled with sand and gravel, cuts across the older gully fill.

FIGURE 3. Twenty-five-meter-wide gully carved into Brule Formation (Tob) and filled with sediments of the Gering Formation (Tmg). Arrow points to area of close-up shown in Figure 4. Brule-Gering contact on left is true. Contact on right is apparent, true slope is nearly vertical.

FIGURE 4. Close-up of a portion of Figure 3 showing steeply sloping, wedge-shaped mass of gravel, and fossil turtle shell (t) in Gering Formation.

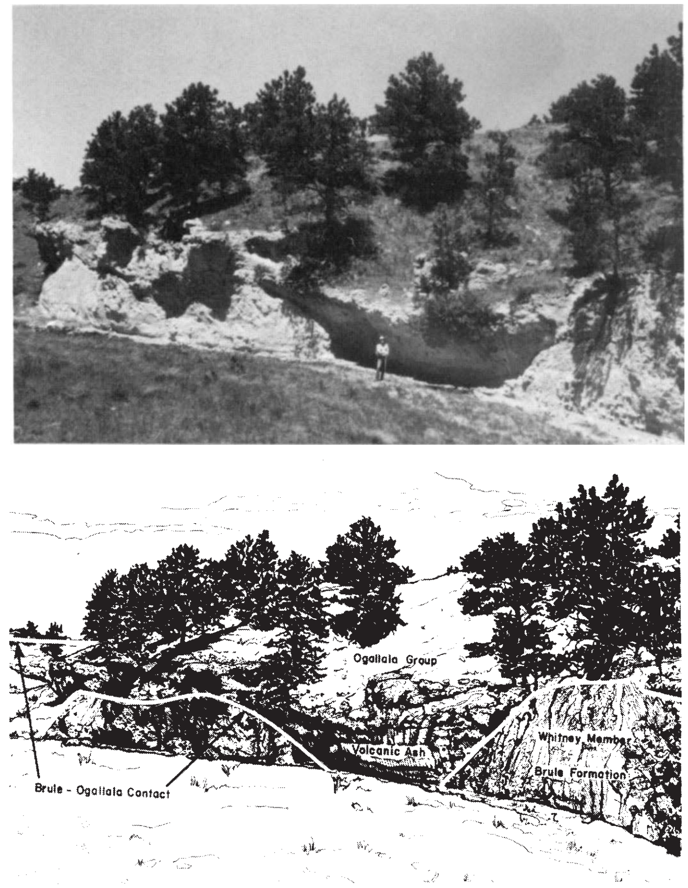

FIGURE 5. Photograph and sketch of gully cut into Brule Formation and filled with sediments of the Ogallala Group. Man is 1.83 m tall.

Site 3

At many localities in the southern Nebraska Panhandle, partially exhumed remnants of paleovalleys are filled with coarse-grained sediments of the Ogallala Group, or younger Pliocene or Quaternary. The bulk of these sediments was derived by stream erosion from older igneous and metamorphic rocks cropping out in the Rocky Mountains in southern Wyoming and northern Colorado. The largest clasts in the gravels, however, are locally derived boulders and blocks more than 1 m in diameter (Fig. 6). These boulders were obviously transported some distance from their points of origin, but how far have they traveled?

Site 3 is one of the few localities found where an answer to this question probably can be given. At this site, a valley side of a younger Ogallala paleovalley (Miocene) carved into older Ogallala and Arikaree beds is partially exposed by recent erosion. Older Ogallala sandstone beds (Miocene) end at the paleovalley side, and coarse sands and gravels, cemented to

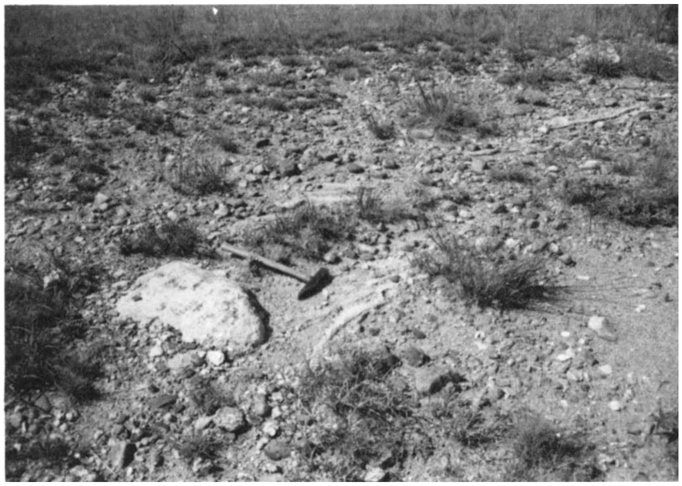

FIGURE 6. White boulder of older Ogallala Group sandstone in a younger Ogallala Group conglomerate. Hammer is 40.6 cm long.

FIGURE 8. Large boulders of older Ogallala sandstone cemented into younger Ogallala arkosic conglomerate. Older Ogallala outcrops on left. Hammer is 40.6 cm long.

form conglomerate along the contact, fill the paleovalley (Fig. 7). Scattered on the exposed sand and gravel surface are large, rounded, white to light gray boulders of Ogallala sandstone that generally increase in number per unit area toward the paleovalley side. At this site, some of the boulders are in contact with weathered Ogallala outcrops and are cemented into conglomerates (Fig. 8). Clearly, the sources of the large boulders in the sands and gravels were outcrops along the valley side, probably less than 100 m upslope or upstream from the site of deposition.

FIGURE 7. Older Ogallala sediments (left) cut by a N60°E-trending younger Ogallala paleovalley. Paleovalley to right of dashed line filled with granitic sand and gravel, including older Ogallala blocks. Arrow points to area shown in Figure 8.

Another remarkable feature of this paleovalley is the slope of its exposed side. This slope is about 55° and is nearly a mirror image of the valley side of a Recent valley only a few meters to the north. The surface of the Recent valley side is even dotted with large tabular blocks of older Ogallala sandstone (Fig. 7) that could be included in fluvial sediments if alluviation were to occur in the valley.

Site 4

Shepherd and Schumm (1974) and Schumm (1977) described the erosional evolution of the valley floor of a model straight stream and illustrated the longitudinal lineations, potholes, erosional ripples, and grooves that were carved into the "bedrock" of the model. They offered evidence that the bedrock floors of some Recent streams had such features and felt that these features should also be present in bedrock-incised paleovalleys.

Site 4 includes a remnant of a valley incised into the Brule Formation during Late Oligocene to Early Miocene time and filled with basal Arikaree Group (Gering Formation) coarse sand and locally eroded gravels up to cobble size. The remnant of the exposed valley floor is about 0.1 km wide, has a relief of 4 to 5 m, and contains deep scour holes and potholes (Figs. 9 and 10). Later stream erosion truncated a part of this old valley floor as well as the sediments covering it.

FIGURE 9. Paleovalley floor (1) cut into Brule Formation and filled with sand and gravel of Gering Formation. Unconformity 2 truncates Gering valley fill and valley floor; P is a filled pothole. Beds above unconformity 2 are part of the Gering Formation. Man is 1.83 m tall.

Site 5

The first four sites are examples of bedrock-incised paleovalleys less than 1 km wide. There is no doubt that these paleovalleys had smaller tributaries entering them, but these tributaries are rarely exposed, or, when exposed, may have been overlooked. Site 5 in the vicinity of Harrisburg, Banner County, Nebraska, illustrates the nature of an ancient larger trunk stream and its tributary system (Fig. 11). At this site, sand and gravel remnants of alluvium-filled tributaries merge with coarse-grained alluvial-fill deposits of ancestral Pumpkin Creek. This Middle to Late Pleistocene alluvium rests upon the stream-eroded Brule Formation and forms a protective cap that has slowed later erosion. The reduced rate of erosion over this gravel-capped area with respect to the rate over the areas of former Brule divides has resulted in an inverted topography with the preserved parts of the drainage network standing topographically high.

The tributaries of the drainage network headed on the upland several kilometers south of the ancestral Pumpkin Creek Valley and carried coarse sand and gravel, reworked from an Ogallala valley fill, combined with Brule and Arikaree clasts, downslope to ancestral Pumpkin Creek. Variations in altitude of the Tertiary–Quaternary contact at sites along the ancestral Pumpkin Creek drainage network indicate that the average slope of the ancestral Pumpkin Creek valley floor was about 3.8 m/km while the average slopes of the floors of the tributaries varied from less than 7.6 m/km to more than 13.2 m/km.

The average slopes of Recent tributaries to Pumpkin

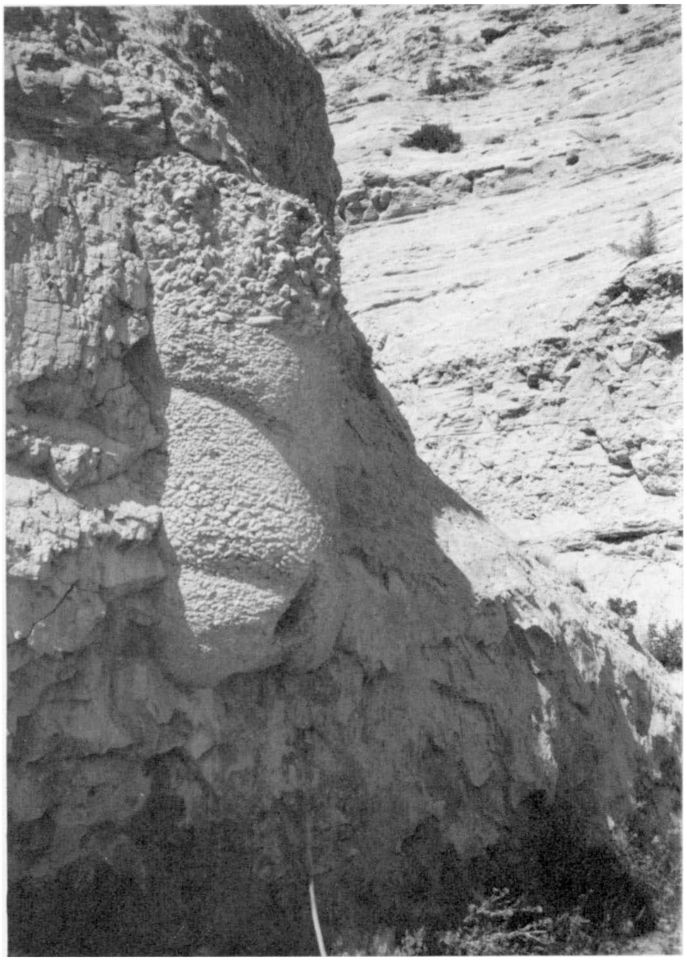

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FIGURE 10. Pothole carved into Brule Formation and filled with cobbles and boulders of the Gering Formation. Surface of pothole is spirally grooved. Pothole is about 2.5 m deep.

Creek vary from less than 7.6 m/km to more than 13.2 m/km. The average slope of the valley floor along Pumpkin Creek is about 3.3 m/km, or somewhat less than ancestral Pumpkin Creek's average slope. The variation in slope between ancient and Recent valley floors indicates that the two floors probably merge downvalley from the study area.

Table II compares the gravel compositions at three sites along one of the Quaternary tributaries with the composition of the main ancestral fill and Recent alluvium. The change in mineralogy from tributary head to tributary mouth reflects mixing of gravels with two distinctly different mineralogies and source areas as the tributary entered the main stream.

Gravel compositions from sediments carried by ancestral Pumpkin Creek differ from those carried by Recent Pumpkin Creek (Table II). These differences probably reflect the fact that anorthosite-rich sediments from the Laramie Range are no longer carried along Pumpkin Creek due to the piracy of the Wyoming part of the creek by Horse Creek (Adams, 1902; Darton, 1903). The anorthosite in the Recent gravels is probably reworked from the older Quaternary gravels south of Pumpkin Creek, while the metamorphic and volcanic clasts are reworked from the Ogallala Group cropping out along the edge of the Cheyenne Tablelands.

TABLE II. Average composition of gravels (16 to 32 mm) in percentage.

Clast Type \ Location	Tributary Gully Head	Tributary Middle Gully	Tributary Gully Mouth	Ancestral Pumpkin Creek Fill	Recent Pumpkin Creek Fill
Quartz	7.9	8.8	7.4	6.0	5.0
Orthoclase	0.6	1.4	------	1.3	------
Granite	63.4	61.7	73.2	37.1	57.8
Anorthosite	0.3	------	4.7	38.8	23.9
Volcanics	4.6	4.5	4.7	2.1	2.6
Quartzite	0.6	0.7	3.8	------	2.7
Metamorphics	21.9	20.4	6.2	1.9	5.0
Chert	------	0.9	T*	5.5	2.1
Sandstone	0.4	0.8	T	3.4	0.3
Claystone/Siltstone	0.1	------	T	0.2	------
Carbonate	------	------	T	1.9	0.6
Unknown	0.1	0.9	------	1.5	------

*T = present at collecting site but not present in sample. Each sample counted contained more than 300 pebbles.

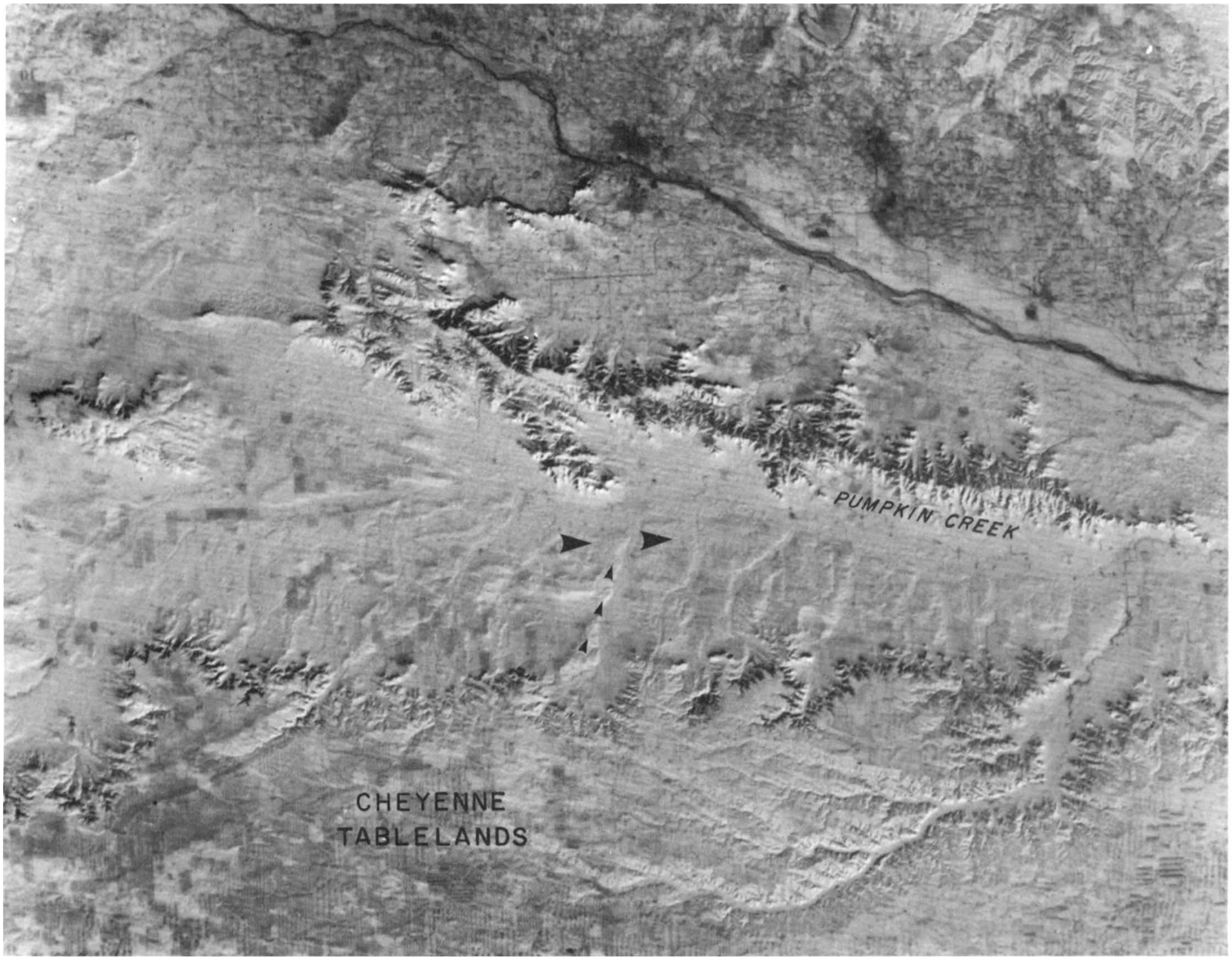

FIGURE 11. Satellite image of Pumpkin Creek Valley and Wildcat Hills showing remnants of tributary (small arrows) and ancestral Pumpkin Creek alluvial fills (large arrows). Arrows point in direction of flow.

Site 6

The flume studies of Shepherd and Schumm (1974) produced a deeply incised inner channel sometimes split to form multiple channels separated by bedrock highs or "islands." The long profile of this inner channel was very irregular and had many reversals of slope.

Similar channels have been reported from the Cenozoic of western Nebraska. The area including site 6 was first reported on by Breyer (1974, 1975). Detailed geologic mapping at site 6 was done by Swinehart and Diffendal (1978). Swinehart (1979) and Swinehart and Diffendal (1982) expanded on the mapping and described probable Pliocene inner channel deposits in this bedrock-incised paleovalley. Swinehart is in the process of mapping the paleovalley system to the west.

A short segment of the incised paleovalley preserved at site 6 is remarkable for several reasons. An anastomosing valley system with bedrock "islands" is present rather than a single valley (Figs. 12, 13, and 14). The valley floor at the eastern end of this network rises in a downstream direction. The individual valleys of the system are about 0.2 km wide, have a relief of about 35 m with respect to the tops of the adjacent highs, and have tops covered with gravel. One valley, approximately 0.2 km wide, is filled with loose, plane-bedded sands and gravels (Fig. 15) at least 35 m thick. This valley fill is very sandy at irregular intervals along its length.

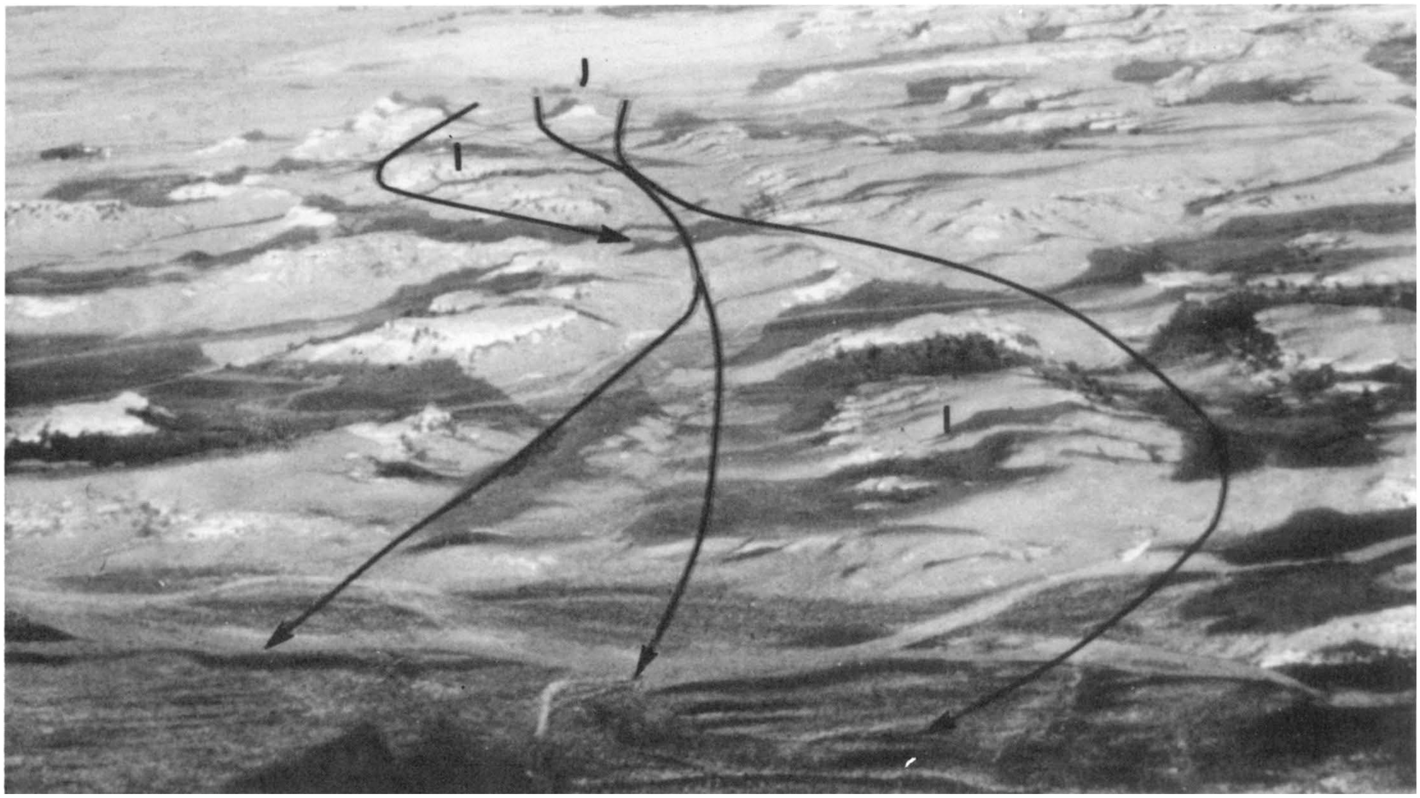

FIGURE 12. Oblique aerial photograph looking west at channel network carved through Ogallala Group beds and into Brule Formation at site 6. Arrows are drawn near middle of each channel. Bedrock islands (I) are between channels. Northern channel is about 0.2 km wide.

FIGURE 13. View of southwestern channel (dashed line) looking east-southeast. Channel edge (CE) is cemented. Channel is about 0.1 km wide. Surface gravel lag of channel fill shown in foreground.

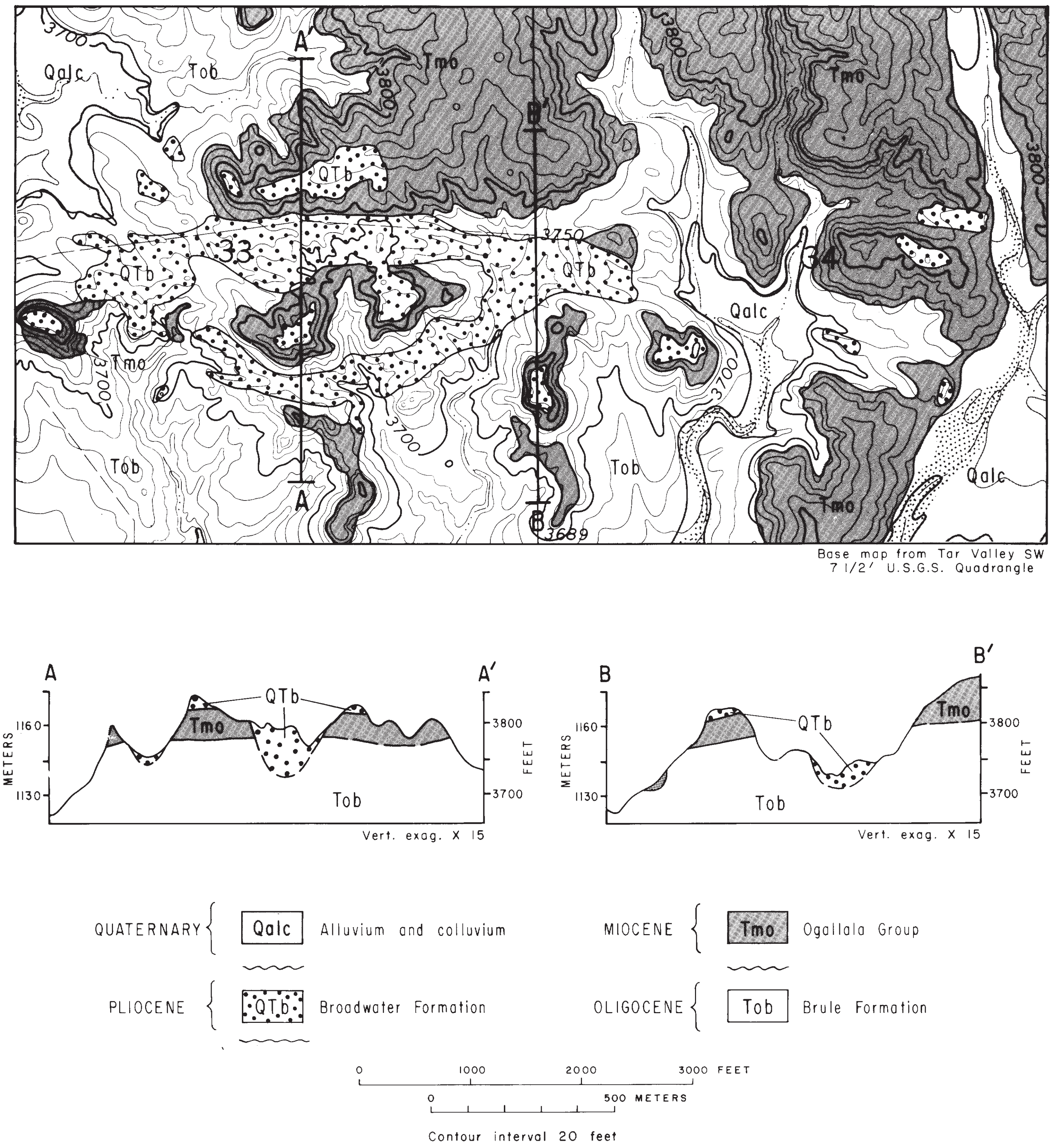

FIGURE 14. Geologic map and cross sections of part of area shown in Figures 12 and 13. Map area includes Sections 33 and 34, T. 19 N., R. 47 W.

FIGURE 15. Outcrop of sand and gravel showing crude bedding and pebble imbrication above hammer. Hammer is 40.6 cm long.

Other examples of similar networks of different ages have been identified in the southern Nebraska Panhandle. Wenzel et al. (1946: Pl. 1) and Souders (1981, personal communication) indicated that channels incised into the Brule Formation and older rocks lie beneath the Quaternary alluvium of the North Platte Valley in Scotts Bluff County. Diffendal (1983) found the same kinds of features at the base of the Ogallala Group in southern Banner County.

CONCLUSIONS AND REGIONAL IMPORTANCE

All six of the reported sites are remnants of valleys carved into bedrock by streams and later filled with sediment primarily transported by streams. All have nearly vertical valley sides at least at some places along the valley lengths. While the sizes and shapes of those valleys varied, all have Recent analogues in the area.

Investigations of the Cenozoic geology of western Nebraska, such as those by Breyer (1974, 1975), Smith and Souders (1975), and DeGraw (1971), contain interpretations of paleovalley systems based at least in part on subsurface data. All of these studies show narrow and deeply incised paleovalleys often filled with coarse-grained sediment. If such features are as common in the subsurface as they are on the surface, then far more of these features may be concealed beneath western Nebraska and adjacent areas of the Great Plains than have been reported previously.

In the future, workers should be aware of the possible variations in geometry and extent of these paleovalleys. Careful work probably will reveal paleovalley tributaries filled with locally or distantly derived sediments or mixtures of the two types markedly different in mineralogy than the sediments filling the main paleovalley. These tributary fills could easily be mistaken for their parent formations during test drilling and surface exploration.

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