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Abstract. Shell Valley, from the mouth of Shell Canyon, to its junction with the Bighorn River in east-central Bighorn County, Wyoming, was mapped and the fluvial landforms were described in detail. The morphologic features of this valley and its major tributaries are largely the product of structurally-controlled stream erosion and alluviation. Their disposition indicates that they have been produced by lateral planation, slope retreat, simple downcutting, and downcutting accompanied by lateral migration of the stream, all of which are still active. Correlation of the local features with some more regional features, which have been dated, indicates that much of the erosional history of Shell Valley was confined to the Pleistocene.

Shell Creek is one of five perennial streams which have their source in the Bighorn Mountains and are tributary to the Bighorn River. It rises in the high mountains near Cloud Peak, passes through the rugged, glaciated upland and thence through the rather spectacular Shell Canyon, and enters the Bighorn Basin just east of the village of Shell, Wyoming.

Shell Valley, from the mouth of Shell Canyon to the junction of Shell Creek with the Bighorn River, is about 17 miles long. The valley is relatively narrow, flat-floored and bordered throughout its length by moderately rugged hills with maximum relief of 600 feet. Because of the arid climate of the eastern Bighorn Basin, these hills are essentially barren of vegetation, in sharp contrast with the summer greenness of the irrigated valley floor. The valley floor widens gradually from the mouth of Shell Canyon to the vicinity of the town of Shell, where it is 0.6 mile wide. West of the town the valley maintains an average width of about 1.3 miles. The rather abrupt widening near Shell is due to the entrance in this area of the only perennial tributaries of Shell Creek. These are Trapper Creek, from the south, and Horse and Beaver creeks, from the north. Only two ephemeral streams of any significance, Red Gulch and Potato Draw, enter Shell Valley below the mouth of Beaver Creek. Both of these enter the valley from the south.

Throughout much of its length Shell Valley occupies a transverse position with respect to the regional strike of the Mesozoic sedimentary rocks which underlie the area. From east to west, these are: the lower flexure of the Bighorn Monocline, Red

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Gulch Syncline, Cherry Anticline and the related Shell Creek Dome, Poverty Flats Syncline, Sheep Mountain Anticline, and the Greybull Dome. These structures control the outcrop patterns of the more resistant formations such as the Triassic, Chugwater; Greybull Sand member of the Cretaceous, Cloverly; and the Peay and Torchlight Sands of the Cretaceous, Frontier.

The combination of its perennial stream, limited area, minimum number of major tributaries, and abundant remnants of older erosion surfaces, with the effects of varying resistance and structural distribution of the underlying rocks makes Shell Valley an almost ideal subject for geomorphic analysis. Detailed field studies were made over a period of eleven weeks during the summer of 1960. Stereoscopic air photo coverage on a scale of 1:20,000 was extensively used, both in the office and in the field. For most of the area, preliminary sheets of 1:24,000 topographic quadrangle maps with contour intervals of 20 and 40 feet became available during the early part of the field season. Additional details were secured by altimeter and plane table surveying. In addition to detailed mapping of the modern valley and the remnants of older valley floors, the field work included careful observation of the modern and ancient alluvial materials. Efforts since the close of the field season have been directed toward the correlation and interpretation of the data.

The more significant results of this study relate to: (1) alluvial morphology of the modern valley; (2) occurrence, nature, and interpretation of the remnants of older surfaces; and, (3) an interpretation of the erosional history of the area.

The Modern Valley

Geomorphic analysis of the modern valley reveals the nature of processes now going on and is essential to any attempt to interpret the geomorphic history of the area. The most significant aspects of the valley are: (1) its natural subdivisions; (2) character of the stream; and, (3) nature and occurrence of recent alluvial fans related to tributaries.

Natural Subdivisions

The most important factor in the development of present aspects of Shell Valley appears to be the influence of the varying resistance to erosion and structure of the bedrock. From the mouth of Shell Canyon, westward, three subdivisions are recognized.

Upper Shell Valley extends from the mouth of the canyon to the vicinity of the town of Shell (Figure 1). Here the valley is transverse to the monoclinal structure of uppermost Paleozoic and lower Mesozoic formations. The major effects of bedrock control in this segment are restriction of valley width by relatively resistant formations, such as the Chugwater, and symmetrical development of the valley.

Middle Shell Valley extends from the vicinity of Shell to the mouth of Potato Draw (Figure 1). This segment of the valley is wider, more open, and distinctly asymmetrical. The north wall of the valley is abrupt, marked by prominent cliffs consisting of the Cretaceous Thermopolis, Mowry, and Frontier formations. These rocks are mainly dark gray to black shales and sandstones. The south side of the valley is characterized by more gentle slopes, underlain by slightly older rocks of the Cloverly and Morrison formations. Here the valley is transverse to the axis of the broad, shallow Red Gulch Syncline. However, the valley is actually parallel to the strike of the beds along the west limb of this structure, as they are influenced by the more distinct and asymmetrical Cherry Anticline to the west (7).

Lower Shell Valley extends from the mouth of Potato Draw to the Bighorn River. Here the valley is essentially transverse to a number of structures, but lies in structural sags between prominent plunging structures. At the mouth of Potato Draw, the valley crosses a sag between the northward-plunging Cherry Anticline and the south edge of Shell Creek Dome. Farther west, the valley lies between the southward-plunging Sheep Mountain Anticline and the essentially symmetrical Greybull Dome. Valley development here has been symmetrical.

Character of the Stream

Since about 1880, there has been considerable modification of the channel of Shell Creek. This has been accomplished for the convenience of cultivation of the alluvial flat, and to expedite expansion of irrigation over larger areas. The first problem in a study of Shell Creek is to discover the channel characteristics prior to modification. The natural channel was about 45 miles long and had an average overall gradient of 13 feet per mile. The average gradient in the upper valley was 29 feet; middle valley, 11 feet; and, lower valley, 10 feet per mile. Its width varied from a minimum of 30 feet near the mouth of the canyon to a maximum of 80 feet near its junction with the Bighorn River.

The stream meandered (sinuosity ratio of 2.64) on a narrow floodplain and had a longitudinal profile that shows some attainment of equilibrium. The present channel is entrenched about five feet below the ordinary floodplain as it existed prior to modification. Locally the entrenchment is somewhat greater because the channel has been artificially diverted across the extraordinary floodplain or through the distal edges of fans.

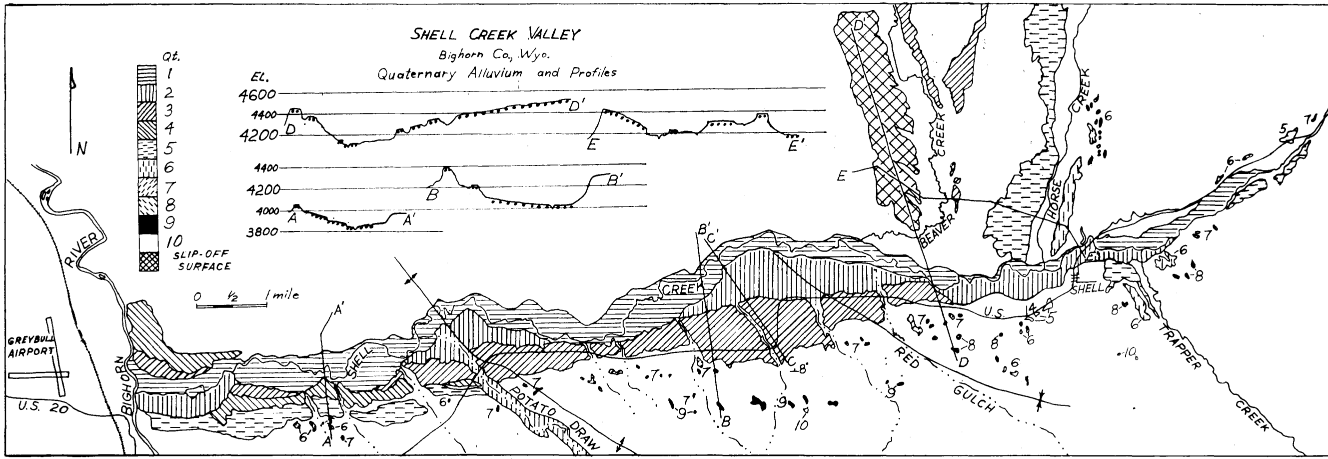

Figure 1. Shell Creek Valley, Bighorn County, Wyoming.

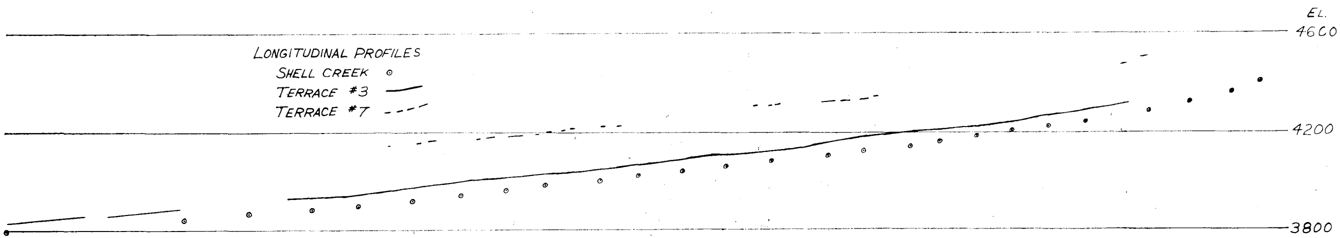

Figure 2. Longitudinal profiles.

Nature and Distribution of Recent Alluvium

Because the natural channel of Shell Creek is part of the floodplain of present (altered) Shell Creek, observation of the gravels is difficult, the natural channel gravels being covered with a mantle of silt and fine sand. Near the mouth of the canyon, where the valley is very narrow, little room is available for diversion; the nature of the gravels in present Shell Creek in this area is assumed to be the same as that of the gravels of the natural channel.

The materials transported by Shell Creek in the upper valley are dominantly of sedimentary origin, mainly carbonate rocks derived from Paleozoic formations in the canyon. Fragments of pre-Cambrian rocks, mainly granites and basaltic rocks, are quite common. The sedimentary gravels occur in near-tabular shape, whereas the igneous gravels tend to be spheroidal.

Throughout the valley, the modern alluvial plain is underlain by a typical succession of materials. The uppermost material, top stratum, consists of silt and fine sand ranging in thickness from zero on modern gravel bars, to seven feet or more under the nautral floodplain surface. The top stratum grades downward into coarse sands and gravels of undetermined thickness. In augering, the gravels are usually reached at depths of 10 feet or less and cannot be penetrated. Information supplied by residents of the valley indicates that the total depth to bedrock does not exceed 35 feet.

Recent Tributary Fans

The junctures of the ephemeral streams with Shell Valley are characterized by alluvial fans over which the tributary streams flow, the fans being graded to Shell Creek, or to the floor of Shell Valley. These fans coalesce to form a broad alluvial apron where the tributaries are not widely-spaced along the valley sides; but, where tributaries are more widely-spaced, the fans produced by the intermittent streams are quite distinct. Gradients of the fans depend in part upon the gradients of the contributing streams and the abruptness with which the streams' gradients change upon entering Shell Valley. Fan gradients range from about 500 feet per mile for the smaller, steeper fans (these fans extend up to 0.3 mile into the valley), to 80-100 feet per mile for fans of greater cross-valley extent.

Average fan alluvial material ranges from coarse sand-size to about four inches, with the sand-size material predominating. Most of the material of the fans is derived from Mesozoic and Cretaceous rocks on either side of the valley, although where the tributary forming the fan has cut through a Shell Creek terrace, reworked Shell Creek gravels may be found incorporated with the angular alluvial material derived from formations adjacent to the valley.

Older Alluvial Surfaces

The older alluvial surfaces of the valley fall into one of two classifications—terraces or fans.

Terraces

Even casual observation in the valley reveals numerous extensive flat areas, underlain by typical alluvial sections, which are separated from the floodplain by conspicuous scarps. Closer examination shows that there is a succession of such flats, each separated from the one above and the one below by scarps. The lowermost flats are the most extensive and are easily identifiable as remnants of former floodplains. Higher remnants are of smaller extent, but nearly all of them clearly display an alluvial section with bedded basal gravels resting on truncated bedrock. Granting some uncertainty in correlating the higher and smaller remants, we have confidence in the conclusion that at least nine older levels of erosion and deposition are represented.

The size of the terrace remnants ranges from small outliers less than 1,000 feet in maximum dimension, to a long surface that is continuous for seven miles. They are distributed from the mouth of Shell Canyon to the Bighorn River. Their gradients are essentially in agreement with that of the natural channel of Shell Creek (Figure 2).

The terrace gravels of each remnant were observed and described on the bases of composition, size and shape of material,, relation to bedrock, imbrication, thickness, and nature of the matrix.

The composition of the material varies, of course, with streams having different source materials. Horse Creek, not having access to crystalline rocks, carries only sedimentary rocks of Paleozoic and Mesozoic ages. Beaver Creek has access to pre-Cambrian rocks, including a distinctive porphyritic gabbro that is found in Shell Creek alluvium and terrace deposits only west of the junction of Shell and Beaver Creeks. Trapper Creek proves somewhat anomalous in that pre-Cambrian igneous gravels are found on high surfaces which have been formed by Trapper Creek, but due to drainage changes in the mountains, no igneous gravels are found in the present stream of on the lower surfaces. The lithology of the material comprising the terrace deposit may thus identify the depositing stream.

Overall size variation of Shell Creek terrace gravels ranges from sub-rounded (granite) boulders having a six-foot maximum diameter, through cobble, pebble, and sand- to silt-sized grains. The matrix of most gravel deposits is composed of fine sand. As would be expected, the average size of the gravels decreases, and the degree of roundness increases in a downstream direction. The gravels seem, for the most part, to be quite evenly distributed with respect to size throughout the thickness of the gravel deposit. The larger gravels are not necessarily found at the bottom of the gravel deposit, although occasionally larger gravels occur along a definite horizon in the gravel bed. The terraces commonly truncate the underlying rocks, as is illustrated by Figure 3. Observed thicknesses of the terrace gravels vary from one to thirty-three feet.

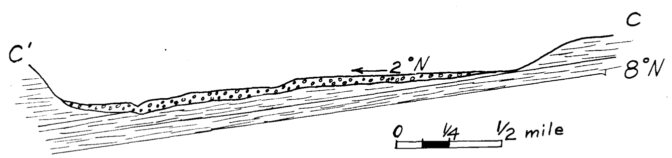

Figure 3. Profile of C C' from Figure 1.

The characteristics of the Upper Valley are all manifestations of the process of valley floor formation as it occurs under the environmental conditions found in the area, the terrace sequence representing the normal, uninterrupted activity of the major stream, Shell Creek. The four paired terrace levels of the Upper Valley have these characteristics in common: (1) their gradients are essentially the same as that of the natural channel in this area; (2) alluvial thicknesses of from 15 to 25 feet occur; (3) imbrication indicates that all had approximately east or northeast sources; (4) all have correlatable remnants down the valley; (5) lithologies are similar, with carbonates abundant in all instances; (6) maximum sizes of the gravels are two feet; and, (7) average gravel size is approximately one inch. Locally, the gravels are cemented to form a conglomerate, as in the number seven terrace just west of the mouth of Shell Canyon. This conglomerate has been previously described and named the Paton Conglomerate (4).

In the Middle Valley are many discontinuous high terrace remnants that lie within one-half to two and one-half miles laterally of the creek, as well as one very continuous lower surface that is directly above the natural flood-plain. The terrace levels have these characteristics in common: (1) the remnants are all on the south side of the valley; (2) gravel thicknesses are variable, but appear to thicken south of the stream in a direction perpendicular to its axis; (3) the maximum gravel dimension is approximately 18 inches; and (4) imbrication indicates an approximately northeast source. Cemented gravels occur on the remnants of number nine terrace south of Shell Creek and four and one-half miles west of Shell.

In the Lower Valley, remnants of the number three and number four terraces are paired, and have the following characteristics in common: (1) alluvial thicknesses are approximately equal; (2) maximum gravel dimensions are about twelve inches; (3) the average gravel sizes are one-quarter to one-half inch; (4) the lithology of the gravels is the same; and, (5) imbrication indicates an easterly source.

Correlation of Terrace Remants

Most of the surface remnants in the Upper Valley are relatively small and discontinuous; whereas, those in the Lower Valley exhibit greater down-valley continuity, as well as being wider and less dissected. Correlation of remnants of former terraces is based primarily upon relative elevations and nature of the gravels, with recent Shell Creek and its tributaries serving as keys, or guides, to the character of the ancient strata. Any judgment made in correlating remnant A with remnant B, if made solely upon a basis of elevations, is prejudiced by a necessarily inferred gradient of the ancient stream. However, comparison of the composition, size, and degree of roundness of the gravels, their imbrication, and the slope of the cut bedrock surface beneath the alluvium serves to confirm correlations based on elevations.

Although scarps separating different terrace levels are usually quite clearly defined, some are indistinct because of the effects of slopewash, dissection, fans, and in the irrigated valley, the effects of cultivation. Minor scarps may continue over distances up to half a mile; then the two surfaces merge and the scarp becomes nonexistent. These small, local scarps are most common on lower levels and may have been formed by a short-lived shift of the stream from the center or one side of the valley to the other, or by a meander loop transgressing into a slightly higher valley floor level or a fan.

Figure 1 shows the nine correlated terrace levels and the present floodplain. They are numbered from one to ten, youngest to oldest.

Fans

Older aggradational landforms other than terraces are the extensive coalescing fans of Potato Draw and Red Gulch, and the fan remnant at the mouth of Horse Creek.

The Red Guch Fan in the Middle Valley is part of a composite fan to which several gulches contribute; this composite fan extends from the Trapper Creek-Shell Valley junction nearly seven miles westward along the south side of Shell Valley. Much of the fan material is derived from the Triassic redbeds which outcrop in the headwaters of Red Gulch to the southeast. Near Shell Creek, fine alluvium of this fan occurs to thicknesses exceeding 15 feet. At the apex of the fan near the point where Red Gulch enters the valley, the fine alluvium is about four feet thick, underlain by at least six feet of gravels ranging up to eight inches in diameter.

The Potato Draw Fan, also located in the Middle Valley, is a composite fan with a thickness of approximately twenty feet, near the creek, the thickness decreasing southward from Shell Creek. Most of the fan material is of sand size, and was derived from south of Shell Valley. The Potato Draw Fan alluvium appears to lie directly on Shell Creek gravels at several localities.

A series of step-like fan remnants at the mouth of Horse Creek Valley indicate that Horse Creek had developed a fan graded to Shell Creek when Shell Creek flowed on the south side of the present valley. The creek has since removed the distal portion of this fan, producing a sharp scarp exposing basal gravels typical of Horse Creek alluvium resting on top stratum of Shell Creek alluvium.

Three minor levels near the mouth of Horse Creek reflect the details of events in the truncation of the major fan.

Discussion and Interpretation

Gradational processes active in the area are, and have been, lateral planation, slope retreat, normal downcutting, and a combination of lateral migration and downcutting, accompanied by contemporaneous alluviation.

Lateral Planation

In the upper and lower portions of the valley, the development has been symmetrical. In both areas, the structural distribution of resistant bedrock serves to control the activities of Shell Creek so that incision below an established floodplain produces paired terraces.

Terrace remnants in both areas reveal typical Shell Creek alluvial sections of essentially uniform thickness resting on truncated bedrock. The combination of evidence clearly indicates that in these areas Shell Creek has developed and incised a sequence of floodplain levels comparable in all respects to the modern valley.

In the Middle Valley, the surfaces reflect the combined processes of down-cutting and concurrent lateral shifting. The directions in which the surfaces slope indicate the approximate direction of lateral shifting. Figure 1 shows that the distribution of the terraces and terrace remnants of the Middle Valley is decidedly asymmetrical in nature. In this area, all remnants lie on the south side of Shell Creek. As the stream shifted laterally (northward) down the dip of the bedrock, it destroyed the floodplain deposit on the north, and left surface remnants on the south. Figure 3 illustrates these relations observed on a remnant of surface number three. Lateral migration down the dip is clearly indicated. The shifting was directed against the north valley wall of Cretaceous (Frontier, Mowry, and Thermopolis) beds. This side of the valley has steep scarps of relatively resistant shales of these formations. These scarps continue to retreat, due to active undercutting by Shell Creek, plus the minor effects of slope wash and erosion by short, steep gulleys.

A prominent remnant on the west side of Beaver Creek also clearly demonstrates the combined processes of downcutting and concurrent lateral shifting. (See Figue 1, cross-sections D D′ and E E′.) The surface produced by this process has a gradient of about 100 feet per mile in a down-valley direction, and of about 200 feet per mile toward Beaver Creek normal to the valley axis, the resulting surface sloping both down- and cross-valley at approximately 250 feet per mile. The surface truncates Cretaceous, Thermopolis beds which dip 10-12 degrees to the west. Thicknesses of the terrace gravels range from 20 feet on the western (upper) edge to 12 feet at the eastern edge. This transversely-sloping surface appears similar to others observed in Shell Valley, except that the direction of slope of this Beaver Creek terrace surface is opposite the dip of the underlying beds.

Several alluvial-covered surfaces approach Beaver Creek from the mountain front on the east, having been formed by streams tributary to Beaver Creek, and having gradients ranging from 150-250 feet per mile. These streams, having a greater water supply from the mountains, were able to erode vigorously in the relatively nonresistant, gently dipping, Jurassic and Cretaceous formations exposed between Beaver Creek and the mountain front. Erosion by these streams, combined with mass wasting, produced a lowering of the topography east of Beaver Creek at a more rapid rate than occurred to the west where the more resistant Cretaceous, Frontier, and Mowry form a more resistant escarpment.

Beaver Creek migrated eastward as it cut downward, forming an alluvial-covered surface sloping both down- and cross-valley, with apparent disregard for the dip of the underlying rocks.

Subsequent incision produced the prominent scarp which separates this surface from the modern floodplain of Beaver Creek.

The common occurrence of terrace remnants with compound slopes (down-valley and transverse) clearly demonstrates the complex processes which have been active in the erosional development of Shell Valley. For these rather unorthodox surfaces, we informally suggest the term *slip-off terraces.* It is obvious that the existence of such surfaces must be considered in any attempt to correlate the many small, scattered remnants occurring along the south side of Shell Valley.

In summary, then, Shell Valley is an area in which the erosional history has been complex. A combination of factors has led to the formation of terraces and assorted surface remnants which reflect the processes of lateral planation, slope retreat, combined down-cutting and lateral migration, incipient pedimentation, and the development of alluvial fans. Detailed mapping of the remnants and the exercise of caution in correlation permits at least tentative conclusions regarding the erosional history. By their positions relative to one another in the valley, age relationships may be ascertained.

Tertiary and Quaternary History of the Area

Several lines of evidence indicate that the Bighorn Basin was filled with sediments to a high level relative to the present surface during Tertiary time. The first is the fact that nearly all the major streams cut across structural barriers in positions that indicate superposition from a higher level (3).

The second is the presence of extensive deposits of stream-rounded gravel at elevations of from 7,000 to 9,000 feet on the flanks of the Bighorn Range (2).

The third is the presence of outliers of Oligocene rocks on top of the Bighorn Mountains just a few miles northeast of Shell Valley (6). According to H. J. Mackin, ". . . The present cycle of degradation was apparently initiated during the Pliocene in the Central Plains area, possibly at an earlier date on the Montana Plains and in Canada ,and at an indeterminate time—possibly late Miocene or early Pliocene—in the Bighorn Basin" (5, page 892). He also states, with reservations, "Alden has shown by relations of terraces with advances of continental ice sheets in the upper Missouri drainage that his number two surface is Pleistocene and this age assignment may be accepted for the number two correlatives in the Bighorn region" (5, page 868). Mackin's number two correlative in the Greybull Valley is the Emblem Bench (5).

The height of the number five terrace in Shell Valley above the Bighorn River is 108 ± 10 feet. This agrees with the height of the Emblem Bench above the Bighorn of 110 ± 10 feet, as determined by Mackin (5) and verified by the writers.

An unconsolidated volcanic ash occurs in the Upper Valley just west of the mouth of Shell Canyon on terrace number seven. It has an index of refraction of 1.492. This index agrees with that of an ash found northeast of Kane, Wyoming, near the junction of the Shoshone and Bighorn Rivers. The Kane ash (1) probably occurs on the Powell Terrace, which has been assigned a Pleistocene age by Mackin (5). Any correlation of surface number seven with the Powell terrace at Kane must be tentative, as we have not studied the latter locality.

These relationships indicate that surfaces in Shell Valley (numbers five and seven) which are intermediate in age, with respect to all surfaces present, correlate with surfaces considered by Mackin to be Pleistocene. The number ten surface is only 200 feet above the number seven in Shell Valley. This is roughly equal to the interval between number seven and the modern floodplain. Thus, it would appear that surface number ten should be no more than twice as old as number seven. If a surface as old as number seven in Shell Valley is clearly Pleistocene, it would not seem unreasonable to conclude that the three higher surfaces (8, 9, and 10) are also Pleistocene ,or certainly not older than late Pliocene.

Additional work will be required to resolve the apparent contradiction of the correlations suggested above. Mackin considers the Emblem Bench and the Powell Terrace to be essentially contemporaneous (5). If our surface number five correlates with the Emblem Bench, then number seven, which is higher, and therefore, older, should not correlate with the Powell Terrace. Detailed study of the ash occurrence near Kane will probably resolve this.

On the basis of the available data, and our interpretation of them, we conclude that the erosional history recorded in Shell Valley occurred during the Quaternary.

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