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1981, pp. 137-144. https://doi.org/10.56577/FFC-32.137

in:

Western Slope (Western Colorado), Epis, R. C.; Callender, J. F.; [eds.], New Mexico Geological Society 32 nd Annual Fall Field Conference Guidebook, 337 p. https://doi.org/10.56577/FFC-32

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ANCIENT DRAINAGE CHANGES IN AND SOUTH OF UNAWEEP CANYON, SOUTHWESTERN COLORADO

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INTRODUCTION

On the first day of the field trip our route takes us through spectacular Unaweep Canyon athwart the high Uncompahgre Plateau —the now "high and dry" abandoned gorge that I believe once carried the combined flows of the ancestral Colorado and Gunnison rivers. From Gateway, at the southwestern end of the canyon, we will go up the Dolores and San Miguel rivers to Uravan and Vancorum, then traverse Paradox Valley along most of its northwestward trending longitudinal axis. At about the middle of the valley, near Bedrock, Colorado, we will cross the Dolores River, which "paradoxically" cuts across the roughly canoe-shaped valley instead of following the longitudinal axis, as do most normal streams, hence the name Paradox Valley.

Evidence to be presented strongly suggests: that the Dolores River once joined the ancestral San Juan River to the southwest but was diverted northward from about the present town of Dolores, Colorado, to join the ancestral San Miguel River; that the combined flows of these two ancestral rivers once joined with the ancestral Colorado River at the southwestern end of ancestral Unaweep Canyon, near the present town of Gateway, Colorado; and that the ancestral upper Colorado River then joined the present Colorado River southwest of the present confluence of the Dolores and Colorado Rivers near Dewey Bridge, in eastern Utah.

Although most of the details of these suggested drainage changes have already been published, it is hoped that this brief summary, which includes some new findings, will be of interest to most participants on the field trip. As these possible drainage changes probably span more than 50 million years, they will be discussed in approximate chronological order.

As will be noted below, there is not universal agreement concerning some of these suggested drainage changes, and a new and quite different interpretation of the changes in and near Unaweep Canyon is given in this guidebook by Sinnock.

DIVERSION OF THE ANCESTRAL DOLORES RIVER

Early Diversion

The present Dolores River heads on the south side of Lizard Head Pass in the San Miguel Range, in Dolores County, Colorado, and flows southwestward in a relatively straight consequent course to the town of Dolores in Montezuma County. There it abruptly turns about 135 degrees to the north and flows in an entrenched meandering course some 110 km north to its confluence with the San Miguel River in Montrose County.

When I worked in the Dolores-Dove Creek area during the 1940's, this abrupt change in the direction of the Dolores River appeared to me to be quite anomalous, but I did not know the reason for this about face until Hunt (1956a, p. 45) suggested that the headward part of the ancestral Dolores River once flowed southwestward to join the ancestral San Juan River, but was diverted northward by the doming and uplift that accompanied the intrusion of the laccolithic Sleeping Ute Mountain", about 30 km southwest of Dolores (see Ekren and Houser, 1965).

The drainage patterns of the Dolores River and other streams, and Hunt's concept (1969, fig. 63) of the possible ancestral patterns, are shown in Figure 1.

Hunt (1956a, p. 45) first postulated that most of the laccolithic mountains were of late Miocene or early Pliocene age, but later (1969, p. 81) he assumed an early Miocene age for the Sleeping Ute and La Sal Mountains, and other laccolithic mountains in the Colorado Plateau. Radiometric age determinations by the K-Ar (potassium-argon) method by Armstrong (1969) for rocks from seven of the eight groups of laccolithic mountains on the Colorado Plateau (Witkind, 1975, p. 245) indicated a Miocene or older age for the La Sal Mountains, but indicated a Late Cretaceous age for Sleeping Ute Mountain. Fission-track and K-Ar dating by Cunningham and others (1977, p. 5) determined an average age of about 70 million years for 5 samples of rock from Sleeping Ute Mountain, indicating a Late Cretaceous age.

Regardless of the exact age of the rocks involved, I am in entire agreement with Hunt that the ancestral Dolores River once flowed southwestward, probably to the ancestral San Juan River, but was later diverted to its present northward course. If Sleeping Ute Mountain was intruded as early as the Cretaceous, the downcutting of the ancestral Dolores may have been impeded by the resistant igneous rocks, and the diversion may have been aided also by warping that accompanied later epeirogenic uplift of the Colorado Plateau. Regardless, the diversion allowed the meandering stream to cut downward into relatively flat-lying Cretaceous sediments, oblivious to the structures that lay beneath.

In a series of eight cross sections, Cater (1970, fig. 13) has clearly shown the gradual growth and eventual erosion and collapse of the Gypsum Valley and Paradox Valley salt anticlines, the products of erosion and solution having been carried away by the Dolores River and its tributaries. Additional geologic and hydrologic data on the salt anticlines, including the Spanish Valley-Moab-Seven Mile faulted anticline, which we will traverse near Moab, Utah, are given by Hite and Lohman (1973, p. 53-57; see also Lohman, 1975).

Later Diversion

Figure 1 shows not only Hunt's concept of the diversion of the ancestral Dolores River, but also the slight monoclinal slip of the San Miguel River southwestward off the flank of the embryonic Uncompahgre arch (fig. 2), the confluence of the Dolores and San Miguel rivers, and in turn tieir confluence with the combined flows of the ancestral Gunnison and Colorado rivers heading southwestward through ancestral Unaweep Canyon to the Colorado River near its confluence with the Green River.

It is perhaps interesting to note that even though the San Miguel probably is older than the diverted reach of the Dolores River, the

*This group of mountains was first referred to as the El Late Mountains by Holmes (1877, p. 237-276). Later the name was changed to Ute Mountain when the range became the principal part of the Ute Mountain Indian Reservation. Still later the name was changed to Sleeping Ute Mountain because when viewed from the east it resembles a human body lying on its back, complete with head, folded arms, knees, and toes. The geology of the mountain has been mapped by Ekren and Houser (1965).

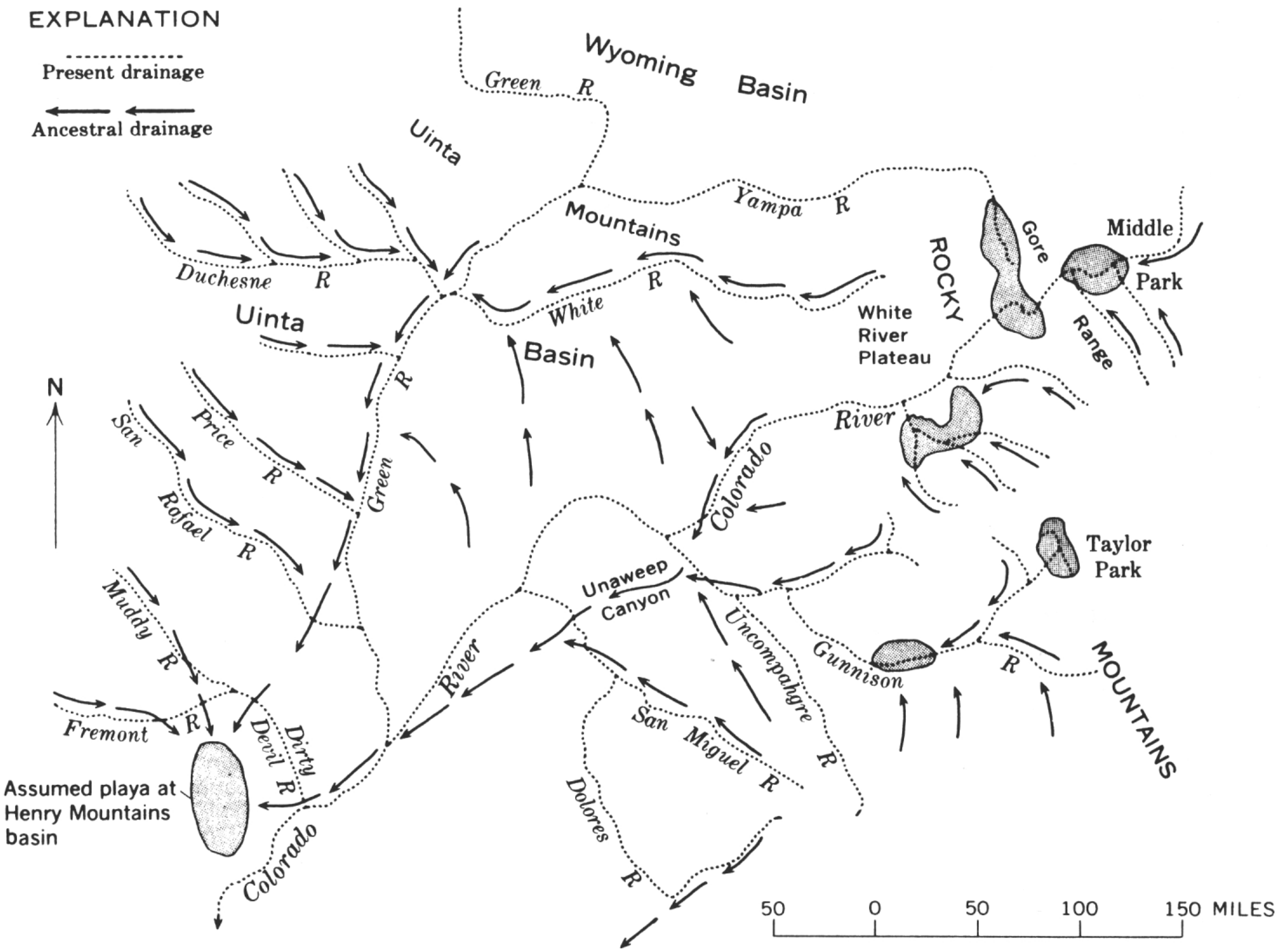

Figure 1. Possible drainage system in the upper Colorado River basin before intrusion of Sleeping Ute Mountain and other laccolithic mountains, and present drainage system (from Hunt, 1969, fig. 63).

name of the latter was applied to the lower reach between the confluence and the Colorado River, presumably because the longer Dolores had the greater flow.

The flow of the Dolores River has been reduced somewhat by a small diversion dam about 1.7 km west of the town of Dolores, from which water flows southward through a tunnel and aqueduct to supply the city of Cortez and westward in canals to irrigate croplands. If and when the McPhee Dam is completed about 15 km downstream from the town of Dolores, the flow of the Dolores will be reduced still more. According to Herb Hand (U.S. Water and Power Resources Service, oral communication, Jan. 1981), the 82-m high dam will impound about 494 million m^3, which hopefully will supply full service irrigation to about 14,000 hectares and supplemental irrigation to about 10,500 hectares, mostly by pumping.

According to Hunt (1956a, p. 82; 1969, p. 103) the detour of the Dolores River around the north side of the La Sal Mountains suggests that the river may have once traversed across or north of the site of these mountains, but later was shifted monoclinally northward after the laccolithic intrusion of the La Sal Mountains. I am in general agreement with his views, which are depicted in Figure 1, but I suggest that the ancestral course or an intermediate course may have been between the old and new routes shown in Figure 1, possibly along a route connecting the present Fisher Valley salt anticline, the faulted salt anticline along the Onion Creek Canyon, and the broad Professor Valley of the Colorado River (Lohman, 1975, fig. 7).

A search of the route has revealed no residual gravels, so if any were present they have long since been removed by erosion, as would be expected. The bedrock geology of the La Sal Mountains has been studied by Hunt (1958) and the surficial geology was studied by Richmond (1962), neither of whom found any residual gravels.

DIVERSION OF THE ANCESTRAL COLORADO AND GUNNISON RIVERS

Unaweep Canyon

Unaweep Canyon is a spectacular deep canyon, or windgap, that crosses the Uncompahgre Plateau, or arch, for a distance of about 70 km between the towns of Whitewater and Gateway, Colorado. It is occupied by paved Colorado Highway 141, which we will traverse on our trip. The inner gorge of the central part of the canyon, which is cut in resistant Proterozoic crystalline rocks and is nearly vertical walled, is from 300 to about 370 m deep and from 400 to 800 m wide in most places and about 1,600 m wide locally.

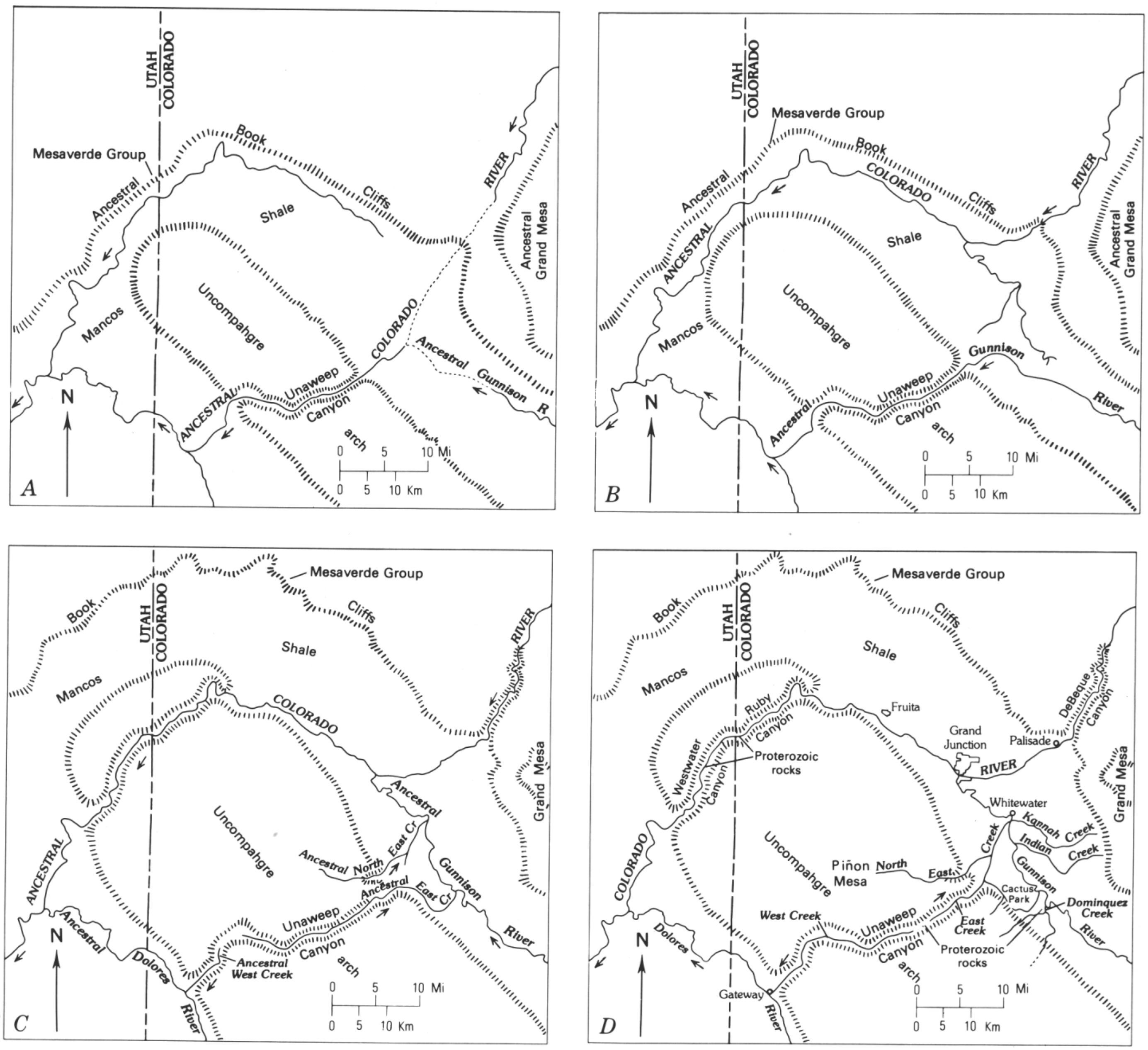

Figure 2. Probable drainage pattern and topographic features at northwestern end of ancestral Uncompahgre arch at four successive stages of development. Solid drainage lines taken from Moab and Grand Junction Quadrangles, Colorado and Utah, scale 1:250,000; dashed drainage lines are as I believe them to have been. **A,** just prior to capture of ancestral Colorado River; **B,** after renewed uplift of the Uncompahgre arch and capture of ancestral Colorado River, and just prior to capture of ancestral Gunnison River; **C,** after probable additional uplift and after abandonment of Unaweep Canyon following capture of ancestral Gunnison River; and **D,** present drainage pattern after latest uplift, shift of Unaweep Divide, and capture of ancestral East Creek (from Lohman, 1981, fig. 34).

The entire canyon, including the gentler slopes of the overlying Mesozoic sedimentary rocks, has maximum depths of 600-1,000 m and widths at the top of 6 to 8 km.

The canyon is now drained by two small streams, one of which flows northeastward (East Creek) and the other southwestward (West Creek) from a barely perceptible divide in the bottom of the gorge (fig. 2-D). The divide, known as Unaweep Divide, has an altitude of about 2,140 m and stands about 760 m higher than Grand Junction and Gateway.

That such an immense canyon could not have been cut by such puny streams flowing in opposite directions was recognized more than 100 years ago by A. C. Peale and Henry Gannett, members of the Hayden Survey. They each concluded correctly that the canyon was cut by a large river, but Peale (1877, p. 58, 59) attributed the cutting to the Gunnison River alone, whereas Gannett (1882, p. 785) attributed it to the Grand* (Colorado) River. Most later workers have agreed with Gannett that the canyon was once oc-

*The present Colorado River northeast from its confluence with the Green River in the middle of Canyonlands National Park in Utah, formerly was called the Grand River, and the Grand and Green rivers joined at the confluence to become the Colorado River. The Grand River was renamed the Colorado River by act of the Colorado State Legislature approved March 24, 1921, and by act of Congress approved July 25, 1921, but the older name Grand is still used for many other features in Colorado and eastern Utah.

cupied by the Colorado River (including its large tributary, the Gunnison River): (Stokes, 1948, p. 38; Shoemaker, 1954; Cater, 1955; Hunt, 1956a, fig. 60; and Lohman, 1961, 1965a, 1965b, 1981). Cater (1966; 1970, p. 71), mainly on the basis of river gravels and overlying fanglomerates near Gateway, later changed his mind and concluded among other things that "Unaweep Canyon was carved by the Gunnison River, and the Colorado River never flowed through it .. ." and that "... the rise of the modern Uncompahgre uplift probably began in mid- or late Pliocene time," not in early Tertiary time as contended by Hunt (1956a, fig. 54) and by me in the four reports cited above. In later reports, Hunt (1969, table 2, fig. 50, 63) and I (Lohman, 1981, and this guidebook) still contend that Unaweep Canyon was cut and occupied by the flow of both the Colorado and Gunnison rivers.

Canyon Cutting

Hunt's (1969, fig. 63) ideas of the possible drainage pattern in early Miocene time, when a somewhat smaller combined flow of the ancestral Colorado and Gunnison rivers flowed through Unaweep Canyon, are shown in Figure 1. If the intrusion of Sleeping Ute Mountain is as old as Late Cretaceous, as noted above, then a comparable drainage pattern may have existed earlier than Hunt indicated, but it may have been less extensive. In Figure 1, some of the headwater streams are shown flowing into temporary playas or lakes. My concept of the major drainage and topographic features just prior to the capture of the ancestral Colorado River is shown in Figure 2A. After having cut through more than a thousand meters of soft Mesozoic and probably also early Tertiary sedimentary rocks, the superposed ancestral river had encountered the hard core of the Uncompahgre arch, which had been uplifted beginning in early Tertiary time. At the time depicted in Figure 2A, probably in mid- to late Pliocene, the river had cut through more than 300 m of Proterozoic granite, gneiss, and schist in Unaweep Canyon. Because of the hardness of these old rocks, downcutting in and upstream from Unaweep Canyon was greatly retarded for a long time.

Not so with the tributary shown at left in Figure 2A, however, which, though carrying much less water than the master stream, had only the soft Mancos Shale to cut. Note that at this time the band of Mancos Shale extended much farther up the flanks of the northwestward-plunging Uncompahgre arch than at present, and some parts of the plateau probably still were covered by the Mancos and possibly by even younger strata. Note also that the ancestral Book Cliffs and Grand Mesa then were closer to the plateau.

Capture of Ancestral Colorado River

Probably in latest Pliocene time additional uplift of the Uncompahgre arch, accompanied perhaps by an unusually large flood, caused the ancestral Colorado River to overflow its banks and spill across a low shale divide into the headwaters of the tributary. As a consequence of the renewed uplift, the river probably was ponded just prior to the spillover.

With this enormously increased supply of water, the tributary cut down rapidly into the soft shale, captured the waters of the ancestral Colorado, and isolated the ancestral Gunnison River, as shown in Figure 2B. Stream capture of this type is appropriately called stream piracy.

Capture of Ancestral Gunnison River

Note in Figure 2B that soon after the capture of the ancestral Colorado River, a tributary was cutting southeastward into the soft shale, and was about to capture the ancestral Gunnison River. The positions of the three streams depicted in Figure 2A suggest that it was most unlikely that both rivers could have been captured simultaneously.

Figure 2C depicts my concept of what the drainage pattern may have been after capture of the ancestral Gunnison River by a tributary of the newly formed and rapidly downcutting ancestral Colorado River. Map C, taken from my 1981 report, differs from that shown in my three earlier reports in that I have shown the divide between ancestral East and West creeks farther southwest. I did so because the repeatedly uplifted Uncompahgre arch was asymmetric in that the crest, at the time Unaweep Canyon was abandoned by the two rivers, was not in the middle of the arch but was near the southwest side. As described by Cater (1970, p. 67), this resulted from the facts that although sharp locally faulted monoclines are found on both sides of the arch, in general the northeastern flank has a rather gentle northeastward dip (Lohman, 1963; 1965a, pl. 1), whereas the southwestern flank of the arch also is bordered by normal faults of considerable vertical displacement (Cater, 1955).

Capture of East Creek

Ample evidence indicates that after abandonment of Unaweep Canyon by the ancestral Colorado and Gunnison River, ancestral East Creek joined the ancestral Gunnison River along the course shown in Figure 2C, but that later, probably in the Pleistocene, East Creek was captured by a tributary of North East Creek to form the present drainage pattern shown in Figure 2D. By comparing Figures 2B and 2C, it is apparent that about 10 km of the old course of East Creek, in what is now known as Cactus Park (fig. 2D), was a part of the former course of the ancestral Gunnison River. Examination of aerial photographs or topographic maps* shows that the remainder of the former course of the ancestral Gunnison River was southeastward and eastward, and probably deviated from the present course of the river near the railroad siding of Huff, about 10 km west of Delta. The northwestern part of this old course probably was at least in part of structural origin, for it lay just southwest of two monoclines of probable early Tertiary age (see Lohman, 1963; 1965a, pl. 1).

The capture of East Creek probably was caused by what may have been the latest uplift of the Uncompahgre arch, probably in early Pleistocene time, which increased the northeastward dip of the strata and the gradient of North East Creek on the northeastern flank of the Uncompahgre arch. This allowed a tributary of North East Creek to cut rapidly headward and capture the smaller East Creek near the top of what is now called Ninemile Hill—the steepest part of Colorado Highway 141 northeast of Unaweep Divide. The gradient of East Creek now averages about 17 m per km in a generally flat-bottomed valley from Unaweep Divide to the northeastern end of Cactus Park, about 60 m per km in a deep V-shaped canyon from there to the confluence with North East Creek, and about 25 m per km in a shallower V-shaped canyon from the confluence to the Gunnison River near Whitewater. A very gentle divide in the NE 1/4 sec. 16, T. 14 S., R. 99 W., at an altitude of about 1930 m, now separates the two parts of beheaded ancestral East Creek—one part draining westward to East Creek and the other draining first southeastward then northeastward to the Gunnison River (fig. 2D).

A small outcrop of terrace deposits containing cobbles and pebbles of basalt, quartzite, granite and other crystalline rocks covers

*See for example the Moab Quadrangle, Colorado and Utah, scale 1: 250,000.

the crest of a small hill in Cactus Park in the NE 1/4 NW 1/4 sec. 6, T. 14 S., R. 99 W. These deposits are about 23 m above East Creek only 1 km to the west, and about 265 m below Unaweep Divide. Although the gravels could have been deposited directly by the ancestral Gunnison River, it seems more likely that they were brought into Unaweep Canyon by either of the two ancestral rivers, then later were reworked and deposited by ancestral East Creek, when it followed the old course shown in Figure 2C. East Creek probably carried much more water during the Pleistocene than it does now.

Studies of the alluvium in Unaweep Canyon in sec. 1, T. 14 S., R. 100 W., by Hunt (1956b, p. 66), made in connection with an archaeological investigation, afforded additional evidence that the capture of East Creek probably occurred in Pleistocene time. He found three succesive deposits of alluvium, which he believed range in age from late Pleistocene to early historic. As the oldest layer was deposited after East Creek had cut down about 23 m below the old gravel deposit, the capture obviously took place earlier—probably in the early Pleistocene.

As pointed out earlier, Cater (1966, 1970, p. 71) believed that Unaweep Canyon was cut and occupied solely by the ancestral Gunnison River and that the ancestral Colorado River never flowed through it. Cater further stated (1966, p. C88, C89) that those of us who believe Unaweep Canyon to be the abandoned channel of the Colorado River have based our assumptions largely on the alignment of the canyon with the course of the Colorado River upstream from Grand Junction. Moreover he noted "... the small size and different topographic characteristics of the valley of East Creek north of Cactus Park as compared with Unaweep Canyon and the old channel of the Gunnison in and southeast of Cactus Park." Finally, Carter stated, "No residual river gravels have been found on the slopes and shoulders of this segment of East Creek valley; their presumed absence supports this [his] argument."

I believe there are ample answers to all these objections, including some additional evidence. First of all, the alignment of the Colorado River in DeBeque Canyon upstream from the Grand Valley with its former course in Unaweep Canyon is indeed striking, as shown in Figure 2, and surely is more than coincidental. After studying the Quaternary geology of Grand and Battlement Mesas, Yeend (1969, p. 19) concluded in part: "If, in fact, the Colorado [River] at one time flowed across the Uncompahgre Plateau through Unaweep Canyon (Lohman, 1961), then the Colorado was even more discordant with the underlying structure than it is now, as it flows in the soft Mancos Shale around the north end of the Uncompahgre uplift. The preglacial drainage on Grand Mesa, along which the high-level gravels are concentrated, lines up closely with the trend of Unaweep Canyon. This fact seems to lend support to the hypothesis that the Colorado River may have flowed through Unaweep Canyon, and that it was superposed upon the Uncompahgre structure from a capping of virtually flat-lying basalts (Hunt, 1956a)."

In several discussions during the last few years with John R. Donnell, U.S. Geological Survey, who mapped Grand and Battlement Mesas, it was learned that a small remnant of the lava on the crest of the Roan Cliffs just southwest of the present town of Parachute (formerly Grand Valley) indicates that the lava flows crossed this part of the ancestral Colorado River valley. However, Donnell reported that although the flows are about 245 m thick on the eastern part of Grand Mesa they thin to only about 60 m along the western rim of the mesa, hence it is not certain whether they reached as far southwest as Unaweep Canyon.

I have already contrasted the striking differences in shape, character and gradient between the gentle flat-bottomed remnant of Unaweep Canyon upstream from Cactus Park with the steep V-shaped canyon of East Creek downstream; it remains to account for the absence of residual gravels on the slopes of the steep "capturing" segment of East Creek canyon north of Cactus Park—a major objection raised by Cater (1966, p. C89).

Unaweep Canyon actually comprises three distinctive segments: 1) A mature central U-shaped, relatively flat bottomed, "fossil" remnant extending about 16 km southwest from the north end of Cactus Park to a reservoir about 6 km west of Unaweep Divide; 2) between the reservoir and Gateway is the generally steep youthful V-shaped lower canyon of West Creek; and 3) northwest from Cactus Park, as noted above, is the steep V-shaped youthful lower canyon of East Creek.

Prior to the renewed uplift of the Uncompahgre arch that brought about the abandonment of Unaweep Canyon, the bottom of the mature northeastward extension of the old canyon was in the Mancos Shale more than 100 m above the present site of Whitewater, and the later uplift that brought about the capture of East Creek increased the difference in altitude still more. Naturally, any gravels in the old mature channel of the ancestral Colorado River have long since been carried away by the rapidly degrading East Creek. Moreover, for similar reasons, no trace of the old mature channel remains between the north end of Cactus Peak and the mouth of DeBeque Canyon (fig. 2D).

Character of Central Remnant of Unaweep Canyon

The U shape of the beautiful, mature, central section of Unaweep Canyon (fig. 3) has prompted many geologists to ponder if the canyon was carved by a glacier. The nearest glaciers, however, were atop towering Grand Mesa to the east, in the San Juan Mountains far to the southeast, and in the La Sal Mountains to the southwest.

The abandonment of Unaweep Canyon discussed above removed the gigantic storm sewer that for millions of years had carried off the erosion products from the canyon walls, resulting from the action of frost, water, wind, and gravity. Since abandonment, rock materials that have fallen from the cliffs of the inner gorge and from the gentler slopes above simply have piled up at the foot of the cliffs to form a canyon equally as U shaped as those actually cut by glaciers.

There has been some speculation as to the depth of fill in the central segment of Unaweep Canyon. I have always considered that it probably is relatively shallow—a few meters at most, but thick enough to supply domestic and stock wells at several of the ranches.

On the basis of geophysical studies by both seismic refraction and electrical resistivity methods, done as a part of a master's thesis, Oesleby (1977, 1978) suggested, among other things, that the valley fill beneath Unaweep Divide is 330 to 395 m thick, and that it becomes thinner both to the southwest and northeast. However, he went on to state (1978, p. 65) that: "Because of the numerous problems encountered in measuring the thickness of fill in Unaweep Canyon by geophysical techniques, ... a simple graphical method was devised to estimate the thickness. The method consists of projecting both bedrock canyon slopes downward until they intersect at the presumed ancient valley-bottom." Oesleby assumed the canyon sides to be V shaped and that all-the fill was derived from the canyon walls and sides. Some of his downward projections coincided with geophysical soundings; others did not.

Figure 3. Unaweep Canyon, looking southwest from rim of inner gorge cut in hard Proterozoic rocks, just to the right of first cattle guard on Divide Road, near the middle of sec. 16, T. 14 S., R. 100 W., about 9 km north of Unaweep Divide, which is just around the corner to the right of the most distant part of the canyon visible. Slope above rim of inner gorge on right are Triassic strata capped by flat bench of the Jurassic Entrada Sandstone. For 4-color reproduction, see Lohman (1981, fig. 36).

I agree that such material as does underlie the floor of the canyon was derived locally, but its derivation would have altered the shape and size of the canyon. Moreover, such canyon walls could be V shaped, vertical, or shaped like the cross section of a boat, so that their downward projection as straight lines might prove quite fallacious; for example, downward projection of vertical walls would extend to infinity. Oesleby finally concluded (p. 77) that a few boreholes are needed to really solve the problem, and I fully agree.

Post Diversion Changes

Unaweep Divide now stands about 760 m above the Dolores River at Gateway and also above the confluence of the Colorado and Gunnison rivers at Grand Junction. It is not certain how much of this interval is due to the several uplifts of the Uncompahgre arch and how much is due to downcutting by the Colorado, Gunnison, and Dolores rivers since the uplifts and the last stream capture. However, in an earlier study of dissected pediments and other old surfaces in the Colorado River valley and Grand Valley between the town of Silt and Grand Junction, I estimated that in the area northeast of the Uncompahgre arch the valleys may have been deepened by erosion as much as 180 to 240 m; if so, the remaining 520 to 580 m may be attributable to the uplifts. The details leading to these conclusions, which are beyond the scope of this paper, are given in the earlier report (Lohman, 1965a, p. 72-74).

POSSIBLE FUTURE STREAM CAPTURES NEAR THE UNCOMPAHGRE ARCH

As stated in earlier reports (Lohman, 1965a, p. 79, 80; 1965b, p. 55; and 1981, p. 83), the Colorado River did not necessarily solve its problems by abandoning its hard rock course in Unaweep Canyon in favor of a soft rock course around the northwestern end of the plunging Uncompahgre arch—it may have just postponed them. As shown in figure 2D, the river has again cut down into its old nemesis—the resistant Proterozoic rocks—in Ruby Canyon at and near the Colorado-Utah border and in nearby Westwater Canyon in eastern Utah, and the Gunnison River has just reached the hard rocks at its confluence with Dominguez Creek, not far upstream from Whitewater. Thus once again hard rock is slowing the downcutting of the river, and will slow it down for a long time to come. Someday, Ruby and Westwater Canyons will be deep gorges like the central segment of Unaweep Canyon. Then it is quite possible that another young tributary may "sneak" around the Uncompahgre arch some distance northwest of these canyons and capture the river into a new soft-rock course. Similarly, when a deep gorge in Proterozoic rocks has been cut by the Gunnison at the mouth of Dominguez Creek, a tributary, such as Indian Creek or Kannah Creek, could cut headward to the east of the canyon and capture the Gunnison upstream from the canyon. Of course, other possible future events, such as renewed uplift, volcanism, or climatic changes could alter, hasten, or prevent such stream diversions.

ACKNOWLEDGMENTS

I am greatly indebted to Charles B. Hunt and James E. Weir, Jr., both formerly with the U.S. Geological Survey for many years, for their kindness and expertise in reviewing this paper. I also wish to thank Ogden Tweto of the Survey, and John R. Donnell, formerly with the Survey, for profitable discussions of some of the problems. Finally, I am indebted to Professor J. C. Harrison, of the Institute for Research in Environmental Sciences, University of Colorado, for kindly loaning me the master's thesis of Oesleby (1978).

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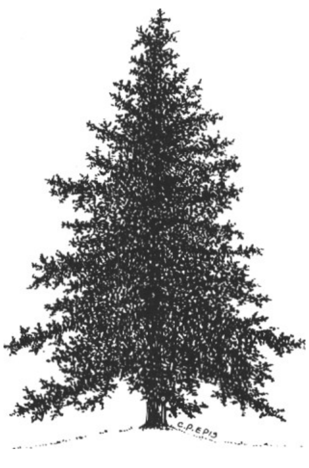

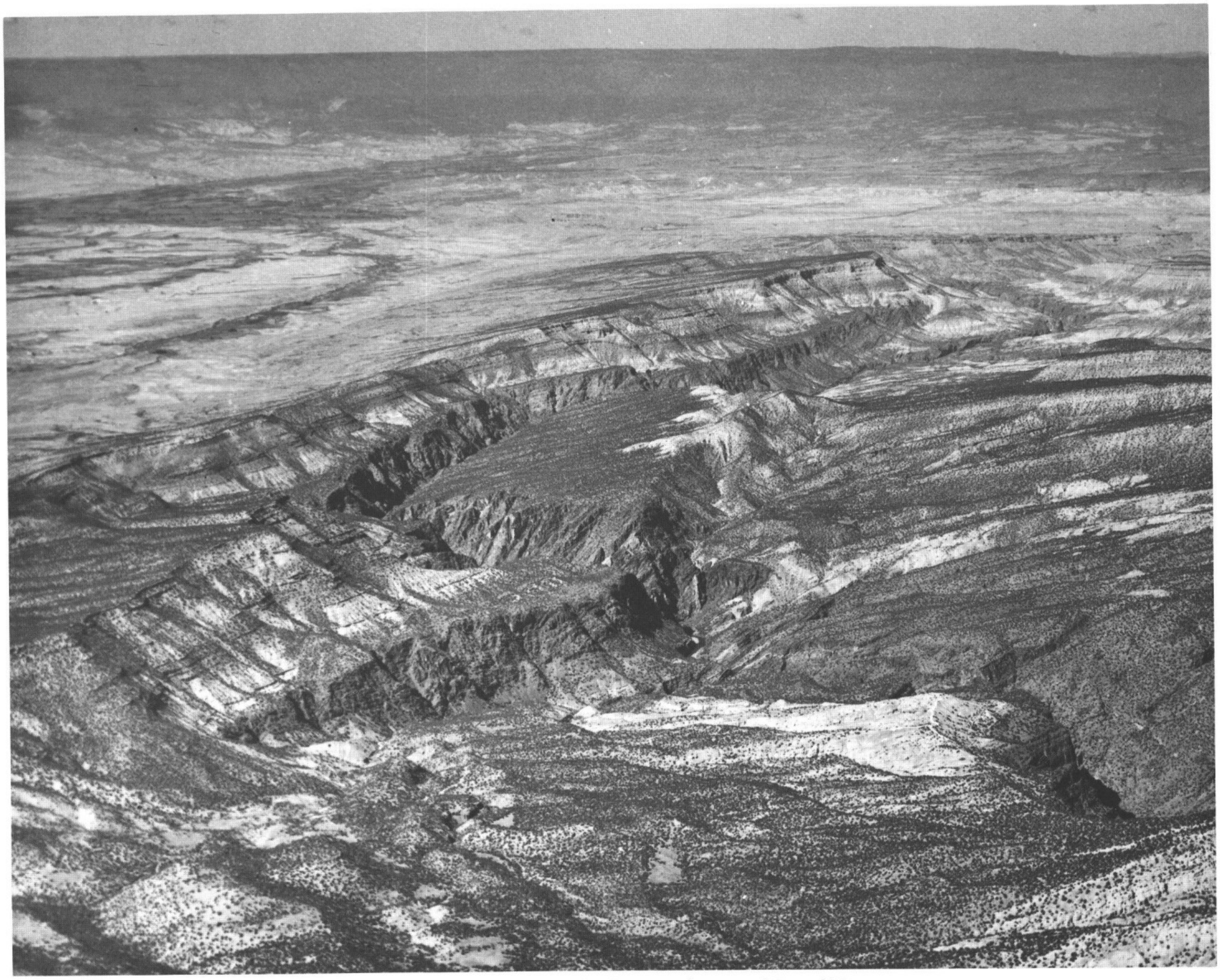

Plunge of Gunnison uplift, looking north toward Grand Mesa.