Paradox Valley, Colorado; A collapsed salt anticline

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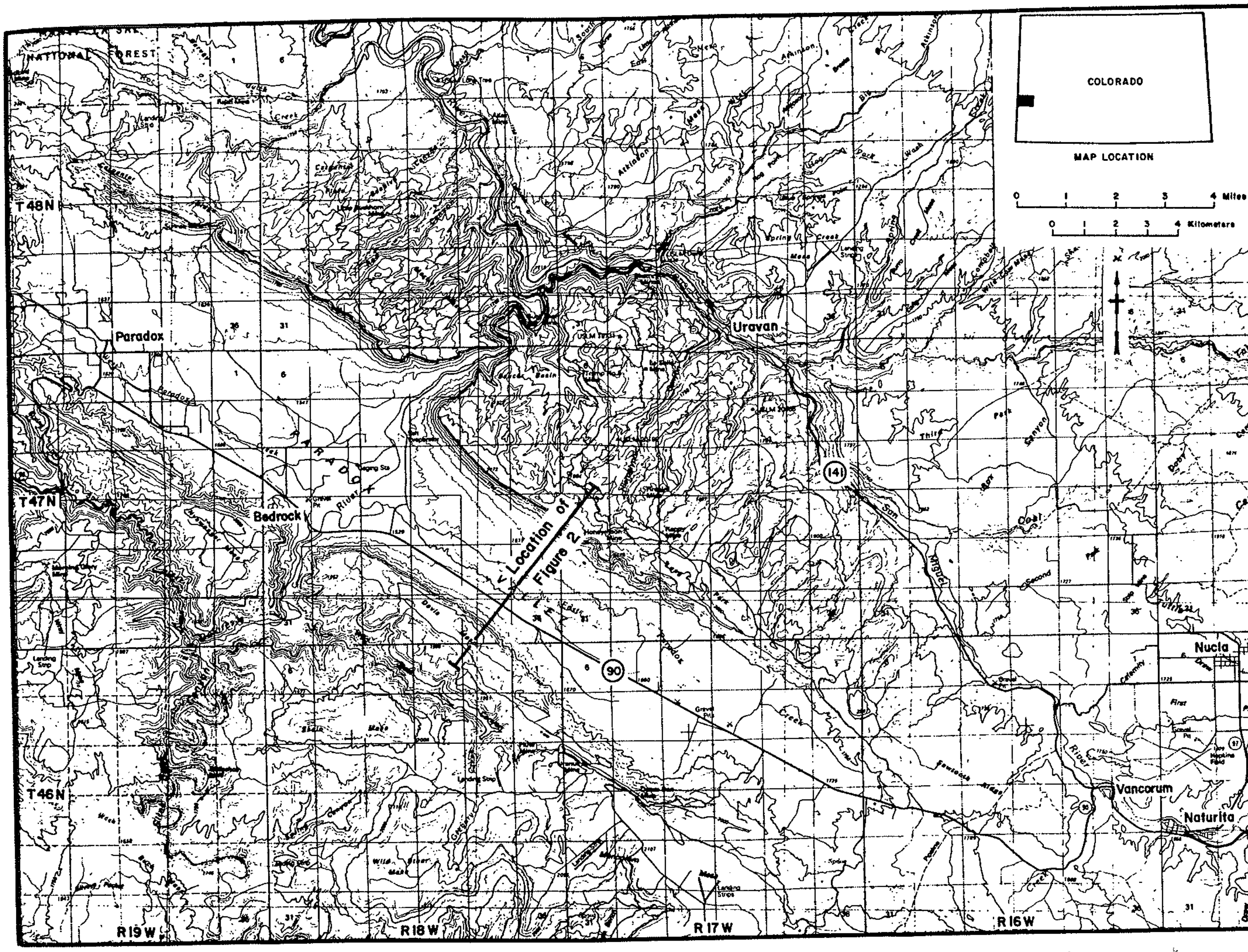

Figure 1. Location map of Paradox Valley, Colorado. Reduced from U.S. Geological Survey Nucla Quadrangle, 1:100,000 scale; contour interval 50 m.

LOCATION AND ACCESS

Paradox Valley is located in west-central Colorado, in western Montrose County (Fig. 1). The valley is approximately 23 mi (37 km) long and averages 3 mi (5 km) in width. It occupies a large part of T.46N.,R.17W.;T.47N.,R.18 and 19W.; and T.48N.,R.19W. Colorado 90 traverses the valley for nearly its full length. This highway begins at Vancorum, which is on Colorado 141 about 2 mi (3 km) west of Naturita, Colorado. Naturita, the largest settlement in the area, is about 100 mi (161 km) south of Grand Junction, Colorado, on Colorado 141. After leaving the northwest end of Paradox Valley, Colorado 90 enters Utah as Utah 46; it joins U.S. 191 some 22 mi (35.4 km) south of Moab, Utah. Paradox and Bedrock, Colorado, are the only settlements in the valley.

County roads (marked with signs) provide access to the rims of the valley as well as the canyon of the Dolores River on both sides of the valley. Molenaar and others (1981, p. 7–9) give a detailed road log of the valley.

The majority of land in the Paradox Valley area is in the public domain, administered by the Bureau of Land Management. West of the Dolores River, the valley floor is nearly all private land, owned by ranchers in Paradox. About 15 percent of the valley floor east of the river is privately owned. The valley rims are all public domain, with the exception of numerous patented mining claims.

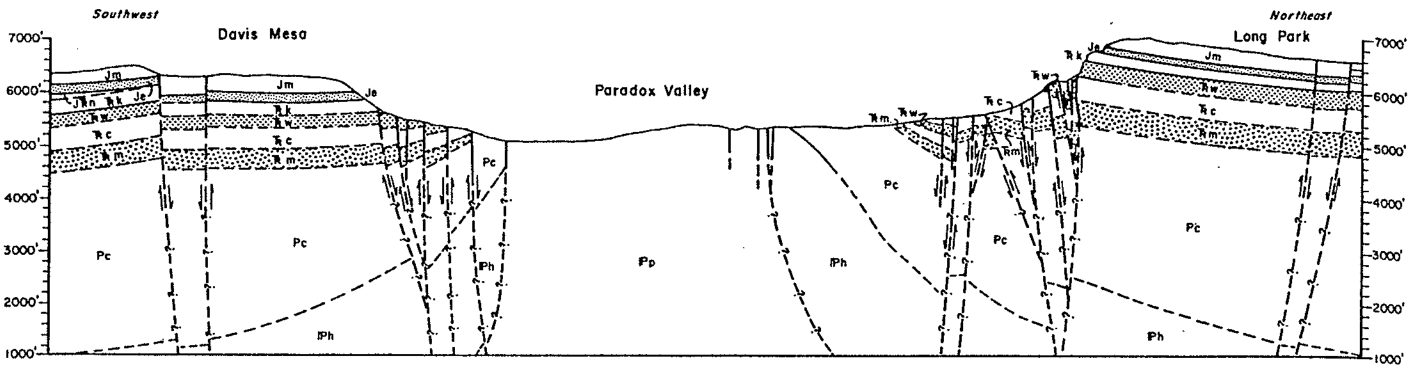

Figure 2. Cross section across Paradox Valley. Location shown on Figure 1. IPp, Paradox Formation; IPh, Honaker Trail Formation; Pc, Cutler Formation; Ŧm, Moenkopi Formation; Ŧc, Chinle Formation; Ŧw, Wingate Sandstone; Ŧk, Kayenta Formation; J Ŧn, Navajo Sandstone; Je, Entrada Sandstone; Jm, Morrison Formation; Modified from Cater (1955b).

SIGNIFICANCE

Paradox Valley is the largest of several salt anticlines in the Paradox basin of southwestern Colorado and southeastern Utah. The valley is the type area of the Paradox Formation of Middle Pennsylvanian age. The valley is an erosional artifact due to solution of the Paradox salt core and subsequent collapse of the anticline. Diapirism of the salt core during the interval from the Late Pennsylvanian through the Late Jurassic is indicated by the stratigraphy of the beds on the flanks of the valley. Carnotite deposits in the Morrison Formation, located on the rim of the valley, have been mined for radium, vanadium, and uranium since 1910.

REGIONAL SETTING

Paradox Valley was named by Henry Gannett in 1875. Gannett, a topographer with the U.S. Geological and Geographical Survey of the Territories (Hayden Survey), noted the paradox in that the valley "was crossed at right angles by the Dolores" (Gannett, 1877, p. 343). The first geologic map with a description of the valley was published by A. C. Peale (1878), a geologist with the Hayden Survey.

The regional geologic setting of Paradox Valley is shown on a map by Williams (1964). Paradox Valley and vicinity have been mapped at the scale of 1:24,000 by the U.S. Geological Survey. These quadrangle maps (Cater, 1954, 1955a, 1955b; Cater and others, 1955; Shoemaker, 1956; Withington, 1955) show various details of the stratigraphic relations and the structure in the valley, which may be difficult for the first-time visitor to observe.

Paradox Valley is the largest of a series of breached anticlinal valleys in the northeastern part of the Paradox basin. The rim of the valley consists of sandstones of Jurassic age, and the valley floor is composed of diapiric Paradox evaporitic rocks of Middle Pennsylvanian age (Fig. 2). The diapiric rocks form structures commonly referred to as salt anticlines of the Paradox basin.

The Paradox basin is about 200 mi (330 km) long and 80 mi (130 km) wide, at its widest point. It was formed in Pennsylvanian time along a dominant set of northwest-trending faults of pre-Pennsylvanian age (Baars and Stevenson, 1981). As the basin subsided, the ancestral Uncompahgre highland was elevated along the northeasternmost of these faults. All of the paralleling faults are downthrown in the northeast direction; the "basement" was lowered stepwise to form the basin. Thus, the deepest part of the basin is along its northeast margin, adjacent to the present-day Uncompahgre Plateau. Salt of the Paradox Formation was deposited as the basin was repeatedly lowered; the thickest deposition occurred in the northeastern part of the basin.

The pre-Pennsylvanian fault that underlies Paradox Valley trends to the northwest into Utah. The same salt core that formed the Paradox Valley is also responsible for the formation of the Castle Valley anticline. The North Mountain intrusive group of the La Sal Mountains, an intrusion of early Miocene age, separates these two collapsed salt anticlines.

The interbedded salt members of the Paradox Formation began to rise diapirically shortly after their deposition, in response to movement along the pre-Pennsylvanian faults. The rising salt core of the Paradox Valley anticline profoundly affected the thicknesses of formations deposited in post-Paradox and pre-Morrison times (see Table 1).

Subsidence of the Paradox basin and simultaneous uplift of the ancestral Uncompahgre highland continued during deposition of the Honaker Trail and Cutler Formations (Pennsylvanian/Permian). As the salt core of the Paradox anticline began to rise diapirically, the Honaker Trail beds were lifted and beveled in response. The Honaker Trail Formation is thinner along the flanks of the present valley than in the adjacent synclines due to this erosion along the anticline. The added weight of the Cutler beds during deposition in the synclines enhanced the movement of the evaporites and squeezed the salt upward and through the overlying Cutler sediments (Cater, 1970, p. 52).

Crustal movements associated with the uplift of the ancestral

TABLE 1. GENERALIZED SECTION OF PALEOZOIC AND MESOZOIC FORMATIONS EXPOSED IN PARADOX VALLEY, COLORADO

System	Formation	Thickness (feet)	Character and distribution
Cretaceous	Mancos Shale	50+	Dark-gray fissile marine shale. Basal beds exposed in center of Coke Oven syncline.
	Dakota Sandstone	150-195	Gray and brown partly conglomeratic sandstone with interbedded carbonaceous shale, all nonmarine, locally coal-bearing. Caps high mesas on each side of valley, also exposed in Coke Oven syncline.
	Burro Canyon Formation	110-200	Light-colored sandstone and conglomerate with interbedded green and purplish shale, nonmarine. Caps mesas on each side of valley.
Jurassic	Morrison Formation	290-420	Brushy Basin Member: varicolored bentonitic mudstone, some sandstone lenses, nonmarine. Forms slopes below Burro Canyon.
		280-350	Salt Wash Member: light-colored lenticular sandstone interbedded with dominantly red mudstone, contains uranium-vanadium deposits, nonmarine. Forms bench on rim of valley.
		60-110	Tidwell Unit: thin-bedded red, gray, green, and brown sandy shale and mudstone, some sandstone lenses, nonmarine. Forms slope below Salt Wash. Previously mapped as Summerville Formation, contains units of the Wanakah Formation (O'Sullivan, 1984).
	Entrada Sandstone	0-150	Slick Rock Member: Light-colored fine- to medium-grained massive and crossbedded sandstone, eolian. Forms a vertical cliff on rim of valley.
		0-80	Dewey Bridge Member: Reddish-brown fine-grained sandstone and siltstone, nonmarine. Forms a cliff below Slick Rock.
	Navajo Sandstone	0-190	Light-colored fine-grained massive and crossbedded sandstone, eolian. Forms a vertical cliff. Present only in the northwest end of the valley.
	Kayenta Formation	0-240	Irregularly bedded red, buff, gray and lavender fine- to coarse-grained sandstone, siltstone and shale, nonmarine. Forms a bench on top of the Wingate.
	Wingate Sandstone	0-100	Reddish-brown fine-grained massive and crossbedded sandstone, predominantly eolian. Forms a vertical cliff on walls of valley.
Triassic	Chinle Formation	0-500	Reddish-brown or varicolored mudstone, siltstone, and sandstone, in part bentonitic, lenses of quartz-pebble conglomerate and grit at base, nonmarine. Forms a steep slope on walls of valley.
	Moenkopi Formation	30-500	Chocolate-brown, reddish-brown, and purple shale, mudstone, and sandstone, in part arkosic and conglomeratic, local gypsum beds near base, marine and marginal marine. Forms a slope in the lower portion of the northeast wall of the valley.
Permian	Cutler Formation	600-3500	Maroon, red, mottled light-red, and purple conglomerate, arkose and arkosic sandstone, thin beds of sandy mudstone, locally reddish-gray marine limestone in lower part, predominately nonmarine. Forms lower slope on the northeast wall of the valley.
Pennsylvanian	Honaker Trail Formation	450-1500	Gray fossiliferous limestone with thin beds of shale, minor arkose, predominately marine. Exposed in the northeast floor of the valley.
	Paradox Formation	2000+	Carbonaceous shale, sandstone, limestone, gypsum and salt, marine. Exposed in floor of valley.

Uncompahgre highland had ceased by the end of Cutler time; however, minor upwelling of evaporites continued through the Triassic and into the Jurassic. As a result, successively older formations dip more steeply on the flanks of the anticline. In general, younger formations were deposited across the upturned and truncated edges of older formations. This process of upturning, erosion, and deposition of overlapping younger formations continued until the time of deposition of the Morrison Formation, when the salt supply from the adjacent synclines had been largely exhausted. Actual wedgeouts and unconformable contacts between beds, which are not normally subjacent, are best seen on the southwest valley wall, southeast of the Dolores River; thinning of the formations can be seen on the northeast wall of the valley.

It appears that the evaporites were probably stable throughout the deposition of Cretaceous sediments. By the end of the deposition of the Mesaverde rocks of Late Cretaceous age, the Paradox salt core had been covered by some 5,000 ft (1,500 m) of sediments, and an anticline had been formed along the old salt structure. The collapse of the crest of the anticline began as grabens were downdropped as much as several hundred feet (few hundred meters). These grabens may have been the result of cessation of the lateral stress that had caused the folding. The grabens remained structurally inactive until the general uplift of the Colorado Plateau began in middle and late Tertiary times.

The uplift of the Colorado Plateau rejuvenated the streams and increased the rate of groundwater circulation. Collapse of the Paradox Valley anticline probably began at the point where the antecedent Dolores River eroded a channel across the anticlinal crest. The canyon cut by the Dolores River exposed the salt to rapid solution and removal, and collapse of the anticlinal crest began. Ancestral East and West Paradox creeks removed material from both the core and from overlying beds during the process of headward erosion. Cater (1970, p. 71) has estimated that the upper surface of the salt core of the anticline was at least 3,000 ft (900 m) higher than the present valley floor.

The Continental Oil Scorup #1 well, which was drilled in 1958 about 1.5 mi (2.5 km) north of Bedrock, penetrated the base of the salt at 14,670 ft (4,471 m) and bottomed in Mississippian rocks at 15,000 ft (4,572 m) (Molenaar and others, 1981,

p. 9). This is the thickest salt section ever penetrated by drilling in the Paradox basin.

STRUCTURAL UNITS

Paradox Valley contains several distinct structural units, which developed as a result of the collapse of the salt anticline. A basinlike downwarp known as the Coke Oven syncline, at the southeast end of the valley, appears to be a result of removal of salt by pressure-induced flowage. The Dry Creek anticline at the southeast end of the valley, on the southwest valley flank, is a result of the draping of sediments over the faulted margin of the Paradox Valley anticline during its collapse.

A central unit occupies most of Paradox Valley where the anticlinal crest was downfaulted. Numerous, closely spaced faults on either side of the valley divide the rocks into long, linear ridges that trend parallel to the valley axis. Most of these ridges have been successively downdropped toward the valley, but a few have been squeezed upward (Fig. 2). The central area retains a salt core in which a number of cupolas are observed.

The northwest unit, which Williams (1964) called the Willow Basin syncline, is a collapsed basin formed by both downsagging and downfaulting. The Mesozoic rocks preserved in this area can easily be viewed from Colorado 90 south of Paradox, Colorado.

ECONOMIC GEOLOGY

The carnotite deposits in the Salt Wash Member of the Morrison Formation of southwestern Colorado have been an important source of radium, vanadium, and uranium since the early 1900s. Two important mining areas are located in the east-central portion of Paradox Valley. The Long Park area is on the north rim, and the Jo Dandy area is on the south side. These deposit clusters are part of a mining region known as the Uravan mineral belt (Fischer and Hilpert, 1952).

The majority of the ore bodies occur in the uppermost sandstone lenses of the Salt Wash Member. A single ore body may range in size from a single fossil log to a mass of impregnated sandstone nearly 100 ft (30 m) wide and 500 ft (150 m) long. Ore thicknesses range from less than 1 ft to over 20 ft (0.3 to 6 m). Ore bodies can occur in clusters elongated parallel to the sedimentary trend of the sandstone host. In unoxidized ore bodies, the principal uranium minerals are uraninite and coffinite. The main uranium minerals in oxidized ores are tyuyamunite and metatyuyamunite, which are more abundant than carnotite.

In past years, brine wells near the Dolores River in the center of the valley have provided salt for livestock as well as uranium-vanadium processing at Uravan, Colorado. As much as 205,000 tons of salt annually enter the Dolores where it crosses Paradox Valley.

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