(200)
TE ...

MF32/GQ61

GEOLOGY OF THE CALAMITY MESA QUADRANGLE, MESA COUNTY, COLORADO

By Fred W. Cater, Jr.,
with a section on "The Mines" by Harold K. Stager

Not to be resource carded Robbins

Trace Elements Memorandum Report 693

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

(200)
16 ...

IN REPLY REFER TO:

File Copy

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON 25, D. C.

JAN 27 1954

AEC - 354/4

Dr. Phillip L. Merritt, Assistant Director
Division of Raw Materials
U. S. Atomic Energy Commission
P. O. Box 30, Ansonia Station
New York 23, New York

Dear Phil:

Transmitted herewith is one copy of TEM-693, "Geology of the Calamity Mesa quadrangle, Mesa County, Colorado," by Fred W. Cater, Jr., with a section on "The Mines" by Harold K. Stager, August 1953.

Mr. Hosted approved on August 27, 1953, our plan to publish this report in the Survey's Quadrangle Map Series.

Sincerely yours,

For W. H. Bradley
Chief Geologist

Geology and Mineralogy

This document consists of 36 pages, plus 1 figure.
Series A.

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

GEOLOGY OF THE CALAMITY MESA QUADRANGLE, MESA COUNTY, COLORADO*

By

Fred W. Cater, Jr.,

with a section on "The Mines" by

Harold K. Stager

August 1953

Trace Elements Memorandum Report 693

*This report concerns work done on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission.

GEOLOGY AND MINERALOGY

Distribution (Series A)	No. of copies
Division of Raw Materials, Washington	1
Division of Raw Materials, New York	1
Exploration Division, GJOO	1
Grand Junction Operations Office	1
Technical Information Service, Oak Ridge	1
U. S. Geological Survey:	
Geochemistry and Petrology Branch, Washington	1
Geophysics Branch, Washington	1
Mineral Deposits Branch, Washington	1
R. P. Fischer, Grand Junction	1
W. A. Fischer, Washington	1
TEPCO, Denver	1
TEPCO, RPS, Washington (Including master)	2
	13

CONTENTS

Page

Abstract 5

Introduction 6

Regional geology 7

Stratigraphy 8

Pre-Cambrian rocks 8

Cutler formation 9

Chinle formation 10

Glen Canyon group 11

Wingate sandstone 12

Kayenta formation 12

Navajo sandstone 13

San Rafael group 13

Carmel formation and Entrada sandstone 14

Summerville formation 15

Morrison formation 16

Salt Wash sandstone member 17

Brushy Basin shale member 18

Burro Canyon formation 19

Dakota sandstone 20

Quaternary alluvium and landslides 21

Structure 21

Regional setting 21

Structure in Calamity Mesa quadrangle 22

Structural history 23

CONTENTS--Continued

Page

Mineral deposits 26

Mineralogy 26

Ore bodies 27

Origin of ore 28

Suggestions for prospecting 30

The mines 31

Maverick mines 31

Arrowhead mines 32

Calamity mines 32

Outlaw mines 33

G-1 mine and Ronnie mine 33

Blue Creek mines 34

Other mines and prospects 34

Literature cited 34

ILLUSTRATION

Preliminary geologic map and section of
the Calamity Mesa quadrangle, Colorado . . . . In envelope

GEOLOGY OF THE CALAMITY MESA QUADRANGLE, MESA COUNTY, COLORADO

by Fred W. Cater, Jr., with a section on
"The Mines" by Harold K. Stager

ABSTRACT

The Calamity Mesa quadrangle is one of eighteen 7½-minute quadrangles covering the principal carnotite-producing area of southwestern Colorado. The geology of these quadrangles was mapped by the U. S. Geological Survey for the Atomic Energy Commission as part of a comprehensive study of carnotite deposits. The rocks exposed in the eighteen quadrangles consist of crystalline rocks of pre-Cambrian age and sedimentary rocks that range in age from late Paleozoic to Quaternary. Over much of the area the sedimentary rocks are flat lying, but in places the rocks are disrupted by high-angle faults, and northwest-trending folds. Conspicuous among the folds are large anticlines having cores of intrusive salt and gypsum.

Most of the carnotite deposits are confined to the Salt Wash sandstone member of the Jurassic Morrison formation. Within this sandstone, most of the deposits are spottily distributed through an arcuate zone known as the "Uravan Mineral Belt". Individual deposits range in size from irregular masses containing only a few tons of ore to large, tabular masses containing many thousands of tons. The ore consists largely of sandstone selectively impregnated and in part replaced by uranium and vanadium minerals. Most of the deposits appear to be related to certain sedimentary structures in sandstones of favorable composition.

INTRODUCTION

The U. S. Geological Survey mapped the geology of the Calamity Mesa quadrangle, Colo., as a part of a comprehensive study of carnotite deposits. The study, covering the principal carnotite-producing area in southwestern Colorado, included detailed examination of mines and geologic mapping of eighteen 7½-minute quadrangles, of which the Calamity Mesa quadrangle is one. Parts of the texts accompanying these maps have been standardized; these parts comprise some descriptions of geologic formations and general descriptions of regional structural setting, geologic history, and ore deposits. A comprehensive report presenting in greater detail the geologic features of the entire area and interpretations of these features is in preparation. Work was started in the area in 1939 as a cooperative project with the State of Colorado and the Colorado Metal Mining Fund, and was continued through 1945 as a wartime strategic minerals project. Since 1947 the Geological Survey has been continuing this geologic study on behalf of the Division of Raw Materials of the Atomic Energy Commission. The Calamity Mesa quadrangle was mapped in 1949.

The Calamity Mesa quadrangle covers about 58 square miles in Mesa County, Colo., and lies in the Canyon Lands division of the Colorado Plateau physiographic province. The quadrangle consists of two topographically contrasting areas; the one to the southwest is a country of canyons, benches, and flat-topped mesas; the one to the northeast is more precipitous and rugged and contains no sizable flat areas. Total relief within the quadrangle is about 3,300 feet; altitudes range from less than 4,900 feet on Blue Creek to 8,184 feet on Pine Hill. All the streams draining the quadrangle empty into the Dolores River a short distance west of the quadrangle.

No accurate information on rainfall is available, but the annual precipitation probably ranges from 10 inches in the lower altitudes to 20 inches in the higher; the quadrangle is semiarid and supports a moderate growth of juniper and piñon on rocky terrain at lower altitudes and scattered ponderosa pines at the highest altitudes. Sagebrush is abundant where soils are thick. Cacti and sparse grass are widely distributed. Most of the quadrangle is accessible over a system of dry-weather roads.

REGIONAL GEOLOGY

Rocks exposed in the 18 quadrangles mapped consist of crystalline pre-Cambrian rocks and sedimentary rocks that range in age from late Paleozoic to Quaternary. Crystalline rocks crop out only in the northeastern part of the area along the flanks of the Uncompahgre Plateau; the rest of the area is underlain by sedimentary rocks. The latest Paleozoic and earliest Mesozoic units wedge out northeastward against the crystalline pre-Cambrian rocks, but later Mesozoic units were deposited on top of the pre-Cambrian rocks. Over most of the region the sedimentary rocks are flat-lying, but in places they are disrupted by high-angle faults or folded into northwest-trending monoclines, shallow synclines, and strongly developed anticlines. The largest of the folds is the Uncompahgre Plateau uplift, a fold nearly 100 miles long that traverses the northeastern part of the area. Well-developed anticlines having intrusive cores of salt and gypsum underlie Sinbad Valley, Paradox Valley, and Gypsum Valley in the central part of the area; the Dolores anticline in the southwestern part of the area probably has a salt-gypsum core, although it is not exposed.

The Calamity Mesa quadrangle lies in the northern part of the 18-quadrangle area; the northeast corner of the quadrangle is traversed by the southwestern flank of the Uncompahgre Plateau. The steeply dipping beds in this flank have been carved into a series of "flatirons" such as Triangle Mesa and Pine Hill.

STRATIGRAPHY

The oldest rocks in the Calamity Mesa quadrangle are pre-Cambrian crystalline rocks that are exposed in the headwater areas of Mesa and Blue Creeks. Overlapping these crystalline rocks are sedimentary rocks of Permian (?) age. Lower Triassic rocks shown on the structure cross-section, do not crop out within the quadrangle, although they are exposed in nearby areas. Upper Triassic rocks crop out in the upper reaches of Mesa and Blue Creeks on the steep "flatirons" in the northeastern part of the quadrangle. Rocks of Jurassic age crop out on the "flatirons", in the canyons, and on mesas and benches flanking the canyons. The higher mesas are capped with Cretaceous rocks. Recent deposits of wind-blown material and sheet wash are widely distributed on the tops of mesas, and alluvium covers the floors of some of the valleys.

The stratigraphic sequence is similar to that studied by Baker (1933) and Dane (1935) in nearby areas in Utah; most of the formations can be traced continuously from the Calamity Mesa quadrangle into Utah.

Pre-Cambrian rocks

A complex of crystalline pre-Cambrian rocks, exposed along the upper reaches of Blue and Mesa Creeks, are the oldest rocks in the quadrangle. No attempt was made to outline on the map the various rocks in the complex because of their intricate interrelations. Most abundant of the rocks is a gray medium-grained gneissic granite. The foliation of this granite strikes in all directions but the dips are mostly vertical. Engulfed in this granite are small masses of quartzite, and hornblende and biotite schists and gneisses that have undergone varying degrees of assimilation. Intruded into this gneissic granite are dikes and irregular bodies of pink coarse-grained granite and dikes of pegmatite, aplite, and dark-colored rock that is altered largely to chlorite. The older, more abundant gneissic granite has been altered considerably in places, with the dark minerals being replaced by chlorite and epidote; the younger, pink granite appears to be essentially fresh. The entire complex in the Calamity Mesa quadrangle has been sheared, faulted, and crushed.

Schist and gneiss, probably belonging to the same series as the masses engulfed in the gneissic granite, are exposed in Unaweep Canyon a few miles north of the quadrangle; Peale (1877) believed these rocks to be of Archean age. Hunter (1925) assigned similar rocks in the nearby Gunnison River area to the Archean and the granitic intrusions to the Algonkian or early Paleozoic.

Cutler formation

The Permian (?) Cutler formation consists of maroon, red, mottled light-red, and purple cross-bedded arkose, arkosic sandstone, and conglomerate and lesser quantities of reddish-brown sandy mudstone. It crops out over small areas in Dark Canyon and in the upper part of the canyon of the North Fork of Mesa Creek; in both places it rests directly on pre-Cambrian rocks. Grains of fresh feldspar and dark minerals, pebbles and boulders of granite, gneiss, schist, and quartzite--material derived almost entirely from the pre-Cambrian--are mixed together in poorly sorted, rudely cross-bedded layers and lenses. Small amounts of reddish-brown sandy mudstone are distributed through the coarser material as thin irregular beds and seams that serve to delineate the otherwise obscure bedding.

The Cutler formation thickens from a knife-edge on the flank of the Uncompahgre Plateau to several thousand feet a few miles southwest of the uplift. A well drilled about 4 miles southwest of the knife-edge of the Cutler, in the canyon of the Dolores River near the town of Gateway, Colo., in the Gateway quadrangle to the west, penetrated more than 7,800 feet of red arkose before reaching the pre-Cambrian basement. This thick sequence of beds includes rocks probably not only of Permian age but of Pennsylvanian as well. Abrupt thinning of the formation toward its source area, coarseness of the material, and rude bedding all indicate that the Cutler in this area was deposited as a fanglomerate.

Chinle formation

Throughout most of the Colorado Plateau Upper Triassic rocks rest unconformably on older rocks. This relationship is strikingly evident in the Calamity Mesa quadrangle and nearby areas. Eastward toward the Uncompahgre Plateau, the Upper Triassic Chinle formation rests in turn first on the Lower Triassic Moenkopi formation, then on the Cutler formation, and finally, on the Uncompahgre Plateau, on pre-Cambrian rocks. Except for disturbances incident to later faulting and uplift, this erosion surface below the Chinle in the vicinity of the Uncompahgre Plateau is remarkably flat. In places, as on the North Fork of Mesa Creek along the eastern margin of the quadrangle, the upper several feet of pre-Cambrian rocks below the unconformity were thoroughly weathered during pre-Chinle time to a red plastic clay in which only the quartz of the parent rocks has been preserved. Elsewhere in the quadrangle decomposition either had not been so complete or the residual clay was stripped away.

In places a discontinuous bed of gypsum as much as 4 feet thick rests on the old surface and seems to have been deposited immediately before or during the earliest stages of the deposition of the Chinle.

The Upper Triassic Chinle formation consists of red to orange-red siltstone, with interbedded red fine-grained sandstone, shale, and limestone-pebble and mud-pellet conglomerate. These lithologic units are lenticular and discontinuous. The lower part of the formation contains numerous lenses of a highly distinctive limestone-pebble and clay-pellet conglomerate; in places the lowermost lenses contain quartz pebbles or consist of a relatively clean quartz grit. These quartz-bearing lenses are probably the stratigraphic equivalent of the Shinarump conglomerate, which is widely distributed in eastern Utah and northern Arizona. Much of the Chinle formation consists of indistinctly bedded red siltstone that breaks into angular fragments. Evenly bedded shale is rare. The sandstone layers differ in bedding characteristics; some layers are massive, whereas others are cross-bedded, and still others are conspicuously ripple-bedded. Almost everywhere the formation crops out as a steep slope broken in places by more resistant ledges of sandstone and conglomerate.

The Chinle formation is about 200 feet thick where exposed in the Calamity Mesa quadrangle, but along the Dolores River a mile or two west of the quadrangle the formation is more than 300 feet thick.

Glen Canyon group

The Glen Canyon group, of Jurassic (?) age, comprises, in ascending order, the Wingate sandstone, the Kayenta formation, and the Navajo sandstone.

Wingate sandstone

The Wingate sandstone conformably overlies the Chinle formation. The sandstone is a massive, fine-grained rock composed of clean, well-sorted quartz sand. It typically crops out as an impressive red, dark-brown wall, stained and streaked in places with a surficial red and black desert varnish. Vertical joints cut the sandstone from top to bottom; the spalling of vertically jointed slabs largely causes the recession of the cliff. The sandstone is divided into horizontal layers by extensive bedding planes spaced 2 to 50 feet apart. Within each horizontal layer the sandstone is cross-bedded on a magnificent scale; great sweeping tangential cross-beds of eolian type, in places extending across the entire thickness of the horizontal layer, are disposed in all directions. The sandstone is rather poorly cemented and crumbles easily; this quality probably accounts for the readiness with which the rock disintegrates in faulted areas.

In the Calamity Mesa quadrangle the Wingate sandstone ranges in thickness from about 300 to nearly 400 feet.

Kayenta formation

The Kayenta formation conformably overlies the Wingate sandstone; the contact between the two formations is gradational in most places. The formation is notable for its variety of rock types. Sandstone, red, buff, gray, and lavender in color, is the most abundant type; but the formation also contains considerable quantities of red siltstone, thin-bedded shale, and conglomerate. The conglomerate contains pebbles of sandstone, shale, and limestone. The sandstone is composed of rounded to subrounded quartz grains and minor quantities of mica, feldspar, and dark minerals. Most of the sandstone is thin-bedded, cross-bedded in part, and flaggy; some is massive.

Individual sandstone beds are lenticular and discontinuous and interfinger with shale and, in places, with conglomerate. The Kayenta typically crops out in a series of benches and ledges. The ledges in many places overhang recessions where softer beds have eroded back. The lower part of the formation is more firmly cemented and forms resistant, thick ledges that protect the underlying Wingate sandstone from erosion.

The Kayenta formation in the Calamity Mesa quadrangle ranges in thickness from less than 90 feet in the eastern part of the quadrangle to 220 feet along the west margin. Abrupt local changes in thickness of 10 to 20 feet are common. The irregular bedding, channel filling, and range of thickness all indicate a fluviatile origin.

Navajo sandstone

The Navajo sandstone conformably overlies the Kayenta formation. The Navajo is a gray to buff massive fine-grained clean quartz sandstone. Tangential cross-beds of tremendous size leave little doubt of the eolian origin of the sandstone. The sandstone weathers by disintegration and tends to develop rounded topographic forms where exposed on slopes or benches and vertical cliffs where protected by overlying rocks.

The Navajo sandstone occurs only in the western part of the quadrangle, where it ranges in thickness from a knife-edge to about 70 feet.

San Rafael group

In this area the San Rafael group, of Middle and Late Jurassic age, comprises, in ascending order, the Carmel formation, the Entrada sandstone, and the Summerville formation. The group crops out in a band along the canyon walls and along the base of the "flatirons" in the northeastern part of the quadrangle. The Carmel formation and the Entrada sandstone were mapped as a single unit because in most places they form a narrow outcrop.

Carmel formation and Entrada sandstone

The Carmel formation consists largely of red to buff, soft, horizontally bedded siltstone, mudstone, and sandstone. In some localities the basal beds consist of reworked Navajo sandstone. Pebbles and angular fragments of white and gray chert, as much as an inch across, are scattered rather abundantly through the lower part of the formation and less abundantly through the upper part. These chert pebbles and angular fragments are sufficiently abundant locally to form layers of conglomerate. Included in these layers are scattered greenish-gray, red, and yellow quartzitic pebbles and cobbles as large as 5 to 8 inches. In many places the upper part of the formation contains scattered barite nodules as much as an inch across.

The Carmel formation ranges from less than 10 feet to 90 feet in thickness. This large range appears to be due chiefly to deposition on irregular, eroded surfaces on the Navajo sandstone or the Kayenta formation. No definite evidence indicates that the Carmel formation in this area is of marine origin, as it is in central Utah, but the probabilities are that the Carmel of southwestern Colorado was deposited in shallow water marginal to a sea.

The Carmel formation grades upward, in most places without a prominent break, into the Entrada sandstone. The Entrada sandstone, known locally as the "slick rim" because of its appearance, is perhaps the most strikingly picturesque of all the formations in the plateau region of Colorado. The smoothly rounded, in places bulging, orange, buff, and white cliffs formed by this sandstone are a distinctive and scenic feature of the region. Horizontal rows of pits resulting from differential weathering and ranging from a few inches to a foot or more across are characteristic of these cliffs. The Entrada consists of alternating horizontally-bedded units and sweeping eolian-type cross-bedded units. The horizontally-bedded units are most common in the basal part and in the uppermost, lighter-colored part of the Entrada, whereas the cross-bedded units are dominant in the middle part. The Entrada sandstone differs from the somewhat similar Wingate sandstone and Navajo sandstone by the sorting of sand into two distinct grain sizes. Subrounded to subangular quartz grains mostly less than 0.15 mm in diameter make up the bulk of the sandstone. The sandstone also contains larger grains, which are well rounded, have frosted surfaces, and range from 0.4 to 0.8 mm in diameter; most of these grains are of quartz, but grains of chert are scattered among them. Most of the larger grains are distributed in thin layers along bedding planes.

The Entrada sandstone attains a thickness of nearly 200 feet on Blue Creek in the southwestern part of the quadrangle; it thins northward and eastward, and on Calamity Creek at the northern edge of the quadrangle is only about 100 feet thick.

Summerville formation

The Summerville formation generally crops out as a steep, debris-covered slope, with very few good exposures. Where exposed, the Summerville exhibits a remarkably even, thin, horizontal bedding. Beds are predominantly red of various shades, although some beds are green, gray, brown, light yellow, or nearly white. Sandy and silty shale predominate, but interbedded with the shale are claystone and fine-grained sandstone.

Well-rounded amber-colored quartz grains with frosted or matte surfaces are scattered through most of the formation, including those beds consisting almost entirely of claystone. Thin beds of autochthonous red and green chert are widespread. A thin, discontinuous bed of dark-gray dense fresh-water limestone occurs in the upper part of the formation. Sandstone beds are thicker and sandstone is more abundant in the lower part of the formation than in the upper part. Commonly the sandstone beds are ripple-marked, and in places they show small-scale low-angle cross-bedding. In the western part of the Calamity Mesa quadrangle these lowermost sandstone beds thicken and form a prominent ledge 25 to 35 feet thick. To the west, in Utah, these beds can be traced into the Moab tongue of the Entrada sandstone; to the south and east they grade into the sandstones and shales of the lower part of the Summerville. In this report these beds are included in the Summerville.

The Summerville formation rests conformably on the Entrada sandstone, and, although a sharp lithologic change marks the contact, deposition was probably continuous. The upper contact of the Summerville is uneven and channeled, and the channels are filled by the overlying basal sandstones of the Morrison formation. Locally, however, the contact is difficult to determine, because the overlying shale and mudstone of the Morrison formation are similar to beds of the Summerville.

The Summerville formation ranges in thickness from about 85 feet to about 95 feet.

Morrison formation

The Morrison formation, of Late Jurassic age, is of special interest economically because of the uranium- and vanadium-bearing deposits it contains.

The formation comprises two members in this area; the lower is the Salt Wash sandstone member and the upper is the Brushy Basin shale member. In the Calamity Mesa quadrangle the Morrison formation ranges in thickness from 600 to 700 feet. The Brushy Basin shale member in general is somewhat thicker than the Salt Wash.

Salt Wash sandstone member

The Salt Wash sandstone member ordinarily crops out above the slope-forming Summerville formation as a series of thick, resistant ledges and benches. Sandstone predominates and ranges in color from nearly white to gray, light buff, and rusty red. Interbedded with the sandstone are red shale and mudstone and locally a few thin lenses of dense gray limestone. Sandstone commonly occurs as strata traceable as ledges for considerable distances along the outcrop, but within each stratum individual beds are lenticular and discontinuous; beds wedge out laterally, and other beds occupying essentially the same stratigraphic position wedge in. Thus, any relatively continuous sandstone stratum ordinarily consists of numerous interfingering lenses, with superposed lenses in many places filling channels carved in underlying beds. Lenses are separated in places by mudstone and contain mudstone seams. Most of the sandstone is fine- to medium-fine-grained, cross-bedded, and massive; single beds or lenses may attain a maximum thickness of 120 feet. Ripple marks, current lineations, rill marks, and cut-and-fill structures indicate that the Salt Wash member was deposited under fluviatile conditions.

The sandstone consists largely of subangular to subrounded quartz grains, but orthoclase, microcline, and albite grains occur in combined amounts of 10 to 15 percent. Chert and heavy-mineral grains are accessory.

Considerable quantities of interstitial clay and numerous clay pellets occur in places, especially near the base of some of the sandstone lenses. Fossil wood, carbonaceous matter, and saurian bones occur locally.

The Salt Wash sandstone member ranges in thickness from 240 feet to about 360 feet in the Calamity Mesa quadrangle.

Brushy Basin shale member

The Brushy Basin shale member contrasts strongly in overall appearance with the underlying Salt Wash sandstone member. Although the lithologic differences are marked, the contact between the two members is gradational. The mapped contact, taken as the base of the lowermost layer of conglomerate lenses, is arbituary in many respects and probably does not mark an identical stratigraphic horizon in all localities.

The Brushy Basin shale member consists predominantly of varicolored bentonitic shale and mudstone, with intercalated beds and lenses of conglomerate and sandstone, and a few thin layers of limestone. Because of its high proportion of soft, easily eroded bentonitic shale and mudstone, the Brushy Basin member forms smooth slopes covered with blocks and boulders weathered from the more resistant layers of the member and from the overlying formations. The shale and mudstone are thin-bedded and range in color from pure white to pastel tints of red, blue, and green. Exposed surfaces of the rock are covered with a loose, fluffy layer several inches thick, caused by the swelling of the bentonitic material during periods of wet weather. Scattered through the shale and mudstone are thin beds of fine-grained hard silicified rock that breaks with a conchoidal fracture. The silica impregnating these beds may have been released during the devitrification of volcanic debris in adjacent beds. Beds of chert-pebble conglomerate, a few inches to 25 feet thick, occur at intervals throughout the member. These conglomerate beds are commonly dark rusty red and form conspicuous resistant ledges. Silicified saurian bones and wood are much more abundant in the Brushy Basin shale member than in the Salt Wash sandstone member, especially in some of the conglomerate beds.

The Brushy Basin shale member, like the Salt Wash sandstone member, undoubtedly was deposited under subaerial conditions. The conglomerate and sandstone lenses mark stream channels that crossed flood plains on which were deposited the fine-grained sediments now represented by the mudstone and shale.

The Brushy Basin shale member ranges from 300 to 400 feet in thickness; local variations in thickness of 20 to 30 feet are common throughout the quadrangle.

Burro Canyon formation

The name Burro Canyon formation was proposed by Stokes and Phoenix (1948) for the heterogeneous sequence of Lower Cretaceous conglomerate, sandstone, shale, and thin lenses of limestone that overlies the Morrison formation. The Burro Canyon characteristically crops out as a cliff or a series of thick, resistant ledges that cap most of the high mesas in the quadrangle. The bulk of the formation consists of white, gray, and red sandstone and conglomerate that form beds up to 100 feet thick. These beds are massive, irregular, and lenticular. Cross-bedding and festoon-bedding are prevalent throughout the formation. The sandstone is poorly sorted and consists of quartz and lesser amounts of chert. The conglomerate consists largely of chert pebbles, but intermixed are pebbles of quartz, silicified limestone, quartzite, sandstone, and shale. In places beds are highly silicified. A considerable part of the formation consists of bright-green mudstone and shale, and locally these predominate over the sandstone and conglomerate. Thin, discontinuous beds of dense gray limestone crop out in a few scattered localities. The formation was undoubtedly deposited under fluviatile conditions. The lower contact is indistinct in many places and appears to interfinger with the upper part of the Brushy Basin shale member; elsewhere local erosion surfaces intervene and the contact is sharp. The upper contact is an erosion surface of regional extent.

In the Calamity Mesa quadrangle the Burro Canyon formation is 120 to 140 feet thick.

Dakota sandstone

The Dakota sandstone, of Early and Late Cretaceous age, crops out as capping beds on Blue and Long Mesas. The Dakota consists principally of gray, yellow, and buff flaggy sandstone; less abundant are conglomerate, carbonaceous shale, and impure coal. Some of the sandstone is fine-grained and thin-bedded, but much of it is coarse-grained and cross-bedded. Scattered through the sandstone are irregular, discontinuous beds and lenses of conglomerate containing chert and quartz pebbles as much as 2 inches across. Interfingering with the sandstone beds are thin-bedded gray and black carbonaceous shale and thin coal seams and beds. Plant impressions are abundant in both the sandstone and the shale. The entire thickness of the Dakota sandstone is not exposed in the quadrangle; the upper beds have been stripped off by erosion, but the beds that remain attain a maximum thickness of about 40 feet.

Quaternary alluvium and landslides

The deposits of Quaternary age consist of wind-deposited material, alluvium, talus, and landslide material. Extensive deposits of light-red sand and silty material mantle the benches and mesa tops. This material appears to be mostly wind-deposited, although much of it has been reworked by water and intermixed with sheet wash. These deposits have not been mapped where they are unusually spotty, discontinuous, or less than a foot thick; the greatest observed thicknesses in some dry washes on mesa tops are about 10 feet. Gravel and alluvium occur in some of the stream beds. Considerable talus covers many of the steeper slopes. Because these various deposits are difficult to differentiate in some places, they have not been separated on the geologic map. Landslides consisting largely of Brushy Basin debris are prominent along the sides of Little Maverick Canyon.

STRUCTURE

Regional setting

Many geologic structures on the Colorado Plateau are so large that a $7\frac{1}{2}$-minute quadrangle covers only a small part of any complete structural unit. The larger structural units consist of salt anticlines, 45 to 80 miles long; uplifted blocks, 50 to 125 miles long, bounded by monoclinal folds; and domical uplifts, 8 to 20 miles across, around stock-like and laccolithic intrusions.

The salt anticlines trend northwest and lie in a group between eastward-dipping monoclines on the west side of the Plateau and westward-dipping monoclines on the east side of the Plateau. The cores of these anticlines consist of relatively plastic salt and gypsum, derived from the

Paradox member of the Pennsylvanian Hermosa formation and intruded into overlying late Paleozoic and early Mesozoic rocks. All the anticlines are structurally similar in many respects, but each exhibits structural peculiarities not common to the rest; furthermore, all are more complex than their seemingly simple forms would suggest. Faults, grabens, and collapse and slump structures alter the forms of the anticlines. Erosion has removed much of the axial parts of these anticlines, leaving exposed large intrusive masses of the Paradox member and forming valleys such as Sinbad Valley, Paradox Valley, and Gypsum Valley in Colorado and similar valleys in Utah. Alternating with these anticlines are broad, shallow, simple synclines.

Structure in Calamity Mesa quadrangle

Two large structural features cross the Calamity Mesa quadrangle; these are the Dolores River syncline in the southwest part of the quadrangle, and the monoclinal fold fronting the Uncompahgre Plateau uplift in the northeast part. Over most of the quadrangle the beds dip less than 4°, but along the monocline dips steepen locally to as much as 30°. Because of the somewhat sinuous trends of both the Dolores River syncline and the monocline, the strikes of beds differ more than is normal elsewhere in the region. The Dolores River syncline trends irregularly northwest and plunges southeast about 1°. The monoclinal fold, where it enters the east edge of the quadrangle, trends northwest; near Mesa Creek it swings north, and where it leaves the north edge of the quadrangle it again turns northwestward. In places this fold is cut by normal faults that dip steeply westward. These faults probably are connected at depth. In the extreme northeast corner of the quadrangle is a northwest-trending fault that borders the southwest side of the Ute Creek graben, a prominent structural feature of the area immediately north of the Calamity Mesa quadrangle. Two other small northwest-trending normal faults that probably are related to the uplift of the Uncompahgre Plateau have been mapped near Calamity Camp and near the center of the quadrangle on Blue Creek.

Structural history

In order to understand the structural history of the Calamity Mesa quadrangle, it is necessary to understand the structural history of the adjoining part of southwestern Colorado. Parts of this history are still in doubt, because no clear record remains of some events; the record of other events, although legible, is subject to different interpretations. All the events described in the following discussion affected the Calamity Mesa quadrangle either directly or indirectly, although the evidence for some of them is not visible within the boundaries of the quadrangle.

Weak compressive forces, which probably began in early Pennsylvanian times, gently warped the region. This warping gave rise to the ancestral Uncompahgre highland, an element of the ancestral Rocky Mountains, and to the basin in which the Paradox member of the Hermosa formation was deposited. These major structural features controlled the pattern and the prevailing northwest-trending grain of the smaller structures later superimposed on them. The boundary between the highland and the basin, which is closely followed by the southwest margin of the present-day Uncompahgre Plateau, was a steep northwest-trending front, possibly a fault scarp, along which were deposited arkosic fanglomerates during late Pennsylvanian and Permian time. The older fanglomerates interfinger with Pennsylvanian marine sedimentary rocks of the Hermosa formation. The bulk of the fanglomerates probably is of Permian age and belong to the Cutler formation. Intrusion of salt from the Paradox member probably initiated by gentle regional deformation, began sometime during deposition of the Permian Cutler formation. Isostatic rise of salt ruptured the overlying Hermosa and Cutler formations, and at the end of Cutler deposition salt broke through to the surface. From then until flowage ceased, late in the Jurassic, the elongate salt intrusions such as those in Paradox Valley and Gypsum Valley stood as actual topographic highs at one place or another along their lengths. The rate of upwelling of additional salt, perhaps accelerated by the increase of the static load of sediments accumulating in the surrounding areas, balanced or slightly exceeded the rate of removal of salt by solution and erosion at the surface. Consequently, all the Mesozoic formations to the base of the Morrison formation wedge out against the flanks of the salt intrusions. Salt flowage was not everywhere continuous or at a uniform rate; rather, in many places it progressed spasmodically. Local surges of comparatively rapid intrusion gave rise to cupolas at different times and in different places along the salt masses. At the beginning of Morrison deposition sediments finally covered the salt intrusions, perhaps because the supply of salt underlying the areas between the intrusions was exhausted. Relative quiescence prevailed throughout the remainder of the Mesozoic and probably through the early part of the Tertiary.

The second major period of deformation occurred in the Tertiary--probably during the Eocene (Hunt, written communication). The region of the salt intrusions was compressed into a series of broad folds, guided and localized by the pre-existing salt intrusions. Although salt flowage was renewed, it seems unlikely that any considerable amount of new salt was forced into the intrusions; flowage probably consisted largely of redistribution of the salt already present. By the end of this period of deformation these folds had attained approximately their present structural form, except for modifications imposed by later collapse of the anticlines overlying the salt intrusions. Owing to the mobility of the rocks in the cores of the anticlines, normal faulting took place along the crests of the anticlines, probably during relaxation of compressive stresses after folding ceased. At this time the crests of the anticlines in places were dropped, as grabens, several hundred to a few thousand feet. A period of crustal quiescence followed, during which the highlands overlying the anticlines and domes were reduced by erosion and topographic relief became low throughout the area.

Then, during the middle Tertiary, the entire Colorado Plateau was uplifted. This uplift rejuvenated the streams and increased ground-water circulation. The crests of the anticlines were breached, and the underlying salt was exposed to rapid solution and removal. With the abstraction of salt, renewed collapse of the anticlines began. Although much of the collapse was due directly to removal of salt by solution, it seems unlikely that all the collapse can be attributed to this process, as was believed by earlier workers in the area. Rather, much of the collapse apparently was caused by flowage of salt from the parts of the anticlines still overlain by thick layers of sediments to the parts from which the overlying sediments had been removed. Once the crests of the anticlines had been breached, the relatively plastic salt offered little support for the beds overlying the Paradox member in the flanks of the anticlines; consequently these essentially unsupported beds slumped, probably along fractures and joints formed during earlier flexures. Small faults and folds in Quaternary deposits may indicate that collapse and local readjustments are still continuing.

MINERAL DEPOSITS

The only commercially important mineral deposits in the Calamity Mesa quadrangle are those that contain uranium, vanadium, and radium. Although deposits containing these metals were discovered in 1899 near Roc Creek, about 5 miles south of the Calamity Mesa quadrangle, intensive mining of these ores did not begin in the Plateau region until 1911. Thereafter the ores were mined primarily for their radium content until 1923, when the Belgian Congo pitchblende deposits began to supply radium. The mines were mostly idle from 1923 until 1937, but since 1937 they again have been exploited intensively, first for vanadium and in more recent years for both vanadium and uranium.

Most of the deposits are restricted to the upper layers of sandstone lenses in the Salt Wash sandstone member of the Morrison formation, but within this layer the deposits have a spotty distribution. Ore bodies range from small, irregular masses, containing only a few tons of ore, to large tabular masses, containing many thousands of tons; but most ore bodies are small and contain only a few hundred tons. The ore consists mainly of sandstone impregnated with uranium- and vanadium-bearing minerals.

Mineralogy

The most common ore minerals are carnotite and a fine-grained, vanadium-bearing, micaceous mineral. Carnotite ($K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$) is a yellow, fine-grained, earthy or powdery mineral. Tyuyamunite ($Ca(UO_2)_2(VO_4)_2 \cdot nH_2O$), the calcium analogue of carnotite, is also present and is nearly indistinguishable from carnotite. The micaceous vanadium mineral, which formerly was thought to be roscoelite, is now considered to be related to the nontronite or montmorillonite group of clay minerals. It forms aggregates of minute flakes coating or partly replacing sand grains and filling pore spaces in the sandstone. It colors the rock gray. Other vanadium ore minerals present are montroseite ($nFeO{\cdot}nV_2O_4{\cdot}nV_2O_3{\cdot}nH_2O$), corvusite ($V_2O_4{\cdot}6V_2O_5{\cdot}nH_2O$), hewettite ($CaO{\cdot}3V_2O_5{\cdot}9H_2O$), pascoite ($2CaO{\cdot}3V_2O_5{\cdot}11H_2O$), and rossite ($CaO{\cdot}V_2O_5{\cdot}4H_2O$). Corvusite and montroseite occur together, forming compact masses of bluish-black ore; hewettite commonly forms bright-red stringers and veinlets along joints and fractures; and pascoite and rossite form bright-orange and yellow efflorescent coatings on protected surfaces where vanadium-bearing ground water evaporates. Recent deeper drilling and mining in the Plateau have indicated that below the zone of oxidation black oxides of uranium and vanadium, accompanied by pyrite and perhaps other sulfides, are more abundant, and uranyl vanadates are scarce or absent.

Ore bodies

The ore consists mostly of sandstone selectively impregnated and in part replaced by uranium and vanadium minerals; but rich concentrations of carnotite and the micaceous vanadium clay mineral also are associated with thin mudstone partings, beds of mudstone pebbles, and carbonized fossil plant material. Many fossil logs replaced by nearly pure carnotite have been found. In general the ore minerals were deposited in irregular layers that roughly followed the sandstone beds. In most deposits the highest grade concentrations of ore minerals occur in sharply bounded, elongate concretionary structures, called "rolls" by the miners. These rolls are encompassed by rich, veinlike concentrations of the micaceous vanadium-bearing clay mineral that curve across bedding planes. Within these rolls this mineral generally is distributed as diffusion layers, the richer layers commonly lying nearer the margins of the rolls; the distribution of carnotite in the rolls is less systematic.

The ore bodies range from small irregular masses containing only a few tons of ore to large tabular masses containing many thousands of tons of ore. Margins of ore bodies may be vaguely or sharply defined. Vaguely defined margins may have mineralized sandstone extending well beyond the limits of commercial ore; on the other hand, sharply defined margins, such as occur along the surfaces of rolls ordinarily mark the limits of both the mineralized sandstone and the commercial ore.

Although many rolls are small and irregular, the larger ones are elongate and may extend with little change of direction for more than 100 feet. The elongate rolls in an ore body or group of ore bodies in a given area generally have a common orientation. This orientation is roughly parallel to the elongation of the ore bodies.

Origin of ore

The origin of the uranium-vanadium ores in the Morrison formation is uncertain and controversial. In some respects the deposits are unique, and much of the evidence concerning the genesis of the ore is either not conclusive or appears to be contradictory. In this brief account only a small amount of evidence can be presented and the hypotheses can only be summarized.

Most of the deposits are closely associated with certain sedimentary features. Layers of ore lie essentially parallel to the bedding; most of the deposits occur in the thicker parts and commonly near the base of the sandstone lenses; the trend of the long direction of the deposits and the trend of the ore rolls in the sandstone are roughly parallel to the trend of the fossil logs in the sandstone and to the average or resultant dip of the cross-bedding in the sandstone. These relations strongly suggest that primary structures in the sediments were instrumental in localizing most of the ore deposits.

Recent investigations have revealed new data bearing on the origin of the ores (Waters and Granger, 1953). Below the zone of oxidation some of the ore consists chiefly of oxides, such as pitchblende and low-valent oxides or vanadium, and small quantities of sulfides such as pyrite, bornite, galena, and chalcopyrite; fully oxidized and fully hydrated minerals are either rare or nonexistent. A hard variety of uraninite, previously reported only from hydrothermal deposits, has been found in the Grey Dawn mine in San Juan County, Utah (Rasor, 1952), and in the Happy Jack mine in White Canyon, Utah. Studies of lead-uranium ratios in ores from the Colorado Plateau indicate that, regardless of where or in what formation found, all the ores are of roughly the same age, and this age is no older than latest Cretaceous (Stieff and Stern, 1952). Some geologists believe field relations in pre-Morrison formations at White Canyon (Benson et al., 1952) and Temple Mountain in Utah indicate that the deposits may be genetically related to faults and fractures. At the Rajah mine near Roc Creek in Colorado, ore occurs along a fault and horsetails out into the wall rock.

Two main hypotheses have arisen to explain the origin of the ores. The oldest and probably the most widely held is the hypothesis that the ores are penesyngenetic and were formed soon after the enclosing rocks were deposited (Coffin, 1921; Hess, 1933; Fischer, 1937, 1942, 1950; and Fischer and Hilpert, 1952). Later movements of ground water may have dissolved and reprecipitated the ore constituents, but the essential materials were already present in the host rocks or in the waters permeating them. Although this hypothesis offers a reasonable explanation for the relation of ores to sedimentary features, it faces some difficulty in explaining: (1) the discrepancy between the age of the uranium and the age of the enclosing rock; (2) the broad stratigraphic distribution of uranium occurrences and association of ores with fractures in a few localities; and (3) the hydrothermal aspect of the mineral suites in some ores. The second hypothesis, and the one the authors favor, is essentially a telethermal hypothesis and assumes the ore to have originated from a hypogene source. Proponents of this hypothesis believe that ore-bearing solutions, originating at depth from an igneous source, ascended along fractures. After these solutions mingled with circulating ground waters, the minerals were precipitated in favorable beds as much as several miles from the fractures. This hypothesis explains more readily the difficulties inherent in the penesyngenetic hypothesis, but poses two other difficulties, namely, the hypothetical location of igneous source rocks, and the difficulty of proving the connection between fractures and faults and the ore deposits. A third hypothesis, advanced by some geologists, suggests that the source of the ore metals was the volcanic material in the beds overlying the ore-bearing sandstones and that these metals were subsequently leached and redeposited in the beds that now contain the ore. This hypothesis encounters not only most of the difficulties in the penesyngenetic hypothesis, but it presents some additional ones of its own.

Suggestions for prospecting

Regardless of the actual origin of the deposits, certain habits of the deposits--habits that have been recognized through geologic mapping and exploration experience--are useful as guides for finding ore (Weir, 1952). In southwestern Colorado most of the deposits are in the uppermost sandstone stratum in the Salt Wash sandstone member of the Morrison formation. Generally the central or thicker parts of the sandstone lenses are more favorable--many deposits are in sandstone that is 40 feet or more thick, few deposits are in sandstone less than 20 feet thick. Cross-bedded, relatively coarse-grained sandstone is more favorable than thinly or evenly bedded, fine-grained sandstone. Light yellow-brown sandstone speckled with limonite stain is more favorable than red or reddish-brown sandstone. Sandstone that contains considerable amounts of gray, altered mudstone or is underlain by a considerable thickness of this rock is more favorable than sandstone containing and underlain by red, unaltered mudstone--this guide is perhaps the most useful in diamond-drill exploration. If the deposits have a hypogene origin, then localities where favorable host rocks are near or coextensive with areas of more intense deformation may be especially favorable for finding ore.

In the Calamity Mesa quadrangle probably the most likely area for finding ore, because of the presence of favorable host rocks, is a zone lying diagonally across the quadrangle, including the north end of Calamity Mesa, most of Outlaw Mesa, and the area north of Moon Mesa. In the Calamity Mesa quadrangle the small faults on Calamity and Blue Creeks are in areas of generally favorable host rocks.

The mines

by Harold K. Stager

Maverick mines

The Maverick mines are among the most productive in the Calamity Mesa quadrangle. These mines, which include the Hidden Treasure and Small Spot mines, are in two large deposits near the base of the top sandstone lens of the Salt Wash sandstone member of the Morrison formation. The ore bodies that occur as irregular tabular masses are as much as 600 feet long and 200 feet wide and range from a few inches to 20 feet in thickness. Rolls and fossil logs are common. The fossil logs, and in some places seams of coaly material as much as 6 inches thick, are richly mineralized. Associated with the micaceous vanadium clay mineral are commercially important quantities of the commonly less abundant vanadium minerals--montroseite, corvusite, pascoite, and hewettite. Carnotite is common, but the ores contain other unidentified uranium minerals that raise the uranium content of the ores to a much higher level than is normal for the Colorado Plateau. Gypsum occurs as fracture fillings and is commonly replaced by the yellow vanadium mineral rossite.

Arrowhead mines

The ore deposits at the Arrowhead mines, located between the Maverick and Calamity mines, are in an essentially continuous thin layer of mineralized material with local thickenings and rolls. The deposits are in the lower part of the top sandstone lens of the Salt Wash sandstone member. The ore minerals are carnotite and the micaceous vanadium mineral. Montroseite, corvusite, and hewettite are present but are not as abundant as in the deposits of the Maverick mines. High grade pockets of carnotite are characteristic of the deposits.

Calamity mines

The ore deposits at the Calamity mines more nearly resemble the common type of deposit found in the Salt Wash sandstone member. Deposits occur in the lower part of the top sandstone lens of the Salt Wash sandstone member. The ore bodies are irregular tabular masses as much as 800 feet long and 300 feet wide. Rolls and fossil logs are common. The ore minerals are carnotite and the micaceous vanadium mineral. Montroseite, corvusite, hewettite, and pascoite, abundant in the Maverick mines, are rare or absent. The deposits of the Calamity mines are well known for large richly mineralized fossil logs.

Outlaw mines

The ore deposits at the Outlaw mines, located along the north rim of Outlaw Mesa, are small but of high grade. The deposits are in the lower part of the top sandstone lens of the Salt Wash sandstone member. Rolls and fossil logs are common and the logs generally are richly mineralized. The ore minerals are carnotite and the micaceous vanadium mineral. High grade pockets of carnotite, commonly associated with fossil logs, are characteristic of the deposits.

G-1 mine and Ronnie mine

The largest mine in the Calamity Mesa quadrangle is the G-1 mine on Outlaw Mesa. The deposit, which is being exploited by the G-1, Ronnie, and several other smaller mines, is a single large mineralized mass that ranges from a few inches to more than 30 feet in thickness and is essentially continuous for a length of 2,500 feet and a width of 1,200 feet. The deposit is near the middle of the upper sandstone lens of the Salt Wash sandstone member. Rolls and fossil logs are present but are not as common as in the deposits of the Calamity group of mines. The ore minerals are carnotite and the micaceous clay mineral. Size and thickness make this deposit unique among deposits in the Morrison formation.

Blue Creek mines

The ore deposits at the Blue Creek mines are small in size and spotty in distribution. Small rolls and fossil logs are common. The ore minerals are carnotite and the micaceous vanadium mineral.

Other mines and prospects

Many other small mines and prospects are scattered along the outcrops of the Morrison formation, especially in the southeastern part of Outlaw Mesa and in the northern part of Blue and Moon Mesas. In the southeastern part of Outlaw Mesa and in the northern part of Blue and Moon Mesas, most of the deposits occur in the uppermost sandstone of the Salt Wash sandstone member, but deposits are not so closely confined to the lens as they are elsewhere in the quadrangle. In general, deposits in the lower beds of the Salt Wash sandstone member are small and of low grade. The principal ore mineral is the micaceous vanadium mineral; carnotite is scarce or absent.

On the north end of Blue Mesa a few well developed rolls have been mined but fossil logs are rare. The ore from most of these rolls was of low grade and contained excessive amounts of lime, which resulted in penalties or in refusal of the ore at the mills.

LITERATURE CITED

Baker, A. A., 1933, Geology and oil possibilities of the Moab district, Grand and San Juan Counties, Utah: U. S. Geol. Survey Bull. 841, 95 p.

Benson, W. E., Trites, A. F., Jr., Beroni, E. P., and Feeger, J. A., 1952, Preliminary report on the White Canyon area, San Juan County, Utah: U. S. Geol. Survey Circ. 217, 10 p.

Coffin, R. C., 1921, Radium, uranium, and vanadium deposits of southwestern Colorado: Colorado Geol. Survey Bull. 16, 231 p.

LITERATURE CITED--Continued

Dane, C. H., 1935, Geology of the Salt Valley anticline and adjacent areas, Grand County, Utah: U. S. Geol. Survey Bull. 863, 184 p.

Fischer, R. P., 1937, Sedimentary deposits of copper, vanadium-uranium, and silver in southwestern United States: Econ. Geology, v. 32, no. 7, p. 906-951.

______________, 1942, Vanadium deposits of Colorado and Utah, a preliminary report: U. S. Geol. Survey Bull. 936-P, p. 363-394.

______________, 1950, Uranium-bearing sandstone deposits of the Colorado Plateau: Econ. Geology, v. 45, no. 1, p. 1-11.

Fischer, R. P., and Hilpert, L. S., 1952, Geology of the Uravan mineral belt: U. S. Geol. Survey Bull. 988-A, p. 1-13.

Hess, F. L., 1933, Uranium, vanadium, radium, gold, silver and molybdenum sedimentary deposits: Ore deposits of the Western States (Lindgren volume), p. 450-481, Am. Inst. Min. Met. Eng.

Hunter, J. F., 1925, Pre-Cambrian rocks of Gunnison River, Colorado: U. S. Geol. Survey Bull. 777, 94 p.

Peale, A. C., 1877, Geological report on the Grand River district: U. S. Geol. Survey Terr. Ann. Rept., p. 64-69.

Rasor, C. A., 1952, Uraninite from the Grey Dawn mine, San Juan County, Utah: Science, v. 116, no. 3004, p. 89-90.

Stieff, L. R., and Stern, T. W., 1952, Lead-uranium ages of some uraninites from Triassic and Jurassic sedimentary rocks of the Colorado Plateau (abs.): Geol. Soc. America Bull., v. 63, no. 12, p. 1299-1300.

Stokes, W. L., and Phoenix, D. A., 1948, Geology of the Egnar-Gypsum Valley area, San Miguel and Montrose Counties, Colo.: U. S. Geol. Survey Prelim. Oil and Gas Inv. Map 93.

Waters, A. C., and Granger, H. C., 1953, Volcanic debris in uraniferous sandstone and its possible bearing on the origin and precipitation of uranium: U. S. Geol. Survey Circ. 224, 26 p.

Weir, D. B., 1952, Geologic guides to prospecting for carnotite deposits on the Colorado Plateau: U. S. Geol. Survey Bull. 988-B, p. 15-27.

LIST OF GOVERNMENT OWNED CLAIMS

1. Sunflower
2. Lost Treasure
3. Hidden Treasure
4. Queen of the Hills
5. Matchless
6. Triumph
7. Mammoth
8. Hummer
9. Calamity No. 24
10. Cracker Jack
11. Calamity No. 9
12. Calamity No. 8
13. Calamity No. 7
14. Calamity No. 23
15. Calamity No. 17
16. Calamity No. 13
17. Calamity No. 18
18. Calamity No. 28
19. Calamity No. 26
20. Calamity No. 25
21. Empire
22. Calamity No. 6
23. Calamity No. 20
24. Calamity No. 27
25. Calamity No. 22
26. Calamity No. 11
27. Dixie
28. Calamity No. 5
29. Calamity No. 21
30. Calamity No. 2
31. Triangle
32. Calamity No. 1
33. Calamity No. 3
34. Calamity No. 10
35. Lucky Boy
36. Blunder
37. Calamity No. 15
38. Calamity No. 14
39. Neglected