GEOLOGY

OF THE

BULL CANYON QUADRANGLE, COLORADO

By Fred W. Cater, Jr.

of these features is in preparation. formation or the Permian Cutler for-

Work was started in the area in 1939 mation, although all crop out in near- The Navajo sandstone ranges in part of the Entrada and the lower Beds of chert-pebble conglomerate, as a cooperative project with the by areas. Colorado Geological Survey Board and the Colorado Metal Mining Fund.

REGIONAL GEOLOGY Rocks exposed in the 18 quadran- Valley and Paradox Valley anticlines. an inch across. gles mapped consist of crystalline rocks of pre-Cambrian age and sedithe flanks of the Uncompangre Plasandstone.

STRATIGRAPHY ilar to that studied by Baker (1933) places, with conglomerate. The good exposures the Summerville ex- taken as the base of the lowermost alluvium, talus debris, and landslides.

The U. S. Geological Survey map- end of the aerial tramway from the ness from 190 to 230 feet, except on disseminated throughout most of the eroded bentonitic shale and mudstone. ped the geology of the Bull Canyon Jo Dandy mine. The outcrop is small the wall of Paradox Valley below the formation, including those beds conquadrangle, Colo., in connection with and is composed of massive sandy Jo Dandy mine, where it wedges out sisting almost entirely of claystone. covered with blocks and boulders a comprehensive study of carnotite cellular gypsum. In exposures out- entirely. Abrupt local changes in Thin beds of autochthonous red and weathered from the more resistant deposits. The study, covering the side the Bull Canyon quadrangle, the thickness of 10 to 20 feet are comprincipal carnotite-producing area in Paradox member contains considera- mon. The irregular bedding, chan- discontinuous bed of dark-gray dense overlying formations. The shales southwestern Colorado, included de- ble black shale and gray sandstone, nel filling, and range of thickness all fresh-water limestone occurs in the and mudstones are thin-bedded and tailed examination of mines and geo- and at depth, below the zone of indicate a fluviatile origin. upper part of the formation. Sand- range in color from pure white to paslogic mapping of eighteen 7½-minute leaching, salt is the most abundant Navajo sandstone.—The Navajo stone beds are thicker and sandstone tel tints of red, blue, and green. Exquadrangles, of which the Bull Cansingle constituent. Beds of the Parsandstone conformably overlies the is more abundant in the lower part posed surfaces of the rock are covered yon quadrangle is one. Parts of the adox member are so highly contorted Kayenta formation. The Navajo is of the formation than in the upper with a layer of loose, fluffy material texts accompanying these maps have that neither the stratigraphic se- a gray to buff massive fine-grained part. Commonly the sandstone beds several inches thick, caused by the been standardized; these parts com- quence nor the true thickness can be clean quartz sandstone. Tangential are ripple-marked, and in places they swelling of the bentonitic material prise some descriptions of geologic determined accurately. Baker (1933, cross-beds of tremendous size leave show small-scale low-angle cross- during periods of wet weather. Scatformations and general descriptions pp. 17-18) and Dane (1935, pp. 27-29) little doubt of the eolian origin of the bedding. of regional structural setting, geo- assigned the Paradox to the lower sandstone. The sandstone weathers The Summerville formation rests are thin beds of fine-grained very logic history, and ore deposits. A Pennsylvanian. The upper or lime- by disintegration and tends to devel- conformably on the Entrada sand- hard silicified rock that breaks with comprehensive report presenting in stone member of the Hermosa forma- op rounded topographic forms where stone, and, although a sharp lithologic a conchoidal fracture. The silica imgreater detail the geologic features tion is not exposed within the quad- exposed on slopes or benches, and ver- change marks the contact, no cessa- pregnating these beds may have been of the entire area and interpretations rangle, nor is the Permian (?) Rico tical cliffs where protected by over-tion of deposition separated the two released during the devitrification of

CHINLE FORMATION and was continued through 1945 as a The Upper Triassic Chinle formathe east and north, and is absent in horizon. The upper contact of the monly dark rusty red and form conwartime strategic minerals project. tion consists of red to orange-red the area between Wild Steer Canyon Summerville is uneven and channeled, spicuous resistant ledges. Silicified Since 1947 the Geological Survey has siltstone, with interbedded red fine- and the walls of Paradox Valley. and the channels are filled by the saurian bones and wood are much been continuing this geologic study on grained sandstone, shale, and limebehalf of the Atomic Energy Commis-stone pebble-clay pellet conglomerate. sion. A small part of the Bull Canyon These lithologic units are lenticular In this area the San Rafael group, ever, the contact is difficult to deter-sandstone member, especially in some quadrangle was mapped in 1944; the and discontinuous. The lower part of Middle and Late Jurassic age, commine, because the overlying shales of the conglomerate beds. The Bull Canyon quadrangle covers lenses of a highly distinctive lime-formation, the Entrada sandstone, mation are similar to beds of the like the Salt Wash sandstone memabout 59 square miles in Montrose stone pebble-clay pellet conglomerate; and the Summerville formation. The Summerville. and San Miguel Counties, Colo., and in places the lowermost lenses contain group crops out in a narrow band The Summerville formation has a der subaerial conditions. The conlies in the Canyon Lands physio- quartz pebbles or consist of a along the canyon walls and on the moderately uniform thickness of glomerate and sandstone lenses mark graphic division of the Colorado Pla- relatively clean quartz grit. These sides of Paradox Valley and Gypsum about 105 feet except where it thins stream channels that crossed floodteau. The western part of the quad- quartz-bearing lenses are probably Valley. The Carmel formation was on the flanks of the Gypsum Valley plains on which were deposited the

rangle is a rugged area of mesas and the stratigraphic equivalent of the mapped with the Entrada sandstone and Paradox Valley anticlines. fine-grained sediments now reprecanyons, whereas the eastern part is Shinarump conglomerate, which is because it is thin and is gradational relatively flat and featureless. Total widely distributed in eastern Utah into the Entrada. relief within the quadrangle is about and northern Arizona. Much of the Carmel formation and Entrada The Morrison formation, of Late ranges from 350 to 500 feet in thick-1,900 feet; altitudes range from about Chinle formation consists of indis-5,320 feet in the canyon of the Dolores tinctly bedded red siltstone that consists largely of red to buff, soft, economically because of the uranium-riations in thickness of 20 to 30 feet River to 7,175 feet on Wedding Bell breaks into angular fragments. horizontally bedded siltstone, mud- and vanadium-bearing deposits it con- are prevalent throughout the quad-Mountain. The Dolores River and its Evenly bedded shale is rare. The stone, and sandstone. In places the tains. The formation comprises two rangle. tributaries drain all the area except sandstone layers vary in bedding basal beds consist of reworked Nava- members in this area; the lower is Dry Creek Basin, in the eastern part characteristics; some layers are mas- jo sandstone. Pebbles and angular the Salt Wash sandstone member, No accurate information on rainfall ded, and still others are conspicuously as much as an inch across, are scat-shale member. In the Bull Canyon was proposed by Stokes and Phoenix is available, but the annual precipita- ripple-bedded. Almost everywhere tered rather abundantly through the quadrangle the Morrison formation (1948) for the heterogeneous sequence tion is probably between 10 and 15 the formation crops out as a steep lower part of the formation and less varies in thickness but generally of Lower Cretaceous conglomerate, inches; the area is semiarid and sup-slope broken in places by more reabundantly through the upper part. ranges from 700 to 800 feet. The Salt sandstone, shale, and thin lenses of ports a moderate growth of juniper sistant ledges of sandstone and con- In places chert pebbles and angular Wash sandstone member and the limestone that overlies the Morrison and piñon on rocky terrain and abunglomerate. dant sagebrush where soils are thick. The base of the Chinle formation is to form layers of conglomerate. In-Cacti and sparse grass are widely not exposed in the Bull Canyon quad-cluded in these layers are scattered ness. In some areas, however, their series of thick, resistant ledges. The

GLEN CANYON GROUP nentary rocks that range in age from The Glen Canyon group, of Juras- ness. This large range appears to be as a series of thick, resistant consists of quartz and lesser amount late Paleozoic to Quaternary. Cryssic (?) age, comprises, in ascending due chiefly to deposition on irregular, ledges and broad benches. Sandstone of chert. The conglomerate consists talline rocks crop out only in the order, the Wingate sandstone, the eroded surfaces of Navajo sandstone predominates and ranges in color from largely of chert pebbles, but internortheastern part of the area along Kayenta formation, and the Navajo or beds of the Kayenta formation. nearly white to gray, light-buff, and mixed are pebbles of quartz, silicified teau; the rest of the area is underlain Wingate sandstone.—The Wingate the Carmel formation of this area is sandstone are red shale and mudstone shale. In places beds are highly silicby sedimentary beds. The latest sandstone conformably overlies the of marine origin as is the Carmel of and locally a few thin lenses of dense ified. A considerable part of the for-Paleozoic and earliest Mesozoic beds Chinle formation. The sandstone is central Utah, but the probabilities gray limestone. Sandstone common-mation consists of bright-green mudwedge out northeastward against the a massive, fine-grained rock composed are that the Carmel of southwestern ly occurs as strata traceable as ledges stone and shale, and locally these crystalline pre-Cambrian rocks, but of clean, well-sorted quartz sand. It Colorado was deposited in shallow for considerable distances along the predominate over the sandstone and later Mesozoic beds were deposited on typically crops out as an impressive water marginal to a sea. outcrop, but within each stratum incomplementate. Thin, discontinuous top of the pre-Cambrian rocks. Over red wall, stained and streaked in The Carmel formation grades up- dividual beds are lenticular and dis- beds of dense, gray limestone crop most of the region the sedimentary places with a surficial red and black ward, in most places without observ- continuous; beds wedge out laterally, out in a few scattered localities. The beds are flat-lying, but in places they desert varnish. Vertical joints cut able breaks, into the Entrada sand- and other beds occupying essentially formation was undoubtedly deposited are disrupted by high-angle faults, or the sandstone from top to bottom; stone. The Entrada sandstone, the same stratigraphic position wedge under fluviatile conditions. The lower folded into northwest-trending mono- the spalling of vertically jointed slabs known locally as the "slick rim" be- in. Thus, any relatively continuous contact is indistinct in many places clines, shallow synclines, and strongly largely causes the recession of the cause of its appearance, is perhaps sandstone stratum ordinarily consists and appears to interfinger with the developed anticlines. The largest of cliff. The sandstone is divided into the most strikingly picturesque of all of numerous interfingering lenses, upper part of the Brushy Basin shale the folds is the Uncompangre Plateau horizontal layers by extensive bed- the formations in the plateau region with superposed lenses in many places member; elsewhere local erosion suruplift, a fold nearly 100 miles long ding planes spaced from 2 to 50 feet of Colorado. The smoothly rounded, filling channels carved in underlying faces intervene and the contact is that traverses the northeast part of apart. Within each horizontal layer in places bulging, orange, buff, and beds. Individual lenses are more or sharp. The upper contact is an erothe area. Well developed anticlines the sandstone is cross-bedded on a white cliffs formed by this sandstone less surrounded by mudstone and consistence of regional extent. having intrusive cores of salt and magnificent scale; great sweeping are a distinctive and scenic feature tain mudstone seams. Most of the gypsum underlie Sinbad Valley, Par-tangential cross-beds of eolian type, of the region. Horizontal rows of sandstone is fine-to medium-fineadox Valley, and Gypsum Valley in in places extending across the entire deep solution pits a few inches to a grained, cross-bedded, and massive; The Dakota sandstone, of early and the central part of the area; the Do- thickness of the horizontal layer, are foot or more across are characteristic single beds or lenses may attain a late Cretaceous age, crops out extenlores anticline in the southwest part in all directions. The sandstone is of these cliffs. The Entrada consists maximum thickness of 120 feet. Fea-sively as capping beds because of its of the area probably has a salt-gyp- rather poorly cemented and crumbles of alternating parallel-bedded units tures indicative of fluviatile origin— resistance to erosion. In the Bull sum core, although it is not exposed. easily; this quality probably accounts and sweeping, colian-type cross-bed-ripple marks, current lineations, rill Canyon quadrangle it crops out on The Bull Canyon quadrangle lies in for the readiness with which the rock ded units. The parallel-bedded units marks, and cut-and-fill structures— Wild Steer and Monogram Mesas and

the central part of the area, about 18 disintegrates in faulted areas. are most common in the basal part are everywhere. miles southwest of the Uncompangre In the Bull Canyon quadrangle the and in the uppermost, lighter-colored The sandstone consists largely of Dakota consists principally of gray, Plateau. The northeast corner of the Wingate sandstone ranges in thick-part of the Entrada, whereas the subangular to subrounded quartz yellow, and buff flaggy sandstone; quadrangle is traversed by the edge ness from 290 to 325 feet, except cross-bedded units are dominant in the grains, but orthoclase, microcline, and less abundant are conglomerate, carof Paradox Valley and the southwest along the walls of Gypsum Valley, middle part. The Entrada sandstone albite grains occur in combined bonaceous shale, and impure coal. corner by the edge of Gypsum Valley. where it thins to 200 feet, and of differs from the somewhat similar amounts of 10 to 15 percent. Chert Some of the sandstone is fine-grained Paradox Valley, where it thins to as Wingate sandstone and Navajo sand- and heavy-mineral grains are acces- and thin-bedded, but much of it is little as 50 feet. The oldest rocks exposed in the Kayenta formation.—The Kayenta distinct grain sizes. Subrounded to terstitial clay and numerous clay Scattered through the sandstone are Bull Canyon quadrangle are of early formation conformably overlies the subangular quartz grains mostly less pellets occur in places, especially near irregular, discontinuous beds and Pennsylvanian age and are exposed Wingate sandstone; the contact bein a small outcrop in Paradox Valley. tween the two formations is grada- bulk of the sandstone. The sandstone lenses. Fossil wood, carbonaceous chert and quartz pebbles as much as Rocks of late Pennsylvanian and Pertional in most places. The formation also contains larger grains, which are matter, and saurian bones occur 2 inches across. Interfingering with mian age, although not exposed with- is notable for its variety of rock well-rounded, have frosted surfaces, locally. in the quadrangle, crop out extensive- types. Sandstone, red, buff, gray, and range from 0.4 to 0.8 mm in dily in adjacent quadrangles. Triassic and lavender in color, is the most ameter; most of these grains are of ranges from 320 to 400 feet in thick- and thin coal seams and beds. Plant rocks are exposed along the sides of abundant type; but the formation also quartz, but grains of chert are scatness and, unlike the underlying forimpressions abound in both the sand-Gypsum Valley and Paradox Valley. contains considerable quantities of tered among them. Most of the mations, does not thin along the flanks stone and the shale. The entire Jurassic rocks crop out along the sides red siltstone, thin-bedded shale, and larger grains are distributed in thin of the Gypsum Valley and Paradox thickness of the Dakota sandstone of Gypsum Valley and Paradox Val- conglomerate. The conglomerate layers along planes of bedding and Valley anticlines. Local changes in is not exposed in the quadrangle; the lev and in the canvon walls and on contains pebbles of limestone, shale, lamination. the benches and slopes below the and sandstone. The sandstone is The Entrada sandstone is 130 to 150 common. mesas. Cretaceous rocks cap the composed of rounded to subrounded feet thick, except along the flanks of Brushy Basin shale member.—The the eastern part of the quadrangle mesas and underlie the floor of Dry quartz grains, and minor quantities the Gypsum Valley and Paradox Val- Brushy Basin shale member con- the beds that remain are probably Creek Basin. Recent deposits of of mica, feldspar, and dark minerals. ley anticlines, where it thins to less trasts strongly in over-all appearance about 150 feet thick. wind-blown material and sheet wash Most of the sandstone is thin bedded, than 100 feet. are widely distributed on top of the cross-bedded in part, and flaggy; some Summerville formation.—The Sumstone member. Although the lithomesas, along the benches, and on the is massive. Individual sandstone merville formation generally crops logic differences are marked, the beds are lenticular and discontinuous out as a steep, debris-covered slope, contact between the two members The deposits of Quaternary age The stratigraphic sequence is sim- and interfinger with shale and, in with very few good exposures. In is gradational. The mapped contact, consist of wind-deposited material,

and Dane (1935) in nearby areas in Kayenta typically crops out in a se-hibits a remarkably even, thin, hori-layer of conglomerate lenses, is arbi-Utah; most of the formations can be ries of benches and ledges. The ledg- zontal bedding. Beds are predomitrrary in many respects, and probably and silty material mantle the benches traced continuously from the Bull es in many places overhang recessions nantly red of various shades, although does not mark an identical strati- and mesa tops. This material ap-Canyon quadrangle into Utah. where softer beds have eroded back. some beds are green, brown, light graphic horizon in all localities. pears to be mostly wind-deposited, PARADOX MEMBER OF THE The lower part of the formation is yellow, or nearly white. Sandy and The Brushy Basin shale member although much of it has been re-HERMOSA FORMATION more firmly cemented and forms silty shale are the most abundant consists predominantly of varicolored worked by water and intermixed with

mosa formation, of Pennsylvanian from erosion.

sive, whereas others are cross-bed- fragments of white and gray chert, and the upper is the Brushy Basin The name Burro Canyon formation

distributed. Most of the quadrangle rangle. The formation, as projected greenish-gray, red, and yellow quartz- thicknesses vary independently, bulk of the formation consists of is accessible over a system of dry- from adjoining quadrangles, probably ite pebbles and boulders as large as whereas in other areas a thinning in white, gray, and red sandstone and ranges from 475 feet to 525 feet in 5 by 8 inches. In many places the one member is accompanied by a conglomerate that form beds up to thickness, except where it thins abupper part of the formation contains thickening in the other. 100 feet thick. These beds are masruptly on the flanks of the Gypsum scattered barite nodules as much as Salt Wash sandstone member.— sive, irregular, and lenticular. Cross-The Carmel formation ranges from ordinarily crops out above the slope-prevalent throughout the formation. less than 10 feet to 90 feet in thick- forming Summerville formation The sandstone is poorly sorted and No definite evidence indicates that rusty red. Interbedded with the limestone, quartzite, sandstone, and

stone by the sorting of sand into two sory. Considerable quantities of incoarse-grained and cross-bedded.

ber, the lower member of the Her- the underlying Wingate sandstone shale to clean, fine-grained sandstone intercalated beds and lenses of con- been mapped where they are unusu-

age, crop out in Paradox Valley a The Kayenta formation in the Bull rounded amber-colored quartz grains thin layers of limestone. Because of

formations. Regionally the upper volcanic debris in adjacent beds. thickness from a maximum of more part of the Summerville intertongue, a few inches to 25 feet thick, occur than 200 feet in the southwest part and the contact does not occur every- at intervals throughout the member. of the quadrangle to a knife-edge in where at the same stratigraphic These conglomerate beds are comoverlying basal sandstones of the more abundant in the Brushy Basin Morrison formation. Locally, how- shale member than in the Salt Wash of the formation contains numerous prises, in ascending order, the Carmel and mudstones of the Morrison for-

MORRISON FORMATION

thickness of as much as 30 feet are upper beds have been stripped off by

with the underlying Salt Wash sand-Gypsum beds of the Paradox mem-resistant, thick ledges that protect kinds of rock but all gradations from bentonitic shale and mudstone, with sheet wash. These deposits have not

are interbedded with them. Well- glomerate and sandstone, and a few ally spotty, discontinuous, or less than

short distance northeast of the lower Canyon quadrangle ranges in thick- with frosted or matte surfaces are its high proportion of soft, easily tered through the shale and mudstone

ber, undoubtedly was deposited un-

sented by the mudstone and shale. The Brushy Basin shale member BURRO CANYON FORMATION

fragments are sufficiently abundant Brushy Basin shale member in gen-formation. The Burro Canyon char-The Salt Wash sandstone member bedding and festoon-bedding are

> DAKOTA SANDSTONE on the floor of Dry Creek Basin. The

the sandstone beds are thin-bedded

erosion; but in Dry Creek Basin in QUATERNARY ALLUVIUM AND

STRUCTURE REGIONAL SETTING

masses of the Paradox member, and probably before middle Tertiary, but are scarce or absent. forming valleys such as Sinbad Val- the date cannot be determined acculev. Paradox Valley, and Gypsum Val-rately. The region of the salt intru-

STRUCTURE IN BULL CANYON

the Bull Canyon quadrangle either directly or indirectly, although the

thicknesses in some dry washes on The boundary between the highland from 1923 until 1937, but since 1937 new data, particularly from newly erally are not richly mineralized. mesa tops is about 10 feet. The floors and the basin, which closely followed they again have been exploited intenof Gypsum and Paradox Valleys are the southwest margin of the present-sively, first for vanadium and in more son formation in southwestern Colo-into an upper and a lower unit by a fer markedly from the wind-deposited steep northwest-trending front, pos- uranium.

tle gravel and alluvium occur in any sediments of the Hermosa formation. range from small irregular masses copyrite - minerals normally asso- the Wild Steer mine is unusual in that of the stream beds. Considerable ta- The bulk of the fanglomerates prob- containing only a few tons of ore to ciated with ores considered to be it lies near the base of the Salt Wash lus debris covers many of the steeper ably are of Permian age and belong large tabular masses containing many of hydrothermal origin. Studies of sandstone member; most of the deslopes. Because these various depost to the Cutler formation. Intrusion thousands of tons; but most ore bodies lead-uranium ratios in the ores of the posits are found in the upper part of its are difficult to differentiate in of salt from the Paradox member, are relatively small and contain only Colorado Plateau indicate that, rethemember. In addition to carnotite some places, they have not been sep- probably initiated by gentle regional a few hundred tons. The ore con- gardless of where or in what forma- and the micaceous vanadium mineral, arated on the geologic map. Land- deformation, began sometime during sists mainly of sandstone impreg- tion the ores are found, all are of the ore-especially in the higher slides consisting largely of Brushy deposition of the Permian Cutler for- nated with uranium- and vanadium- roughly the same age and this age is grades—also contains considerable Basin debris are prominent along the mation. Isostatic rise of salt rupbearing minerals. sides of Paradox Valley in the north-tured the overlying Hermosa and eastern part of the quadrangle. Cutler formations, and at the end of

consist of salt anticlines, 45 to 80 miles additional salt, perhaps accelerated calcium analogue of carnotite, is also from relaxation of early Tertiary stone that trends about N. 75° W. long; uplifted blocks, 50 to 125 miles by the increase of the static load of present and is nearly indistinguish- compressional stresses; but most of The ore minerals are carnotite and long, bounded by monoclinal folds; sediments accumulating in the able from carnotite. The micaceous the deposits cut by faults are offset the micaceous vanadium mineral; and domical uplifts, 8 to 20 miles surrounding areas, balanced or vanadium mineral, which formerly along the faults. In view of these these occur as low-grade disseminaacross, around stocklike and lacco- slightly exceeded the rate of re- was thought to be roscoelite, is now relations, mineralization during early tions in the sandstone and as highermoval of salt by solution and erosion considered to be related to the non- Tertiary time seems more probable grade concentrations confined largely The salt anticlines trend northwest at the surface. Consequently, all the tronite or montmorillonite group of than mineralization shortly after the to numerous rolls. The rolls curve and lie in a group between eastward- Mesozoic formations to the base of clay minerals. It forms aggregates deposition of the formations contain- slightly, but most have an over-all dipping monoclines on the west side the Morrison formation wedge out of minute flakes coating or partly reing the ore. If mineralization took trend of about N. 75°W., parallel to of the Plateau and westward-dipping against the flanks of the salt intru- placing sand grains and filling pore place in the Tertiary, then a hypogene the trend of the enclosing lens of monoclines on the east side of the sions. Salt flowage was not every- spaces in the sandstone. It colors the source for most of the metals in the channel sandstone. There is a fair Plateau. The cores of these anti- where continuous and at a uniform rock gray. Other vanadium ore deposits seems reasonable. chance that additional ore could be clines consist of relatively plastic salt rate; rather, in many places it prominerals present are vanoxite and gypsum, derived from the Paragrees gressed spasmodically. Local surges (2V₂O₄·V₂O₅·8H₂O?), montroseite SUGGESTIONS FOR PROSPECTING east of these mines along the prodox member of the Hermosa forma- of comparatively rapid intrusion gave (NFeO·NV₂O₄·NH₂O·NV₂O₃), cor- Regardless of the origin of the ore, jected extension of the thick channel tion and intruded into overlying late rise to cupolas at different times and vusite (V2O4.6V2O5.NH2O), and certain features associated with the sandstone. Paleozoic and early Mesozoic rocks. in different places along the salt hewettite (CaO·3V2O5·9H2O). Cor- deposits in the Salt Wash sandstone About half a mile south of Fawn All the anticlines are structurally masses. At the beginning of Mor- vusite and montroseite occur to- member of the Morrison formation Springs promising new deposits have similar in many respects, but each rison time sediments finally covered gether, forming compact masses of are useful guides for finding ore; been discovered in another thick lens exhibits structural peculiarities not the salt intrusions, perhaps because bluish-black ore, whereas hewettite nonetheless, their presence does not of sandstone. These deposits appear common to the rest; furthermore, all the supply of salt underlying the commonly forms stringers and vein-necessarily portend the presence of to be similar to the Tea Pot Dome are more complex than their seem- areas between the intrusions was ex- lets along joints and fractures. Re- ore. In general most ore deposits deposits. ingly simple forms would suggest. hausted. Relative quiescence pre- cent deeper drilling and mining in the occur in the lower and thicker parts Other mines and prospects.—Many Faults, grabens, and collapse and vailed throughout the remainder of Plateau have indicated that below the of sandstone lenses. Sizable quanti-other small mines and prospects are slump structures alter the forms of the Mesozoic and probably through zone of oxidation black oxides of uraties of ore are found mostly in sand-scattered along the outcrops of the the anticlines. Erosion has removed the early part of the Tertiary. nium and vanadium, accompanied by stone lenses more than 20 feet thick. Morrison formation, especially in the much of the axial parts of these anti
The second major period of deforpyrite and perhaps other sulfides, are

Sandstone likely to contain ore is

Bull Canyon area and along the rim

dip at angles of less than 2°; only near salt intrusions. Owing to the mobil- deposits the highest-grade concentra- rocks, such as the rocks both overly- minerals. simple downfold rimmed by cuestas At this time the crests of the antiof Cretaceous sandstone. The rocks clines in places were dropped, as gramineral that curve across bedding

the older pre-Morrison formations dip throughout the area.

rangle, it is necessary to understand breached, the relatively plastic salt the structural history of the carno- offered little support for the beds tite-producing region of southwestern overlying the Paradox in the flanks Most deposits of uranium and va- as richly mineralized as they composits of copper, vanadium-urani-Colorado as a whole. Parts of this of the anticlines; consequently these nadium in the Morrison formation in monly are in other deposits. Some um and silver in southwestern history are still in doubt, because no essentially unsupported beds slumped, southwestern Colorado appear to be of the richest ore consists of concenclear record remains of some events; probably along fractures and joints rather closely related to sedimentary trations of vanoxite and corvusite in 32, no. 7, pp. 906-951. the record of other events, although formed during earlier flexures. Small structures; they show little apparent small spherical masses 4 to 12 inches Fischer, R. P., 1942, Vanadium deposlegible, is subject to different inter- faults and folds in Quaternary depos- control by faults or folds. Layers of across. pretations. All the events described its may indicate that collapse and lo- ore lie essentially parallel to the bed- The zone of collapse faulting that inary report: U. S. Geol. Survey in the following discussion affected cal readjustments are still continuing. ding; most of the deposits occur in borders Paradox Valley cuts through Bull. 936-P, pp. 363-394. evidence for some of them is not visi
The only commercially important the sandstone; the trend of the long dible within the quadrangle boundaries. mineral deposits in the Bull Canyon rection of the deposits and the trend of Monogram group.—The ore depos-45, no. 1, pp. 1-11. Mild compressive forces, which quadrangle are those that contain the rolls in the sandstone are roughly its at the Monogram group of mines Hess, F. L., 1933, Uranium, vanadiprobably began in early Pennsylva- uranium, vanadium, and radium. Al- parallel to the trend of the fossil logs more nearly resemble the normal type um, radium, gold, silver and molybnian time, gently warped the region. though deposits containing these in the sandstone and to the average of deposit found in the Salt Wash denum sedimentary deposits: Ore This warping gave rise to the ancesmetals were discovered in 1899 near or resultant dip of the cross-bedding sandstone member. The ore miner-deposits of the Western States tral Uncompangre highland, an ele- Roc Creek, about 15 miles north of in the sandstone. Largely because als are carnotite and the micaceous (Lindgren volume), pp. 450-481, ment of the ancestral Rocky Mounthe Bull Canyon quadrangle, intensive of these circumstances, earlier invesvanadium mineral. Vanoxite, corvutam. Inst. Min. Met. Eng. tains, and to the basin in which the mining of these ores did not begin in tigators of the deposits (Coffin, 1921; site, and hewettite, so abundant in the Stokes, W. L., and Phoenix, D. A.,

a foot thick; the greatest observed tures later superimposed on them. ores. The mines were mostly idle Recent investigations have revealed are common, although the logs gen-

covered with soils that generally dif- day Uncompangre Plateau, was a recent years for both vanadium and rado and from older formations in mudstone lens as much as 25 feet material on the mesas. These valley sibly a fault scarp, along which were Most of the deposits are restricted that seem to require some revision of the upper unit and near both the top soils are derived not only from wind- deposited arkosic fanglomerates dur- to the upper layer of sandstone lenses earlier hypotheses of origin. Below and the base of the lower unit. Nublown material but also from the dising late Pennsylvanian and Permian in the Salt Wash sandstone member, the zone of oxidation some of the ores merous faults with displacements of integration of the rocks exposed on time. The older fanglomerates inter- but within this layer the deposits have consist chiefly of oxides and sulfides, a few feet cut the deposits. the valley walls and floors. Very lit-finger with Pennsylvanian marine a spotty distribution. Ore bodies such as pitchblende, bornite, and chal-Wild Steer mine.—The ore body at MINERALOGY

Cutler deposition salt broke through The most common ore minerals formations in regions remote from ically distributed high-grade lenses to the surface. From then until flow- are carnotite and a fine-grained, the salt anticlines, has revealed many and pockets containing vanoxite and age ceased, late in the Jurassic, the vanadium-bearing, micaceous min-deposits that appear to show genetic corvusite are characteristic of the Many geologic structures in the elongate salt intrusions such as those eral. Carnotite (approximately relations to faults and fractures. In deposit. Colorado Plateau are so large that a in Paradox Valley and Gypsum Val- K₂O·2UO₃·V₂O₅·3H₂O), is a yel- the salt-anticline region some deposits Tea Pot Dome mines.—The Tea Pot 7½-minute quadrangle covers only a ley stood as actual topographic highs low, fine-grained, earthy or powdery in the Morrison formation appear. Dome mines are the largest in the small part of any complete structural at one place or another along their material. Tyuyamunite (approxi- to be related to the oldest set of area drained by Bull Canyon. The unit. The larger structural units lengths. The rate of upwelling of mately CaO · 2UO 3 · V2O 5 · 4H2O), the faults, that is, those faults resulting deposits are in a thick channel sand-

ORE BODIES

gypsum cores of these anticlines, and topographic relief became low in the rolls is less systematic. from a few inches to 15 feet in thick-associated with the ore minerals. The ore bodies range from small ness and is essentially continuous Rolls are common. more steeply than the younger; how
Then, during the middle Tertiary, irregular masses containing only a along the outcrop for a distance of On the Gray and Black Point claims, ever, these relations can be more the entire Colorado Plateau was up- few tons of ore to large tabular about 3,000 feet. In a number of re- southwest of the Monogram group, clearly seen in nearby areas outside lifted. This uplift rejuvenated the masses containing many thousands spects this deposit is unique among a number of small deposits have been streams and increased ground-water of tons of ore. Margins of ore bodies deposits in the Morrison formation. mined from a conglomeratic lens in Particularly striking are the com- circulation. The crests of the anti- may be vaguely or sharply defined. Associated with the usual micace- the lower part of the Brushy Basin plex systems of faults that cut the clines were breached, and the under- Vaguely defined margins may have ous vanadium clay mineral are com- shale member. The ore was mostly sides of Gypsum Valley and Paradox lying salt was exposed to rapid mineralized sandstone extending well mercially important quantities of the of low grade, and its distribution was Valley. In general the blocks and solution and removal. With the abbeyond the limits of commercial ore; commonly less abundant vanadium spotty and irregular. slivers formed by these faults are straction of salt, renewed collapse of on the other hand, sharply defined minerals - vanoxite, corvusite, and downthrown toward the valleys, but the anticlines began. Although much margins, such as occur along the surhewettite. Not much carnotite is some blocks form small horsts. Im- of the collapse was due directly to faces of rolls, ordinarily mark the visible, although the ore contains con- Baker, A. A., 1933, Geology and oil mediately southwest of the Mono- removal of salt by solution, it seems limits of both the mineralized sand- siderable uranium. Gypsum satu- possibilities of the Moab district, gram group of mines a small graben, unlikely that all the collapse can be stone and the commercial ore. rates the sandstone as a cement and Grand and San Juan Counties, about 1,000 feet wide and several attributed to this process, as was be- Although many rolls are small and as fracture fillings. Considerable py- Utah: U. S. Geol. Survey Bull. 841, miles long, separates the intensely lieved by earlier workers in the area. irregular, the larger ones are elongate rite is disseminated through the ore 95 pp. faulted walls of Paradox Valley from Rather, much of the collapse was apand may extend with little change of or occurs as crystals in clusters 2 to Coffin, R. C., 1921, Radium, uranium, the long dip slopes that form Mono- parently due to flowage of salt from direction for more than 100 feet. The 6 inches across. the parts of the anticlines still over- elongate rolls in an ore body or group The deposit consists of an essen- western Colorado: Colorado Geol. lain by thick layers of sediments to of ore bodies in a given area gener-tially continuous layer of rather unithe parts from which the overlying ally have a common orientation. This formly distributed low-grade dissem- Dane, C. H., 1935, Geology of the

> ORIGIN OF ORE MINERAL DEPOSITS
>
> lenses, commonly near the base of in the zone offset the ore as much as ing sandstone deposits of the Colo-

other parts of the Colorado Plateau, thick. Deposits occur in the base of

clines, leaving exposed large intrusive mation occurred in the Tertiary— more abundant, and uranyl vanadates more highly cross-bedded and coarser- of Paradox Valley. In the Bull Cangrained than sandstone likely to be you area most of the larger deposits barren. Within ore bodies concentra- occur in the uppermost sandstone tions of mudstone pebbles and "trash" beds of the Salt Wash sandstone ley in Colorado and similar valleys in sions was compressed into a series of The ore consists mostly of sand- pockets" containing abundant plant member, but deposits are not so close-Utah. Alternating with these anti- broad folds, guided and localized by stone selectively impregnated and in remains may localize rich concentra- ly confined to those beds as they are clines are broad, shallow, simple syn- the pre-existing salt intrusions. Al- part replaced by uranium and vana- tions of ore. In the vicinity of ore elsewhere in western Colorado. One clines. Some of these synclines die though salt flowage was renewed, it dium minerals; but rich concentra- bodies the sandstone is characteristi- of the more productive mines, the seems unlikely that any considerable tions of carnotite and the micaceous cally a light yellow brown, and is Ground Hog mine, is in a conglomeramount of new salt was forced into vanadium clay mineral are also asso- speckled with limonite stains. Prob- atic bed in the lower part of the the intrusions; flowage probably conciated with thin mudstone partings, ably the most useful of all guides in Brushy Basin shale member. In gensisted largely of redistribution of the beds of mudstone pebbles, and car-The Bull Canyon quadrangle lies salt already present. By the end of bonized fossil plant material. Many deposits, however, is the presence of Salt Wash are small and consist of near the southeast end of the system this period of deformation these folds fossil logs replaced by nearly pure a considerable amount of altered gray irregular masses of relatively highof salt anticlines, between the Para- had attained approximately their carnotite have been found. In gen- mudstone within or immediately un- grade ore. These deposits characterdox Valley and Gypsum Valley antipresent structural form, except for eral the ore minerals were deposited derlying the ore-bearing sandstone. istically contain copper carbonate clines. Most of the rock strata in the modifications imposed by later colini irregular layers that roughly folquadrangle either are horizontal or lapse of the anticlines overlying the lowed the sandstone beds. In most then the more intensely deformed beds rarely contain any visible copper the edges of Gypsum Valley and Par- ity of the rocks in the cores of the tions of ore minerals occur in sharply ing and surrounding the salt intruadox Valley do the dips steepen apanticlines, normal faulting took place bounded, elongate concretionary sions, probably are favorable places tween the Jo Dandy and Monogram preciably. The Dry Creek Basin along the crests of the anticlines, structures, called "rolls" by the to look for new deposits, provided groups are a number of mines known syncline, of which only the northwest probably during relaxation of comminers. These rolls are encompassed that formations and rock types known as the Opera Box group. The geo-

In order to understand the structur- sediments had been removed. Once orientation is roughly parallel to the inated ore. The margins of the ore Salt Valley anticline and adjacent al history of the Bull Canyon quad- the crests of the anticlines had been elongation of the ore bodies. body are indefinite, and rolls are areas, Grand County, Utah: U. S.

and vanadium deposits of southits of Colorado and Utah, a prelim-

Paradox member of the Hermosa the Plateau region until 1911. There- Hess, 1933; and Fischer, 1937, 1942, Jo Dandy deposits, are either very 1948, Geology of the Egnar-Gypsum formation was deposited. These ma- after, the ores were mined primarily 1950) believed that the ore minerals rare or absent. The ore bodies are Valley area, San Miguel and Montjor structural features controlled the for their radium content until 1923, were precipitated from ground water, sharply defined irregular tabular rose Counties, Colorado: U. S. Geol. pattern and the prevailing northwest- when the Belgian Congo began to either during or shortly after deposi- masses as much as 600 feet long and Survey Prelim. Oil and Gas Inv., trending grain of the smaller struc- supply radium from rich pitchblende tion of the containing sandstone. 350 feet wide. Rolls and fossil logs Map 93.

UNITED STATES GEOLOGICAL SURVEY W. E. WRATHER, DIRECTOR

DEPARTMENT OF THE INTERIOR

no older than early Tertiary. De- vanoxite and corvusite. Copper cartailed study of newly discovered de- bonate stains are common. Fairly posits, particularly from pre-Morrison well defined rolls and numerous errat-

found by exploring the ground south-

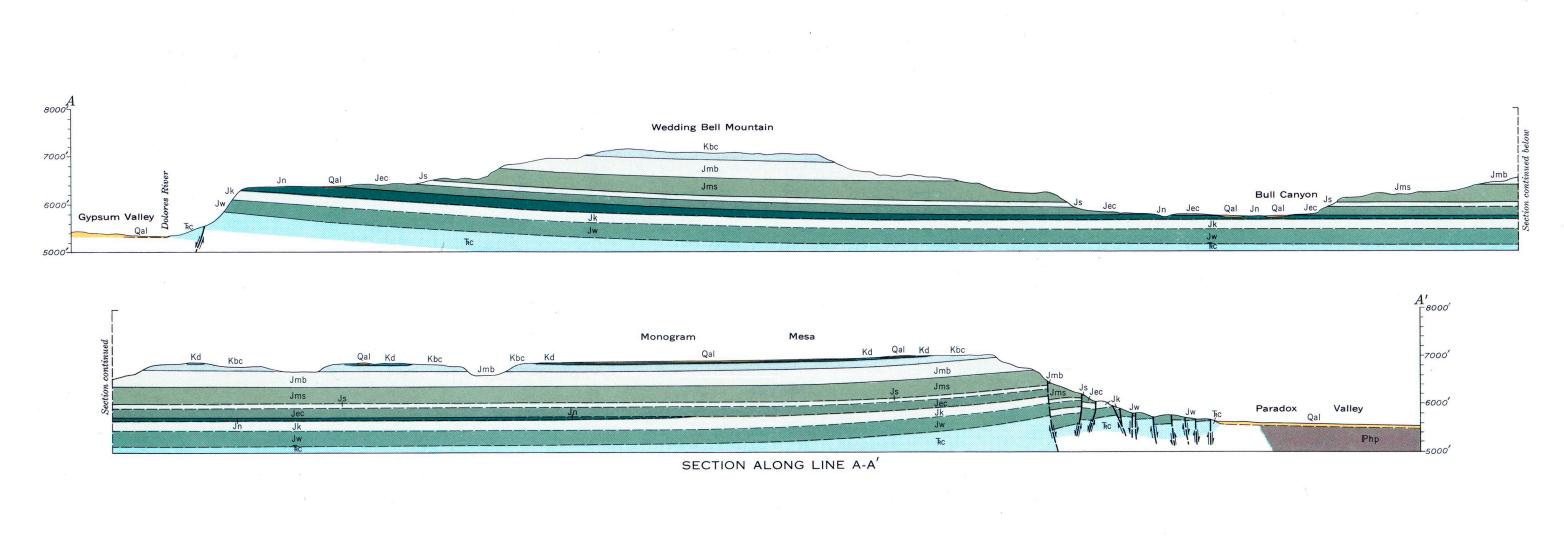
posits are intermediate between those

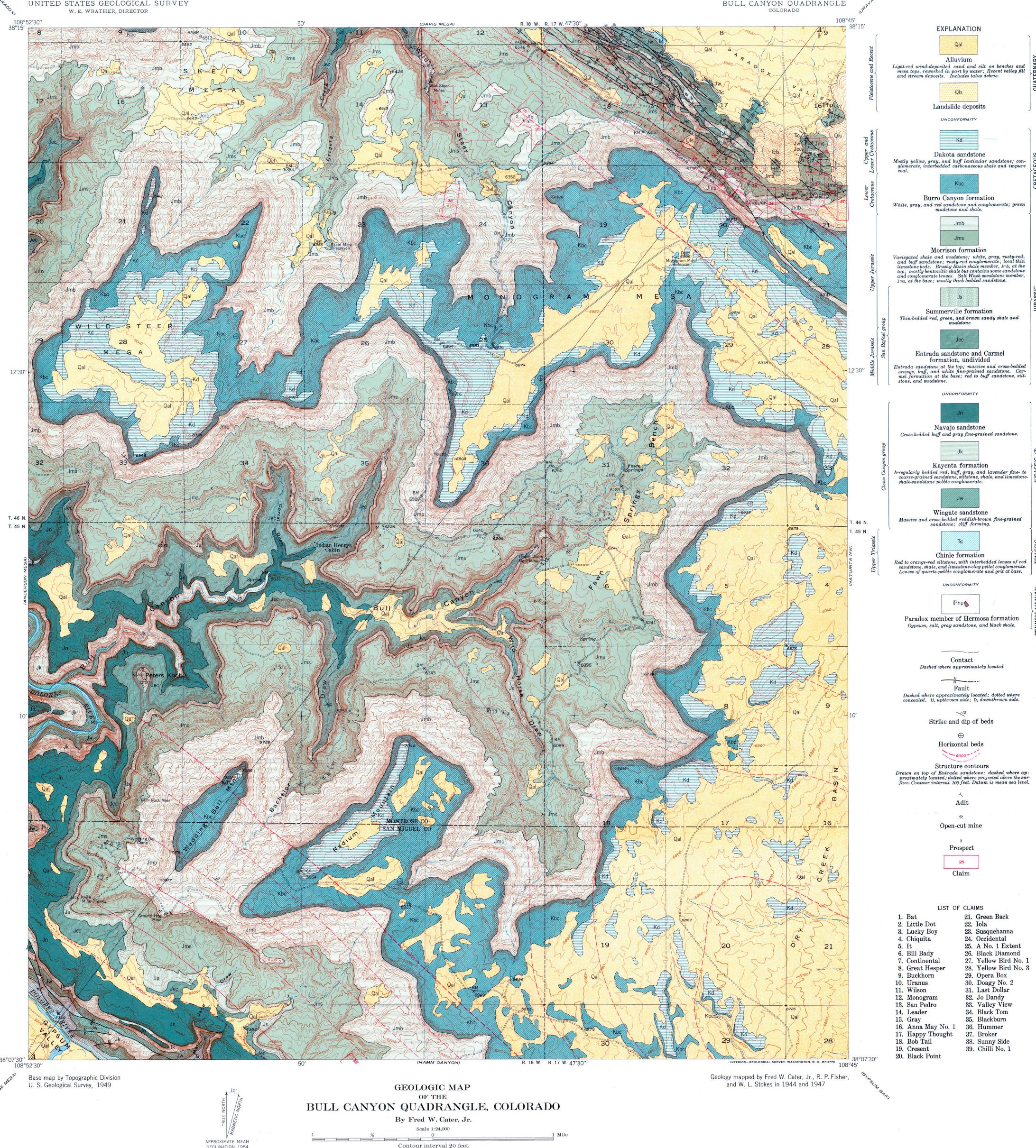
end lies within the quadrangle, is a pressive stresses after folding ceased. by rich, veinlike concentrations of to be hosts for ore are present. logic features of the Opera Box demarginal to Gypsum Valley and Parbens, several hundred to a few planes. Within these rolls this min- Jo Dandy group.—The most pro- Monogram deposits. Carnotite and adox Valley are upturned sharply thousand feet. A period of crustal eral generally is distributed as diffu- ductive mines in the Bull Canyon the micaceous vanadium mineral are along the flanks of the anticlines that quiescence followed, during which the sion layers, the richer layers com- quadrangle are those of the Jo Dandy the important ore minerals, but vanunderlie these valleys. The pre-Mor- highlands overlying the anticlines and monly lying nearer the margins of group. All the mines of this group oxite, corvusite, and hewettite are rison formations thin against the salt- domes were reduced by erosion and the rolls; the distribution of carnotite are in one large deposit that ranges also present. Gypsum and pyrite are

> rare. In general neither lenses of Geol. Survey Bull. 863, 184 pp. mudstone pebbles nor fossil logs are Fischer, R. P., 1937, Sedimentary dethe thicker parts of the sandstone the ore body, and some of the faults Fischer, R. P., 1950, Uranium-bear-

> > rado Plateau: Econ. Geology, vol.

Base map by Topographic Division U. S. Geological Survey, 1949 APPROXIMATE MEAN DECLINATION, 1954





Datum is mean sea level 1954

GEOLOGY OF THE