UNITED STATES
DEPARTMENT OF THE INTERIOR
FRED A. SEATON, SECRETARY

DEFENSE MINERALS EXPLORATION ADMINISTRATION

REPORT OF EXAMINATION BY FIELD TEAM
REGION III

DMEA 4136

Sylvia and Ruth K. Claims

Urado Uranium Corporation

Montrose County, Colorado

Uranium

Joint Engineering and Geological Report

by

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DMEA 4196

SYLVIA AND RUTH K. CLAIMS
URADO URANIUM CORPORATION
MONTROSE COUNTY, COLORADO

INTRODUCTION AND SUMMARY

Urado Uranium Corporation, 304 Main Street, Grand Junction, Colorado, has applied for aid in an exploration project for uranium on the Sylvia and Ruth K. claims in the Long Park area of the Uravan district. The application proposed a two-stage exploration project consisting of 22,390 feet of core and non-core drilling in 41 holes at a total estimated cost of $105,860.00.

The claims were examined on March 26, 1956, by an examining team from the Geological Survey and the Bureau of Mines.

The property consists of four claims in secs. 35 and 36, T. 47 N., R. 17 W., and secs. 1 and 2, T. 46 N., R. 17 W., N. M. P. M., Montrose County, Colorado. The altitudes range from about 6,250 feet near the north line of the claims to about 6,600 feet near the southeast corner. Two holes were drilled on the property by the Geological Survey and one by the applicant.

The principal uranium deposits in the Long Park area are found in sandstone units restricted to the upper 100 feet of the Salt Wash member of the Jurassic Morrison formation. Primary sedimentary structures in the ore-bearing sandstone units apparently are closely associated with localization of ore. An echelon arrangement of ore

deposits in the Long Park region is probably caused by an en echelon arrangement of sedimentary structures which trend easterly. However, in the immediate vicinity of the claims the long axes of ore bodies generally strike northeast.

Ore deposits in the vicinity are as much as 300 feet wide and 1,800 feet long and average 3 to 4 feet thick. The possibility of finding ore bodies ranging in size from 550 tons to 20,000 tons is considered good.

A two-stage project consisting of drilling 22,590 feet in 41 holes at a total estimated cost of $60,800.00 is recommended.

ACKNOWLEDGMENTS

The examining team was accompanied by Robert L. Boardman of the Geological Survey and by H. A. Culp, representing the applicant. A large amount of the information used in appraising the proposed project was furnished by district geologist, Boardman.

The Atomic Energy Commission was consulted regarding the project before the examination was made.

Suggestions of John E. Crawford, W. P. Williams, and George C. Selfridge, of DMEA were carefully considered.

LOCATION, TOPOGRAPHY, AND CLIMATE

The property consists of four unpatented claims in the Long Park area of the Uravan mining district, secs. 35 and 36,

T. 47 N., R. 17 W., and secs. 1 and 2, T. 46 N., R. 17 W., N. M. P. M., Montrose County, Colorado (figs. 1 and 2). The claims are at the head of a small draw which runs northeast. Rainfall is light and work can be carried on throughout the year.

A 1,000-foot access road connects the property with an all-weather county road from whence it is 12 miles north to State Highway 141 at Uravan and 110 miles northeast to Grand Junction, Colorado.

Labor, supplies and light equipment can be obtained at Uravan and heavy equipment can be purchased at Grand Junction. The nearest railroad is the Denver and Rio Grande Western at Grand Junction. Ore-buying depots are maintained at Uravan and Grand Junction. Water for drilling purposes can be obtained from small reservoirs in Long Park.

HISTORY AND PRODUCTION

Long Park contains many uranium-vanadium mines from which ore has been mined for many years. The four claims comprising the property were located by H. D. Clark and S. W. Jones in 1950 and 1951. No ore has been produced from the property. Two holes that encountered ore were drilled on the Ruth K. No. 3 claim, and an ore body was discovered by Geological Survey drilling to the east of the property. An application which included the subject claim

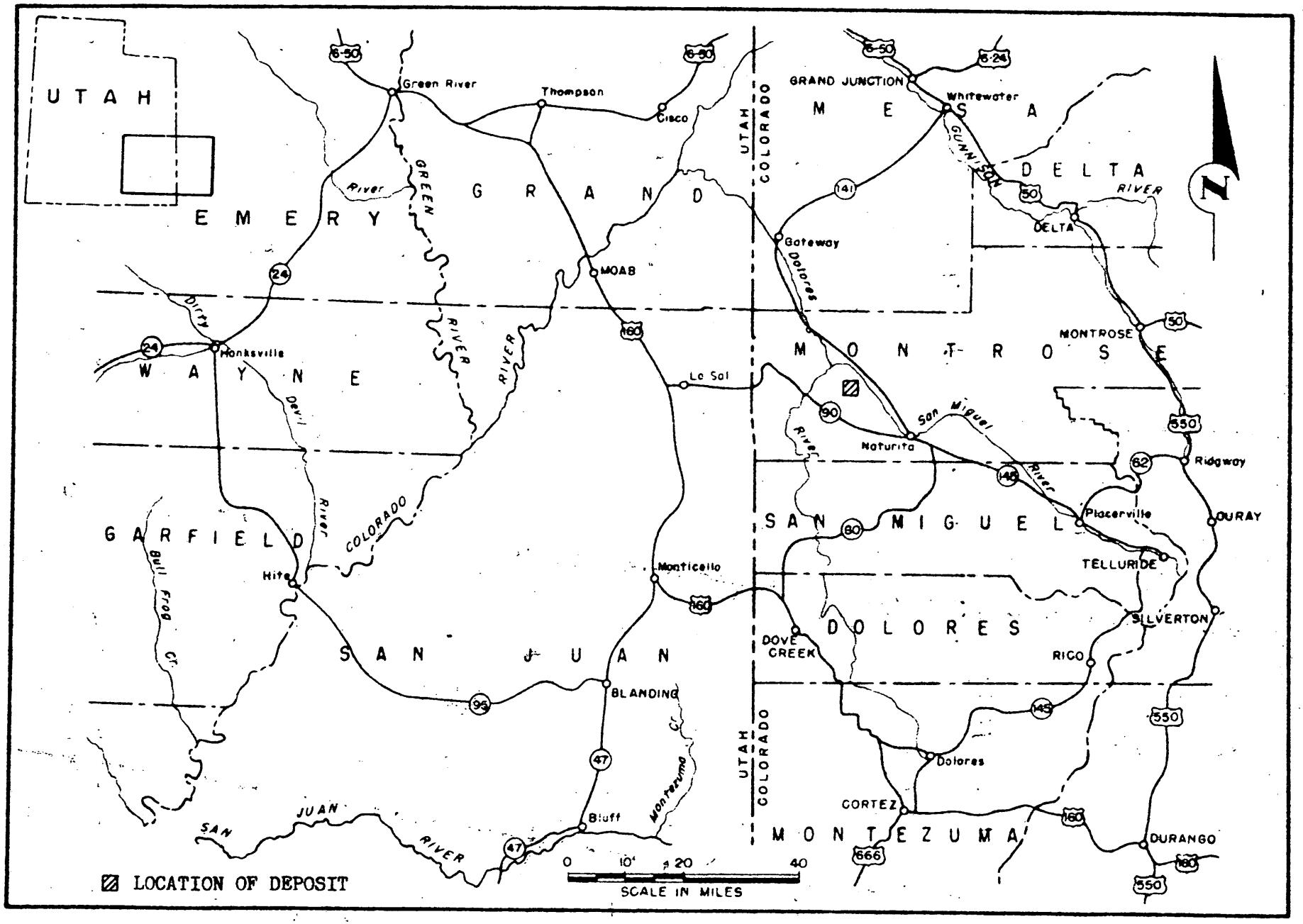

FIGURE 1 - LOCATION MAP, SILVIA AND RUTH K. CLAIMS, URADO URANIUM CORPORATION, MONTROSE COUNTY, COLO. DMEA 4136

was submitted previously under DMEA Docket 3550 but was denied because of conflicts on the Ruth K. No. 2 and No. 3 claims.

The total production of the Long Park district through 1955 was about 445,000 tons averaging 0.33 percent U_3O_8 and 1.93 percent V_2O_5.

OWNERSHIP AND EXTENT

The four claims listed in the application are recorded in the records of the County Clerk and Recorder of Montrose County, Colorado, as follows:

Claim	Book	Page	Discovery Date	Recorded by
Ruth K. No. 4	343	232	Not stated (8/22/50)	N. D. Clark
Sylvia	343	433	2/11/51	N. D. Clark & S. W. Jones
Sylvia No. 2	343	433	2/11/51	" " " " "
Sylvia No. 3	343	434	2/11/51	" " " " "

The transfer of the above claims by the locators to Engineers Associates, Inc., was not noticed in the records but is presumed to be correct as of the opinion given by Bryant, Petrie, and Waldeck, law firm of Montrose, Colorado.

On March 1, 1954, Engineers Associates, Inc., leased the claims to Louis F. Gaggini for a period of ten years. On March 15, 1954, Gaggini granted a sublease on the property to Worcester Mines. A lease and supplemental agreement whereby Worcester Mines surrendered its rights to the mining lease was dated March 4, 1954. A new ten year lease on the claims was granted by Engineers Associates, Inc.,

to Louis P. Gaggini and Geo-Engineering. On March 5, 1955, Louis P. Gaggini and Geo-Engineering assigned their interests in the lease to Urado Uranium Corporation.

PRESENT STATUS

Exploration and development

Exploration on the property consists of location pits and one hole drilled by the applicant and two holes drilled by the Geological Survey (fig. 2 and table 1). Eight holes were drilled on the adjoining Ruth K. No. 3 claim, which is excluded from this application because of existing conflicts, and another barren hole not shown on figure 2 was drilled on the Ruth K. No. 2 which is also excluded from the subject application. Two company holes, RK 3 and RK 8 cut ore-grade material according to company data and two holes, RK 4 and RK 6, were in weakly mineralized ground (fig. 2).

Mining and milling equipment and other facilities

There is no mining or milling equipment on the property. Facilities consist of two access roads.

GEOLOGY

The rocks exposed in the Long Park area of the Uravan district are marine and terrestrial formations ranging in age from late Paleozoic to late Mesozoic. Quaternary alluvium and landslide material are present locally (fig. 3).

All known uranium-vanadium deposits in the area are in the Morrison formation of late Jurassic age except for one small prospect in a conglomeratic bed in the overlying Burro Canyon formation of Cretaceous age. The Morrison formation is divided into two two members, the Salt Wash member, and the overlying Brushy Basin member. This report is concerned with proposed exploration for ore deposits in the sandstone units of the Salt Wash member of the Morrison formation. A generalized stratigraphic section for the area in the vicinity of the claims is given in table 2 and a detailed description of individual formations is presented below.

The ore-bearing Salt Wash member of the Morrison formation averages about 300 feet in thickness and is made up of terrestrial sandstone, siltstone, and mudstone beds. About 50 percent of the Salt Wash is made up of sandstone units, although the ratio of sandstone to siltstone and mudstone varies considerably within short distances. Generally three to five sandstone units, each 20 or more feet thick, are present along the outcrop of the Salt Wash. Such sandstone units are a few hundred feet to several thousand feet in horizontal extent.

Most uranium-vanadium deposits in the Long Park area are contained in the upper 100 feet of the Salt Wash member. The sandstone units in this stratigraphic zone are crossbedded and medium- to medium-fine-grained. Locally they are quartzitic and are brown, light gray, light red or white and contain varying

amounts of limonite, disseminated pyrite and carbonaceous material. Cut and fill structures, ripple marks, current lineations and rill marks suggest that the Salt Wash was deposited under fluvial conditions. Mudstone and siltstone in contact with upper sandstone units of the Salt Wash are generally red, reddish brown, green and gray. Interstitial clay, clay pellets and thin seams of mudstone are included in the sandstone units. Disseminated pyrite and carbonaceous material are found in some mudstone and siltstone beds. The contact of the Salt Wash member with the overlying Brushy Basin member is gradational, although there is a marked contrast in the overall appearance of the two members.

The Brushy Basin member, which is about 400 feet thick in the Long Park area, is made up of variegated shale, claystone and mudstone beds, that range in color from pure white to pastel shades of red, blue, and green. These fine-grained rocks are interbedded with sandstone and conglomeratic units. A few thin layers of quartzitic sandstone and siliceous limestone are also present. The shale and mudstone beds are bentonitic and form smooth rounded slopes covered with a loose, fluffy layer of material caused by swelling of the bentonite.

The Burro Canyon formation is a heterogeneous sequence of lower Cretaceous conglomerate, sandstone, shale and thin lenses of limestone that overlies the Brushy Basin member of the Morrison formation. Crossbedding and festoon structures indicate a fluvial

origin. The lower contact is indistinct and the formation appears to interfinger with the upper part of the Morrison formation. The upper contact is an erosional surface of regional extent. In the vicinity of the subject property the Burro Canyon averages from 50 to 125 feet in thickness.

The Long Park area lies on the northeast flank of the Paradox salt anticline which trends in a northwesterly direction. The beds dip from 2° to 9° but high on the flank of the Paradox anticline, the dip steepens to as much as 15°. The strike of the bed is generally N 45° W. High angle faults and intensely jointed strata are common along the sides of Paradox valley. The best developed joint system in the Long Park area parallel the strike of the northwest trending Paradox anticline, and another set of joints strikes essentially normal to the trend of the major structure.

The ore-bearing Salt Wash member of the Morrison formation is not exposed on the subject property. The claims lie partly on the Burro Canyon formation and partly on the Brushy Basin member of the Morrison formation. A thin cover of Quaternary alluvium and blowsand is present in some places. The local dip of the beds is from 6° to 8° and the strike is generally northwest. The depth to the ore-bearing sandstone ranges from about 385 feet on the central part of the property to as much as 600 feet on the northwest and southeast parts of the property.

ORE DEPOSITS

Most of the uranium-vanadium deposits in the Long Park area are found in sandstone units in the upper 100 feet of the Salt Wash member of the Morrison formation. Mineralized rock consists principally of sandstone impregnated with uranium and vanadium minerals in a ratio of 1 to 6. Small amounts of uranium and vanadium are contained in mudstone pebbles and seams or replace carbonaceous material. Ore bodies range from small irregular masses containing a few tons of ore to large tubular masses containing thousands of tons of ore. Mineralized rock lies essentially parallel to the sandstone beds but does not follow the beds in detail. In some deposits the highest grade of ore occurs in sharply bounded elongate concretionary structures or "rolls" which cross bedding planes.

Mineralized rock at or near the surface is sandstone impregnated with carnotite and its calcium analogue tyuyamunite. Metatyuyamunite, rauvite, pascoite, hewettite and hummerite have also been identified in the oxidized ores. Less oxidized minerals including uraninite, coffinite, corvusite, and montroseite are found at greater depths. Copper minerals are rare in the upper sandstone units of the Salt Wash. A few small but high-grade deposits, present in lower sandstone units of the Salt Wash member, contain substantial amounts of secondary copper minerals associated with uranium-vanadium minerals.

The origin of the ore and factors that controlled its localization are little understood. Primary sedimentary structures in the ore-bearing sandstone units apparently are closely related to localization of ore. Trends of sedimentary structures are generally easterly to southeasterly. The strike of mineralized logs and the long axes of ore bodies are nearly parallel to the strike of primary sedimentary structures. En echelon arrangement of ore bodies is probably caused by en echelon arrangement of these structures.

It does not appear that origin and localization of uranium and vanadium deposits are related to fractures. Apparently fractures served as avenues for secondary migration of small amounts of uranium-vanadium leached from early ore minerals by ground water solutions. Known faults that cross ore deposits in the area displace ore layers and some faults contain breccia derived from ore layers.

Geologic features and habits of ore bodies useful in exploring for uranium and vanadium deposits have been recognized through drilling experience and geologic studies. The following geologic guides (Weir 1952) were used by the Geological Survey in exploring for ore deposits in the Long Park area:

1. The ore-bearing sandstones are 25 feet or more thick in the vicinity of ore deposits.

2. The ore-bearing sandstones are dominantly light brown or light gray and have no reddish cast in the vicinity of ore deposits.

3. Mudstone and siltstone in contact with ore-bearing sandstone is green or grey near ore deposits instead of red or reddish brown.

4. The ore-bearing sandstone commonly contains abundant limonite stains or disseminated pyrite near ore deposits.

5. Carbonized plant remains are abundant in or near ore deposits. No single one of the foregoing guides is persistent enough to be used alone in appraising favorable ground.

Some of the ore deposits found by the Geological Survey and by private industry in the Long Park area are shown on figure 3 in order to illustrate their geometric configuration and their areal distribution in relation to the applicant's claim. In section 27 the long axes of the ore deposits trend easterly and northeasterly and range in width from about 200 feet to 400 feet and are as much as 2,200 feet long. The ore deposits in the vicinity of the subject claims are elongate in a northeasterly direction and average about 300 feet in width and as much as 1,800 feet long. These dimensions suggest that probable ore deposits underlying the subject claims could range from 200 feet to 300 feet in width and 500 to 900 feet in length with an average thickness of 3 to 4 feet.

ORE RESERVES

There are no known ore reserves on the property.

By U. S. G. S. standards indicated and inferred reserves of class I material found by Geological Survey drilling in the Long

Park area total about 250,800 short tons averaging 0.31 percent U_3O_8 and 2.04 percent V_2O_5 (table 3).

Class I reserves are 1 foot or more thick and contain 0.10 percent U_3O_8 or 1.0 percent V_2O_5 in accordance with the Atomic Energy Commission purchase price and the mill cutoff for vanadium.

In the vicinity of the applicant's claims three ore deposits designated as K, L, and X were found by Government drilling (fig. 3). Table 4 gives the tonnage, grade, and average thickness of these deposits.

PROPOSED EXPLORATION AND COSTS

The applicant's proposed DMEA project consists of 41 holes requiring an estimated 22,590 feet of drilling costing $2.864 per foot. Costs were calculated on the basis of three bids obtained from independent drilling contractors. The cost of the project was estimated at $105,860.00.

The program is set up in two stages. Stage I, consisting of 5,590 feet in 11 holes, would explore for ore deposits in favorable ground delineated by Geological Survey drilling. An estimated 4,490 feet of non-core footage and 1,100 feet of core-bit footage are proposed. Stage I holes would be located on north trending fences and would be at least 400 feet apart and about 400 feet away from any previously drilled holes. The positions of the holes on one fence would be staggered in relation to the holes on another fence (fig. 2).

Stage II drilling would consist of an estimated 30 holes totaling 16,800 feet to offset mineralized holes found by Stage I drilling. Although the applicant does not propose a minimum spacing for Stage II holes, the substantial size of ore bodies in this area and the depth to the ore-bearing sandstone preclude drilling offset holes closer than 100 feet to mineralized holes.

The applicant's estimated costs follow:

Independent contracts

5,590 feet of core and non-core drilling at $2.66/ft.	$14,867.50	
16,800 feet of core and non-core drilling at $2.653/ft.	44,660.00	
Bulldozing 46 days at $100/day	4,600.00	
Total independent contracts		$64,127.50

Labor and supervision

Typist 12 months at $60/mo.	$ 720.00	
Draftsman 12 months at $150/mo.	1,800.00	
Sampler and field assistant at $375/mo. (12 months)	4,500.00	
Consultant 12 months at $1,250/mo.	15,000.00	
Total labor and supervision		$22,020.00

Operating materials and supplies

Office supplies 12 months at $150/mo.	$ 1,800.00	
Survey stakes and field supplies	100.00	
Total operating material and supplies		$ 1,900.00

Operating equipment

None

Rehabilitation and repairs

None

New buildings, improvements, installations

Rental on trailer house 12 months at $50/mo.	$ 600.00		
Miscellaneous			
Accounting and office 12 months at $100/mo.	$ 1,200.00		
Payroll taxes	700.00		
Total miscellaneous		$ 1,900.00	
Contingencies		$13,212.50	
Analytical costs			
300 chemical analyses at $7 each		$ 2,100.00	
Total estimated costs for 22,390 feet of drilling			$105,860.00
Estimated cost per foot			$ 4.73
Time for completion			12 months

Engineer's estimate of costs

The drilling plan, as submitted by the applicant, appears to be suitable. Two proposed holes were located too close to the west boundary of the Ruth K. No. 4 claim. These two holes were moved to locations at least 100 feet from the outer perimeter of the claim with the applicant's consent.

The engineer's estimated costs follow:

Stage I

Independent contracts

1,100 feet of core drilling at $3.50/ft.	$ 3,850.00	
4,490 feet of non-core drilling at $1.75/ft.	7,857.50	
Bulldozing 80 hours at $12/hr.	960.00	
Total independent contracts		$12,667.50

Labor and supervision

Engineer-geologist 3 months at $600/mo.	$ 1,800.00	
Total labor and supervision		$ 1,800.00

Operating materials and supplies

100 core boxes at $1.10 each	$ 110.00	
Total operating materials and supplies		$ 110.00

Operating equipment (rental)

Jeep for engineer 3,000 miles at $0.10/mile	$ 300.00	
Total operating equipment		$ 300.00

Rehabilitation and repairs

None

New buildings, improvements, installations, etc.

None

Miscellaneous

Bookkeeping and typing 3 months at $60/mo.	$ 180.00	
Workmen's compensation, liability insurance, & payroll taxes 6 percent of $1,980	118.80	

Stakes, sacks, paper, etc.	$ 100.00		
Total miscellaneous		$ 393.80	
Total estimated cost of Stage I drilling			$15,876.30
Estimated cost per foot (5,590 feet of drilling)			$ 2.73
Estimated incidental allowance to cover everything except individual contracts and assaying ($2,608.40 ÷ 5,590) per foot			$ 0.47

Stage II

Stage I and Stage II drilling are under similar conditions and costs will be about the same.

Summary of costs

Stage I

1,100 feet of core drilling at $3.50/ft.	$ 3,850.00	
4,490 feet of non-core drilling at $1.75/ft.	7,857.50	
Bulldozing 80 hours at $12/hr.	960.00	
Incidental allowance 5,590 feet at $0.47/ft.	2,627.30	
	$15,294.80	
22 chemical analyses at $5 each	110.00	
Total estimated cost of Stage I		$15,404.80

Stage II

5,000 feet of core drilling at $3.50/ft.	$10,500.00
13,800 feet of non-core drilling at $1.75/ft.	24,150.00

Bulldozing 200 hours at $12/hr.	$ 2,400.00		
Incidental allowance 16,800 feet at $0.47/ft.	7,896.00		
	$44,946.00		
90 chemical analyses at $5 each	450.00		
Total estimated cost of Stage II drilling		$45,396.00	
Total estimated cost of project			$60,800.80
Government participation 75 percent, or			$45,600.60
Length of time for completion			1 year

Drilling contract costs on similar projects recently completed show that the estimated costs are in order:

Uranium Prospectors - Non-core $1.70/ft. Core $3.40/ft. Incid. $0.40/ft.

Norbute - Non-core $1.41/ft. Core $2.05/ft. Incid. $0.30/ft.

In general Stage I holes (fig. 2) would be drilled at least 400 feet apart and 400 feet away from any previous holes and no hole should be drilled closer that 100 feet from the outer boundary of the claim block. Approval of Stage II drilling is to be dependent on the results of Stage I drilling.

No Stage II hole should be drilled closer than 100 feet from any previously drilled hole. All holes to be cored "BX" size through the upper 100 feet of the Salt Wash member of the Morrison formation.

Maximum drilling allowable is as follows:

Stage	No. of holes	Feet non-core	Feet core	Total drilling	No. of assays	Hours bulldozing
I	11	4,490	1,100	5,590	22	80
II	30	13,800	3,000	16,800	90	200
Total	41	18,290	4,100	22,390	112	280

CONCLUSIONS AND RECOMMENDATIONS

It is concluded that the subject claims are located in a geologically favorable area based on results of extensive geologic studies and diamond drilling that was carried out in the area by the Geological Survey. Chances are good of finding ore bodies on the property that may range in size from 550 tons to 20,000 tons, averaging 10,000 tons with a grade of 0.27 percent U_3O_8 and 1.70 percent V_2O_5. It is recommended, therefore, that the project herein outlined be completed under a DMEA contract. It should be required that Stage II holes have prior approval of the field team before they are drilled. Chemical assays should be made on all samples showing significant radioactivity.

Table 1 - Summary of data from holes drilled by the USGS on and near the Ruth K. and Sylvia claims

Hole No.	Collar Elev. (feet)	Depth to top of ore-bearing sandstone (feet)	Thickness of ore-bearing sandstone (feet)	Thickness of mineralized zone (feet)	Chemical Assay $\%U_3O_8$	Chemical Assay $\%V_2O_5$	U.S.G.S. Classification
537	6249.0	385.7	12.1	none	---	---	Unfavorable
538	6392.0	384.5	43.0	none	---	---	Favorable
539	6494.5	355.8	47.8	none	---	---	Favorable
1254	6502.4	525.0	45.0	0.9	0.035	0.13	Mineralized
1256	6746.0	501.0	56.0	0.3	0.055	0.12	Ore hole
				0.5	0.11	0.12	
				0.2	0.26	0.57	
				0.4	0.45	0.26	

Table 2 - Generalized stratigraphic section for the area in the vicinity of the Ruth K. and Sylvia group of claims.

Age	Formational Unit	Average thickness (feet)
Quaternary	Alluvium	0 - 3
----------	Unconformity ----------	----------
Cretaceous	Burro Canyon formation	50 - 110
Jurassic	Morison formation	
	Brushy Basin member	400
	Salt Wash member	300

Table 3 - Summary of indicated and inferred reserves found by the Geological Survey drilling in the Long Park area.

Reserves	Grade Cutoff	Short Tons	Percent U_3O_8	Percent V_2O_5	Pounds U_3O_8	Pounds V_2O_5
(Indicated)	0.10% U_3O_8 or 1.00% V_2O_5	168,300	0.31	2.13	1,045,500	7,169,600
	0.05% U_3O_8 or 0.50% V_2O_5	294,500	0.23	1.60	1,354,700	9,424,000
(Inferred)	0.10% U_3O_8 or 1.00% V_2O_5	82,500	0.30	1.85	495,000	3,052,500
	0.05% U_3O_8 or 0.50% V_2O_5	121,100	0.21	1.55	508,600	3,869,700

Table 4 - Tonnage grade and average thickness of reserve blocks L, K, and X near the Ruth K and Sylvia Claims.

Reserve Block	Short Tons	Average Thickness	Grade $\%U_3O_8$	Grade $\%V_2O_5$
		Indicated Class I		
K	21,800	3.2 feet	0.80	0.91
L	600	4.2 feet	0.30	2.21
X	550	4.0 feet	0.29	1.00
		Inferred Class I		
K	5,700	2.5 feet	0.34	0.50
L	4,700	2.5 feet	0.29	2.18
X	550	4.0 feet		
		Indicated Class II		
K	39,800	2.9 feet	0.14	0.77
L	4,600	2.7 feet	0.24	1.95
X	---	---	---	---
		Inferred Class II		
K	10,300	2.8 feet	0.25	0.97
L	3,100	2.6 feet	0.23	1.90
X	550	4.0 feet	0.29	1.00

U S DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

DEFENSE MINERALS EXPLORATION ADMINISTRATION
DOCKET 4136
APRIL 1956

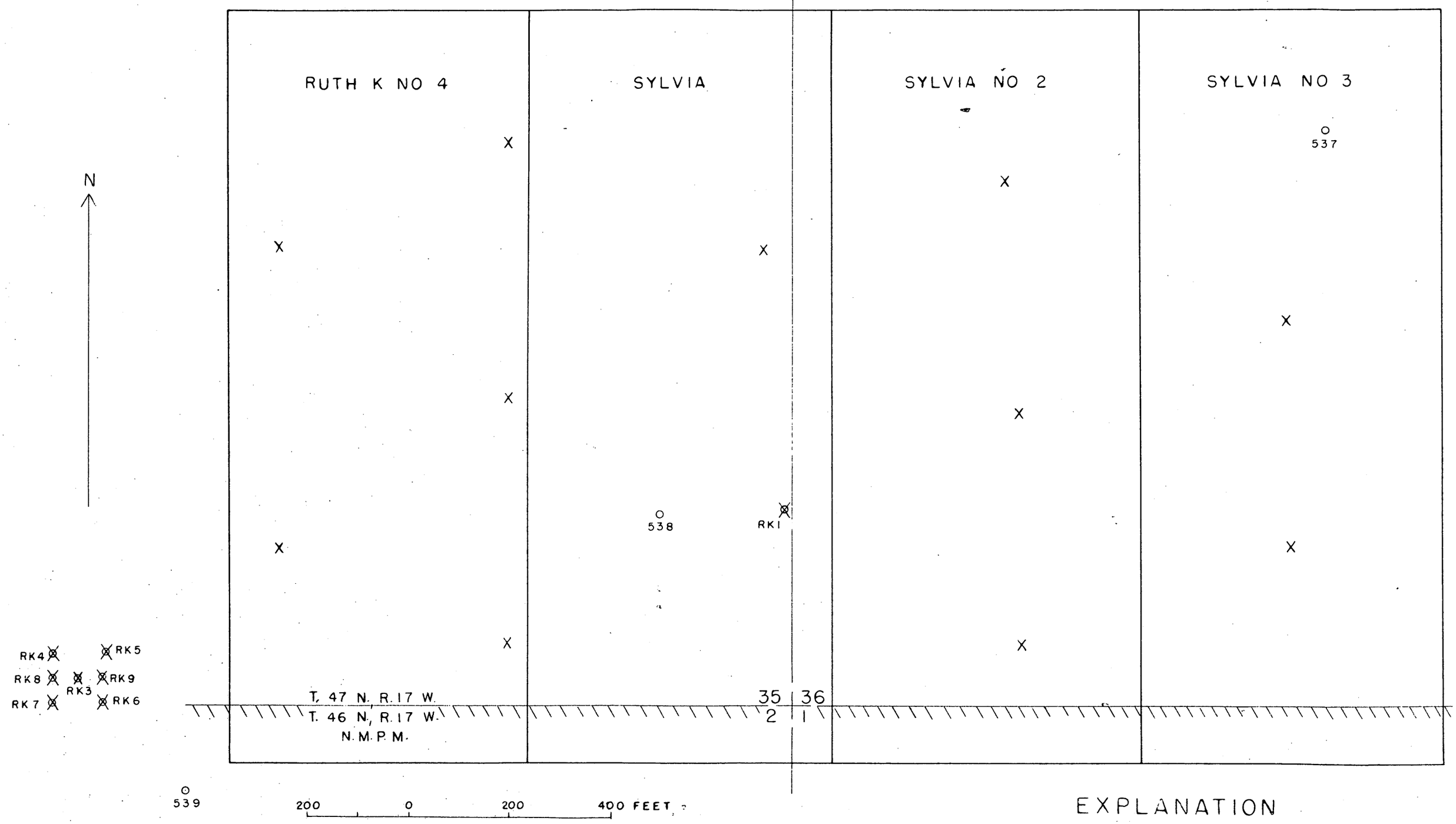

FIGURE 2. SKETCH MAP SHOWING PART OF THE RUTH K AND SYLVIA GROUP OF CLAIMS, PROPOSED HOLE LOCATIONS AND PREVIOUS DRILL HOLE LOCATIONS, URADO URANIUM CORPORATION, MONTROSE COUNTY, COLORADO.

GEOLOGIC INVESTIGATIONS OF
RADIOACTIVE DEPOSITS
SEMIANNUAL PROGRESS REPORT
June 1, 1957 - November 30, 1957
COLORADO PLATEAU DISTRICT

Uravan district, Colorado

by R. L. Boardman

The Uravan district, one of the most productive vanadium-uranium districts in the Colorado Plateau, covers about 300 square miles in the northwestern part of Montrose County and the southwestern part of Mesa County, Colo. The Geological Survey began geologic work in the district in 1939 and has carried on surface and underground geologic mapping, detailed sedimentary and mineralogic studies of vanadium-uranium-bearing beds, and large-scale diamond-drill exploration to search for minable vanadium-uranium deposits and to appraise the vanadium-uranium potential of the district. The geologic studies undertaken in the district by the Geological Survey were aimed primarily to obtain a better understanding of the distribution and localization of the vanadium-uranium deposits. Field work in the Uravan district was terminated in fiscal year 1957.

Stratigraphy

Nearly all of the consolidated rocks that crop out in the Uravan district are sedimentary formations ranging in age from Pennsylvanian to Cretaceous. One exposure of Precambrian intrusive and metamorphic crystalline rocks lies in the northwestern part of the district. Maximum thickness of exposed sedimentary rocks in the district is about 3,000 feet. A generalized stratigraphic section of sedimentary rocks in the Uravan district is given in Table A.

Structure

The Uravan district is in the northeastern part of the Paradox Basin, on the north side and near the east end of the belt of northwest-trending salt anticlines. It lies on the south side of the northwest-trending Uncompahgre uplift. The predominant northwest grain of the Uncompahgre uplift and the series of five salt anticlines is the most striking structural feature in this part of the Colorado Plateau.

The district extends northward from the center of Paradox Valley, near the axis of the collapsed Paradox Valley salt anticline, to the faulted, monoclinal southwest flank of the Uncompahgre uplift. The broad, shallow San Miguel syncline, which separates these two anticlines trends northwest through the central part of the district. Throughout most of the district beds dip less than 5° toward the axis of the San Miguel syncline, but dips increase sharply along the flank of the Paradox Valley anticline and near the Uncompahgre uplift. A series of closely spaced normal strike faults cut the side of Paradox Valley, and normal strike faults are present along the flank of the Uncompahgre uplift, but in most of the district, only minor faults are present.

The best developed joints parallel the strike of the major folds. A poorly defined joint set strikes approximately normal to the trend of the major folds.

Ore deposits

Most of the vanadium-uranium deposits in the Uravan district are in sandstone units in the upper part of the Salt Wash member of the Morrison formation. Mineralized rock in this zone consists mostly of sandstone impregnated with vanadium and uranium minerals. Lesser amounts

of vanadium and uranium minerals impregnate mudstone pebbles, films, and seams, and impregnate or replace carbonaceous material. Ore bodies range from small irregular masses containing a few tons of ore to large tabular or lens-shaped masses containing many thousands of tons of ore. The mineralized rock forms layers that are essentially parallel to the sandstone beds, but in places the ore layers curve across bedding planes in the sandstone to form rolls. Vanadium-uranium ore and the habits of ore bodies in the upper part of the Salt Wash have been described by Fischer (1942).

There are many vanadium-uranium deposits in conglomeratic sandstone beds in the Brushy Basin member of the Morrison formation and in the lower part of the Salt Wash member, but only a few of these deposits are known to contain over 1,000 tons of ore. Manganese minerals are commonly associated with vanadium and uranium minerals in most Brushy Basin deposits, whereas secondary copper minerals are commonly associated with the vanadium and uranium minerals in deposits in the lower part of the Salt Wash.

A small outcrop of mineralized conglomerate near the base of the Burro Canyon formation has been prospected in the southern part of the district. This is the only known occurrence of vanadium and uranium minerals not in the Morrison formation in the district.

The Uravan mineral belt (Fischer and Hilpert, 1952) strikes north through the western part of the district and contains all but four of the large deposits in the district. Generally, the deposits tend to occur stratigraphically higher from west to east in the belt, although

the principal deposits are nevertheless in sandstone units in the upper part of the Salt Wash. Most of the deposits in the lower part of the Salt Wash are in the western part of the belt and those in the Brushy Basin in the eastern part of the belt.

The metal ratio of vanadium to uranium in ore produced from the Uravan district is about 4:1.

Mineralogy of the ore

Most mineralized rock in the upper part of the Salt Wash at or near the surface consists of oxidized vanadium and uranium minerals in light-brown to yellow-brown limonite-stained sandstone. Gray vanadium hydromica of uncertain composition is the principal vanadium mineral and carnotite is the principal uranium mineral. In general, as the depth to ore increases, the mineralized rock consists of less oxidized vanadium and uranium minerals in light- to dark-gray pyritic sandstone. There is no consistent depth at which these changes take place. The degree of oxidation is dependent on several factors, the most important of which are the proximity or relationship to the ground-water table or to local perched water tables, and the relative porosity and permeability of mineralized beds and enclosing host rock. Corvusite and montroseite (vanadium-bearing minerals) and coffinite (a uranium-bearing mineral) are common ore minerals in unoxidized and partly oxidized sandstone. Weeks (1956) has described in detail the mineralogy and oxidation of the Colorado Plateau uranium ores.

Origin and localization of the ore

The source of the vanadium and uranium and the factors that controlled emplacement of ore bodies in the Uravan district are undetermined. Based on the field studies that have been made in the district,

the deposits are most easily explained if it is assumed that the ore elements were part of the original composition of the sediments at the time of deposition and were subsequently concentrated by solution and precipitated in approximately the present positions of the ore bodies. Several relationships that bear on origin and localization of ore in the district were reported by Boardman, Ekren, and Bowers (1956) and are summarized below.

Trends of primary sedimentary structures in upper sandstone lenses of the Salt Wash in the southern part of the Uravan district are generally east to southeast. The strike of mineralized fossil logs, and the long axes of the ore bodies and ground appraised as favorable for ore deposits are nearly parallel to the strike of primary sedimentary structures. An en echelon arrangement of ore deposits in the southern part of the district is probably caused by an en echelon arrangement of sedimentary structures.

Although such features as primary sedimentary structures, carbonaceous material, gray or green mudstone, and limonite or pyrite content apparently are related to the localization of most of the ore deposits in the Uravan district, these sedimentary and lithologic features are abundant in many places in adjacent barren sandstone. The chemical and/or physical factors that controlled the precipitation of uranium and vanadium and the emplacement of the deposits are unknown.

There is no significant difference in the U_3O_8 and V_2O_5 contents of oxidized and relatively unoxidized ore. It is probable, therefore, that there has been essentially no change in uranium-vanadium content

by oxidation, and that oxidation has taken place nearly in situ in most deposits.

It is unlikely that the origin and localization of uranium-vanadium deposits in the district are related to fractures. Fractures apparently served as avenues for only secondary migration of small amounts of uranium and vanadium leached from early ore minerals by ground-water solutions. Known faults in the district that cross ore bodies displace the ore layers and some faults contain ore gouge and breccia derived from these layers.

The concept of the Uravan mineral belt is supported by the results of exploration and geologic studies in the district. The common orientation of ore rolls and fossil logs nearly normal to the trend of the belt in the explored area is believed to be directly related to easterly or southeasterly sedimentary trends. Where sedimentary trends parallel the mineral belt, the orientation of ore rolls and fossil logs is likewise parallel to the belt. Except for four large deposits east of the belt near the Paradox Valley rim, there are only small deposits known outside the belt in the Uravan district.

Although the concept of the Uravan mineral belt cannot be seriously questioned, the reasons for its existence and localization are matters of conjecture. The belt represents a zone where favorable geologic environment controlled deposition of ore minerals. The southern part of the Uravan district has been explored as much as 5 miles east of the mineral belt and no lithologic change in the ore-bearing beds has been detected in drill cores. The only change noted is a much lower background

radioactivity of the ore-bearing and adjacent beds, as shown on gamma-ray logs of drill holes. In this ground, low background radioactivity is present even where other geologic criteria are appraised as favorable for the proximity of ore. This suggests that the uranium content of the ore-bearing solutions decreased eastward.

Exploration conducted by the U. S. Geological Survey

The Geological Survey conducted a large-scale program of diamond-drill exploration in the Uravan district between March 1948, and August 1955. This drilling consisted of 3,390 holes totaling about 1,285,000 feet. The average depth of hole was about 380 feet. This drilling resulted in the discovery of about 960,000 tons of indicated and inferred reserves of ore in layers 1 foot or more thick containing 0.10 percent or more U_3O_8 or 1.0 percent or more V_2O_5. The average grade of these reserves is about 0.35 percent U_3O_8 and 2.20 percent V_2O_5.

A summary of the drilling and reserves discovered in each of the areas explored in the Uravan district was reported in 1957 (TEI-690, p. 331-333). In that report the Horse Mesa area was included in the Gateway district but is now considered part of the Uravan district.

The U. S. Atomic Energy Commission has granted 11 mining leases on deposits discovered in the Uravan district through the Geological Survey's exploration program. These 11 leases have yielded about 30 percent of the ore produced in the Uravan district.

Results of drilling in the Uravan district have demonstrated that the following are the most useful geologic guides for exploration for vanadium-uranium deposits.

1. Interstitial mudstone grains in the ore-bearing sandstone units and most mudstone beds in contact with these units are green or gray near ore deposits, instead of red or red-brown. In general, the host sandstone unit becomes more favorable as the thickness of these green or gray beds increases. Few large deposits occur in sandstone units that are in contact with less than 0.5 feet of green or gray mudstone.

2. Ore-bearing sandstone units are 25 feet or more thick and are dominantly light brown or light gray, instead of red or white, in the vicinity of large ore deposits.

3. Ore-bearing sandstone units commonly contain abundant carbonized plant remains and abundant limonite or disseminated pyrite near ore deposits.

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To Bill with best regards.
Dan

ZONAL DISTRIBUTION OF ELEMENTS IN SOME URANIUM-VANADIUM ROLL AND TABULAR ORE BODIES ON THE COLORADO PLATEAU

By DANIEL R. SHAWE, Denver, Colo.

Work done in cooperation with the U.S. Atomic Energy Commission

Abstract.—Uranium, vanadium, and selenium are zonally distributed within and near some uranium-vanadium roll and tabular ore bodies in sandstone on the Colorado Plateau. The zones are concentric with the curved boundaries of the rolls, and parallel to the boundaries of tabular bodies. The zones are compatible with a theory that ore and other introduced elements were precipitated at an interface between two solutions with different properties, now represented by the ore boundary.

The form of Colorado Plateau uranium-vanadium roll and tabular ore bodies, particularly the roll type, and variations in shape of the ore bodies related to variations in sandstone host-rock lithology, indicate ore deposition at an interface between two solutions with different properties. If the interface theory is correct, different elements may be arranged in zones related to the postulated interface position, reflecting chemical and physical gradients that existed across the interface.

New chemical data on the eU, U, V, Cu, Pb, Zn, As, and Se content of roll ore bodies in mines in Colorado and Utah, and comparison of the U, V, and Se data with previously published data for roll and tabular ore bodies in the same and other mines in Colorado, Utah, and New Mexico, show that these elements are, in fact, systematically and similarly zoned in both types of ore bodies.

Data on some other elements indicate similarities in their distribution, too, but these data are not presented in this paper.

PHYSICAL CHARACTERISTICS OF DEPOSITS

Roll ore bodies

Roll ore bodies are long and narrow, and lie with their axes parallel to sandstone stratification and direction of greatest permeability of the sandstone. They have crescent-shaped or more complex cross sections whose edges cross the bedding of the host rock. Rolls are common in uranium-vanadium deposits in the Morrison Formation (Upper Jurassic). Their general form was first made clear by Fischer (1942, p. 367, 379–380), and some details of roll ore bodies have been published more recently (Shawe, 1956; Shawe and Granger, 1965). Commonly the "inner" or concave surface of a crescent-shaped roll appears to be a sharp boundary between ore-grade and less mineralized sandstone, whereas the "outer" or convex surface is diffuse, showing a gradual decrease of ore-mineral concentrations into less mineralized sandstone. The sharply defined inner side of a roll is believed to represent approximately the position of the solution interface. Uranium and vanadium ore and other minerals commonly occur in visible "bands" or zones concentric with the curved boundaries of the rolls. Roll ore bodies may form the lateral edges of tabular ore bodies, and in such deposits are merely the sharply curved lateral terminations of the tabular bodies which are otherwise nearly concordant with bedding of the host rock. Many tabular ore bodies are not modified by roll-like forms.

Tabular ore bodies

Tabular ore bodies are roughly lenticular in cross section, nearly concordant to sandstone stratification, and commonly are elongate in plan with their long axes parallel to the direction of greatest permeability of the sandstone. They are the most common type of uranium ore body on the Colorado Plateau. Epigenetic minerals occur in layers near and parallel to some tabular layers of uranium and vanadium ore minerals

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illustrates the similar, regular distribution of zones enriched in uranium, vanadium, and selenium. Selenium is most highly concentrated close to the sharp boundary between weakly mineralized rock and ore in all examples for which data are available. The partly oxidized tabular ore layer in the Section 15 mine, however, is unique in having high-selenium layers at both the top and the bottom edges of uranium ore. The edge of strongest vanadium mineralization generally lies at the sharp visible ore boundary, whereas the edge of strongest uranium mineralization lies farther within the ore body in most cases. The distribution of vanadium in the partly oxidized tabular layer in the Section 15 mine is also unique in that the vanadium-enriched zone is below rather than above the uranium-enriched zone. In general, uranium-to-vanadium ratios increase abruptly at the boundary between weakly mineralized rock and ore; in some ore bodies the relative increase in uranium occurs at the edge of the vanadium-rich layer and in others at the edge of the uranium-rich layer.

The consistent repetition of the pattern of distribution of the zones in these suites of samples collected from random cross sections of ore bodies shows that the zones truly have shell-like configurations parallel or concentric with the ore boundaries.

CONCLUSIONS

Similarity in the zonal distribution of uranium, vanadium, and selenium near the edges of both rolls and tabular uranium-vanadium ore bodies suggests that both types were formed the same way, a conclusion already apparent where the two forms of ore bodies occur together and are physically continuous. The zonal distribution of elements also is compatible with a theory that ore and other elements were precipitated in the vicinity of an interface between two solutions, now marked by the sharp concave edge of roll ore bodies, or one (generally the upper?) edge of tabular ore layers. The zonation of the layers of different elements is believed to be related to the different responses of the elements to an interface that existed between two chemically and physically different solutions. Elements which are concentrated in the zones may have come from either or both of the solutions, and were moved to the interface because of differences in chemical (such as concentration, Eh, pH) and physical (such as temperature, density) potentials at the interface. Apparently oxidation of the ore deposits has not affected the gross distribution of uranium, vanadium, and selenium.

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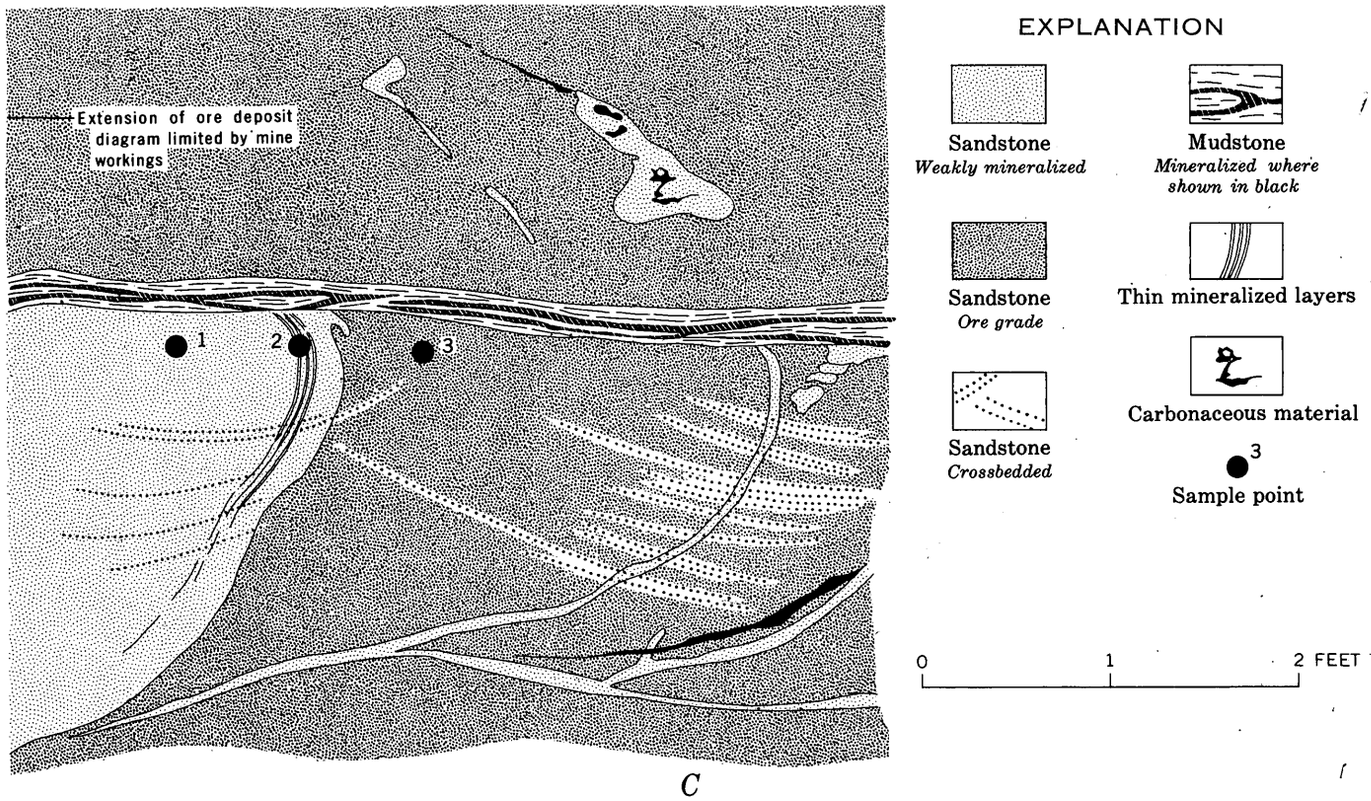
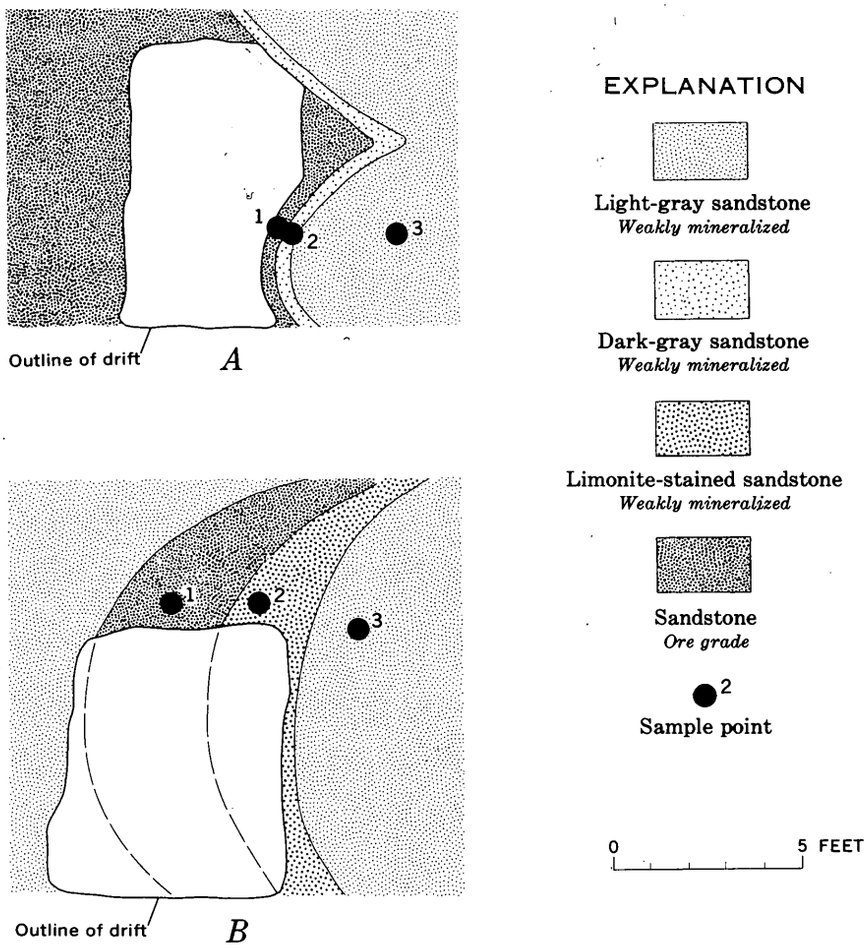


C

[Analysts: Sylvia Furman, H. H. Lipp, J. McClure, J. P. Schuch, and C. E. Thompson, U.S. Geological Survey]

Sample No.	Laboratory No.	Percent			Parts per million				
		eU	U	V	Cu	Pb	Zn	As	Se
A									
1	211102	0.004	--------	0.3	20	20	20	20	10
2	211103	.005	0.006	.2	20	20	<20	50	20
3	211104	.003	--------	.3	20	20	<20	40	20
4	211105	.003	--------	.2	20	30	<20	10	200
5	211106	.065	.068	1.5	20	20	20	40	70
6	211107	.11	.12	2.5	20	20	<20	40	15
7	211108	.073	.12	2.5	20	20	<20	60	7
8	211109	.016	.021	2.5	20	<20	<20	20	10
9	211110	.041	.051	2.5	20	20	<20	40	10
10	211111	.13	.15	2.5	20	20	<20	90	15
B									
1	211093	0.009	0.011	0.09	20	20	20	40	20
2	211094	.008	.009	.09	20	<20	20	10	10
3	211095	.030	.027	.2	20	<20	20	20	50
4	211096	.22	.34	1.2	20	<20	20	100	150
5	211097	.26	.40	1.5	20	<20	20	150	20
6	211098	.39	.61	1.2	20	<20	20	150	1,500
C									
1	211099	0.008	0.012	0.09	20	<20	<20	10	40
2	211100	.10	.15	.2	20	<20	<20	20	1,500
3	211101	.17	.17	6.0+	20	20	20	40	30

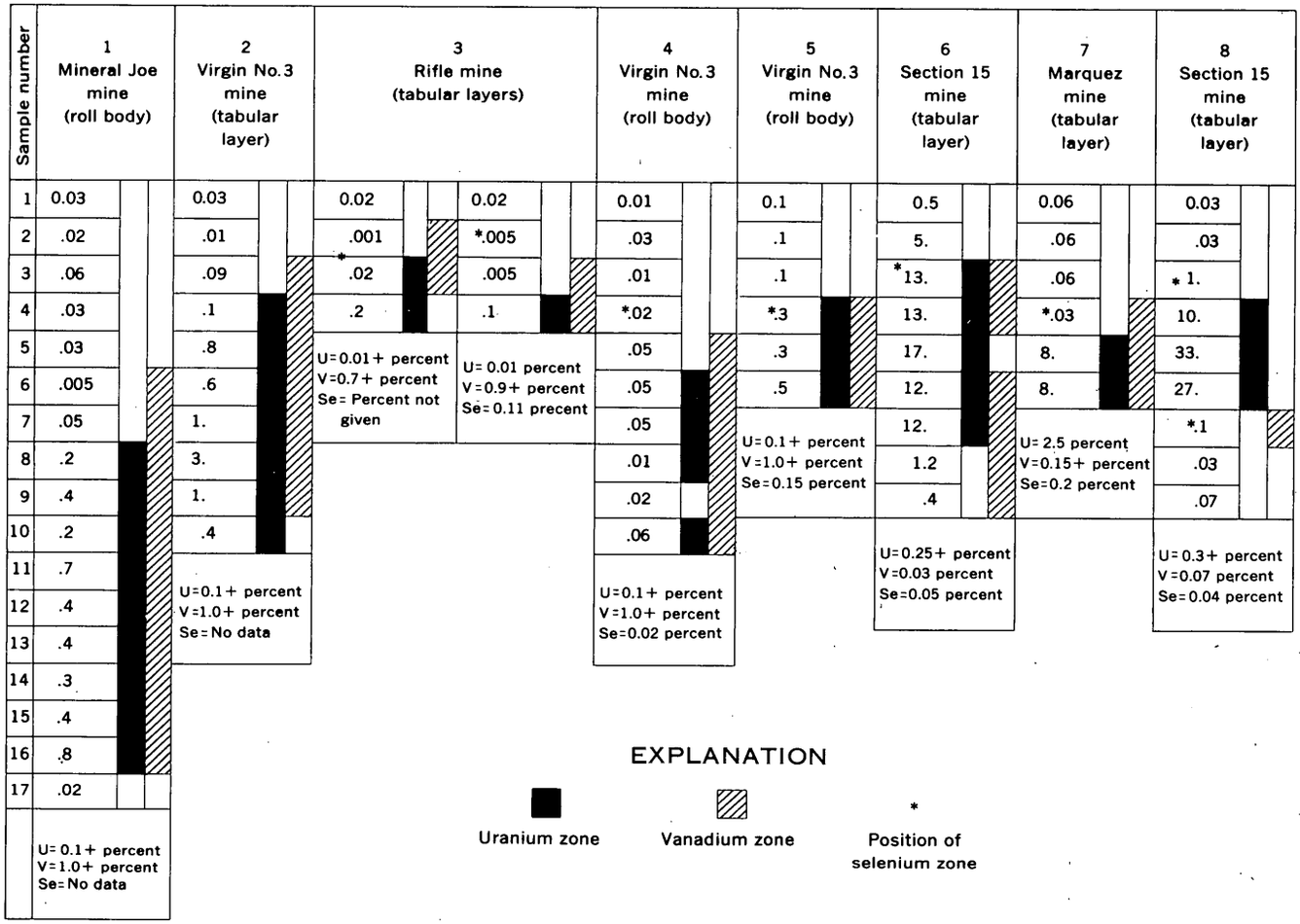
Montrose County, Colo. *A*, "S" roll ore body; *B*, ore roll with irregular edge; *C*, simple roll ore body.



[Analysts: M. Finch, C. G. Angelo, H. H. Lipp, G. T. Burrow, J. P. Schuch, E. C. Mallory, Jr., and H. E. Crowe, U.S. Geological Survey]

Sample No.	Laboratory No.	Percent			Parts per million				
		eU	U	V	Cu	Pb	Zn	As	Se
A									
1	224015	0.014	0.013	0.61	<10	10	20	40	7
2	224017	.004	.009	.06	<10	<10	<10	100	8
3	224014	.002	.002	<0.06	<10	20	<10	<10	200
B									
1	224016	0.011	0.005	0.82	<10	10	<10	60	1
2	224018	<.001	-------	.06	<10	<10	10	20	9
3	224013	.002	.003	<0.06	20	<10	<10	60	2

FIGURE 3.—Sections and chemical analyses of roll ore bodies in two mines in the Yellow Cat area, Thompson district, Grand County, Colo. *A*, unoxidized roll ore body in the Allor No. 12 mine; *B*, oxidized roll ore body in the Little Pittsburg No. 5 mine.



1, Calculated from Garrels and others (1959, table 1).
2, Calculated from Garrels and others (1959, table 3).
3, Calculated from Fischer (1960, fig. 7, samples 1 and 4).
4, Calculated from analyses accompanying figure 2*A* (this paper).
5, Calculated from analyses accompanying figure 2*B* (this paper).
6, Calculated from Granger and others (1961, fig. 5a).
7, Calculated from Granger and others (1961, fig. 5b).
8, Calculated from Granger and others (1961, fig. 5c).

FIGURE 4.—Diagram comparing uranium-vanadium ratios, and positions of higher grade uranium, vanadium, and selenium zones in some Colorado Plateau uranium-vanadium deposits. Cut-off grade for uranium, vanadium, and selenium content is listed at the bottom of each column of samples.

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

EXPLORATION FOR URANIUM-VANADIUM DEPOSITS BY THE U. S. GEOLOGICAL SURVEY IN THE CLUB MESA AREA URAVAN DISTRICT, MONTROSE COUNTY, COLORADO

By
R. L. Boardman, L. R. Litsey, and H. E. Bowers

MINERAL INVESTIGATIONS
FIELD STUDIES MAP MF 169

PUBLISHED BY THE U. S. GEOLOGICAL SURVEY
WASHINGTON, D. C.
1958

MAP MF 169

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
W. E. WRATHER, DIRECTOR

PRELIMINARY GEOLOGIC MAP OF THE URAVAN QUADRANGLE, COLORADO

By
Fred W. Cater, Jr., and E. J. McKay

MINERAL INVESTIGATIONS
FIELD STUDIES MAP MF 24

PUBLISHED BY THE U. S. GEOLOGICAL SURVEY
WASHINGTON, D. C.
1955

MAP MF 24

The series of Geologic Quadrangle Maps of the United States continues the series of quadrangle maps begun with the folios of the Geologic Atlas of the United States, which were published from 1894 to 1945. The present series consists of geologic maps, supplemented where possible by structure sections, columnar sections, and other graphic means of presenting geologic data, and accompanied by a brief explanatory text to make the maps useful for general scientific and economic purposes. Full description and interpretation of the geology of the areas shown on these maps are reserved for publication in other channels, such as the Bulletins and Professional Papers of the Geological Survey. Separate maps of the same areas, covering bedrock, surficial, engineering, and other phases of geology, may be published in the geologic quadrangle map series. Each edition is issued in flat form, 25 x 30 inches, and folded, 9¼ x 11¾ inches.

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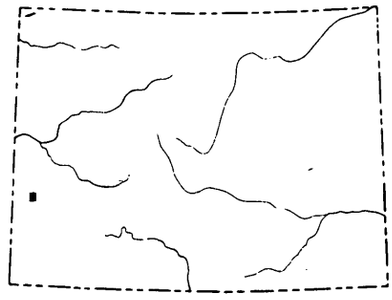
UNITED STATES GEOLOGICAL SURVEY
W. E. WRATHER, DIRECTOR

GEOLOGIC QUADRANGLE MAPS OF THE UNITED STATES

GEOLOGY OF THE URAVAN QUADRANGLE COLORADO

By

Fred W. Cater, Jr., A. P. Butler, Jr., and E. J. McKay



INDEX MAP OF COLORADO

PUBLISHED BY THE U. S. GEOLOGICAL SURVEY
WASHINGTON, D. C.
1955

MAP GQ 78

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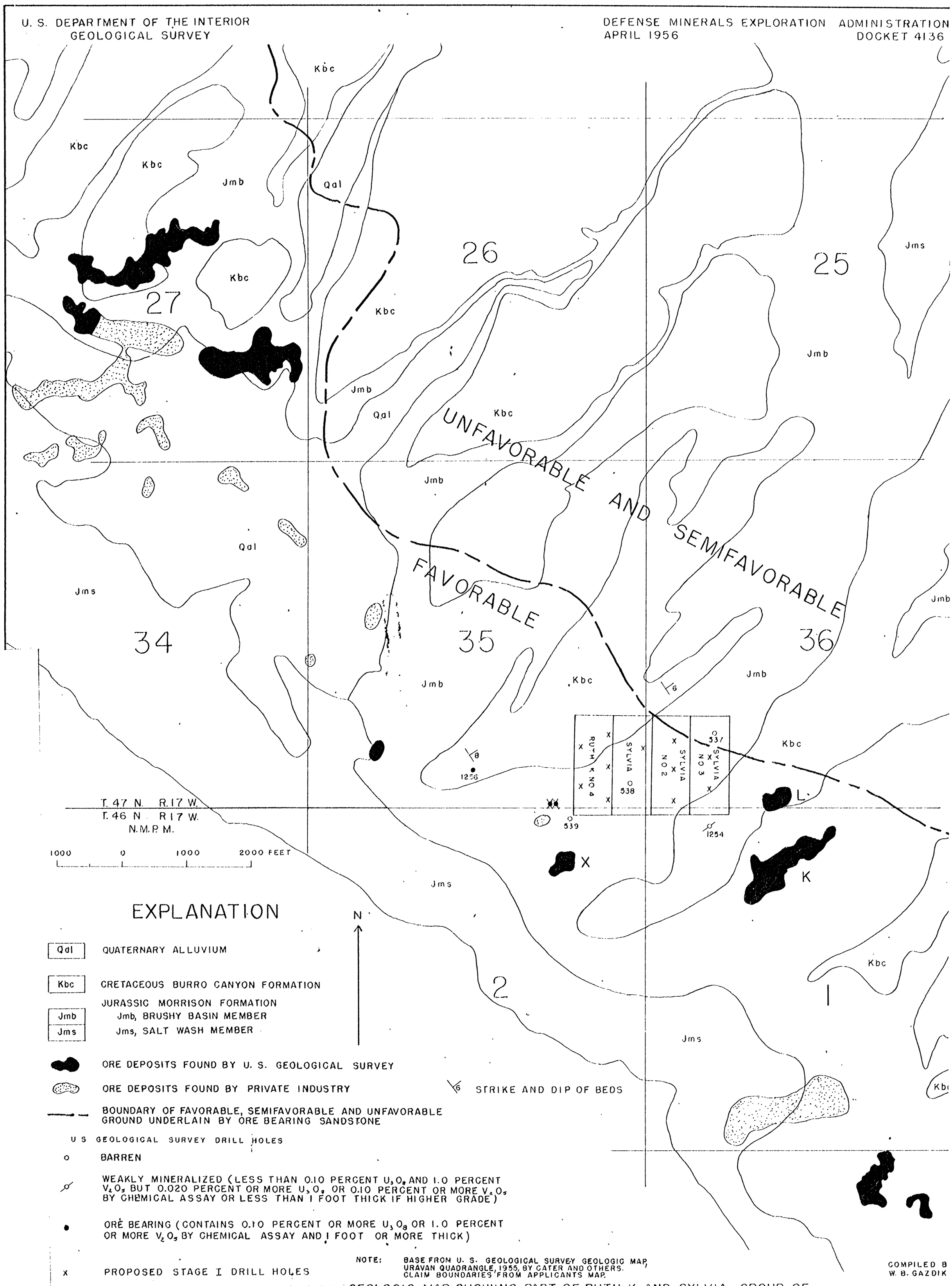


FIGURE 3. GEOLOGIC MAP SHOWING PART OF RUTH K AND SYLVIA GROUP OF CLAIMS, URADO URANIUM CORPORATION, MONTROSE COUNTY, COLORADO.

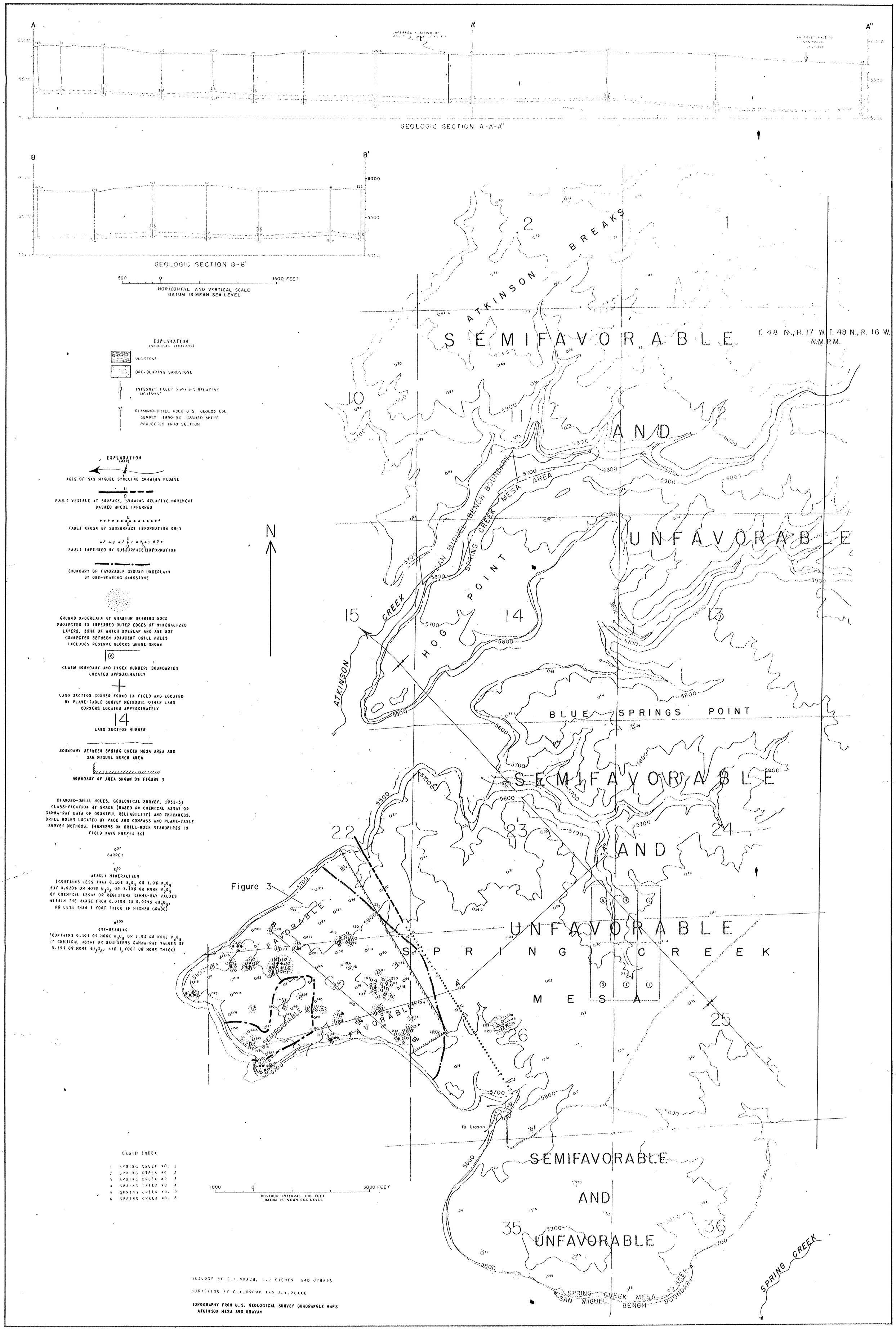
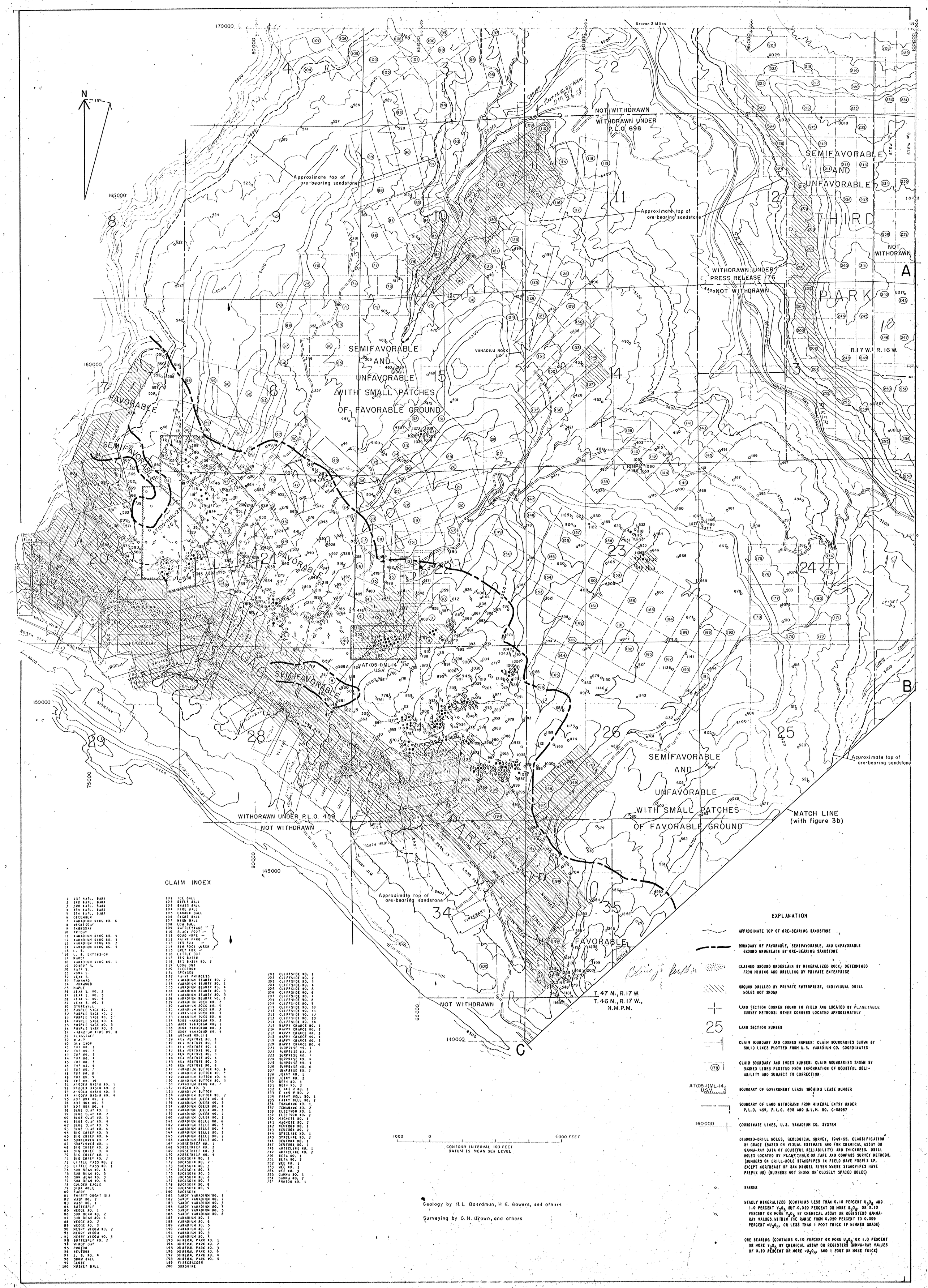


Figure 2. GEOLOGIC MAP AND SECTIONS OF THE SPRING CREEK MESA AREA, MONTROSE COUNTY, COLORADO



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77 SUN BEAM NO. 4
78 GOLDEN EAGLE
79 SINK HOLE
80 FAERY
81 THIRTY EIGHT SIX
82 WASP NO. 2
83 WASP NO. 1
84 BUTTERFLY
85 WEDGE NO. 1
86 SUN BEAM NO. 2
87 SUN BEAM NO. 1
88 WEDGE NO. 2
89 WEDGE NO. 3
90 MERRY WIDOW NO. 2
91 MERRY WIDOW
92 MERRY WIDOW NO. 3
93 BUTTERFLY NO. 2
94 WINDY DAY
95 PROTON
96 NEUTRON
97 J. B. NO. 4
98 SNOW BALL
99 GLOBE
100 MUSKET BALL
101 ICE BALL
102 RIFLE BALL
103 BRASS BALL
104 FIRE BALL
105 CARBON BALL
106 EIGHT BALL
107 HIGH BALL
108 LOW BALL
109 RATTLESNAKE
110 BLACK FOOT
111 GOOD HOPE
112 FAIRY KING
113 RED FOX
114 RIM ROCK WEEB
115 GREY FOX
116 LITTLE DOT
117 BIG BASIN
118 BIG BASIN NO. 2
119 LOOK OUT
120 ELECTRON
121 SPENSER
122 FAIRY PRINCESS
123 VANADIUM BEAUTY NO. 2
124 VANADIUM BEAUTY NO. 1
125 VANADIUM BEAUTY NO. 4
126 VANADIUM BEAUTY NO. 3
127 VANADIUM BEAUTY NO. 5
128 VANADIUM BEAUTY NO. 6
129 VANADIUM ROCK NO. 2
130 VANADIUM ROCK NO. 4
131 VANADIUM ROCK NO. 3
132 VANADIUM ROCK NO. 5
133 VANADIUM ROCK NO. 6
134 BOOK VANADIUM NO. 2
135 BOOK VANADIUM NO. 1
136 BOOK VANADIUM NO. 3
137 BOOK VANADIUM NO. 4
138 ARTHUR ROLLIE
139 NEW VENTURE NO. 8
140 NEW VENTURE NO. 7
141 NEW VENTURE NO. 1
142 NEW VENTURE NO. 2
143 NEW VENTURE NO. 3
144 NEW VENTURE NO. 4
145 NEW VENTURE NO. 5
146 NEW VENTURE NO. 6
147 VANADIUM BUTTON NO. 6
148 VANADIUM BUTTON NO. 5
149 VANADIUM BUTTON NO. 4
150 VANADIUM BUTTON NO. 3
151 VANADIUM KING NO. 7
152 VIRGIN NO. 3
153 VANADIUM BUTTON
154 VANADIUM BUTTON NO. 2
155 VANADIUM QUEEN NO. 6
156 VANADIUM QUEEN NO. 5
157 VANADIUM QUEEN NO. 4
158 VANADIUM QUEEN NO. 3
159 VANADIUM QUEEN NO. 2
160 VANADIUM QUEEN NO. 1
161 VANADIUM BELLE NO. 6
162 VANADIUM BELLE NO. 5
163 VANADIUM BELLE NO. 4
164 VANADIUM BELLE NO. 3
165 VANADIUM BELLE NO. 2
166 VANADIUM BELLE NO. 1
167 HORSETHIEF NO. 1
168 HORSETHIEF NO. 2
169 HORSETHIEF NO. 3
170 HORSETHIEF NO. 4
171 BUCKSKIN NO. 1
172 BUCKSKIN NO. 2
173 BUCKSKIN NO. 3
174 BUCKSKIN NO. 4
175 BUCKSKIN NO. 5
176 BUCKSKIN NO. 6
177 BUCKSKIN NO. 7
178 BUCKSKIN NO. 8
179 BUCKSKIN NO. 9
180 BUCKSKIN
181 SANDY VANADIUM NO. 1
182 SANDY VANADIUM NO. 2
183 SANDY VANADIUM NO. 3
184 SANDY VANADIUM NO. 4
185 SANDY VANADIUM NO. 5
186 SANDY VANADIUM NO. 6
187 VANADIUM NO. 1
188 VANADIUM NO. 6
189 VANADIUM NO. 5
190 VANADIUM NO. 2
191 VANADIUM NO. 3
192 VANADIUM NO. 4
193 MINERAL PARK NO. 1
194 MINERAL PARK NO. 2
195 MINERAL PARK NO. 3
196 MINERAL PARK NO. 6
197 MINERAL PARK NO. 4
198 MINERAL PARK NO. 5
199 FIRECRACKER
200 SUNSHINE
201 CLIFFSIDE NO. 1
202 CLIFFSIDE NO. 2
203 CLIFFSIDE NO. 3
204 CLIFFSIDE NO. 4
205 CLIFFSIDE NO. 5
206 CLIFFSIDE NO. 6
207 CLIFFSIDE NO. 7
208 CLIFFSIDE NO. 8
209 CLIFFSIDE NO. 9
210 CLIFFSIDE NO. 10
211 CLIFFSIDE NO. 11
212 CLIFFSIDE NO. 12
213 CLIFFSIDE NO. 13
214 CLIFFSIDE NO. 14
215 HAPPY CHANCE NO. 1
216 HAPPY CHANCE NO. 2
217 HAPPY CHANCE NO. 3
218 HAPPY CHANCE NO. 4
219 HAPPY CHANCE NO. 5
220 HAPPY CHANCE NO. 6
221 SURPRISE NO. 1
222 SURPRISE NO. 2
223 SURPRISE NO. 1
224 SURPRISE NO. 4
225 SURPRISE NO. 5
226 SURPRISE NO. 6
227 SURPRISE NO. 7
228 JERRY NO. 1
229 JERRY NO. 2
230 BETH NO. 1
231 BETH NO. 2
232 E AND J NO. 1
233 E AND J NO. 2
234 FARRY BELL NO. 1
235 FARRY BELL NO. 2
236 TOMAHAWK NO. 1
237 TOMAHAWK NO. 2
238 ELECTRON NO. 1
239 ELECTRON NO. 2
240 MACHETE NO. 1
241 MACHETE NO. 2
242 NEUTRON NO. 1
243 NEUTRON NO. 2
244 SYNCLINE NO. 1
245 SYNCLINE NO. 2
246 DEUTRON NO. 1
247 DEUTRON NO. 2
248 ANTICLINE NO. 1
249 ANTICLINE NO. 2
250 BETA NO. 1
251 BETA NO. 2
252 WEE NO. 1
253 WEE NO. 2
254 WEE NO. 3
255 GAMMA NO. 1
256 GAMMA NO. 2
257 PROTON NO. 1

1000 0 4000 FEET
CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL

Geology by R.L. Boardman, H.E. Bowers, and others

Surveying by G.N. Brown, and others

EXPLANATION

APPROXIMATE TOP OF ORE-BEARING SANDSTONE

BOUNDARY OF FAVORABLE, SEMIFAVORABLE, AND UNFAVORABLE GROUND UNDERLAIN BY ORE-BEARING SANDSTONE

CLAIMED GROUND UNDERLAIN BY MINERALIZED ROCK, DETERMINED FROM MINING AND DRILLING BY PRIVATE ENTERPRISE

GROUND DRILLED BY PRIVATE ENTERPRISE, INDIVIDUAL DRILL HOLES NOT SHOWN

LAND SECTION CORNER FOUND IN FIELD AND LOCATED BY PLANETABLE SURVEY METHODS; OTHER CORNERS LOCATED APPROXIMATELY

25 LAND SECTION NUMBER

CLAIM BOUNDARY AND CORNER NUMBER: CLAIM BOUNDARIES SHOWN BY SOLID LINES PLOTTED FROM U.S. VANADIUM CO. COORDINATES

(178) CLAIM BOUNDARY AND INDEX NUMBER: CLAIM BOUNDARIES SHOWN BY DASHED LINES PLOTTED FROM INFORMATION OF DOUBTFUL RELIABILITY AND SUBJECT TO CORRECTION

AT(05-1)ML-14 U.S.V. BOUNDARY OF GOVERNMENT LEASE SHOWING LEASE NUMBER

BOUNDARY OF LAND WITHDRAWN FROM MINERAL ENTRY UNDER P.L.O. 459, P.L.O. 698 AND B.L.M. NO. C-08967

160000 COORDINATE LINES, U.S. VANADIUM CO. SYSTEM

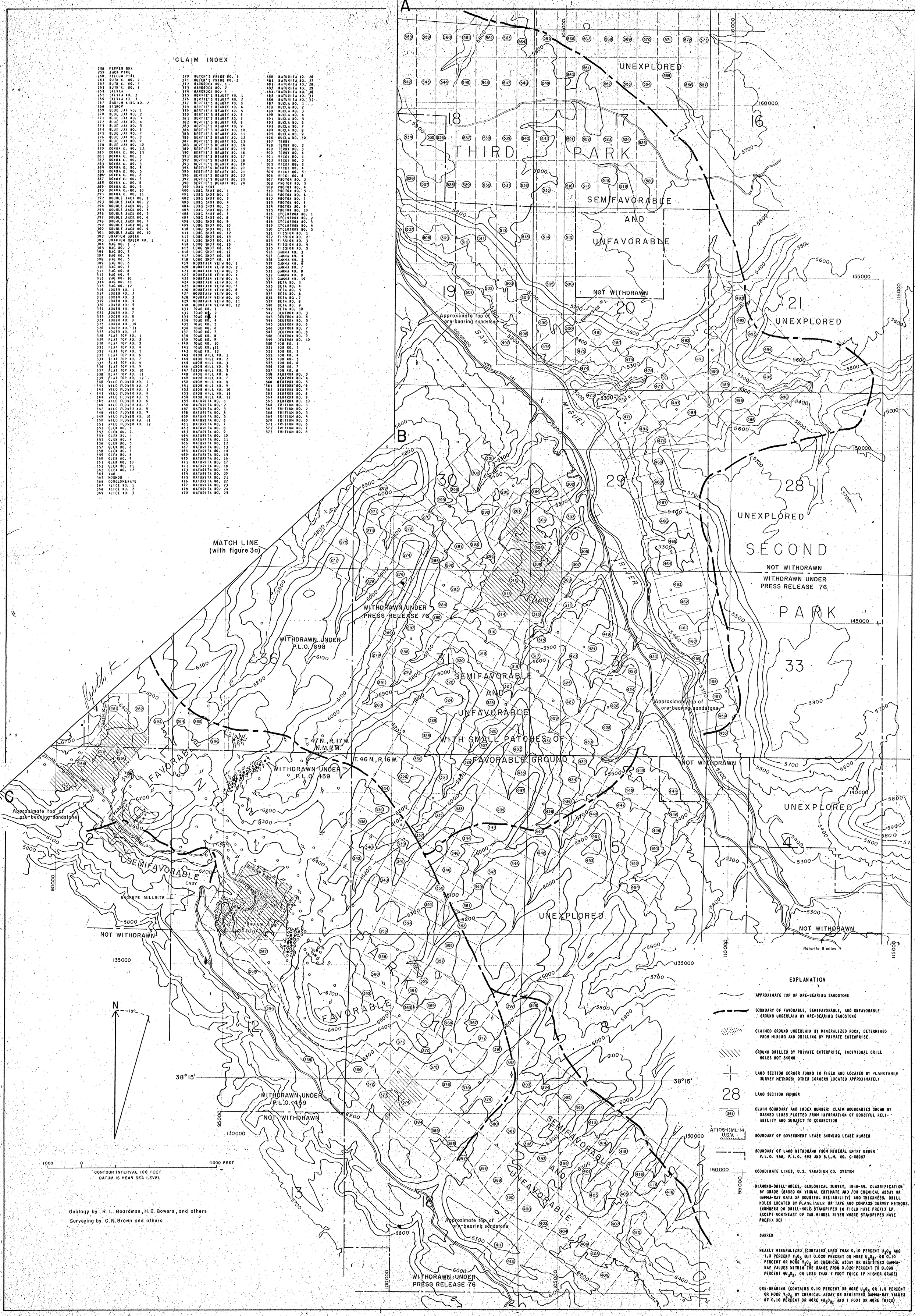
DIAMOND-DRILL HOLES, GEOLOGICAL SURVEY, 1949-55. CLASSIFICATION BY GRADE (BASED ON VISUAL ESTIMATE AND /OR CHEMICAL ASSAY OR GAMMA-RAY DATA OF DOUBTFUL RELIABILITY) AND THICKNESS. DRILL HOLES LOCATED BY PLANETABLE OR TAPE AND COMPASS SURVEY METHODS. (NUMBERS ON DRILL-HOLE STAKEPIPES IN FIELD HAVE PREFIX LP, EXCEPT NORTHEAST OF SAN MIGUEL RIVER WHERE STAKEPIPES HAVE PREFIX UD) (NUMBERS NOT SHOWN ON CLOSELY SPACED HOLES)

BARREN

WEAKLY MINERALIZED (CONTAINS LESS THAN 0.10 PERCENT U_3O_8 AND 1.0 PERCENT V_2O_5 BUT 0.020 PERCENT OR MORE U_3O_8, OR 0.10 PERCENT OR MORE V_2O_5 BY CHEMICAL ASSAY OR REGISTERS GAMMA-RAY VALUES WITHIN THE RANGE FROM 0.020 PERCENT TO 0.099 PERCENT eU_3O_8, OR LESS THAN 1 FOOT THICK IF HIGHER GRADE)

ORE BEARING (CONTAINS 0.10 PERCENT OR MORE U_3O_8 OR 1.0 PERCENT OR MORE V_2O_5 BY CHEMICAL ASSAY OR REGISTERS GAMMA-RAY VALUES OF 0.10 PERCENT OR MORE eU_3O_8, AND 1 FOOT OR MORE THICK)

Figure 3a. MAP OF THE SOUTHWESTERN PART OF THE URAVAN DISTRICT, MONTROSE COUNTY, COLORADO



CLAIM INDEX

258	PEPPER BOX	370	BUTCH'S PRIDE NO. 1	480	NATURITA NO. 26
259	JACK PINE	371	BUTCH'S PRIDE NO. 2	481	NATURITA NO. 27
260	YELLOW PINE	372	HARDROCK NO. 1	482	NATURITA NO. 28
261	RUTH K. NO. 2	373	HARDROCK NO. 2	483	NATURITA NO. 29
262	RUTH K. NO. 3	374	HARDROCK NO. 3	484	NATURITA NO. 30
263	RUTH K. NO. 4	375	BERTIE'S BEAUTY NO. 1	485	NATURITA NO. 31
264	SYLVIA	376	BERTIE'S BEAUTY NO. 2	486	NATURITA NO. 32
265	SYLVIA NO. 2	377	BERTIE'S BEAUTY NO. 3	487	NUCLA NO. 1
266	SYLVIA NO. 3	378	BERTIE'S BEAUTY NO. 4	488	NUCLA NO. 2
267	RADIUM KING NO. 2	379	BERTIE'S BEAUTY NO. 5	489	NUCLA NO. 3
268	BISHOP	380	BERTIE'S BEAUTY NO. 6	490	NUCLA NO. 4
269	BLUE JAY NO. 1	381	BERTIE'S BEAUTY NO. 7	491	NUCLA NO. 5
270	BLUE JAY NO. 2	382	BERTIE'S BEAUTY NO. 8	492	NUCLA NO. 6
271	BLUE JAY NO. 3	383	BERTIE'S BEAUTY NO. 9	493	NUCLA NO. 7
272	BLUE JAY NO. 4	384	BERTIE'S BEAUTY NO. 10	494	NUCLA NO. 8
273	BLUE JAY NO. 5	385	BERTIE'S BEAUTY NO. 11	495	NUCLA NO. 9
274	BLUE JAY NO. 6	386	BERTIE'S BEAUTY NO. 12	496	NUCLA NO. 10
275	BLUE JAY NO. 7	387	BERTIE'S BEAUTY NO. 13	497	TERRY
276	BLUE JAY NO. 8	388	BERTIE'S BEAUTY NO. 14	498	TERRY NO. 2
277	BLUE JAY NO. 9	389	BERTIE'S BEAUTY NO. 15	499	TERRY NO. 3
278	BLUE JAY NO. 10	390	BERTIE'S BEAUTY NO. 16	500	TERRY NO. 4
279	DONNA K. NO. 12	391	BERTIE'S BEAUTY NO. 17	501	VICKI NO. 1
280	DONNA K. NO. 13	392	BERTIE'S BEAUTY NO. 18	502	VICKI NO. 2
281	DONNA K. NO. 1	393	BERTIE'S BEAUTY NO. 19	503	VICKI NO. 3
282	DONNA K. NO. 2	394	BERTIE'S BEAUTY NO. 20	504	VICKI NO. 4
283	DONNA K. NO. 3	395	BERTIE'S BEAUTY NO. 21	505	VICKI NO. 5
284	DONNA K. NO. 4	396	BERTIE'S BEAUTY NO. 22	506	VICKI NO. 6
285	DONNA K. NO. 5	397	BERTIE'S BEAUTY NO. 23	507	PROTON NO. 2
286	DONNA K. NO. 6	398	BERTIE'S BEAUTY NO. 24	508	PROTON NO. 3
287	DONNA K. NO. 7	399	LONG SHOT	509	PROTON NO. 4
288	DONNA K. NO. 8	400	LONG SHOT NO. 1	510	PROTON NO. 5
289	DONNA K. NO. 9	401	LONG SHOT NO. 2	511	PROTON NO. 6
290	DONNA K. NO. 10	402	LONG SHOT NO. 3	512	PROTON NO. 7
291	DONNA K. NO. 11	403	LONG SHOT NO. 4	513	PROTON NO. 8
292	DOUBLE JACK NO. 1	404	LONG SHOT NO. 5	514	PROTON NO. 9
293	DOUBLE JACK NO. 2	405	LONG SHOT NO. 6	515	PROTON NO. 10
294	DOUBLE JACK NO. 3	406	LONG SHOT NO. 7	516	CYCLOTRON NO. 1
295	DOUBLE JACK NO. 4	407	LONG SHOT NO. 8	517	CYCLOTRON NO. 2
296	DOUBLE JACK NO. 5	408	LONG SHOT NO. 9	518	CYCLOTRON NO. 3
297	DOUBLE JACK NO. 6	409	LONG SHOT NO. 10	519	CYCLOTRON NO. 4
298	DOUBLE JACK NO. 7	410	LONG SHOT NO. 11	520	CYCLOTRON NO. 5
299	DOUBLE JACK NO. 8	411	LONG SHOT NO. 12	521	FISSION NO. 1
300	DOUBLE JACK NO. 9	412	LONG SHOT NO. 13	522	FISSION NO. 2
301	DOUBLE JACK NO. 10	413	LONG SHOT NO. 14	523	FISSION NO. 3
302	URANIUM QUEEN	414	LONG SHOT NO. 15	524	FISSION NO. 4
303	URANIUM QUEEN NO. 1	415	LONG SHOT NO. 16	525	FISSION NO. 5
304	BAG NO. 1	416	LONG SHOT NO. 17	526	GAMMA NO. 3
305	BAG NO. 2	417	LONG SHOT NO. 18	527	GAMMA NO. 4
306	BAG NO. 3	418	LONG SHOT NO. 19	528	GAMMA NO. 5
307	BAG NO. 4	419	MOUNTAIN VIEW NO. 1	529	GAMMA NO. 6
308	BAG NO. 5	420	MOUNTAIN VIEW NO. 2	530	GAMMA NO. 7
309	BAG NO. 6	421	MOUNTAIN VIEW NO. 3	531	GAMMA NO. 8
310	BAG NO. 7	422	MOUNTAIN VIEW NO. 4	532	GAMMA NO. 9
311	BAG NO. 8	423	MOUNTAIN VIEW NO. 5	533	GAMMA NO. 10
312	BAG NO. 9	424	MOUNTAIN VIEW NO. 6	534	BETA NO. 3
313	BAG NO. 10	425	MOUNTAIN VIEW NO. 7	535	BETA NO. 4
314	BAG NO. 11	426	MOUNTAIN VIEW NO. 8	536	BETA NO. 5
315	BAG NO. 12	427	MOUNTAIN VIEW NO. 9	537	BETA NO. 6
316	JOKER NO. 1	428	MOUNTAIN VIEW NO. 10	538	BETA NO. 7
317	JOKER NO. 2	429	MOUNTAIN VIEW NO. 11	539	BETA NO. 8
318	JOKER NO. 3	430	MOUNTAIN VIEW NO. 12	540	BETA NO. 9
319	JOKER NO. 4	431	TOAD NO. 1	541	BETA NO. 10
320	JOKER NO. 5	432	TOAD NO. 2	542	DEUTRON NO. 3
321	JOKER NO. 6	433	TOAD NO. 3	543	DEUTRON NO. 4
322	JOKER NO. 7	434	TOAD NO. 4	544	DEUTRON NO. 5
323	JOKER NO. 8	435	TOAD NO. 5	545	DEUTRON NO. 6
324	JOKER NO. 9	436	TOAD NO. 6	546	DEUTRON NO. 7
325	JOKER NO. 10	437	TOAD NO. 7	547	DEUTRON NO. 8
326	JOKER NO. 11	438	TOAD NO. 8	548	DEUTRON NO. 9
327	JOKER NO. 12	439	TOAD NO. 9	549	DEUTRON NO. 10
328	FLAT TOP NO. 1	440	TOAD NO. 10	550	ION NO. 1
329	FLAT TOP NO. 2	441	TOAD NO. 11	551	ION NO. 2
330	FLAT TOP NO. 3	442	TOAD NO. 12	552	ION NO. 3
331	FLAT TOP NO. 4	443	KNOB HILL NO. 1	553	ION NO. 4
332	FLAT TOP NO. 5	444	KNOB HILL NO. 2	554	ION NO. 5
333	FLAT TOP NO. 6	445	KNOB HILL NO. 3	555	ION NO. 6
334	FLAT TOP NO. 7	446	KNOB HILL NO. 4	556	ION NO. 7
335	FLAT TOP NO. 8	447	KNOB HILL NO. 5	557	ION NO. 8
336	FLAT TOP NO. 9	448	KNOB HILL NO. 6	558	NEUTRON NO. 3
337	FLAT TOP NO. 10	449	KNOB HILL NO. 7	559	NEUTRON NO. 4
338	FLAT TOP NO. 11	450	KNOB HILL NO. 8	560	NEUTRON NO. 5
339	FLAT TOP NO. 12	451	KNOB HILL NO. 9	561	NEUTRON NO. 6
340	WILD FLOWER NO. 1	452	KNOB HILL NO. 10	562	NEUTRON NO. 7
341	WILD FLOWER NO. 2	453	KNOB HILL NO. 11	563	NEUTRON NO. 8
342	WILD FLOWER NO. 3	454	KNOB HILL NO. 12	564	NEUTRON NO. 9
343	WILD FLOWER NO. 4	455	NATURITA NO. 1	565	NEUTRON NO. 10
344	WILD FLOWER NO. 5	456	NATURITA NO. 2	566	TRITIUM NO. 1
345	WILD FLOWER NO. 6	457	NATURITA NO. 3	567	TRITIUM NO. 2
346	WILD FLOWER NO. 7	458	NATURITA NO. 4	568	TRITIUM NO. 3
347	WILD FLOWER NO. 8	459	NATURITA NO. 5	569	TRITIUM NO. 4
348	WILD FLOWER NO. 9	460	NATURITA NO. 6	570	TRITIUM NO. 5
349	WILD FLOWER NO. 10	461	NATURITA NO. 7	571	TRITIUM NO. 6
350	WILD FLOWER NO. 11	462	NATURITA NO. 8	572	TRITIUM NO. 7
351	WILD FLOWER NO. 12	463	NATURITA NO. 9	573	TRITIUM NO. 8
352	GLEN NO. 1	464	NATURITA NO. 10		
353	GLEN NO. 2	465	NATURITA NO. 11		
354	GLEN NO. 3	466	NATURITA NO. 12		
355	GLEN NO. 4	467	NATURITA NO. 13		
356	GLEN NO. 5	468	NATURITA NO. 14		
357	GLEN NO. 6	469	NATURITA NO. 15		
358	GLEN NO. 7	470	NATURITA NO. 16		
359	GLEN NO. 8	471	NATURITA NO. 17		
360	GLEN NO. 9	472	NATURITA NO. 18		
361	GLEN NO. 10	473	NATURITA NO. 19		
362	GLEN NO. 11	474	NATURITA NO. 20		
363	GLEN NO. 12	475	NATURITA NO. 21		
364	VAN	476	NATURITA NO. 22		
365	MORMON	477	NATURITA NO. 23		
366	CONGLOMERATE	478	NATURITA NO. 24		
367	ALICE NO. 1	479	NATURITA NO. 25		
368	ALICE NO. 2				
369	ALICE NO. 3				

Figure 3b. MAP OF THE SOUTHEASTERN PART OF THE URAVAN DISTRICT, MONTROSE COUNTY, COLORADO

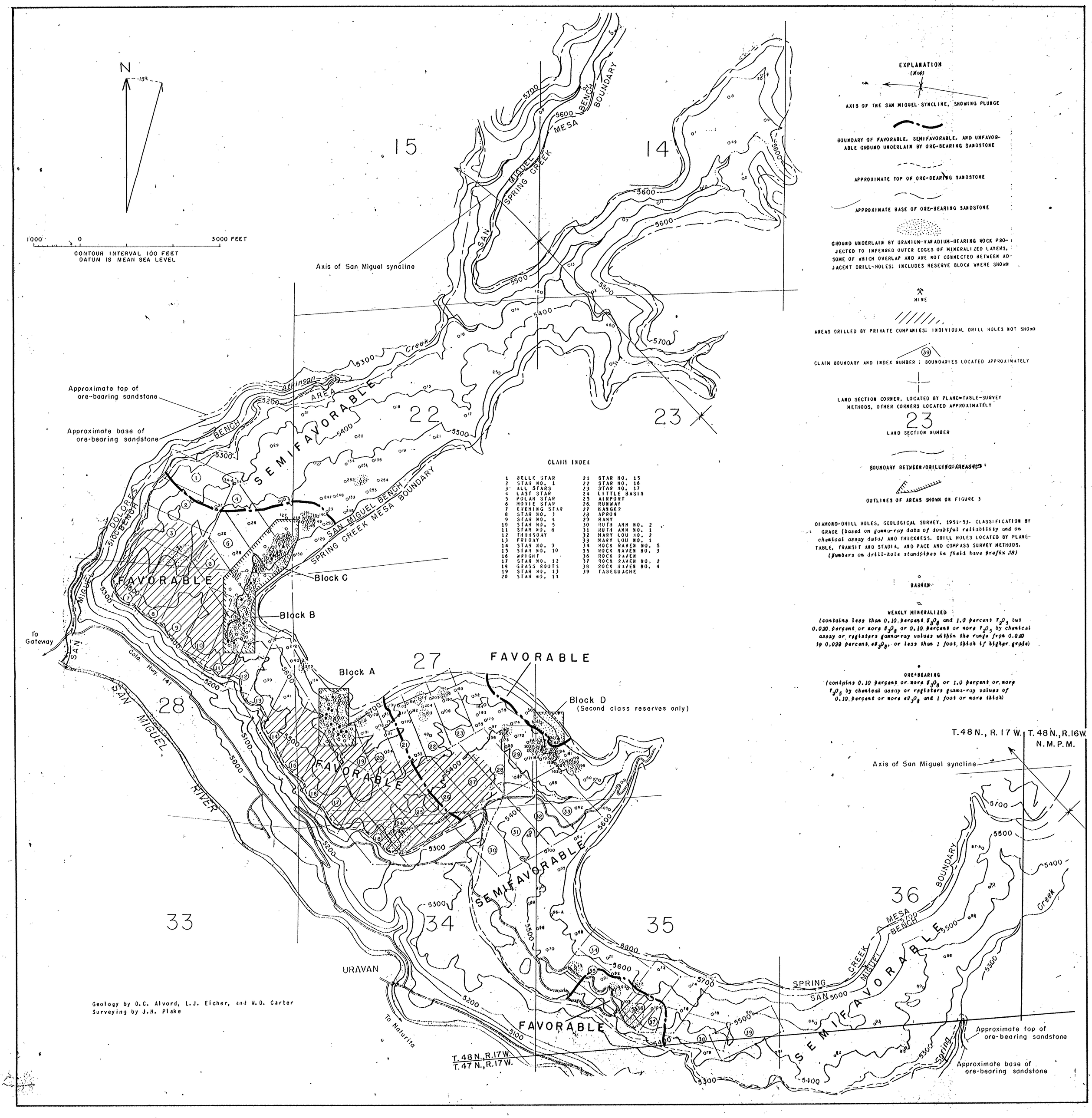
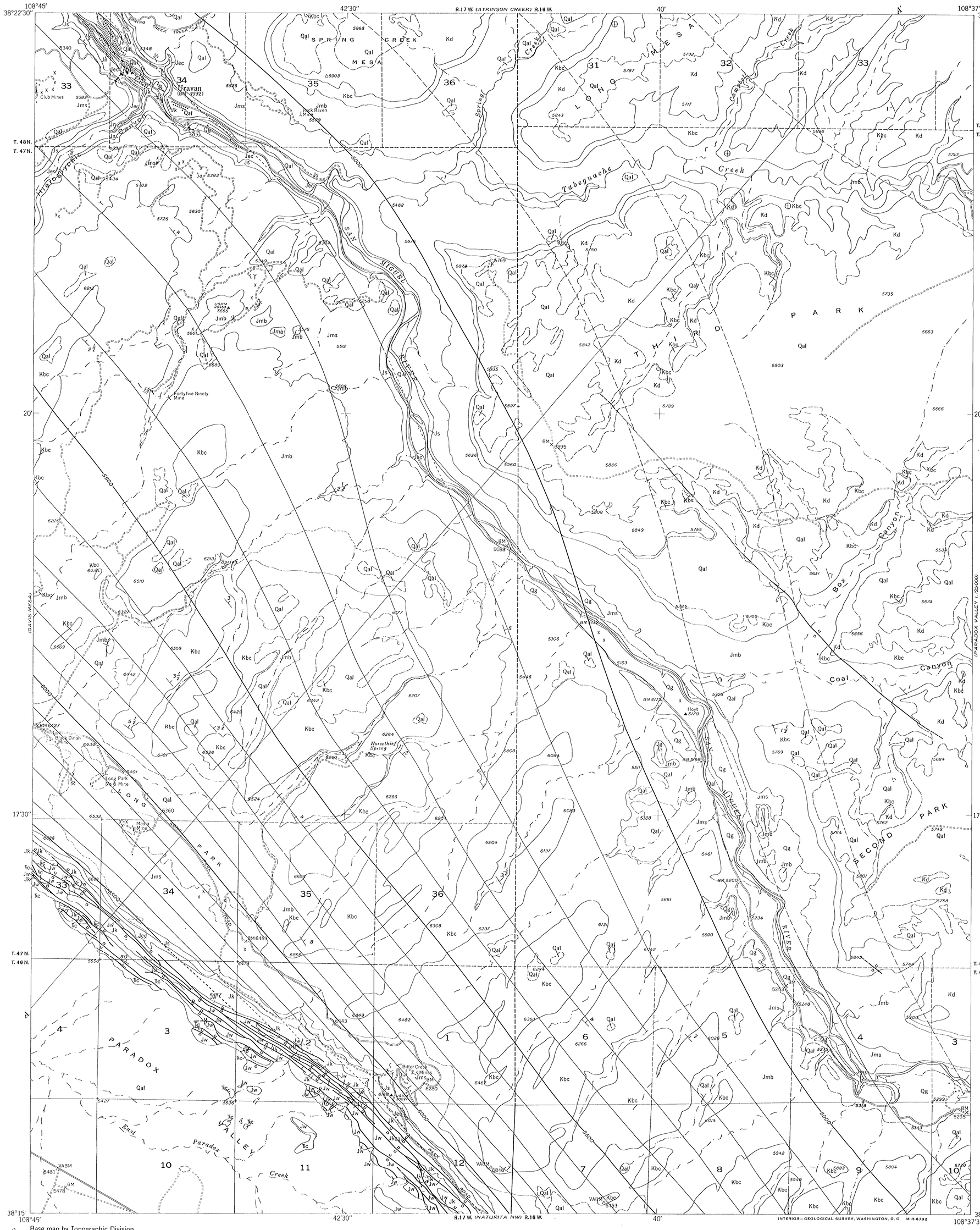


Figure 2. MAP OF SAN MIGUEL BENCH, MONTROSE COUNTY, COLORADO.

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
W. E. WRATHER, DIRECTOR

PREPARED IN COOPERATION WITH THE
U. S. ATOMIC ENERGY COMMISSION
COLORADO GEOLOGICAL SURVEY BOARD
AND COLORADO METAL MINING FUND BOARD

MINERAL INVESTIGATIONS
FIELD STUDIES MAP MF24



Base map by Topographic Division
U. S. Geological Survey, 1949

Geology by A. P. Butler, 1941, F. W. Cater, Jr., and E. J. McKay, 1948.

EXPLANATION

QUATERNARY — *Pleistocene and Recent*

Qal — Alluvium
Light-red sand and silt, mostly wind-deposited and reworked by water; sandy gravel valley fill.

Qg — Terrace gravels
Pebbles and cobbles of intrusive and extrusive rocks.

UNCONFORMITY

CRETACEOUS — *Upper Cretaceous*, *Lower Cretaceous*

Kd — Dakota sandstone
Gray, yellow, and buff flaggy sandstone with interbedded carbonaceous shale and impure coal.

Kbc — Burro Canyon formation
White, gray, and red sandstone and conglomerate with interbedded green and purplish shale.

JURASSIC — *Upper Jurassic*, *Middle and Upper Jurassic*, *San Rafael group*

Jmb, Jms — Morrison formation
Variegated shale and white and gray sandstone and conglomerate (Jmb); white and buff sandstone with minor amounts of mudstone (Jms).

Js — Summerville formation
Predominantly red and brown thin-bedded mudstone; thin beds of chert and limestone.

Jec — Entrada sandstone and Carmel formation undivided
Orange, buff, and white fine-grained sandstone at the top; red sandstone and mudstone at the base.

UNCONFORMITY

JURASSIC(?) — *Glen Canyon group*

Jn — Navajo sandstone
Gray to buff crossbedded fine-grained quartz sandstone.

Jk — Kayenta formation
Red, buff, gray, and lavender shale, siltstone, and fine- to coarse-grained sandstone.

Jw — Wingate sandstone
Fine-grained reddish-brown sandstone, thick bedded, massive, and crossbedded.

TRIASSIC — *Upper Triassic*

Ꞧc — Chinle formation
Red to orange-red siltstone and fine-grained sandstone, shale, and conglomerate.

Contact
Dashed where approximately located.

Indefinite contact
Includes inferred contacts and indefinite boundaries of surficial deposits.

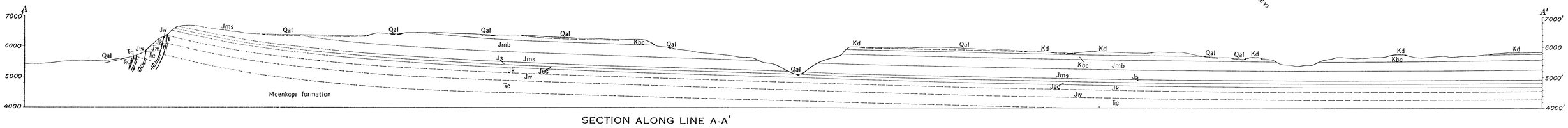
Fault
Dashed where approximately located; dotted where concealed. u, upthrown side; d, downthrown side.

Strike and dip of beds

Horizontal beds

Structure contour
Drawn on top of Entrada sandstone; dashed where inferred or approximately located; short dashes indicate projection above surface. Contour interval 100 feet. Datum is mean sea level.

Note: Some small areas of outcrop are not marked. Contacts are not closed when the contact touches a river.



SECTION ALONG LINE A-A′

PRELIMINARY GEOLOGIC MAP
OF THE
URAVAN QUADRANGLE, COLORADO
By
Fred W. Cater, Jr. and E. J. McKay

Scale 1:24000

1 ½ 0 1 Mile

1955

APPROXIMATE MEAN DECLINATION, 1955

MINERAL INVESTIGATIONS
FIELD STUDIES MAP MF 24

Since the preparation of this map the age designation of the Glen Canyon group has been changed in U. S. Geological Survey usage to Triassic and Jurassic; the age designation of the Wingate sandstone has been changed to Triassic; and the age designation of the Navajo sandstone has been changed to Jurassic.

For sale by U. S. Geological Survey, price 50 cents

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

UNITED STATES
ATOMIC ENERGY COMMISSION

URAVAN QUADRANGLE
COLORADO–MONTROSE CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)

Mapped, edited, and published by the Geological Survey

Control by USGS and USC&GS

Topography from aerial photographs by multiplex methods
Aerial photographs taken September 1947. Field check, 1948

Polyconic projection. 1927 North American datum
10,000-foot grid based on Colorado coordinate system, south zone

Dashed land lines indicate approximate location
Land lines omitted in part of T.47 N.–R.16 W. and T.46 N.–R.17 W. because of insufficient data

TRUE NORTH
MAGNETIC NORTH
15°
APPROXIMATE MEAN DECLINATION, 1948

SCALE 1:24000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO OR WASHINGTON 25, D. C.

ROAD CLASSIFICATION

HARD-SURFACE ALL WEATHER ROADS		DRY WEATHER ROADS
Heavy-duty	4 LANE 16 LANE	Improved dirt
Medium-duty	4 LANE 16 LANE	Unimproved dirt
Loose-surface, graded, or narrow hard-surface		

U. S. Route — State Route

URAVAN, COLO.
N3815—W10837.5/7.5

EDITION OF 1949

THE TOPOGRAPHIC MAPS OF THE UNITED STATES

The United States Geological Survey is making a series of standard topographic maps to cover the United States. This work has been in progress since 1882, and the published maps cover more than 47 percent of the country, exclusive of outlying possessions.

The maps are published on sheets that measure about 16½ by 20 inches. Under the general plan adopted the country is divided into quadrangles bounded by parallels of latitude and meridians of longitude. These quadrangles are mapped on different scales, the scale selected for each map being that which is best adapted to general use in the development of the country, and consequently, though the standard maps are of nearly uniform size, the areas that they represent are of different sizes. On the lower margin of each map are printed graphic scales showing distances in feet, meters, miles, and kilometers. In addition, the scale of the map is shown by a fraction expressing a fixed ratio between linear measurements on the map and corresponding distances on the ground. For example, the scale $\frac{1}{62,500}$ means that 1 unit on the map (such as 1 inch, 1 foot, or 1 meter) represents 62,500 of the same units on the earth's surface.

Although some areas are surveyed and some maps are compiled and published on special scales for special purposes, the standard topographic surveys and the resulting maps have for many years been of three types, differentiated as follows:

1. Surveys of areas in which there are problems of great public importance—relating, for example, to mineral development, irrigation, or reclamation of swamp areas—are made with sufficient detail to be used in the publication of maps on a scale of $\frac{1}{31,680}$ (1 inch = one-half mile) or $\frac{1}{24,000}$ (1 inch = 2,000 feet), with a contour interval of 1 to 100 feet, according to the relief of the particular area mapped.

2. Surveys of areas in which there are problems of average public importance, such as most of the basin of the Mississippi and its tributaries, are made with sufficient detail to be used in the publication of maps on a scale of $\frac{1}{62,500}$ (1 inch = nearly 1 mile), with a contour interval of 10 to 100 feet.

3. Surveys of areas in which the problems are of minor public importance, such as much of the mountain or desert region of Arizona or New Mexico, and the high mountain area of the northwest, are made with sufficient detail to be used in the publication of maps on a scale of $\frac{1}{125,000}$ (1 inch = nearly 2 miles) or $\frac{1}{250,000}$ (1 inch = nearly 4 miles), with a contour interval of 20 to 250 feet.

The aerial camera is now being used in mapping. From the information recorded on the photographs, planimetric maps, which show only drainage and culture, have been made for some areas in the United States. By the use of stereoscopic plotting apparatus, aerial photographs are utilized also in the making of the regular topographic maps, which show relief as well as drainage and culture.

A topographic survey of Alaska has been in progress since 1898, and nearly 44 percent of its area has now been mapped. About 15 percent of the Territory has been covered by maps on a scale of $\frac{1}{500,000}$ (1 inch = nearly 8 miles). For most of the remainder of the area surveyed the maps published are on a scale of $\frac{1}{250,000}$ (1 inch = nearly 4 miles). For some areas of particular economic importance, covering about 4,300 square miles, the maps published are on a scale of $\frac{1}{62,500}$ (1 inch = nearly 1 mile) or larger. In addition to the area covered by topographic maps, about 11,300 square miles of southeastern Alaska has been covered by planimetric maps on scales of $\frac{1}{125,000}$ and $\frac{1}{250,000}$.

The Hawaiian Islands have been surveyed, and the resulting maps are published on a scale of $\frac{1}{62,500}$.

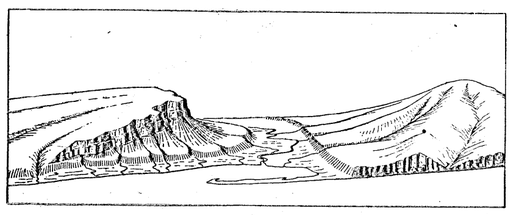
A survey of Puerto Rico is now in progress. The scale of the published maps is $\frac{1}{30,000}$.

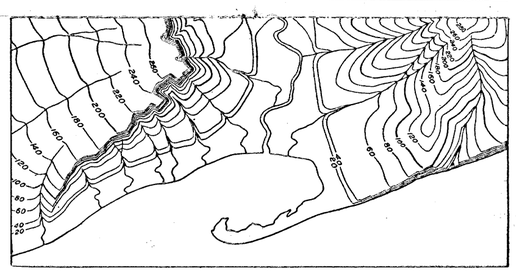
The features shown on topographic maps may be arranged in three groups—(1) water, including seas, lakes, rivers, canals, swamps, and other bodies of water; (2) relief, including mountains, hills, valleys, and other features of the land surface; (3) culture (works of man), such as towns, cities, roads, railroads, and boundaries. The symbols used to represent these features are shown and explained below. Variations appear on some earlier maps, and additional features are represented on some special maps.

All the water features are represented in blue, the smaller streams and canals by single blue lines and the larger streams by double lines. The larger streams, lakes, and the sea are accentuated by blue water lining or blue tint. Intermittent streams—those whose beds are dry for a large part of the year—are shown by lines of blue dots and dashes.

Relief is shown by contour lines in brown, which on a few maps are supplemented by shading showing the effect of light thrown from the northwest across the area represented, for the purpose of giving the appearance of relief and thus aiding in the interpretation of the contour lines. A contour line represents an imaginary line on the ground (a contour) every part of which is at the same altitude above sea level. Such a line could be drawn at any altitude, but in practice only the contours at certain regular intervals of altitude are shown. The datum or zero of altitude of the Geological Survey maps is mean sea level. The 20-foot contour would be the shore line if the sea should rise 20 feet above mean sea level. Contour lines show the shape of the hills, mountains, and valleys, as well as their altitude. Successive contour lines that are far apart on the map indicate a gentle slope, lines that are close together indicate a steep slope, and lines that run together indicate a cliff.

The manner in which contour lines express altitude, form, and grade is shown in the figure below.





The sketch represents a river valley that lies between two hills. In the foreground is the sea, with a bay that is partly enclosed by a hooked sand bar. On each side of the valley is a terrace into which small streams have cut narrow gullies. The hill on the right has a rounded summit and gently sloping spurs separated by ravines. The spurs are truncated at their lower ends by a sea cliff. The hill at the left terminates abruptly at the valley in a steep scarp, from which it slopes gradually away and forms an inclined tableland that is traversed by a few shallow gullies. On the map each of these features is represented, directly beneath its position in the sketch, by contour lines.

The contour interval, or the vertical distance in feet between one contour and the next, is stated at the bottom of each map. This interval differs according to the topography of the area mapped: in a flat country it may be as small as 1 foot; in a mountainous region it may be as great as 250 feet. In order that the contours may be read more easily certain contour lines, every fourth or fifth, are made heavier than the others and are accompanied by figures showing altitude. The heights of many points—such as road intersections, summits, surfaces of lakes, and benchmarks—are also given on the map in figures, which show altitudes to the nearest foot only. More precise figures for the altitudes of benchmarks are given in the Geological Survey's bulletins on spirit leveling. The geodetic coordinates of triangulation and transit-traverse stations are also published in bulletins.

Lettering and the works of man are shown in black. Boundaries, such as those of a State, county, city, land grant, township, or reservation, are shown by continuous or broken lines of different kinds and weights. Public roads suitable for motor travel the greater part of the year are shown by solid double lines; poor public roads and private roads by dashed double lines; trails by dashed single lines. Additional public road classification if available is shown by red overprint.

Each quadrangle is designated by the name of a city, town, or prominent natural feature within it, and on the margins of the map are printed the names of adjoining quadrangles of which maps have been published. More than 4,100 quadrangles in the United States have been surveyed, and maps of them similar to the one on the other side of this sheet have been published.

Geologic maps of some of the areas shown on the topographic maps have been published in the form of folios. Each folio includes maps showing the topography, geology, underground structure, and mineral deposits of the area mapped, and several pages of descriptive text. The text explains the maps and describes the topographic and geologic features of the country and its mineral products. Two hundred twenty-five folios have been published.

Index maps of each State and of Alaska and Hawaii showing the areas covered by topographic maps and geologic folios published by the United States Geological Survey may be obtained free. Copies of the standard topographic maps may be obtained for 10 cents each; some special maps are sold at different prices. A discount of 40 percent is allowed on an order amounting to $5 or more at the retail price. The discount is allowed on an order for maps alone, either of one kind or in any assortment, or for maps together with geologic folios. The geologic folios are sold for 25 cents or more each, the price depending on the size of the folio. A circular describing the folios will be sent on request.

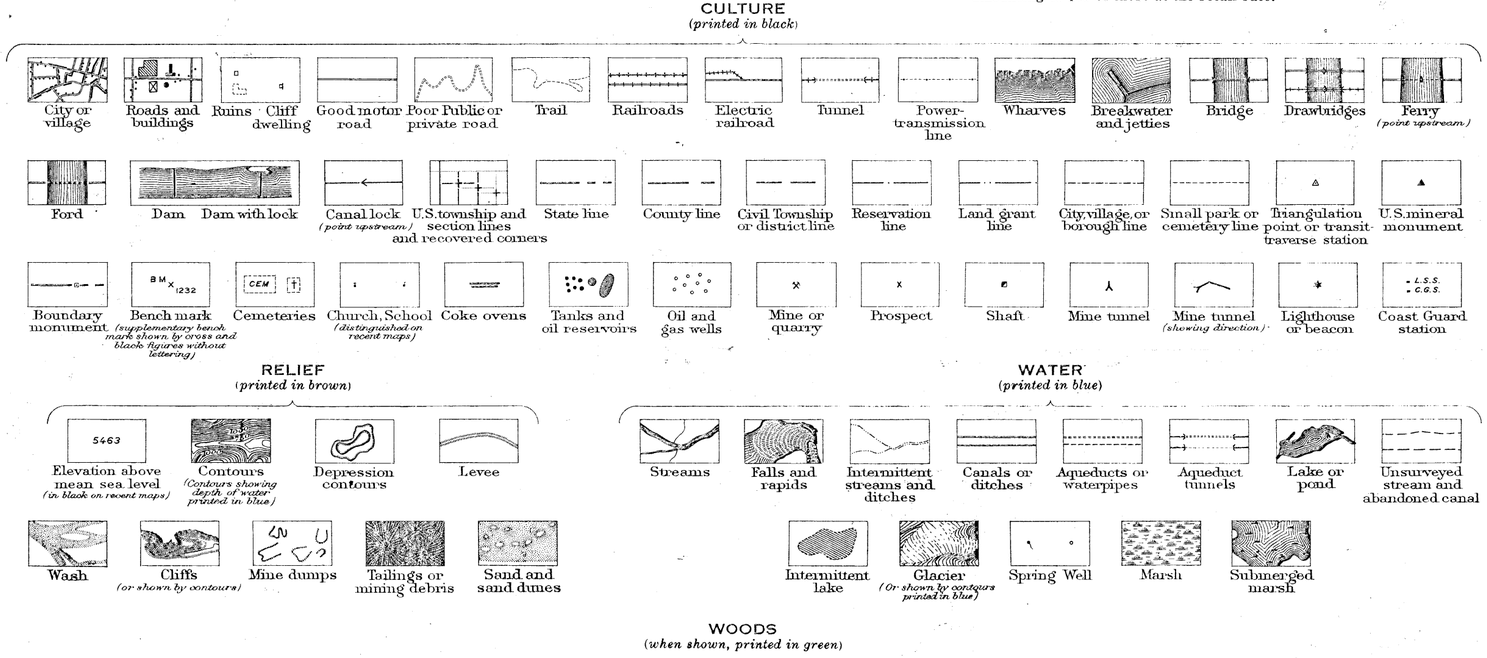
Applications for maps or folios should be accompanied by cash, draft, or money order (not postage stamps) and should be addressed to

THE DIRECTOR,
United States Geological Survey,
Washington, D. C.

November 1937.

NOTE:—Effective on and after October 1, 1946, the price of standard topographic quadrangle maps will be 20 cents each, with a discount of 20 percent on orders amounting to $10 or more at the retail rate.

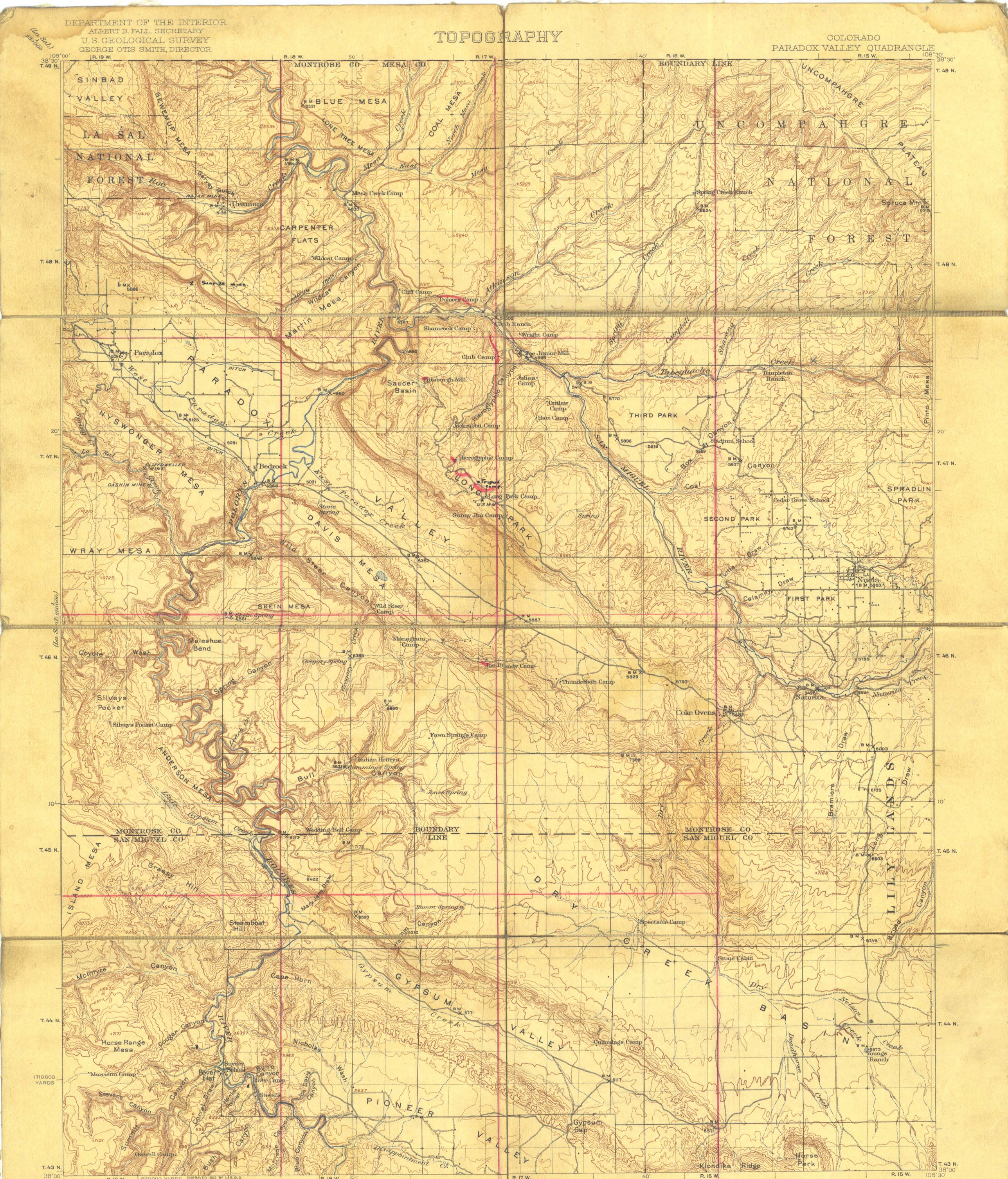
STANDARD SYMBOLS



DEPARTMENT OF THE INTERIOR
ALBERT B. FALL, SECRETARY
U. S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

TOPOGRAPHY

COLORADO
PARADOX VALLEY QUADRANGLE



R. B. Marshall, Chief Geographer.
C. H. Birdseye, Geographer in charge.
Topography by C. L. Nelson, D. H. Watson, C. A. Stonesifer, C. W. Rowell, and W. F. Hicks.
Control by C. F. Urquhart, C. W. Rowell, and R. W. Burchard.
Surveyed in 1914–1916.

620000 YARDS ENGRAVED 1922 BY U.S.G.S.

Scale 1:125000
Contour interval 100 feet.
Datum is mean sea level.

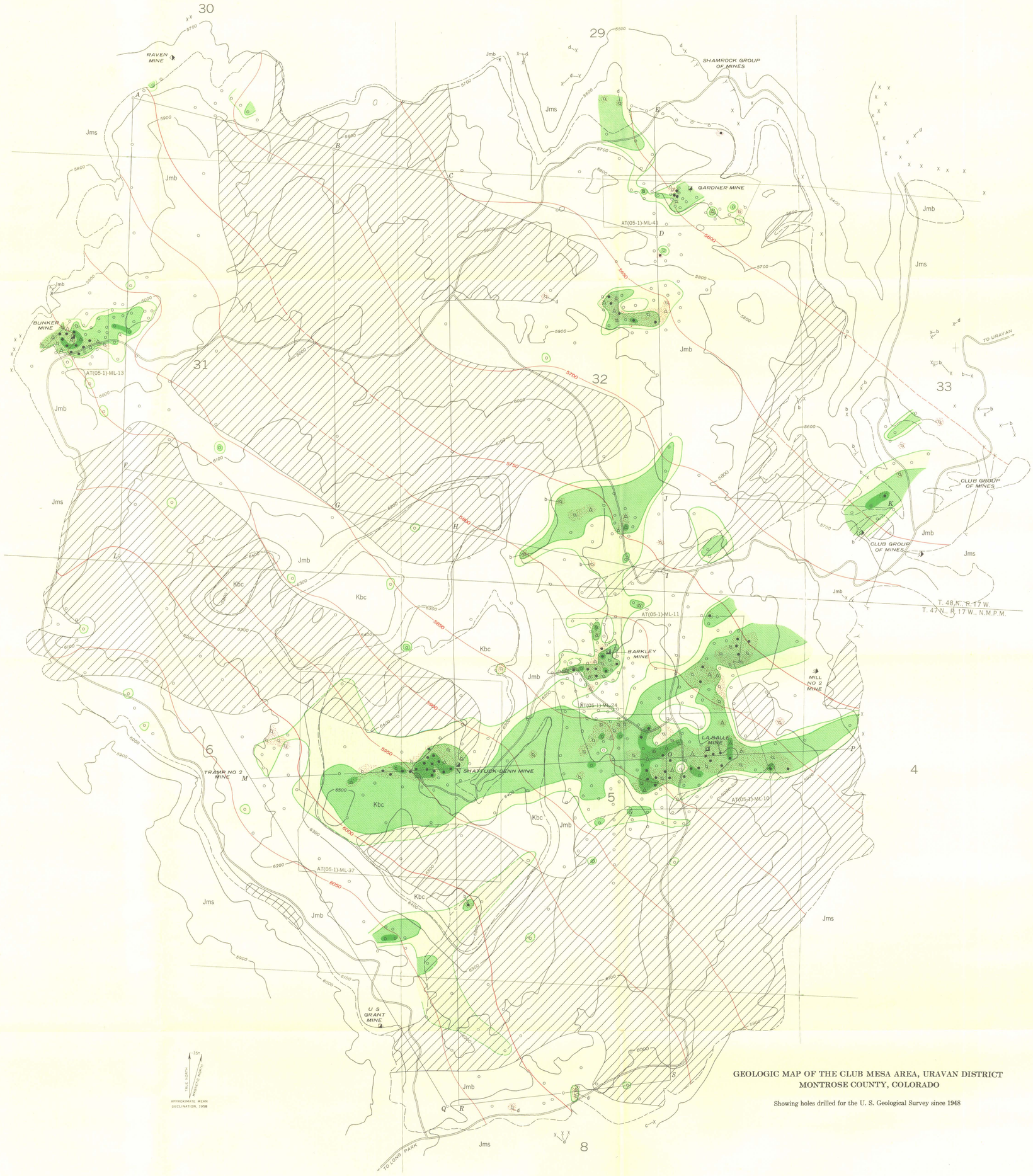
APPROXIMATE MEAN DECLINATION 1916

DIAGRAM OF TOWNSHIP

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Polyconic projection. North American datum.
5000 yard grid based upon U. S. zone system, E.

PARADOX VALLEY
Edition of 1922.



GEOLOGIC MAP OF THE CLUB MESA AREA, URAVAN DISTRICT
MONTROSE COUNTY, COLORADO

Showing holes drilled for the U. S. Geological Survey since 1948

EXPLANATION

Kbc — Burro Canyon formation (CRETACEOUS)

Jmb / Jms — Morrison formation; *Jmb, Brushy Basin member; Jms, Salt Wash member* (JURASSIC)

Contact
Dashed where approximately located

6000 / 6050 — Structure contour
Drawn on top of Salt Wash member of Morrison formation. Long dashes where approximately located; short dashes where projected above the surface. Contour interval 50 feet

M—N—O—P — Lines of section of fence diagram

Land section corner
Located by plane-table survey methods; other corners located approximately

AT(05-1)-ML-13 — Boundary of U.S. Atomic Energy Commission lease showing lease number

Vertical shaft

Vertical shaft
Sunk on drill hole in barren rock

Vertical shaft
Sunk on drill hole in mineralized rock

Inclined shaft

Adit

Prospect
Note: Mine or prospect is in sandstone unit "a" unless designated "b", "c", or "d" (Salt Wash member of Morrison formation) or "Jmb" (Brushy Basin member of Morrison formation)

Ground underlain by uranium-vanadium-bearing rocks
Found in the Salt Wash member of Morrison formation by drilling for U. S. Geological Survey and projected to inferred outer edges of mineralized layers. Some layers overlap and are not connected between adjacent drill holes. Mineralized rock is in sandstone unit "a" unless designated "b" or "d" (Salt Wash member of Morrison formation)

Drill hole in barren rock

Drill hole in weakly mineralized rock
(Salt Wash member of Morrison formation)

Drill hole in weakly mineralized rock
(Brushy Basin member of Morrison formation)

Drill hole in ore-grade rock
(Salt Wash member of Morrison formation)

Drill hole in ore-bearing rock
(Salt Wash member of Morrison formation)

Diamond-drill holes, 1948-1958. Classification by grade (based on radiometric and chemical assays, and gamma-ray data of doubtful reliability) and thickness. Drill holes located by plane table, transit, and stadia. (Numbers on drill-hole standpipes in field have prefix CM.)

Weakly mineralized.—*Contains less than 0.10 percent U_3O_8 and 1.0 percent V_2O_5, but 0.020 percent or more U_3O_8 or 0.10 percent or more V_2O_5 by chemical assay, or registers gamma-ray values within the range from 0.020 percent to 0.099 percent eU_3O_8.*

Ore grade.—*Contains 0.10 percent or more U_3O_8 or 1.0 percent or more V_2O_5 by chemical assay, or registers gamma-ray values of 0.10 per cent or more eU_3O_8, but is less than 1 foot thick.*

Ore bearing.—*Contains 0.10 percent or more U_3O_8 or 1.0 percent or more V_2O_5 by chemical assay, or registers gamma-ray values of 0.10 percent or more eU_3O_8, and is 1 foot or more thick*

Area of ore-bearing sandstone units in the upper part of the Salt Wash member of the Morrison formation that are less than 30 feet thick

0.1 to 0.5 feet thick — 0.5 to 3.0 feet thick — 3.0 feet or more thick

Thickness of green or gray mudstone in contact with ore-bearing sandstone units in the upper part of the Salt Wash member of the Morrison formation

EXPLORATION FOR URANIUM-VANADIUM DEPOSITS BY THE U. S. GEOLOGICAL SURVEY IN THE CLUB MESA AREA URAVAN DISTRICT, MONTROSE COUNTY, COLORADO

By
Robert L. Boardman, Linus R. Litsey, and Howard E. Bowers

INTRODUCTION

The Club Mesa area is in the western part of the Uravan district, Montrose County, Colo.; it covers about 6 square miles in Tps. 47 and 48 N., R. 17 W., New Mexico principal meridian. (See index map.) The area is immediately west of Uravan, Colo., and is bounded approximately by the San Miguel River to the north and northeast, the Dolores River to the northwest, Saucer Basin to the southwest, and Hieroglyphic Canyon to the southeast.

Club Mesa is one of the most productive areas for uranium-vanadium ore in southwestern Colorado. The average grade of this ore has ranged from about 0.25 to 1.50 percent U_3O_8 and 1.5 to 5.0 percent V_2O_5.

Between 1948 and 1953, the U. S. Geological Survey, on behalf of the Division of Raw Materials of the U. S. Atomic Energy Commission, conducted diamond-drill exploration in the Club Mesa area to find minable uranium-vanadium deposits and to appraise uranium-vanadium reserves. Most of the drilling was done in unexplored ground away from known deposits and all drilling was contracted for by the U. S. Geological Survey. Private industry has done a like amount of drilling, mostly in the vicinity of mines or prospects or near outcrops of the ore-bearing strata. In 1943 51 holes were drilled for the U. S. Bureau of Mines and the U. S. Geological Survey (Huleatt, Hazen, and Traver, 1946) in the vicinity of the Shamrock group of mines, in sec. 29 (see geologic map). Only the holes drilled for the Geological Survey since 1948 are shown on the geologic map. Most of the interpretations of the subsurface geology are based on this drilling; therefore, interpretations are incomplete near the older mines and prospects and in areas drilled by private companies.

This publication summarizes some of the results of U. S. Geological Survey investigations in the Club Mesa area, and presents a compilation of available geologic data that would be helpful in future exploration. Detailed geologic logs of holes drilled for the Survey in the Club Mesa area on public land that is no longer withdrawn from mineral entry are on open file for public inspection in the U. S. Geological Survey office, Grand Junction, Colo.

Many Survey geologists contributed to the exploration program in the Club Mesa area. Leonid Bryner directed most of the exploration work. In addition, the geology and ore deposits of four 7½ minute quadrangles, each including part of the Club Mesa area, have been described by Cater (1955); Cater, Butler, and McKay (1955); and McKay (1955a,b).

Detailed studies of surface geology and mine workings were made in the Club Mesa area in 1945-1946 by the Union Mines Development Corp. on behalf of the Manhattan District, predecessor of the U. S. Atomic Energy Commission. The results of these studies (C. T. Smith, written communication, 1946) were helpful in interpreting stratigraphic relationships and in correlating drill-hole and outcrop data.

GEOLOGY

Rocks exposed in the Club Mesa area are sedimentary formations of Mesozoic age that dip about 3° NE. Pre-Morrison formations of Triassic and Jurassic age are exposed in the canyon walls that surround all but the southernmost part of the area. The Morrison formation of Late Jurassic age crops out in much of the Club Mesa area and is the host formation for all uranium-vanadium deposits known in the area. It is overlain in the south-central part of the mesa by sandstone and conglomerate remnants of the Burro Canyon formation of Early Cretaceous age.

The Morrison formation in the Club Mesa area is divided into the Salt Wash member and the overlying Brushy Basin member. The Salt Wash member ranges in thickness from about 200 to 300 feet and is composed of fluvial sandstone and mudstone beds. Commonly, 3 to 5 sandstone units, each 20 feet or more thick, are present in the Salt Wash member. These units are dominantly lenticular and pinch or swell in short distances; they split or merge in many places, as shown on the fence diagram. They range from a few hundred feet to several thousand feet in horizontal extent. The sandstone units at the top and base of the Salt Wash generally are the thickest and most continuous. The thicker sandstone units in the upper 100 feet of the Salt Wash are the principal host beds for uranium-vanadium deposits in the Club Mesa area. The sandstones in the Salt Wash range from medium to fine grained and are light brown, gray, light red, or white. They contain varying amounts of limonite and pyrite, and carbonized plant material. The sandstones commonly exhibit abundant primary sedimentary structures including festoon cross-bedding, cut-and-fill structures, and current lineation marks. Mudstone beds are interbedded with the sandstone units of the Salt Wash, and they are red, red brown, green, or gray and contain sparse carbonaceous material and disseminated pyrite in many places. Thin seams and lenses of mudstone and beds of clay-pebble conglomerate are present locally in the sandstone units.

The overlying Brushy Basin member ranges in thickness from 400 to 450 feet. It consists of variegated mudstone with lesser amounts of sandstone, conglomeratic sandstone, and silicious limestone. Only a few small uranium-vanadium deposits are in the Brushy Basin in the Club Mesa area; they are in sandstone or conglomeratic sandstone beds near the base of the member.

The contact between the Salt Wash and Brushy Basin members is gradational and has been placed by the authors at the top of the uppermost recognizable sandstone unit of the Salt Wash member. Over most of the Club Mesa area this contact conforms to the top of sandstone unit a of the Salt Wash (geologic map and fence diagram). In the southern part of the area, where this unit is missing, the contact is placed at the top of sandstone unit b of the Salt Wash.

The Club Mesa area is about midway down the northeast flank of the Castle Valley-Paradox Valley anticline (index map). The principal joint set in the rocks parallels the northwest strike of the regional folds. Another joint set strikes approximately normal to this trend but is not well defined. No faults are known in the explored area.

ORE DEPOSITS

Nearly all of the known uranium-vanadium deposits in the Club Mesa area are in sandstone units in the upper part of the Salt Wash member. The deposits are irregularly shaped and contain a few tons of ore to many thousand tons of ore. The mineralized rock is mostly sandstone impregnated with uranium and vanadium minerals. Lesser amounts of these minerals impregnate mudstone pebbles, films, and seams. Some of the richest bodies of ore are fossil tree trunks and branches that have been impregnated or replaced by uranium and vanadium minerals. The mineralized rock forms layers that are essentially parallel to the host sandstone beds, but in places the ore layers curve across bedding planes in the sandstone to form rolls. Uranium-vanadium ore and the habits of ore bodies in the upper part of the Salt Wash have been described by Fischer (1942).

In the Club Mesa area, ore ranges from the gray and yellow oxidized type, most common near the surface, to the blue-black, partly oxidized type, prevalent in the deepest workings. Carnotite and tyuyamunite (yellow uranium-vanadium minerals), gray vanadium silicate minerals, and blue-black vanadium-bearing corvusite are the principal ore minerals.

The Club Mesa area lies within and along the western margin of the Uravan mineral belt (index map; Fischer and Hilpert, 1952). The parallelism of easterly trends of ore, trends of ground appraised as favorable for ore, and trends of primary sedimentary structures in the Club Mesa area has been described by Boardman, Ekren, and Bowers (1956). No relation has been found between known fractures in the area and the origin and localization of ore.

The most productive mines or groups of mines in the area are labeled on the geologic map. The Club group of mines (sec. 33) and the La Salle (sec. 5), Tramp No. 2 (sec. 6), and Bunker mines (sec. 31) have been the largest producers, in decreasing order. Prior to 1942 the Club group of mines had yielded more than 150,000 short tons of ore (Fischer, 1942), and there has been intermittent production from the group since that time. Ore deposits at or near the surface constituted the only deposits mined before 1950. Since then large ore bodies have been found under deeper cover and mining operations have been carried on at progressively greater depths. The Shattuck-Denn (sec. 5) and La Salle mines are the deepest in the Club Mesa area; their vertical shafts are about 500 and 250 feet deep, respectively.

All the large deposits in the area are in the uppermost sandstone unit of the Salt Wash member of the Morrison formation except in the northwest part of the Club group of mines where ore is found in the next lower sandstone unit. Less than 1 percent of the total uranium-vanadium production from the Club Mesa area has come from deposits in the lower part of the Salt Wash member and in the Brushy Basin member.

GEOLOGIC GUIDES TO ORE

Several geologic features are useful in prospecting for uranium-vanadium deposits in the Club Mesa area. These features are commonly associated with ore deposits and with ground near ore deposits; thus they provide broader targets than do the deposits themselves.

McKay (1955c) noted that in the Uravan district, uranium-vanadium deposits are more prevalent in areas where the upper sandstone unit of the Salt Wash member of the Morrison formation is predominantly lenticular, exhibits scour-and-fill bedding, and is underlain by continuous green or gray mudstone. These guides are useful in appraising the relative favorableness of ground close to the outcrop.

Other geologic features in the vicinity of uranium-vanadium deposits can be recognized in drill cores and have been shown by Weir (1952) to be useful small-scale guides to ore in appraising the upper sandstone units of the Salt Wash member in southwestern Colorado. The geologic criteria that are the most useful small-scale guides for exploration in the Club Mesa area are listed below in the order of their importance.

1. Interstitial mudstone grains in the ore-bearing sandstone units and most mudstone beds in contact with these ore-bearing units are green or gray near ore deposits, instead of red or red brown. In general, the host sandstone unit becomes more favorable as the thickness of these green or gray beds increases.
2. Ore-bearing sandstone units are 30 feet or more thick and are dominantly light brown or light gray, instead of red or white, in the vicinity of large ore deposits.
3. Ore-bearing sandstone units commonly contain abundant carbonized plant remains and abundant limonite or disseminated pyrite near ore deposits.

The relationship between mineralized ground, thickness of ore-bearing sandstone units, and relative amounts of green or gray mudstone in contact with these units is shown on the geologic map.

DIAMOND DRILL EXPLORATION

Diamond drilling began in the Club Mesa area on March 6, 1948, and was completed on January 6, 1953. The drilling was done on seven contracts and consisted of 662 holes totaling 170,095 feet. The average depth of the holes was 257 feet. The location and classification of 660 holes are shown on the geologic map; two holes are not shown because they were abandoned before penetrating beds of the Salt Wash member of the Morrison formation. Most of the drill holes were logged by a gamma-ray logging instrument.

Drilling in the Club Mesa area was planned to explore the principal uranium- and vanadium-bearing sandstone units in the upper part of the Salt Wash member. Most of the holes drilled during the first contract were spaced at about 1,000-foot intervals along three north-trending lines about 3,000 feet apart; these lines were perpendicular to the eastward trend of the known deposits, and they were planned to locate and roughly delimit ground appraised as geologically favorable for ore. During succeeding contracts, additional wide-spaced holes (more than 500 feet apart) were drilled to outline more precisely the favorable ground; moderate-spaced holes (200-500 feet apart) were drilled to search for deposits in favorable ground; and close-spaced holes (less than 200 feet apart) were drilled to delimit the most promising deposits discovered by moderate- and wide-spaced drilling. About 30 percent of the total footage was expended in wide-spaced holes, about 25 percent in moderate-spaced holes, and about 45 percent in close-spaced holes. In general, holes that penetrated mineralized rock in mining claims were not offset as the discovery was considered sufficient incentive to the claim owner to block out the deposit. About 95 percent of the total footage drilled was in unexplored public land that had been withdrawn from mineral entry; the remaining footage drilled was in mining claims staked prior to the land withdrawal.

Of the 660 holes completed, 195 penetrated mineralized rock (rock containing 0.02 percent or more U_3O_8 or 0.10 percent or more V_2O_5). The mineralized layers are in the upper part of the Salt Wash member in 181 holes and in the lower part of the Brushy Basin member in 14 holes.

In the Salt Wash member, 74 holes penetrated material classed as "ore" (rock 1 foot or more thick containing 0.10 percent or more U_3O_8 or 1.0 percent or more V_2O_5), and 37 penetrated mineralized layers of ore grade but less than 1 foot thick. The mineralized rock in all but 2 of these 111 holes is in the uppermost sandstone unit of the Salt Wash member. The ore layers are in the bottom half of the host sandstone unit in about 90 percent of the holes in ore and in the bottom quarter of the unit in over 60 percent of these holes. None of the mineralized layers penetrated in the Brushy Basin member are ore grade.

Indicated and inferred reserves of "ore" (see above) discovered as a result of the drilling conducted by the U. S. Geological Survey total about 200,000 short tons averaging about 0.35 percent U_3O_8 and 1.80 percent V_2O_5. About 80 percent of the estimated reserves were included in the six mining leases (see geologic map) granted by the U. S. Atomic Energy Commission on deposits discovered by the drilling, and a large part of these reserves have subsequently been mined. About 15 percent of the estimated reserves were in mining claims, and 5 percent in small deposits in public land. Bush and Stager (1956) defined the types of reserves, and described the method of their calculation and the probable accuracy of ore-reserve estimates for uranium-vanadium deposits on the Colorado Plateau.

All the large uranium-vanadium deposits found by the drilling in the Club Mesa area are in or near the thickest parts, locally, of the host sandstone units, and generally are within a few hundred feet of appreciable thinning of these units. Where ore was penetrated, the host sandstone units range in thickness from 25 to 96 feet and average about 50 feet in thickness. About 75 percent of the holes in ore, accounting for nearly 90 percent of the estimated ore reserves, penetrated host sandstone units ranging in thickness from 30 to 60 feet.

Results of the drilling in the Club Mesa area show the relative thickness of the ore-bearing sandstone units of the Salt Wash member and the amount of green or gray mudstone in contact with these units to be the most consistent recognizable geologic criteria associated with mineralized rock and ore deposits. Approximately 86 percent of the holes in mineralized sandstone units of the Salt Wash and 93 percent of the holes in ore penetrated host sandstone units 30 feet or more thick that are in contact with at least 6 inches of green or gray mudstone (see geologic map). These mudstone beds may be at the top, base, or included in the host sandstone unit. If these minimum thicknesses are used as cutoffs to determine ground favorable for ore, about 10 percent of the Club Mesa area explored by the Survey can be classified as favorable and contains nearly all the ore reserves discovered. Most of the favorable ground so defined lies in an eastward trending zone ranging from 1,000 to 3,000 feet in width and approximately 2 miles long, extending from the Tramp No. 2 mine on the west to the Club group of mines on the east. About 85 percent of the ore reserves found by drilling are in this zone. In addition, several smaller areas of favorable ground are present: (1) in sec. 32, between the Barkley and Gardner mines; (2) in sec. 31, east of the Bunker mine; and (3) in secs. 5 and 6, north-northeast of the U. S. Grant mine (see geologic map). Many of these smaller areas have been explored by only a few drill holes and probably will be the most rewarding areas for future exploration.

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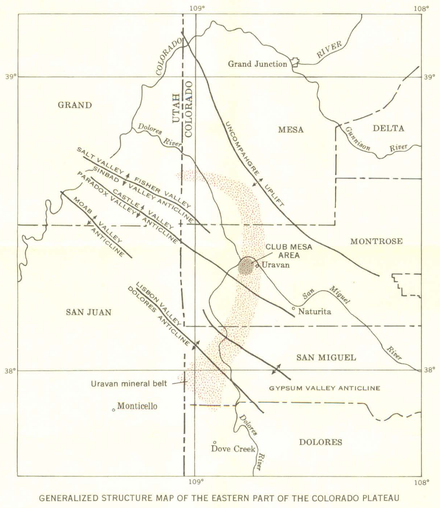
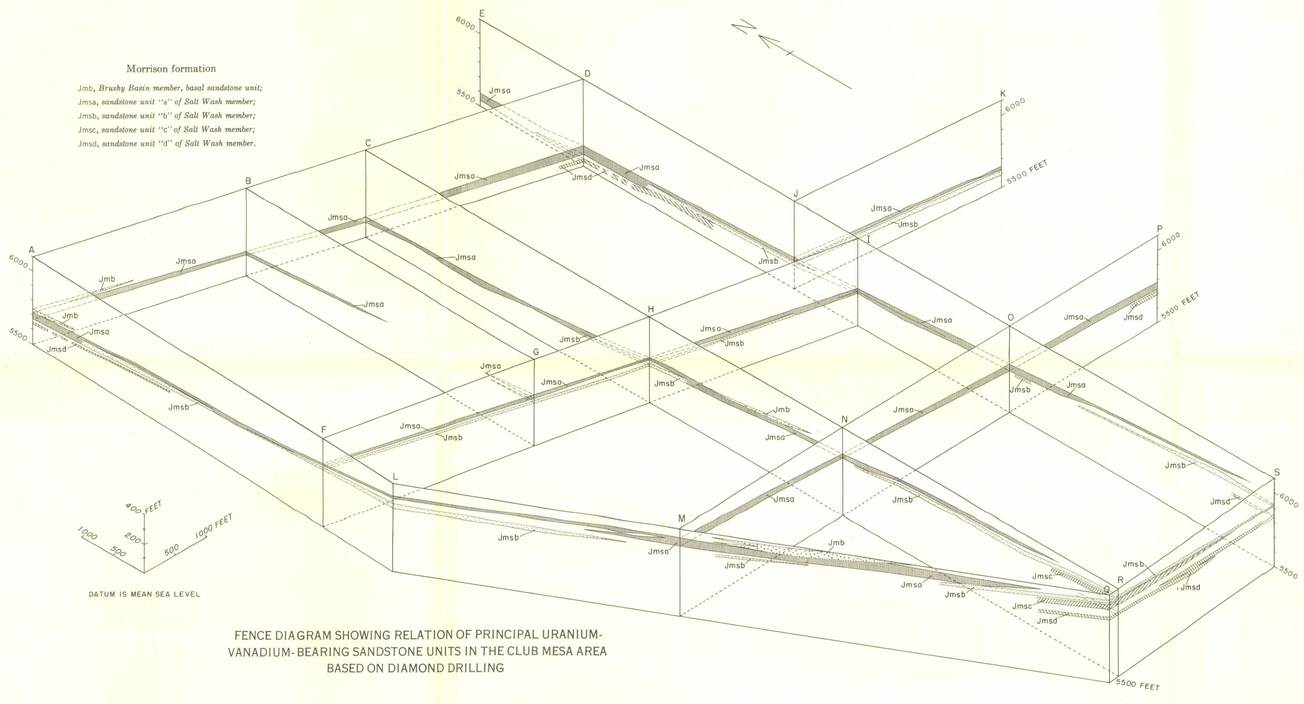


GENERALIZED STRUCTURE MAP OF THE EASTERN PART OF THE COLORADO PLATEAU

0 10 20 30 40 Miles

Morrison formation

Jmb, Brushy Basin member, basal sandstone unit;
Jmsa, sandstone unit "a" of Salt Wash member;
Jmsb, sandstone unit "b" of Salt Wash member;
Jmsc, sandstone unit "c" of Salt Wash member;
Jmsd, sandstone unit "d" of Salt Wash member.



FENCE DIAGRAM SHOWING RELATION OF PRINCIPAL URANIUM-VANADIUM-BEARING SANDSTONE UNITS IN THE CLUB MESA AREA BASED ON DIAMOND DRILLING

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—M R-2183

EXPLORATION FOR URANIUM-VANADIUM DEPOSITS BY THE U.S. GEOLOGICAL SURVEY IN THE CLUB MESA AREA, URAVAN DISTRICT, MONTROSE COUNTY, COLORADO

By
R. L. Boardman, L. R. Litsey, and H. E. Bowers

Topography by U.S. Geological Survey, 1949

Geology mapped in 1955

Scale 1:7200

500 0 500 1000 1500 2000 2500 Feet

Contour interval 100 feet
Datum is mean sea level

1958

For sale by U. S. Geological Survey, price 75 cents

GEOLOGY
OF THE
URAVAN QUADRANGLE, COLORADO

By
Fred W. Cater, Jr., A. P. Butler, Jr., and E. J. McKay

INTRODUCTION

The U. S. Geological Survey mapped the geology of the Uravan quadrangle, Colo., as 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 Uravan quadrangle is one (fig 1). 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 with the cooperation of the Colorado State Geological Survey Board and the Colorado Metal Mining Fund Board and continued through 1945 as a wartime strategic minerals project. Since 1947 the U.S. Geological Survey has been continuing this geologic study on behalf of the Division of Raw Materials of the Atomic Energy Commission. Part of the Uravan quadrangle was mapped in 1941, the rest was mapped in 1948; the mines were examined by R. L. Boardman.

The Uravan quadrangle covers about 59 square miles in Montrose County, Colo., and lies in the Canyon Lands division of the Colorado Plateaus physiographic province. The quadrangle is largely a rugged area of mesas and canyons, but considerable areas on the larger mesas and in Paradox Valley are relatively flat and featureless. Total relief within the quadrangle is about 1,900 feet; altitudes range from about 4,940 feet in the canyon of the San Miguel River to 6,849 feet on the northeast rim of Paradox Valley. The San Miguel River and its tributaries drain all the area except Paradox Valley, which is drained by East Paradox Creek.

No accurate information on rainfall is available, but the annual precipitation is probably between 10 and 15 inches; the area is semiarid and supports a moderate growth of juniper and piñon on rocky terrain and abundant sagebrush where soils are thick. Cacti and sparse stands of grass are widely distributed. Most of the quadrangle is accessible over state Highway 141 and 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 beds are flat lying, but in places they are disrupted by highangle faults or are 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 (fig. 1). 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 (fig. 1).

The quadrangle lies in the east-central part of the 18-quadrangle area, about 8 miles southwest of the Uncompahgre Plateau; the southwest corner of the quadrangle is traversed by the edge of Paradox Valley.

STRATIGRAPHY

The oldest rocks exposed in the Uravan quadrangle are Upper Triassic strata that crop out along the sides and on the floor of Paradox Valley. Rocks of Pennsylvanian and Permian age, although not exposed within the quadrangle, crop out extensively in adjacent quadrangles. Jurassic rocks crop out along the sides of Paradox Valley and in the canyon walls and on the benches and slopes below the mesas. Cretaceous rocks cap the mesas. Recent deposits of windblown material and sheet wash are widely distributed on top of the mesas, along the benches, and on the valley floors. Terrace gravels occur along the San Miguel River at various altitudes up to 700 feet above the present river level.

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 Uravan quadrangle into Utah.

CHINLE FORMATION

The Upper Triassic Chinle formation consists of red to orange-red siltstone, with interbedded red fine-grained sandstone, shale, and limestone-pebble and clay-pellet conglomerate. These lithologic units are lenticular and discontinuous. The lower part of the formation contains numerous lenses of a 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 crossbedded, 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 base of the Chinle formation is not exposed in the Uravan quadrangle. The formation, as projected from adjoining quadrangles, probably ranges from 375 feet to 425 feet in thickness, except where it thins abruptly on the flanks of the Paradox Valley anticline.

GLEN CANYON GROUP[1]

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 or 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 crossbedded on a magnificent scale; great sweeping tangential crossbeds 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 Uravan quadrangle the Wingate sandstone, where exposed, ranges in thickness from 160 to 240 feet, a thickness somewhat less than normal because of thinning on the flanks of the Paradox Valley anticline.

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, crossbedded 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 recesses 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 Uravan quadrangle ranges in thickness from 190 to 210 feet. Abrupt local changes in thickness of 10 to 20 feet are common. The irregular bedding, channel filling, and range of thickness all indicate a fluvial origin.

Navajo sandstone.—The eastern edge of the Navajo sandstone follows an irregular course through the westernmost part of Colorado, and the only Navajo in the Uravan quadrangle is part of a fairly large disconnected lens that crops out around the town of Uravan. The Navajo, which conformably overlies the Kayenta formation, is a massive, fine-grained, gray to buff, clean quartz sandstone. Tangential crossbeds of tremendous size leave little doubt of the eolian origin of the sandstone, although around Uravan crossbeds are not so large, and horizontal bedding planes are more common than in other areas. The sandstone is friable and weathers to rounded topographic forms where exposed on slopes or benches and vertical cliffs where protected by overlying rocks. It reaches a maximum thickness in the quadrangle of 40 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 narrow band along the San Miguel River in the northwestern part of the quadrangle and the northeast side of Paradox Valley. 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, nonresistant, 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 in diameter, 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. In many places the upper part of the formation contains scattered barite nodules as much as an inch in diameter.

The Carmel formation ranges from less than 10 feet to 20 feet in thickness. This range appears to be due chiefly to deposition on irregular, eroded surfaces of Navajo sandstone or beds of the Kayenta formation. No definite evidence indicates that the Carmel formation of this area is of marine origin as is the Carmel of central Utah, but the probabilities are that the Carmel of southwestern Colorado was deposited in shallow water marginal to a sea.

[1]Since the preparation of this report the age designation of the Glen Canyon group has been changed in U. S. Geological Survey usage to Triassic and Jurassic; the age designation of the Wingate sandstone has been changed to Triassic; and the age designation of the Navajo sandstone has been changed to Jurassic.

The Carmel formation grades upward, in most places without prominent breaks, into the Entrada sandstone. The Entrada sandstone, known locally as the "slick rim" because of its appearance, is perhaps the most 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 crossbedded units. The horizontally bedded units are most common in the basal part and in the uppermost, lighter-colored part of the Entrada, whereas the crossbedded 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 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 is 90 to 110 feet thick in the Uravan quadrangle.

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, brown, light yellow, or nearly white. Sandy and silty shales are the most abundant kinds of rock, but all gradations from claystone to clean, fine-grained sandstone are interbedded with them. Well-rounded amber-colored quartz grains with frosted or matte surfaces are disseminated throughout most of the formation, including beds consisting almost entirely of claystone. Thin beds of authigenic 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 crossbedding.

The Summerville formation rests conformably on the Entrada sandstone, and, although a sharp lithologic change marks the contact, no cessation of deposition separated the two formations. The upper contact of the Summerville is uneven and channeled, and the channels are filled by the overlying basal sandstone beds of the Morrison formation. Locally, however, the contact is difficult to determine, because the overlying beds of shale and mudstone of the Morrison formation are similar to beds of the Summerville.

In the Uravan quadrangle the Summerville formation is about 100 feet thick.

MORRISON FORMATION

The Morrison formation, of Late Jurassic age, is of special interest economically because of the uranium- and vanadium-bearing deposits that 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 Uravan quadrangle the Morrison formation ranges in thickness from 600 to 750 feet. The Salt Wash sandstone member and the Brushy Basin shale member in general are of approximately equal thickness. In some areas, however, their thicknesses vary independently, whereas in other areas a thinning in one member is accompanied by a thickening in the other.

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; other 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, crossbedded, 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 was deposited under fluvial 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 from 300 to 360 feet in thickness and, unlike the underlying formations, does not thin along the flanks of the Paradox Valley anticline. Local changes in thickness of as much as 30 feet are common.

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 arbitrary 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 of material 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 fluvial 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 500 feet in thickness; local variations in thickness of 20 to 30 feet are common.

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. 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. Crossbedding 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 the 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 fluvial conditions. The lower contact is indistinct in many places and the formation 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.

The Burro Canyon formation in the Uravan quadrangle is 160 to 200 feet thick; abrupt local variations in thickness of 10 to 30 feet are common.

DAKOTA SANDSTONE

The Dakota sandstone, of Early and Late Cretaceous age, 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 crossbedded. 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 shales and thin coal seams and beds. Plant impressions abound in both the sandstone and shale.

The entire thickness of the Dakota sandstone is not exposed in the quadrangle; the upper beds have been stripped off by erosion; but as much as 100 feet of Dakota beds are preserved in a few places. It crops out extensively as capping beds on the mesas northeast of the San Miguel River because of its resistance to erosion.

QUATERNARY DEPOSITS

The deposits of Quaternary age consist of wind-deposited material, alluvium, talus, and terrace gravel. Extensive deposits of light-red sandy 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 is about 10 feet. The floor of Paradox Valley is covered with soils that generally differ markedly from the wind-deposited material on the mesas. These valley soils are derived not only from windblown material but also from the disintegration of the rocks exposed on the valley walls and floors. Gravel and alluvium cover the floor of the San Miguel River valley. Considerable talus covers many of the steeper slopes. Terrace gravel containing pebbles and cobbles of various intrusive and extrusive rocks from the headwater areas of the river in the San Juan Mountains occurs along the San Miguel River at several altitudes up to 700 feet above the stream. Because these various deposits, other than the terrace gravel, are difficult to differentiate in some places, they have not been separated on the geologic map.

STRUCTURE

REGIONAL SETTING

Many geologic structures on the Colorado Plateau are so large that a 7½-minute quadrangle covers only a small part of any complete structural unit. The larger structural units consist of salt anticlines, 25 to 65 miles long (fig. 1); uplifted blocks, 50 to 125 miles long, bounded by monoclinal folds; and domical uplifts, 8 to 20 miles across, around stocklike 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 URAVAN QUADRANGLE

The Uravan quadrangle lies near the southeast end of the system of salt anticlines, and is crossed by the northeast flank of the Paradox Valley anticline. The San Miguel syncline crosses the northeast part of the quadrangle. Most of the rock strata in the quadrangle either are horizontal or dip at angles of less than 2°; only near the edge of Paradox Valley do the dips steepen appreciably. The rocks marginal to Paradox Valley are upturned sharply along the flanks of the anticline that underlies the valley. The pre-Morrison formations thin against the salt-gypsum cores of these anticlines, and the older pre-Morrison formations dip more steeply than the younger; however, some of these relations can be seen more clearly in nearby areas outside the quadrangle.

Particularly striking are the complex systems of faults that cut the sides of Paradox Valley. In general the blocks and slivers formed by these faults are downthrown toward the valleys, but some blocks form small horsts. These faults formed with collapse of the anticline because abstraction of the underlying salt, by both solution and plastic flowage, left the overlying beds unsupported. The two faults of small displacement that cut Second and Third Parks probably also reflect a gravity adjustment to the abstraction of salt.

STRUCTURAL HISTORY

In order to understand the structural history of the Uravan 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 Uravan quadrangle either directly or indirectly, although the evidence for some of them is not visible within the quadrangle boundaries.

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 of Pennsylvanian age 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 belongs 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 period, 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 below 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 deposition of the Morrison, 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), but the date cannot be determined accurately. 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.

During the middle Tertiary the entire Colorado Plateau was uplifted. This uplift rejuvenated the streams and increased groundwater 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 of the Hermosa formation 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 Uravan quadrangle are those that contain uranium, vanadium, and radium. Although deposits containing these metals were discovered in 1899 near Roc Creek, about 10 miles northwest of the Uravan 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 layer of sandstone lenses in the Salt Wash sandstone member, 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 relatively 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 material. 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 $[nFeO \cdot nV_2O_4 \cdot nV_2O_5 \cdot nH_2O]$, corvusite $[V_2O_4 \cdot 6V_2O_5 \cdot nH_2O]$, and hewettite $[CaO \cdot 3V_2O_5 \cdot 9H_2O]$. Corvusite and montroseite occur together, forming compact masses of bluish-black ore, whereas hewettite commonly forms stringers and veinlets along joints and fractures. 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 are also 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. 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 rolls 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. 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 crossbedding 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 of 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 Gray Daun 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 that 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 originated at depth from an igneous source and ascended along fractures. After these solutions mingled with circulating ground waters the minerals precipitated in favorable beds as much as several miles from fractures. This hypothesis explains more readily the difficulties inherent in the penesyngenetic hypothesis, but it poses two other difficulties: (1) the hypothetical location of igneous source rocks, and (2) 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 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. Crossbedded, 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 Uravan quadrangle the most likely area for finding ore, because of the presence of favorable host rocks, is the part north of Paradox Valley and west of a line roughly between the Bitter Creek mines and Spring Creek Mesa. The largest mines are in the Long Park area, an area cut by many joints and relatively close to the faults paralleling Paradox Valley. The faults northeast of the San Miguel River are in areas of generally unfavorable host rocks.

THE MINES
By Robert L. Boardman

Numerous carnotite deposits are scattered over the west half of the Uravan quadrangle, and several of the mines have been among the larger ore producers on the Colorado Plateau. Most of the deposits are in the uppermost layer of sandstone lenses of the Salt Wash sandstone member of the Morrison formation.

Recently, extensions of old deposits and new discoveries have been found by extensive drilling programs in the southwest quarter of the Uravan quadrangle. Most of the exploration near old workings and in areas where the ore zone is relatively shallow in depth has been conducted by private industry; however, in areas where the ore zone is deeper and where the cost of drilling has been too great for private concerns, the exploration has been undertaken by the Geological Survey on behalf of the Atomic Energy Commission.

Long Park No. 6 mine.—The Long Park No. 6 mine is one of the most productive in the area. The ore is erratically distributed through two ore layers in a relatively thin sandstone lens in the upper Salt Wash. The lens is 20 to 25 feet thick, whereas the other large deposits in the Long Park area are in sandstone lenses more than 30 feet thick. Some of the ore bodies are lenticular, others are tabular; rolls occur in both types. The chief ore minerals are carnotite and the micaceous vanadium clay mineral; these occur as disseminations in the sandstone. Carnotite is also present along mudstone seams and in trash pockets. Local concentrations of corvusite, hewettite, and montroseite form scattered high-grade pockets commonly associated with fossil logs or other carbonaceous material. The trend of the ore bodies, mineralized logs, and rolls is east to northeast.

Black Dinah mine.—The Black Dinah mine is one of the oldest large producers in the Long Park area. The deposits are in the upper part of the Salt Wash in a sandstone stratum 30 to 35 feet thick, consisting of three large overlapping lenses of ore. The ore in these lenses consists of sandstone impregnated with disseminated carnotite and the micaceous vanadium clay mineral. The few scattered rolls and mineralized logs trend east to northeast. Small amounts of corvusite and hewettite occur locally.

Bitter Creek mines.—Deposits in the Bitter Creek mines are large, extensive, and of unusual mineralogic interest. They occur in the uppermost Salt Wash in a sandstone lens about 50 to 60 feet thick that dips about 15° to the northeast. The ore bodies near the outcrop consist of broad rolls and lenticular masses associated with abundant gypsum seams of an inch or more in thickness. The ore is relatively low grade in this part of the mine, and consists predominantly of the micaceous vanadium clay mineral disseminated in the sandstone. Carnotite occurs in relatively small amounts as stainings along fractures and in association with mudstone seams. The ore bodies down dip remote from the outcrop are predominantly high-grade pockets erratically distributed in a gray sandstone devoid of limonite stains. Less gypsum is found at depth, but the ore commonly is associated with finely disseminated pyrite and with carbonaceous material. The ore minerals are corvusite, hewettite, vanadium clay, montroseite, and one or more unidentified black uranium minerals. The rich pockets become smaller and more erratically distributed with increasing depth. Some widely scattered mineralized logs are present in the lower workings. The logs and rolls in the Bitter Creek group generally trend northeast.

Other deposits.—Elsewhere in the western half of the Uravan quadrangle, a large number of small deposits have been worked. Most of these are similar to the larger deposits but are generally of lower grade.

The Rock Raven mine, a small mine in the northwest corner of the quadrangle, is unique in that the ore occurs in a conglomeratic sandstone lens of the Brushy Basin shale member of the Morrison formation, about 100 feet above the uppermost sandstone stratum of the Salt Wash sandstone member. The ore occurs in tabular, irregular, and lenticular masses; rolls are poorly defined and mineralized logs are absent. Ore minerals are micaceous vanadium clay and carnotite. Some of the carnotite occurs in mudstone seams and along bedding planes of the sandstone.

The Rambler workings in the Club group of mines expose large, essentially tabular ore bodies. Ore also occurs in numerous large rolls and as high-grade replacement of fossil trees or in haloes surrounding fossil wood and trash. Ore minerals are predominantly carnotite and micaceous vanadium clay. The ore bodies and better developed rolls are oriented in a general northeasterly direction.

Recently, drilling by the Geological Survey on behalf of the Atomic Energy Commission has partially outlined large ore bodies a few thousand feet northeast of the Black Dinah mine. These deposits are in the uppermost Salt Wash sandstone stratum in a lens about 40 feet thick. The sandstone appears gray and unoxidized in the drill core. The ore apparently is associated with pyrite and gypsum, and is composed of vanadium clay minerals and one or more unidentified black uranium minerals.

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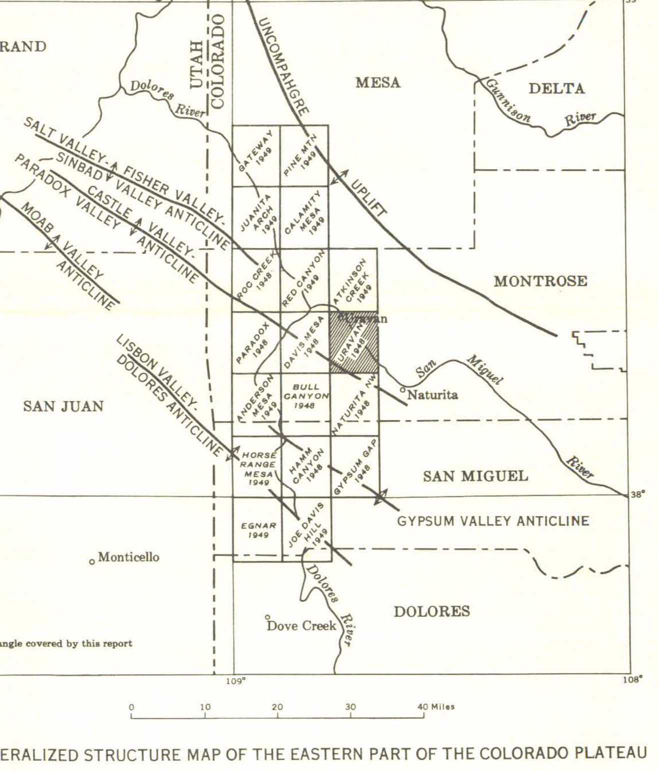
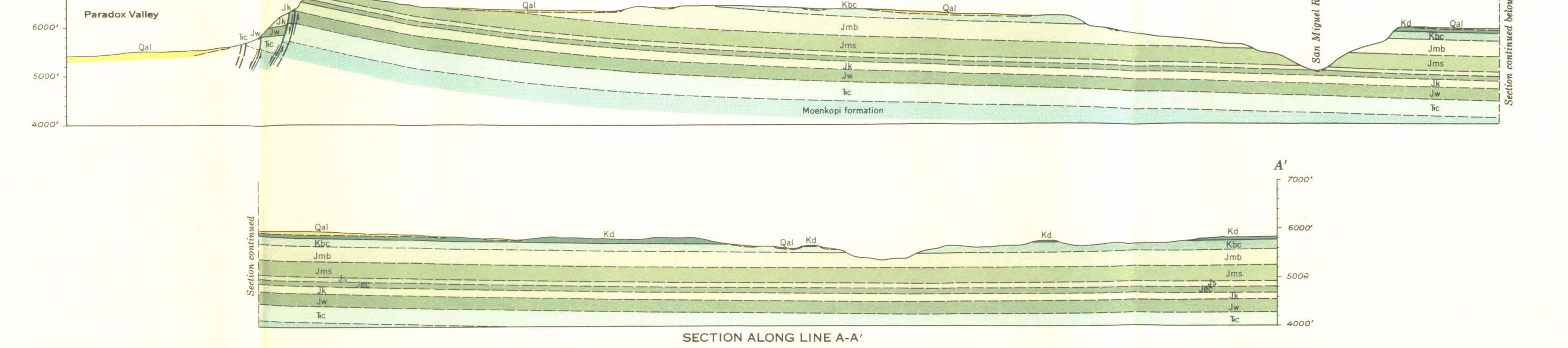


FIG. 1—GENERALIZED STRUCTURE MAP OF THE EASTERN PART OF THE COLORADO PLATEAU



SECTION ALONG LINE A-A'

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
W. E. WRATHER, DIRECTOR

PREPARED IN COOPERATION WITH THE
U. S. ATOMIC ENERGY COMMISSION
COLORADO GEOLOGICAL SURVEY BOARD
AND COLORADO METAL MINING FUND BOARD

GEOLOGY OF THE
URAVAN QUADRANGLE
COLORADO
GQ 78

Base map by Topographic Division
U. S. Geological Survey, 1949

Geology mapped in 1941 by A. P. Butler Jr., and by F. W. Cater Jr. and E. J. McKay in 1948

EXPLANATION

QUATERNARY — Pleistocene and Recent

Qal — **Alluvium**
Includes colluvium, talus, sheet wash, wind-blown deposits, valley fill, and stream deposits, undifferentiated.

Qg — **Terrace gravel**

UNCONFORMITY

CRETACEOUS

Lower and Upper Cretaceous — Kd — **Dakota sandstone**
Yellowish, lenticular sandstone and conglomerate with interbedded carbonaceous shale and impure coal.

UNCONFORMITY

Lower Cretaceous — Kbc — **Burro Canyon formation**
White, gray, and red sandstone and conglomerate with interbedded green and purplish shale.

JURASSIC

Upper Jurassic — Jmb, Jms — **Morrison formation**
Variegated shale and mudstone; white, gray, rusty-red, and buff sandstone; rusty-red conglomerate; local thin limestone beds. At the top the Brushy Basin shale member, Jmb, consisting largely of bentonitic shale but including some sandstone and conglomerate lenses, and at the base the Salt Wash sandstone member, Jms, with more numerous and thicker sandstone beds.

San Rafael group — Js — **Summerville formation**
Thin-bedded red, gray, green, and brown sandy shale and mudstone.

Middle and Upper Jurassic — Jec — **Entrada sandstone and Carmel formation undivided**
Orange, buff, and white, fine-grained, massive and crossbedded Entrada sandstone at the top. Red sandstone and mudstone of the Carmel formation at the base.

UNCONFORMITY

JURASSIC(?) — Glen Canyon group*

Jn — **Navajo sandstone**
Buff and gray crossbedded, fine-grained sandstone.

Jk — **Kayenta formation**
Irregularly bedded, red, buff, gray, and lavender shale, siltstone, and fine- to coarse-grained sandstone.

Jw — **Wingate sandstone**
Fine-grained reddish-brown, cliff-forming sandstone, thick-bedded, massive and crossbedded.

TRIASSIC — Upper Triassic

Ꞧc — **Chinle formation**
Red to orange-red siltstone, with interbedded lenses of red sandstone, shale, and limestone-pebble and clay-pellet conglomerate. Lenses of quartz-pebble conglomerate and grit at base.

Contact
Dashed where approximately located.

Fault
Dashed where approximately located; dotted where concealed. U, *upthrown side;* D, *downthrown side.*

Strike and dip of beds

Horizontal beds

Structure contours
Drawn on top of Entrada sandstone; dashed where approximately located; short dashes indicate projection above surface. Contour interval 100 feet. Datum is mean sea level.

Adit

Prospect

Outline of patented claim
Located only approximately for purpose of discussion in the text (not accurate to the scale of the map).

LIST OF PATENTED CLAIMS

1. Commodore
2. Yellow Jacket
3. Rambler
4. Beta
5. J. B. No. 2
6. J. B. No. 1
7. J. B. No. 3
8. J. B. No. 4
9. Faery Queen
10. Fortyfive Ninety Mine
11. Black Dinah Mine
12. Saturday
13. Friday
14. Long Park No. 5
15. Velvet
16. Long Park No. 2
17. Long Park No. 4
18. Long Park No. 6 Mine
19. Long Park No. 3
20. Jerome
21. Long Park No. 7
22. Long Park No. 8
23. Medina Mine
24. Sunny Jim
25. Tipperary
26. Dan Patch
27. Blue Bell
28. Radium King

*Since the preparation of this report the age designation of the Glen Canyon group has been changed in U. S. Geological Survey usage to Triassic and Jurassic; the age designation of the Wingate sandstone has been changed to Triassic; and the age designation of the Navajo sandstone has been changed to Jurassic.

TRUE NORTH — MAGNETIC NORTH — 15°
APPROXIMATE MEAN DECLINATION, 1955

GEOLOGIC MAP
OF THE
URAVAN QUADRANGLE, COLORADO

By
Fred W. Cater, Jr., A. P. Butler, Jr., and E. J. McKay

1:24000
1 ½ 0 1 Mile
Contour interval 20 feet
Datum is mean sea level

1955