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DRILLING RESULTS AND FAVORABILITY CRITERIA IN BULL CANYON, MONTROSE AND SAN MIGUEL COUNTIES, COLORADO

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ABSTRACT

The Bull Canyon area, tributary to the Dolores River, is in Montrose and San Miguel Counties, southwestern Colorado. The Atomic Energy Commission diamond drilled 844 holes totalling 99,930 feet in the Salt Wash sandstone member of the Jurassic Morrison formation in this area between June 1952 and April 1953.

Practically all the production of uranium-vanadium ore in Bull Canyon comes from the ore-bearing sandstone units, namely the First Rim ore sandstone and the Third Rim ore sandstone. First Rim orebodies occur from 30 to 60 feet above the base of the Salt Wash; commercial deposits in the Third Rim are found in the interval from 250 to 280 feet above the base of the Salt Wash.

The use of various ore guides, or favorability criteria, is explained in the text and illustrated by subsurface favorability maps.

INTRODUCTION

Location and Accessibility

The Bull Canyon district (fig. 1) of Montrose and San Miguel Counties, Colorado, is bounded on the south by Gypsum Valley, on the west by the Dolores River, and on the north by the south wall of Paradox Valley. The eastern boundary is topographically indefinite.

Bull Canyon may be reached via Gateway or Naturita, thence through Paradox Valley and over the south scarp of Paradox Valley. The area is now accessible throughout the year but mad and snow may make travel difficult at times during the winter and early spring months.

Drilling Areas

The usefulness of subsurface methods and the feasibility of wagon drilling for development altered the original plans 1/ to drill only areas "A", "B", "C", and "D". Determination of favorable areas by primary, wide-spaced grid-drilling, and the decision not to develop orebodies completely, left footage available for the Starlight, Wedding Bell, Horsehair and Fawn Springs Bench area (fig. 2).

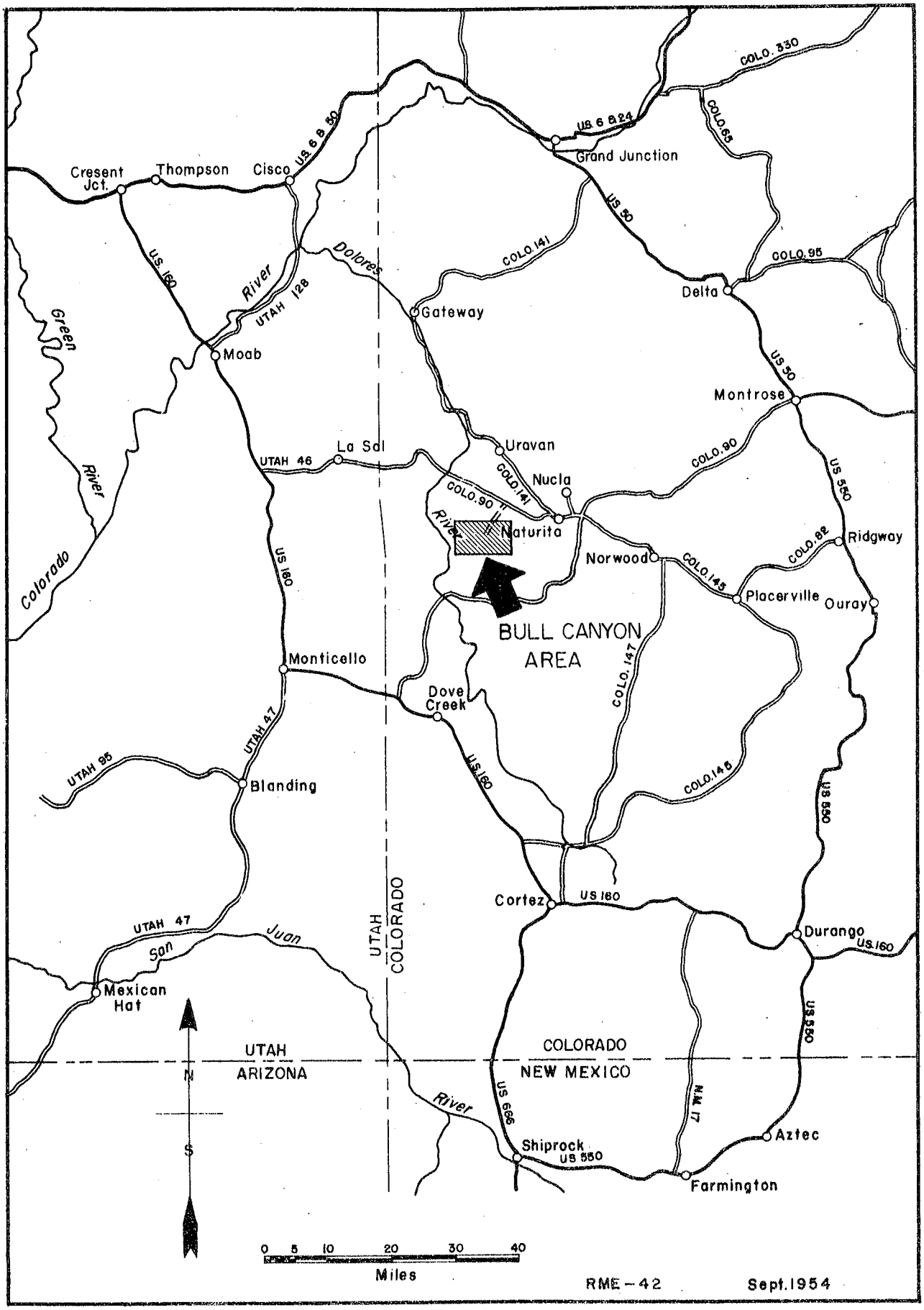

Figure 1. Location of the Bull Canyon area, Montrose & San Miguel Counties, Colorado

Types of Drilling

The drill footage for Contract AT(30-1)-1264 is divided, by areas, into investigative (primary, wide-spaced grids), explorative (secondary grids in favorable ground) and developmental (offset holes) (Table 1).

An additional 2,783 feet of wagon drilling, involving 30 holes, was completed in the Starlight and "C" areas under Contract AT(30-1)-1185.

TABLE 1 - TYPES OF DRILLING AT BULL CANYON UNDER CONTRACT AT(30-1)-1264

Area	Types of drilling, feet			Total
	Investigative	Explorative	Developmental	
A	5,800	5,800	13,500	25,100
B	4,600	4,500	11,200	20,300
C	2,500	2,100	—	4,600
D	2,000	—	1,100	3,100
Starlight	4,200	1,300	—	5,500
Wedding Bell	7,000	1,100	10,200	18,300
Horsehair	—	—	3,200	3,200
Fawn Springs Bench	10,000	4,500	4,500	19,000
Bachelor Draw	400	—	—	400
Wild Steer	400	—	—	400
TOTAL	36,900	19,300	43,700	99,900

HISTORY OF OPERATIONS

A small amount of high-grade, hand-sorted vanadium ore was taken from Bull Canyon during the First World War.

The Standard Chemical Company located most of the present-day prospects in 1920. When these became invalid, they were relocated by Clyde Grabill, John Carver, and Jim Elmer. Later these claims were sold and additional locations made by other people. Principal producers in Bull Canyon now are

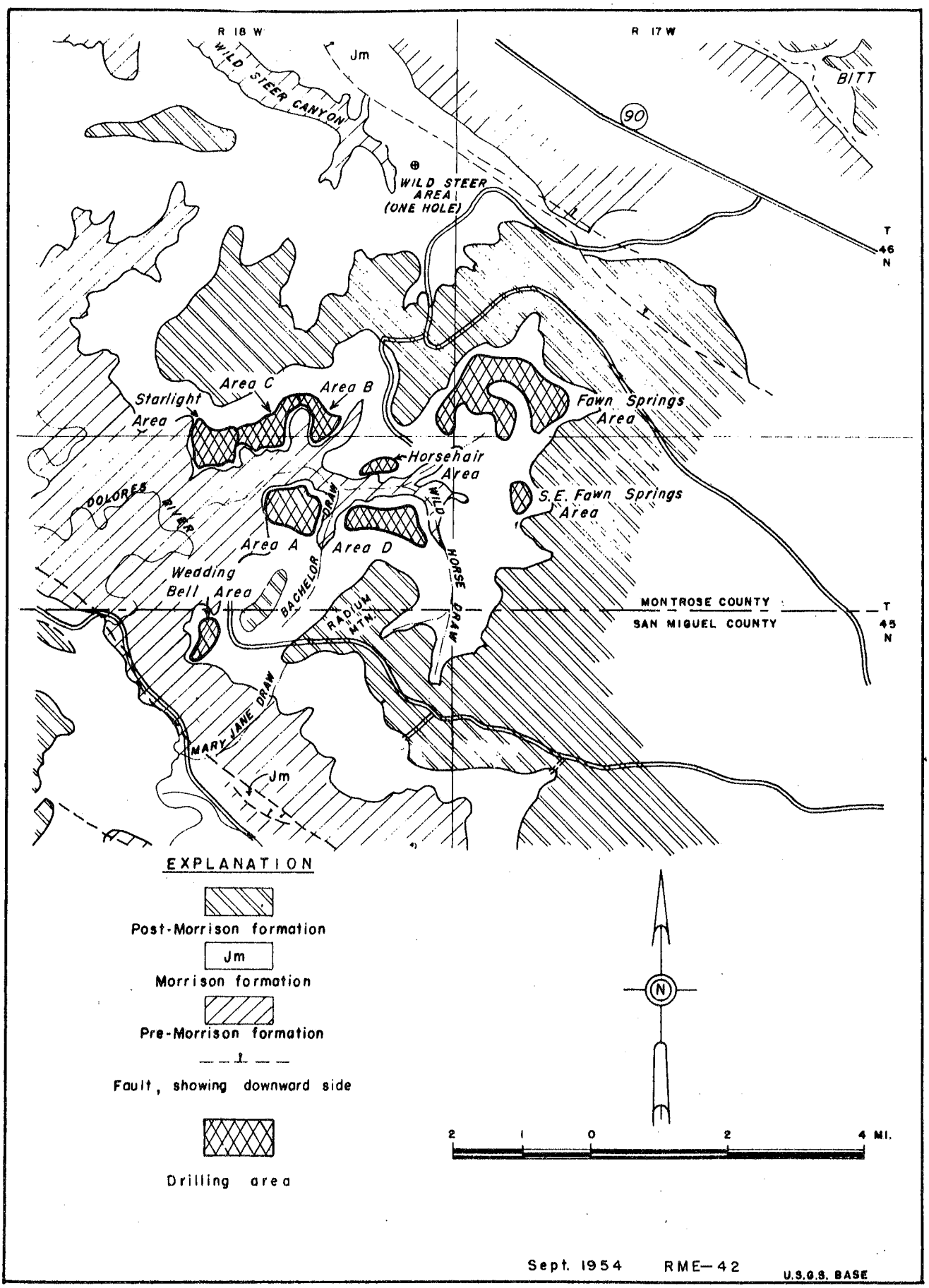

Figure 2. Geologic map showing location of Bull Canyon drilling area, Montrose and San Miguel Counties, Colorado

U. S. Vanadium Company, Vanadium Corporation of America, and Camoose Uranium Mines of America which recently purchased properties of J. R. Simplot Company.

GENERAL GEOLOGY

Topography

Topography ranges from gentle to rugged; total relief is about 2,200 feet.

Nearly vertical cliffs of the Wingate sandstone and the basal Kayenta formation rise from the valley floors. The upper Kayenta weathers back into broad benches from which rise characteristic rounded masses of the overlying weathered Navajo sandstone. The Entrada sandstone overlies the Navajo and forms the smooth, vertical to rounded cliffs from which the common name "Slick Rim" has been derived. Above the Entrada the steep slopes of the Summerville formation are overlain by small vertical sandstone cliffs or rims of the Salt Wash member of the Morrison formation. The Brushy Basin shale member forms steep, gravel-strewn slopes which are capped by vertical cliffs of the Burro Canyon formation.

Drainage from the area discharges into the Dolores River, a superimposed stream which has cut a deep, meandering gorge across Paradox and Gypsum valleys, as well as the intervening Bull Canyon area.

Structure

The Bull Canyon district is a broad area of nearly horizontal sediments located between two northwest trending anticlinal valleys, namely, Paradox Valley to the north and Gypsum Valley to the south. Dips from 10° to 20°, which are common along the valley walls, flatten to zero in the central portion of the district. Within the Bull Canyon drilling areas, the dip seldom exceeds 1°. In the Wedding Bell area, the dip becomes about $4\frac{1}{2}^{\circ}$.

Stratigraphy

An incomplete section of the Glen Canyon group, which includes the Wingate, Kayenta and Navajo sandstones, measures 515 feet.

The Triassic Wingate sandstone is a reddish-buff, massive cliff-former. The Jurassic (?) Kayenta formation is composed of red, irregularly bedded sandstones, conglomerates, and mudstone lenses. The lower portion is cliff-forming, and the upper part forms a bench. The Jurassic Navajo sandstone is a light-colored, massive, cross-bedded, aeolian sandstone, which weathers to rounded masses and cliffs.

The Upper Jurassic San Rafael group is represented by the Entrada sandstone and the Summerville formation. The Entrada, about 175 feet thick

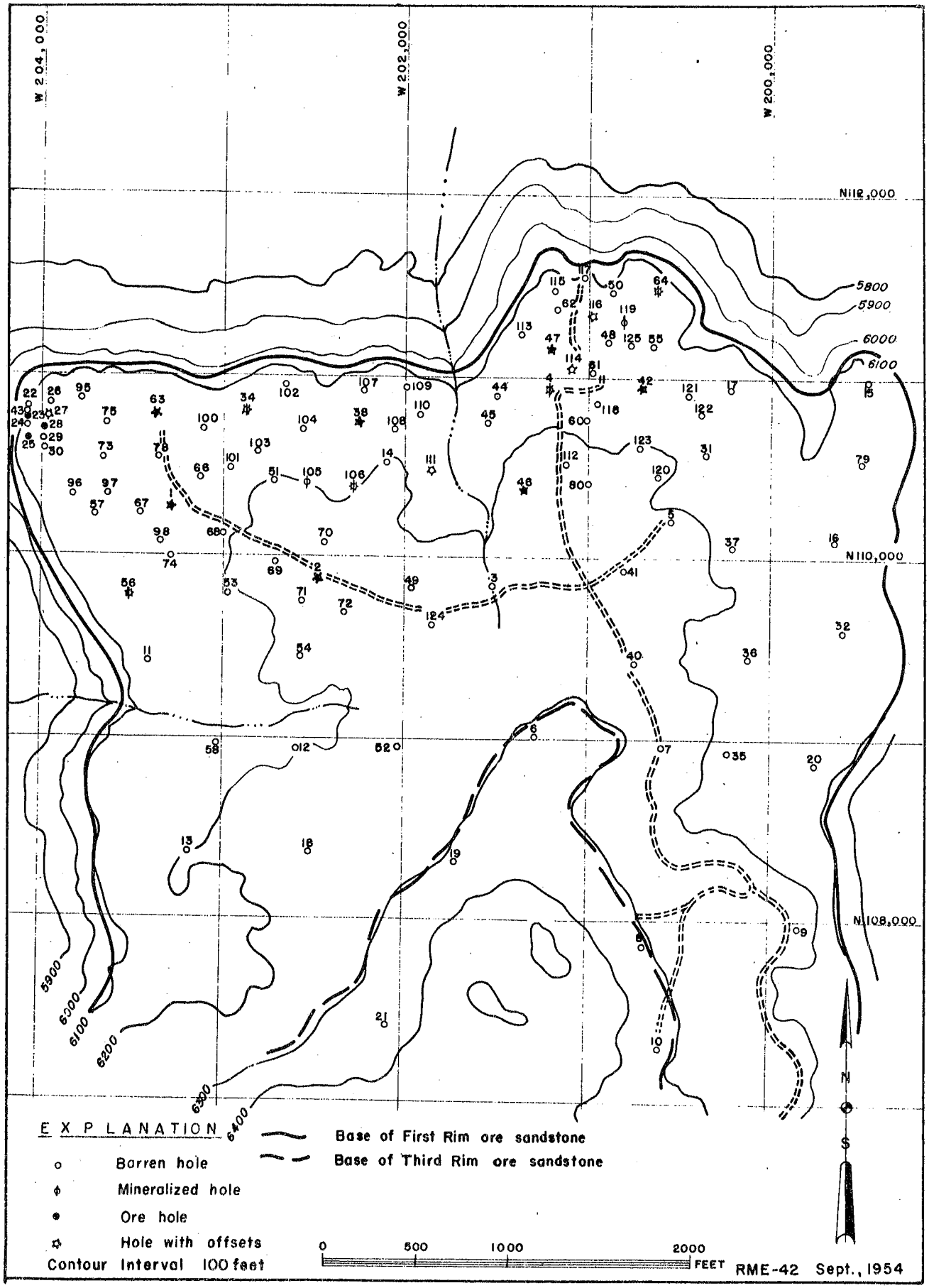

Figure 3. Area "A" base map, Bull Canyon district, Montrose County, Colorado

in this area, is a red and gray, massive sandstone which weathers to characteristic steep, rounded, smooth, bare cliffs. The Summerville formation consists of about 40 feet of thin-bedded, red and light gray shales, siltstones and sandstones, which together erode to steep slopes.

The Salt Wash member of the Upper Jurassic Morrison formation, about 350 to 420 feet thick in Bull Canyon, is composed of sandstone and red and gray-green mudstone and siltstone. The sandstones are lenticular, red, yellowish-brown, and light gray, very fine- to fine-grained, massive and cross-bedded. The thick sandstones form cliffs, and the predominantly mudstone sections form slopes. Carbonaceous material is abundant in places and is commonly associated with much limonitic staining. Logs and bone fragments are present. Mudstone galls, seams, and splits are common. Thick mudstone layers may lens out within short distances, and sandstone thicknesses change rapidly.

Uranium-vanadium mineralization occurs in four stratigraphic positions in the Salt Wash. The first lies 10 feet above the Summerville-Salt Wash contact, in the First Rim sandstone, a unit which is 80 to 150 feet thick. The Wild Steer mine is the only producer in this zone at present. The second stratigraphic position, also in the First Rim sandstone, is from 25 to 60 feet above the base of the Salt Wash member and is commercially important. The third, a minor ore zone, occurs in the Second Rim sandstone. The Big Bull mine in area "D" is the largest presently known in this horizon. The fourth and most productive horizon in the Bull Canyon area is the Third Rim sandstone which lies from 250 to 280 feet above the base of the Salt Wash. The First and Third Rim sandstones are the important producers at this time.

The Brushy Basin member of the Morrison formation is composed of red and green mudstones with medium- to very coarse-grained and conglomeratic sandstones near the base.

The steep slopes of the Brushy Basin member are topped by the cliff-forming Burro Canyon formation which consists of light-colored conglomeratic sandstones and red and green mudstones.

Outcrops of gray and green mudstones and gray and brown, medium-grained sandstones which occur locally in the area, may constitute the Dakota formation.

AREA "A" a/

Area "A" (figs. 2 and 3) is largely situated on the upper surface of the First Rim ore sandstone. Portions of the southern part of the area are on the bench formed by the Second and Third Rim sandstones. The drilling area is bounded on the north and west by Bull Canyon, on the east by Bachelor Draw, and on the south by the steeply sloping outcrop of the Brushy Basin mudstones.

a/ by J. V. A. Sharp

Plan of Drilling

Prior to work by the Commission, the only drilling in the area was a small amount of wagon drilling adjacent to the mines.

The first stage of drilling by the Commission consisted of a 500-foot square grid. Subsurface maps, incorporating results of this drilling, outlined areas favorable for the occurrence of ore in the northern third of the area drilled. Second stage drilling consisted of reducing the grid in favorable areas to 250-foot centers. In areas found to be extremely favorable, the grid was reduced to 125-foot centers.

With the exception of several low-grade occurrences, all mineralized holes were offset with a six-spot pattern (holes 60° apart) alternately 30 and 45 feet from the original hole. Difficulties due to terrain distorted both grid and offset drilling patterns.

Geology of the Deposits

A large number of mineralized outcrops and mine workings, all small, are in the First Rim ore sand in the northern portions of the area (fig. 4). Two small mines are present in the Third Rim ore sand. Primary sedimentary structures indicate an east to east-northeast sedimentary trend in the First Rim sandstone.

First Rim Ore Sandstone

All mineralization in this unit is in a zone 10 to 40 feet above the base.

Deposits in Area A are tabular, highly carbonaceous and often closely associated with a green mudstone or mudstone gall lens. No pronounced rolls were observed.

Mineralization, both on the rim and that located by drilling, is of the carnotite-vanadium type, with grade averaging about 0.30 percent U_3O_8 and 2 percent V_2O_5. Malachite and azurite occur in several of the mineralized outcrops.

Third Rim Ore Sandstone

There has been limited production in this sandstone unit from the Calverts No. 2 and April mines.

Subsurface Geology

The stratigraphic unit used in the preparation of subsurface maps was chosen somewhat arbitrarily as the lower 55 feet of the First Rim sandstone.

The chief ore guides in area "A" are the same as in the other First Rim sandstone drilling areas. Methods and maps used are also like those used in the other areas.

The carbon[a/] map (fig. 4) shows by relative numerical values based on abundance and thickness the amount of carbon present in the 55-foot unit. With one exception, orebodies containing more than one ore hole are present in areas within the 5 contour. Upon this basis all ground outside of the 5 contour is considered to be unfavorable for the occurrence of large amounts of ore. Favorable ground is present in four places. The two in the northern part of the drilling area have good control while those in the southern portion of the drilling area are based upon comparatively few holes.

The favorable (non-hematitic) color map (fig. 5) shows the number of feet of gray and limonitic rock in the 55-foot unit. No mineralization was found in holes containing less than 40 feet of favorable color; accordingly, areas with less than 40 feet of favorable color were empirically considered to be unfavorable.

The limonitic sandstone map (fig. 6) shows the number of feet of limonitic sandstone in the 55-foot unit. While several mineralized holes are present in areas containing less than 25 feet of limonitic sandstone, no ore was developed in these areas. Areas with less than 25 feet of limonitic sandstone present are therefore considered to be unfavorable for the occurrence of ore. In the northern part of the drilling area, where the control is good, two favorable areas are present. The three favorable areas in the southern part of the drilling area are based upon figures from comparatively few drill holes.

By combining, in an arbitrary manner, the figures indicating amount of carbon, favorably colored rock, and limonitic sandstone present, a composite favorability rating for each hole was attained and a map was constructed (fig. 7).

While several mineralized grid holes had ratings of slightly less than 70, no ore was found in these areas. Therefore, a rating of 70 or better is empirically considered to denote ground favorable for the occurrence of ore. The favorable ground outlined by this method coincides with the ground in the northern part of the drilling area in which all the orebodies and most of the mineralized outcrops occur. A second area of favorable ground extends along the eastern edge of the drilling area, and within its limits is a small mine working.

The mudstone/sandstone map (fig. 8) of the 55-foot unit indicates a northeast trend, as do primary sedimentary structures observed on the rim.

Radioactivity maps are not included in this report because inconsistencies in the radiometric data are of such magnitude that gamma log information could not be used for favorability purposes.

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a/. The term carbon, as used in this report, is not restricted to elemental carbon; rather it includes, as in the vernacular of Plateau geologists, all types of carbonaceous plant materials.

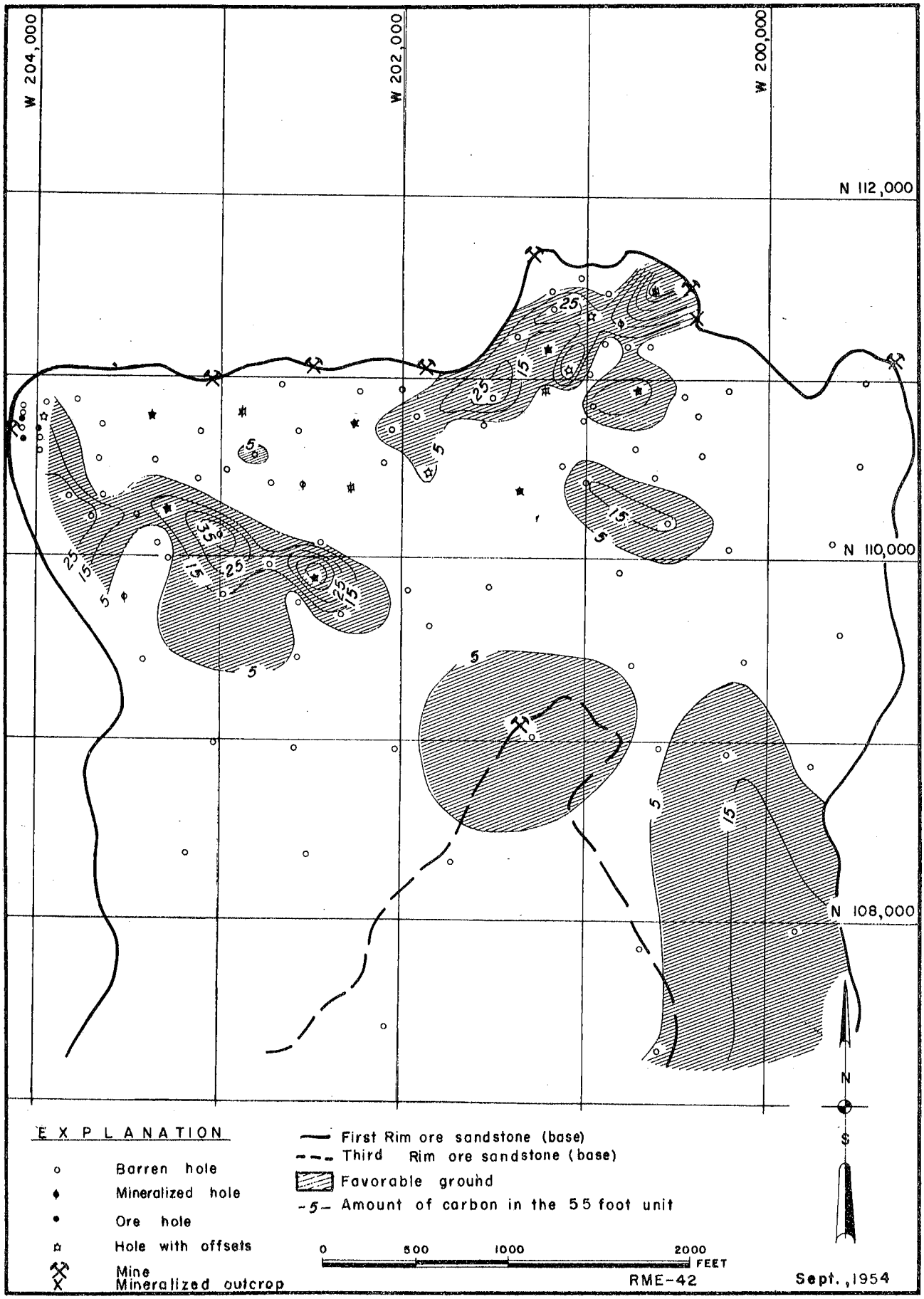

Figure 4. Quantitative carbon, area "A", Bull Canyon district, Montrose County, Colorado

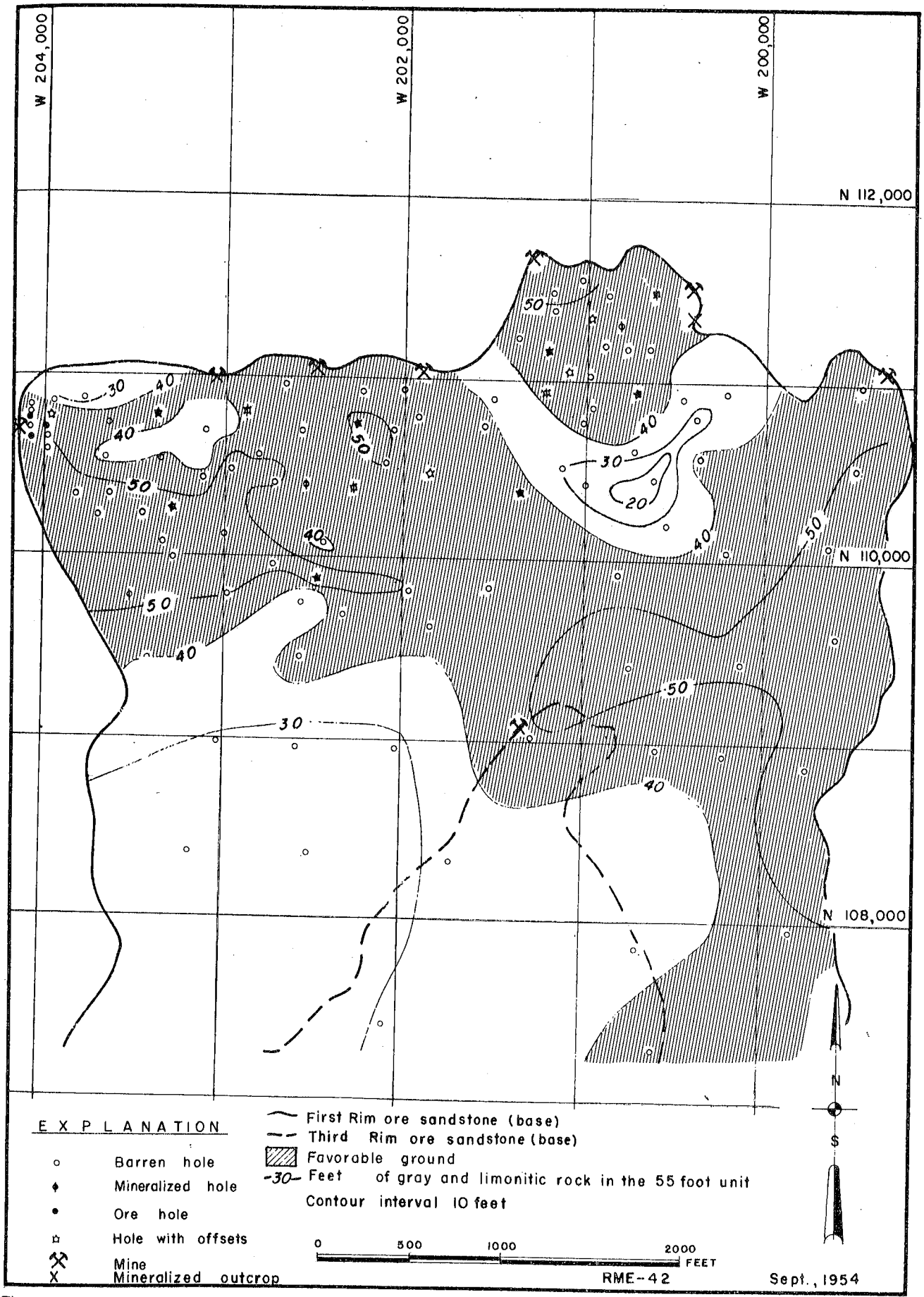

Figure 5. Feet of non-hematitic rock, area "A", Bull Canyon district, Montrose County, Colorado

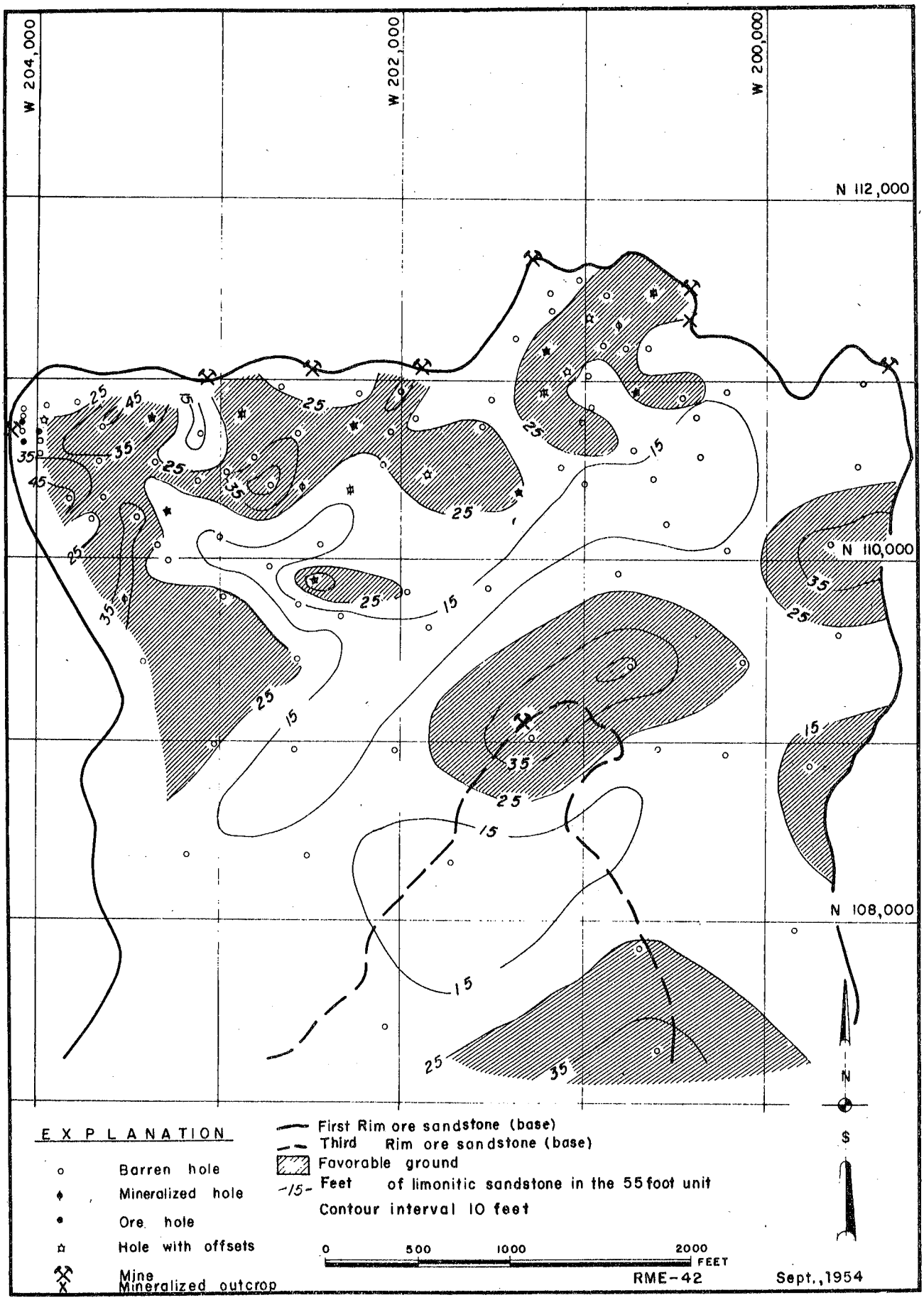

Figure 6. Feet of limonitic sandstone, area "A", Bull Canyon district, Montrose County, Colorado

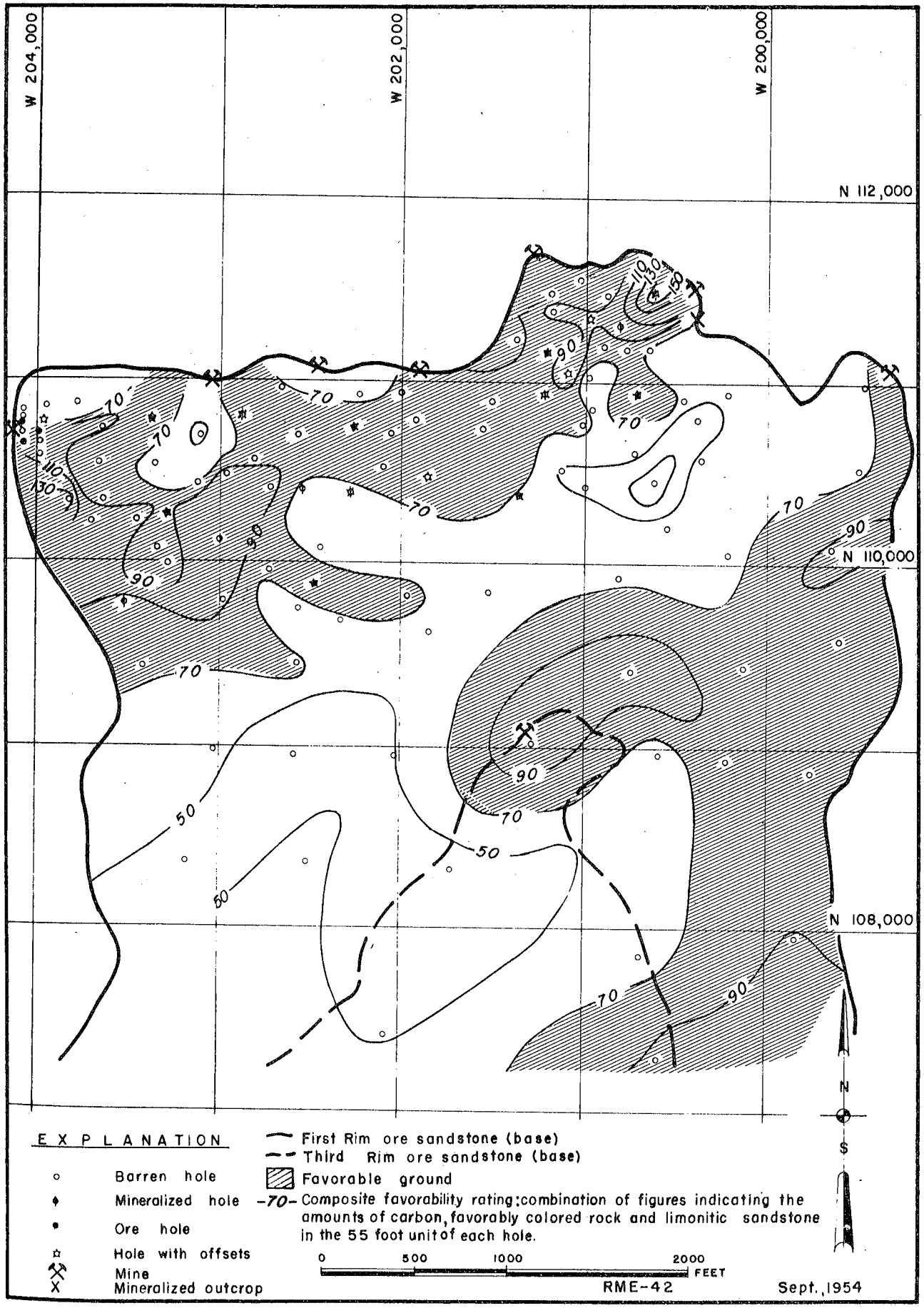

Figure 7. Composite favorability map, area "A", Bull Canyon district, Montrose County, Colorado

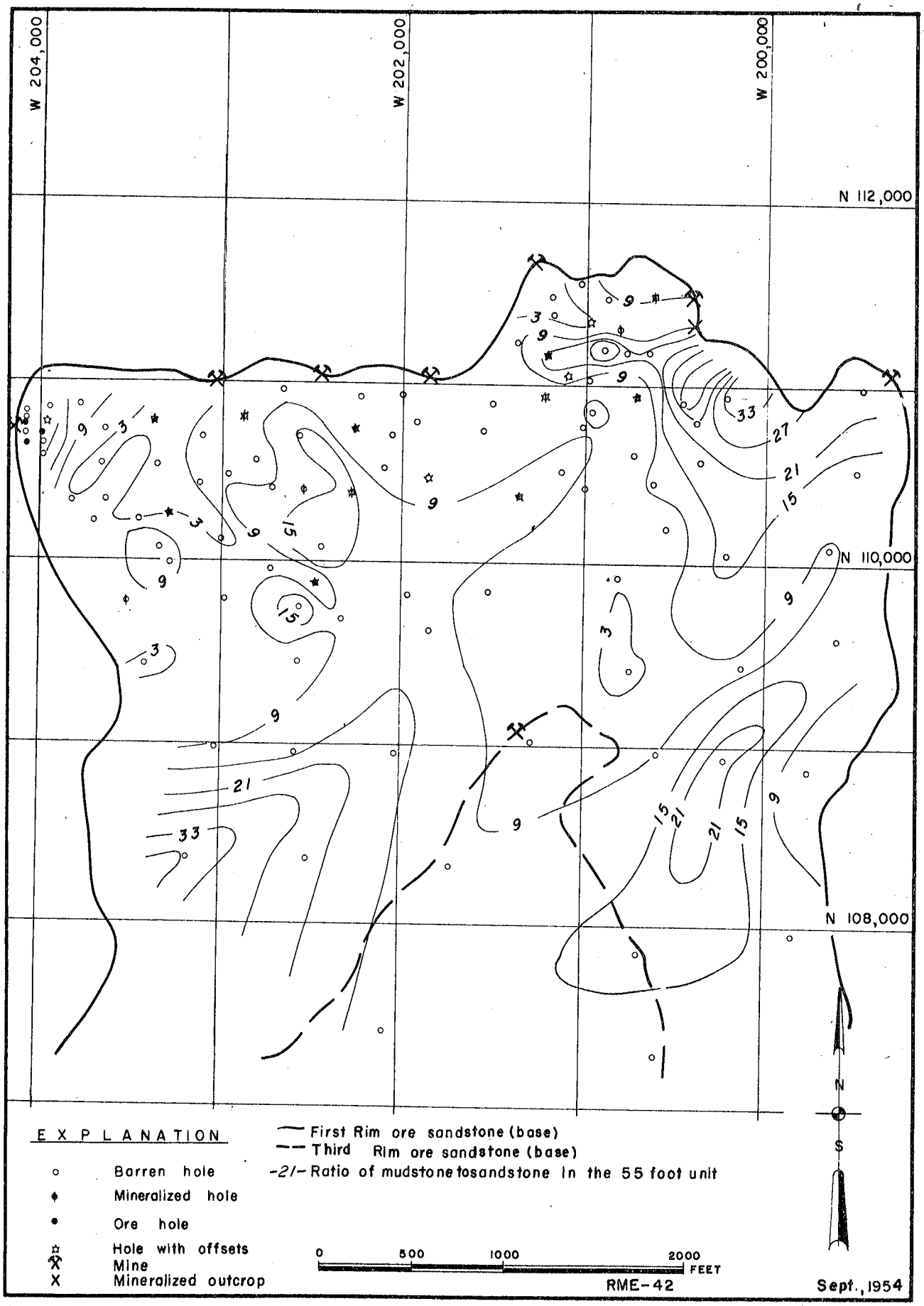

Figure 8. Mudstone/sandstone map, area "A", Bull Canyon district, Montrose County, Colorado

Conclusions

While the general absence of rim and drill-hole mineralization in the favorable ground outlined on the eastern edge of the drilling area is not encouraging, it is thought that tightening of the north-south grid lines to 250-foot centers might be worthwhile on the basis of subsurface information. Due to the shallow depths required, this work could be accomplished by wagon drilling.

The small size of orebodies developed and the high density of holes indicate that further large-scale drilling in the favorable ground along the northern edge of the drilling area will probably be unsuccessful.

AREA "B" a/

Introduction

Area "B" consists of two relatively flat benches formed by the First and Third Rim sandstone units of the Salt Wash member. In area "B", the First Rim averages 50 feet thick and the Third Rim about 25 feet. Area "B" (figs. 2 and 9) is bounded on the south, east and west by deep canyons and on the north by the steep Brushy Basin slopes at the foot of Wild Steer Mesa.

Plan of Drilling

The shallower grid holes were drilled first. The grid pattern of drilling was abandoned early, partly because of limiting topography and partly because information gained from the initial shallow holes revealed that a revision of the original recommendation was advisable. Revision was based on information compiled on subsurface maps.

Thirty-six grid holes were drilled on the lower bench. With the exception of two, no deep holes were completed on the upper bench until the lower bench was adequately explored. Most deeper holes on the upper bench were drilled in an attempt to follow possible extensions of known orebodies; the remainder were used to test favorable ground and to obtain geologic information.

Geology of the Deposits

During the course of the project, mineralized outcrops were noted (fig. 9), and mines examined for shapes of orebodies, general trends, and types of ore. Compass readings on festoon bedding and lineation in the mineralized outcrop along the 6,000-foot contour in the southeast portion of the area vary progressively from east to N. 30° E.

Uranium-vanadium deposits in area "B" form elongated tabular bodies of irregular oval shapes within horizontal sandstone strata. Roll type orebodies are common. Within a deposit, the ore minerals may occur in one

a/ By R. G. Blair

to three layers, separated by one or two feet of barren or weakly mineralized rock. Two mineralized layers may join to form a thicker layer in the richest part of the orebody. The average thickness of mineralization is about two feet, although one drill hole penetrated over ten feet.

The main ore zone in area "B" is in the First Rim sandstone from 10 to 50 feet above the base of the Morrison formation. Weak mineralization in higher zones, probably the Second and Third Rim sandstones, was encountered in several of the deeper holes and on outcrops. This mineralization was not visible in the core but was indicated on the gamma ray log between 110 and 225 feet above the producing ore horizon or First Rim.

Two varieties of ore are present in this area. The most common is megascopically homogeneous and apparently a greenish-black mixture of vanadium and carnotite which coats sand grains and, in the low-grade deposits, is intimately mixed with silt or clay. This variety may contain from 0.01 percent U_3O_8 to as much as 0.70 percent U_3O_8. The second type of ore is a mixture of yellow uranium and black vanadium minerals, with mottled appearance. It is usually richer than the greenish-black ore, having a grade which is rarely below 0.50 percent U_3O_8 and runs as high as 2.00 percent U_3O_8. This mottled ore usually forms the core of the deposits and is absent in the smallest orebodies.

Subsurface Geology

In area "B", the base of the ore-bearing sandstone lens is well defined by interbedded red and gray or green mottled mudstones, usually contorted and silty. The top of the ore interval is marked by the lowermost mudstone bed within the ore-bearing lens, which can be recognized in all holes. This interval was used in the construction of most subsurface maps.

Subsurface maps were constructed to show: feet of limonitic sandstone (fig. 10); feet of non-red sandstone (fig. 11); feet of sandstone (fig. 12); mudstone-sandstone ratio; maximum amplitude isoradiometric maps (fig. 14); and a composite favorability map (fig. 13).

All holes were logged with a Scherbatskoy logging unit as soon after being drilled as possible. The radiometeic log was useful in locating and measuring mineralization in the rare cases where core recovery was very low. In addition, favorable areas were outlined by contouring maximum amplitude values (fig. 14).

Limonite and carbonaceous trash are both important ore guides. The map showing the number of feet of limonitic sandstone in the ore zone (fig. 10) indicates a close association between high limonite content and

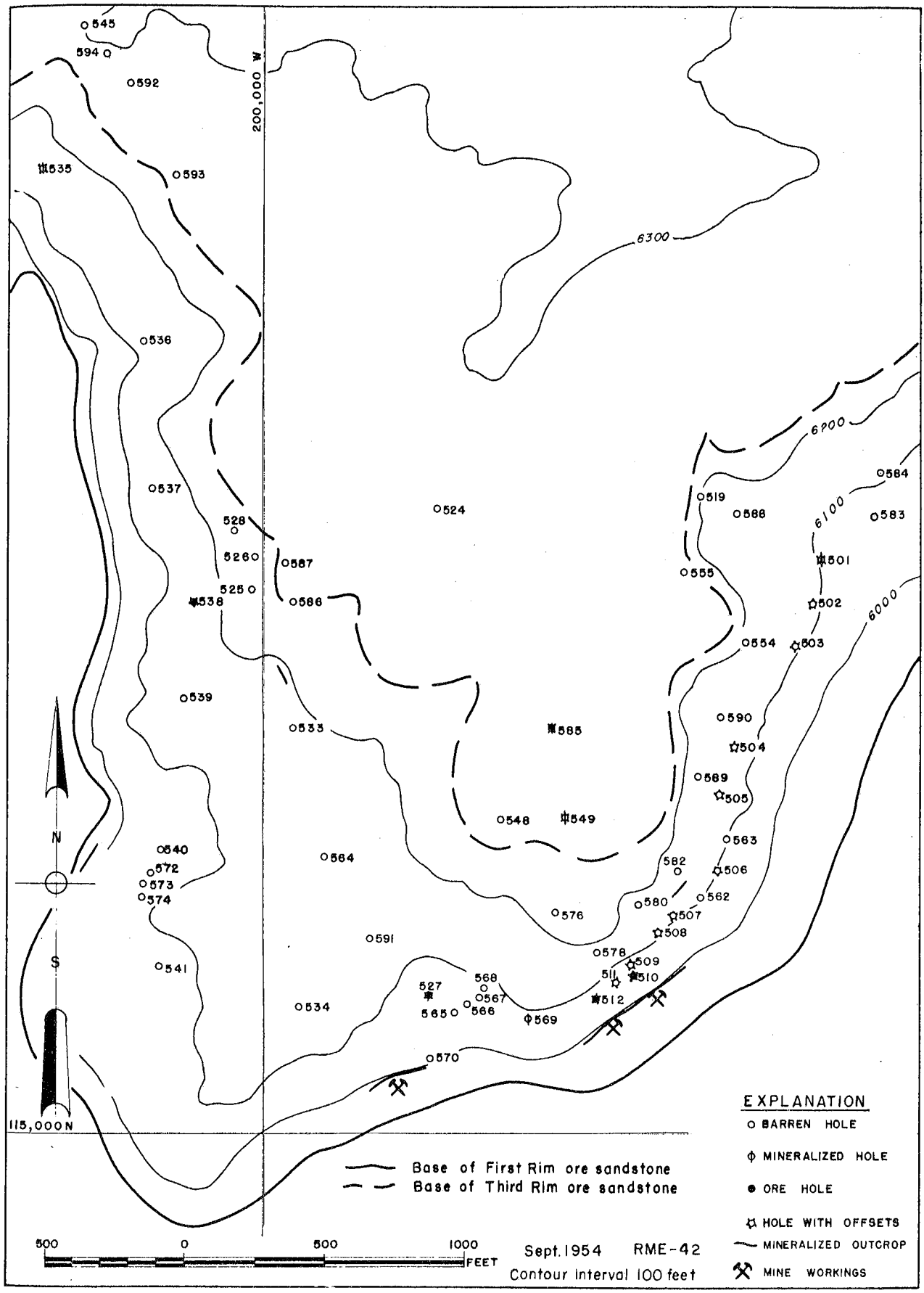

Figure 9. Area "B" base map, Bull Canyon district, Montrose County, Colorado

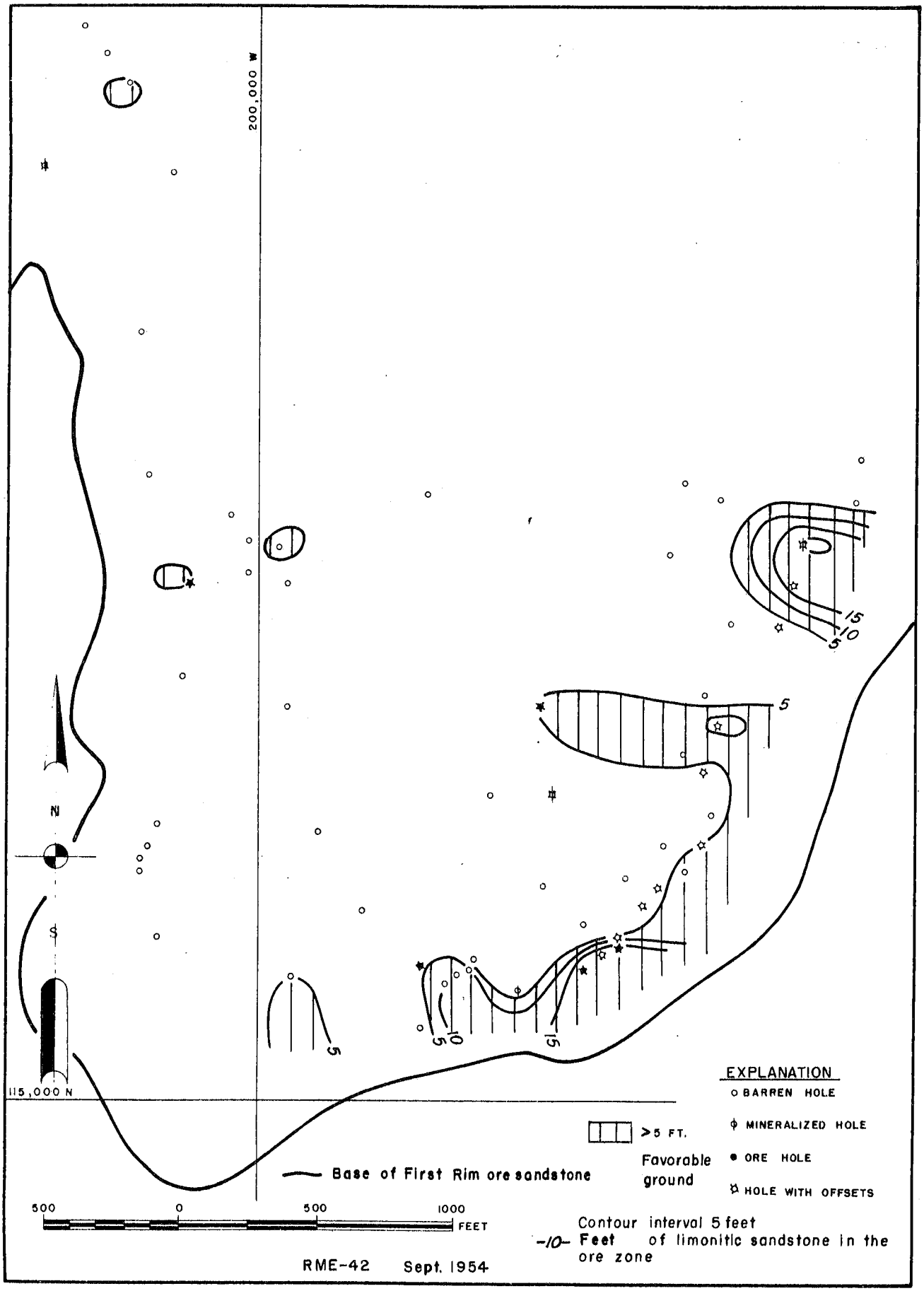

Figure 10. Feet of limonitic sandstone, area "B", Bull Canyon district, Montrose County, Colorado

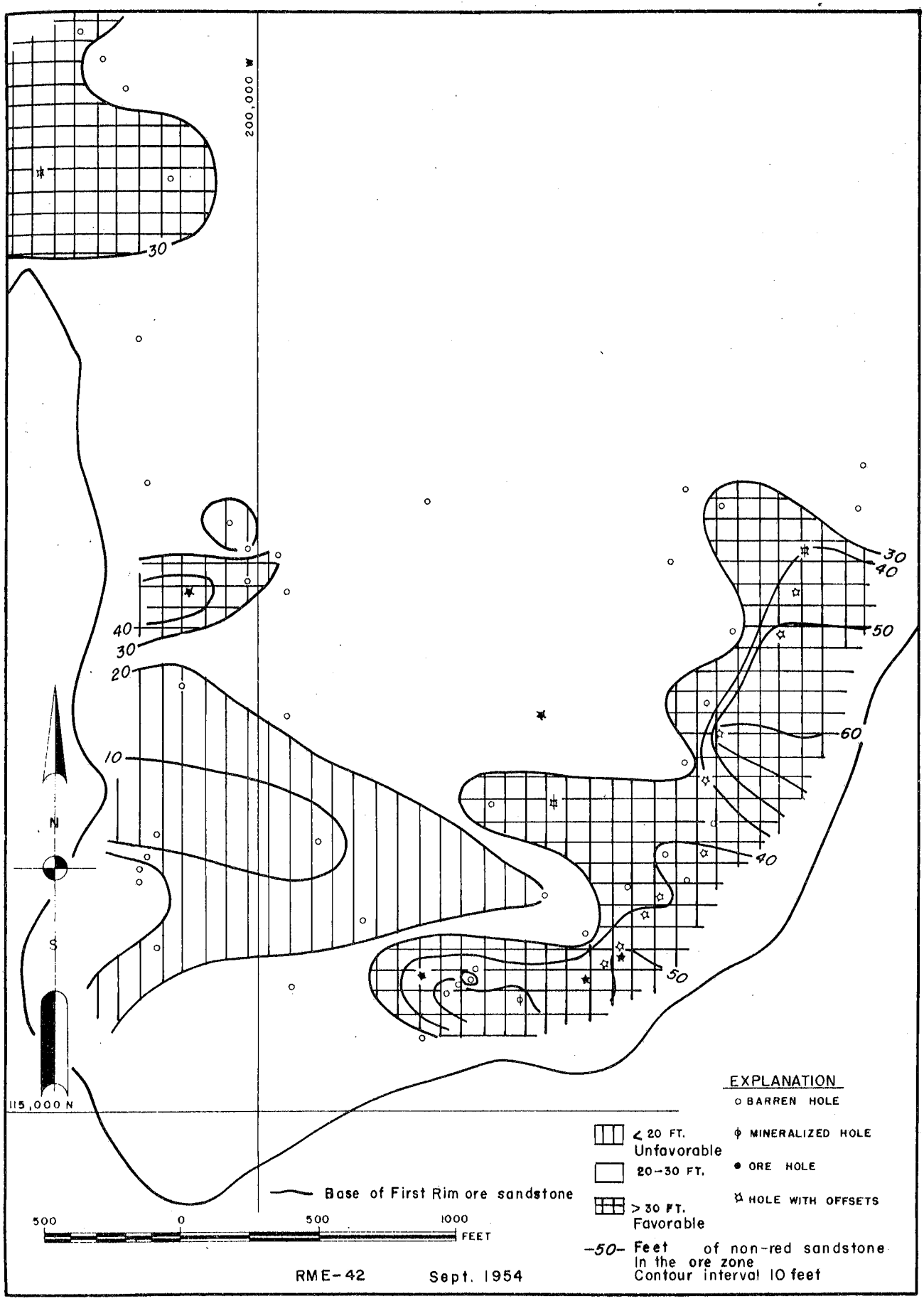

Figure 11. Feet of non-red sandstone, area B, Bull Canyon, Montrose County, Colorado

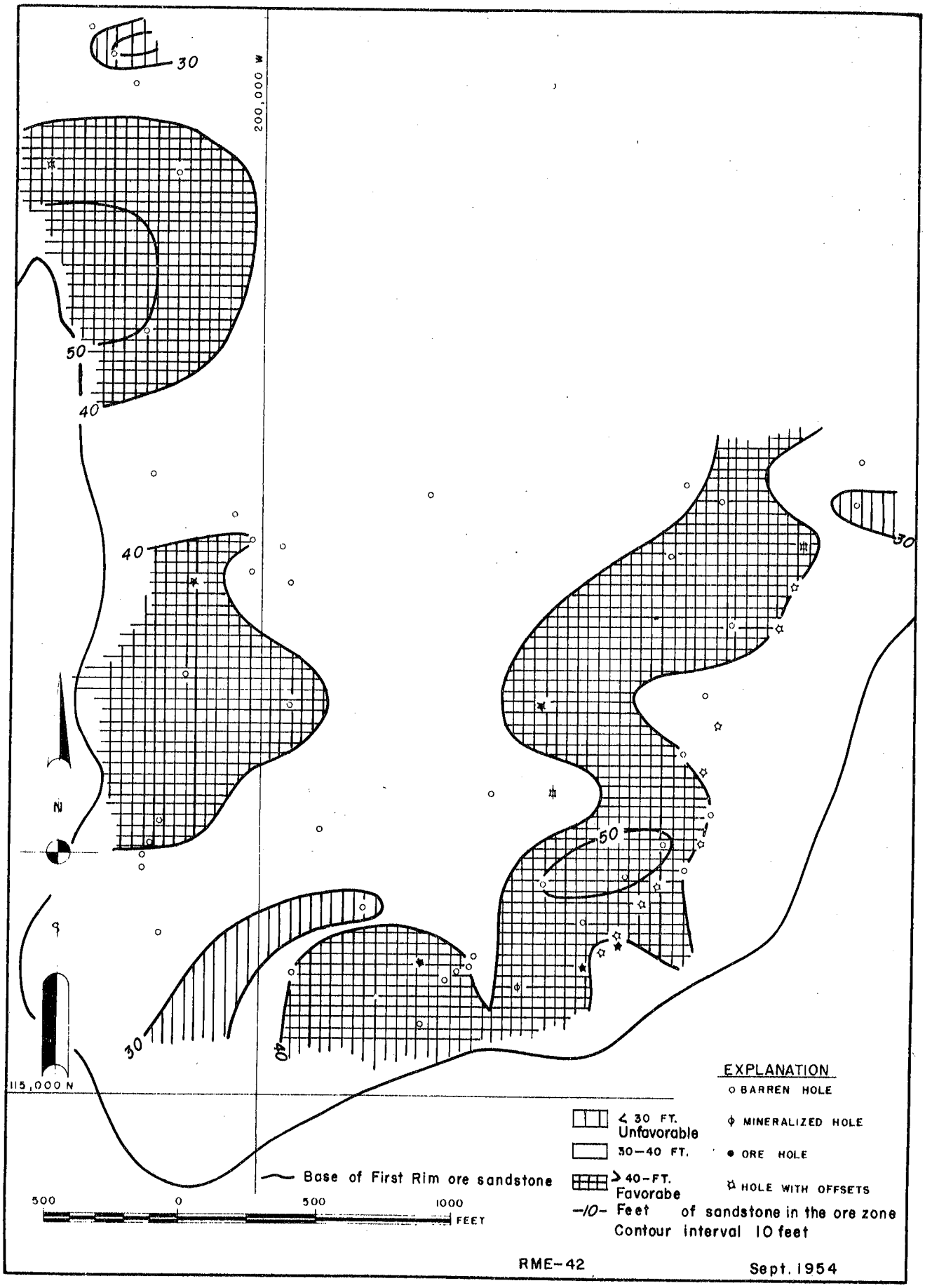

Figure 12. Feet of sandstone, area "B", Bull Canyon district, Montrose County, Colorado

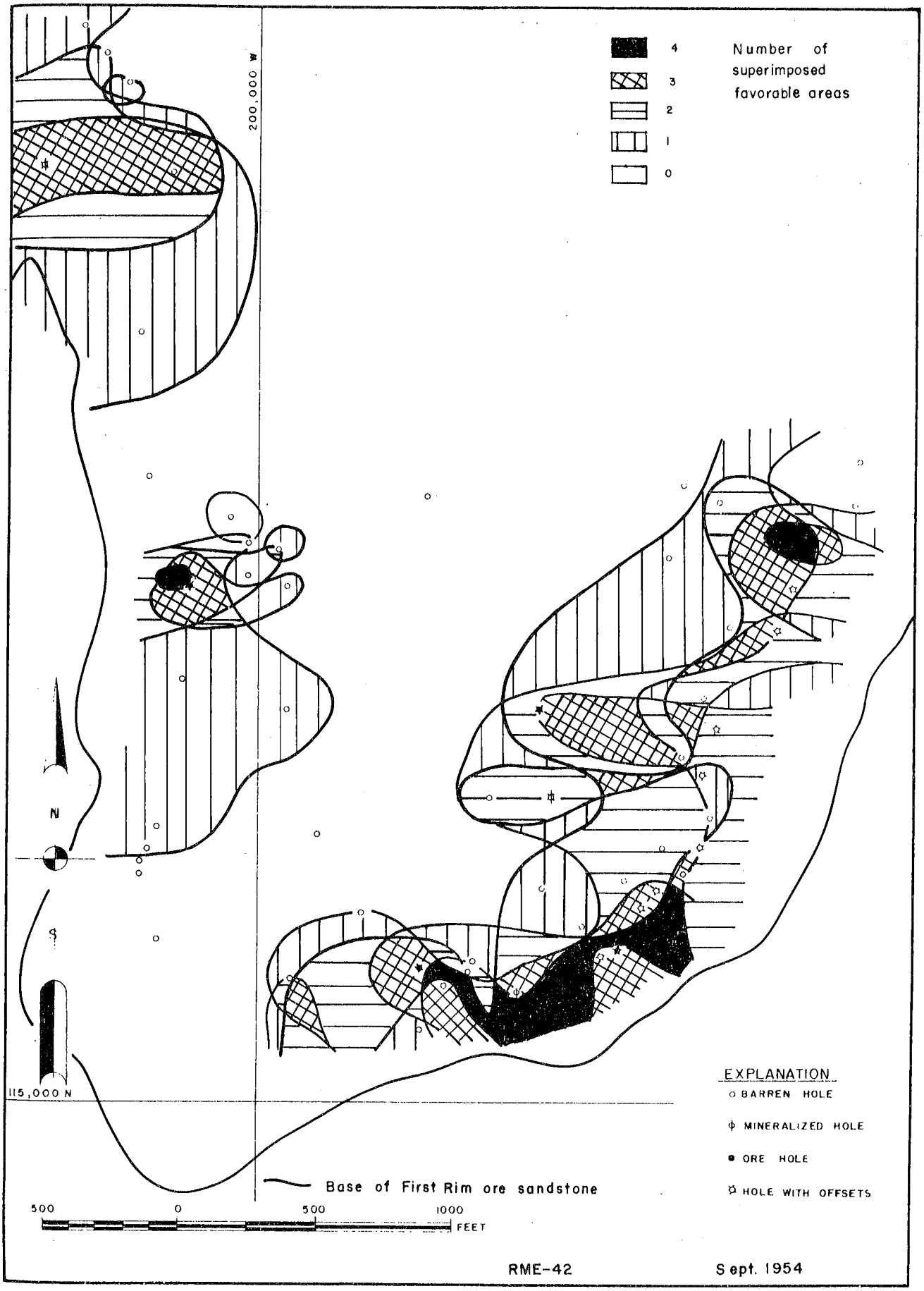

Figure 13. Composite favorability map, area "B", Bull Canyon district, Montrose County, Colorado

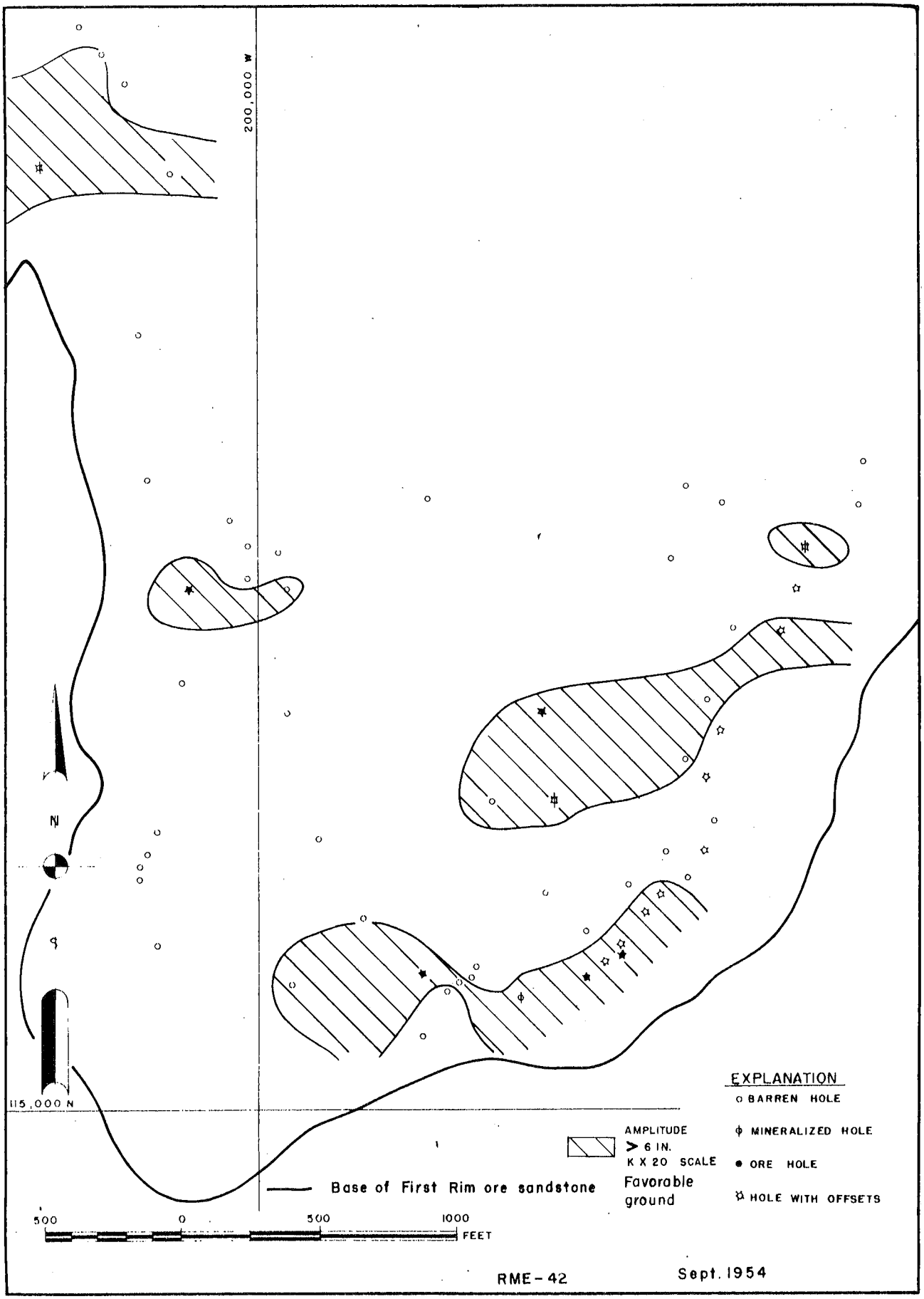

Figure 14. Maximum amplitude isorad, area "B", Bull Canyon district, Montrose County, Colorado

ore. A similar correlation between ore and carbonaceous material is shown in the following table:

	No. of holes	Percent of holes Containing Carbonaceous Material
Barren	71	42
Mineralized	40	57
Ore	26	77

AREA "C" a/

Introduction

Like other First Rim drilling areas in the Bull Canyon district, area "C" is a bench on the upper surface of the First Rim ore sandstone. The drilling area (figs. 2 and 15) is bounded on the east and south by Bull Canyon, on the west by the Starlight drilling area, and on the north by a cliff of Third Rim ore sandstone.

Plan of Drilling

The initial grid consisted of holes spaced on 500-foot centers along three north-south lines 1,000 feet apart.

Upon the completion of the initial grid drilling, favorable areas were drilled out to 500-foot centers, and particularly auspicious areas to 250-foot centers.

The success achieved by Commission and private wagon drilling indicates that future drilling in area "C" can be accomplished largely by this method.

Geology of the Deposits

While drilling was in progress, mapping of the First Rim sandstone was undertaken. This included mapping the orientation of primary sedimentary structures and rim mineralization of which a large amount was present. Results indicate an east to northeast sedimentary trend. The highest level of mineralization is south of a line running east-northeast from the Starlight No. 8 mine (fig. 16), an area which includes the two working mines in the drilling area, the Patty No. 5 and the Sunrise No. 3.

All mineralization disclosed by drilling and rim examination in area "C" occurred in one sandstone lens having a thickness ranging from 15 to 60 feet.

Deposits are tabular, highly carbonaceous, and often associated with a mudstone layer. Mineralization is of the usual carnotite-vanadium association, but is generally of a higher grade than that found in the other drilling areas in Bull Canyon.

a/ By J. V. A. Sharp

The Sunrise No. 3 and the Patty No. 5 orebodies are several thousand tons in size.

Subsurface Geology

The ore-bearing sandstone lens was identified in drill core through correlation of associated mudstones and silty sandstones. The lens is usually divided into two parts by a mudstone-silty sandstone layer. The upper division of the sandstone lens is of major economic importance, containing the Patty No. 5 mine, a large producer.

The three main guides to ore in the First Rim sandstone of other Bull Canyon drill areas are valid criteria for the finding of ore in area "C". These are: 1. relative abundance of carbonaceous matter, as shown by arbitrary numerical values (fig. 16); 2. number of feet of non-hematitic rock in the ore lens (fig. 17); and 3. number of feet of limonitic sandstone in the ore lens (fig. 18). By combining values for the three criteria in an arbitrary manner, favorability ratings for all holes were derived and contoured (fig. 19).

Although Commission drilling intercepted relatively little mineralization, large portions of area "C" are regarded as favorable for the occurrence of ore. Discoveries made by private wagon drilling programs in these areas substantiate this conclusion.

The favorable ground, which includes most of area "C", is probably an extension of favorable areas in the vicinity of the Starlight No. 7 and No. 8 mines to the west. This trend may extend eastward to the favorable portions of the "B" drilling area, several thousand feet distant. Favorability seems to decrease northward from this favorable ground but the amount of drilling is insufficient to rule out these areas as uneconomic.

Because radioactivity maps give much the same results as the favorability maps, none are included in this report. The mudstone-sandstone ratio map (fig. 20) indicates a pronounced northeast sedimentary trend. This corresponds with the orientation of primary sedimentary structures observed on the rim.

AREA "D" a/

Introduction

Topography and surface geology of area "D" (figs. 2 and 21) are essentially the same as in area "A" and will not be repeated here.

Subsurface Geology

The First Rim sandstone in area "D" (fig. 21) is similar in many respects to that in area "A". As in area "A", a correlation of the top

a/ C. D. Thompson

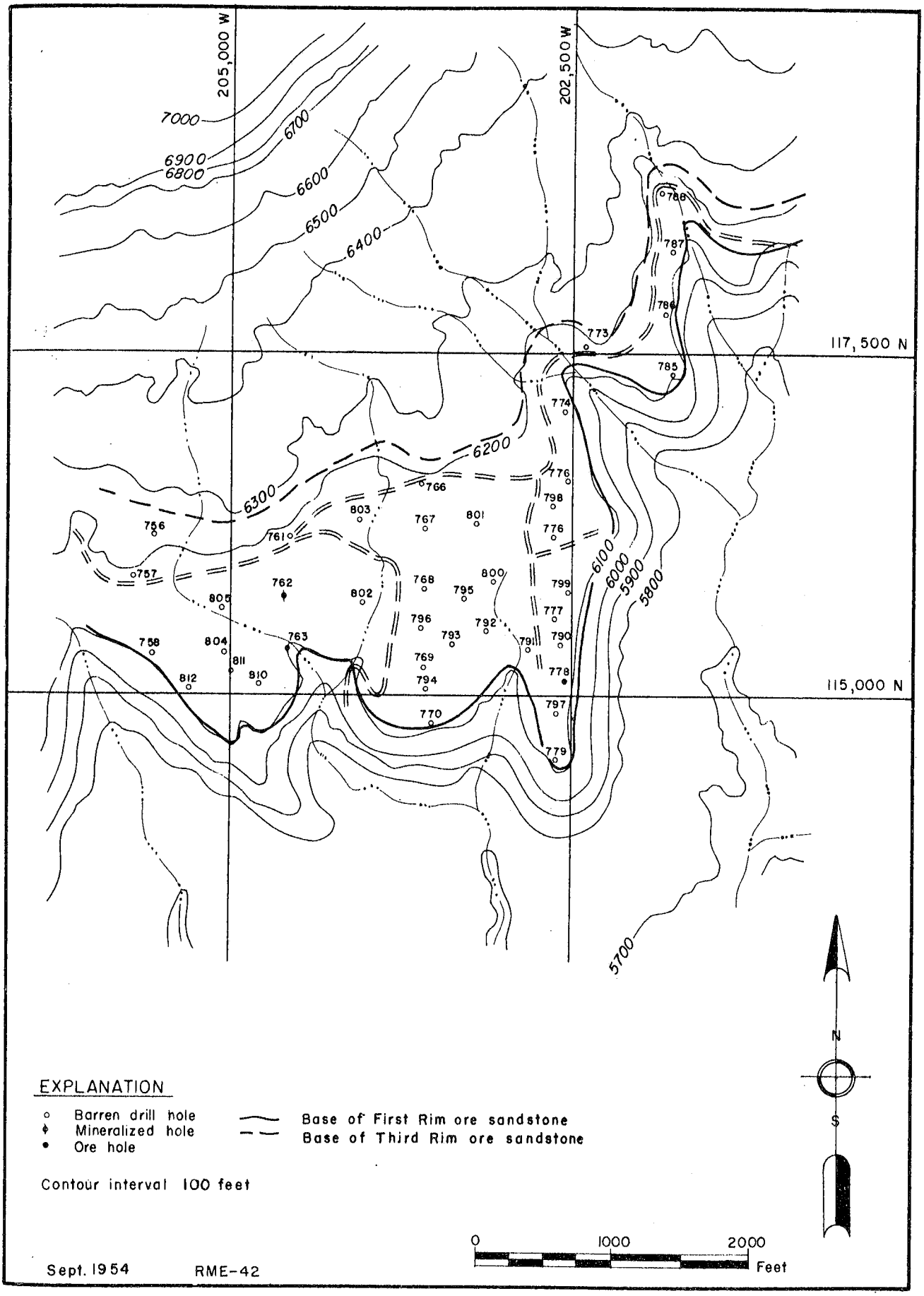

Figure 15. Area "C" base map, Bull Canyon district, Montrose County, Colorado

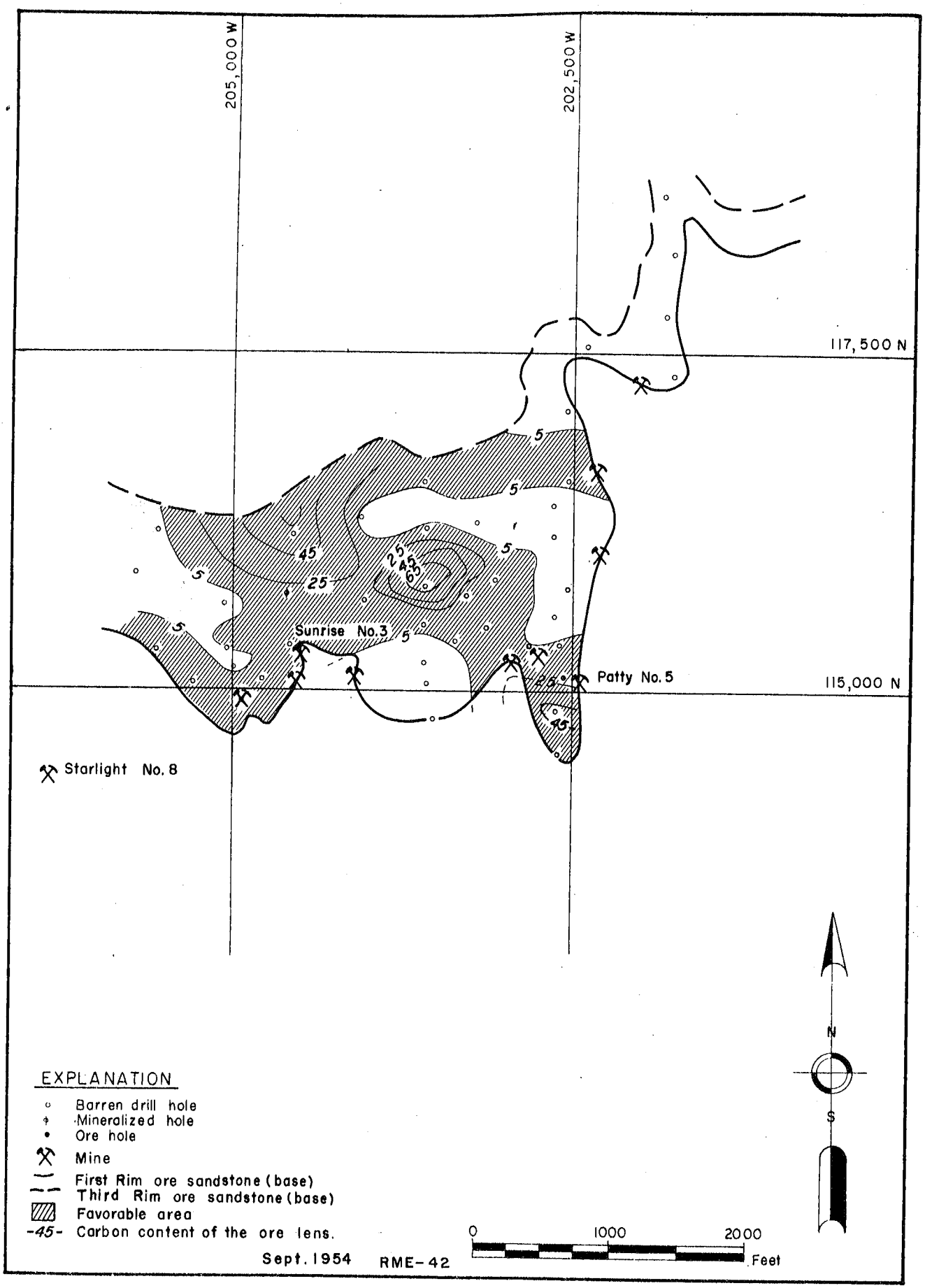

Figure 16. Quantitative carbon, ared "C", Bull Canyon district, Montrose County, Colorado

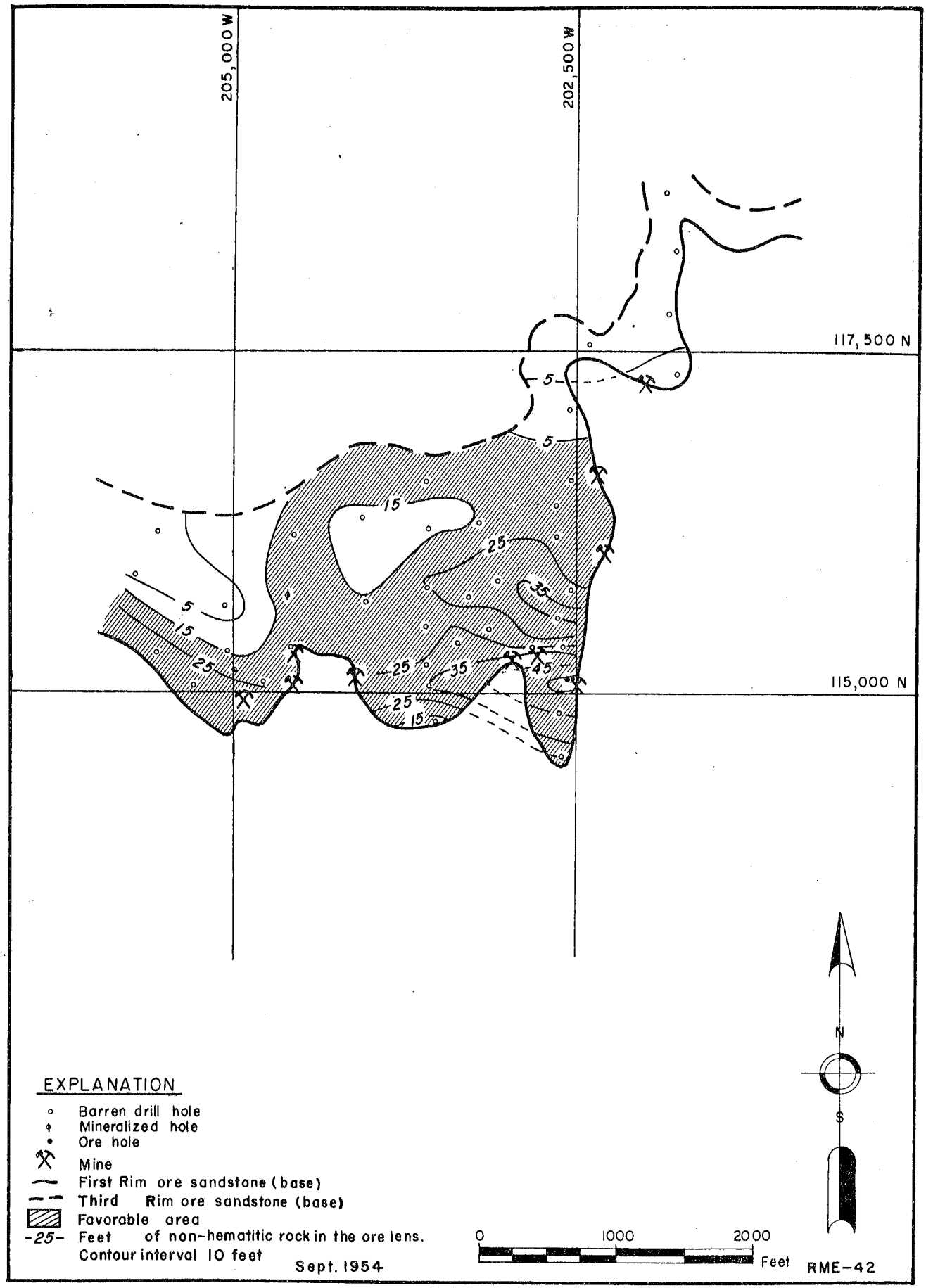

Figure 17. Feet of non-hematitic rock, area "C", Bull Canyon district, Montrose County, Colorado

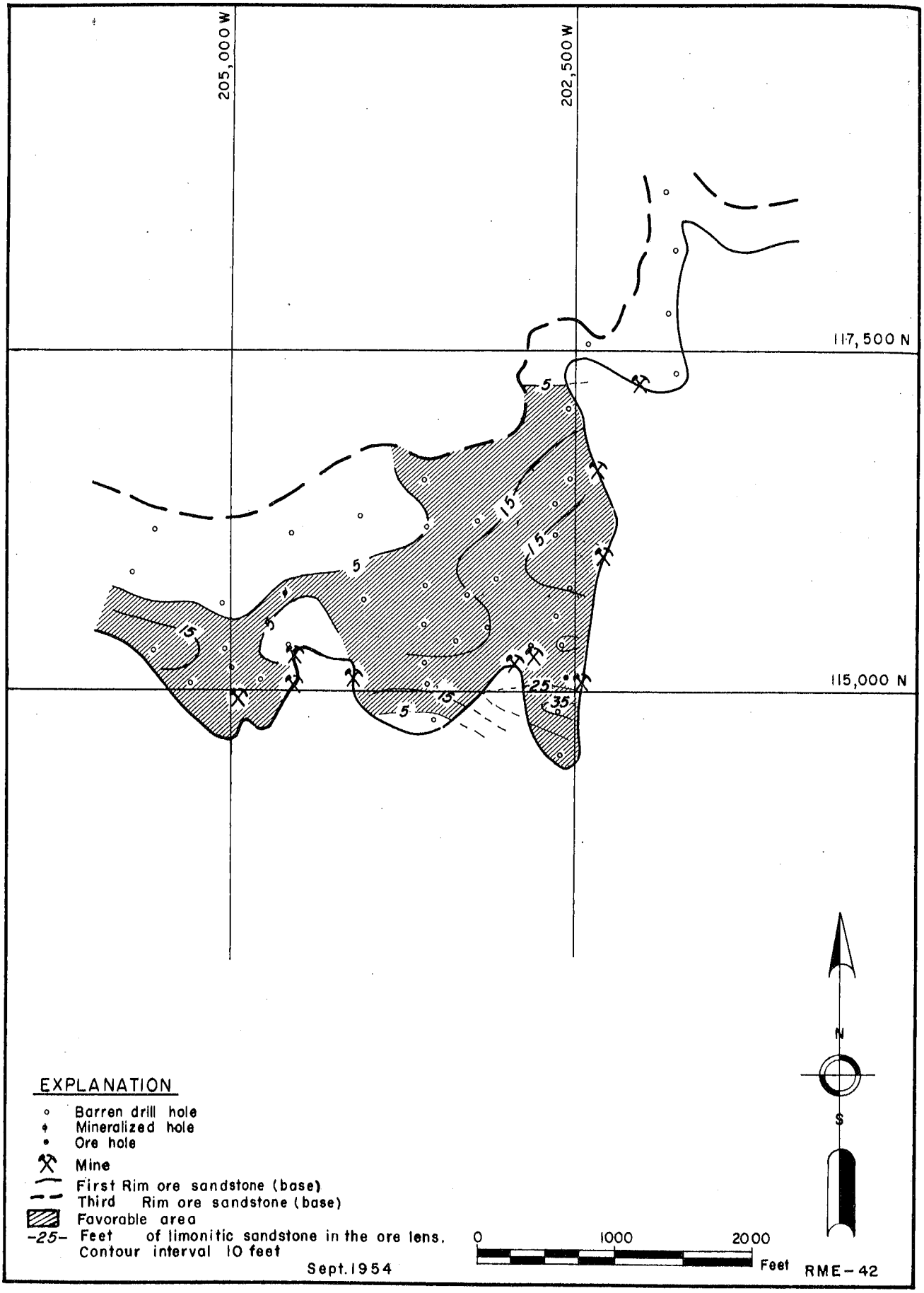

Figure 18. Feet of limonitic sandstone, area "C", Bull Canyon district, Montrose County, Colorado

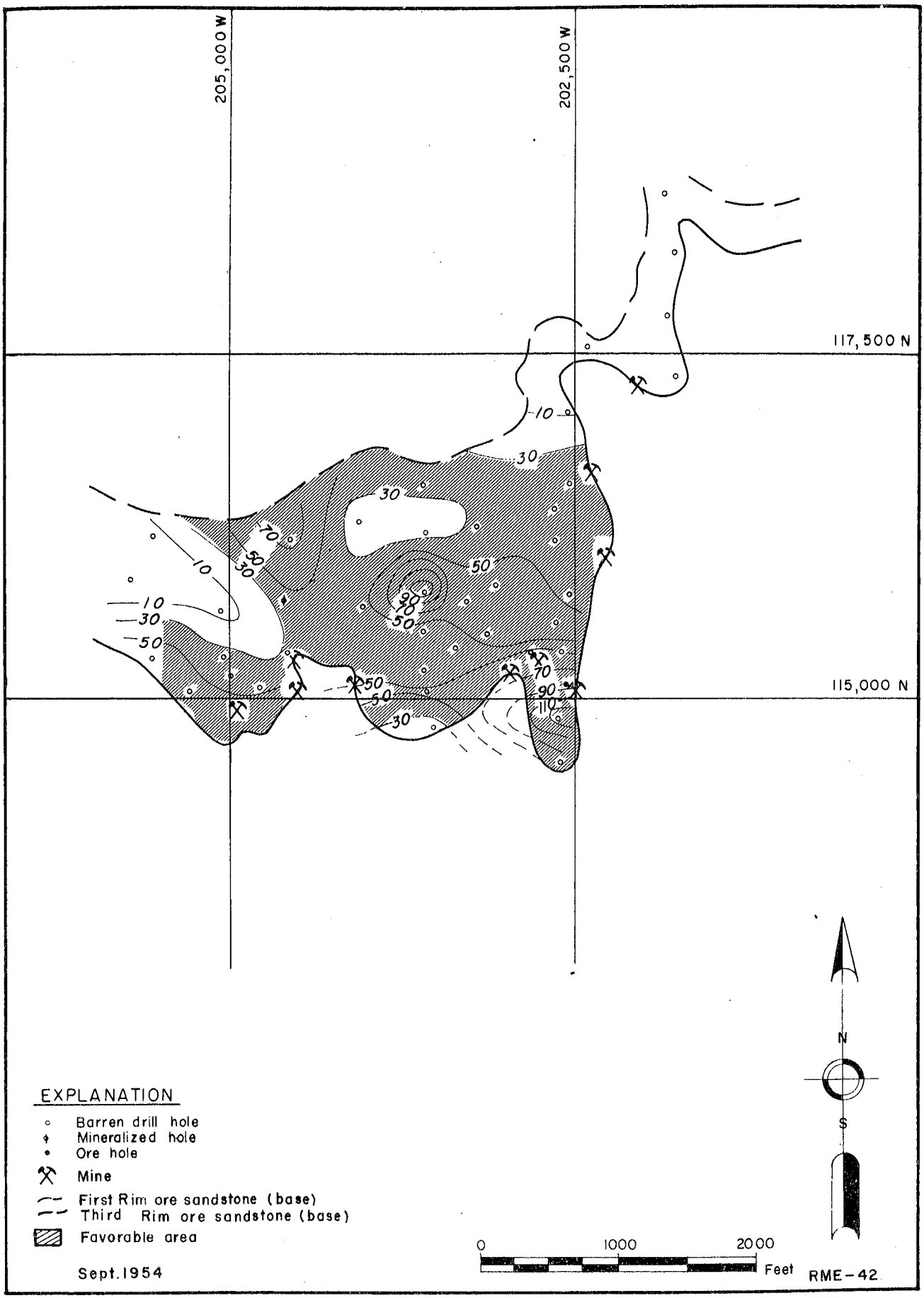

Figure 19. Composite favoribility map, area "C", Bull Canyon district, Montrose County, Colorado

of the First Rim sandstone is unreliable. Therefore, as only the lower contact against mudstone is well defined, a unit of constant thickness (40 feet) which includes the ore horizon was chosen as the stratigraphic interval from which data were collected for preparation of subsurface maps.

Subsurface maps were prepared to show: feet of limonitic sandstone (fig. 23); amount of carbon, expressed by arbitrary numerical values (fig. 22); mudstone-sandstone ratio (fig. 24); and background radiometric (isorad) valves (fig. 25). Because of the low values on the background isorad map, the lack of mineralization in the cores, and the poor results of previous wagon drilling in the area, only a few holes were drilled through the First Rim sandstone during the Commission drilling program.

While the main ore zone is unproductive in area "D", some ore has been produced from the Second Rim sandstone. Six holes were drilled through this horizon behind the Big Bull mine (fig. 21) and of these, two are in ore. While the sand in this zone is more silty than normal, the ore guides and nature of the orebody are similar to those found in the First Rim sandstone in area "A".

A line of shallow development holes was drilled close to the rim through the Third Rim sandstone in area "D" in conjunction with the Camel and Broomstock discoveries. The area in the vicinity of the Camel discovery is considered unfavorable because of the lack of limonite and carbon in the sand. One of the holes behind the Broomstock discovery is mineralized. As the size of the area drilled in the Third Rim sandstone is small, no reliable information concerning the favorability of that horizon in this area is available.

STARLIGHT AREA [a/]

Introduction

The Starlight drilling area (figs. 2 and 26) is a relatively level bench eroded from the thick mudstone section that immediately overlies the First Rim ore sandstone. The drilling area is bounded on the south and west by Bull Canyon, on the north by the rugged slope of the Third Rim ore sandstone, and on the east by area "C".

Plan of Drilling

The initial grid consists of four lines of holes at 1,000-foot intervals, with the holes spaced at 500-foot centers within the lines. Three of the lines are oriented normal to the N. 55° E. sedimentary trend. The grid was filled out to 250-foot centers immediately northwest of the Starlight No. 8 mine (fig. 26).

Upon completion of first stage drilling, a number of areas were found to be sufficiently favorable to warrant further drilling. In several of these, second stage drilling was begun. In the favorable areas northwest of the Starlight No. 8 mine, the 250-foot grid was extended to the northwest while a 125-foot grid was started in the favorable part of the drilling area previously

a/ By J. V. A. Sharp

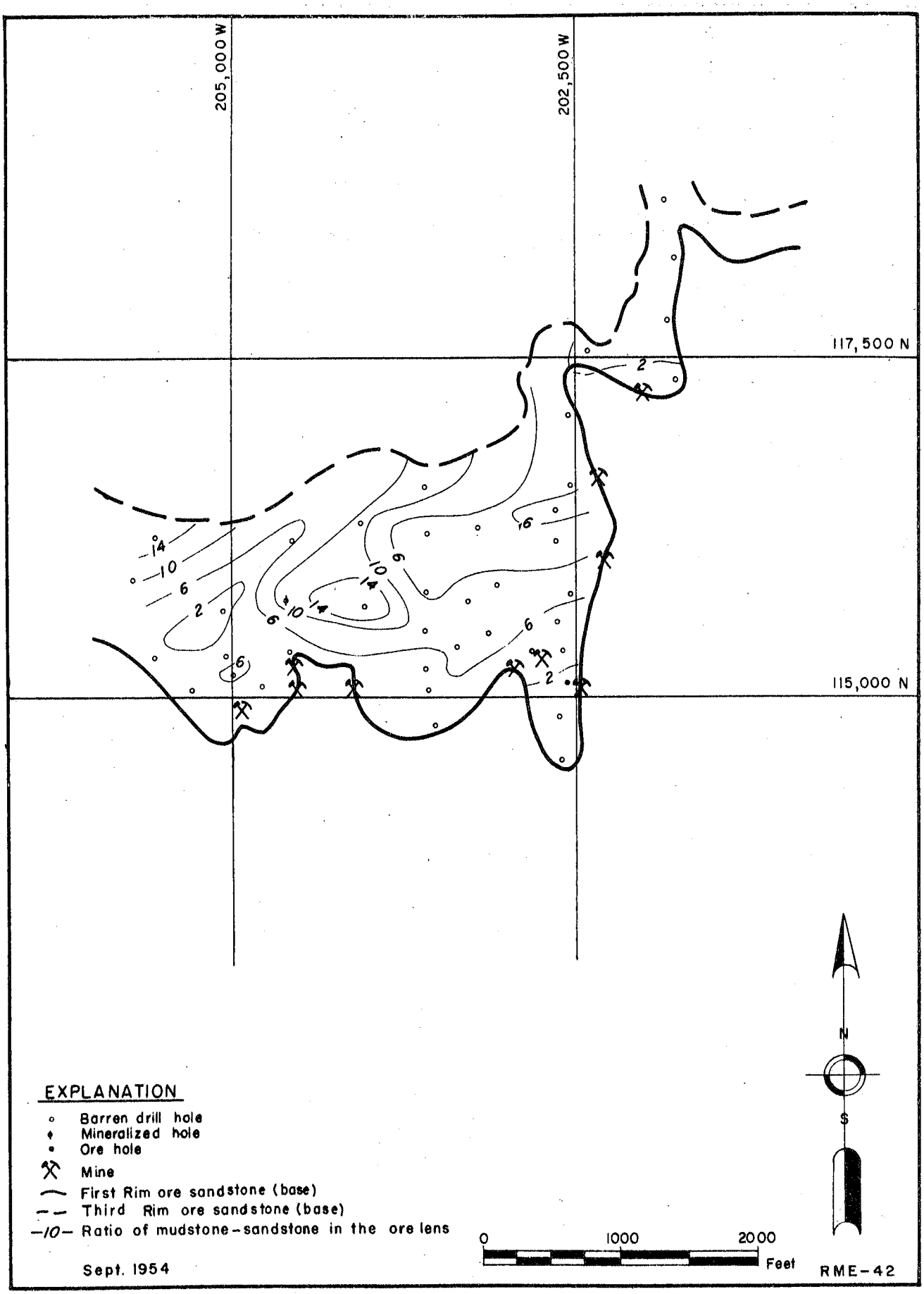

Figure 20. Mudstone/sandstone map, area "C", Bull Canyon district, Montrose County, Colorado

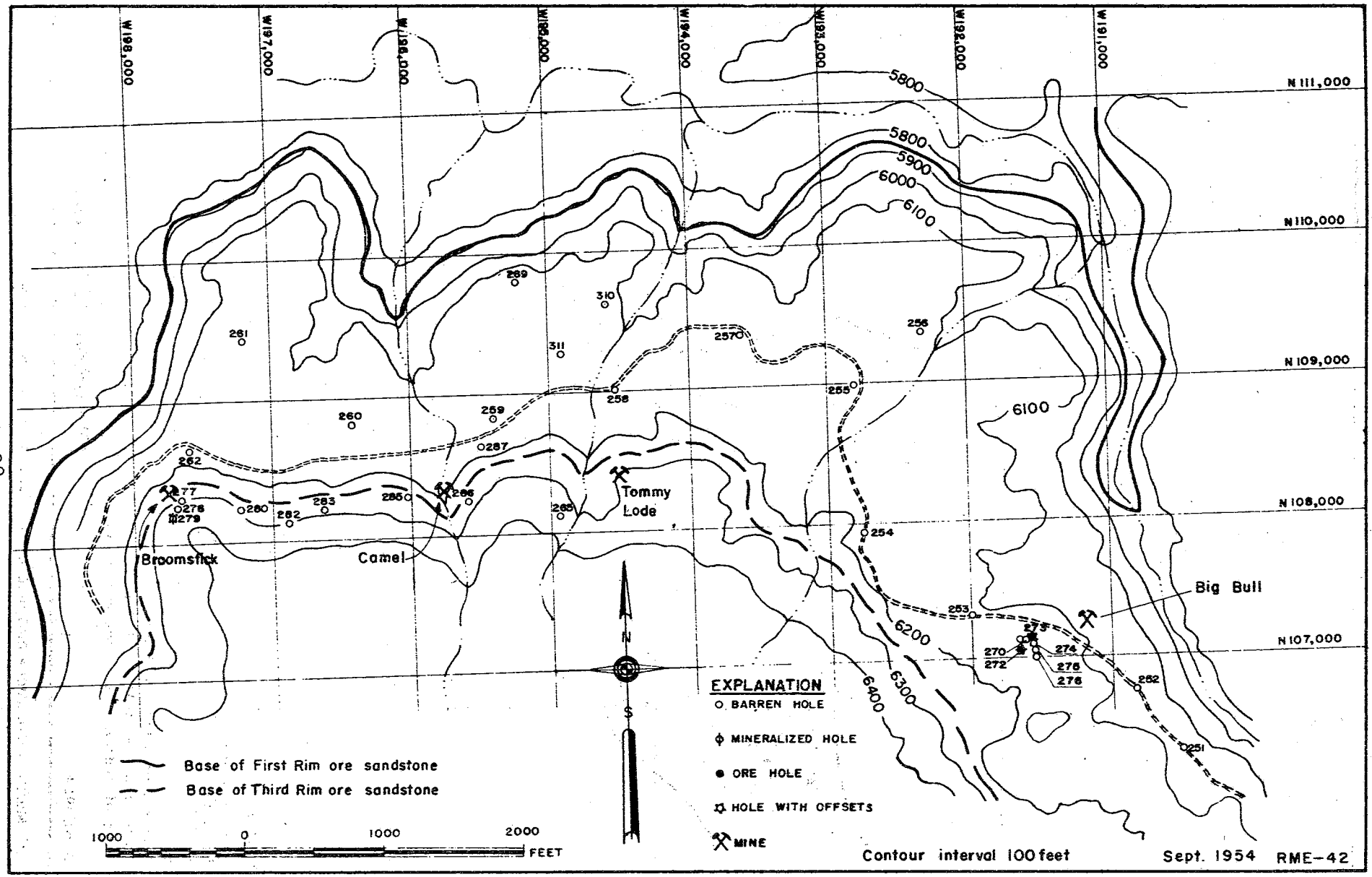

Figure 21. Area "D" base map, Bull Canyon district, Montrose County, Colorado

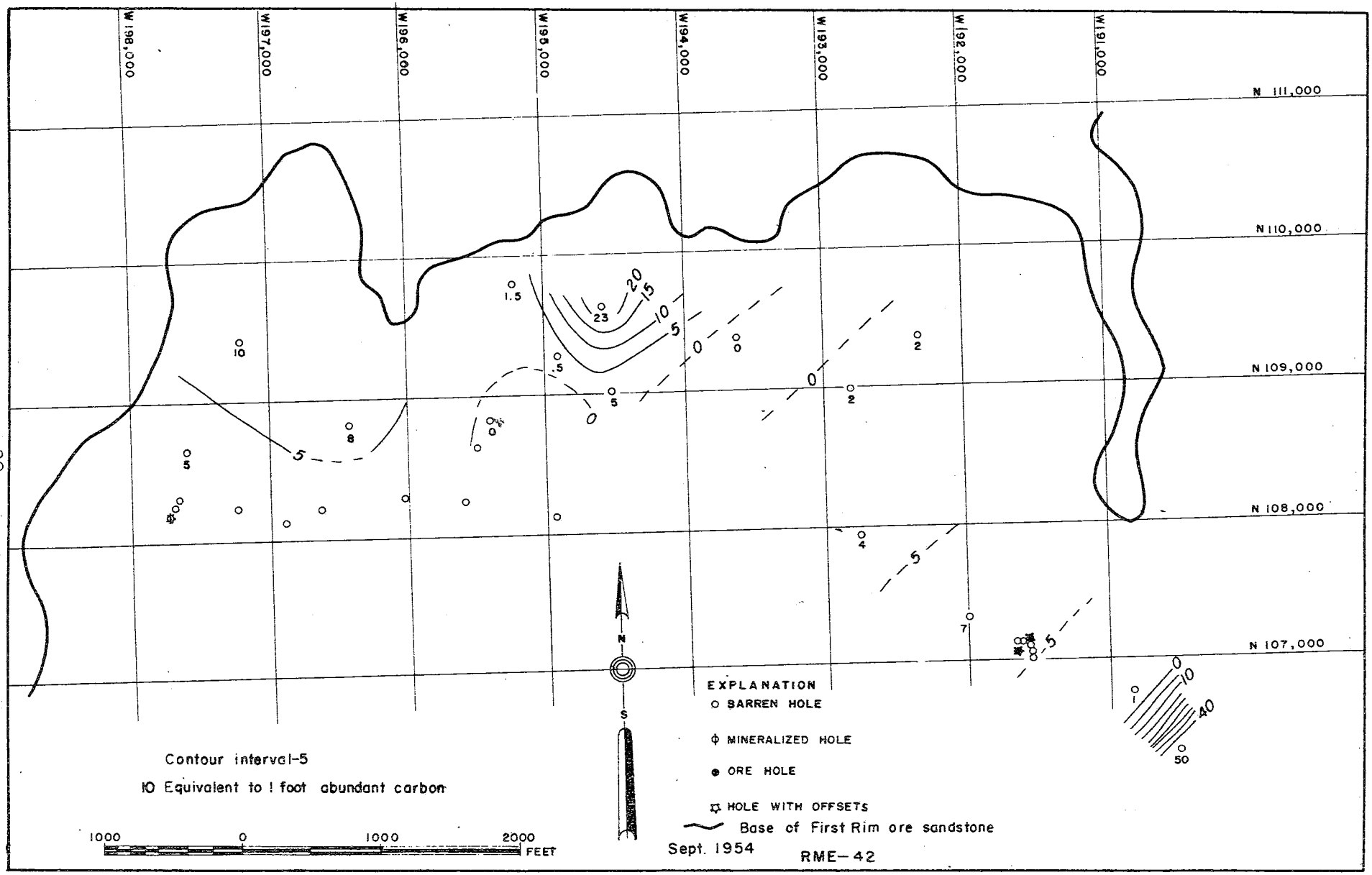

Figure 22. Quantitative carbon, First Rim, area "D", Bull Canyon, Montrose County, Colorado

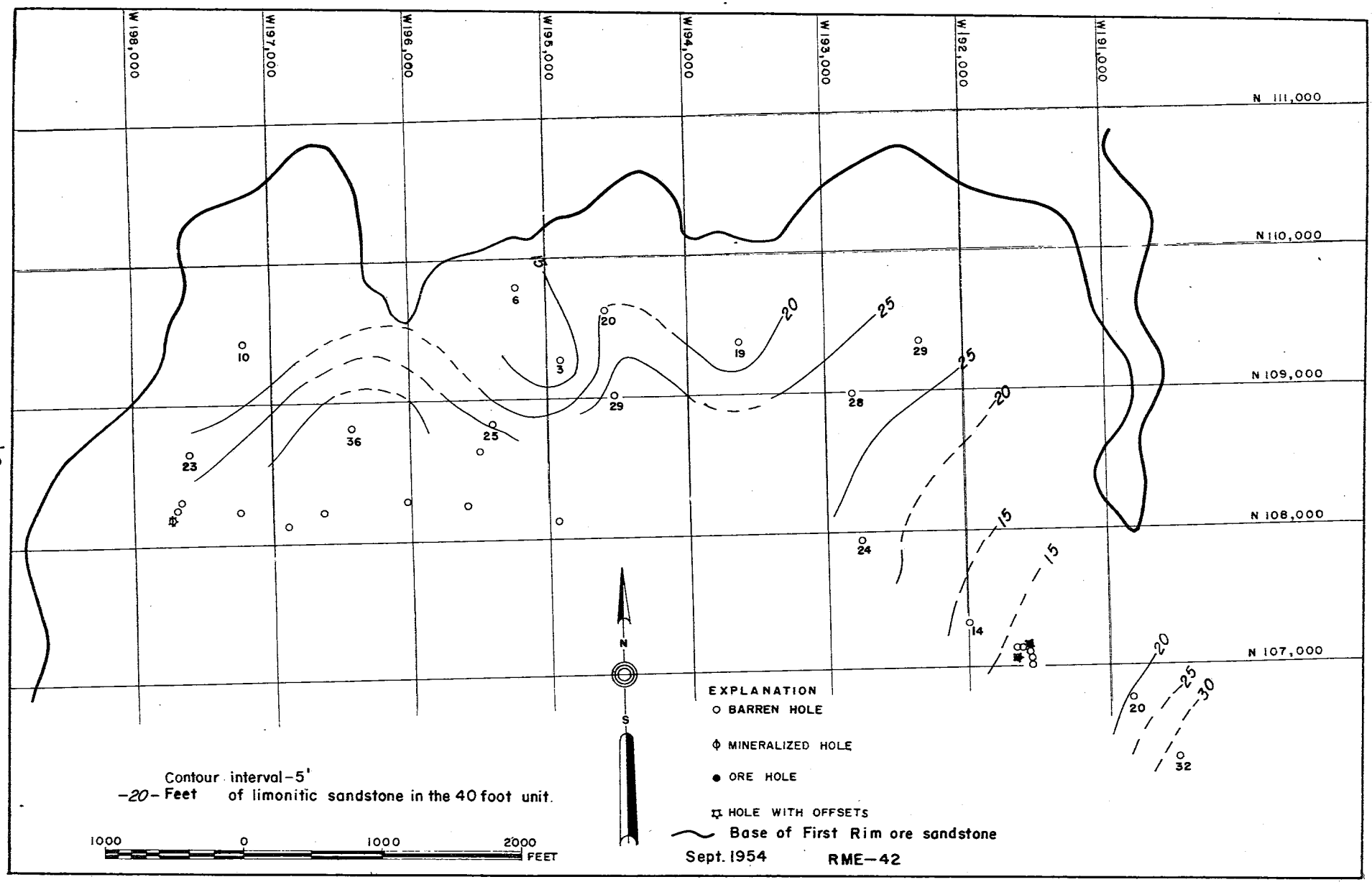

Figure 23. Feet of limonitic sandstone, First Rim, area "D", Bull Canyon, Montrose County, Colorado

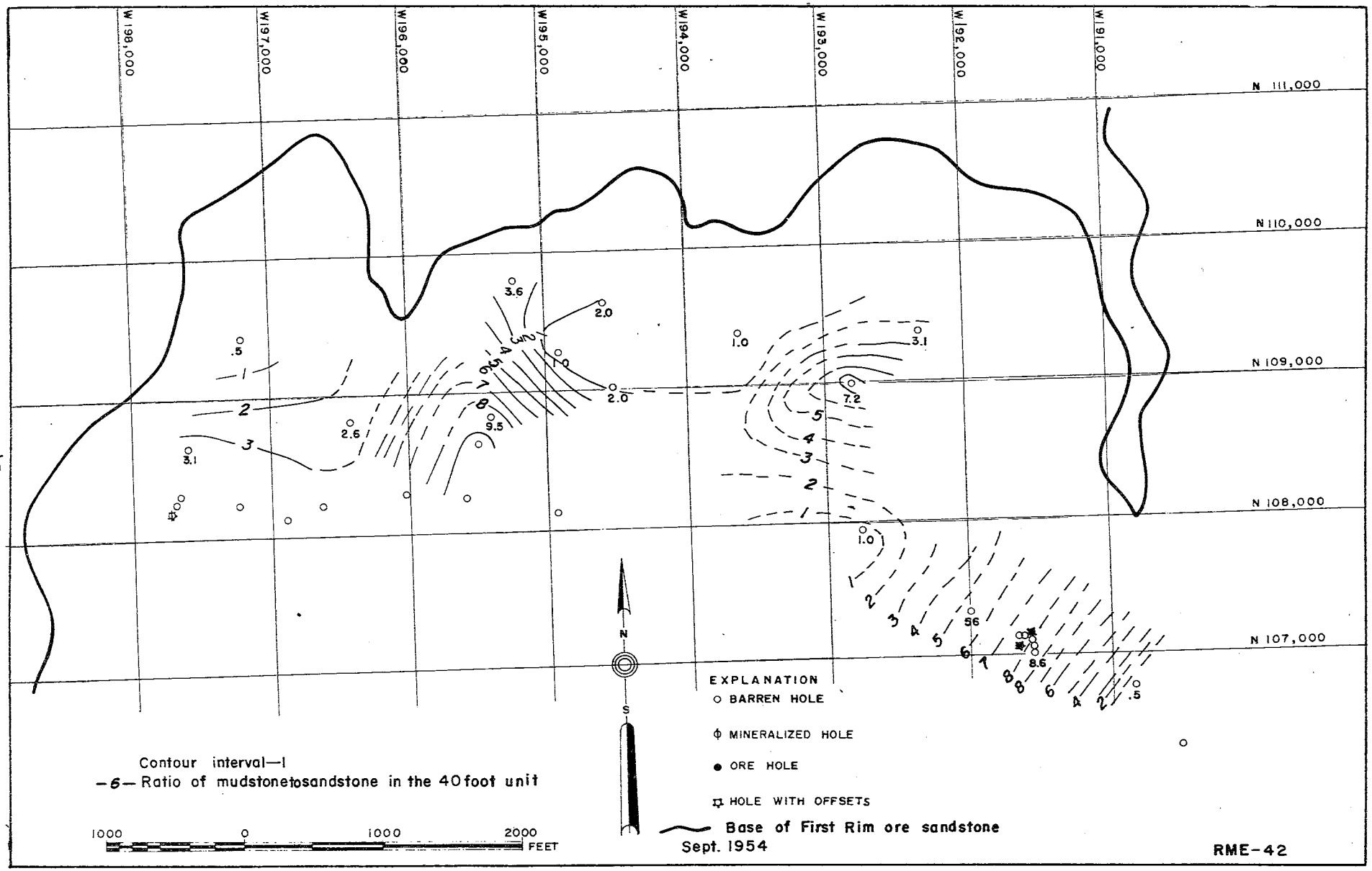

Figure 24. Mudstone/sandstone map, First Rim, area "D", Bull Canyon, Montrose County, Colorado

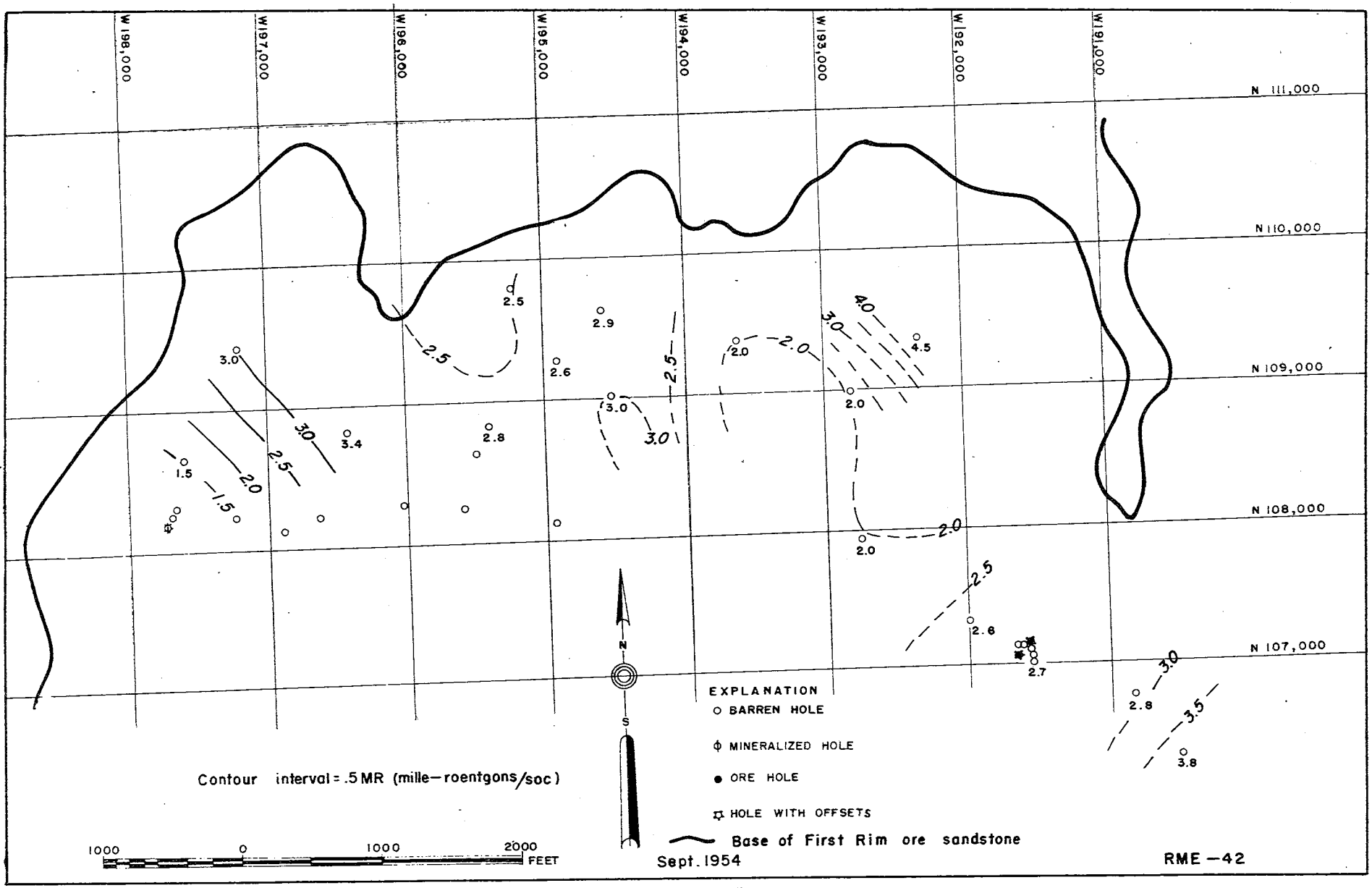

Figure 25. Background isorad map, First Rim, area "D", Bull Canyon, Montrose County, Colorado

drilled on 250-foot centers. Several holes on 250-foot centers were placed around hole BC-880 in the southwestern part of the drilling area. Two shallow development holes were drilled behind the Starlight No. 7 mine along the sedimentary trend.

When stage two drilling was partially completed, it was decided to discontinue diamond drilling and to obtain further subsurface data with rented wagon drills to determine the feasibility of future large-scale wagon drilling. The 125-foot grid was finished by the wagon drill. Results show that drilling can be satisfactorily accomplished by this method in the Starlight area.

The owner of claims in the Starlight drilling area has completed some wagon drilling and Porta drilling near the Starlight No. 8 mine, the mineralized outcrop near BC-879, and around ore hole BC-752 where considerable ore was blocked out.

Geology of the Deposits

Rim information, including primary sedimentary trends and mineralization, was mapped before drilling began. Extensive mineralization was noted on the eastern edge of the drilling area in the vicinity of the Starlight No. 7 and No. 8 mines. Several smaller mineralized outcrops are also present: one on the southwestern edge of the drilling area; two others on the western edge of the drilling area. A dominant N. 55° E. trend is indicated by the primary sedimentary features cross-bedding and stream flow lineation. Histograms based upon orientation of primary sedimentary structures are in agreement with this figure, although a marked southeast trend is noted in several places (fig. 26). Mineralized logs in the Nadine drift of the Starlight No. 8 mine were oriented normal to the sedimentary trend and arranged en echelon.

In the Starlight area, mineralization, with one exception, occurs in a lens 15 to 45 feet thick which lies immediately above the base of the First Rim ore sandstones. The exception, an unimportant low-grade deposit, occurs in a highly carbonaceous mudstone somewhat higher in the First Rim sandstone.

The deposits exposed on the rim and located by the drill are tabular, highly carbonaceous and often closely associated with a mudstone layer.

Although several drill holes and the Starlight No. 7 mine have disclosed what is known as "blue-black" ore containing uraninite and corvusite, most of the mineralization has been the usual carnotite-vanadium association. Secondary chalcocite associated with carbonaceous matter occurs in the Purple Death drift of the Starlight No. 8 mine.

Subsurface Geology

The ore-bearing sandstone lens was correlated by means of incorporated mudstones and silty sandstones. This lens is usually divided by a discontinuous mudstone and silty sandstone layer into two parts, the lower of

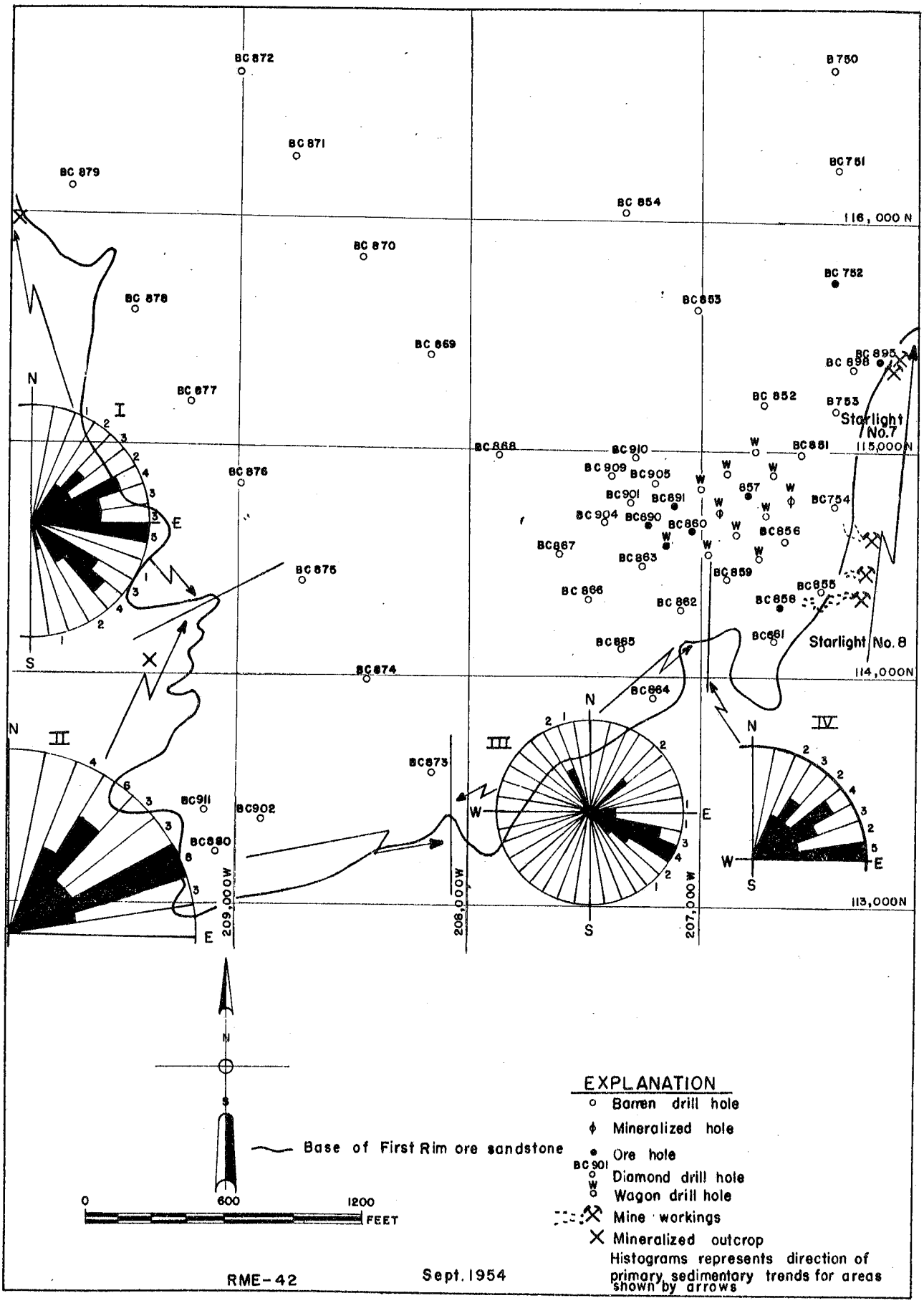

Figure 26. Starlight area base map, Bull Canyon district, Montrose County, Colorado

which is the chief ore horizon. This lens is present to the east in area "C", where it is also ore-bearing.

Correlation of the ore-bearing lens becomes somewhat vague in the northwestern part of the drilling area due to the gradual pinching out of the mudstones and silty sandstones used in correlating the top of the lens. Subsurface maps included in this report were made using data taken from the ore-bearing lens.

In the First Rim ore sandstone of the Bull Canyon district, three ore guides have proved useful in the determination of favorable ground, namely: 1. amount of carbonaceous matter; 2. the amount of non-hematitic rock; and 3. the amount of limonitic sandstone.

In an attempt to express the relative content of carbon in core, arbitrary numerical values were chosen. The results (fig. 27) show relatively large amounts of carbon present in mineralized areas, and relatively small amounts in barren areas.

Figure 28 shows the number of feet of non-hematitic rock, including both sandstone and mudstone, in the ore lens. High numbered contours outline mineralized areas.

Figure 29 shows the number of feet of limonitic sandstone in the ore lens. High numbered contours outline most of the mineralized areas.

By combining the values used on the carbon, limonite, and non-hematitic maps with equal weight on each, an arbitrary composite favorability rating for each hole was derived. These ratings show (fig. 30) high values surrounding mineralized areas and indicate other areas suitable for future drilling.

As radioactivity maps give much the same results as the favorability map, none are reproduced here. The deposition of ore appears to have been localized along lines of paleostream flow which are reflected in the sedimentary trends, making it possible to project mineralization and favorable areas into undrilled ground.

Trends of the sedimentary structures observed on the rim were projected to guide development drilling immediately behind the rim. Drilling along such a trend behind the Starlight No. 7 and No. 8 mines led to the discovery of ore (fig. 26). Sedimentary trends from the various lithofacies maps are used for the same purposes when drilling at a distance from the rim. An isopach map of the ore-bearing sandstone lens (fig. 31) indicates a dominant northeast sedimentation trend with a less important southeast trend. This is in agreement with the orientation of the primary structures on the rim (fig. 26).

Northwest of the Starlight No. 8 mine, two northeast-trending areas of mineralization are parallel to the sedimentation trend and are separated by a northeast-trending barren area in which a conspicuous thinning of the ore sand takes place (fig. 31).

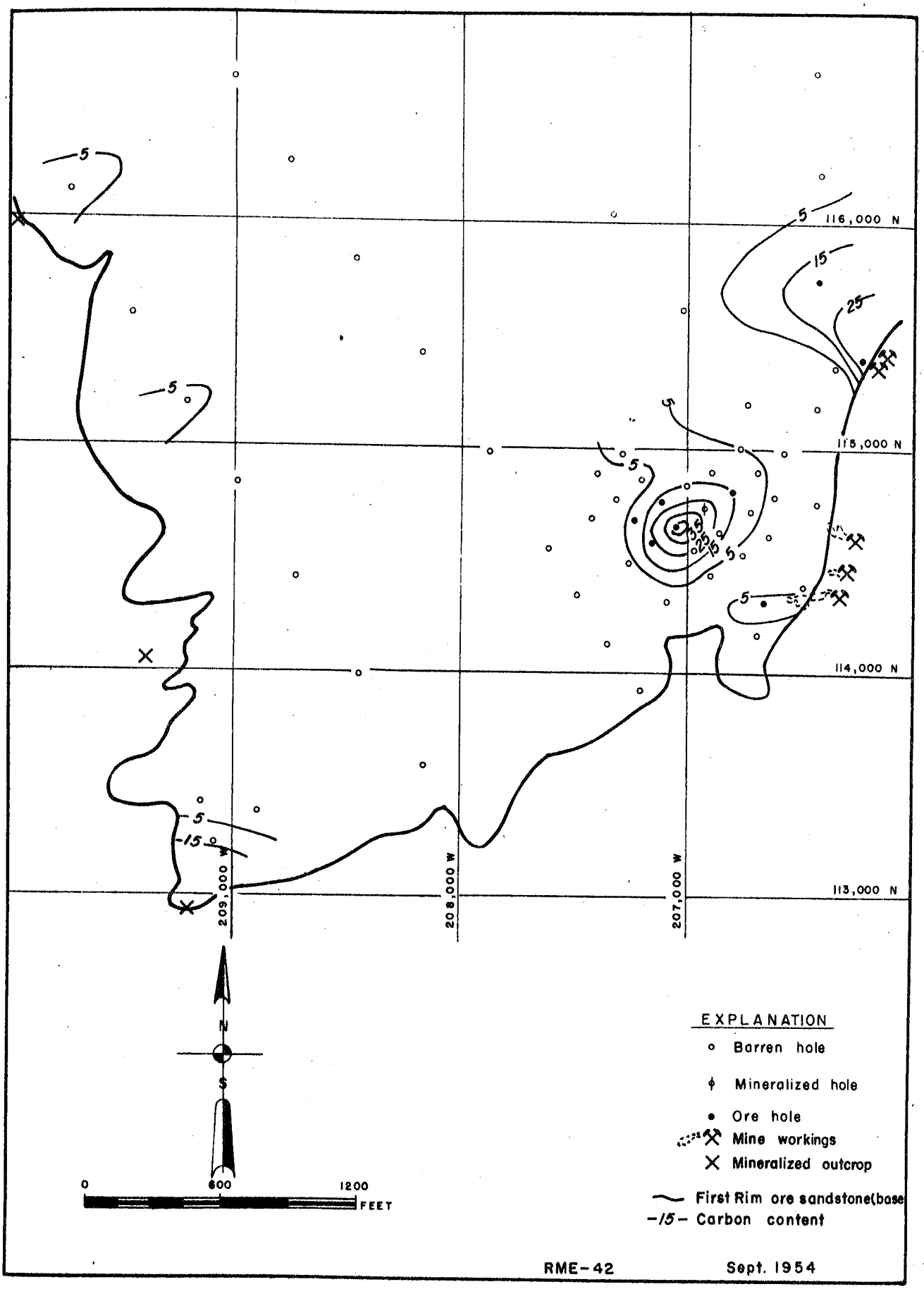

Figure 27. Quantitative carbon, Starlight area, Bull Canyon district, Montrose County, Colorado

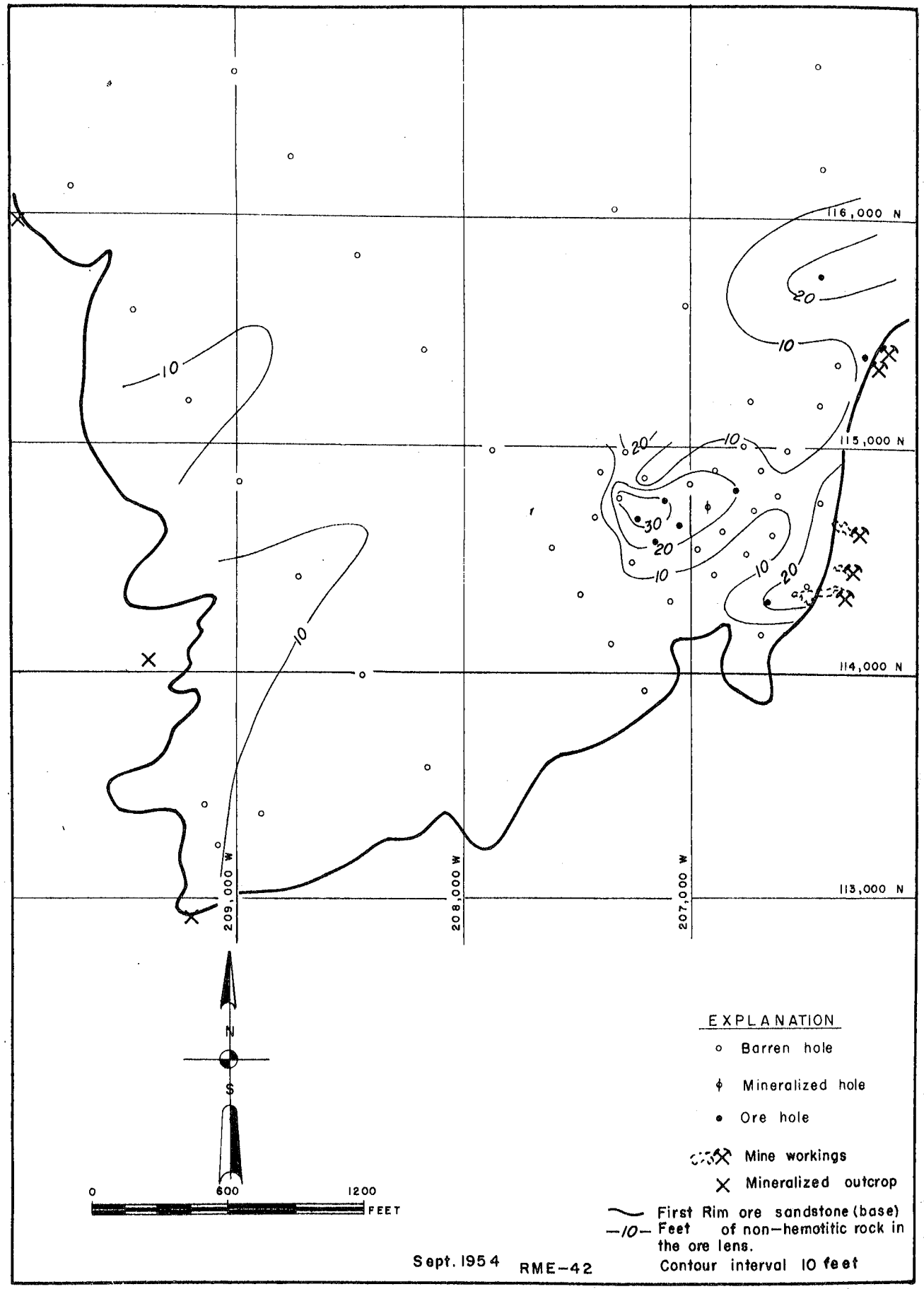

Figure 28. Feet of non-hematitic rock, Starlight area, Bull Canyon district, Montrose County, Colorado

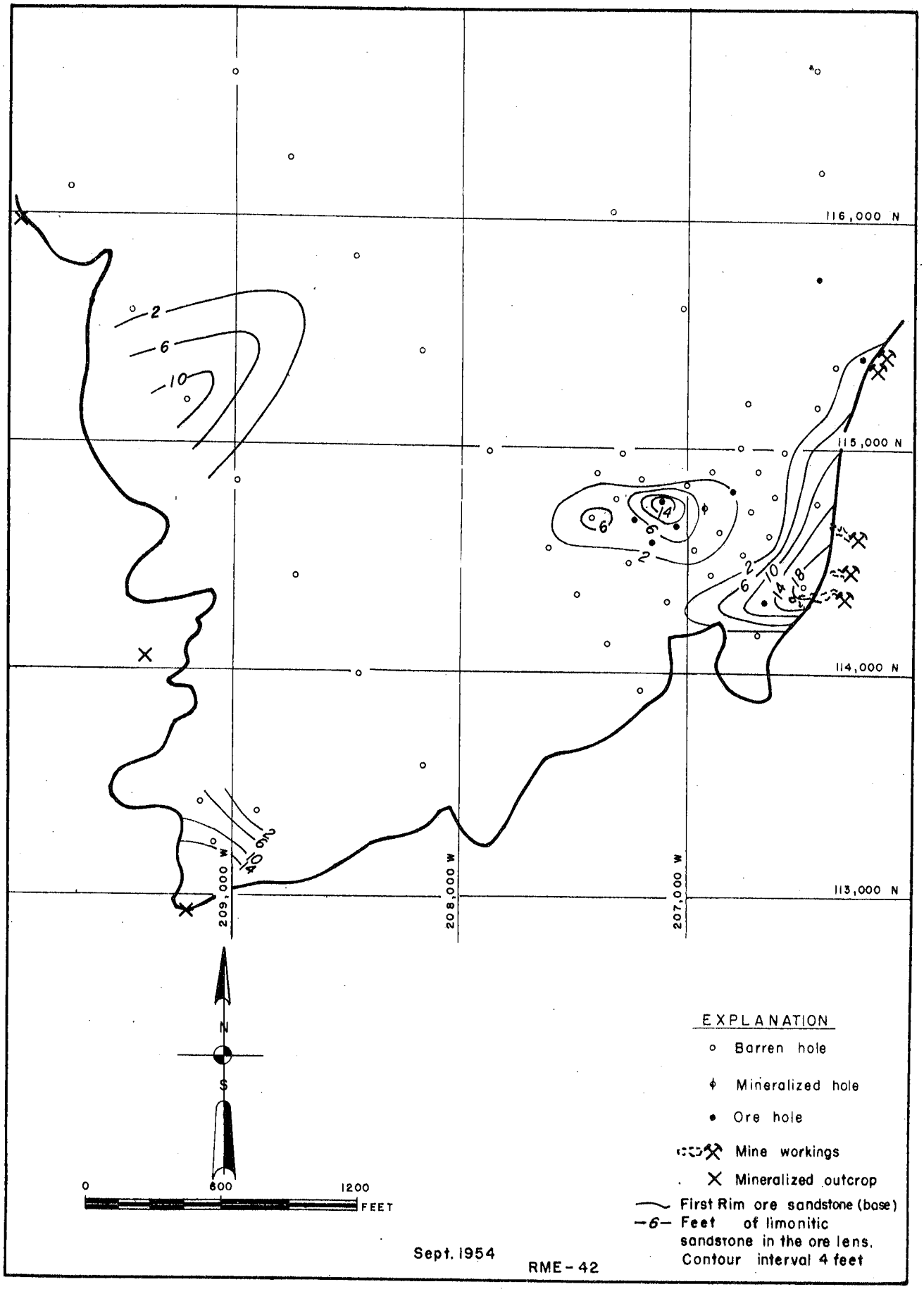

Figure 29. Feet of limonitic sandstone, Starlight area, Bull Canyon district, Montrose County, Colorado

The mineralization found 500 feet northwest of the Starlight No. 8 mine follows a N. 55° E. sedimentation trend. The Purple Death drift of the Starlight No. 8 mine also follows a distinct east-northeast sedimentary trend.

WEDDING BELL AREA a/

Introduction

The Wedding Bell area lies south of Bull Canyon proper, adjacent to Gypsum Valley, on the southwest slope of Wedding Bell Mountain (fig. 2). A profile of steep slopes and narrow benches, typical topographic expression of the Morrison formation, characterizes the drilling area. Deep ravines, reflecting the influence of a joint system, are numerous in the northern part of the area and have limited the drilling there.

Beds strike northwest, paralleling the major structural features of the region. Dips, which range from 4.5° north in the southwest to about 2° in the northeast section, are greater than found elsewhere in Bull Canyon due to the proximity of the nearby Gypsum Valley anticline.

The original drilling program 2/ was designed to cross the trends of the known ore deposits and consisted of a double row of holes on 100-foot centers. Of the 28 planned, twenty-one holes were drilled; of these, four cut ore and eleven were mineralized. Drilling results, together with the favorable character of the rim, prompted extension of the grid to the east. The drill area was limited by irregular terrain, and by depths of the proposed holes, which were considered excessive at that time.

Location and Access

The Wedding Bell area is in southwestern Colorado in T. 45 N., R. 18 W., San Miguel County, near the Montrose County line. The area lies on the southwest slope of Wedding Bell Mountain overlooking Gypsum Valley.

A gravel road, improved by the Commission, connects the area with Colorado Highway 90 in Paradox Valley via Monogram Mesa. The area is 11 miles from Bull Canyon junction on this road, which is passable at all times by truck and pickup, and in dry weather by automobile.

A dirt road, passable in dry weather only, connects the area with Dry Creek Basin.

General Geology

While the Gypsum Valley escarpment exposes sediments of Triassic and Jurassic age, only the Jurassic Morrison and Cretaceous Burro Canyon formations crop out in the drilling area. A previous study of the geology was made by J. F. Emerson 3/ and by Blum and Mathewson 2/.

a/ By C. D. Thompson

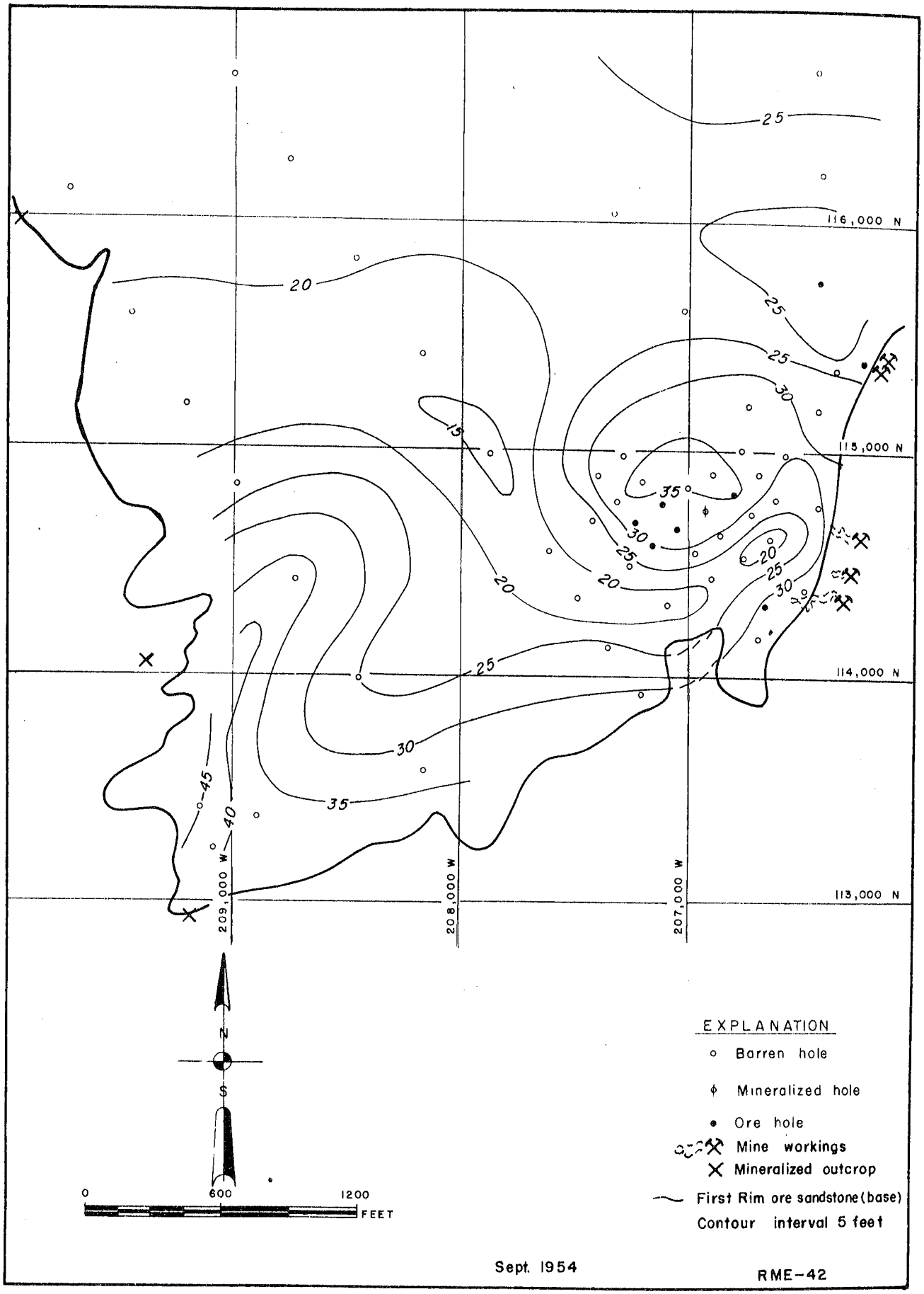

Figure 31. Isopach map of the ore-bearing sandstone lens, Starlight area, Bull Canyon district, Montrose County, Colorado

Examination of the outcrop of the ore-bearing horizon shows that the ore sandstone thins and becomes pink toward the southeast. Festoon cross-bedding and lineation indicate that the ore sandstone has a southeasterly and easterly trend. Ore roll trends are generally easterly.

Approximately 20 feet above the Third Rim ore sandstone is a minor ore sandstone lens locally called the "Jack Knife" horizon. It is a light red, fine-grained, well-sorted sandstone, and contains a large amount of iron oxide which gives the rock a mottled appearance. The unit is less than 25 feet thick and is unfavorable over most of the Wedding Bell area. However, in the south and southwestern section, two mines, the Jack Knife and the Gopher, have been developed in this zone. Present drilling has discovered ore near the Jack Knife deposit. The controlling features of the ore are the same as in the Third Rim sandstone and will not be repeated.

No faulting or subordinate fold structures were observed within the drilling area. Major joints form a conjugate system striking northeast and northwest.

Ore Deposits

The orebodies in the Wedding Bell area are representative of the carnotite-vanadium type of uranium deposits. They vary in size from partially mineralized logs to large tabular deposits containing several thousand tons. Ore rolls are common.

The main ore production comes from the Third Rim sandstone, which is about 230 feet above the base of the Salt Wash and from 25 to 43 feet thick in the drilling area. The typical ore host rock is a fine-grained, limonitic sandstone which is generally more than 30 feet thick in the vicinity of the ore and contains significant quantities of carbonaceous material.

Geological criteria which proved to be most effective in delineating favorable ground in the Wedding Bell drilling area were presence or absence of green mudstone at the base of and within the ore sandstone, relative abundance of carbon and limonite within the sandstone, and thickness of the enclosing lithologic unit.

Work by the U. S. Geological Survey 4/ in Salt Wash ore deposits of the Uravan Mineral Belt indicates that a thick sandstone is necessary for the development of large orebodies. In the Wedding Bell area, the larger ore deposits occur where sandstone thickness exceeds 30 feet (fig. 33). While ore is present in sandstones of lesser thickness, the deposits now known are small.

Limonite is a common accessory mineral in the mineralized zones of the Salt Wash sandstones and occurs both as a mineral coating on quartz and chert sand grains and as individual masses where associated with carbon.

As all phases of alteration of pyrite to limonite have been observed within the Salt Wash sandstones, most of the limonite probably results from oxidation of disseminated pyrite.

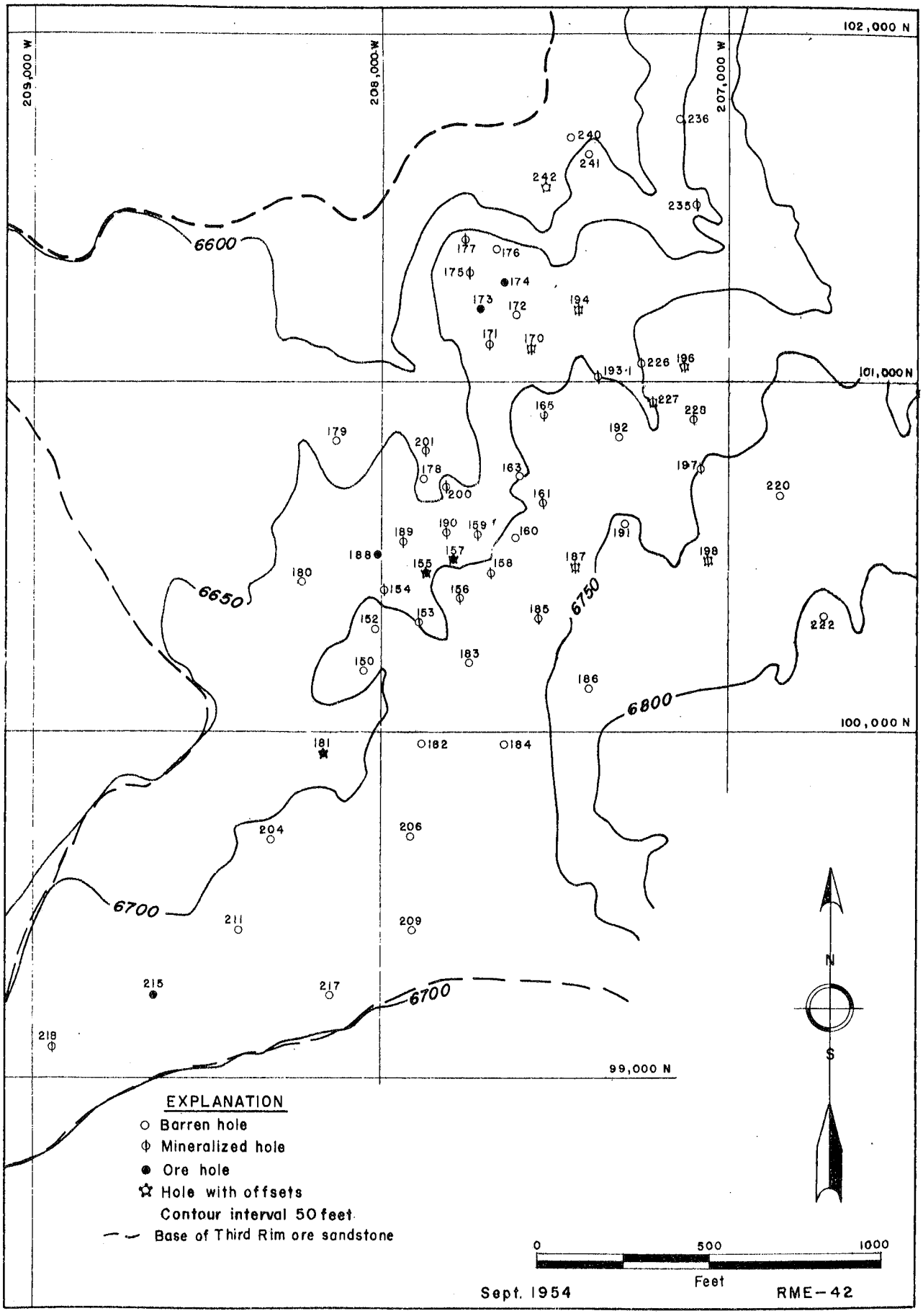

Figure 32. Wedding Bell area base map, Bull Canyon district, San Miguel County, Colorado

The genetic relationship between the occurrence of limonite and uranium is not known, although a positive spatial relationship exists between the two (fig. 34).

A subsurface map showing, by arbitrary numerical units, the relative abundance of carbon in the sandstone in the Wedding Bell area (fig. 35) agrees very well with the favorable areas indicated by other criteria.

Green mudstone and siltstone are, in nearly all cases, found associated with uranium mineralization on the Colorado Plateau. This was found to be true in the Wedding Bell area, and the presence of green mudstone was helpful in delineating favorable ground.

A background isorad map (fig. 36) was constructed and found to be reliable in delineating favorable areas.

HORSEHAIR AREA a/

Introduction

The Horsehair area (fig. 2) is located on a flat, narrow bench about 1,000 feet long and 300 feet wide formed on top of the First Rim sandstone unit.

The surface geology was mapped in detail by J. E. Morgan 5/ whose observations indicated an abrupt change in paleostream flow and the probable existence of a sedimentary trap favorable to mineralization behind the rim. Some representative sedimentary trends are shown in figure 38.

Some mineralization occurs along the outcrop and there has been intermittent mining activity in the area since the early 1920's.

Subsurface Geology

Mineralization in the Horsehair area occurs 40 to 55 feet above the base of the Salt Wash member of the Morrison formation in the First Rim sandstone, which is very lenticular in this area. The base of this unit is well defined by a persistent mudstone bed. The top of the unit in the drill holes is indicated without difficulty by a thin green mudstone seam which produces a slight radioactive anomaly.

Although the low density of drill holes in a north-south direction makes subsurface maps unreliable, four were constructed; namely, isoradiometric, mudstone-sandstone ratio, number of feet red-colored rock, and number of feet limonitic sandstone. From these four maps, a composite favorability map was made (fig. 38).

FAWN SPRINGS BENCH AREA a/

Introduction

Fawn Springs Bench, a Third Rim sandstone drilling area, comprises about three square miles of relatively level, gently undulating land

a/ By R. G. Blair

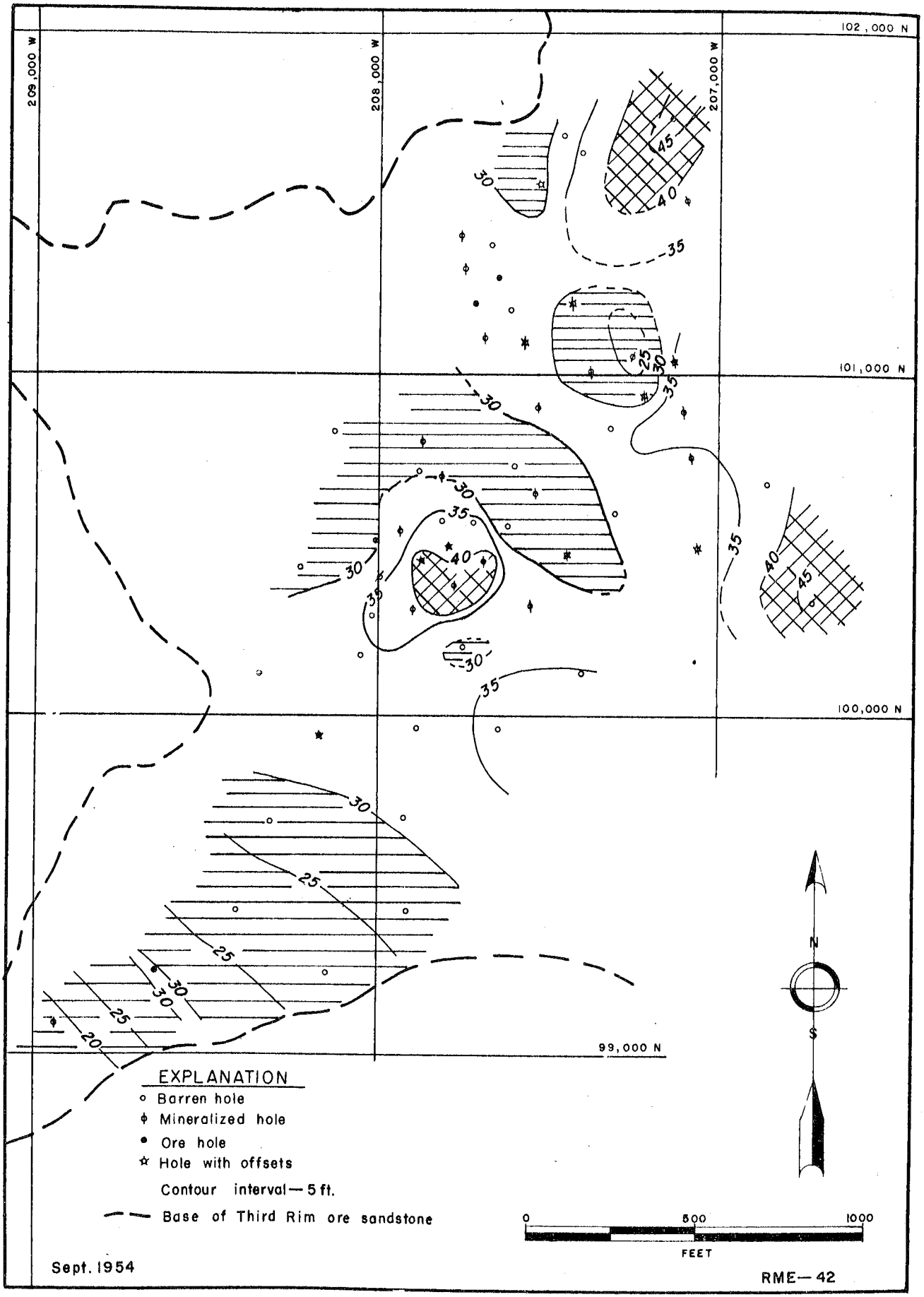

Figure 33. Sandstone isopach map, Wedding Bell area, Bull Canyon, San Miguel County, Colorado

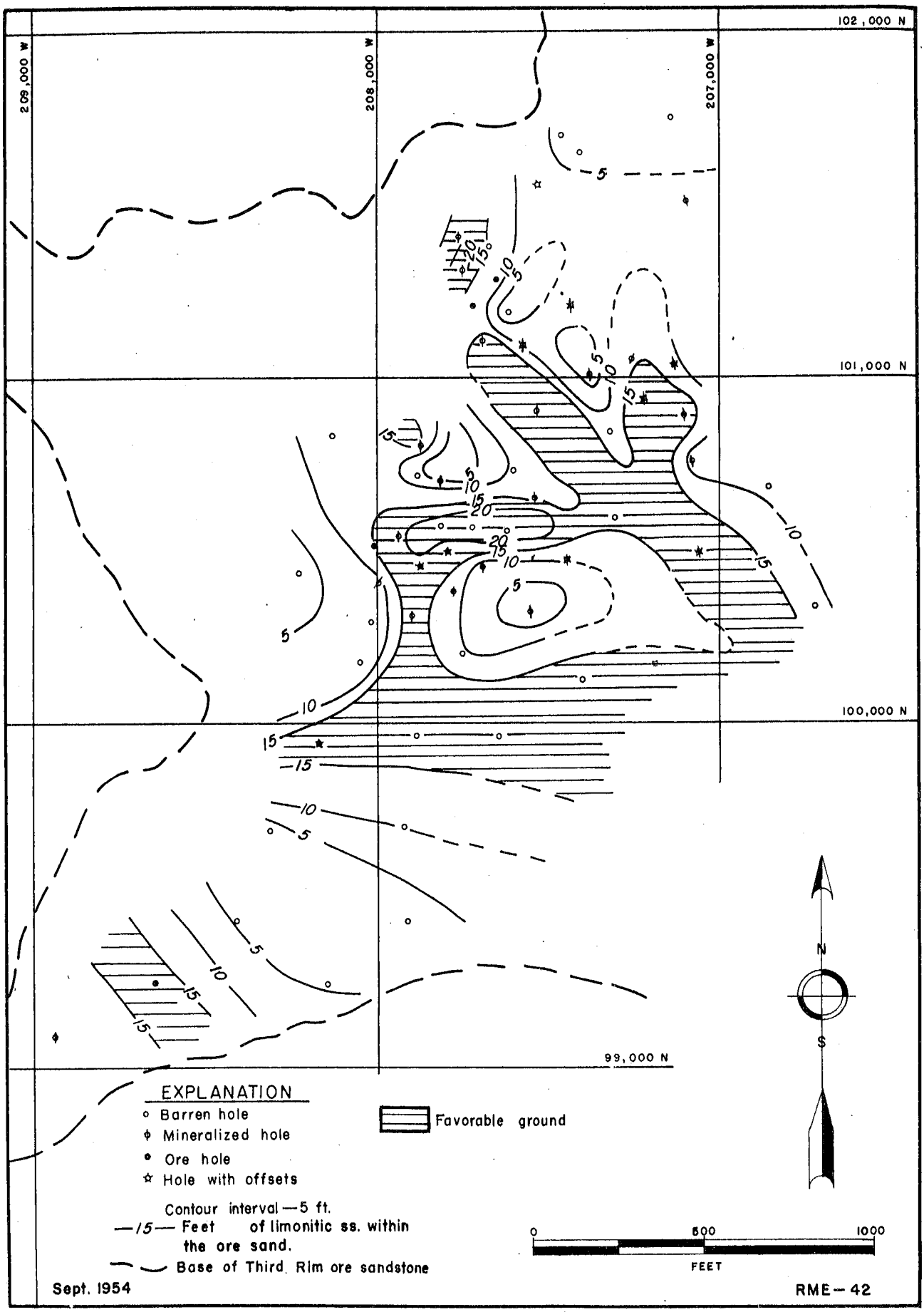

Figure 34. Feet of limonitic sandstone, Wedding Bell area, Bull Canyon, San Miguel County, Colorado

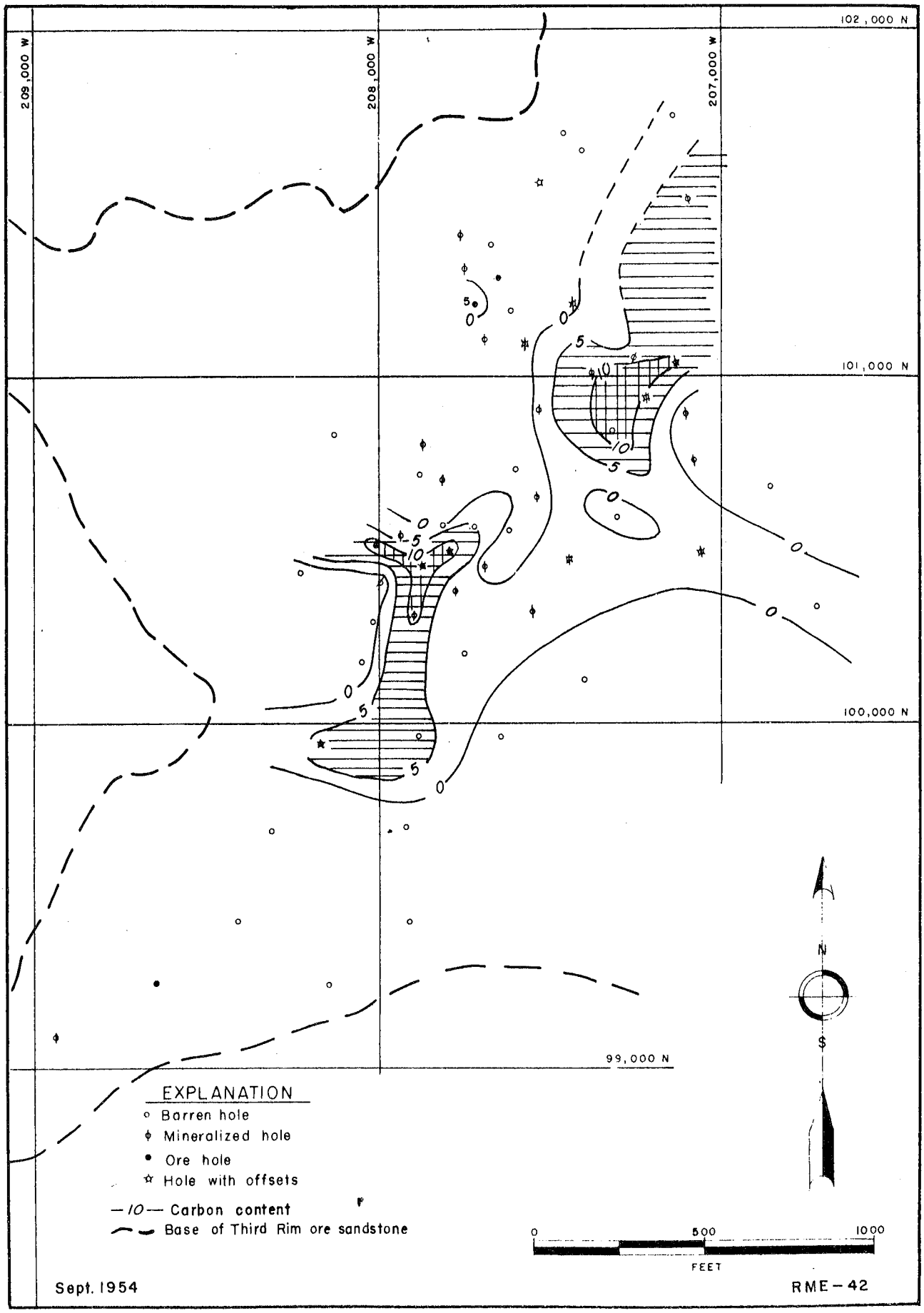

Figure 35. Quantitative carbon map, Wedding Bell area, Bull Canyon, San Miguel County, Colorado

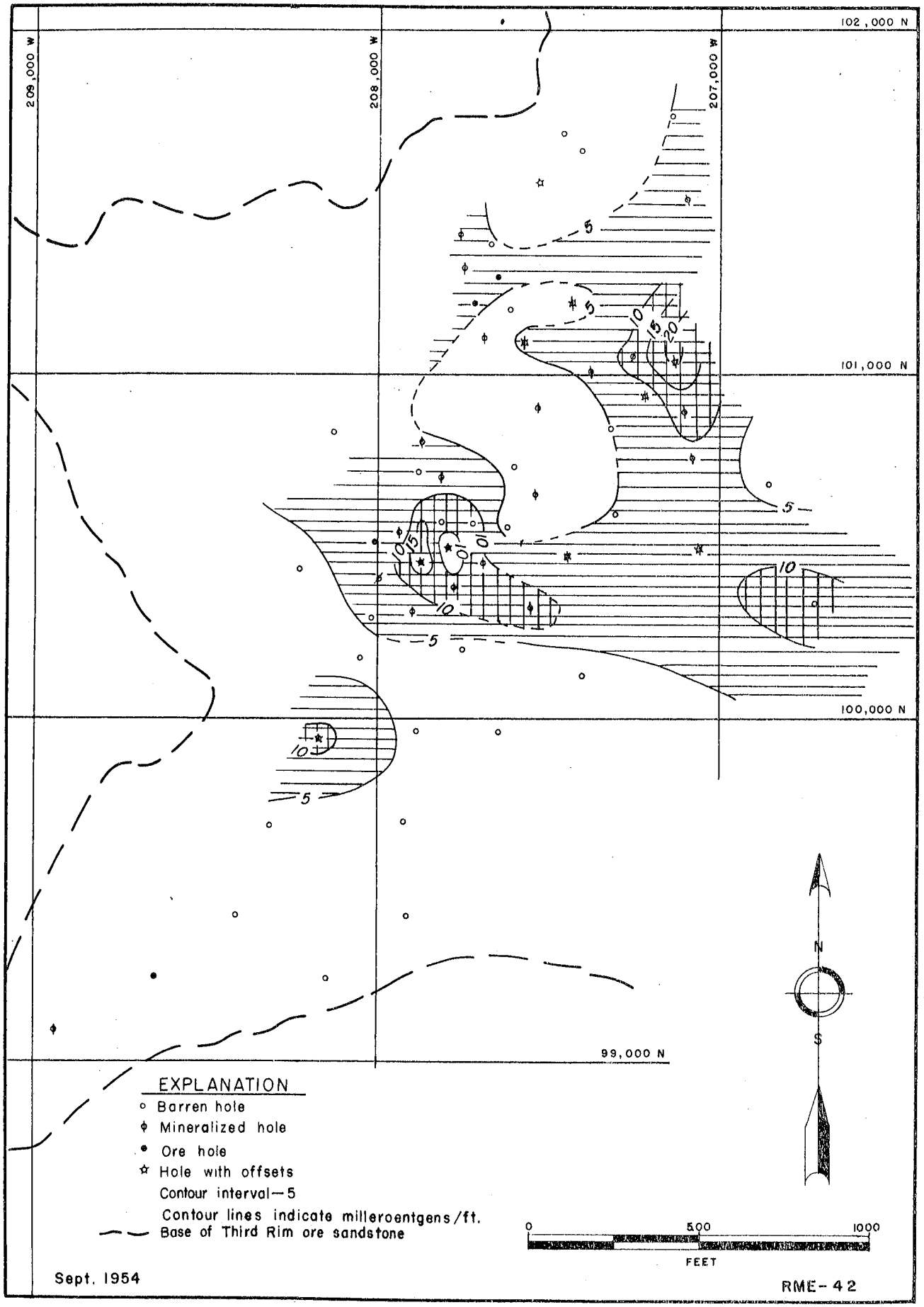

Figure 36. Background isorad map, Wedding Bell area, Bull Canyon, San Miguel County, Colorado

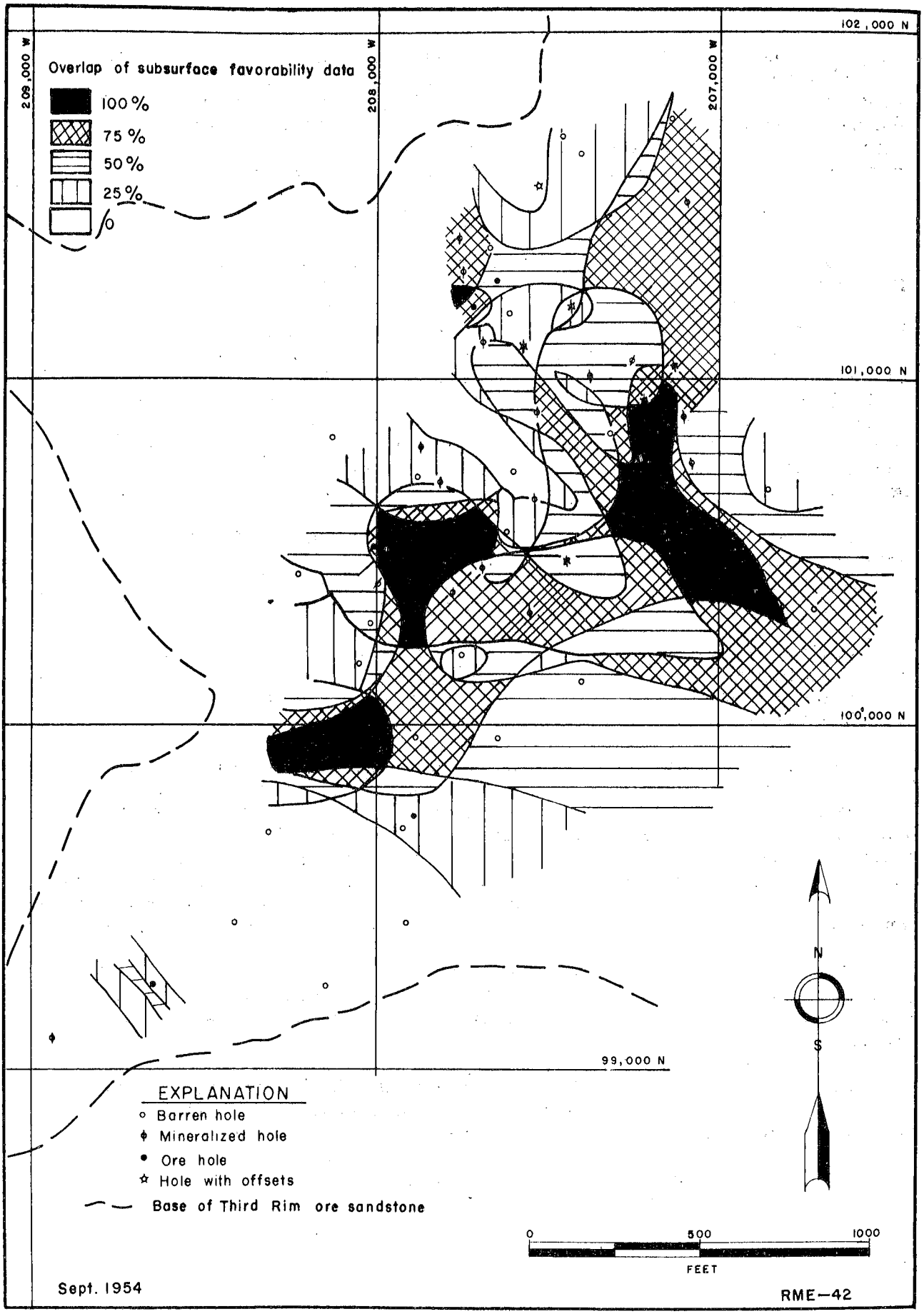

Figure 37. Composite favorability map, Wedding Bell area, Bull Canyon, San Miguel County, Colorado

(figs. 2 and 39). It is bounded on the east, north, and west by the steep Brushy Basin slopes which are capped by the Burro Canyon formation on Monogram Mesa. The southern edges are delimited by deep washes and Bull Canyon proper. The latter starts at Monogram reservoir and bisects the central bench in a southwesterly direction. Where the Third Rim sandstone has been stripped by erosion, the First Rim sandstone forms level benches.

Plan of Drilling

More than 700 wagon and diamond drill holes have been drilled in the Fawn Springs Bench by private concerns. Atomic Energy Commission drilling was directed toward exploration of ground thought to be favorable on the basis of this private drilling, and toward the exploration of undrilled ground. Most of the Commission drilling was concentrated north of the 115,000 N. co-ordinate. Initially, holes were drilled on small-spaced grids (200 feet) behind known orebodies and among wider-spaced private drill holes. A primary grid oriented north and east, and measuring 400 x 800 feet, was then extended into undrilled areas. Favorable sandstones were further explored, and upon completion of the primary grid, offsetting was done.

Fourteen holes were drilled in a southeastern area which had not been previously explored (fig. 40).

Geology of the Deposits

Sedimentary structures along the rim show a general southeast to east sedimentary trend. Sandstone color changes are not very evident, a reflection of the high percentage of favorably colored sandstones in the Fawn Springs Bench area.

The deposits are in lensing sandstones and occur as both tabular bodies and as rolls. The correlated zone ranges from 5 to 83 feet in thickness and ore layers are as thick as 12 feet. Mineralized layers, separated by barren rock, join to form locally thicker layers. An association between thickness of the ore sandstones and the sizes of the orebodies was observed. The larger deposits seem to lie in sandstones which are comparatively thick and which thicken a great deal over short distances. Smaller bodies occur in thinner portions of the sandstone lenses.

Mineralization is the carnotite-vanadium type found mainly as sand grain coatings and fillings in interstices of the sandstones. In places, uranium-vanadium minerals encrust fracture surfaces of both sandstones and mudstones.

Limonite and carbon are closely associated with the deposits. Thinly layered alternating bands of carbon flakes and brown, limonite-stained sandstone form a "zebra-banding" sometimes seen in the mines.

In the eastern part of the area there is a belt of intense mineralization. Within this belt, which trends N. 20° E. to N. 30° E., the

a/ By R. E. Dickson

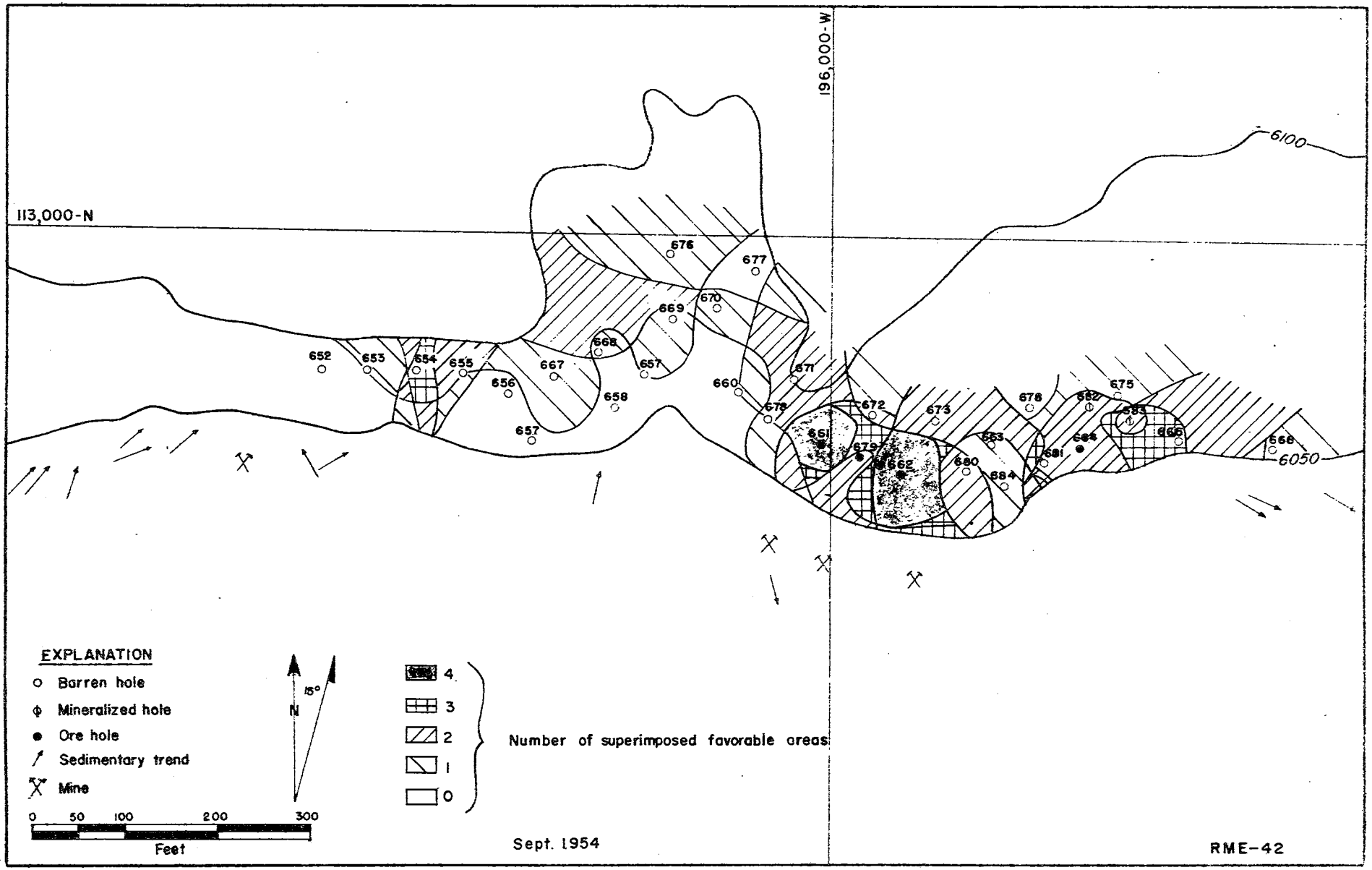

Figure 38. Composite favorability map, Horsehair area, Bull Canyon, Montrose County, Colorado

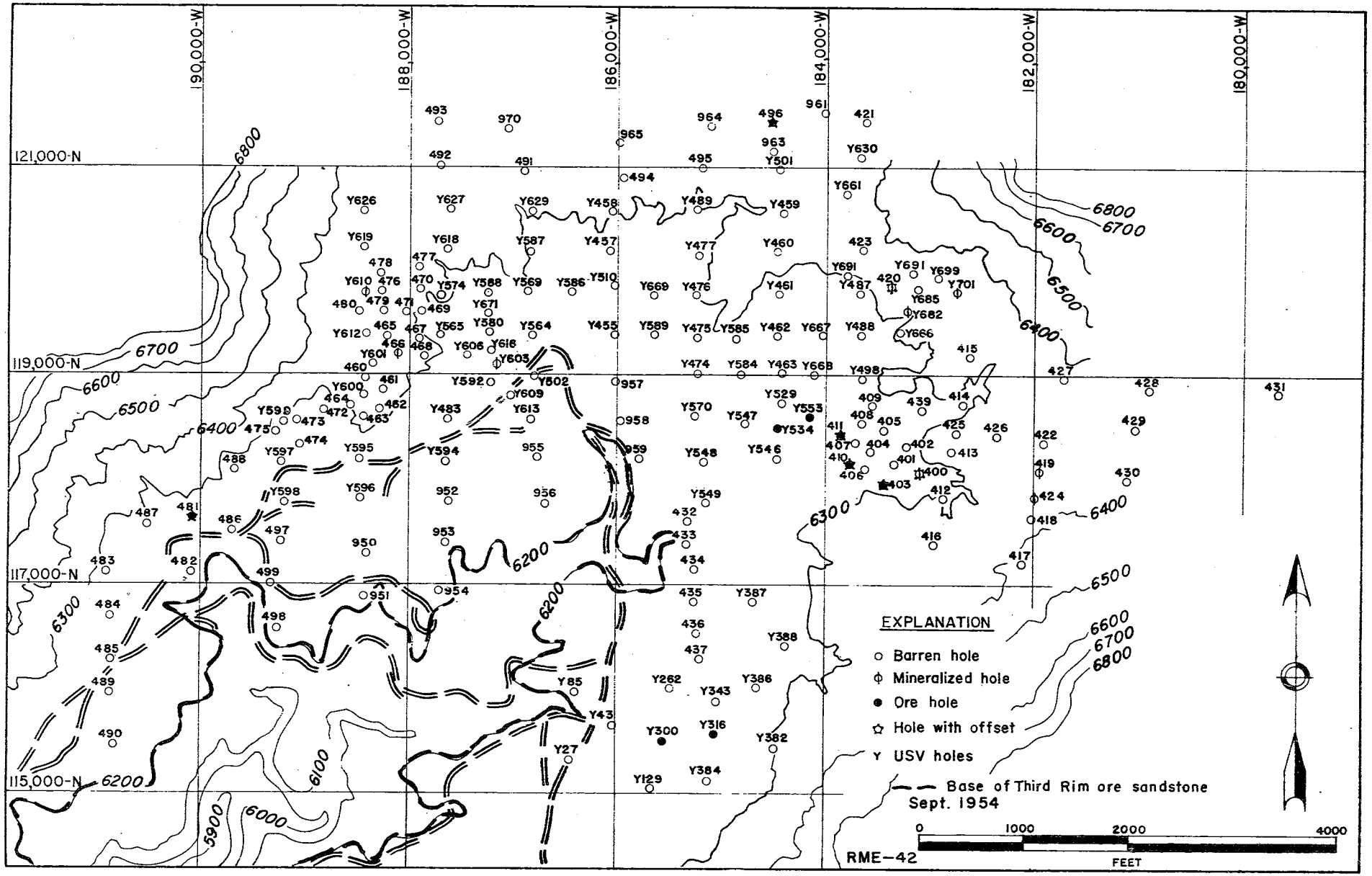

Figure 39. Drilling area of Fawn Springs Bench, Bull Canyon, Montrose County, Colorado

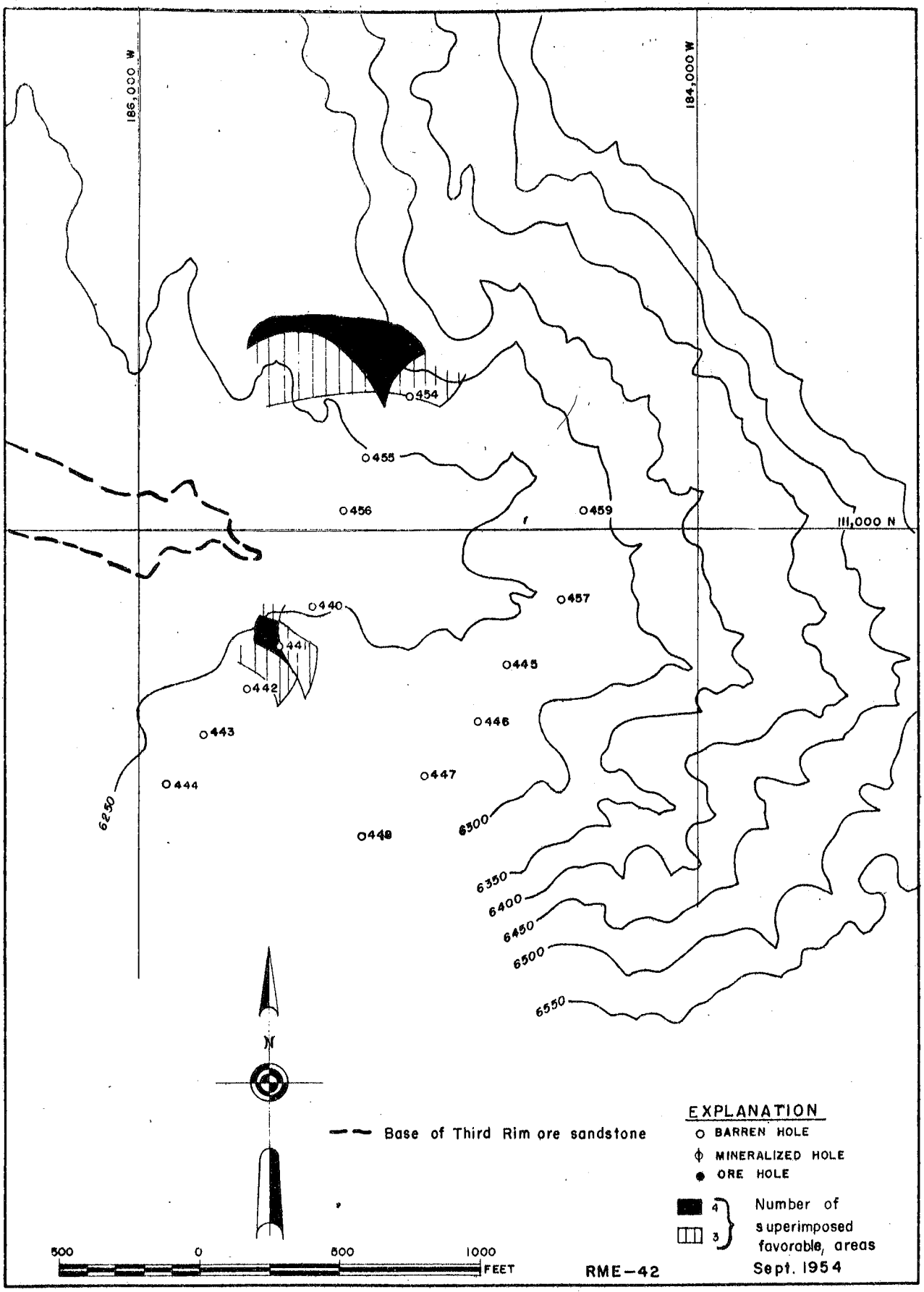

Figure 40. Composite favorability map, Fawn Springs area southeast, Bull Canyon district, Montrose County, Colorado

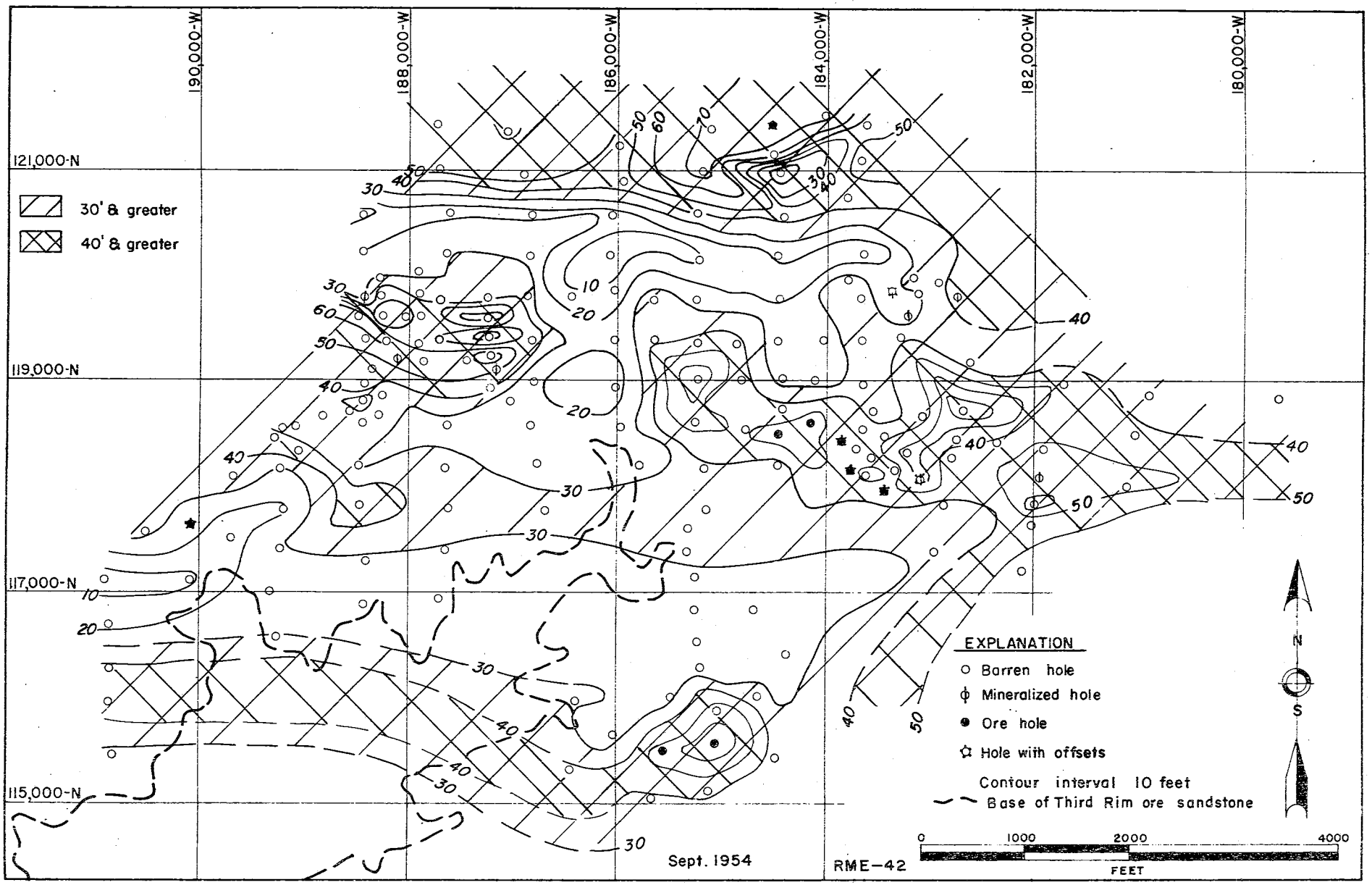

Figure 41. Ore sand thickness, Fawn Springs Bench, Bull Canyon, Montrose County, Colorado

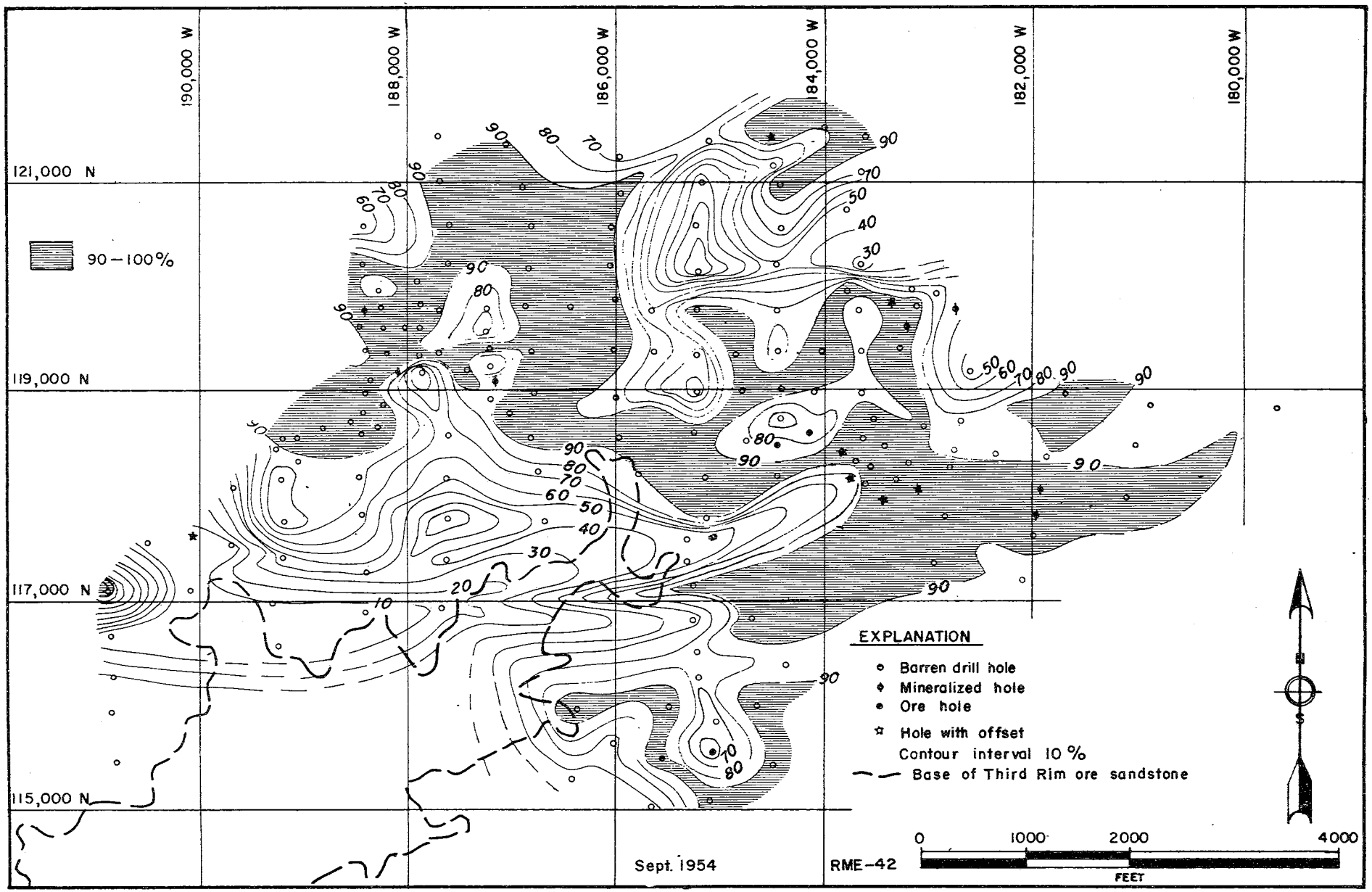

Figure 42. Percent favorably colored sandstone, Fawn Springs Bench, Bull Canyon, Montrose County, Colorado

orebodies are large and numerous, some containing over ten thousand tons of ore. Elsewhere the known deposits are relatively small, comprising only several hundred tons of ore.

Subsurface Geology

Apparently, elongate sandstone lenses lie at various elevations separated by mudstone. The intertonguing of the sandstone and mudstone lenses makes physical correlation difficult. A constant thickness correlation could not be used because the exact dip in this area is unknown. To overcome some of the difficulties encountered in lithologic correlation, fence diagrams were constructed. These diagrams aided in visualizing lithologic variations between drill hole logs, both Commission and private. An attempt was then made to correlate the entire ore sandstone unit and, despite some uncertainties in correlation, it is felt that the completed subsurface maps give some reflection of favorable and unfavorable ground.

Commission drill holes were too widely spaced to permit the construction of usable subsurface maps based on these holes alone; therefore, those maps were made for which data could be abstracted from private drill logs made in the area, namely, an ore sandstone thickness map (fig. 41) and a percent favorably colored sandstone map (fig. 42).

It should be noted that ore hole 481 in the western part of the area (fig. 39) is located 43 feet below the base of the Third Rim sandstone. Consequently, the favorability maps (figs. 41, 42) which are based on Third Rim sandstone geology, do not apply to this lower unit.

BACHELOR DRAW a/

Introduction

The Bachelor Draw drilling area is located on the steep rocky slopes of the Brushy Basin member of the Morrison formation in Bachelor Draw. The drilling area is bounded on the west by the Wedding Bell Mountain; on the north by "A" drilling area, Bachelor Draw, and "D" drilling; on the east and south by Radium Mountain (fig. 2).

Geology

In the southern part of the Wedding Bell drilling area, a favorable eastward trend is present. This trend was traced by diamond drilling to the slope of Wedding Bell Mountain, where it apparently continues in an eastward direction under the mountain.

Reconnaissance of the Third Rim ore sandstone exposures in the northeastern part of Bachelor Draw by J. E. Morgan 2/ has shown that mineralization trends east to northeast.

a/ By J. V. A. Sharp

A test hole drilled by the Commission in Bachelor Draw, roughly halfway between the two mineralized areas previously mentioned, disclosed a favorable appearing ore sand.

The strong east to northeast trends in the mineralized areas would seem to indicate that favorable ground may occur in the southwestern part of Bachelor Draw and on Wedding Bell Mountain between the Wedding Bell drilling area and the northeast part of Bachelor Draw.

WILD STEER CANYON

Introduction

The Wild Steer Drilling area is located in a westerly draining tributary canyon near the head of Wild Steer Canyon. Located in sec. 13, T. 46 N., R. 18 W., the area is north of Monogram Mesa and east of Skein Mesa.

Geology

One hole was drilled in the Wild Steer area to determine if the Wild Steer uranium-vanadium ore deposits or the favorable host rock enclosing them extends eastward from the Wild Steer mine. The drill hole penetrated unfavorable rock throughout the upper portion of the Salt Wash, but the First Rim ore sandstone, which is the host lentil for the Wild Steer deposits, was semi-favorable.

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