

Geology of the Uravan Mineral Belt

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By R. P. FISCHER and L. S. HILPERT

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By R. P. FISCHER and L. S. HILPERT

ABSTRACT

The name "Uravan mineral belt" is applied to a narrow, elongate area in southwestern Colorado in which carnotite deposits in the Morrison formation have a closer spacing, larger size, and higher grade than those in adjoining areas. The belt extends from Gateway through Uravan to Slick Rock.

The deposits within the belt tend to be clustered in patches of favorable ground 1,000 ft or more in width and usually a mile or more in length. These patches of favorable ground, and the deposits within them, generally are elongate normal to the trend of the mineral belt. Similarly the fossil logs and the ore rolls within the deposits have a dominant orientation normal to the belt. The mineral belt probably was localized by geologic conditions extant during the time the ore-bearing Morrison formation was deposited. These geologic relations allow the projection of the belt under deep cover between points of exposure and offer the chance of discovering moderately large reserves of carnotite ore in the unexplored parts of the belt.

The U. S. Geological Survey has done intensive diamond-drill exploration in parts of the Uravan mineral belt since 1947. The concept of the geologic relations of the mineral belt, and certain geologic features that can be recognized in drill core, have been useful in guiding this exploration. These features, consisting of the thickness and color of the ore-bearing sandstone, the color of mudstone associated with the sandstone, and the presence of abundant carbonaceous material in the ore-bearing sandstone, are briefly described. Exploration is done in three stages. During the first stage, holes are drilled at a wide spacing, approximately 1,000 ft apart, to find and roughly delimit favorable ground. During the second stage, the favorable ground is drilled with holes at a moderate spacing, 100 to 300 ft apart, to search for ore deposits. In the third stage of drilling, offset holes are drilled at 50- or 100-foot intervals around a discovery hole to extend and roughly outline the deposit.

INTRODUCTION

Carnotite deposits are widespread in southwestern Colorado and the adjoining parts of Utah, Arizona, and New Mexico (fig. 1). They are the principal domestic sources of uranium and vanadium. During the past several years, increasing attention has been focused on several

Mining Fund, but mostly as a wartime strategic minerals project. Since 1947, on the behalf of the Atomic Energy Commission, the Geological Survey has been continuing these geologic studies and has been conducting a program of diamond-drill exploration (Fischer, 1949). Exploration has been concentrated in the area of the Uravan mineral belt, where the promise of new discoveries is best.

DESCRIPTION OF THE CARNOTITE DEPOSITS

The ore, averaging about 0.25 percent U_3O_8 and 2 percent V_2O_5 , impregnates sandstone. The ore bodies are irregular tabular layers, with an average thickness of 2 to 4 ft. They lie generally parallel to the sandstone bedding. They range in size from a few feet wide, containing only a few tons of ore, to several hundred feet wide, which may contain many thousand tons. In most areas the deposits are confined largely to sandstone in a single stratigraphic zone. Within this zone the deposits have a spotty distribution but tend to be clustered in relatively small, poorly defined patches.

The deposits are thought to have formed from ground-water solutions migrating through ore-bearing beds, probably soon after the accumulation of the sands. Precipitation likely resulted from slight changes in the chemical composition of the solutions, perhaps in the environment of decaying organic material.

CONCEPT OF THE MINERAL BELT

The idea of the mineral belt was first conceived by the Geological Survey in 1943. Its recognition is based largely on evidence resulting from local and regional geologic study. The belt was first considered to be rather vaguely defined, but evidence accumulated since shows the belt to be fairly well defined.

The mineral belt appears to be a narrow, elongate area in which the carnotite deposits generally have closer spacing, larger size, and higher grade than those in the adjoining areas and the region as a whole. Not only does the area of the mineral belt include some of the most productive mines in the region, but recent exploration within it has yielded important discoveries and has shown a high proportion of ground that can be classified as favorable for carnotite deposits. In spite of these rather obvious relations, however, the idea of the belt probably could not be conceived on the basis of private exploration and mining alone, at least at the present stage of development of the region, because the local favorable trends in the vicinity of all the known deposits within the belt are about perpendicular to the trend of the belt itself, thus focusing attention in another direction.

EXTENT AND CHARACTER

The area of this mineral belt, as it can be delimited with present knowledge, is shown on plate 1. It extends from the western part of the Gateway district southeastward to the Uravan district and from there southward to the Gypsum Valley and Slick Rock districts. Nearly all the deposits within this area are in sandstone beds near the middle of the Morrison formation. Because the belt is fairly well defined in the vicinity of Uravan, where it contains the largest known carnotite deposits, the name "Uravan mineral belt" is proposed.

The mineral belt is most easily recognized in the Gateway and Uravan districts, where it ranges from 1 to several miles in width. Its favorableness decreases gradually toward its margins, which generally cannot be sharply defined. Within this belt, the deposits tend to be clustered in patches of favorable ground 1,000 to several thousand feet wide and usually at least several thousand feet long. These patches, and the deposits within them, tend to be elongate across the belt, that is, normal to the trend of the belt, although they do not necessarily extend completely across it. The ground between these groups of deposits, even though within the margins of the belt, is less favorable and contains few if any deposits. These patches of less favorable or unfavorable ground are 1,000 to several thousand feet wide.

South of the Uravan district the belt seems to be broader and the margins less well defined. The deposits in the belt are also smaller and more scattered, but otherwise they have the same geologic relations to the belt as the deposits in the Uravan and Gateway districts.

Although the mineral belt is well defined in the vicinity of Gateway, it is not projected west of the State line (pl. 1) for lack of definite evidence of its extension into Utah. Some of the geologic relations on Polar Mesa, however, support the concept of the mineral belt, so that ultimately it may be reasonable to extend it as far west as Polar Mesa.

GEOLOGIC RELATIONS

PRODUCTION DATA

Plate 1 shows the deposits in the main carnotite-producing region of southwestern Colorado and southeastern Utah. These deposits yielded about 725,000 tons of carnotite ore during the 1936-43 period of intensive mining. Of this amount, about 565,000 tons (78 percent) was mined from deposits in the Uravan mineral belt. Mines that produced more than 20,000 tons of ore during this period, and nearly all mines that produced more than 10,000 tons, are within the limits of the belt.

ASSAY DATA

In 1944, the Geological Survey compiled all available assay data, in order to determine whether or not the uranium and vanadium values are distributed in any systematic manner. This study showed that many deposits outside the mineral belt have ratios of uranium to vanadium ranging from 1 part U_3O_8 to 10 to 20 parts V_2O_5 , whereas most deposits in the belt have ratios ranging from 1 part U_3O_8 to 5 or 10 parts V_2O_5 .

FOSSIL LOGS AND ORE ROLLS

Fossil tree trunks and branches are common in the ore-bearing sandstone. Some are 1 ft or more in diameter and as much as 100 ft long. These logs were rafted into place by streams that deposited the enclosing sands, and when they came to rest in the stream beds, many of them were oriented parallel to the general direction of stream movement, as evidenced by lensing and foreset-bedding of the sandstone.

Ore rolls are peculiar concretionary structures in the ore. They are conspicuously elongate in one direction, ranging from 10 to 100 ft or more in length. Locally the long axes of the rolls have a common trend, which is parallel to the dominant orientation of the fossil logs. Ore bodies are also elongate in this same general direction (Fischer, 1942, p. 390).

The common orientation of ore rolls and fossil logs is about normal to the local trend of the Uravan mineral belt (pl. 2). The alinement of ore deposits in a cluster, and the trend of favorable ground enclosing the cluster, likewise are generally normal to the local trend of the mineral belt (see pp. 6-10 and figs. 2, 3, 4, 5). It must be assumed that some geologic conditions having widespread influence controlled the orientation of the fossil logs and the ore rolls in the area of the mineral belt.

STRUCTURE AND STRATIGRAPHY

Regional mapping and regional stratigraphic studies now in progress have shown that the Uncompahgre element of the ancestral Rocky Mountains has influenced the geologic history of the carnotite-bearing region. This element, whose southwestern edge was essentially in the same position as the southwestern flank of the present Uncompahgre Plateau, was raised as a high land mass in late Paleozoic time, and contributed much of the material that formed the thick strata of late Paleozoic and early Mesozoic age in the region to the south and west. Even after the Uncompahgre element was worn down and covered by a thin veneer of Jurassic strata, it presumably

still influenced sedimentary and ground-water conditions in the carnotite region, owing to the greater settling through compaction of the thicker series of sedimentary rocks there. It is also probable that the structural zones of weakness, which localized the Paradox Valley and Gypsum Valley folds and the other so-called salt anticlines in the region, developed originally during late Paleozoic time.

Regional deformation during Tertiary time raised the Uncompahgre structure as a highland and accentuated the anticlinal folds of the Paradox Valley and Gypsum Valley structures. This deformation also caused intensive faulting in places in the region. Although the structural environment of the carnotite deposits differs from place to place, neither the distribution of the deposits in general nor the character of individual deposits seem to be genetically influenced by the regional structures that developed during Tertiary time. This evidence permits the concept of the Uravan mineral belt crossing these Tertiary structures without regard to them and allows the projection of the mineral belt under deep cover between points of exposure.

A few miles north and east of the Uravan mineral belt, the carnotite-bearing beds change in lithologic character—the sandstone is more thinly and evenly bedded and finer-grained. Although this change is imperceptible locally, it undoubtedly expresses differences in the geologic environment during the time when these beds accumulated. It is probable that this environmental difference, and the resulting change in lithologic character, influenced ground-water conditions in the ore-bearing beds, and probably localized the Uravan mineral belt.

RESULTS OF EXPLORATION AND MINE DEVELOPMENT

Plate 3 shows the Uravan mineral belt and the locations of four specific areas within the belt where exploration and mine development are far enough advanced to show the relations of the ore deposits, and of the more favorable ground enclosing them, to the mineral belt. Of the four areas shown in plate 3, the relatively large Outlaw Mesa area (fig. 2) probably best illustrates the significant relations.

OUTLAW MESA AREA

Prior to the start of exploration on Outlaw Mesa by the Geological Survey in 1949, only a few deposits were known along the outcrop at the rim of the mesa. As most of these deposits are small, they offered little encouragement for subsurface exploration behind the outcrop, and very little subsurface exploration had been undertaken in this area by private capital. Only the geologic concept of a mineral belt

projecting through this area, as suggested by the Geological Survey in 1945 (Stokes and Fischer), justified planning intensive exploration.



FIGURE 2.—Map of the Outlaw Mesa area, showing the relations of the deposits and favorable ground to the UraVAN mineral belt.

Although exploration by the Geological Survey is not yet complete on Outlaw Mesa, enough detail is now known to show the distribution of the more favorable ground. The mineral belt, about 2 miles wide, is constituted in part by several patches of favorable ground that

range in size from 1,000 to several thousand feet in width and more than 1 mile in length. The long axes of these favorable patches generally are normal to the trend of the mineral belt. Likewise, the long axes of the individual deposits are normal to the trend of the belt and average about N. 45° E. The favorable patches are separated from one another by one to several thousand feet of ground that is not so favorable. The less favorable ground within the belt, like that outside the belt, contains relatively few deposits, most of which are small.

CALAMITY MESA AREA

West of Outlaw Mesa the mineral belt trends N. 70° W. across the Calamity Mesa area (fig. 3). Although this trend bears more westward than the trend across nearby Outlaw Mesa (see pl. 3 and fig. 2), the same relations of the favorable ground, and of the deposits contained within it, to the mineral belt apply to the Calamity Mesa area as well as to Outlaw Mesa. In the western part of the Calamity area the orientation of the deposits is about N. 10° E. In the eastern part the deposits show a rough orientation of about N. 30° E., which is intermediate between the orientation of the deposits in the western part of the Calamity area and the orientation of the Outlaw Mesa deposits. The long axes of the patches of favorable ground on Calamity Mesa are about normal to the trend of the mineral belt. Further

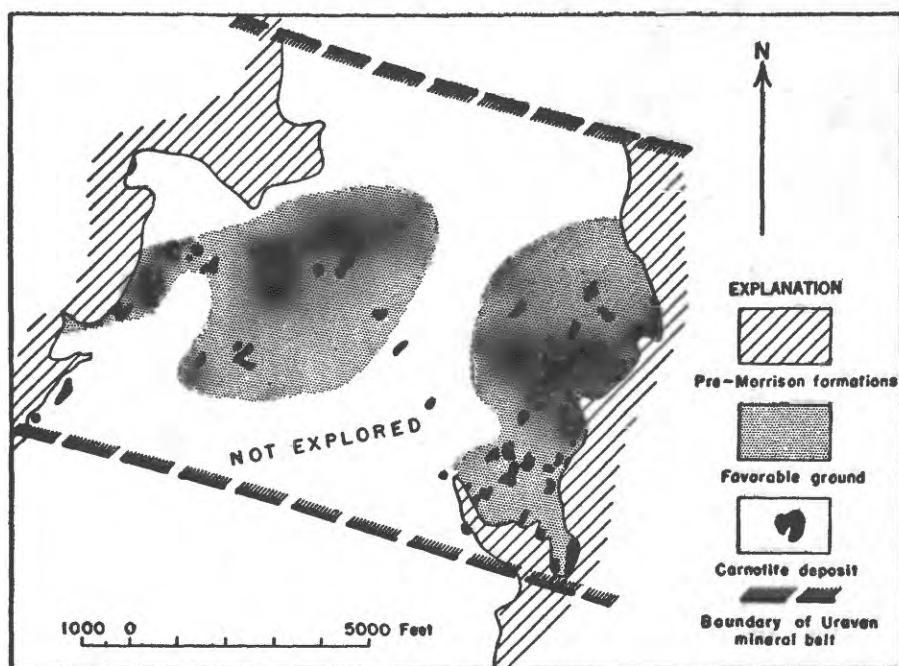


FIGURE 3.—Map of the Calamity-Mesa area, showing the relations of the deposits and favorable ground to the Urean mineral belt.

mine development and exploration, especially in the western part of the area, probably will show these relations more clearly.

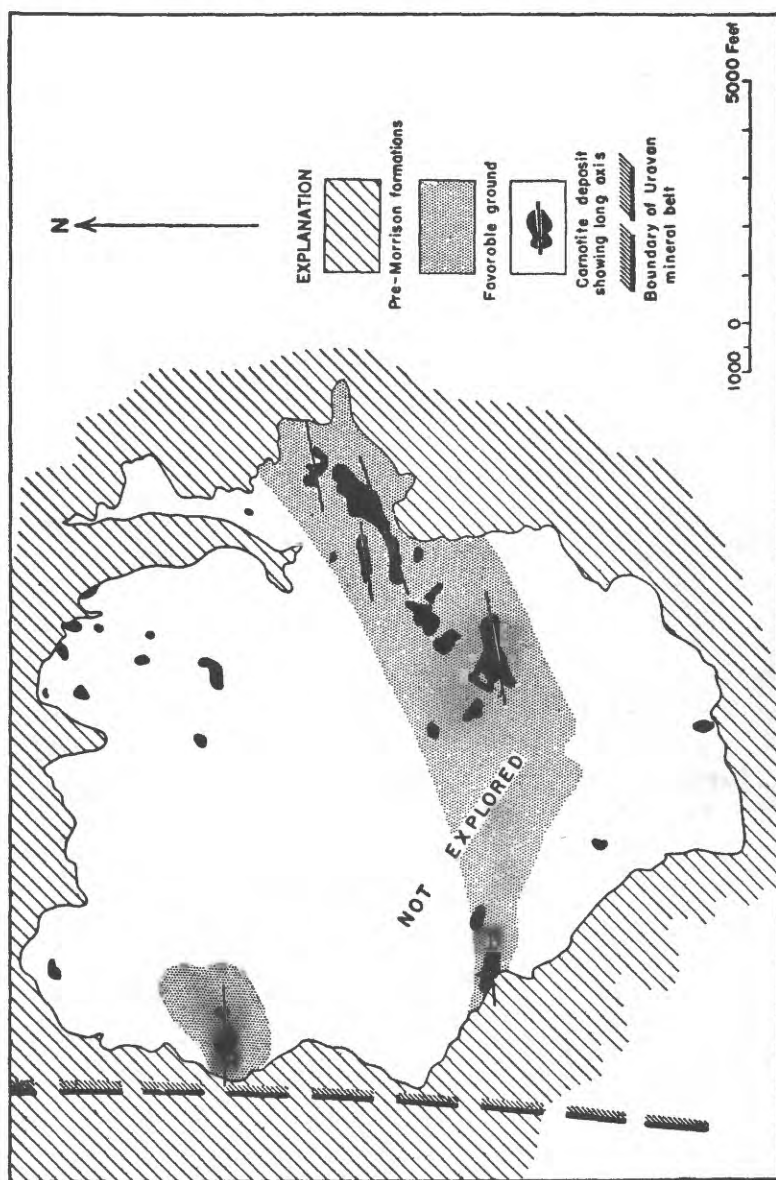


FIGURE 4.—Map of the Club Mesa area, showing the relations of the deposits and favorable ground to the Uravan mineral belt.

CLUB MESA AREA

Near Uravan, the mineral belt is about 5 miles wide and trends south (see pl. 3). On Club Mesa, which occupies the western half of the belt, the long axis of the largest patch of favorable ground, as defined at present, trends about N. 60° E. across the mineral belt (fig. 4).

The deposits within this ground are elongate in a N. 70° to 80° E. direction, more nearly normal to the local trend of the mineral belt, and they have an en echelon arrangement. These relations were first noted in 1942 by Fischer (1942, p. 387). Exploration since 1948 has shown this relationship more clearly, defined the more favorable ground, and shown the relations between the deposits and the favorable ground.

LONG PARK AREA

The present stage of exploration and mine development indicates that the Long Park area contains favorable ground that is about 1 to 2 miles wide and 5 miles long (fig. 5). This ground, and the clusters of deposits within it, trend about N. 60° W. Within these clusters, however, most of the individual deposits trend about N. 70° W., as shown by mine development, and are roughly arranged en echelon. These relations are similar to those on Club Mesa.

The large deposit in the north-central part of the Long Park area (see fig. 5) is known only by diamond drilling. This deposit apparently has an axial trend of N. 60° W., but actually there may be two or more smaller deposits that appear as one because of the pattern of drilling used. If so, it is probable that the individual deposits constituting this cluster may be expected to have an en echelon arrangement.

In spite of the peculiar en echelon arrangement of the deposits in the clusters of deposits, and the favorable ground containing them, in the Club Mesa and Long Park areas, both the deposits and the favorable ground have a general trend that is nearly normal to the mineral belt. The reasons for the en echelon arrangement of the deposits in the Club Mesa and Long Park areas are not known. Perhaps the explanation will be found by continued exploration and development.

GEOLOGICAL SURVEY EXPLORATION IN THE MINERAL BELT

Based on a general directive from the Atomic Energy Commission, the exploration work of the Geological Survey has the major objective of testing broad areas of unexplored ground away from known deposits, in order to find deposits that might support new mining operations in ground that probably will not be tested by private enterprise because of the risk of a poor yield. If reasonable success is to be obtained in exploring large areas of untested ground with a minimum amount of drilling, geologic guides to ore must be recognized and followed. These features and their application to exploration drilling are briefly described.

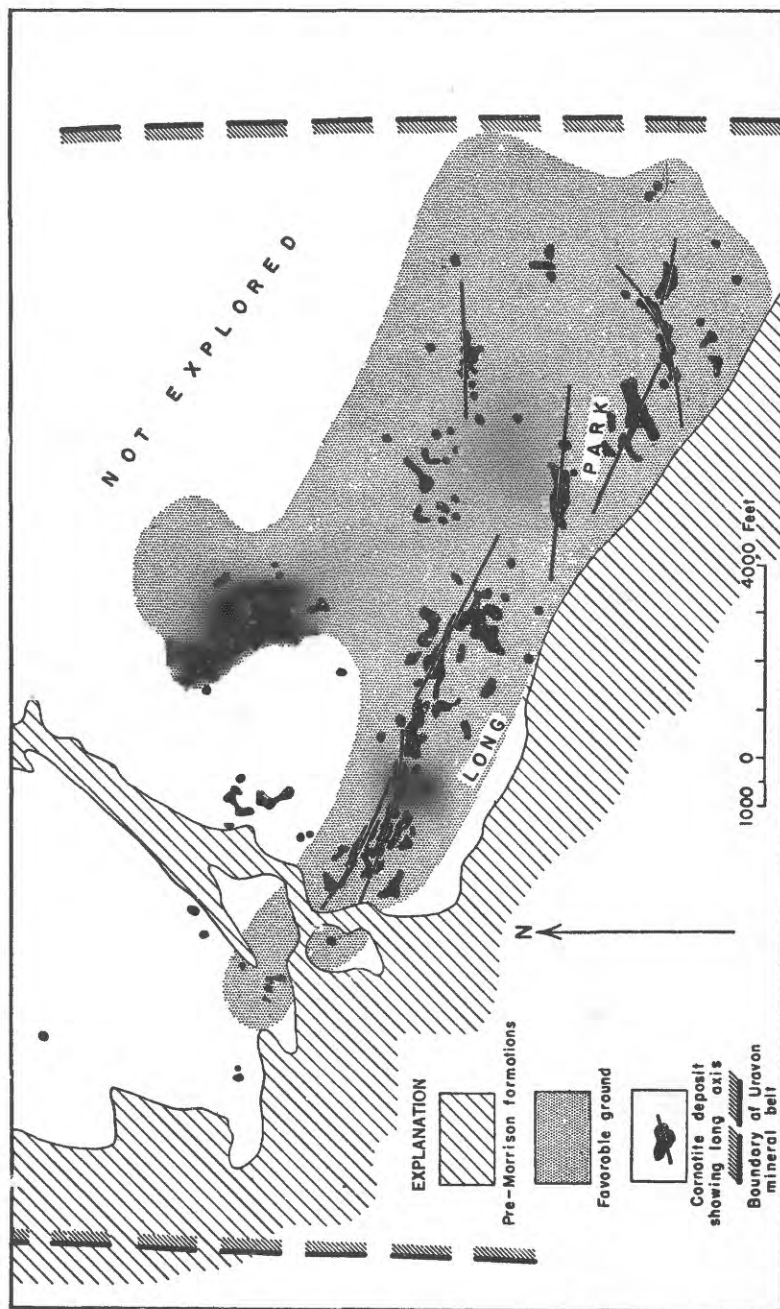


FIGURE 5.—Map of the Long Park area, showing the relations of the deposits and favorable ground to the UraVAN mineral belt.

GEOLOGIC GUIDES TO ORE

The most useful features in guiding exploration are thickness and color of the ore-bearing sandstone, color of mudstone associated with the sandstone, and the presence of abundant carbonaceous material within the ore-bearing sandstone (Weir, 1952).

The sandstone beds of the Morrison formation containing the carnotite deposits are lenticular and in places 50 ft or more thick. Most of the deposits are in or near the thicker, central parts of the lenses. No large ore body has been found by Survey drilling in sandstone that is less than about 40 ft thick. This minimum thickness of 40 ft is an important criterion in recognizing favorable ground, when holes are widely spaced. Not all thick sandstone is favorable, however.

The sandstone enclosing most of the ore bodies is dominantly pale to light-yellow brown, speckled with limonite stain. In most places this favorable color and staining extend several hundred feet beyond ore deposits. Farther away from deposits, the sandstone in many places has a reddish-brown color. Sandstone with a reddish cast may contain a few ore deposits, but most of them are small. Generally, a pronounced red color is indicative of unfavorable ground.

The ore-bearing sandstone is interbedded with mudstone, and contains thin lenses of mudstone and mudstone pebble conglomerate. This mudstone is normally red, but near ore deposits the mudstone within the sandstone and mudstone immediately beneath the ore-bearing sandstone is altered to gray. The presence of considerable altered mudstone is probably the most useful guide in recognizing ground favorable for ore, in both the first and second stages of drilling.

Carbonized plant remains are common in the ore-bearing sandstone. Although the fossil plants are rather erratically distributed, most of the carnotite deposits are in parts of the sandstone that contain fairly abundant plant remains. Thus, the presence of carbonized plant remains in drill core is indicative of favorable ground and suggests the proximity of ore.

Because individual features vary from place to place, they must be treated with caution when appraising an area from wide-spaced drill holes. An appraisal based on all these features, expressed best in numerical terms, is more valuable than the use of any one alone. By this method, numerical values are assigned to the combination of geologic features in each drill hole, to express the range from minimum to maximum favorableness.

APPLICATION OF GEOLOGIC GUIDES

After selection of an area thought to be reasonably favorable for ore, on the basis of geologic conditions, the exploration work of the Geological Survey in southwestern Colorado is done in three general

stages. During the first stage, holes are drilled at a wide-spacing, usually about 1,000 ft apart, for geologic information. On the basis of the guides to ore outlined above, ground which is geologically favorable for ore can be recognized with wide-spaced drilling and unfavorable ground, where drilling on closely spaced patterns would be less productive or fruitless, can be eliminated. Where no definite trends of sedimentary structures or an alinement of ore bodies is recognized, the widely spaced holes are drilled essentially on a coordinate system, at 500- to 1,000-ft intervals; but where trends have been developed—such as in parts of the Uravan mineral belt—holes are drilled along two or more lines perpendicular to the trend, the lines being 2,000 or more feet apart and the holes along the lines 500 to 1,000 ft apart.

In the second stage of drilling, holes are drilled in the favorable ground at moderate spacing, approximately 100 to 300 ft apart, the interval and pattern being planned to cut with at least one hole each, all, or nearly all the deposits of average size that can be expected in the area. For success at this stage of work the drill need not cut ore of commercial grade and thickness—the weakly mineralized sandstone and thin layers of ore that commonly extend beyond the limits of commercial bodies offer a larger target and a lead to ore bodies if any are present. In the second stage of drilling, where no definite trends or orientations of ore bodies are recognized, the holes are drilled essentially on a coordinate system; but where definite trends of deposits have been established, holes can be drilled along lines perpendicular to the trend, the lines being somewhat farther apart than the holes along the lines. The erratic and unpredictable trend and shape of individual deposits, however, necessitates caution in selecting the proper spacing of the lines of holes.

Where ore or a show of mineralized rock is cut by a hole drilled in the first or second stage of drilling, a third stage of drilling is done in which usually four offset holes are drilled about 50 to 100 ft from the discovery hole to cut any extension of the lead in that hole. Where an extension is proved by one or more holes, other holes are drilled in the general direction of the extension at about 100- to 200-foot intervals until the deposit is roughly outlined.

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