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A geological study of the Irvine Ranch Area, Johnson and Campbell counties, Wyoming

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A GEOLOGICAL STUDY OF THE IRVINE RANCH AREA, JOHNSON AND CAMPBELL COUNTIES, WYOMING

BY

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THESIS

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ABSTRACT

The discovery of uranium in the Powder River Basin, Wyoming, by the U. S. Geological Survey in 1952 has lead to an extensive exploration program throughout the region by both private and governmental agencies. This report is a geological study of an area in the southwestern part of the basin.

Geological and radiometric mapping carried out as a part of this report indicated several areas of uranium occurrence. Some of these occurrences warrant tests by drilling.

Mineralogical and petrographic study has shown the principal uranium minerals to be carnotite and metatyuyamunite. The mineralization occurs in arkosic sandstones. Assays of the uranium deposits are usually below one percent U_3O_8, but occasional samples range up to 25 percent U_3O_8. The origin of the deposits is attributed to percolating ground water.

An examination of mining and haulage costs and of ore prices has been made for the area. With this background, the geological study indicates a reasonable possibility that commercial ore is present within the area.

A GEOLOGICAL STUDY OF THE IRVINE RANCH AREA, JOHNSON AND CAMPBELL COUNTIES, WYOMING

INTRODUCTION

The harnessing of atomic power has initiated a tremendous search for deposits of uranium to supply the demands of the growing industry. In the United States much of the exploration has taken place along the flanks of the Rocky Mountains, and uranium ore has been found in every state in the region.

One area of activity is in the vicinity of the Pumpkin Buttes in the Powder River Basin of Wyoming. This study concerns a part of the Pumpkin Buttes District, herein designated as the Irvine Ranch Area.

Acknowledgements

The author wishes to express his grateful appreciation to all those individuals and organizations who gave willingly and generously of their time and information. Particular credit is due the following: Mr. Edward L. Benoit of the University of Oklahoma for his able field assistance; Professor Ray E. Morgan of the Geology Department, Missouri School of Mines and Metallurgy, for his expert advice, help and guidance throughout the project; and the Geology Department of the Missouri School of Mines and Metallurgy for the use of their facilities and equipment, and for the valuable suggestions and assistance of many of the staff members.

GEOGRAPHIC DESCRIPTION

Location and Accessibility

Most of the Irvine Ranch Area is located in the southeastern part of Johnson County, Wyoming, with a small part of the area extending east into Campbell County (Figure 1). Section and township corners are missing in T 43 N, R 77 W; T 44 N, R 77 W; and T 44 N, R 78 W; however, approximate locations can be postulated by the extension of land lines from adjoining townships.

The legal description of the area, obtained in the above manner, is as follows:

> All of Sec 5 and 6; W ½, Sec 4; N ½, Sec 7 and 8; NW ¼, Sec 9, T 42 N, R 76 W.
>
> All of Sec 5, 6, 7, 8, 17, 18, 19, 20, 29, 30, 31, and 32; W ½, Sec 4, 9, 16, 21, 28, and 33, T 43 N, R 76 W.
>
> All of Sec 17, 18, 19, 20, 31, and 32; W ½, Sec 16, 21, 28, and 33; S ½, Sec 7 and 8; SW ¼, Sec 9, T 44 N, R 76 W.
>
> All of Sec 1, 2, 3, 4, 5, and 6; N ½, Sec 7, 8, 9, 10, 11, and 12, T 42 N, R 77 W.
>
> All of T 43 N, R 77 W.
>
> All of Sec 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, and 36; S ½, Sec 7, 8, 9, 10, 11, and 12, T 44 N, R 77 W.
>
> All of Sec 1; N ½, Sec 12; E ½, Sec 2, 11, 14, 23, 26, and 35, T 43 N, R 78 W.
>
> All of Sec 13, 24, 25, and 36; E ½, Sec 14, 23, 26, and 35; S ½, Sec 12; SW ¼, Sec 11, T 44 N, R 78 W, Johnson and Campbell Counties, Wyoming.

The total area studied contains approximately 120 square miles (43,000 acres).

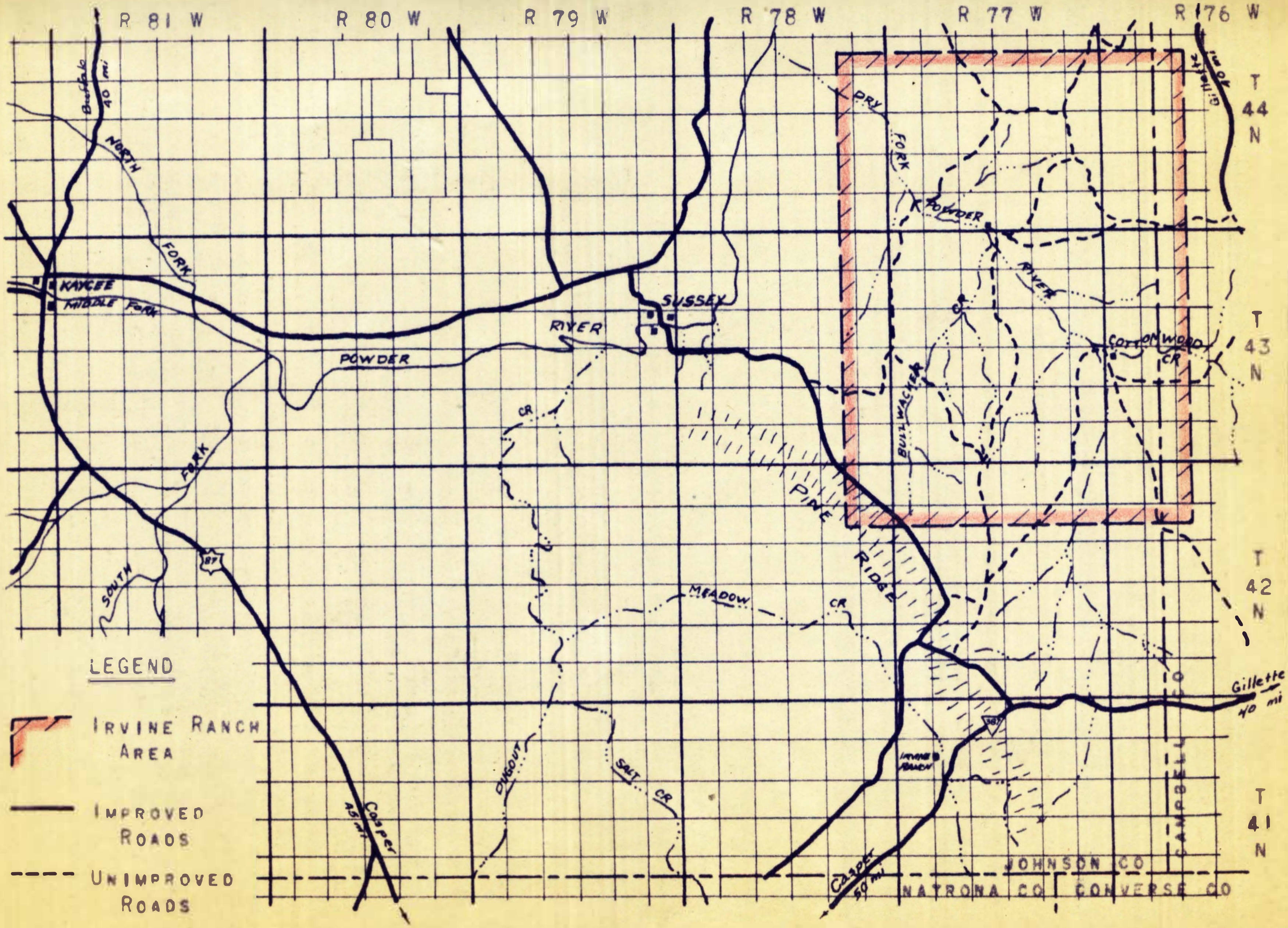


FIG. I. LOCATION MAP – IRVINE RANCH AREA, JOHNSON AND CAMPBELL COUNTIES, WYOMING

The area is situated about 60 miles northeast of Casper, 25 miles northeast of Edgerton, 45 miles southwest of Gillette, 25 miles east of Kaycee, and about 10 miles east of Sussex. The nearest post office is at Sussex, but the post office at Edgerton was more convenient and gave faster service. Casper is the largest city in the region and provides the most reliable source of supplies.

Throughout most of the year, the area is accessible by automobile on unmaintained dirt roads. These roads become impassable to all traffic at times of heavy snow or rainfall. Both the north-south highway (U. S. 87) and the east-west highway (Wyo. 387) are good hard surfaced roads, as is the Kaycee-Sussex road. All other maintained roads have either gravel or poor asphalt surfaces.

To avoid locked gates, rough roads and wash-outs, the easiest access to the area is from the south as follows: Turn north off State Highway 387 on a hard surfaced road about 12 miles east of the town of Edgerton. This is the first road east of the Pine Ridge, and is marked "Private Road, Continental Oil Company". Follow this road about three miles to where an abandoned coal pit can be seen on the right. Turn right onto a graveled road, and at about 200 yards, turn right again on the first trail this direction. From this point the most heavily traveled trail leads to the center of the area.

Railroad facilities are available at Casper, Gillette and Douglas; and commercial air transportation is available at Casper. In addition, there are several small private air fields at various ranches and towns in and close to the area.

Topography and Drainage

Most of the area is rolling prairie which is dissected by dry washes and gullies (Figures 2 and 3). Very good topographic control of the region is given by maps published by the U. S. Geological Survey. The Irvine Ranch Area covers parts of four 7.5 minute quadrangle sheets: the Dry Fork Ranch, House Creek, Fort Reno and Fort Reno S. E. These proved to be very satisfactory base maps for most of the field work. The topographic map accompanying this report (Plate 1) is a composite of parts of these four quadrangles.

The average elevation is slightly less than 5,000 feet with a maximum relief of about 500 feet. The Pumpkin Buttes (Figures 2 and 4) just to the east, however, rise to more than 6,000 feet, nearly 1,000 feet above the highest point in the Irvine Ranch Area.

The drainage is dendritic. The most important stream is the Dry Fork of the Powder River and its tributaries, Bullwhacker Creek, Cottonwood Creek, and several unnamed creeks. Willow Creek drains the northeast corner of the area. The divide between it and the Dry Fork forms a prominent ridge (Figure 4).

The annual rainfall is only 10 to 20 inches; consequently, the streams are intermittent. Small springs, which either disappear within a short distance or form small water holes,

Fig. 2. Rolling prairie with North Pumpkin Butte in the background.

Fig. 3. View from Dry Fork-Willow Creek divide looking south.

Fig. 4. Dry Fork - Willow Creek divide with North Butte in the background.

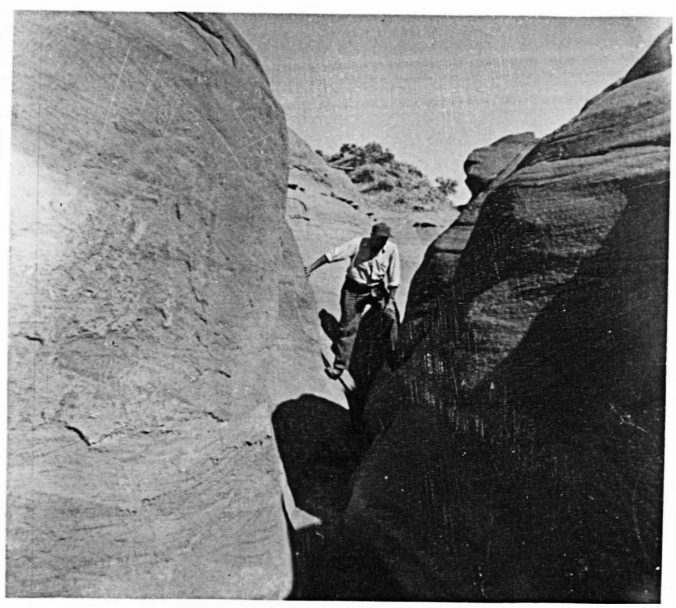


Fig. 5. Gully through cross-bedded sandstone.

are found along most of the valleys. The washes and gullies are steep-walled (Figure 5), and rapid runoff causes flash floods in the major streams (Figure 6).

Vegetation

Sage brush, buck brush, and scattered clumps of buffalo grass are the most conspicuous forms of vegetation on the rolling hills, but some of the valleys contain stunted cottonwood and willow trees (Figure 7) as well as occasional hay meadows. Pine Ridge and the Pumpkin Buttes support growths of Ponderosa Pine.

Culture and Industry

No permanently occupied habitations exist within the area. The only buildings are at cattle and sheep camps and are either abandoned or only temporarily used during lambing, shearing, or branding seasons. One of these (Figure 8) was the base camp for the field work. Many large ranches are scattered throughout the basin, and there are numerous small ranches in the irrigated regions along the Powder River.

The only industries are ranching and mining. One uranium mine (Wydal Mine) is in operation, and there are several small coal pits along Pine Ridge. The famous Salt Creek, Teapot Dome, Meadow Creek, and Sussex oil fields lie a few miles to the southwest of the area. These fields show prominent surface structures (Figure 9), and the producing horizons range from Cretaceous to Pennsylvanian.

Fig. 6. Flash flood in Dry Fork Creek - stream was dry 15 minutes prior to photo and retreated to a trickle in less than an hour.

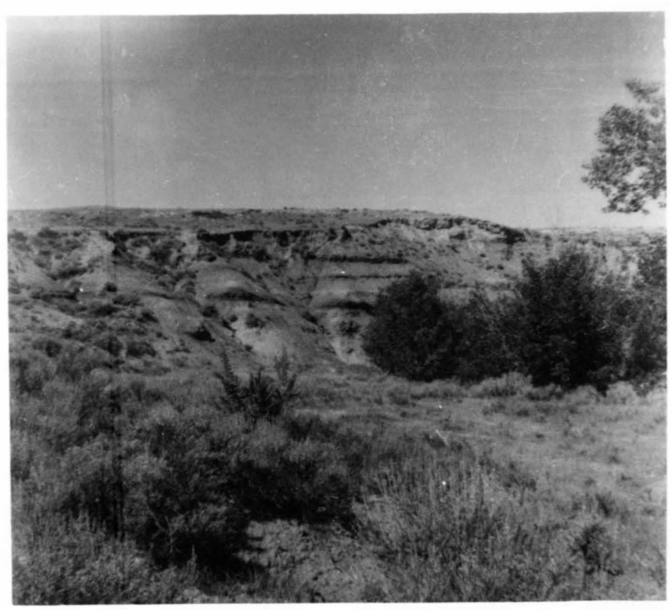


Fig. 7. Typical vegetation - Sage brush growing on the slope in the foreground and cottonwoods and willows in the wash. Coal beds cause dark bands along the bluff.

Fig. 8. Irvine shearing camp used as a base camp for field work in this study.

Fig. 9. Surface Structure - Salt Creek Oil Field.

OBJECTIVES AND METHODS

Purpose of the Investigation

This investigation was undertaken to study systematically the stratigraphic, structural and mineralogical relationships in the Irvine Ranch Area. The study should be of some use in determining the origin, size and future economic possibilities of the uranium deposits. It is hoped that the results may be applied to increase the knowledge of uranium deposits, both in the Pumpkin Buttes Area and elsewhere.

Methods of Investigation

Most of the field work was done by automobile using U. S. Geological Survey topographic maps (Plate 1) for base control. Outcrops were plotted on these maps and elevation control was obtained from the contours. Several outcrops of the red sandstone zone were located by flying over the area (Figure 10).

A Precision Scintillator was used for radiometric reconnaissance (Figure 11). Plane table mapping, controlled by U. S. Geological Survey bench marks and triangulation stations, was done in areas of high radioactivity.

Stratigraphic relationships were studied by mapping outcrops and uranium occurrences (Plate 2), and by measuring detailed stratigraphic sections (Plate 3 and Table 1). Samples were collected and brought into the laboratory for radiometric, chemical, petrographic and x-ray analysis.

Fig. 10. Airplane used for reconnaissance.

Fig. 11. Field Assistant checking radiometric anomaly with scintillometer.

PREVIOUS WORK

Uranium was discovered in the Pumpkin Buttes Area in 1951 by J. D. Love of the U. S. Geological Survey as a result of airborn radiometric reconnaissance by the Survey for the Atomic Energy Commission. Prior to Love's discovery, geological work in this part of the Powder River Basin was confined primarily to coal investigations by the U. S. Geological Survey (Stone and Lupton, 1910; Gale and Wegemann, 1910; Wegemann, 1928) and to regional reconnaissance undertaken to some extent by the U. S. Geological Survey (Darton, 1906; Love and Weitz, 1951; Pierce and Girard, 1952), but largely done by private companies in their search for oil (Blackstone, 1949; Fenwick, 1949).

Most of the data obtained by the oil companies in their surface geological work and geophysical reconnaissance is confidential, and detailed information is unavailable for publication. Personal conversations with various company officials indicate that neither geology nor geophysics has proven very satisfactory or reliable in the central part of the basin.

Most early references to the Eocene and younger formations are vague generalizations about both surface and subsurface relationships. The Wasatch formation is usually described as a shale-siltstone-sandstone sequence with beds of carbonaceous shale and coal (Darton, 1906; Eardley, 1951). No attempt was made to subdivide it into component members.

Since the discovery of uranium, several reports have been published about the Pumpkin Buttes Area (Love, 1951;

Davidson, 1953; Troyer and others, 1954; Sharp, 1956). Most of the recent reports on uranium occurrences in Wyoming (Grutt, 1956; Vine, 1956), or in the United States (McKelvey, 1955; Finch, 1956; McKelvey and others, 1956; Butler and others, 1956) make general reference to the Pumpkin Buttes deposits.

REGIONAL GEOLOGY

The Irvine Ranch Area is situated near the synclinal axis of the Powder River Basin of northeastern Wyoming and southeastern Montana. The area is basin-like in both its structural and topographic features. It is bordered on the east and northeast by the Black Hills, on the southeast by the Hartville Uplift, on the south by the Laramie Range and Casper Mountain, and on the west by the Big Horn Mountains.

The east-west distance across the basin is about 120 miles. The north-south distance is nearly 250 miles. The regional geology is shown on a geological map by Love and Weitz (1951), and the structure is shown on a structural contour map of the Powder River Basin by Pierce and Girard (1952). A generalized compilation of both of these maps for the southwestern part of the Powder River Basin is shown in Figure 12.

Stratigraphy

The Fort Union formation (Paleocene), the Wasatch formation (Eocene) and the White River formation (Oligocene) are the only units exposed over the deeper parts of the

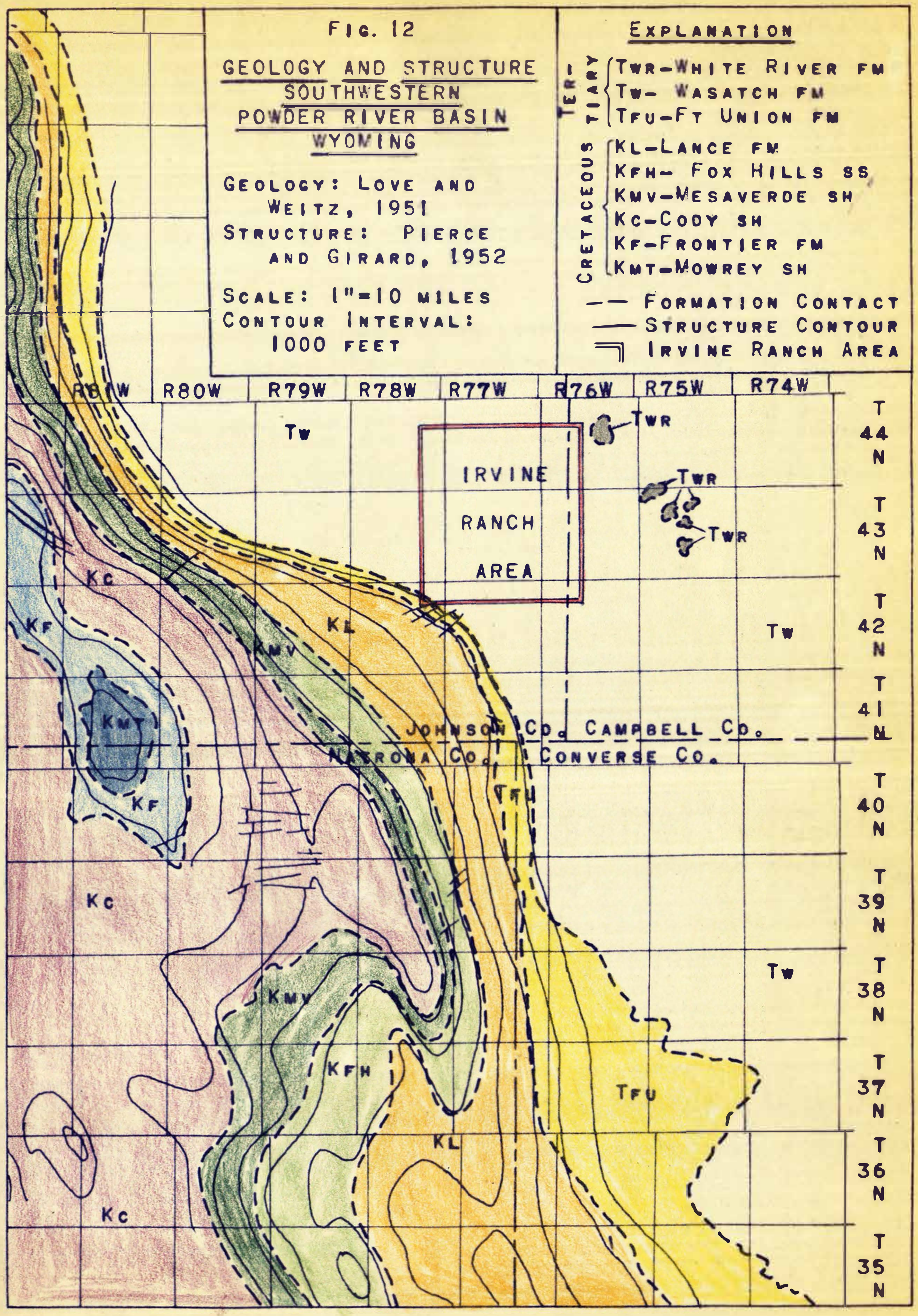


Fig. 12
GEOLOGY AND STRUCTURE
SOUTHWESTERN
POWDER RIVER BASIN
WYOMING
Geology: Love and Weitz, 1951
Structure: Pierce and Girard, 1952
Scale: 1"=10 miles
Contour Interval: 1000 feet
Explanation
Tertiary
Twr-White River fm
Tw- Wasatch fm
Tfu-Ft Union fm
Cretaceous
Kl-Lance fm
Kfh- Fox Hills ss
Kmv-Mesaverde sh
Kc-Cody sh
Kf-Frontier fm
Kmt-Mowrey sh
Formation Contact
Structure Contour
Irvine Ranch Area
R81W
R80W
R79W
R78W
R77W
R76W
R75W
R74W
T 44 N
T 43 N
T 42 N
T 41 N
T 40 N
T 39 N
T 38 N
T 37 N
T 36 N
T 35 N
IRVINE RANCH AREA
Tw
Twr
Kc
Kf
Kmt
Kmv
Kl
Kfh
Tfu
Johnson Co.
Campbell Co.
Natrona Co.
Converse Co.

structural basin, and older rocks outcrop along the flanks of the uplifts surrounding the basin (Figures 12 and 13).

The Paleocene, Eocene and Oligocene rocks in the center of the basin have a combined thickness of more than 6,000 feet. The underlying Cretaceous rocks have a thickness of about 7,000 feet. The pre-Cretaceous rocks, post-Precambrian strata have a combined thickness greater than 3,000 feet. The sedimentary section above the Precambrian basement, therefore, is approximately 16,000 feet thick.

The entire Paleocene, Eocene and Oligocene sequence was called Fort Union by Darton (1906), and other early workers accepted this classification. The discovery of *Coryphodon* teeth (lower Eocene) in the upper part of the formation and the presence of ferruginous beds in the lower part of the formation caused Wegemann (1928) to divide the sequence into the Fort Union and Wasatch formations. Wegemann put the contact at the top of coal bed H (Plate 3). This is a prominent coal in the southwestern part of the basin and is correlative with the Roland coal in the north and northeastern parts of the basin. In 1955, Hose found that the coal occurs progressively lower in the stratigraphic section northeast of the Sussex oil field and raised the base of the Wasatch about 470 feet to coincide with the base of the lowest red siltstone in the area. Hose reported an angular unconformity between the two formations at this locality.

On the basis of both lithology and vertebrate fossils, Love (1952) determined that the cap rock of the Pumpkin Buttes

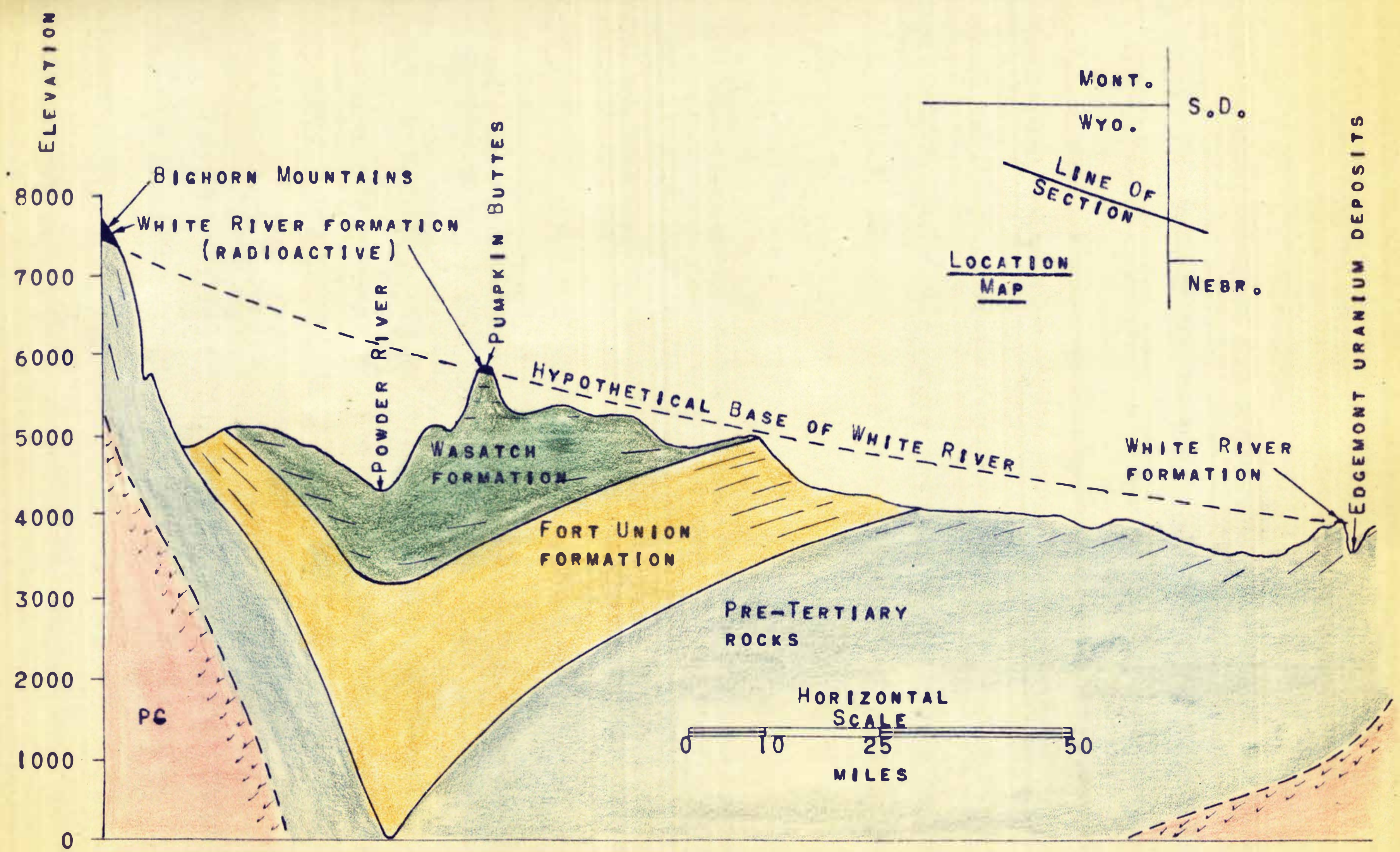


FIG. 13

SECTION ACROSS POWDER RIVER BASIN
FROM BIGHORN MOUNTAINS TO EDGEMONT AREA, SOUTH DAKOTA
(ADAPTED FROM LOVE, 1952)

is Oligocene and that it overlies the Wasatch with a slight erosional unconformity.

The Wasatch formation consists of about 1,500 feet of sandstones, shales, mudstones and siltstones, with many carbonaceous beds and lignitic coals. These rock types are discontinuous laterally and are normally undifferentiated in mapping. Darton (1906) distinguished the Kingsbury conglomerate, an alluvial fan which outcrops southwest of Buffalo, as a separate formation. Later work (Gale and Wegemann, 1908) has shown it to be a basal member of the Wasatch formation.

The Eocene and upper Paleocene show fluvial characteristics. A study of clastic sediments by Davidson (1953-a) has indicated a granitic source to the southeast for the middle and upper Wasatch sandstones in the Pumpkin Buttes Area. According to Darton (1906), the Kingsbury conglomerate was derived from Paleozoic and Precambrian exposures in the Big Horn Mountains.

The Upper Cretaceous and the lower Fort Union formations are sandstones with some shale and coal. At most localities no evidence of a large break between the Cretaceous and Paleocene is apparent. There are, however, local evidences of angular unconformities (Eardley, 1951).

Structure

The Powder River Basin was formed by post-Cretaceous deformation associated with the Laramide orogeny. This phase of Rocky Mountain deformation apparently began during late Cretaceous or early Paleocene, and continued throughout Paleocene and Eocene times, diminishing in intensity during the Eocene (Darton, 1906; Eardley, 1951; Hose, 1955; Osterwald, 1956).

Along the axis of the basin, the Precambrian is approximately 12,000 feet below sea level (Eardley, 1951; Love, 1952; Osterwald, 1956). Precambrian rocks are exposed on Cloud Peak in the Big Horn Mountains less than 100 miles to the west at elevations of over 13,000 feet and in the Black Hills to the east at elevations of 6,000 to 7,000 feet. There is, therefore, a relative uplift of as much as 20,000 feet between the Powder River Basin and adjoining uplifts.

The synclinal axis is near the western edge of the basin. The rocks rise rapidly toward the Big Horn Mountains to the west and slope more gently upward to the east. Throughout most of the basin the Eocene rocks are nearly horizontal and lie unconformably on Paleocene (See Figure 13).

Numerous anticlinal structures surround the basin, and many of these structures produce oil. Seismic and surface studies, however, indicated nothing but gentle swells and depressions in the central part of the basin (Fenwick, 1949; Love, 1952). Wegemann and others (1928) reported a slight anticlinal structure in the vicinity of the Pumpkin Buttes, and Troyer and others (1954) show this on a structural contour map of the Pumpkin Buttes Area. The generalized structural pattern for the Pumpkin Buttes Area, as shown in Figure 14, is based upon Troyer's map, which has been

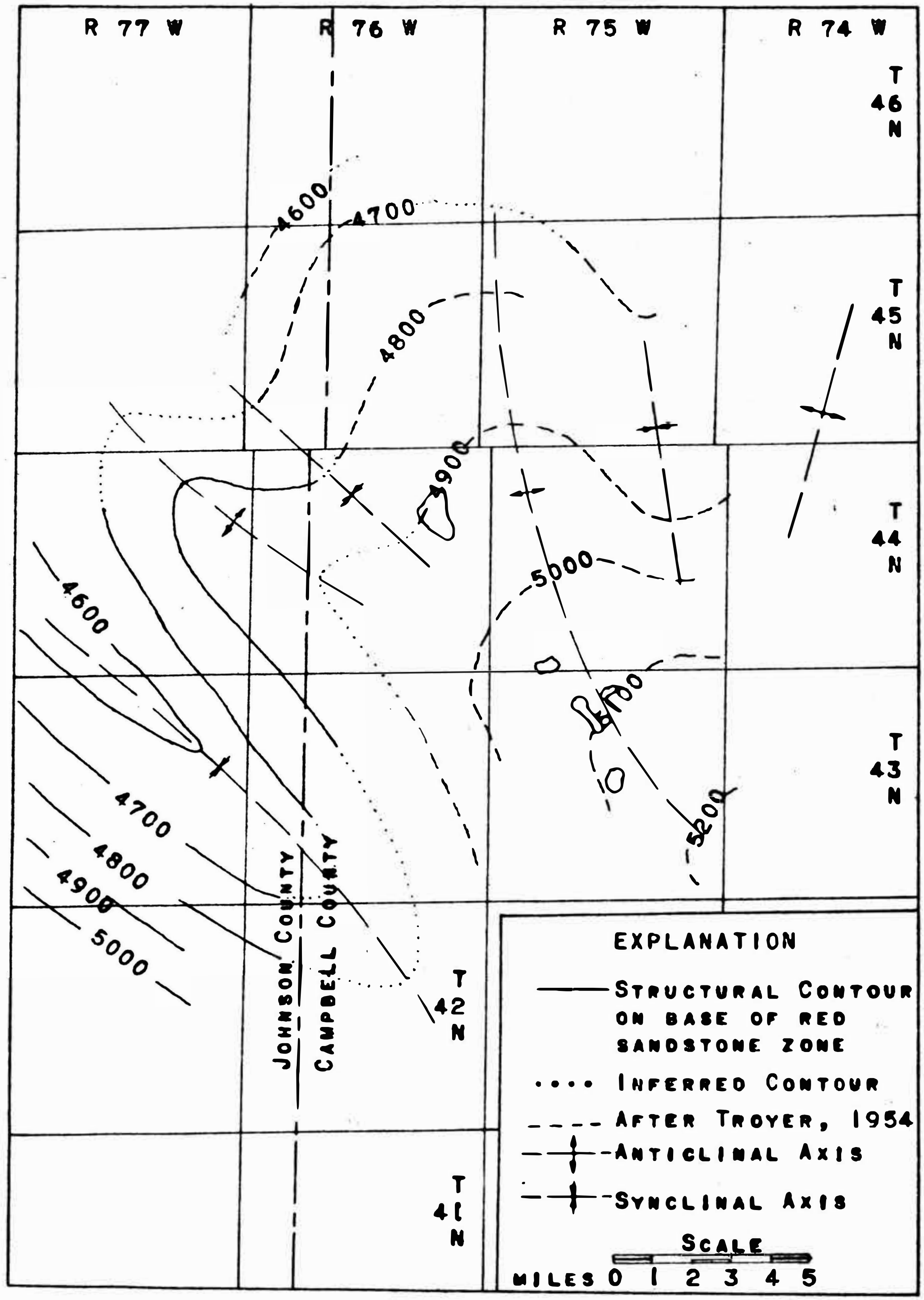


Fig. 14

STRUCTURAL CONTOUR MAP OF THE PUMPKIN BUTTES AREA WYOMING modified to incorporate additional information gathered during this study (Plate 2).

GEOLOGY OF THE IRVINE RANCH AREA

The geology and structure of the Irvine Ranch Area are indicated on Plate 2. The Wasatch formation is exposed over most of the area mapped, the only exception being the southwest corner where the Fort Union formation forms the Pine Ridge. The White River formation caps the Pumpkin Buttes a few miles east of the area. The relationships and lithology of the different formations are shown in the composite columnar section of Tertiary formations (Plate 3, Section 1).

Stratigraphy

Fort Union Formation: The Fort Union formation is a non-marine, ferruginous sandstone of Paleocene age. It marks a transition from the widespread Cretaceous formations and the separated basin-type deposits of the Eocene. In most localities where it is exposed, the Fort Union is conformable with the underlying Cretaceous. This indicates that the major Laramide uplifting did not begin until late Fort Union or post-Fort Union time. Like much of the Upper Cretaceous, the Fort Union thins eastward across the basin suggesting that earlier formed Rocky Mountains to the west provided the Fort Union sediments.

Following or during the late stages of Fort Union deposition there was extensive uplifting, folding and faulting around the margins of the Powder River Basin.

The uplift produced angular unconformities between the Fort Union formation and the overlying Wasatch. In places this discordance is as great as 45 degrees (Hose, 1955).

Wasatch Formation: The Wasatch formation is nearly 1500 feet thick in the Irvine Ranch Area where much of the section is exposed. The formation consists of discontinuous, interbedded mudstones, claystones, shale, siltstones, thin carbonaceous shales and lignite coals, with lenses of cross-bedded sandstone up to 100 feet thick. The lithology changes both vertically and laterally, and most beds can be traced only short distances (seldom more than a mile or two) on a single outcrop.

In the area mapped, as in the rest of the Pumpkin Buttes Area, there is a zone of sandstone lenses about 500 to 1,000 feet above the base of the Wasatch formation. In many places iron oxide stain gives a distinctive red color to this sandstone horizon (Figures 15 and 16). The same type of sandstone is buff to gray in other parts of the Powder River Basin. The uranium deposits are closely associated with the iron oxides. Although uranium seldom occurs in the red sandstone, it is often found near the contact of the red with adjoining buff or gray sandstone.

More than 30 stratigraphic sections were measured in the Irvine Ranch Area. Most of these are either in or immediately below the red sandstone zone. These sections were integrated into four composite sections (Plate 3, Sections 2, 3, 4 and 5). The detailed descriptions are given in Appendix I.

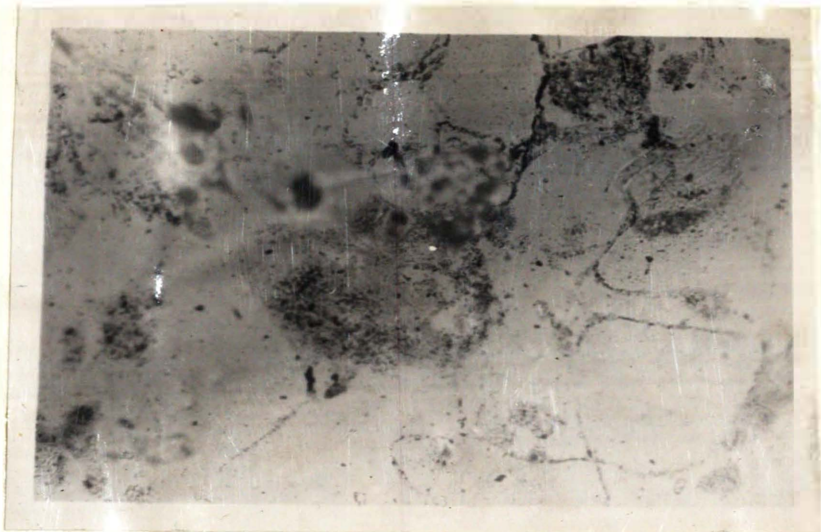


Fig. 15. Thin-section of red sandstone showing iron oxide coating the sand grains.

Fig. 16. Red sandstone outcrop.

The red stain bears no apparent relationship to bedding, grain size or sorting. Color changes occur with no other visible changes in the rock. Red colors are common to all sand sizes from very coarse to very fine and are common to beds showing various degrees of sorting. Optical examination showed no difference in mineralogy between the red and buff sandstones other than the color of the iron compounds present. The various color facies of the sandstone showed no appreciable difference in relative abundance of magnetite or magnetic minerals. This is not in agreement with the conclusions of Miller and Folk (1955).

Many theories for the origin of red sandstone have been presented. A good summary of the problem is given by Van Houten (1948), and he feels that red sandstone may possibly result from several causes. One cause may be the precipitation of iron oxides and hydroxides carried in solutions or colloidal suspension. These solutions were possibly contemporaneous with the deposition of the sandstone, but additional iron may have been added by percolating ground waters. The precipitation is related to the increasing alkalinity of the solutions as they moved through the rock.

There is also the possibility of alteration of some of the arkosic minerals present in the sandstone by post-depositional solutions to form the red iron oxides. Some evidence indicates that the red color was originally more widespread than at present but that solutions have altered the iron causing the color to change from red to buff or gray.

Thin bands of yellow and gray sandstone occur within the red (Figure 16). These bands are contiguous to minute fractures. It is probable that solutions traversing the fractures caused the difference in color by altering the iron compounds which stain the sandstone.

According to Van Houten (1948), the solutions carrying the soluble or colloidal iron compounds were differentially precipitated causing the color variation. He thought that decaying vegetation in many areas produced organic acids which tended to keep the iron in solution. Conversely, areas lacking in decaying vegetation would be likely to have deposition of iron compounds.

Sedimentary analyses were made of several of the sandstone samples with the following results:

Sorting: Sieve analyses of the samples show the sorting to be variable, but for the most part, the sorting coefficient was about 1.2 to 1.5. Typical histograms and cumulative curves are shown in Figure 17.

Grain size: Sieve analyses show most of the sand to be fine to medium grained (Figure 17). There were many cases of coarse to very coarse sand observed in the field, especially in conglomeritic lenses. A general increase in grain size from north to south was noticed. This supports Davidson's (1953) paper on grain size distribution.

Mineralogy: The predominant constituent of the sandstone is quartz (50 to 80 percent), with feldspars (orthoclase, microcline and some plagioclase) constituting about 10 to 30 percent of each sample. Some of the feldspar grains are somewhat altered, and most sand grains are coated with either red or brown iron oxides. Occasional quartz grains show silica overgrowths. Accessory minerals include garnet, tourmaline, mica, epidote, hornblende, biotite, muscovite, chlorite, sphene and magnetite. Calcite cement is common. Clay (kaolin) is present between the grains in a few of the samples.

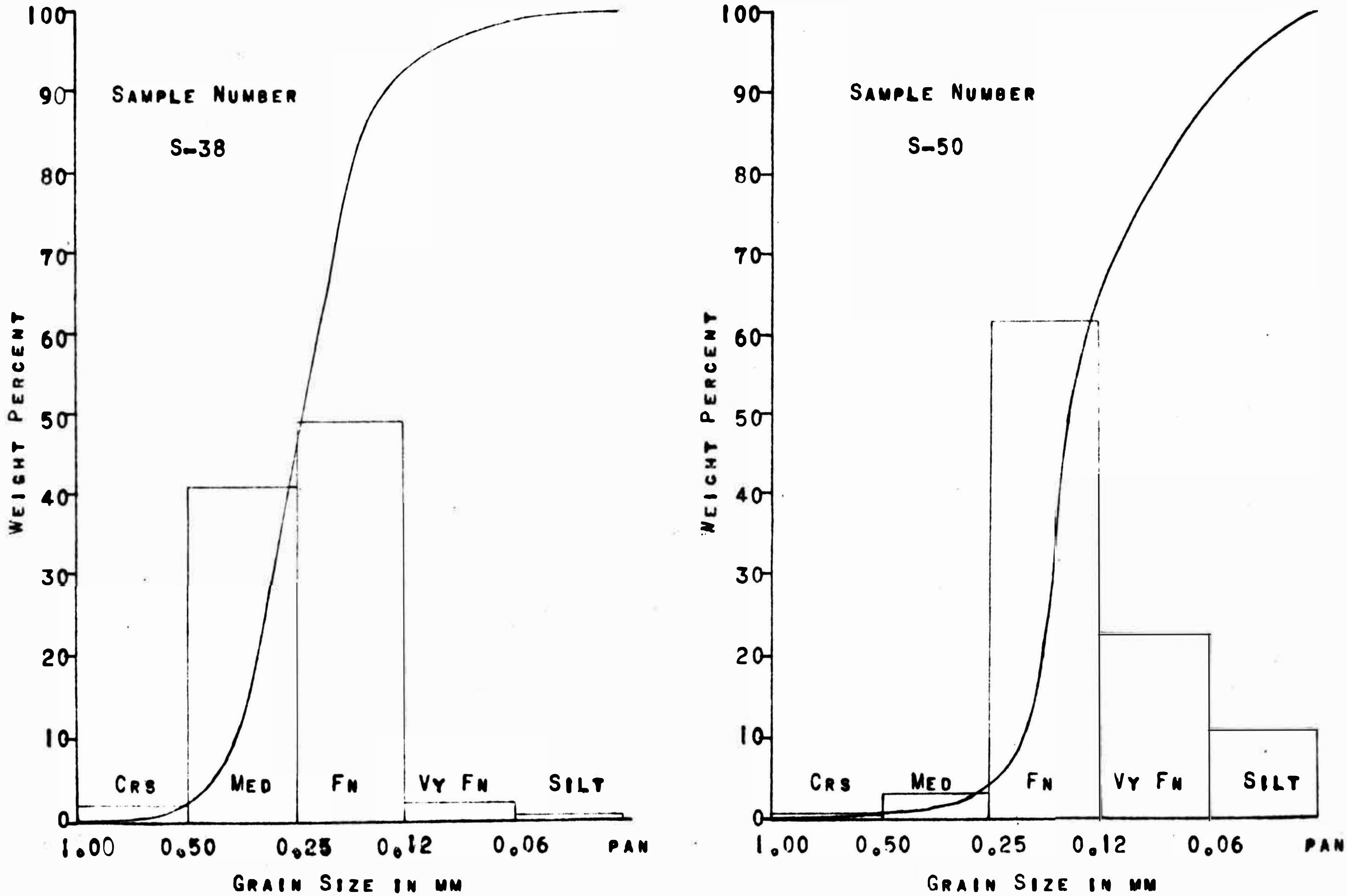


Fig 17

TYPICAL HISTOGRAMS AND CUMULATIVE CURVES - RED SANDSTONE ZONE

Roundness and Sphericity: The grains are subangular to subrounded and have a sphericity of approximately 0.7 to 0.9.

Most of the sandstone is loose and friable. In some localities the sandstone is cemented by calcite to form concretions. These are either hard "cannon-ball" concretions (Figure 18) or elongated elliptical sandstone "logs" or "rolls" (Figure 19). Throughout much of the Pumpkin Buttes Area, uranium ore is localized in or near the latter type of concretion. The concretions range in size from a few inches to several feet in diameter and may be several hundred feet long. All the concretions observed show a general north-south orientation.

The sandstones are massive and are normally cross-bedded. The lenses are usually 20 to 50 feet thick, but may be over 100 feet thick in places. They interfinger with finer grained clastics, and in some cases appear to be channel fills. Most reports on the area consider them to be channel or flood plain deposits derived from a granitic area to the southeast (Love, 1952; Davidson, 1953; Troyer and others, 1954; Sharp and others, 1956).

Although individual sandstone lenses are not extensive enough to provide structural control, the zone of red sandstone occurrence seems to be persistent (Plate 3). The base of this zone was mapped in the Irvine Ranch Area (Plate 2). The top of the zone is not exposed in the area, and any strata lying above the mapped base may contain red sandstone lenses. All known uranium ore in the

Fig. 18. Outcrop of "cannon-ball" concretions.

Fig. 19. Sandstone "rolls" or "logs" in Wasatch formation.

Wasatch formation of the Pumpkin Buttes Area occurs within this zone.

The sedimentary environment of the Wasatch formation was fluvial, with deposition occurring in separate depressions. A warm, humid climate (Wegemann, 1928; Van Houten, 1948) supported much vegetation which was deposited in the various basins and formed discontinuous coals. Plant remains are common throughout the section, and several bone fragments were found near the base of the red zone. The bone fragments have been tentatively identified [1], on the basis of size only, as <u>Coryphodon</u>, a large land vertebrate of early Eocene age.

(1) Identification by Dr. J. R. MacDonald, So. Dak. School of Mines and Technology, Rapid City, South Dakota.

<u>White River Formation:</u> Although the White River formation does not outcrop in the Irvine Ranch Area, Love (1952) attributes the uranium occurrences in the region to solutions of uranium from the tuffs of the White River formation followed by redeposition and concentration in the Wasatch.

The White River in the Pumpkin Buttes Area was first identified by Love, and is considered Oligocene in age. It consists of a coarse grained to conglomeritic sandstone in which most of the pebbles are derived from the Big Horn Mountains to the west. About 15 percent of the pebbles are Tertiary volcanics similar to those farther west and different than the volcanics to the south and east. The grains are held together by silica cement and form the highly resistant caprock over the Pumpkin Buttes.

The caprock is overlain in some places by a white and pink tuff and bentonitic claystone facies which correlates with similar deposits in all directions. Love believes that this facies once covered the entire Powder River Basin (Figure 13).

The White River formation overlies the Wasatch formation with an erosional unconformity marked by local channel filling (Troyer and others, 1954).

Structure

The structural map of the Irvine Ranch Area (Plate 2) is drawn on the base of the red sandstone zone. Vertical control is based on the topographic map (Plate 1).

A synclinal axis in the Wasatch formation nearly parallels the axis of the Powder River Basin and follows the general course of the Dry Fork of the Powder River. An anticlinal nose is present in the northern part of the area. A synclinal depression in the northeast corner separates the anticlinal nose from the Pumpkin Buttes Anticline to the east (Figure 14).

The Wasatch formation in the Irvine Ranch Area does not dip more than five degrees except where locally affected by slumping, and usually the dips are so slight as to be imperceptible to the eye. Due to Laramide uplifting of the Big Horn Range the Fort Union formation dips 15 to 20 degrees northeast in the southwest corner of the area. A cross-section of the area is shown in Figure 20.

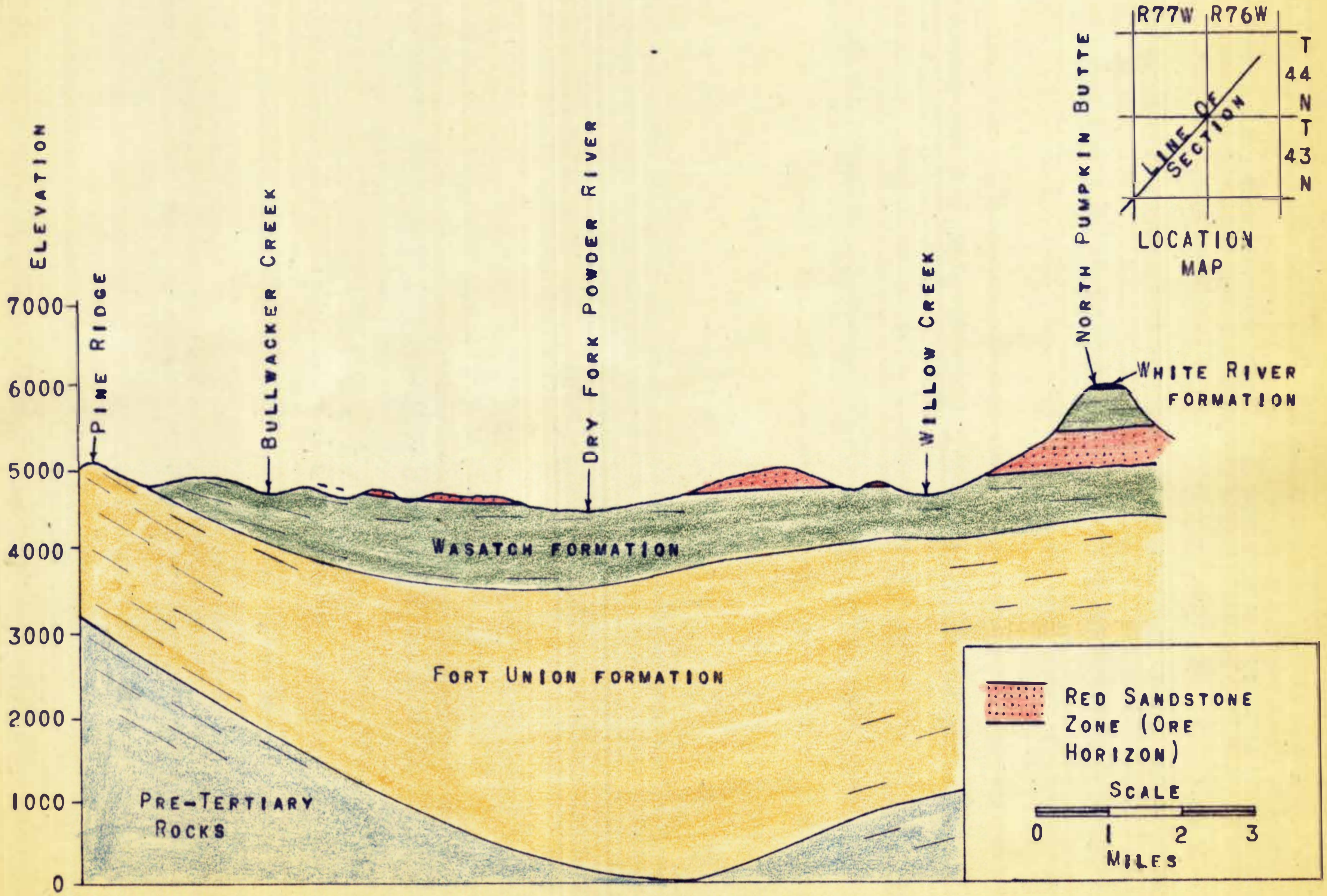


FIG 20

SECTION ACROSS IRVINE RANCH AREA
FROM PINE RIDGE TO NORTH PUMPKIN BUTTE

ORE OCCURRENCES

All of the known uranium deposits of the Pumpkin Buttes Area occur in a sandstone zone which extends from about 500 feet above the base of the Wasatch formation to about 800 feet above the base (Plate 3). Due to erosion of the upper horizons, only the lower 150 to 200 feet of the zone is present in the Irvine Ranch Area.

The ore-bearing horizon is characterized by numerous lenses of red sandstone which are found only in this zone. The areal extent of the zone is shown in Figure 21.

The uranium ores are found in two types of deposits. Carnotite and metatyuyamunite disseminated through porous sandstones form the most important type. Of lesser importance are small, highly radioactive concretions which contain yellow and orange uranium minerals associated with dark bands of iron and manganese oxides.

Most of the uranium occurs in buff or tan sandstones and usually occurs near the contact of the buff or tan sandstone with red sandstone. Only two occurrences of ore enclosed by red sandstone were observed. In both cases the mineralization was near the red-buff contact and appeared to be in an extension of red sandstone into the buff.

Although uranium is found throughout the red sandstone zone, most of the occurrences were within a hundred feet of the base (Plate 2). The mineralization shows no definite relationship to sedimentary features such as bedding, grain size, or sorting within the zone. Hard layers of calcareous sandstone occur irregularly throughout the deposits.

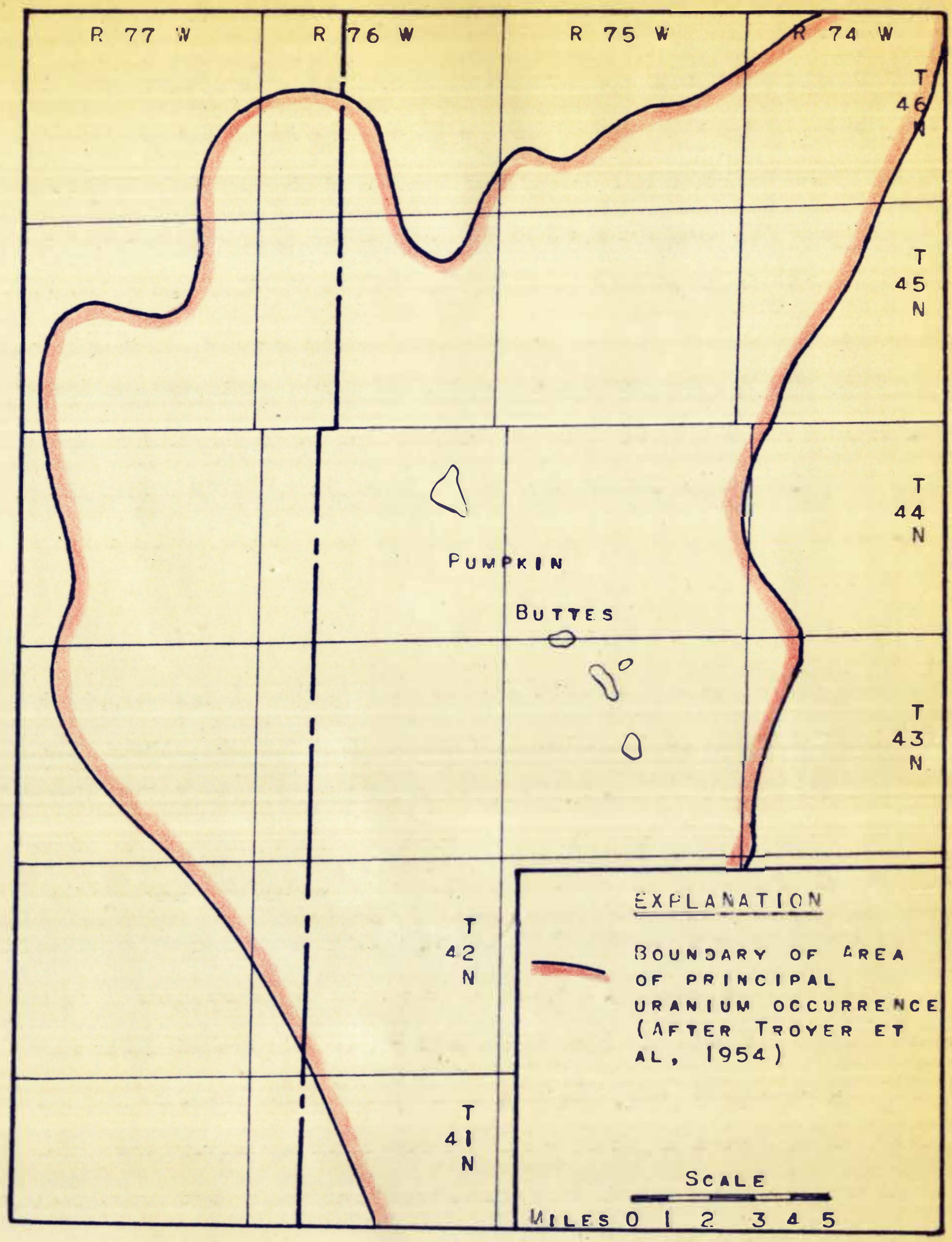


FIG. 21

AREA OF PRINCIPAL URANIUM OCCURRENCES
PUMPKIN BUTTES, WYOMING

Carbonaceous plant material is disseminated through most of the mineralized sandstone and is frequently associated with pockets of high-grade ore (Figure 22). The uranium minerals occur as grain coatings or interstitial material between the sand grains (Figures 23 and 36).

The samples were all examined megascopically and with the binocular microscope. Selected specimens were cut and polished and were examined in reflected light with the petrographic microscope. Thin sections were also prepared and examined by transmitted light. Where necessary, x-ray and chemical analyses were made. Brief sample descriptions are given in Appendix II.

All samples were examined radiometrically with the Precision Model 111 Scintillator (Figure 24). The samples were also analyzed with the Scalar Counter, manufactured by Nuclear Research and Development Corporation, St. Louis, Missouri (Figure 25).

Scalar Counter Procedure

A set of standard values was found by testing samples which had been analyzed by the Atomic Energy Commission and determining the radiation of these in counts per minute (Table 1). These values were than set up in graphical form (Figure 26) using percent U_3O_8 as abscissa and counts per minute as ordinate. The values were plotted on log-log paper. The accuracy of the graph is proportional to the accuracy of the counting.

The radiation from each sample was counted for ten minutes and the average count per minute determined.

Fig. 22. Carbonaceous plant material in ore bearing sandstone.

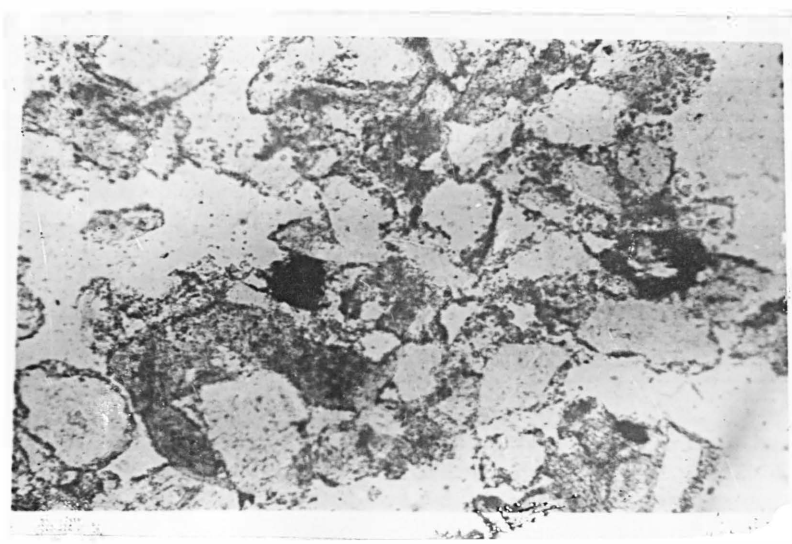


Fig. 23. Microphoto of a thin section showing interstitual carnotite coating sand grains. The dark fringes around the grains are carnotite.

Fig. 24. Precision 111
Scintillator.

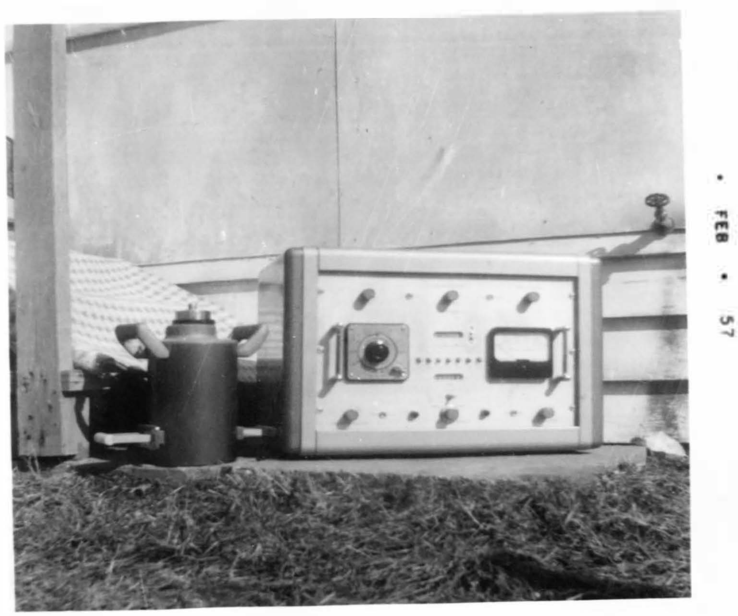


Fig. 25. Scalar Counter

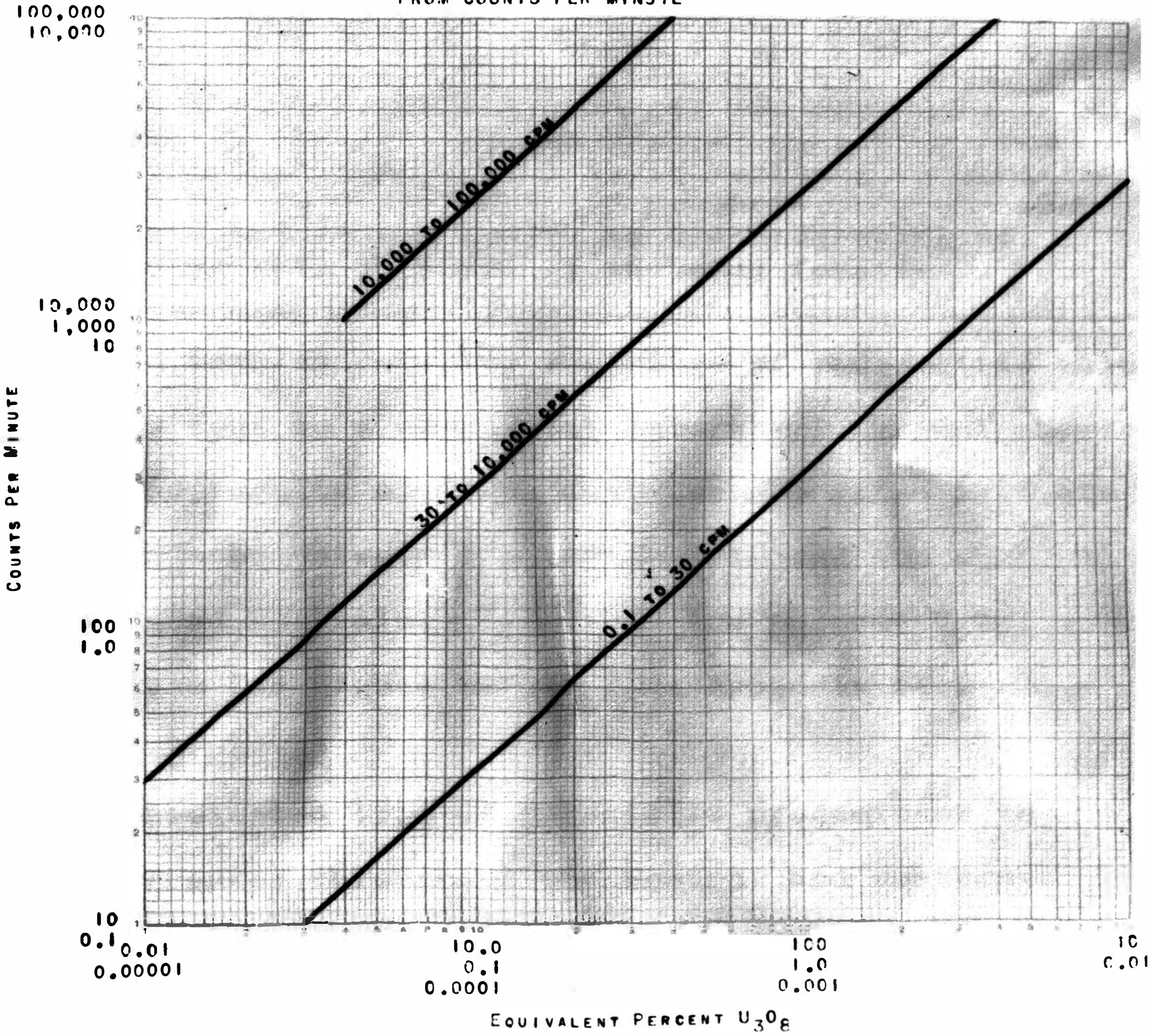
Table 1

Counts per minute from standard samples as measured on the Scalar Counter.

Sample No.	Chemical Assay Percent U_3O_8	Counts per minute
1	0.1	293.6
2	0.3	817.8
3	0.5	1341.4
4	0.75	2115.4
5	1.0	2620.0
6	1.5	4068.6

Fig. 26

CURVE FOR OBTAINING
EQUIVALENT PERCENT U_3O_8
FROM COUNTS PER MINUTE



Calibration of the counter with no samples in the sample holder gave an average background count of 20 counts per minute. The count for each sample was adjusted for this constant. By the use of the graph (Figure 26) the equivalent percent [2] U_3O_8 was obtained for each sample (Appendix II).

---

(2) Equivalent percent U_3O_8 is based on the assumption that all of the radioactivity of a sample arises from uranium and its disintegration products and that none of the radioactivity arises from the thorium series or from potassium; and that the uranium is in radioactive equilibrium with all of its disintegration products, wherein each radioactive product in the series is disintegrating at exactly the same rate at which it is being formed.

Selected samples covering the range of radiometric values obtained were sent to a commercial laboratory for wet chemical analysis. The results of these analyses are given in Table 2. The correspondence between the radiometric and the chemical analyses is good for values less than one percent U_3O_8, and is fairly close for higher values (see Appendix II).

Disseminated Deposits

The disseminated type of deposit is predominant in uranium occurrences throughout the central and western parts of the Irvine Ranch Area. These deposits are extremely irregular in size and shape, but are normally fairly constant in ore grade, averaging about 0.15 to 0.35 percent U_3O_8. Some pockets of higher grade ore occur within the disseminated deposits, but these are small and their occurrence is irregular.

The dominant uranium mineral of the disseminated deposits is carnotite. It occurs as a very fine-grained coating on

Table 2

Chemical Analyses of Selected Samples

ENGINEERS
INSPECTIONS and TESTS

The Bruce Williams Laboratories

ESTABLISHED 1898
Main Office 618-622 Joplin Street Telephone MA 3-1556
JOPLIN, MISSOURI

CHEMISTS
INDUSTRIAL and ANALYTICAL

Batesville, Ark.
151 No. Central
Telephone 1309

Picher, Oklahoma
Connell Hotel Bldg.
Telephone 710

Emporia, Kansas
321 Union St.
Telephone 3684

St. Louis, Missouri
306 Valley Drive
Telephone Hobart 7-3226

CORRECTED CERTIFICATE

Mr. Gale Butterfield
Nagagomi Court #4
Rolla, Missouri

1-9-57

OUR NO.	MARK	DESCRIPTION	URANIUM AS U_3O_8
756472	Sample #10		0.500
473	#14		0.026
474	#16		4.20
475	#21		7.13
476	#30		0.020
477	#37		0.160
478	#46		17.60
479	#50		1.040

Bruce Williams

the sand grains and as a crystalline aggregate filling the pore spaces between the sand grains (Figure 23). The carnotite is usually bright yellow or yellow-green in color. Even small amounts of the mineral give the host sandstone a distinctive yellow color.

Sharp and others (1956) reported tyuyamunite, metatyuyamunite, uranophane, and very rarely hewetite as interstitial filling in the disseminated deposits of the eastern part of the Pumpkin Buttes Area. They distinguished the uranophane and hewetite on the basis of their acicular habit and optical properties; however, in the Irvine Ranch Area, most of the minerals of the disseminated deposits are too finely crystalline to be determined optically. X-ray and chemical analysis was therefore employed. Most samples collected for this study gave no indication of the presence of uranium minerals other than carnotite and metatyuyamunite.

Calcite and calcareous cement were present in some of the samples and absent in others. No definite relationship between the calcite content and uranium mineralization could be established. There was, however, a noticeable relationship between the uranium mineralization and the color of the iron compounds present. In places the iron compounds give the sandstones a distinctive red color, and where not stained red, the sandstone is buff or gray in color. The red sandstone does not normally contain uranium mineralization. The contact between the red sandstone and the buff or gray sandstone is usually fairly sharp but may be quite irregular and gradational. The uranium generally occurs in the buff or gray sandstones at or near the contact with the red.

It may be that the state of hydration of the iron compounds is related to factors effecting ore deposition. Apparently the buff sandstone, in which the iron oxides are presumably hydrated, is a more favorable host rock than is the red sandstone.

The only operating mine in the Irvine Ranch Area during the time of this study was the Wydal Mine in the NW$\frac{1}{4}$, Sec 10, T 43 N, R 77 W. This mine was shipping about 300 tons of ore containing about 0.20 percent U_3O_8 per month from a disseminated type ore body. The extent of the body had been partially determined by drilling and probing the drill holes with a Geiger counter (Figures 27 and 28).

The mining was done by removing the overburden with a bulldozer (Figure 29), and digging and loading the ore with a 180 degree backhoe mounted on a tractor (Figure 30). The small size and easy maneuverability of the backhoe permitted selective mining necessary to maintain the grade of the ore.

Holes were drilled on ten foot centers through the ore body and loaded with light charges of dynamite. The blast from the charge broke but did not mix the rock. This permitted easy removal of both ore and overburden without mixing the two.

Another mining venture, the Kram Mine, was started a short distance to the north of the Wydal Mine and along the

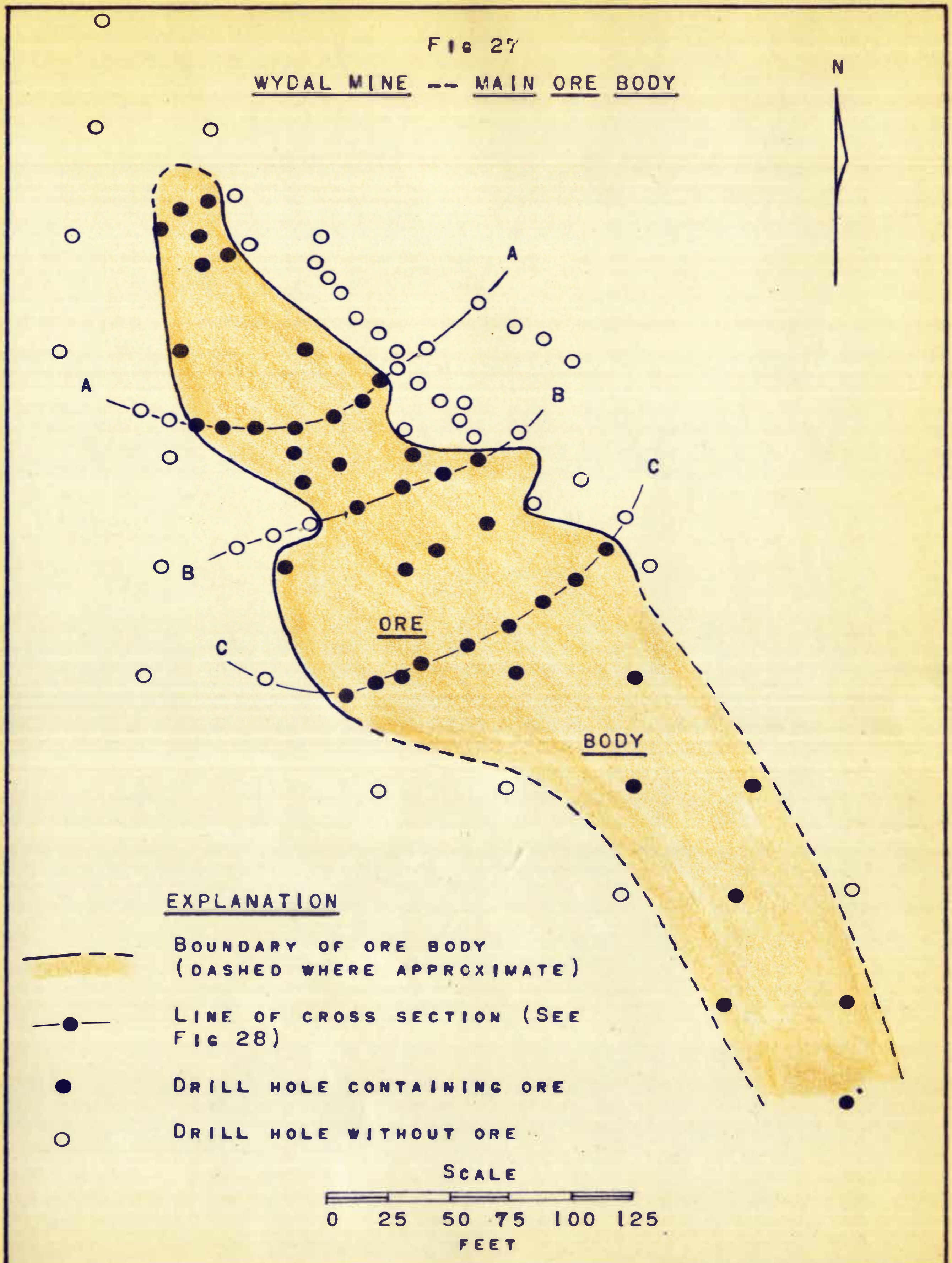


Fig 27
WYDAL MINE -- MAIN ORE BODY
N
A
A
B
B
C
C
ORE
BODY
EXPLANATION
Boundary of ore body (dashed where approximate)
Line of cross section (See Fig 28)
Drill hole containing ore
Drill hole without ore
Scale
0 25 50 75 100 125
FEET

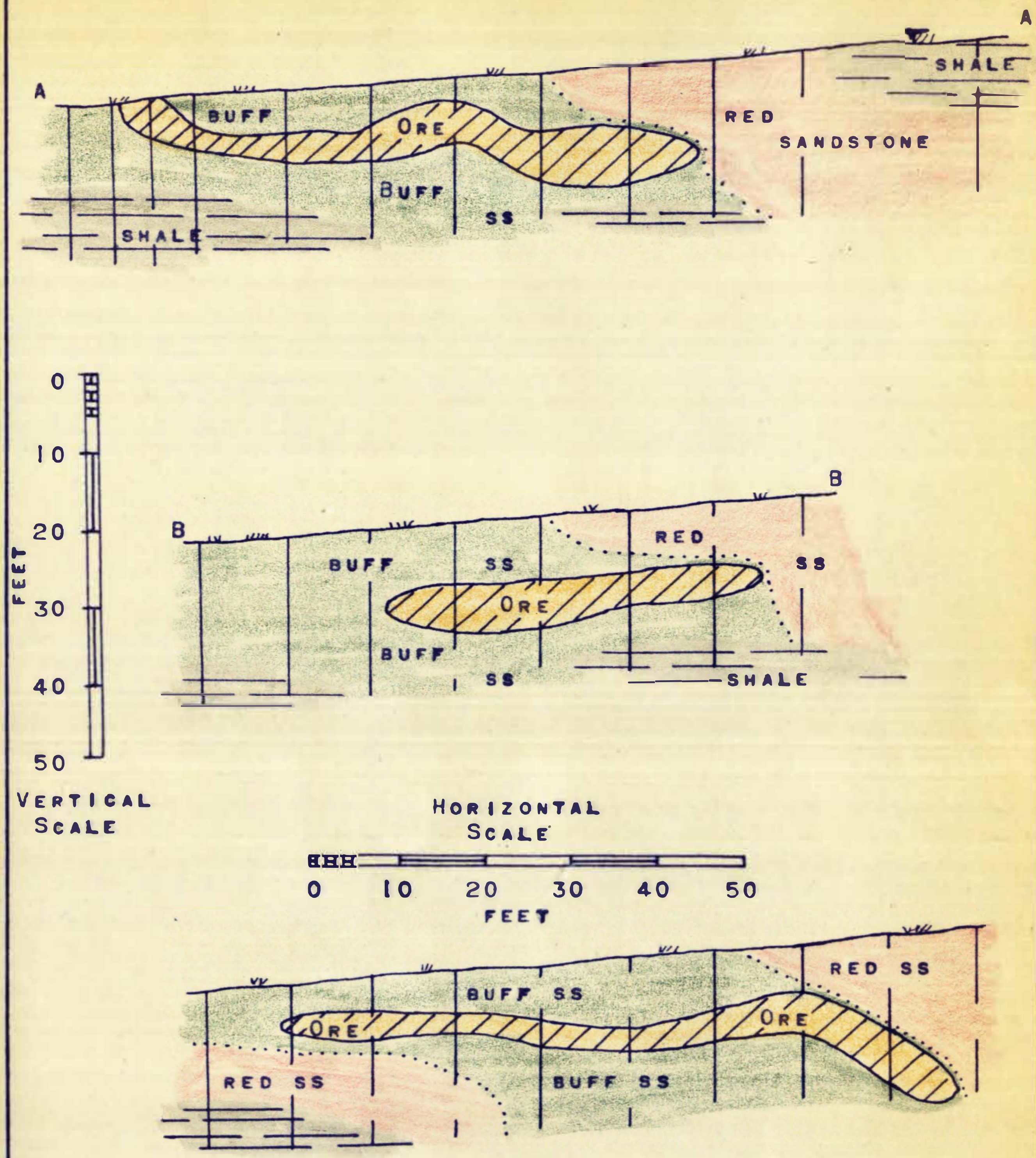


FIG 28

SECTIONS ACROSS WYDAL MINE ORE BODY

Fig. 29. Bulldozer removing
overburden at Wydal Mine.

Fig. 30. Tractor with backhoe
loading ore at Wydal Mine.

same ridge. Several loads of ore were shipped from this property but due to insufficient grade the ore was rejected by the buying station at Riverton, Wyoming. It appeared that more selective mining at the Kram operation would have resulted in ore of sufficient grade to have merited acceptance.

A radiometric survey of the ridge between the two mines was made. The radiometric contours are shown in Figure 31.

A radiometric survey was also made of an anomaly near the center of Sec 28, T 44 N, R 77 W. This survey is shown in Figure 32. Yellow disseminated ore was found near the base of the soil zone and also in thin (one to four inch), nearly vertical veins. This is one of the most promising undrilled anomalies of the area.

Other prospective localities which appeared to justify drilling are the anomalies in the NE$\frac{1}{4}$, Sec 27 (Figure 33); NE$\frac{1}{4}$, Sec 35; NW$\frac{1}{4}$, Sec 36, T 44 N, R 77 W; and NW$\frac{1}{4}$, Sec 35, T 43 N, R 77 W. Abandoned mines were found in the SE$\frac{1}{4}$, SE$\frac{1}{4}$, Sec 35, T 43 N, R 77 W (Sundance Mine - Figure 34); and in the NE$\frac{1}{4}$, Sec 20, T 44 N, R 77 W.

Concretionary Deposits

Concretionary uranium deposits are normally very small concretions of high grade material with values running as high as 25 percent U_3O_8. These deposits occur as small rounded or tabular concretions (Figure 35). Unfortunately the size of individual concretions is normally very small, the average concretion being only a few inches across.

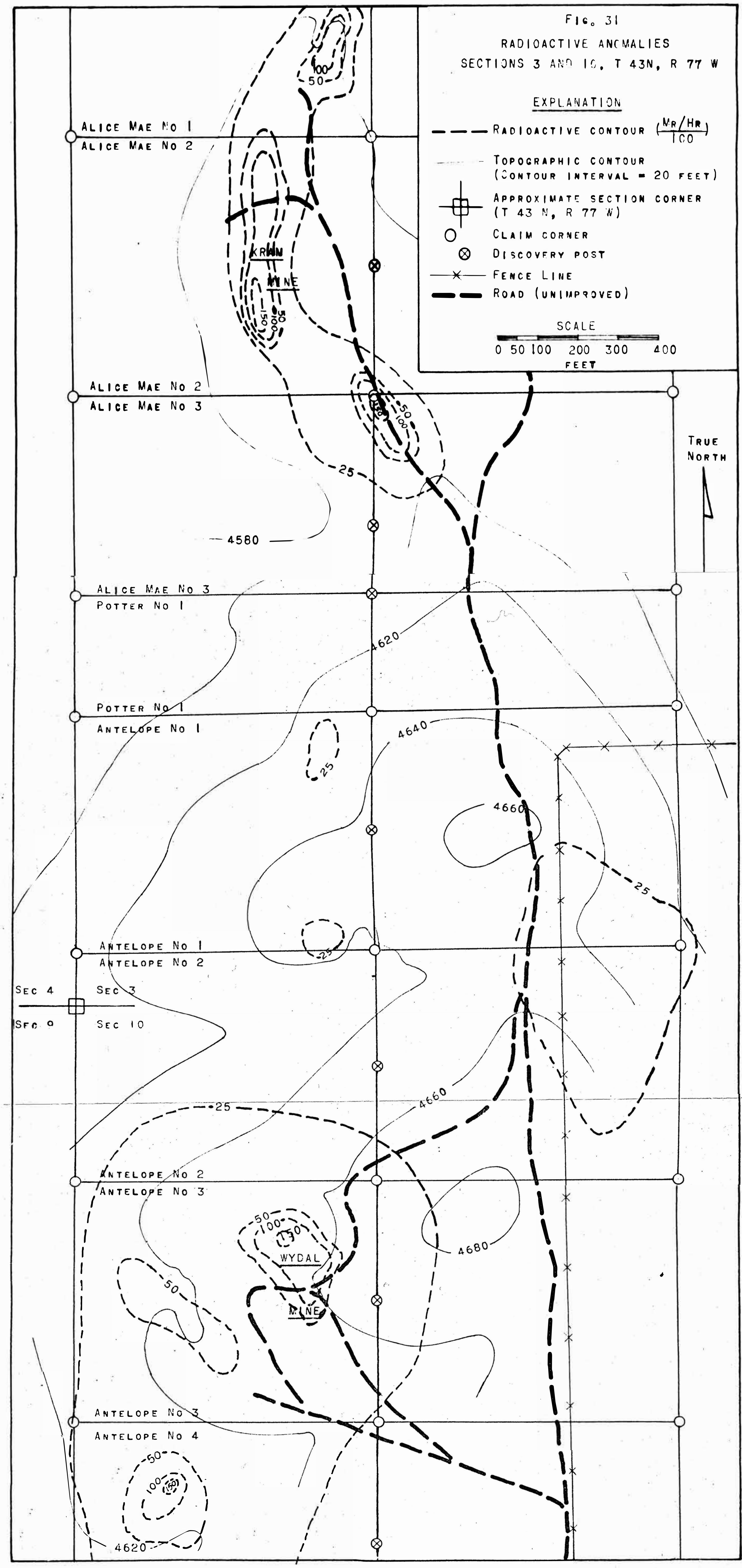


Fig. 31
RADIOACTIVE ANOMALIES
SECTIONS 3 AND 10, T 43N, R 77 W
EXPLANATION
Radioactive contour (Mr/Hr / 100)
Topographic contour (Contour interval = 20 feet)
Approximate section corner (T 43 N, R 77 W)
Claim corner
Discovery post
Fence Line
Road (unimproved)
SCALE
0 50 100 200 300 400
FEET
True North
Alice Mae No 1
Alice Mae No 2
Alice Mae No 3
Potter No 1
Antelope No 1
Antelope No 2
Antelope No 3
Antelope No 4
Sec 4
Sec 3
Sec 9
Sec 10
KRAM
MINE
WYDAL
MINE
4580
4620
4640
4660
4680

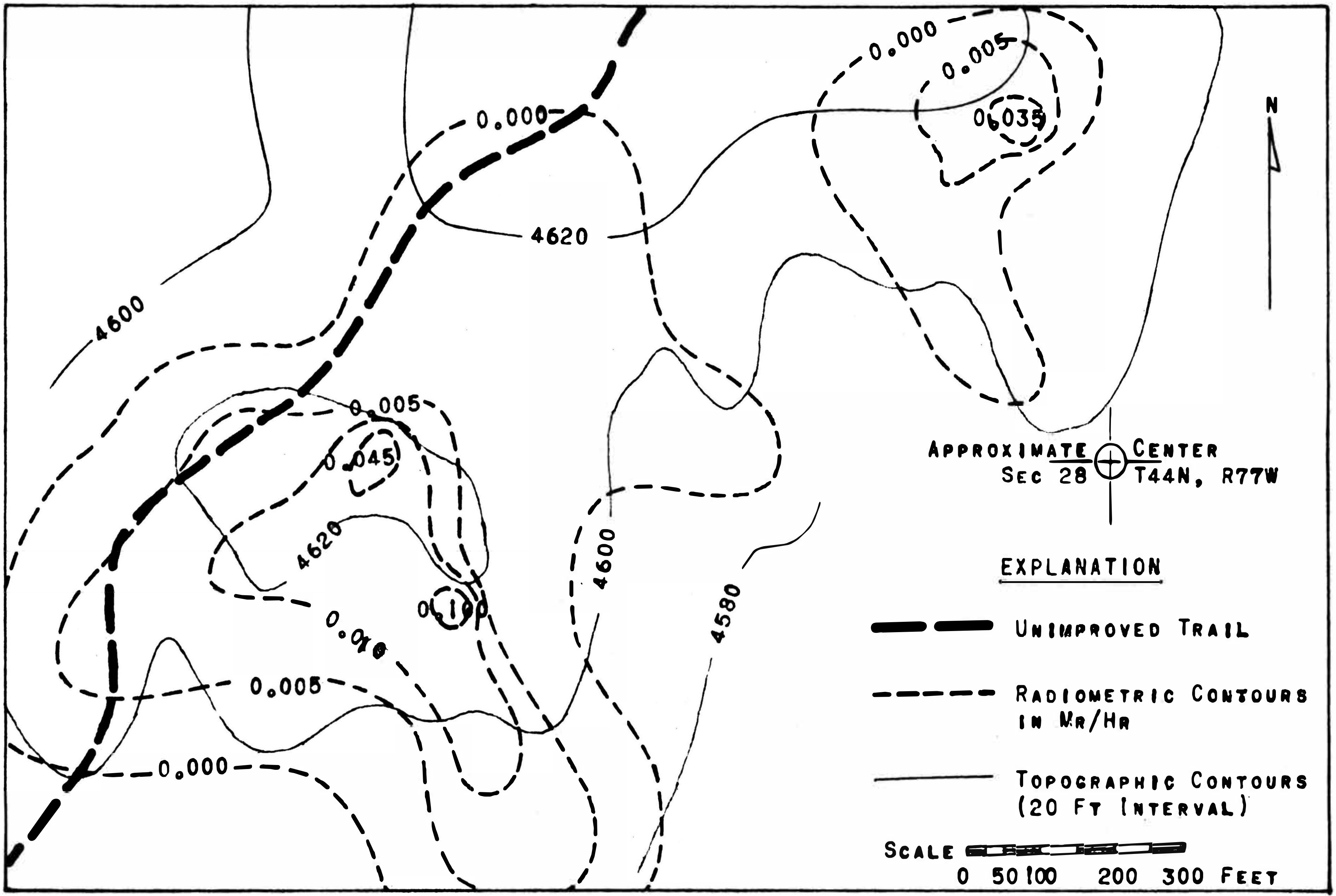


Fig. 32

MAP OF RADIOACTIVE AREA IN SEC 28, T 44 N, R 77 W.

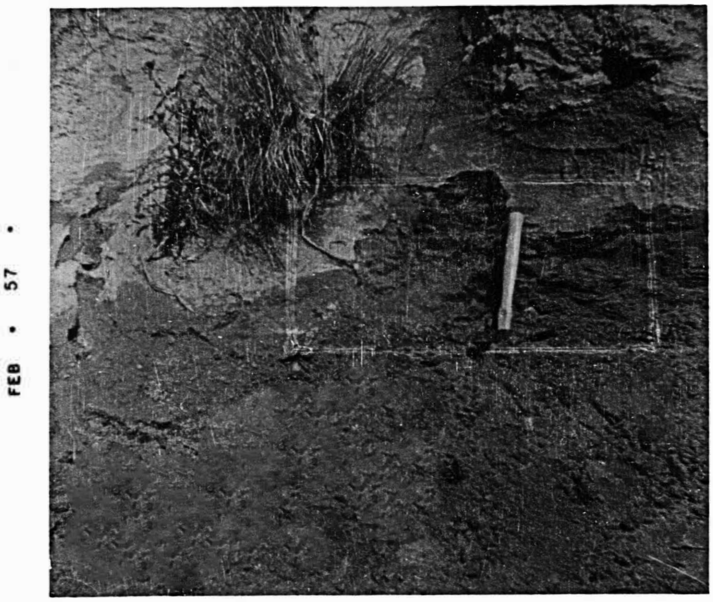


Fig. 33. Uranium mineralization disseminated in buff sandstone, Sec 27, T 44 N, R 77 W.

Fig. 34. Open face at Sundance Mine (abandoned)

Fig. 35. Tabular concretions containing uranium minerals.

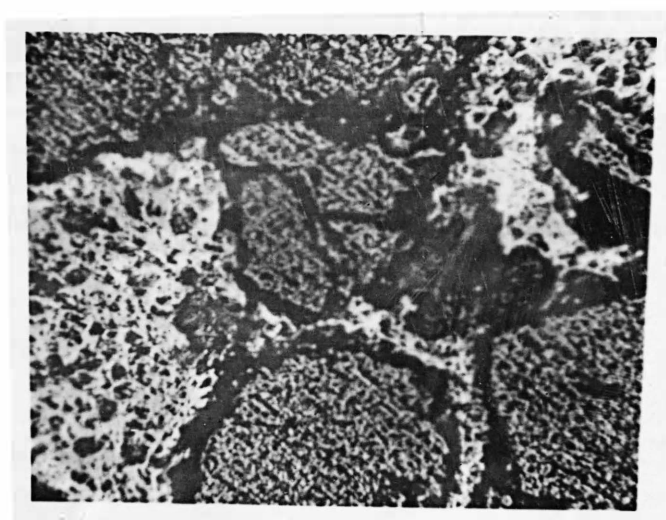


Fig. 36. Microphotograph of a polished surface of concretionary sample S-46. Dark grains are sandstone (quartz) with light-colored carnotite filling the spaces between the sand grains.

Concretions occur in groups within the sandstone, and there may be as many as ten or twelve within a few feet of each other. The small size of the concretions keeps them from being of economic value.

The concretionary deposits present a more complicated mineralogic problem than do the disseminated deposits. They normally consist of a core of dark minerals surrounded by bright colored uranium oxides. The central core ranges in thickness from a tenth of an inch to an inch or more, and the bordering zones of oxidized minerals may be several inches thick.

The dark core contains iron and manganese oxides (pyrolusite ?) associated with a black, opaque, resinous appearing mineral which resembles uraninite or pitchblende. These minerals occur as interstitial filling between sand grains. X-ray diffraction patterns from this material are shown in Figure 37. These patterns have the spacings recorded in Table 3. The spacings could not be correlated with any published data on uranium, thorium or vanadium minerals.

The dark core of a concretion is normally bounded by a zone of orange, yellow, and yellow-green, platy uranium minerals. The orange minerals generally occur next to the black core and may be somewhat disseminated within the core. The orange mineral was determined both optically and by x-ray diffraction to be carnotite. The yellow to yellow-green mineral also borders the black but may be separated from it

Fig. 37

X-ray Diffraction

Pattern of Dark Mineral

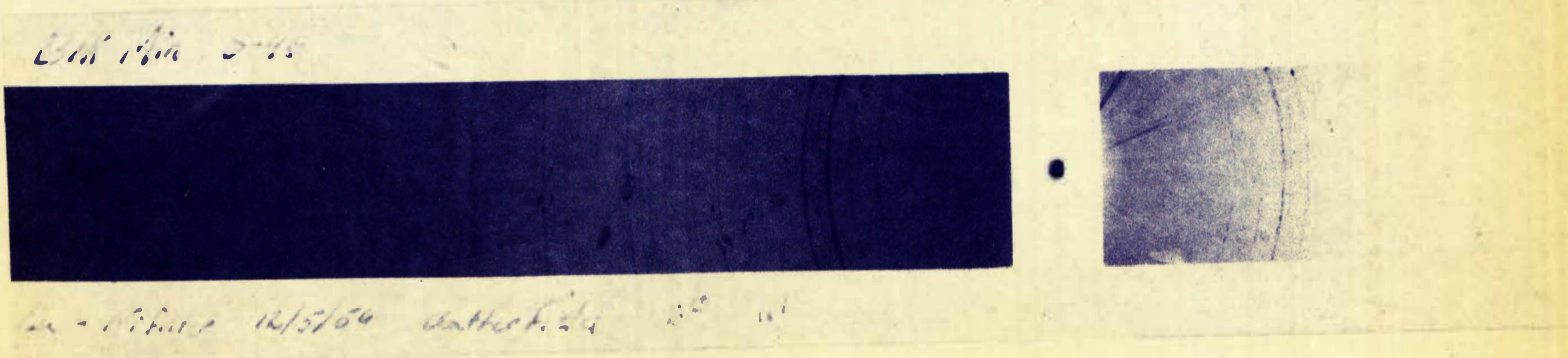


Fig. 37

X-ray Diffraction

Pattern of Dark Mineral

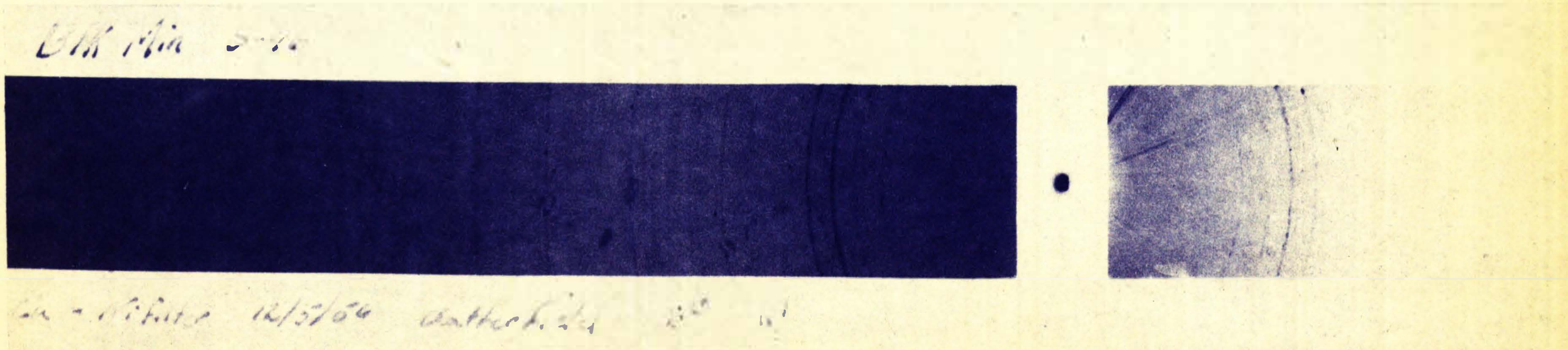


Table 3

d-SPACINGS OF DARK MINERAL

Sample No: S-46

Target: Copper Filter: Nickel

Line No.	Intensity	dA
1	1	4.67
2	1	4.04
3	3	3.83
4	5	3.69
5	3	3.48
6	2	3.20
7	8	3.02
8	1	2.18
9	3	2.08
10	1	2.01
11	3	1.91
12	4	1.87
13	1	1.71
14	1	1.62
15	2	1.60
16	3	1.51

Note: The sample was also found to contain much quartz, the spacings of which are omitted in the above table.

by a zone of the orange carnotite. This mineral was also identified as carnotite. A polished section demonstrating mineral relationships is shown in Figure 36 of this report. A typical x-ray pattern of carnotite is shown in Figure 38, and corresponding d-spacings are given in Table 4.

The radioactive concretions are usually found in sandstones which are coarser in texture than the sandstones which contain disseminated deposits.

<u>Origin of Uranium Deposits</u>

Sharp and others (1956) say, "because all deposits (of the Pumpkin Buttes Area) are in sandstone units enclosed by almost impermeable non-uraniferous rocks, the uranium source may be constituents of the sandstone". Field examination of the Irvine Ranch Area did not substantiate the idea that the uranium bearing sandstones were enclosed by impervious rocks. Although there were many shale bodies within the red sandstone zone (Plate 3), and shales occurred both above and below the sandstones, there is no evidence that the sandstone lenses were discontinuous to the point of being completely isolated from each other. In fact, mapping of the zone and measurement of sections would tend to support the opposite idea.

There are no known igneous intrusions, dikes, sills, or major mineralized fault zones within the Pumpkin Buttes Area. Without some such evidence of magmatic activity, there is no justification of proposing a magmatic origin for the deposits, and so far as is known, there has been no such proposal for this area.

Fig. 38

X-ray Diffraction

Pattern of Carnotite

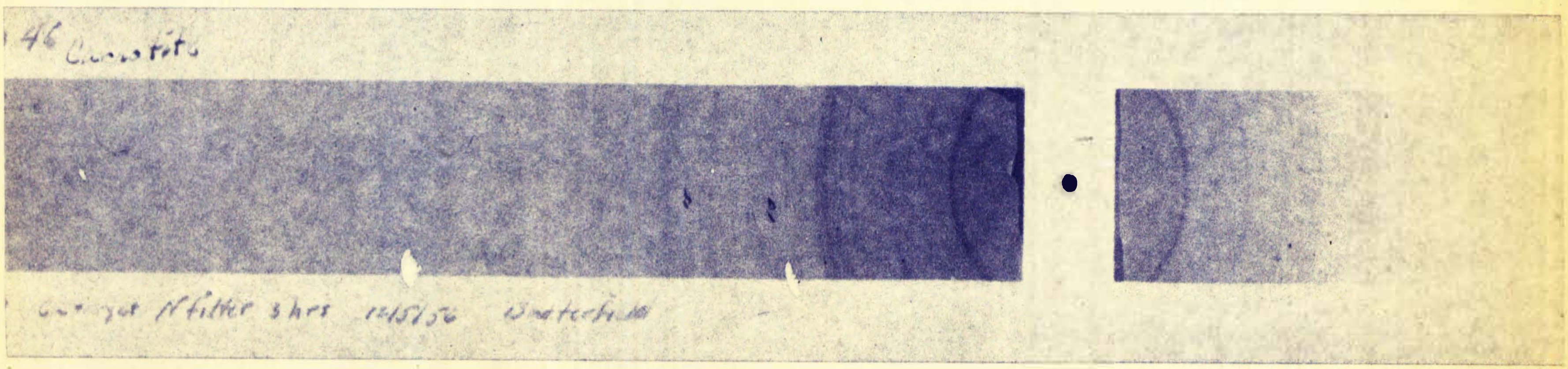


Table 4

d-SPACINGS OF CARNOTITE

Sample No: S-46

Target: Copper Filter: Nickel

Line No.	This Report Intensity	This Report dA	Frondel and others, 1956 Intensity	Frondel and others, 1956 dA
1	10	6.49	10	6.56
2	2	5.07	1	5.12
3	8	4.20	3	4.25
4	8	3.53	5	3,53
5	2	3.25	3	3.25
6	9	3.10	7	3.12
7	1	2.70	1	2.71
-	-	----	½	2.59
8	1	2.56	2	2.57
9	1	2.48	1	2.48
10	1	2.15	3	2.16
11	1	2.05	1	2.03

Note: The sample also contained a small amount of quartz, the spacings of which are omitted from the above table.

Uranium mineralization could conceivably have taken place contemporaneously with the deposition of the host sandstone, but is generally considered to be later (Love, 1952; Vine, 1956). Radioactive dating of the uranium compared to ^{14}C dating of carbonaceous material in the sandstone indicates that the uranium minerals are considerably younger than the host sandstone.

Possible genetic relationships between uranium and petroleum have been suggested (Vine, 1956). There are several petroleum occurrences within short distances of the area. The petroleum bearing formations are considerably older than those containing uranium deposits and it becomes difficult to confirm a direct relationship. A relationship apparently exists, however, between the uranium mineralization and carbonaceous plant material within the sandstone (Figure 22).

Love (1952) proposed that the uranium in the Wasatch formation was derived from the volcanic tuffs and claystones of the White River formation (Oligocene). He found this formation to have abnormally high radioactivity, and concluded that the White River formation at one time covered the entire Powder River Basin. Computations of the amount of available uranium from weathering of the formation (Vine, 1956) show that there would have been sufficient uranium available to provide all known concentrations in the area.

Acidic rain waters, relatively high in CO_2, would tend to dissolve the uranium minerals of the tuff and carry

The new uranium procurement program will provide a guaranteed market for all uranium concentrates produced by domestic mills from domestic ores, subject to compliance with Commission specifications and to a stipulation that the Commission reserves the right to limit its purchases from any one mining property or mining operation to 500 tons of U_3O_8 per year. No commitment has been made for purchase of vanadium after March 31, 1962. The new program will go into effect April 1, 1962, and will continue through December 31, 1966.

Under the new program the Commission has established a base price for uranium concentrates. They will no longer buy untreated ore as was formerly the case. The base price will be $8 per pound of U_3O_8 contained in concentrates that comply with specifications. This arrangement is applicable to the type of high-grade concentrates now being sold under agreements between private milling companies and the government.

If in excess of 500 tons of U_3O_8 per year is purchased from any one mining property or mining operation the price paid for the excess may be less than $8 per pound of U_3O_8.

A schedule of present prices for various assays of crude ore, including grade premiums, development allowance, initial production bonus and mileage (as applicable to the Irvine Ranch Area) is given in Table 5.

Table 5

Schedule of Ore Prices

Grade Percent U_3O_8	Pounds U_3O_8 Per Ton	Price Per Ton	Grade Premium	Mine Develop. Allowance	Price Before Prod. Bonus & Haulage	Initial Prod. Bonus	Haulage @ 100 Miles	Total
0.10	2.00	$ 3.00	--	$ 1.00	$ 4.00	$ 3.00	$ 6.00	$ 13.00
0.15	3.00	7.50	--	1.50	9.00	7.50	6.00	22.50
0.20	4.00	14.00	--	2.00	16.00	14.00	6.00	36.00
0.25	5.00	17.50	0.75	2.50	20.75	17.50	6.00	44.25
0.30	6.00	21.00	1.50	3.00	25.50	21.00	6.00	52.50
0.35	7.00	24.50	2.25	3.50	30.25	24.50	6.00	60.75
0.40	8.00	28.00	3.00	4.00	35.00	28.00	6.00	69.00
0.45	9.00	31.50	3.75	4.50	39.75	31.50	6.00	77.25
0.50	10.00	35.00	4.50	5.00	44.50	35.00	6.00	85.50
1.00	20.00	70.00	14.50	10.00	94.50	70.00	6.00	170.50
5.00	100.00	350.00	94.50	50.00	494.50	350.00	6.00	850.50
10.00	200.00	700.00	194.50	100.00	994.50	700.00	6.00	1700.50

Current prices on uranium ore as set forth in Domestic Uranium Program Circular 5 (revised) are as follows:

U_3O_8 Assay:	Payment per pound U_3O_8
0.10 percent	$ 1.50
0.11 percent	1.70
0.12 percent	1.90
0.13 percent	2.10
0.14 percent	2.30
0.15 percent	2.50
0.16 percent	2.70
0.17 percent	2.90
0.18 percent	3.10
0.19 percent	3.30
0.20 percent and more	3.50

There is no payment made for ores assaying less than 0.10 percent U_3O_8.

Private industry is showing much interest in harnessing the atom as a source of peacetime energy. There seems little doubt that atomic fuel will tend to replace conventional fuel such as coal in stationary electric generating plants, whereas the coal will be more economically utilized as a source of chemicals. Furthermore, nuclear energy will find increasing use in powering ships and submarines, where the weight of shielding devices is relatively unimportant.

Lessening of government controls and release of classified research will tend to accelerate peacetime use of atomic energy, thus furnishing an expanding market for uranium ore.

An inhibiting factor, however, is the possibility of government requisition of all uranium fuels in the event of war.

Another problem faced by United States uranium producers is the fact that most of our uranium ores are low grade. These domestic ores would be at a disadvantage in nonsubsidized competition with high grade African and Canadian ore.

Exploration and Mining Costs

Many of the uranium deposits of the Irvine Ranch Area are of high enough grade to be commercial ore. The biggest problem is one of volume, for many of the deposits are very small, and considerable exploratory and "block-out" drilling should be done prior to expending any money for equipment or development.

The main geologic guide to uranium deposits at present is the red sandstone zone. If the sandstone bodies are stream channels as postulated (Love, 1951; Troyer and others, 1954; Sharp and others, 1956), it is to be expected that additional drilling may deliniate the stream patterns and provide a more accurate guide to the location of ore.

Exploration holes can be located anywhere there is a possibility of hitting the red sandstone zone. Radiometric anomalies provide a good basis for exploration, but the absence of an anomaly should not in itself condemn an otherwise favorable location, for only a few feet of overburden will completely absorb the radiation of most of the deposits.

Although cores would provide more information than cuttings, poor core recovery and higher costs than conventional drilling make coring unattractive. Because radioactivity increases in the drill holes with time, due presumably to accumulation of radon gas, it is desirable to probe drill holes immediately after drilling.

The cost of exploratory drilling in this area is about \$ 0.50 to \$ 1.00 per foot depending on depth, distance between holes, terrain, and number of holes. "Block-out" drilling can be contracted for somewhat less cost per foot than exploratory drilling. This is because "block-out" holes are closer spaced than exploratory holes. "Block-out" holes should not be over 50 feet apart, and preferably should be spaced as close as 20 feet to more accurately evaluate the deposits. Typical drilling equipment is shown in Figures 39 and 40.

Aerial reconnaissance has proven useful both for locating radiometric anomalies, and for finding outcrops not normally visible from the ground. In many cases the saving of time will more than offset the cost of aerial exploration.

The uranium deposits observed are all close to the surface. For this reason open pit mining is the only method used in the area. A minimum of equipment would include a bulldozer for removing overburden, a power shovel or loader of such a nature that mining can be selective, haulage trucks, a compressor and drill, and such accessory equipment as hand tools, chains, bits and Geiger counter or scintillometer.

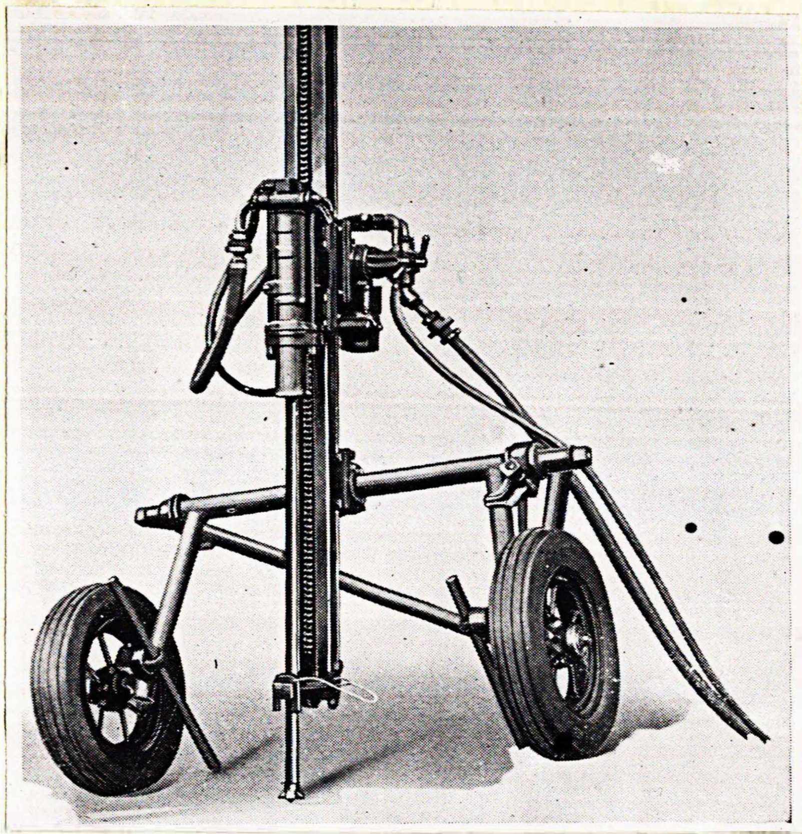


Fig. 39. Wagon Drill

Fig. 40. Rotary Drill

Actual mining costs can only be approximated on the basis of other operations. Wydal Mining Company estimated that their costs, other than exploration and transportation, ran about $ 5.00 per ton. (3) Sundance Mining Company

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(3) Personal conversation, August 1956.

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estimated that their mining costs averaged $ 3.00 per ton (4).

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(4) Personal conversation, July 1956.

The ore from both mines, as well as other similar ores seen in the area, assayed between 0.15 percent and 0.35 percent U_3O_8. The vanadium content was variable, but averaged about $ 1.00 per ton. Moisture content ran about seven percent, thus lessening the value of shipped ore by that amount. The actual selling price of the ore ran between $ 10.00 and $ 40.00 per ton. Selective mining tends to upgrade the ore but reduces volume, and an optimum uranium content would have to be determined for each deposit.

Mine run values in the Wydal area were usually in the neighborhood of 0.20 percent U_3O_8; however, it was possible to ship ore either richer or leaner than this. Most operators felt that maintaining ore at not less than 0.20 percent made for the most profitable operation.

Ore shipments and payments were governed by contracts with the mill at Riverton and were on a monthly settlement basis. Common practice was to build up volume during the early part of the month and ship high-grade during the last of the month to build up average tenor.

The nearest buying station for the ore is at Riverton, Wyoming, a distance of 190 miles. The current trucking rate for contract trucking is $ 9.00 per ton, of which $ 6.00 per ton is recovered under the government mileage allowance program.

Land Ownership

Nearly all of the surface rights in the Irvine Ranch Area are privately owned, with most of the land belonging to the Irvine Ranch; however, the majority of the mineral rights are federally owned and open to claiming.

During the early stages of exploration in the region, the Pumpkin Buttes Mining District, with offices in Gillette, Wyoming, was formed. Most of the founders of the district were landowners, and as a result, the laws of the district gave many advantages to the owner of surface rights and penalized the prospectors with large filing fees and royalties. As much as $ 60,000.00 [5] has been paid for the privilege of prospecting a ranch. Now that the boom is over in the area and many prospectors have gone to greener appearing pastures, prospecting and development can be carried out on either private or federal land by establishing friendly relations with the ranchers and working out equitable agreements for both parties.

(5) Paid by San Juan Uranium Corp. to Earl Brown, November, 1955.

Lease costs and royalty payments are still high ($ 0.50 to $ 1.00 per acre per year rentals and 10 to 15 percent royalty). These payments should continue to drop, and a royalty of two to five percent should take care of surface damage on private land overlying federally owned minerals.

State owned land (school sections) are leased through the Wyoming Land Office at Cheyenne, Wyoming.

SUMMARY AND CONCLUSIONS

The Irvine Ranch Area is situated in the southwestern part of the Powder River Basin, Wyoming. At the time of this study uranium was being mined from one open pit within the area. Several other localities appear to warrant testing by drilling.

The uranium deposits are in a zone of red and buff sandstone lenses. These lenses occur about 500 to 1000 feet above the base of the Wasatch formation (Eocene). The Wasatch formation is exposed over most of the area studied. The zone of sandstone lenses was delineated by stratigraphic studies and geological mapping.

Scintillometer surveys indicated several areas of relatively high radioactivity. Uranium bearing samples were collected in the areas of radioactive anomalies.

The most abundant uranium mineral is carnotite. This is associated with metatyuyamunite and other less important uranium and vanadium minerals. The mineralization occurs in arkosic sandstone lenses as interstitial material coating the sand grains and filling the pore spaces between the grains

Two types of deposits were recognized: (1) disseminated deposits in soft sandstones, and (2) concretionary deposits of small size and high grade. Only the disseminated deposits appear to be large enough to be of commercial value.

The uranium may have been derived from radioactive volcanic tuffs and bentonitic claystones which once covered the entire area (Love, 1952). It is likely that the uranium was dissolved out of the volcanic material and carried in solution by percolating ground water. A change in the acidity of the uraniferous solutions may have caused precipitation of the uranium.

Strong indications of uranium are confined to the zone of sandstone lenses. Commercial production, furthermore, is limited to buff and gray sandstone in close proximity to red sandstone. It seems likely that the same environmental conditions that caused precipitation of uranium also altered the iron compounds which color the host rocks. This color relationship provides one of the main guides to the location of ore bodies.

Appendix I

DESCRIPTION OF
COMPOSITE STRATIGRAPHIC SECTIONS
IRVINE RANCH AREA
JOHNSON AND CAMPBELL COUNTIES, WYOMING

Locations of sections are shown on the index map of Plate 3.

Composite Section No 2

Thickness in feet	From	To	Description
1	177	178	Shale, maroon, fissile. Overlain by sandstone, gray to buff, cross-bedded, at least 8 feet thick.
24	153	177	Shale, gray with variable maroon zone at base; sandstone lenses, gray to buff throughout.
25	128	153	Shale, gray, with many inter-bedded sandstone and siltstone lenses up to 10 feet thick. Coal seams occur locally, and there are sporadic concretions about 12 feet below the top of the unit.
1	127	128	Shale, maroon, carbonaceous, grades laterally to coal.
3	124	127	Siltstone, gray.
1	123	124	Concretions, yellow-brown, soft.
4	119	123	Sandstone, buff to tan, fine grained, small concretions.
7	112	119	Shale, gray.
3	109	112	Sandstone, buff to tan, massive.
17	92	109	Shale, gray with maroon and tan streaks; local concretionary layers.

Appendix I (Cont)

Thickness in feet	From	To	Description
4	88	92	Siltstone, buff to gray, grades laterally to gray shale.
10	78	88	Shale, and claystone, gray with maroon fissile stringers; sandstone lenses locally.
2	76	78	Shale, dark brown to maroon, fissile; carbonaceous streaks with some coal, yellow staining.
6	70	76	Claystone, gray, tan stained, selenite along fractures.
3	67	70	Siltstone, gray, locally with pink to orange stringer near the top.
7	60	67	Claystone, gray.
3	57	60	Sandstone, light gray, fine, grading laterally to tan siltstone, with large calcareous concretions.
11	46	57	Shale, gray with maroon bands, tan stains in upper portion, locally sandy.
18	28	46	Sandstone, buff, massive, with gray siltstone.
3	25	28	Siltstone,buff to gray, carbonaceous, with thin coal stringers.
1	24	25	Shale, gray to maroon, carbonaceous, silty at top.
5	19	24	Sandstone, buff, silty, yellow stained in places.
3	16	19	Shale, dark gray to black, carbonaceous, yellow stain, much coal.
16	0	16	Sandstone, gray to buff, massive, some calcareous concretions; interbedded with shale, gray.

Composite Section No 3

3	226	229	Shale, maroon, fissile, yellow stained much selenite, overlain by shale and siltstone, gray.

Appendix I (Cont)

Thickness in feet	From	To	Description
9	217	226	Sandstone, gray to buff, interbedded shale, gray.
10	207	217	Sandstone and siltstone, gray to buff.
16	191	207	Shale, gray, with thin layers of maroon, carbonaceous shale.
70	121	191	Sandstone, red, pink, maroon; grades laterally to buff, cross-bedded, slightly radioactive sandstone. Some calcareous concretions, sandstone rolls and clay galls near base. Local interfingering of gray and maroon shale.
4	117	121	Shale, maroon, fissile, with some shale, gray.
3	114	117	Siltstone, gray.
2	112	114	Shale, maroon, fissile.
12	100	112	Shale, gray, interbedded with buff sandstone.
1	99	100	Shale, maroon, fissile, carbonaceous, yellow stains.
5	94	99	Siltstone, gray to tan.
2	92	94	Concretions, brown, hard, grade laterally to sandstone, buff, hard.
10	82	92	Siltstone, gray, soft.
15	67	82	Mostly covered; top part is shale, maroon, at least 2 feet thick.
20	47	67	Sandstone, buff, medium to fine, cross-bedded, limonite stains.
3	44	47	Siltstone, gray, soft.
2	42	44	Concretions, brown, hard.
5	37	42	Shale, and siltstone, gray, mostly covered.

Appendix I (Cont)

Thickness in feet	From	To	Description
1	36	37	Sandstone, buff to brown, calcareous.
3	33	36	Siltstone, gray.
4	29	33	Sandstone, buff, soft to hard, some calcareous concretions locally.
3	26	29	Shale, gray.
1	25	26	Shale, maroon, fissile.
7	18	25	Siltstone, brown, and shale, gray.
3	15	18	Shale, maroon, fissile, carbonaceous.
5	10	15	Siltstone, gray, with buff sandy stringers.
7	3	10	Sandstone, buff, fine, soft, massive.
3	0	3	Shale, maroon, very fissile, slightly carbonaceous.

Composite Section No 4

3	368	371	Concretions, hard, brown, calcareous, overlain by shale and siltstone, gray.
11	357	368	Sandstone, buff, soft, some calcareous concretions.
11	346	357	Shale, gray, silty, grading upward to siltstone, gray, sandy.
10	336	346	Shale and siltstone, gray, with sandstone, buff in upper 2 feet.
1	335	336	Shale, maroon, fissile.
15	320	335	Siltstone, gray, and buff sandstone with some concretions.
4	316	320	Sandstone, fine, buff; calcareous concretions.

Appendix I (Cont)

Thickness in feet	From	To	Description
6	310	316	Siltstone, gray, soft.
1	309	310	Shale, maroon.
10	299	309	Siltstone, gray, with interbedded sandstone, buff, yellow stained.
1	298	299	Shale, maroon.
17	281	298	Shale, gray, with thin buff sandstone, 12 feet below the top of the unit.
2	279	281	Shale, maroon, fissile, carbonaceous.
30	249	279	Sandstone, gray to tan, fine cross-bedded, interfingered with shale in lower 10 feet.
4	245	249	Shale, gray, concretions near base.
10	235	245	Sand to sandstone, gray to buff, lenticular, small concretions. Some interbedded shale in upper 5 feet.
8	227	235	Shale, gray, brown stains; some small calcareous concretions.
1	226	227	Coal and maroon shale.
3	223	226	Shale, gray, yellow stained.
10	213	223	Sandstone, buff to gray, with gray shale, and brown siltstone.
12	201	213	Siltstone, gray, with buff to gray sandstone beds, silty.
1	200	201	Shale, maroon, fissile, carbonaceous.
3	197	200	Shale, buff, with gray to buff sandstone.
1	196	197	Shale, maroon, carbonaceous, fissile.

Appendix I (Cont)

Thickness in feet	From	To	Description
5	191	196	Siltstone, dark gray, weathers light gray with tan (limonite?) spots.
15	176	191	Sandstone, buff, cross-bedded locally, contains gray shale near the top.
20	156	176	Sandstone, red to buff, soft, cross-bedded, contains hard sandstone rolls and interbedded shale locally. Small ironstone concretions occur near the base. Radioactivity and yellow to yellow-green uranium minerals occur locally in the buff portion of the sandstone.
2	154	156	Shale, gray.
2	152	154	Concretions, brown, hard.
18	134	152	Shale, gray, silty, with sandstone and siltstone lenses throughout. Local concretions 3 feet above the base.
2	132	134	Shale, maroon, fissile, grades laterally to gray shale.
12	120	132	Sandstone, buff, massive, with gray siltstone in upper 4 feet.
8	112	120	Shale and siltstone, gray.
1	111	112	Shale, maroon, carbonaceous.
7	104	111	Siltstone, gray, interbedded with buff sandstone and with thin bands of maroon shale.
2	102	104	Shale, maroon, fissile, carbonaceous.
5	97	102	Siltstone, dark gray with sandstone lenses; grades laterally to shale gray.
12	85	97	Sandstone, buff to gray, cross-bedded, soft.

Appendix I (Cont)

Thickness in feet	From	To	Description
1	84	85	Shale, maroon to gray, fissile, carbonaceous.
7	77	84	Shale, gray, with thin maroon bands, locally sandy.
2	75	77	Shale, maroon, carbonaceous.
14	61	75	Shale, gray, with sandstone lenses, buff, cross-bedded, soft. Ironstone concretions.
2	69	61	Concretions, brown to tan, hard, calcareous.
25	34	59	Shale and siltstone, gray, with about 40% sandstone, buff, lenticular, often cross-bedded.
5	29	34	Shale, gray.
2	27	29	Shale, maroon, yellow stain.
21	6	27	Shale, gray to dark gray, concretions and/or maroon shale locally at 6 feet.
3	3	6	Sandstone, buff to gray, lenticular, silty. Some gray shale.
3	0	3	Shale, red to maroon, fissile, carbonaceous, yellow stains; thin coal occurs locally at base. Shale underlies the coal.

Composite Section No 5

16	252	268	Shale, dark gray, and siltstone, buff, overlain by sandstone, maroon massive, consolidated to friable, ripple marked, at least 20 feet thick.
1	251	252	Siltstone, dark brown, hard, ripple marks.
6	245	251	Sandstone, buff, soft.
1	244	245	Concretions, brown, hard.
13	231	244	Siltstone, gray, sandy.

Appendix I (Cont)

Thickness in feet	From	To	Description
3	228	231	Concretions, brown, hard, with hard ripple marked sandstone.
20	208	228	Siltstone, gray, mostly covered.
4	204	208	Sandstone, ripple marked; hard, buff weathering to brown.
10	194	204	Sandstone and siltstone, gray.
1	193	194	Shale, maroon, fissile, carbonaceous.
6	187	193	Sandstone, buff, soft.
21	166	187	Siltstone, gray, sandy.
2	164	166	Sandstone, buff, soft.
15	149	164	Shale beds 3 to 4 feet thick alternating with 1 foot beds of maroon, fissile, carbonaceous shale.
80	69	149	Sandstone, red to orange, cross-bedded, coarse to fine; many hard sandstone rolls, and some clay galls and ironstone concretions throughout.
6	63	69	Shale, gray.
15	48	63	Sandstone, light maroon, cross-bedded.
14	34	48	Sandstone and siltstone, gray to buff, some yellow and red staining.
3	31	34	Shale, light gray to maroon, fissile.
8	23	31	Sandstone, buff, lenticular, soft, with dark gray shale.
2	21	23	Shale, dark gray.
6	15	21	Siltstone, gray.
1	14	15	Shale, maroon, fissile, carbonaceous, yellow stained.

Appendix I (Cont)

Thickness in feet	From	To	Description
10	4	14	Siltstone, dark gray to buff.
3	1	4	Shale, light gray.
1	0	1	Shale, maroon, fissile, yellow stained, carbonaceous; overlies gray shale and siltstone.

Appendix II

SAMPLE ANALYSES AND DESCRIPTIONS

IRVINE RANCH AREA

(1) Sample No.	(2) Location	Percent U_3O_8 (Equiv)	Percent U_3O_8	Percent V_2O_5	Sample Description	Remarks
S-1	28-44-77	0.02	----	----	Sandstone, gray, loose	Channel from small pit
S-2	28-44-77	0.002	----	----	Sand, pink	Grab from pit
S-3	28-44-77	0.43	----	----	Sand, brown, carbonaceous	Grab, top-soil
S-4	28-44-77	0.24	----	----	Sand, brown, dirty	Shallow pit, channel sample
S-5	28-44-77	0.38	----	----	Sand, brown, with yellow and green mineralization	Grab, hi-grade
S-6	28-44-77	0.28	----	----	Sand, gray to pink	Channel
S-7	27-44-77	0.001	----	----	Sandstone, dark red, fine	East wall of gully
S-8	27-44-77	0.01	----	----	Sandstone, brown to tan	Overlies red sandstone
S-9	27-44-77	0.18	----	----	Sandstone, buff with yellow-green ore	Near head of gully

Appendix II (Cont)

(1) Sample No.	(2) Location	Percent U_3O_8 (Equiv)	Percent U_3O_8	Percent V_2O_5	Sample Description	Remarks
S-10	27-44-77	0.49	0.500	----	Sandstone, tan, carbonaceous, green ore	Hi-grade, head of gully
S-11	27-44-77	0.75	----	----	Sandstone, buff, carbonaceous, yellow-green stain	Horizontal vein about 2" thick along bluff face
S-12	28-44-77	0.40	----	----	Sandstone, loose, brown with vertical green vein	Grab-host sandstone
S-13	28-44-77	0.31	----	----	Sandstone, buff with bright green streaks	Grab-Hi-grade of green vein
S-14	17-43-77	0.027	0.026	----	Sandstone, dark maroon with black spots	Band 6 to 12" thick in red sandstone blowout
S-15	35-43-77	0.015	----	----	Shale, black, fissile, carbonaceous	Lies between two red sandstone lenses
S-16	20-43-76	4.60	4.20	----	Sandstone, coarse, much yellow-green mineralization (carnotite)	Borders hard black sandstone layer
S-17	20-43-76	13.80	----	----	Sandstone, concretion black, hard, heavy. Orange and black mineralization	Thin, horizontal, concretionary layer
S-18	35-43-77	0.13	----	----	Sandstone, buff, fine, yellow mineralization	From 4' of buff sandstone between two red

Appendix II (Cont)

(1) Sample No.	(2) Location	Percent U_3O_8 (Equiv)	Percent U_3O_8	Percent V_2O_5	Sample Description	Remarks
S-19	30-43-77	3.30	----	----	Sandstone, fine to medium, hard calcareous, black and yellow mineralization	----
S-20	Various	----	----	----	Metallic concretions from different localities	----
S-21	30-43-77	9.0	7.13	----	Sandstone concretion, black, heavy, some yellow, green and orange minerals	Small deposit along edge of wash
S-22	31-43-77	0.085	----	----	Sandstone concretion, red and black coarse	From ridge just south of Cook 17 Mile Stage Station
S-23	13-43-77	0.003	----	----	Shale, brown to black, very fissile, carbonaceous	Below red sandstone zone, above S-25
S-24	13-43-77	0.003	----	----	Siltstone, gray, massive	Below S-25
S-25	13-43-77	0.004	----	----	Coal (lignite), fissile, contains some selenite	Forms one of the bands in Fig. 8
S-26	10-43-77	2.00	----	----	Sandstone, bright yellow, carbonaceous	Wydal Mine
S-27	10-43-77	0.024	----	----	Sandstone, pink	Wydal Mine

Appendix II (Cont)

(1) Sample No.	(2) Location	Percent U_3O_8 (Equiv)	Percent U_3O_8	Percent V_2O_5	Sample Description	Remarks
S-28	10-43-77	0.27	----	----	Sandstone, gray with yellow stain and carbonaceous material	Wydal Mine
S-29	10-43-77	0.145	----	----	Shale, gray, slightly carbonaceous	At base of ore zone, Wydal Mine
S-30	10-43-77	0.013	0.020	----	Sandstone, gray to white slightly calcareous	Wydal Mine
S-31	10-43-77	0.005	----	----	Sandstone, red	Wydal Mine
S-32	10-43-77	0.005	----	----	Sandstone, pale yellow, fine, carbonaceous	Wydal Mine
S-33	10-43-77	1.49	----	----	Sandstone, bright yellow, medium to coarse	Wydal Mine
S-34	10-43-77	0.30	----	----	Sandstone, gray to buff, carbonaceous, some yellow stain	Wydal Mine
S-35	10-43-77	0.007	----	----	Sandstone red and buff	Red-buff contact, Wydal Mine
S-36	3-43-77	0.007	----	----	Sandstone yellow to tan, very fine, calcareous	Kram Mine
S-37	3-43-77	0.11	0.160	----	Sandstone, light tan to yellow, fine, brown stains, calcareous	Kram Mine

Appendix II (Cont)

(1) Sample No.	(2) Location	Percent U_3O_8 (Equiv)	Percent U_3O_8	Percent V_2O_5	Sample Description	Remarks
S-38	3-43-77	0.001	----	----	Sandstone, red, medium soft	Kram Mine
S-39	3-43-77	0.65	----	----	Sandstone, red to buff with some yellow mineralization	Red-buff contact, Kram Mine
S-40	3-43-77	0.006	----	----	Sandstone, gray with much yellow, very soft and loose	Kram Mine
S-41	3-43-77	2.48	----	----	Sandstone, brown to buff with yellow mineralization and much black carbonaceous material	Kram Mine
S-42	3-43-77	0.28	----	----	Sandstone, brown, medium	Kram Mine
S-43	3-43-77	0.006	----	----	Siltstone, gray micaceous with some quartz grains	Kram Mine
S-44	3-43-77	0.010	----	----	Sandstone, red with some brown stains, many small clay particles	Kram Mine
S-45	3-43-77	0.275	----	----	Sandstone, gray to buff, fine, yellow stain, many thin carbonaceous bands	Kram Mine
S-46	20-43-76	18.5	17.60	----	Sandstone, yellow to red,	Forms hard layers

Appendix II (Cont)

(1) Sample No.	(2) Location	Percent U_3O_8 (Equiv)	Percent U_3O_8	Percent V_2O_5	Sample Description	Remarks
S-47	20-43-76	0.08	----	----	Sandstone concretion, hard, black, heavy, metallic appearance	Forms thin concretionary layer
S-48	3-43-77	1.03	----	----	Sandstone, red, containing embayment of yellow uranium mineralization	Kram Mine
S-49	20-43-76	23.8	----	----	Sandstone, yellow to black	Similar to S-46
S-50	3-43-77	1.00	1.040	----	Sandstone, buff with disseminated yellow mineralization, carbonaceous	Kram Mine
S-51	4-42-76	7.6	9.7	.68	Sandstone	----
S-52	18-44-76	.39	.28	.38	Sandstone	----
S-53	13-44-77	.073	.016	.09	Sandstone	----
S-54	9+10-43-77	.323	.519	.69	Sandstone	----
S-55	20-43-77	.091	.064	.98	Sandstone	Ironstone
S-56	20-43-77	.044	.031	.22	Sandstone	Ironstone
S-57	9-43-77	.29	.49	.51	Sandstone	----
S-58	12-42-78	.001	.003	----	Sandstone	Coal near siltstone

Appendix II (Cont)

(1) Sample No.	(2) Location	Percent U_3O_8 (Equiv)	Percent U_3O_8	Percent V_2O_5	Sample Description	Remarks
S-59	4-42-76	.12	.15	.1	Sandstone	----
S-60	8-43-77	----	----	----	----	Ironstone
S-61	5-43-77	0.057	0.028	0.05	Sandstone	Ironstone

1. See Plate 2. Sample analyses and descriptions S-51 through S-61 are as reported by Troyer and others (1954).

2. Numbers indicate section, township and range.

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