Geology and Uranium Deposits of the Pumpkin Buttes Area of the Powder River Basin Wyoming

GEOLOGICAL SURVEY BULLETIN 1107-H

Prepared on behalf of the U.S. Atomic Energy Commission

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By W. N. SHARP, E. J. McKAY, F. A. McKEOWN, *and* A. M. WHITE

CONTRIBUTIONS TO THE GEOLOGY OF URANIUM

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By W. N. Sharp, E. J. McKay, F. A. McKeown, and A. M. White

ABSTRACT

The Pumpkin Buttes area is on the east flank of the synclinal structural trough of the Powder River Basin of northeastern Wyoming, and is astride a broad anticlinal nose that trends southwest toward the deep part of the Basin. The area is underlain by clastic sedimentary rocks of the Wasatch formation of Eocene age. Several prominent buttes in the area are capped by similar rocks of the White River formation of Oligocene age.

The Wasatch formation, of fluviatile origin, is about 1,500 feet thick and is composed of sandstone lenses randomly dispersed through a sequence of drab yellowish-gray to tan claystone, siltstone, carbonaceous shale, and thin coal seams. The sandstone lenses, which contain all the known occurrences of uranium in the area, are from 500 feet to several miles wide, 1 to 8 miles long, and 10 to 100 feet thick. The sandstone is generally yellowish brown to grayish yellow, medium to coarse grained, and arkosic, but many lenses in the vicinity of the buttes are red or partly red. The contacts between red and drab parts transect all sedimentary structures and lithology within a sandstone unit. Commonly, the sandstone is cemented into concretionary masses by calcite or manganese oxide.

Red sandstone in the Wasatch formation is in a vertical interval of 500 feet in the middle of the Wasatch section and in a zone 20 miles wide and more than 30 miles long. This zone overlies shallow anticlinal structures in beds of the Wasatch and more prominent basement structural features.

Uranium deposits are closely related to the hematite-red coloring in the sandstone lenses. Tyuyamunite, metatyuyamunite, carnotite, uranophane, and trace amounts of hewettite and pascoite are disseminated in yellowish-brown or grayish-yellow sandstone where it is in contact with red sandstone. Calcite is generally abundant at the contact. Where the contact is very irregular and forms irregular podlike extensions of red into drab sandstone, concentrations of secondary uranium minerals may occur in the drab sandstone. Uraninite, pyrite, and paramontroseite associated with coalified wood occur as cement in pods in red sandstone near irregular contacts with drab sandstone. Uranophane is chiefly in the cores and is peripheral to manganese oxide concretions. Pyrolusite, manganite, and psilomelane are the chief manganese minerals. All uranium minerals are contemporaneous with calcite. The concentrations of uranium, vanadium, iron, manganese minerals, and calcite seem to have formed by the redistribution and concentration of original components of the sandstone lenses. This is suggested by (a) the apparent redistribution of limy material within sandstone lenses, (b) the epigenetic drab-to-red color change associated with uranium deposits in sandstone lenses, (c) the general unaltered condition

of clay beds and the low uranium content of coal and carbonaceous shale between sandstone lenses, and (d) the lack of faults and widespread sandstone units that would serve as channels for interformational or intraformational circulation of mineralizing waters.

Oxidized uranium and vanadium minerals and manganese oxides formed in a general alkaline oxidizing environment. Unoxidized minerals, paramontroseite and uraninite with associated pyrite, formed in small local zones of a low redox potential, predominantly around coalified wood.

INTRODUCTION

LOCATION, PHYSIOGRAPHY, AND ACCESSIBILITY

The Powder River Basin is the largest of the intermontane basins of Wyoming and comprises about 12,000 square miles of mostly undulating prairie and dissected badland terrain in the northeastern part of the state (fig. 86). It is a structural basin open to the north and bounded on the east, south, and west by the Black Hills, by the Laramie Range and the Hartville uplift, and by the Bighorn Mountains, respectively (pl. 10). Drainage is to the north by the Powder River and to the east by the Belle Fourche and Cheyenne River systems. Most of the Powder River Basin is at an altitude of 4,000 to 5,000 feet, with the exception of the Pumpkin Buttes in the south-central part of the Basin. The buttes attain an altitude of 6,000 feet, and local relief is about 1,500 feet.

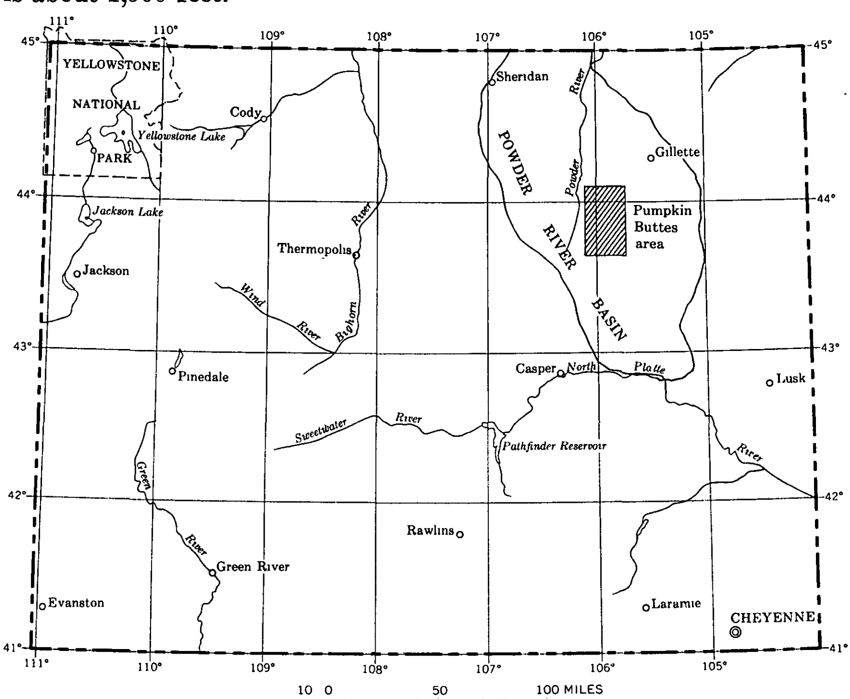

FIGURE 86.—Index map of Wyoming, showing the Powder River Basin and the Pumpkin Buttes area.

Like most of the basins of this part of the country, the environment of the Powder River Basin is semiarid. The winters are long and severe and the summers generally hot and dry. Precipitation is about 10 inches per year, and temperatures range from more than 110° F in summer to less than −40° F in winter. The whole region is sparsely populated. Gillette, the county seat of Campbell County, has a population of about 2,000 and is the chief commercial center of the region. Stock raising is the principal industry in the area.

The Powder River Basin is accessible by U.S. Highways 14 and 16 from the east and northwest, and by Wyoming Route 59 from the south. Wyoming Route 387 crosses the south end of the Pumpkin Buttes area, and a graveled road, known locally as the Savageton Road, passes east of the buttes; a graded dirt road leads from the Savageton Road to the John R. Christensen ranch southwest of North Butte. Ranch roads give access to the rest of the area.

The Chicago, Burlington, and Quincy Railroad serves Gillette.

PREVIOUS INVESTIGATIONS

Uranium was discovered by the U.S. Geological Survey in the Pumpkin Buttes area in October 1951, and a brief reconnaissance of the area was conducted in November of that year (Love, 1952). This and subsequent investigations by airborne parties of the U.S. Geological Survey and the U.S. Atomic Energy Commission and by ground parties led to the discovery of more than 250 localities of anomalous radioactivity near the buttes.

During the summer of 1952, a Geological Survey field party further investigated the distribution, occurrence, and habit of uranium minerals in the Pumpkin Buttes area. Selected areas were auger-drilled and bulldozed to supplement studies of poor exposures. A reconnaissance geologic map of part of the area was prepared (Troyer and others, 1954). Parts of the area were drilled by the Atomic Energy Commission and by private companies; both plug bit and core methods were used.

PURPOSE AND SCOPE OF PRESENT INVESTIGATION

Present geologic studies were directed toward identification of the geologic, chemical, and physical factors that controlled uranium deposition and toward determination of criteria for discovery of additional deposits. During the summers of 1953 and 1954, eight 7½-minute quadrangles (pl. 11) were mapped geologically on aerial photographs, and several mine areas were mapped in detail by planetable methods. Study of the occurrence and habit of uranium minerals was continued, to establish the relation of mineralization to local geologic features. The Atomic Energy Commission continued its drilling program during this time, and, in order to secure representative stratigraphic information of the area, six deep core holes were drilled in widely separated localities.

ACKNOWLEDGMENTS

The geologic investigations in the Pumpkin Buttes area were done on behalf of the Division of Raw Materials of the U.S. Atomic Energy Commission. Part of the material used in this report was compiled from information gathered by the Atomic Energy Commission drilling program and by their aerial surveys with scintillation-type radiation meters. Residents of the Pumpkin Buttes area and personnel of private companies were helpful, and cooperated in all stages of the investigations.

Many Geological Survey geologists have contributed to the Powder River Basin studies. S. R. Wallace, P. E. Soister, and D. F. Davidson made substantial contributions. Chemical, spectrographic, and X-ray analytical work was done in both the Denver and Washington laboratories of the Survey. Acknowledgment is made of the mineralogical studies by Alice D. Weeks and Robert G. Coleman. Recognition also is due geophysicists of the Geological Survey who flew low-level airborne reconnaissance over the area.

GEOLOGY

GEOLOGIC SETTING OF THE POWDER RIVER BASIN

The Powder River Basin lies along the eastern margin of the Rocky Mountain system. The basin is larger and less deformed than most other intermontane basins in Wyoming, Montana, and Colorado. Structural asymmetry in the basin is similar to that of other intermontane basins in that the deeper parts lie close to the higher mountain masses. This asymmetric basin structure is reflected by strata that dip gently westward on the east side and relatively steeply eastward on the west side of the basin.

In the Pumpkin Buttes area, rocks of Oligocene age (White River formation) unconformably overlie northwestward-dipping strata of early Eocene age (Wasatch formation) in the middle of the basin and overlie older rocks on uplands surrounding the basin. Underlying the 4,000 to 6,000 feet of sedimentary rocks of Tertiary age, including the Fort Union formation of Paleocene age, are 7,000 feet of Cretaceous rocks, 1,100 feet of Jurassic and Triassic rocks, and 2,000 feet of Paleozoic rocks. Total thickness of sediments overlying Precambrian crystalline rocks in the Powder River Basin is estimated to exceed 16,000 feet.

In contrast to other intermontane basins, the Eocene sedimentary rocks covering the deeper parts of the Powder River Basin were derived from one principal source area in the southeast rather than from several peripheral highland areas. If sediments derived from the Black Hills area were deposited in the basin, they have been completely eroded. Most of the material derived from the higher Bighorn Mountains was probably deposited in the Bighorn Basin. Fanglomerate deposited locally along the Bighorn Mountain front in the Powder River Basin between the cities of Buffalo and Sheridan interfingers with and grades into early Eocene fine-grained sedimentary rocks but does not affect the general facies pattern in the basin. Features such as primary sedimentary structures in sandstone, shapes of sandstone lenses, and a regular directional change in size and amount of coarse-grained clastic sedimentary rocks indicate the direction to the source area of sediments. In the Pumpkin Buttes area, foresets and channels of the crossbedded sandstone units are oriented northward, predominantly northwestward; the long dimensions of sandstone lenses trend northward; and size and amount of coarse-grained clastic material decreases from southeast to northwest. All these data point to the southeast as the direction from which the sediments of Eocene age in the basin were derived.

In most of the other basins in the Rocky Mountain region, red-banded claystone, siltstone, and thin sandstone strata of early Eocene age are common. The sequence apparently is derived in part from red upland soils or upturned Triassic red beds and has a transitional contact with underlying drab Paleocene strata wherever it is found. The transition zone also coincides with a widespread change in fauna throughout the Rocky Mountain region. In the Powder River Basin, however, such characteristics of lithology are manifest, as far as is known, only in a small area southwest of Pumpkin Buttes near Great Pine Ridge. Throughout most of the basin, red banding is absent in Eocene rocks, and the Paleocene and Eocene sedimentary rocks are similar lithologically.

PALEOGEOGRAPHY

After withdrawal of the Cretaceous sea, the south and west sides of the Powder River Basin were repeatedly uplifted and continuously eroded. Contemporaneous subsidence in the basin was apparently rapid enough to maintain a warm, wet climate and a combination of piedmont and swampy lowland topography that probably controlled the character of terrestrial sediments of Paleocene and early Eocene age. Freshwater sandstone, shale, claystone, and coal beds of Fort Union age contain fossil remains of arboreal land mammals, turtles, garfish, and flora typical of an environment having an altitude of not more than 1,000 feet above sea level (Van Houten, 1945). Fluvial deposition continued apparently unbroken; conglomerate, sandstone, siltstone, claystone, and organic material of the Wasatch formation were laid down over the beds of the Fort Union. The predominance of gray and generally drab (tan to yellowish-gray) fine-grained sedimentary rocks and the many coal beds in the Wasatch in a wide peripheral zone suggest that deposition of these flood-plain deposits occurred in a generally reducing environment. In the central zone, an apparent locus of paleodrainage, where sandstone lenses make up one-third or more of the section, an overall slightly oxidized condition of the coarse-grained lenses probably was not changed appreciably after deposition, and a brown or tan color was general. Red sediments, if supplied to the basin in general, probably were altered to brown during transportation.

Regional uplift in late Eocene or Oligocene time raised the surrounding highlands and the sedimentary rocks of the basin to their present altitude. During Oligocene time, most, if not all, of the basin was buried by sediments derived from Precambrian and Paleozoic rocks of the Bighorn Mountains and from volcanic centers to the west. The higher altitude and more arid climate resulted in the decrease of forests and in the development of a prairie environment. The land surface of this period is represented by the erosion surface that is the top of Pumpkin Buttes. Although the record of later Tertiary sedimentation is no longer present in the Powder River Basin, the adaptation of animals, particularly the hoofed mammals, to progressively more arid conditions is indicated in adjacent plains areas (Mackin, 1937).

STRATIGRAPHY

Rocks exposed in the Pumpkin Buttes area are the Fort Union, Wasatch, and White River formations of Tertiary age. Parts of these formations are shown graphically on plate 13 in a stratigraphic cross section measured from Great Pine Ridge to North Pumpkin Butte, thence to South Pumpkin Butte.

Stratigraphic relations of the Wasatch and Fort Union formations have been studied by the Geological Survey in conjunction with coal-resource studies in the Powder River Basin and in the Pumpkin Buttes area. Results of these studies were reported by Wegemann and others (1928), Dobbin and Barnett (1927), Winchester (1912), and Wegemann (1913). Wegemann (1917) was first to report the presence of Wasatch vertebrate fossils in the Basin. The early Oligocene (White River) age of the caprock on the Pumpkin Buttes and the early Eocene age of the Wasatch formation were established by detailed stratigraphic work by members of later U.S. Geological Survey field parties (Love, 1952; Troyer and others, 1954).

FORT UNION FORMATION

The Fort Union formation of Paleocene age is exposed on Great Pine Ridge about 15 miles southwest of the Pumpkin Buttes. The formation consists of about 2,800 feet of gray to buff fine- to coarse-grained lenticular sandstone, bluish-white shale, and coal beds. Coal bed "H" (pl. 13) was regarded by Wegemann and others (1928) as the top of the Fort Union formation. G. H. Horn (oral communication, 1955) of the Geological Survey, however, traced this bed northward from Wyoming Highway 387 to the vicinity of Sussex (pl. 10) and found that coal bed "H" occurs progressively lower in the Fort Union formation. In the section of the Fort Union measured for the present work (pl. 13), coal bed "H" is 525 feet below the base of the Wasatch formation.

WASATCH FORMATION

The Wasatch formation is composed of claystone, relatively continuous coal beds, thin-bedded siltstone and fine-grained sandstone, and grayish-tan or red and pink medium- to coarse-grained lenticular sandstone. Sandstone in the Wasatch over most of the Basin is yellowish-gray or drab, and the claystone is gray and greenish gray. In the vicinity of Pumpkin Buttes, some of the sandstone is in shades of red. Pink- to red-banded claystone and siltstone occur at the base of the Wasatch only near Great Pine Ridge and make transitional but mappable contact with otherwise lithologically similar but drab sedimentary rocks of the Fort Union.

The Wasatch formation in the Pumpkin Buttes area has a measured thickness of about 1,575 feet (pl. 13). The lower 325 feet measured near the Dry Fork of the Powder River and the upper 1,250 feet measured on and near North Butte were connected through the intervening distance by mapping virtually flat-lying carbonaceous shale beds. Designation of the Wasatch-Fort Union boundary in the Willow Creek core hole (pl. 13) cannot be made with confidence because the two formations cannot be distinguished lithologically. Correlation of stratigraphic sections measured on the several buttes shows that the southward thinning of the upper part of the Wasatch is related to an unconformity below the White River formation.

The geologic map (pl. 10) of the Powder River Basin shows the distribution of coarse- and fine-grained clastic rocks in the Wasatch formation. The exposure of the Wasatch is divided thereon into three areas, in which the formation is composed dominantly of (a) very coarse grained and conglomeratic clastics; (b) interbedded fine- to coarse-grained clastics—sandstone and claystone; and (c) dominantly fine-grained clastics—claystone and siltstone.

Stratigraphic sections and geologic mapping show that sandstone units are not restricted to one or several stratigraphic zones; but are erratically scattered vertically through the Wasatch formation, and that sandstone lenses are a more dominant component of the total Wasatch section in a central zone of the basin than in marginal areas.

Sandstone composes about one-third of the total thickness of the Wasatch formation in measured sections on the Pumpkin Buttes. The relative amount of coarse- and fine-grained clastic sedimentary rocks in other parts of the basin cannot be measured directly because the top of the Wasatch and the overlying White River formation have been removed by erosion. The facies pattern (pl. 10) was obtained by reconnaissance methods, and relations among facies of the Wasatch are somewhat generalized because of the random distribution, vertically and horizontally, of the lithologic components.

In the southern Powder River Basin, the central zone of dominant sandstone consists of coarse-grained and conglomeratic sandstone lenses interbedded with some fine-grained sedimentary rocks. Northward a decrease in grain size and amount of sandstone and an increase in the amount of claystone can be observed (pl. 10). This bedded sandstone and claystone facies that underlies the mapped area persists northward to the vicinity of Gillette. Fine-grained sediments, claystone, and siltstone predominate east, west, and north of the central area of interbedded sandstone and claystone. Bordering the interbedded sandstone-claystone facies, and transitional to the peripheral area that is dominantly claystone and siltstone, is an interval 2 to 5 miles wide in which the proportional amount of sandstone progressively decreases. Thick coal beds are restricted to the periphery of the interbedded sandstone and claystone facies and to the areas in which claystone predominates.

Teeth of vertebrates collected in the Wasatch and listed on plate 13 were identified by Jean Hough of the U.S. National Museum. These fossils are diagnostic of Gray Bull and Lost Cabin faunas of early Eocene age that are also found in the Wind River and Bighorn Basins (Van Houten, 1945).

WHITE RIVER FORMATION

The White River formation was first recognized on the Pumpkin Buttes by Darton about 1900 (1905, pls. 35 and 44). This observation was apparently overlooked by later workers, and sedimentary beds of the White River group in the basin were included in the Wasatch formation (Wegemann, 1917; Wegemann and others, 1928). The rocks capping the Buttes were again recognized as White River by Love in 1952, and the identification as White River was supported by vertebrate fossils (Love, 1952). Love divided the White River on

Pumpkin Buttes into three facies: a basal soft coarse-grained sandstone facies, a middle caprock facies of coarse-grained sandstone and conglomerate indurated with chalcedonic cement, and an upper facies now consisting of erosional remnants of white tuff and bentonitic claystone. Results of later studies, however, showed that the thick basal sandstone facies is lithologically similar to sandstone in the Wasatch formation, and the boundary was moved up to an unconformity at the base of the conglomeratic caprock. The White River formation capping Pumpkin Buttes is 30 to 50 feet thick and is composed of lenticular crossbedded sandstone beds that locally fill channels cut in underlying soft sandstone and finer clastic sedimentary rocks of the Wasatch formation. The caprock lies unconformably on progressively older beds of the Wasatch from North Butte to South Butte. This relation is shown by southward thinning of a stratigraphic interval above a traced horizon in the Wasatch between stratigraphic sections (pl. 13) and in cross section *A′–A″* of plate 12.

Vertebrate fossils (pl. 13) found in the caprock and the overlying tuffaceous sedimentary rocks are diagnostic of faunas of early Oligocene age. The probable source of the White River sediments was from the west because the caprock is cut by channels suggesting northeasterly flow. The caprock contains conglomerate with pebbles of quartzite, limestone, chert, and gneiss similar to the rocks of Precambrian and Paleozoic age in the Bighorn Mountains.

STRUCTURE

Regional structure of the Powder River Basin commonly is shown by configuration on the top of the Precambrian rocks. The trace of the axis of the basin on the top of the Precambrian rocks projects to the surface close to the flank of the Bighorn Mountains. West of the Pumpkin Buttes, the axis curves to the southeast around the structural domes of Salt Creek anticline. The area of the buttes is on the east flank of the syncline and astride a broad anticlinal nose that trends southwest toward the deep part of the basin trough (pl. 10; fig. 87). Another closer fold trending southwest passes through Middle Buttes.

Reconnaissance mapping of surface rocks southwest and west of the buttes and the measurement of sections southwest of the buttes toward the Great Pine Ridge indicate that the Powder River and, southward, the Dry Fork follow the synclinal trough in the surface rocks. The trace of the basin axis on the Precambrian basement lies to the west of the axis in surface rocks and indicates that the axial plane of the basin structure is inclined steeply to the west.

The surface rocks in the area contain no extensive unit or bed on which attitudes and configuration can be readily measured. The

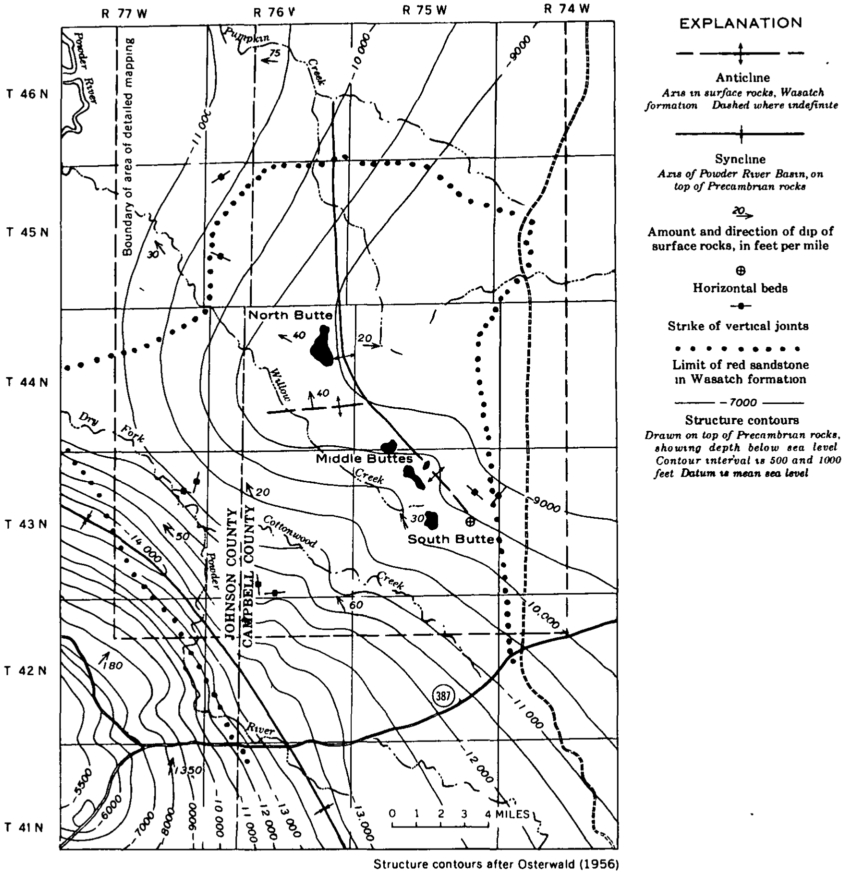

FIGURE 87.—Map showing surface structure in Pumpkin Buttes area superimposed on structure contours on Precambrian rocks.

nearly flat lying lensing and swelling sandstone units are poor sources of structural data. A few coal and carbonaceous shale beds offer some control, but these beds are exposed only in narrow drainage channels and have no great lateral exposure. Dips can be calculated only by careful mapping of a sandstone unit for several miles. In that distance irregularities of sandstone thickness, lower contacts, and local variations can be generalized into a regional attitude. The amount and direction of dip shown on figure 87 were derived from study of the geologic map (pl. 11).

The Wasatch rocks exposed in the Pumpkin Buttes area generally dip northwestward. The amount of dip ranges from about 20 to 100 feet per mile.

The axis of a slight anticlinal fold in surface rocks trends north on the east side of North Butte and southeast along the east side of Middle and South Buttes. The bend is apparently caused by the Precambrian basement structure. In part, this anticline is confirmed by eastward-dipping coal beds in the Belle Fourche River valley east of the map area. The east-west axis of a poorly defined anticline between North and North Middle Buttes is evident in the surface rocks. The gentle fold can be seen on section *A′–A″*, plate 12, in beds 6, 8, and 10. This anticline overlies the prominent plunging nose of the Precambrian basement rocks and is transverse to the structure along the buttes.

The base of the White River cap that overlies the beds of the Wasatch on the buttes is gently irregular and marks an erosional unconformity. Along the axis of the buttes, the base of the White River formation, as well as the erosion surface that tops the buttes dips very slightly southward—approximately 75 feet in 9½ miles. This slight dip may be due to a late Tertiary regional adjustment but more logically reflects the natural surface dip in Tertiary time. In short, the Pumpkin Buttes are erosion remnants supporting a post-Oligocene erosion surface along the axis of a broad anticline that was formed in sediments of the Wasatch before Oligocene time.

No faults have been recognized in the Pumpkin Buttes area. West of the mapped area, along the Powder River, several minor reverse faults offset coal beds a few feet. The faults trend N. 82° E., N. 15° E., and N. 80° W. and dip 40° to 50° north and east. They could not be traced from the cutbank outcrop either on the surface or on aerial photographs.

Jointing in the calcareous or concretionary sandstone is commonly about N. 60° E. throughout the area of the Pumpkin Buttes. Joint fractures in the less cemented sandstone are filled at places with white punky calcium carbonate.

Sandstone dikes 1 to 2 feet wide cut clay and siltstone above or below a sand lens at several places in the southern part of the area. They trend N. 40° E. to N. 80° E., a strike that is similar to that of conspicuous regional jointing.

PUMPKIN BUTTES AREA

WASATCH FORMATION

Rocks of the Wasatch formation are well exposed in the Pumpkin Buttes area, particularly on the flanks of the buttes and in the adjacent dissected country to the west. In this area the lithology ranges from claystone to very coarse, poorly sorted sandstone, and it includes claystone, marlstone, siltstone or mudstone, carbonaceous shale and lignite, and sandstone. These units generally are relatively thin and

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have common physical properties throughout the area around the buttes.

The claystone is medium dark gray to dark greenish gray and locally weathers white. The units are generally 5 to 10 feet thick, but some are 30 feet thick. The thick units tend to become divided laterally by beds of siltstone or carbonaceous shale, or they are interrupted by channels filled with coarse-grained sandstone. The claystone generally has little or no fissility and is massive or blocky and only slightly plastic. Examination of some of the greenish-gray clay units disclosed finely divided pyrite specks throughout.

Marlstone or fine-grained limestone locally forms thin narrow lenses in the fine-grained clastic sedimentary rocks. The marlstone is light gray and weathers to a moderate brown on outcrop. It has a few widely scattered invertebrate fossils and plant roots. Many narrow divide ridges and low knobs are capped with this marlstone, which also forms narrow ledges on cutbanks and on the flanks of the buttes. Analyses of two specimens indicate 46 percent $CaCO_3$.

Siltstone, locally more nearly a mudstone, is the most abundant lithologic component of the Wasatch. It is generally drab yellowish brown to pale yellowish gray; locally, it is thin bedded and shaly or massive and blocky. Small nodules of pyrite cementing the clastic material are locally abundant. Several small zones are rich in small pelecypod shells. Finely divided carbonaceous "trash" is also plentiful locally. This rock weathers light gray on scattered outcrops because of a salt bloom. The near-surface rock generally contains abundant fine-grained gypsum.

Carbonaceous shale beds are numerous in the Pumpkin Buttes area, and no less than five separable units are exposed on the flanks of North Butte; few of them are traceable for more than a mile or two. However, a coal and carbonaceous shale seam several feet thick is exposed in the cutbank along Willow Creek and is traceable downstream almost to the reentrant at the Powder River, a distance of nearly 10 miles. A lignite seam also is conspicuous in Pumpkin Creek, north of the buttes, and can be mapped for more than 6 miles along the creek. The carbonaceous shale beds contain large amounts of coarsely crystalline gypsum. In some places, pyrite is concentrated in a thin layer overlying carbonaceous shale.

One-third of the exposed Wasatch section of the Pumpkin Buttes area is made up of generally separated, lensing sandstone units of large and small size dispersed at random throughout the predominantly fine grained clastic sedimentary series. These sandstone lenses contain all the uranium deposits so far found in the area; they will be discussed in detail.

SANDSTONE UNITS

DISTRIBUTION

The irregular distribution of sandstone throughout the Wasatch formation in the Pumpkin Buttes area is shown both in the stratigraphic sections (pl. 13) and in the geologic sections (pl. 12).

Outcrops of the sandstone are rather randomly distributed throughout the area. To the west of the buttes, a badland topography of ridges and gullies has an extremely rugged surface; to the east of the buttes, the less active Belle Fourche drainage system has formed a gently rolling land surface. Owing to the difference in topography, the sandstone exposure pattern is much more complex and complete in the area west of the buttes. Sandstone lenses cap most of the ridges and the many small rock cones in the area. Hard calcareous sandstone is a protective capping to the underlying soft material on some of the smaller topographic highs. On the other hand, the long drainage-divide ridges are maintained and were probably begun because of the porosity of the sandstone. Meteoric water soaks down so readily that there is no surface runoff to erode the ridge.

SIZE

The sandstone units generally range from seams a few feet thick to lenses 100 feet thick. Average thickness is from 20 to 30 feet. Inasmuch as these units are of fluvial origin, many are elongate in shape and fill distinct channels cut in underlying claystone or siltstone. Cutbanks expose cross sections of lenses 100 to 200 feet across and 40 feet thick at midpoint that thin abruptly to a featheredge. Most of the sandstone lenses, however, are larger, and are as much as 6 to 8 miles by 4 to 5 miles in areal extent and from a few to 50 feet thick. The largest single mappable sandstone (No. 8 on pl. 11) is traceable for more than 12 miles northwestward across the area. Such sandstone probably was deposited by coalescing shallow channels of a braided stream.

SEDIMENTARY STRUCTURES

Most of the narrow sandstone bodies fill discrete channels in the underlying rock, and are roughly planoconvex in cross section. In some localities, a channel has been cut down through the intervening strata and into a slightly lower channel sandstone; thus, the sandstone filling the upper channel is in direct contact with the lower one. The contact is marked in places by a reworked discontinuous carbonaceous shaly sandstone zone as much as 3 feet thick; it is almost impossible to delineate the contact between the two sandstone bodies where this shaly zone is absent. A thin tongue of sandstone generally extends laterally from the upper part of the sandstone lens into the surrounding finer grained sedimentary rock. This thin tongue represents the stratigraphic position of the sandstone, whereas the base of the channel-filling part may lie as much as 40 feet or more below this position. In some places, more than one thin tongue extends from the thick main body of sandstone into the surrounding sedimentary layers; these tongues probably indicate contemporaneous deposition of the sandstone and the adjacent fine-grained sediments. In a few places, at least two subparallel channels connected by thin sandstone beds lie several hundred feet apart horizontally and in the same stratigraphic interval.

In many places, one or more marlstone beds averaging 1 to 2 feet in thickness appear to occupy approximately the same stratigraphic position as the channel sandstone lateral to their edges.

The more widespread sandstone bodies commonly have flatlying lower contacts over much of their extent. They may immediately overlie carbonaceous shale or coaly beds 1 to 2 feet thick. Toward their edges these sandstones contain more silt and become finer grained. Normal to their sedimentary trend they may pinch out in several different ways, the most common of which is by the thinning of tongues away from the main part of the sandstone. In one place a sandstone lens decreases in thickness from at least 40 to 0 feet in a distance of not more than 300 feet. Thick carbonaceous shale units lie above and below the sandstone at a thin pinchout and are contiguous beyond it. Not far from this locality, the same sandstone undergoes an abrupt facies change to silt. Fragments of shaly siltstone occur in the sandstone and become more numerous laterally until the sandstone interval is occupied entirely by siltstone.

The most conspicuous sedimentary structure within the sandstone is aqueous cross-lamination. Foreset and bottomset laminae are well preserved, but the topset laminae generally were removed prior to deposition of the succeeding bed. A typical cross-laminated bed is about 1.5 to 2 feet thick and is overlain by as many as a dozen similar beds in a vertical distance of 20 feet. The foreset laminae commonly have the same general north-northwesterly direction of dip. Festoon cross-lamination in northward-plunging troughs 1 to 6 feet wide is not uncommon. Some channel sandstone bodies are exposed in steep banks or cliffs that are normal to the trend of the channels. The cross-lamination here is also in the shape of small troughs about 1 to 3 feet wide. In some places the cross-lamination is very complex and the direction of dip may change several times in as many feet of strata. Current-ripple marks have been observed locally, but they are generally absent or obscured.

Contorted bedding due predominantly to deposition in turbulent water is common. Generally associated with the turbulent zones are "trash piles." The "trash piles" are pockets as much as 10 feet across that consist of sandstone and large amounts of clay and mudstone fragments and carbonaceous material. A few mudstone lenses occur in the sandstone, but most commonly the sandstone is clean except near margins. Clay gall and mudstone-pebble conglomerate and breccia are found in the sandstone, commonly in the basal parts. The material was probably derived from the beds adjacent to the sandstone during scouring and filling of the channels. Many of the channel sandstones have also incorporated fragments that are identical with the underlying carbonaceous shale. Most of this material is present in the lower part of the sandstone.

Most thick sandstone beds exhibit graded bedding although the feature is not generally conspicuous. The basal part generally has the coarsest sand grains, and the upper part grades into silt. The thick main part of sandstone commonly alternates from fine grained to coarse grained, but is predominantly medium grained. The coarsest particles present are rare small pebbles less than 1 cm in diameter.

One of the most conspicuous features of the sandstone lenses is the epigenetic concretions consisting of sand grains tightly cemented by calcium carbonate ($CaCO_3$). These are most common in thick sandstone lenses. Their shape and size range from round "cannonball" types, usually 6 to 10 inches in diameter, through "dumb-bell" types to cylindrical bodies about 6 feet in diameter. These concretions occur at irregular levels in the sandstone. Outside these concretions the sandstone is generally only slightly calcareous.

Pyrite nodules partly altered to limonitic minerals are common in some of the drab sandstone which apparently has not been long exposed to weathering. Ironstone (porous to siliceous limonitic material and sand cemented with limonite and hematite) is abundant in the red sandstone and present in some of the drab sandstone. Much of the ironstone has formed around and replaced wood.

Silica-cemented sandstone is rare in the Wasatch of the Powder River Basin. In view of the association of siliceous zones with uranium in coarse-grained clastic rocks in other areas of sedimentary rocks it may be significant that several small areas containing siliceous-hematitic sandstone lenses were mapped in the region.

Just to the north of the Pumpkin Buttes area and in an east-west line are three buttes; the largest, known as Black Butte, is 7 miles north of Savageton on the Gillette road. East of this butte, two others are approximately equally spaced across 5 miles. These buttes are supported by a series of interfingering sandstone lenses that are highly siliceous and rich in ferric oxides. As this highly competent rock weathers out at the top and along the slopes of the buttes, it forms irregular benches. Great blocks of the material fall and collect in a jumbled mass around the flanks. The claystone and siltstone that are with the sandstone in the buttes are not silicified or visibly altered. Similar siliceous-hematitic rock caps a small cone 2½ miles south of South Butte. Locally, this cone is called Little Black Butte.

The significance of these siliceous rocks in the Wasatch, peripheral to the area of uranium deposits, is not known but the spatial relation suggests a possible genetic association.

COLOR IN SANDSTONE

The sandstone lenses of the Pumpkin Buttes area range from grayish yellow and pale yellowish orange to pink, moderate red, and grayish red. The significant feature of the coloration is that there is a limitable area in which the sandstone is red or partly red (pl. 14). The area of abundant red sandstone is fairly well defined in surface rocks north, east, and west of the buttes; its southern limit, however, is far south of the area and is undefined. Red sandstone is found at depths of 450 and 500 feet in two of the deep core holes in the area (pl. 13), and the vertical range of red color indicated by these and other stratigraphic data suggest a zone containing red sandstone in the middle part of the Wasatch formation with a lens-shaped cross section (pl. 12). The red color within this area contrasts sharply with the normal drab color of most of the sandstone in the Wasatch formation in other parts of the Powder River Basin. Inasmuch as the sandstones are randomly spaced lensing units separated horizontally and vertically, the boundary between the areas of red and drab colors in sandstone is not a contact. The farthest extent in all directions of red color in any sandstone is termed the "limit." Not all sandstone lenses within this limit are red. Many small lenses and parts of some large lenses are drab. In partially red sandstone, the boundary between red and drab color is a generally sharp contact that transects variation of lithology and sedimentary structure within the sandstone.

The red color in sandstone bears a close spatial relation to uranium deposits; consequently, the nature and properties of this color were examined and studied in detail.

A review of the literature (Hofer and Weller, 1947; Hager, 1928; Van Houten, 1948) concerned with the color of sedimentary deposits, particularly of sandstone, shows that the red and yellow coloring agents are iron oxides or oxide hydrates with variable amounts of water. The drab colors, light brown to yellow, are due predominantly to goethite ($\alpha Fe_2O_3 \cdot H_2O$). Lepidocrocite ($\gamma Fe_2O_3 \cdot H_2O$) may be present in part, but this mineral is unstable and alters to maghemite (γFe_2O_3), which in turn alters to hematite (αFe_2O_3). Colors of red are due to hematite. These coloring agents have been identified principally by X-ray diffraction patterns of synthesized material.

Attempts to isolate the coloring agent from naturally colored sandstone in the Powder River Basin have not been successful. A study of thin sections shows that the red coloring materials are microscopic coatings on sand grains either as a clayey crust or as extremely small disseminated specks. A satisfactory method for removal of this coating without upsetting the chemical state has only recently been found in ultrasonic agitators. Techniques involving attrition and concentration have failed generally to give satisfactory results. The red component separated ultrasonically from pink and grayish-pink sandstone from the Inyan Kara group in the Black Hills, which is similar in color to sandstone of the Pumpkin Buttes area, gave good hematite X-ray patterns (A. J. Gude, 3d, oral communication, 1955).

Besides the difficulty in isolating the coloring agent from the sand, there is a further difficulty involving the particle size of the material. It has been found that the natural coloring agent in some red clastic sedimentary deposits is in particles too small to give diagnostic X-ray patterns (Alice D. Weeks, written communication, 1951). It also has been demonstrated that a change in particle size is in part responsible for the variation in shades of red from pink and red to grayish red in a sandstone (Weiser, 1935, p. 33).

Assays of samples of red and drab sandstone from various places in the Pumpkin Buttes area indicate fairly conclusively that the total iron content of these two types of sandstone is similar; furthermore, the content of other metal components such as manganese does not vary appreciably (table 1). The average content of total iron or Fe_2O_3 in the red sandstone is only 0.38 percent more than in the drab sandstone. This difference is not considered significant because in sandstone of either color the iron content can vary as much as 0.5 percent within a distance of a few inches.

Samples PR–51–S1 and PR–51–S2 (table 1), one red and one drab, were taken with care from positions close together across a color contact to determine differences in state of iron as well as in total iron content. The results, though perhaps not conclusive for the whole area, support the conclusion that the color of the sandstone generally does not reflect greater or less content of some specific metal but rather a predominance of one form of oxidized iron over another—hematite (αFe_2O_3) in the red sandstone and limonitic minerals ($\alpha Fe_2O_3 \cdot H_2O$, $\gamma Fe_2O_3 \cdot H_2O$) in the yellowish-brown to grayish-yellow sandstone.

The problem of how this color change developed in the sandstone of the Pumpkin Buttes is complicated by the spatial relation. Sand-

TABLE 1.—*Partial chemical analyses of drab and red sandstone from Pumpkin Buttes area*

[Analysts: D. L. Schafer, J. P. Schuch, Mary Finch, E. C. Mallory, Jr., H. E. Bivens, J. E. Wilson, C. G. Angelo, J. S. Wahlberg, W. D. Goss, J. W. Patton, J. W. T. Meadows, Wayne Mountjoy, H. H. Lipp, and S. P. Furman]

	Drab sandstone, sample—									Red sandstone, sample—						
	PR-246 J-3	PR-246 J-7	PR-253 S2	PR-246 J-2	PR-119 MS-3a	PR-119 MS-4b	PR-119 MS-6a	PR-119 MS-7b	PR-51-S2	PR-51-S1	PR-253-S1	PR-247-M2A	PR-119 MS-1a	PR-119 MS-1b	PR-119 MS-6c	PR-119 MS-8b
U	0.10	0.003	0.003	0.37	<0.002	0.005	<0.002	<0.002	0.002	0.001	0.039	0.002	0.002	--------	<0.002	<0.003
V_2O_5	.14	<.1	--------	.28	.16	.08	.12	.07	<.1	<.1	--------	<.1	.16	.12	.08	.07
Mn	[1] .02	[1] .03	--------	.02	.18	.14	.02	.009	[1] .015	[1] .026	--------	[1] .03	.17	.13	.028	.16
FeO	--------	--------	--------	--------	--------	--------	--------	--------	.36	.36	--------	--------	--------	--------	--------	--------
Fe_2O_3	--------	--------	--------	--------	--------	--------	--------	--------	1.72	1.85	--------	--------	--------	--------	--------	--------
Total Fe as Fe_2O_3 [2]	2.73	3.58	2.02	2.91	3.83	2.18	3.52	3.10	2.12	2.25	2.99	2.89	5.42	3.10	3.59	2.64
$CaCO_3$	1.2	.3	--------	.6	--------	--------	--------	--------	.4	.5	--------	20.7	--------	--------	--------	--------
pH [3]	--------	--------	--------	--------	8.1	8.0	8.1	7.9	8.1	8.3	--------	--------	8.2	8.1	8.0	8.4

[1] As MnO.
[2] Average total Fe_2O_3 in drab sandstone, 2.88 percent; in red sandstone, 3.26 percent.
[3] Measured in slurry of crushed material in water with solids-to-water ratio of 1:1.

stone colored by yellow and brown hydrated iron oxide is in direct contact with sandstone colored red to pink by iron oxide almost without water of hydration. The contact, which shows little or no control by sedimentary structures, grain size, or terrestrial gravitation, is very sharp at most places and includes a zone of no more than a few millimeters. Such a contact might have been formed because of an abrupt geothermal gradient or at a liquid-gas interface, but so little is known about the conditions of formation of the various ferric oxides that the solution of the problem after the reconstruction of the geochemical history remains hypothetical.

URANIUM DEPOSITS

More than 250 uranium occurrences in the Pumpkin Buttes area have been examined or studied in detail. The occurrences are within an area of about 350 square miles, elongate from north to south, with the Pumpkin Buttes in the center (pl. 14). Most of the occurrences are west of the buttes. This preferential distribution, however, may be more apparent than real. The area west of the buttes has been dissected into a badland type of topography that has a much higher percentage of outcrop area than the rolling grassland north, east, and south of the buttes. The probability that mineral deposits are exposed west of the buttes is therefore greater.

The deposits have a variety of irregular shapes that are primarily a function of the distribution and shape of calcite-rich, manganese oxide rich, or hematitic (red) zones in the sandstone. Inasmuch as uranium minerals are generally distributed in and around these zones, the shapes of the uranium deposits may best be considered as incomplete shells a few inches to several feet thick with very irregular bumpy surfaces. The irregular surfaces of several "shells" may coalesce to form tonguelike or podlike extensions of buff sandstone several feet thick and rich in uranium minerals (fig. 101; pl. 16).

All the deposits are in sandstone lenses within a stratigraphic interval of 500 to 1,000 feet below the top of the Wasatch formation. The distribution of the deposits within the lenses and of the lenses within the 500-foot interval seems random. The stratigraphic interval and area that contain uranium deposits are characterized by an abundance of red sandstone (pls. 13, 14).

Megascopic uranium minerals occur at most of the deposits; at other deposits, the uranium is a part of other minerals, such as limonite or possibly clay, and is only detected at outcrops with a Geiger or scintillation counter. The largest deposits contain as much as 5,000 tons of ore, although the great majority contain less than 100 tons. The large deposits have an average grade of about 0.3 percent uranium. The smaller deposits have a very wide range in grade; many contain less than 0.1 percent uranium; others contain as much as 5 percent uranium.

CLASSIFICATION OF OCCURRENCES

The occurrences of uranium in the Pumpkin Buttes area may be conveniently classified into three types according to their habits and mineralogical associations. These types are: (a) oxidized uranium minerals disseminated in porous sandstone and concentrated around calcite-enriched sandstone, (b) oxidized uranium minerals enclosed in or closely associated with manganese oxide nodular concretions, and (c) nodular concretions of uraninite with pyrite.

Disseminated and concretionary forms of uranium minerals occur in the same deposit. Nodular masses of uraninite- and pyrite-cemented sandstone were found, and paramontroseite together with minor coffinite was found in similar habit. Manganese oxide nodules with uranium, though in the same deposit, are separated spatially from disseminated minerals and uraninite concretions.

The oxidized uranium minerals disseminated in drab sandstone are found almost exclusively at and near the contact of the red and drab color. The largest concentrations occur where this color contact is irregular and forms elongate extensions. At places calcite is concentrated in the drab sandstone near the color contact and may have caused the deposition of uranium minerals. Concretionary forms, both those that contain secondary minerals and those that are uraninite, are found within the red sandstone.

These observations are large-scale generalizations and are not to be confused with local small-scale exceptions to the major features of the deposits. Very locally, the sandstone is white around zones rich in uraninite or paramontroseite. Places within red sandstone are mottled grayish white and grayish red, and nodules of manganese oxides with uranium minerals are found in this varicolored zone.

DISSEMINATED HABIT

Oxidized uranium minerals disseminated predominantly in drab to grayish sandstone have been mined at several places. The general characteristics of such deposits are similar everywhere. The Blowout deposit (loc. 253, pls. 11, 14), Jeannette deposit (loc. 246), and localities 50, 51 and 103 typify disseminated uranium occurrences. Yellow to greenish-yellow uranium minerals interstitial to sand grains are in drab sandstone along a color contact and around calcite concretions. Calcite at places cements the sandstone into elongate concretions, and oxidized uranium minerals may be disseminated in a zone several inches thick around such calcite-rich zones. Yellow uranium minerals may occur in a zone several inches to several feet wide that parallels a contact of red and drab sandstone (fig. 102; pl. 16). Irregularities in a generally smooth color contact seem especially favorable sites for concretions of uranium.

Oxidized uranium minerals at the mined areas were distributed in drab sandstone throughout their extensions into red sandstone. A similar condition occurs where the red color intersects the underlying claystone at a low angle; a wedge of drab sandstone lies between the two. Some of these places were intensely enriched in uranium. The ends of the red sandstone lobes also seem to be places around which uranium minerals concentrated.

The drab sandstone containing disseminated uranium minerals is generally very friable except where it is cemented with calcite. Diffusion bands of limonite stain are common but seem to have no relation to the uranium minerals.

The distribution of disseminated occurrences suggests that they are more common at the periphery of the area of red sandstone in the Pumpkin Buttes area than in the center. In particular, the largest known deposits—the Blowout, Jeannette, Moe 14—occur near the periphery.

CONCRETIONARY HABIT

MANGANESE NODULES

Most of the uranium occurrences in the Pumpkin Buttes area exposed in outcrop are associations of secondary uranium minerals with concretionary masses of manganese oxides. These occurrences are mainly rounded to irregular-shaped concretionary masses of black iron-bearing manganese oxides replacing and cementing sandstone. They range in size from less than 1 inch to 2 feet across.

The more regular-shaped concretions (fig. 88), spherical or tubular, have a concentric arrangement of components (fig. 89). Uranium minerals generally are enclosed in a shell of barren submetallic manganese oxides.

The irregular-shaped masses are flat to curving and generally elongate. Uranium minerals are mixed with specks of manganese oxide in zones peripheral to barren masses of manganese oxide, or uranium minerals may be partly enclosed in irregularities in the manganese oxide mass. Manganese oxides with uranium minerals generally occur as isolated concretions. In a few places, masses of manganese oxide with intermixed uranium minerals comprise coalescing spheroidal forms that make up ledges 10 feet across and 20 feet long.

Coalified and ferruginous woody material is common in or around some nodules. It seems probable that organic material localized some of the early components of these concretions—uranium, manganese, and iron in reduced forms. Subsequent oxidation of these metals would prepare these sites for continued deposition of manganese as

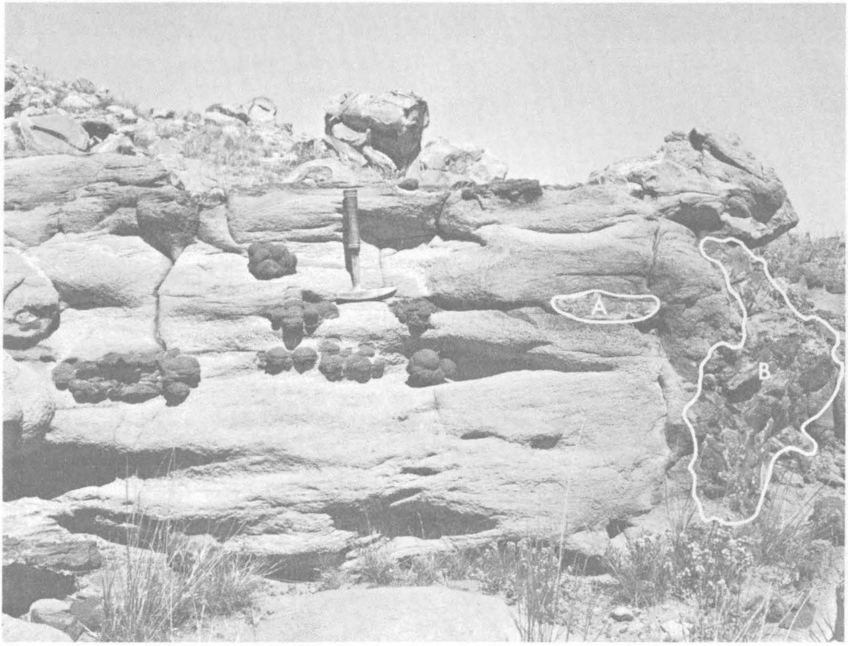

FIGURE 88.—Manganese-oxide concretions in red sandstone exposed at the South School Section deposit (loc. 119, pl. 11). At right (A) is a broken concretion containing yellow uranium minerals; at extreme right (B) are fossil wood fragments in a jumbled zone rich in manganese oxide and uranium.

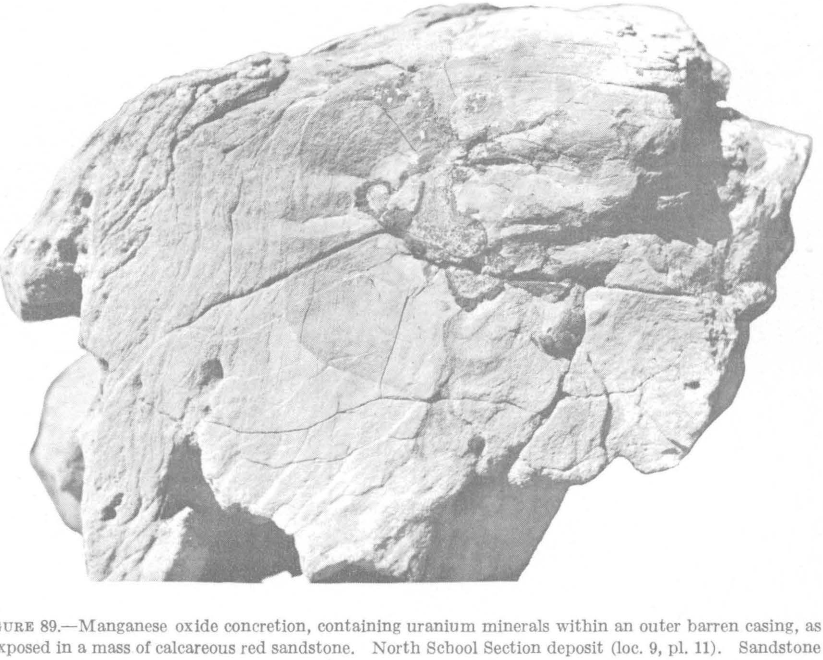

FIGURE 89.—Manganese oxide concretion, containing uranium minerals within an outer barren casing, as exposed in a mass of calcareous red sandstone. North School Section deposit (loc. 9, pl. 11). Sandstone mass is 2½ feet across.

MnO_2, similar to manganese oxide deposition associated with concretions in environments free of organic material.

Manganese oxide nodules are found only within red sandstone. Where they are particularly abundant, the sandstone is continuously red, the bedding is generally contorted, and the larger calcite-cemented sandstone concretions are common. The nodules seem to have no consistent areal or stratigraphic pattern of distribution within individual sandstone lenses.

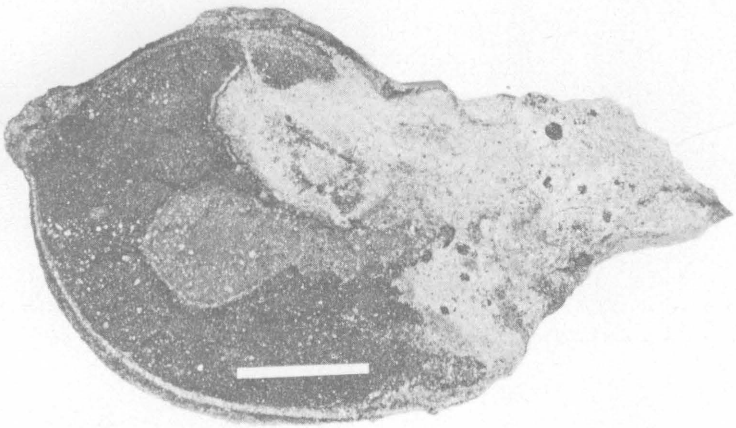

FIGURE 90.—Section through accretionary mass of uraninite cementing sand grains.

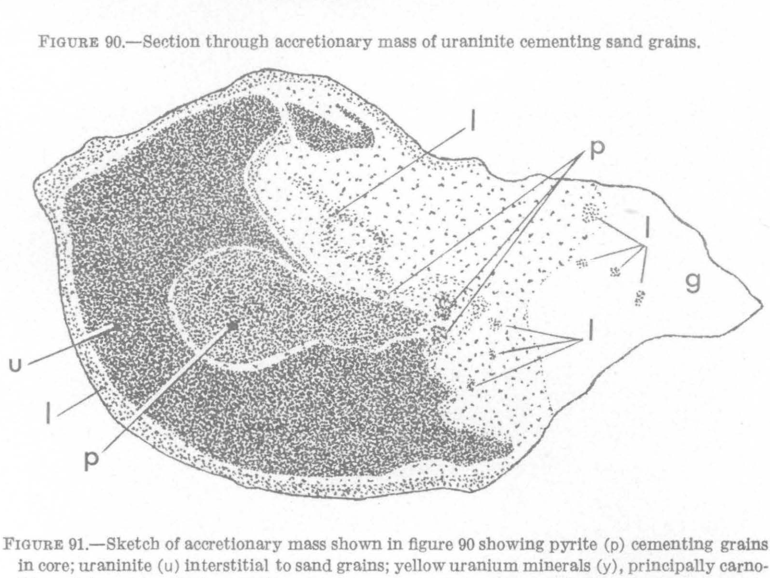

FIGURE 91.—Sketch of accretionary mass shown in figure 90 showing pyrite (p) cementing grains in core; uraninite (u) interstitial to sand grains; yellow uranium minerals (y), principally carnotite and tyuyamunite in oxidation rims around uraninite and as filling between sand grains, generally at the breached side of the mass; limonitic alteration rims (l) and blebs of altered pyrite in oxidized zone; gray and pink sandstone host rock (g). (White strip is 1 in. long.)

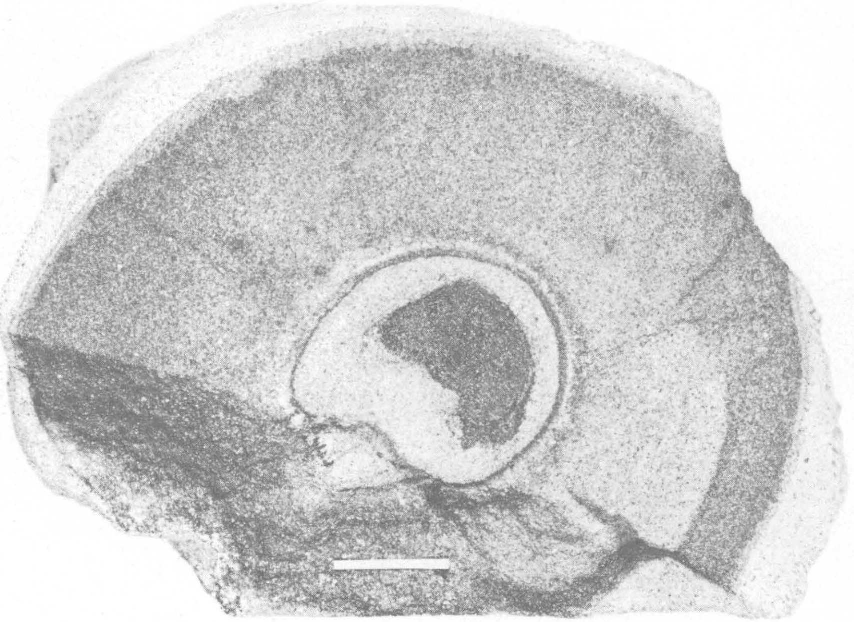

FIGURE 92.—Section through uraninite-bearing concretion from the Jeannette 1 mine (loc. 246, pl. 11).

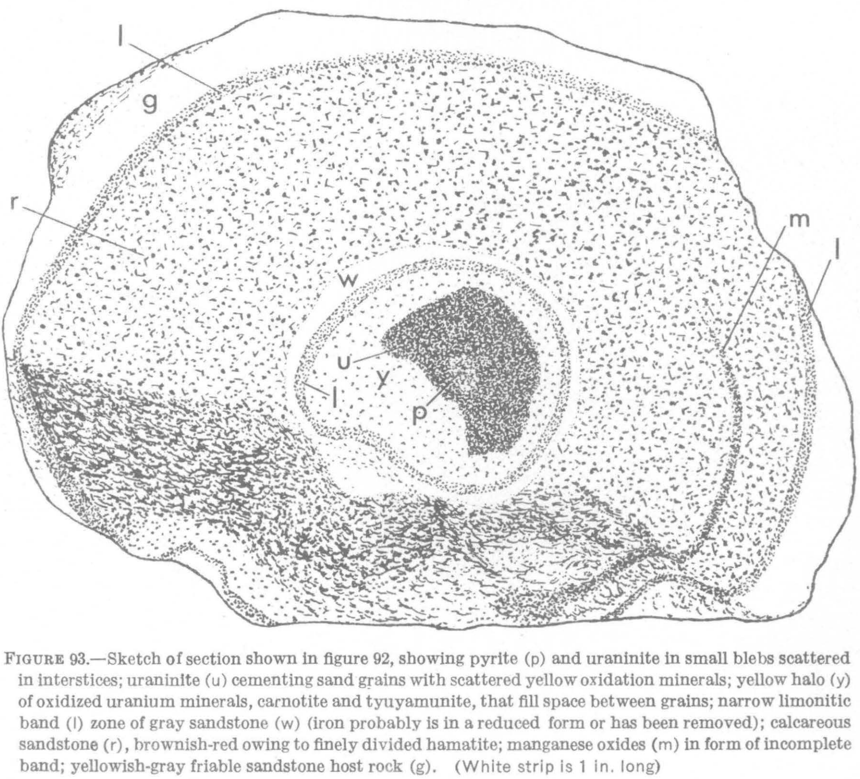

FIGURE 93.—Sketch of section shown in figure 92, showing pyrite (p) and uraninite in small blebs scattered in interstices; uraninite (u) cementing sand grains with scattered yellow oxidation minerals; yellow halo (y) of oxidized uranium minerals, carnotite and tyuyamunite, that fill space between grains; narrow limonitic band (l) zone of gray sandstone (w) (iron probably is in a reduced form or has been removed); calcareous sandstone (r), brownish-red owing to finely divided hamatite; manganese oxides (m) in form of incomplete band; yellowish-gray friable sandstone host rock (g). (White strip is 1 in. long)

URANINITE NODULES

Black pitchy uraninite that cements sand into concretionary masses much like the manganese oxides has been found within 30 feet of the surface at two (Jeannette 1 and Blowout, locs. 246 and 253, pls. 11, 14) of the largest deposits mined in the northeastern part of the Pumpkin Buttes area. It has been tentatively identified mixed with paramontroseite from locality 247. The concretionary masses are crudely spherical or tubular in shape and range in size from about ½ to 8 inches across. Elongate masses may be more than 1 foot long.

Pyrite is generally associated with the concretions and occurs either as a core or as small blebs scattered within or at the edge of the uraninite-rich sandstone (figs. 90, 91). However, here and there coalified woody material is in contact with, or nearly surrounded by, uraninite; and no pyrite is visible. In one hand specimen the remains of a woody fragment were encased in pyrite, which in turn had uraninite and oxidized uranium minerals enclosing it. The core material of this specimen was porous and limonitic, whereas in general such woody matter is coalified.

Inasmuch as the concretionary masses of uraninite have been found relatively close to the surface, all specimens are encased in thick zones extremely rich in oxidized uranium minerals (figs. 92, 93).

RELATION OF URANIUM DEPOSITS TO SANDSTONE LENSES

Uranium minerals in the Pumpkin Buttes area are in sandstone lenses. No preferential distribution of the deposits within a lens was shown by mapping or deduced from field observations.

At the several mined deposits, which are dominantly of a disseminated type of ore, such as the Blowout, Jeannette 1, and Moe 14, the greater part of the ore occurred in the lower half of the sandstone unit. An unknown amount of sandstone has been eroded from the top of the lenses containing these deposits, however; so no valid inference about the distribution of uranium minerals throughout the sandstone can be made. At other deposits, such as the Brown, Craney Draw, and Channel, concentrations of uranium minerals occur at random in the lenses. Many sandstone lenses have uranium near their margins; others have it along the thickest parts. Erosion of the margins and much of the center part of most sandstone lenses precludes making any reasonable inference about the lateral distribution of uranium.

The disseminated deposits transect sedimentary structures and slight changes in lithology and show no consistent spatial relation to shape of sandstone-filled channels. Within a uraniferous zone, however, uranium minerals seem to have an affinity for carbonized, or ferruginous, fossil woody material and may be concentrated around this and sulfide nodules.

The random distribution of manganese oxide concretions in a sandstone base indicates little or no control by the shape and size of the lens. At localities 85 and 86 (pls. 11, 14) they are within a few inches of the base of the sand. At localities 9 and 10 they are near the tops and throughout the central parts of the lenses. Elsewhere they are in marginal as well as in central channel zones.

Manganese oxide concretions are apparently associated with zones in sandstone lenses deposited from turbulent water. These zones lack the regular crossbedding common in most of the sandstone and are a jumble of sandstone and extraneous material (fig. 88). Trashy materials, clay galls and chips, finely divided carbonaceous material, and pieces of fossil wood are more common here than elsewhere.

The uraninite and unoxidized ore material have been found only at excavated places 20 to 30 feet below the surface, generally close to the base of a lens.

RELATION OF URANIUM DEPOSITS TO COLOR IN SANDSTONE

A close spatial relation of concentrations of uranium minerals to red zones in sandstone is the most definitive and probably the most significant large-scale feature readily observed in the Pumpkin Buttes area. All occurrences of the disseminated type of deposit have uranium minerals scattered in drab sandstone adjacent to red sandstone zones. The concretionary types of uranium deposits are in red sandstone. Although these relations are valid at all deposits, not all red sandstone in the Pumpkin Buttes area has associated uranium. Similarly the red-drab color contacts at deposits are not continuously mineralized; the uranium minerals occur here and there along or near the color contacts in zones that range from a few inches to several feet thick.

The richest and largest concentrations of uranium minerals are where the color contact is irregular and podlike tongues of red sandstone extend into buff sandstone (see pl. 16), or where a wedge of buff sandstone underlies a red-colored zone that meets a claystone at a low angle.

At some places, such as the Brown deposit (loc. 31, pls. 11, 14) and locality 245, the greatest concentration of uranium minerals is where the sandstone is the darkest red.

At the Blowout deposit a 5- to 10-foot-thick zone of a very white altered sandstone overlies part of the mineralized zone. At both the

Blowout and Jeannette deposits, the sandstone, instead of being continuously red, is at places mottled red and white—a feature that indicates alteration. The only differences noted between altered white sandstone and the other sandstone, except for color, are that the altered rocks seem to have more clay and less total iron. Because the altered sandstone now has a high redox potential, the lack of red color is not likely to be due to the presence of ferrous rather than ferric compounds.

RELATION OF URANIUM TO CALCITE

Although calcite is ubiquitous in the Pumpkin Buttes area, at places it appears to be a local control for the deposition of uranium. Calcite occurs as interstitial cement in sandstone, as the major constituent of thin limestone lenses, and as a minor constituent of many siltstones and claystones. As an interstitial mineral, the calcite cements the sandstone into the spherical and large elongate concretionary masses that are so common in the buttes area. Uranium minerals are only associated with calcite where it is the interstitial cement in sandstone.

Throughout the area where a sandstone is partially red, accretionary calcite may cement the drab sand along the color contact in a layer 2 to 6 inches thick. Elongate hard calcite concretions are common locally at this contact. At the uranium deposits, a zone of yellow uranium minerals several inches to more than a foot thick commonly rims the calcite concretionary masses and may fill in the sandstone between closely spaced concretions. Much of this accretionary calcite along a color contact has higher than normal radioactivity, even though uranium minerals are not visible. Also the calcite generally is not fluorescent. This association of uranium with calcite (fig. 102) is well shown on outcrops in Craney Draw.

Calcite concretions in red sandstones generally do not have uranium minerals disseminated in or around them unless uraninite or manganese oxide is also present. Both manganese oxide and uraninite nodular concretions have much interstitial calcite. Many manganese oxide concretions, particularly those of concentric structure enclosing uranium minerals, have a core of calcite.

RELATION OF URANIUM TO MANGANESE OXIDE

The close association of the manganese oxides (manganite, psilomelane, and pyrolusite) with uranium minerals (principally uranophane and an orange carnotite) is the chief characteristic of the concretionary manganese type of deposit. Unlike the peripheral relation between red sandstone-calcite concretions and disseminated uranium minerals, manganese oxides enclose or are intimately intergrown with secondary uranium minerals (figs. 94, 96). Another difference between the disseminated occurrence and this concretionary type of oc-

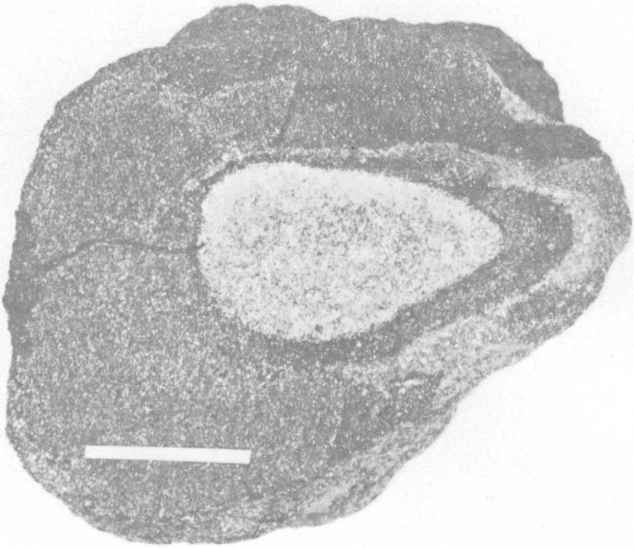

FIGURE 94.—Section through a manganese oxide concretion. Sand grains, cemented by manganese oxides, completely encased a core of sand grains and yellow uranium minerals. (White strip is 1 in. long.)

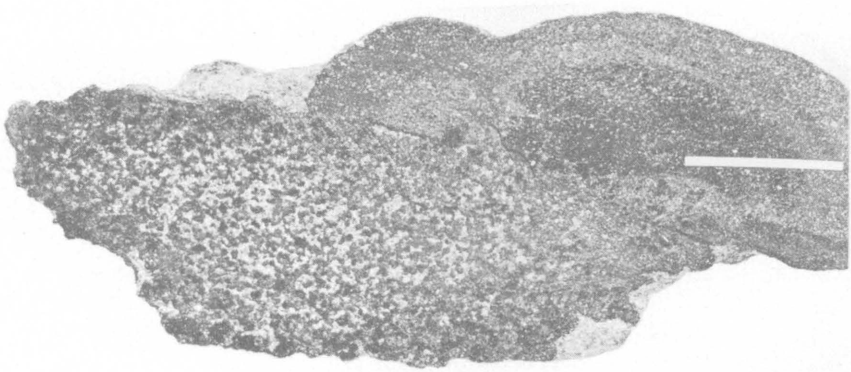

FIGURE 95.—Section through irregular-shaped manganese oxide concretion. Yellow uranium minerals are mixed with blebs of manganese oxides in the central part. (White strip is 1 in. long.)

currence is that the concretionary type generally contains more uranium. Some nodules contain as much as 25 percent U_3O_8. Such concentrations however, generally are less than 1 foot across.

Ideally, the nodules have a concentric structure. An outer casing from ½ to 2 inches thick, depending on the size of the nodule, consists of black submetallic manganese oxides cementing and replacing sand grains. Inside this casing is a zone of gray sandstone rich in interstitial uranophane and containing abundant disseminated blebs of black manganese oxide. This zone grades into a core of little or no manganese oxide that may or may not contain uranium minerals. Uranium minerals in the core are the vanadates carnotite and tyuyamunite. Some of the concentric forms have a barren core of gray sandstone or coarsely crystalline calcite.

The manganese oxides may cement zones of sandstone as much as 1 foot thick and 10 to 15 feet feet across (loc. 119, pls. 11, 14). These zones have spheroidal surfaces and do not follow any particular sedimentary structures though they may form ledgelike zones crudely parallel to bedding. The uranium minerals in the ledgelike zones occur in local concentrations randomly distributed throughout the mass. Where there is relatively much uranium and little manganese, the manganese minerals occur as small blebs about one-eighth inch across, disseminated in the rich uraniferous part of the sandstone.

Not all manganese nodules contain or are associated with uranium minerals. Generally in the nonuraniferous nodules, manganese oxides replace more of the sandstone, making a denser concretion than one containing uranium minerals. These nonuraniferous nodules may be within several feet of nodules rich in uranium minerals.

MINERALOGY

Sandstone from the Pumpkin Buttes area generally contains 40 to 70 percent quartz, quartzite fragments, and chert; about 15 percent feldspar; and minor amounts of chlorite, muscovite, biotite, clay, pyrite, marcasite, gypsum, garnet, tourmaline (elbaite), epidote, hornblende, aegirine, hypersthene, and zircon. Calcite, as cement, is at places a major component. Alteration of feldspar to sericite and clay is rare. Locally uranium, vanadium, and manganese minerals are abundant and the occurrences of these minerals are shown on plates 11 and 14. A list of minerals in these occurrences includes: tyuyamunite, metatyuyamunite, carnotite, uranophane, uraninite, coffinite, liebigite, bayleyite, pascoite, hewettite, paramontroseite, manganite, pyrolusite, psilomelane, pyrite, and native selenium.

Tyuyamunite or metatyuyamunite and carnotite generally occur as irregular-shaped aggregates of microcrystals and rarely have the typical platy habit of uranyl vanadates. They coat sand grains and fill interstices between sand grains and fractures in the detrital minerals and calcite. Fractures in the detrital minerals are also commonly filled with calcite. Both calcite and feldspar are replaced by metatyuyamunite and carnotite; replacement of feldspar, however, is rare. No particular kind of feldspar seems to be replaced more than another. (See fig. 96).

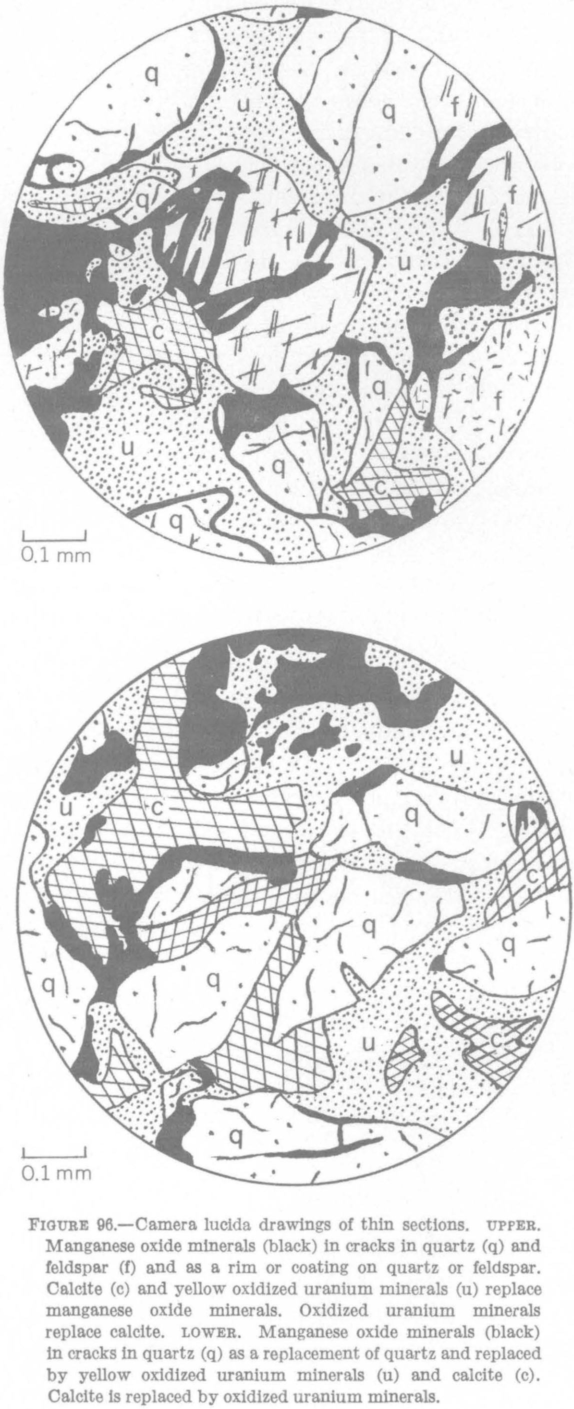

FIGURE 96.—Camera lucida drawings of thin sections. UPPER. Manganese oxide minerals (black) in cracks in quartz (q) and feldspar (f) and as a rim or coating on quartz or feldspar. Calcite (c) and yellow oxidized uranium minerals (u) replace manganese oxide minerals. Oxidized uranium minerals replace calcite. LOWER. Manganese oxide minerals (black) in cracks in quartz (q) as a replacement of quartz and replaced by yellow oxidized uranium minerals (u) and calcite (c). Calcite is replaced by oxidized uranium minerals.

Orange to amber carnotite with a resinous luster has been observed at a few localities (Nos. 222, 246, 9, and 119, pls. 11, 14) closely associated with manganese oxide minerals. The carnotite elsewhere is pulverulent and a characteristic yellow. The orange variety of the mineral in manganese oxide concretions may be more highly hydrated than the type commonly seen.

Studies of thin sections, field observations, and identification of yellow uranium minerals by X-ray powder patterns indicate that metatyuyamunite and carnotite are more abundant than other uranium minerals.

Uranophane occurs much like metatyuyamunite and carnotite. It replaces calcite and fills cracks in calcite and the detrital minerals. Much uranophane forms microscopic aggregates of radiating fibers. Some cavities, several millimeters across along bedding planes in sandstone, have cottonball-like clusters of acicular uranophane crystals that can easily be seen with a hand lens. The uranophane grew on massive limonite that coated the walls of the cavities. The clusters are white, unlike most uranophane, which is characteristically lemon yellow. The crystals range from about 0.5 to 1.0 mm in length and radiate from a common center to form balls about a millimeter in diameter. In thin section, acicular crystals of uranophane generally are normal to the surfaces on which they grew. In one particular section that contains both uraninite and uranophane, some of the uraninite has altered to uranophane. Though uranophane generally is later than the manganese oxide minerals, at some places blades or needles of the two minerals are intergrown, which indicates that they were deposited contemporaneously.

Uraninite has been identified in sandstone from the Jeannette 1 deposit (loc. 246, pls. 11, 14) and the Blowout deposit (loc. 253). The uraninite is a black, dull to vitreous coating on sand grains, or an interstitial filling which cements the sand into irregular-shaped masses (figs. 97, 98). In polished section the uraninite is isotropic, light gray, and somewhat brighter than quartz. Between crossed nicols it has a brown cast and some brown internal reflections. It is medium hard and brittle—a property that causes contacts with other minerals and fractures to widen during grinding by caving of the edges. The rims of uraninite on sand grains may be as much as 0.05 mm thick, and their outer surfaces are commonly nodular or nearly botryoidal. Some smooth-edged, fingerlike projections, however extend into calcite with little or no relation to cleavage trends (fig. 99). Shrinkage cracks are strongly developed in the uraninite that completely fills the interstices as well as in that which only rims the sand grains (fig. 98). Where

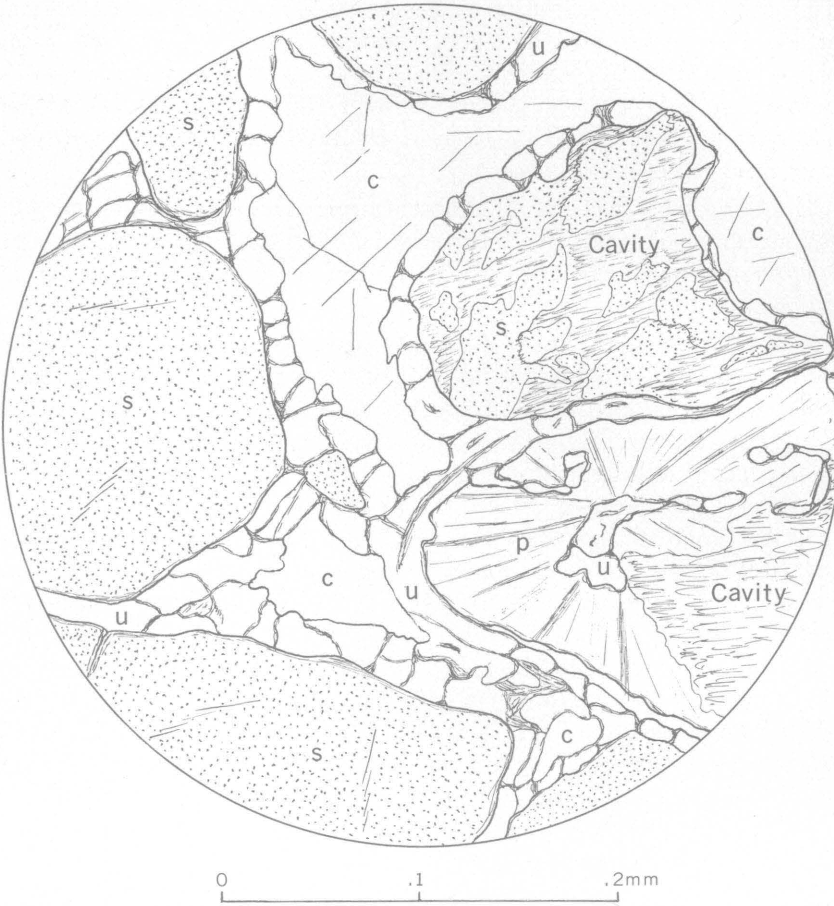

FIGURE 97.—Camera lucida drawing of polished section showing sand grains (s) coated with uraninite (u) with shrinkage cracks. Uranophane (p) is overgrowth on a sand grain. Calcite (c) fills interstices.

uraninite does not fill interstices, calcite generally fills in the central part (figs. 97, 99). The calcite is interpreted to be later than uraninite, principally because of its position relative to the uraninite coating sand grains. At no place does uraninite occur in the cleavage of calcite or show clear-cut replacement of calcite, and the nodular and botryoidal structure and shrinkage cracks suggest that uraninite was deposited in a void as a colloid (Bastin, 1950).

An X-ray powder pattern of a concentrate of the black cementing material gave a distinct but diffused, broad-line pattern for uraninite, which suggests perhaps an extreme fineness of grain size.

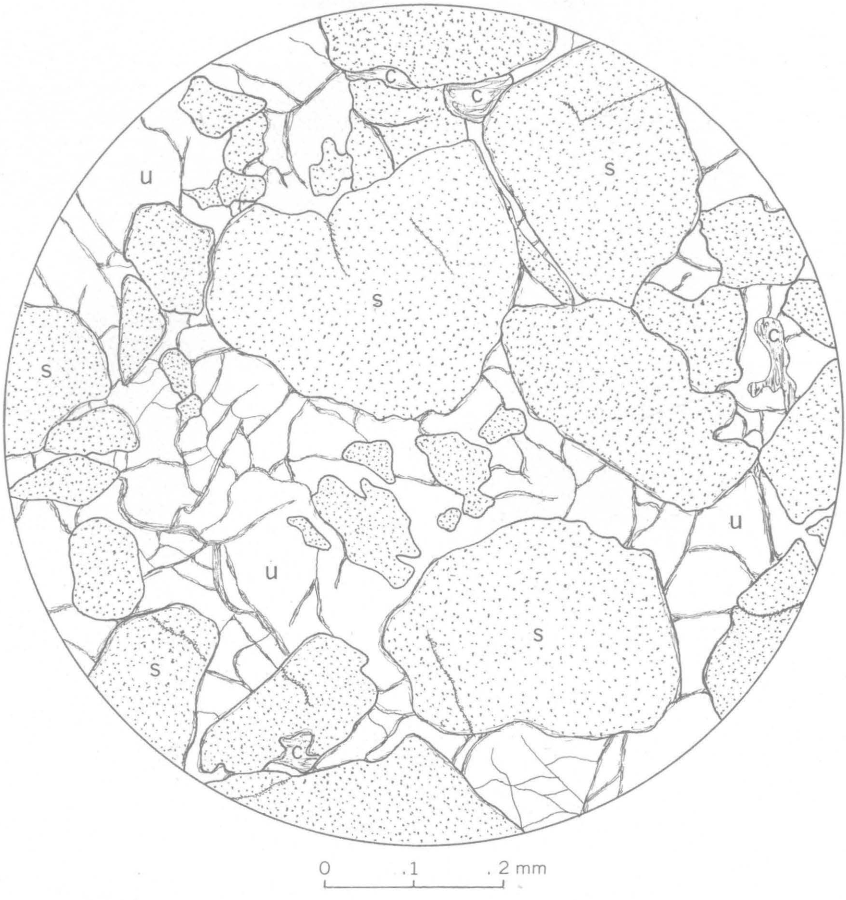

FIGURE 98.—Camera lucida drawing of polished section showing uraninite (u) filling between sand grains (s); cavity (c). Shrinkage cracks in uraninite indicate deposition as a colloid.

A semiquantitative spectrographic analysis of the same material made by George W. Boyes, Jr., gave the following results:

XX.	X.	0.X	0.X–	0.0X+	0.00X+	0.00X–
U	V	Mg	Ti	Fe	Ni	Cu
Si	Al		Mn		Sr	
	Ca		Ba			
			Zr			

NOTE.—Example of plus and minus notation:

Subgroup	Estimated range (percent)
0.X+	0.5–1
.X	.2– .5
.X–	.1– .2
XX.	>10

FIGURE 99.—Camera lucida drawing of thin section showing calcite-filled (c) interstice and nodular uraninite (black) that rims detrital quartz (q) and feldspar (f).

Liebigite and bayleyite occur at a small seep (loc. 29, pls. 11, 14) as incrustations on sandstone and carbonaceous shale at the base of a sandstone lens. A mixture of these minerals, both hydrated carbonates of uranium, is light green to yellow green and fluoresces bluish green. Water from the seep at this locality contains 0.04 ppm (parts per million) uranium.

Pascoite, a calcium vanadate, was identified by X-ray methods. It was found at locality 222 (pls. 11, 14) as orange spots on gray sandstone in the dump material. The rock had been exposed to the weather during the winter, and the pascoite probably was a recently developed mineral formed during evaporation of accumulated moisture.

Hewettite (a calcium vanadate that forms in acid environments) probably is present in small amounts as minute prismatic crystals at most occurrences in the area. It was identified in ore rock associated with tyuyamunite, carnotite, and uranophane from Moe 14 (loc. 222, pls. 11, 14) and the Brown deposits (loc. 31). At both places, the mineral was in clusters of radiating needles less than 1 micron wide and 5 to 10 microns long. Yellow- to red-brown pleochroism was detectable in some crystals.

Paramontroseite, V_2O_4 (Evans and Mrose, 1955), a black submetallic metastable vanadium oxide, has been identified by X-ray analysis from locality 247 (pls. 11, 14) on the Van Irvine Ranch. Like uraninite, paramontroseite fills the interstices between sand grains and cements them to form irregular concretionary masses as much as a foot across. In polished section, the mineral completely fills the spaces between sand grains and does not appear to replace the sand grains. It is gray, slightly lighter than quartz gray, and very soft. Anisotropism is strong and the mineral exhibits many bright multicolored internal reflections.

A spectrographic analysis of a bromoform concentrate of the black interstitial material was made by R. G. Havens with the following results:

x.	x.–	0.x+	0.x	0.0x	0.0x–	0.00x	0.000x+
V	U	Mg	Mn	Ti	Sr	Cr	Pb
Si	Al		Na	Ba		Cu	
Ca	Fe					Zr	

K=0 (sensitivity 1 percent); Cd=0.02; Co=0.002; Yb=0.001
See page 573 for range of values.

In outcrop much of the sandstone containing paramontroseite is coated with an unidentified yellow, green, and blue-green efflorescence. This efflorescence gives a good positive vanadium test and probably comprises several vanadium salts.

Because the paramontroseite-cemented sand is moderately radioactive, an autoradiograph was made of a polished slab. The resulting negative showed definite zones in which there were many small spots of radiation emission. A series of separations was run on the black material from the zone showing radioactive spots, and the heavy fractions were analyzed by X-ray powder diffraction methods; coffinite was found to be present.

Manganese oxide nodules, which make up the most abundant type of concretions, are sand grains tightly cemented by mixtures of finely crystalline pyrolusite, manganite, and psilomelane. All three minerals have been identified by X-ray powder patterns and studied in polished sections. These minerals occur much like uraninite; they rim detrital minerals and fill interstices. They generally fill cracks in detrital minerals (fig. 96) and replace some feldspar, particularly along cleavages. Rarely does manganese oxide replace quartz. In polished section, the manganese oxide material is white to very light gray, and in some places it has a slight yellow hue. It is medium hard and strongly anisotropic.

Selenium is probably ubiquitous in the rocks and soils of the Powder River Basin in abnormal amounts. Evidence of this is the general distribution of selenium-bearing plant life: *Astragalus bisulcatus*, *A. pectinatus*, and *Stanleya.* At the Blowout mine (loc. 253, pls. 11, 14), native selenium is present as minute acicular crystals in dark-red sandstone. The crystals were first observed as a silvery metallic float on the surface of a water slurry of the red sand. Under high magnification the crystals were deep red in transmitted light. Identification was confirmed by X-ray methods. An analysis of a sample of the red sandstone showed 500 ppm selenium and 0.045 percent uranium.

A group of six specimens of pyrite-cemented sand were analyzed for trace metals by R. G. Coleman. The results were noted and discussed in an article by Coleman and Delevaux (1957). Three of these specimens were from barren drab sandstone lenses, and three were from widely separated uranium deposits. All six pyrite samples contained abnormally high amounts of selenium when compared to common sedimentary pyrite, which generally has less than 0.0005 percent selenium (table 2). This would be expected as the Powder River Basin is a known high-selenium area. The pyrite from the mineralized sandstone, however, had a significantly larger amount of selenium than that from barren sandstone. Unlike the pyrite from the Colorado Plateau, the pyrite in the basin showed no apparent change in nickel: cobalt ratio over that in common sedimentary pyrites (R. G. Coleman, written communication, 1957). A complete spectrographic analysis of the six samples is given in table 2.

THERMOLUMINESCENCE TESTS

Thermoluminescence tests were made of 12 samples of sandstone from the Pumpkin Buttes area. These samples were selected to represent all the widespread types of sandstone: red, buff, calcite rich, and uranium bearing. Such tests indicate the metastable energy state of certain minerals—a condition probably brought about by gamma radiation such as might come from uranium-bearing ground water or other solutions (Daniels and others, 1953). Some minerals, one of which is quartz, if heated give off an excess energy as luminescence at particular temperature levels and with particular intensities. The red zones of the sandstone lenses in the Pumpkin Buttes area could

TABLE 2.—*Analyses of concretionary pyrite from barren and mineralized sandstone, Pumpkin Buttes area*

[Analysts: Joseph Haffty; Maryse Delevaux (Coleman and Delevaux, 1957, p. 518)]

	Barren sandstone, sample—			Mineralized sandstone, sample—		
	PR-219-S (Craney Draw)	PR-219-S2 (Craney Draw)	PR-219-S3 (Willow Creek)	PR-246-S (Jeannette Mine)	PR-247-S (Van 1 claim)	PR-220-S ("Channel" claim)
Semiquantitative spectrographic methods						
Range (percent)						
More than 10	Fe	Fe	Fe	Fe	Fe	Fe
5–10						
1–5						
0.5–1						
0.1–.5	Al, As	Al	Si	Si, As, Al	Al	Al
0.05–.1	Si, Mg	As, Si	Al		As, Si, Mg	Mg
0.01–.05	Ba, Na	Mg, Na, Ba, Ni, Ti, Zr.	Na, As	Na, Ni	Na	Ba, Si, Na, As
0.005–.01	Zr, Ni, Mn	Mn	Mn	Mg, Zr	Ba	Mn, Ti
0.001–.005	Ti, Cu, Sr	Sr, Cu, Co, Pb.	Ni, Mg, Pb, Sr, Cu, Ba, Zr.	Ba, Mn, Cu, Sr.	Cu, Mn, Ni, Zr, Sr.	Cu, Zr, Ni, Sr
0.0005–.001	Cr		Cr, Ti	Ag	Ti	
0.0001–.0005	Ag					
Chemical methods						
Constituent (percent)						
Se	0.008	0.006	0.004	0.03	0.17	0.01
Ni	.008	.02	.005	.01	.003	.004
Co		.002				

be the result of passing uranium-bearing solutions and may show this by a high thermoluminescence.

An instrument to measure thermoluminescence, built by William W. Vaughn of the U.S. Geological Survey, consisted of a 5819 photomultiplier tube mounted in an inverted position in a lightproof box. The intensity of light given off by a heated sample under the photomultiplier tube was recorded on the X-axis of the chart paper of a recording potentiometer. The sample was heated at a rate of about 1°C per second, and the temperature was measured by a thermocouple. The temperature change was recorded by movement along the axis of the chart paper on the recorder. The resulting glow curve (Saunders, 1953) is a plot of intensity of light emission as a function of temperature.

The following procedure, which was developed by E. V. Post (written communication 1954), was used for testing thermoluminescence. All samples described in table 3 were crushed and screened to minus 80, plus 170 mesh, and treated with aqua regia for 16 hours. The samples were then thoroughly washed in distilled water and dried at room temperature. Samples weighing approximately 200 mg were measured with a small scoop and spread evenly over the bottom of a 25 ml crucible. Several equal parts of 6 of the 12 samples were tested to

TABLE 3.—*Descriptions of sandstone samples used in thermoluminescence tests*

Sample	Location	Color	Calcite rich	Uranium minerals present
1	Jeannette 1 deposit	Drab	No	Yes.
2	do	do	No	(?).
3	do	do	No	No.
4	do	Red	Yes	No.
5	"Blowout" deposit	Drab	Yes	No.
6	do	do	Yes	No.
7	White River formation, top of South Butte.	White	No	No.
8	Craney Draw area, near deposit	Drab	No	No.
9	do	do	No	Yes.
10	do	Red	No	No.
11	Craney Draw area, away from uranium deposit.	Drab	No	No.
12	do	Red	No	No.

determine the reproducibility of the thermoluminescence measurements. The peak intensities as recorded on the recording potentiometer were reproducible to within 20 percent of the average value of the peak intensity of several aliquot parts of the same sample. The temperature of the peak intensities varied as much as 20 percent from the average of several tests on equal parts of the sample, though most determinations were within 10 percent of the average.

The results (fig. 100) of the tests indicate that neither the intensity of thermoluminescence nor the temperature at which the thermoluminescent phenomenon took place can be correlated with any recognized characteristic such as color or composition of the sandstone. Furthermore, the shapes of the thermoluminescence curves are all similar; they all have a secondary peak within a temperature range of 250° to 275° C.

Samples of sandstone from the Inyan Kara group (a sequence of rocks which contains uranium deposits and which is similar to the Wasatch formation) from near Edgemont, S. Dak., tested in the same manner, were only one-eighth as thermoluminescent as sandstone from the Wasatch formation.

The thermoluminescence of a rock is a function of so many unmeasurable variables that it is difficult to make reasonable conclusions when there is no statistical or empirical correlation between temperature or intensity of thermoluminescence and some other characteristic of the rock.

Though the intensity of thermoluminescence is generally proportional to the amount of radiation received, a saturation point can be reached. For example, "* * * alkali halides and limestone reach saturation after about 100,000 roentgens of Co^{60} radiation. Continued irradiation may simply give a constant thermoluminescence intensity or may give a decreasing intensity * * *" (Daniels, and others, 1953). This characteristic may explain the lack of correlation between ther-

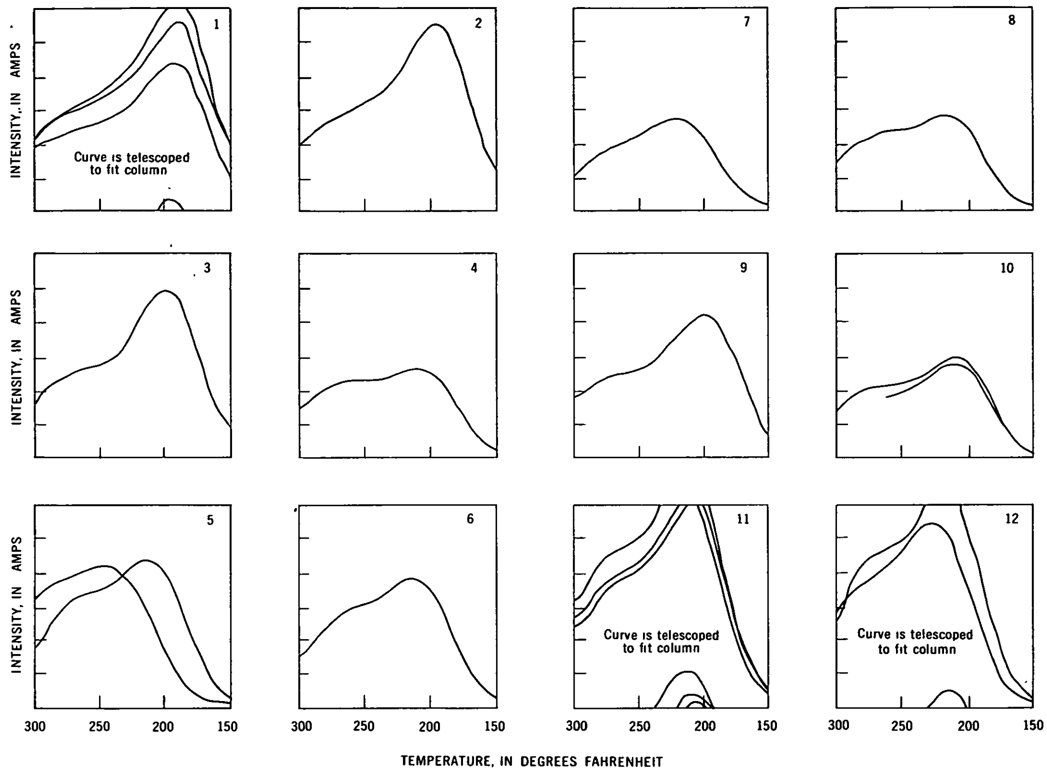

Figure 100.—Glow curves of samples from Pumpkin Buttes area. For description of samples, see table 3.

moluminescence intensity and the various types of sandstone from the Wasatch formation that were tested. If the minerals in the sandstone had reached saturation, the presence of concentrations of uranium or passage of uraniferous solutions through them probably would have little further effect on the thermoluminescence of the minerals. This inference is further supported by consideration of the amount of radiation inherent in the rock. Measurements with scintillation and Geiger counters show that the sandstone in the Wasatch formation commonly has a radioactivity of about 0.02 mr per hr. This is approximately 0.2 roentgens per year. If only one-tenth of this radiation is effective in producing thermoluminescence of minerals, 5 million years would be long enough for at least some crystals to reach saturation. As the sediments of the Wasatch formation are probably derived from Precambrian rocks, it seems likely that most of the minerals have reached thermoluminescent saturation.

Another inference that may be made from the thermoluminescence tests is that the sandstone of the Wasatch formation probably has never been heated to a temperature in excess of 220°C, because all samples gave a high thermoluminescence near or slightly below this temperature. On the other hand, the lack of thermoluminescence below approximately 150°C indicates that the rock may have been heated to as much as 125° C.

CONTROLS OF MINERALIZATION

The restricted areal and stratigraphic distribution of the red sandstone zone (and uranium deposits in this zone) in the Wasatch formation suggests a regional control that must have had a differential relation to this area of the Powder River Basin. Other general features of the formation point up such a regional condition that affected the Pumpkin Buttes area differently from the rest of the northern and central part of the Powder River Basin. For example, marginal to the red sandstone zone on the north are areas of ferruginous siliceous sandstone lenses. On the west is a less well defined area of sandstone containing ferruginous zones (ironstone), some of which are radioactive (Troyer and others, 1954, p. 17). The ferruginous sandstone is not commonly abundant in the Wasatch formation or throughout the red color zone. Also, the larger known uranium deposits are found near the lateral margins of the red sandstone zone. Such regional features as these, as well as the local features associated with the red sandstone zone, reflect a change in the geochemical environment, which in turn reflects a change in geologic conditions in this part of the Powder River Basin.

A spatial relation between geologic structure and the red sandstone zone is shown in figure 87. The intersection of the north- to northwest-trending Pumpkin Buttes anticlinal fold on the shallow east limb of the basin structure and a northeast-trending fold reflected in the Precambrian basement rocks coincides with the red sandstone zone in the Pumpkin Buttes area. Work southeast of the Pumpkin Buttes has revealed that the red sandstone zone and the uranium deposits continue southeastward and appear to overlie a positive fold feature on the east side of the basin syncline in the southern part of the basin. From these spatial relations, it seems reasonable to associate the red sandstone zone in the Pumpkin Buttes area genetically with the basement structures, slightly reflected in the surface rocks, and the process of late structural development. This rock deformation could have been the mechanism that changed the geochemical balance in the area and began the changes in mineralogy and concentration of metals found in and about the red sandstone zone of the Wasatch formation.

In contrast to the red sandstone zone which, more than any other feature, reflects a large-scale controlling mechanism, the association of uranium deposits to separated sandstone lenses reflects local control and a local intrinsic source of uranium and the associated metal minerals.

The conclusion is that the concentrations of uranium, vanadium, iron, manganese minerals, and calcite in the sandstone lenses of the Wasatch formation in the Pumpkin Buttes area may best be explained by the redistribution and concentration or intralens accretion of the originally more dispersed components of the sandstone lenses. Also, the regional mechanism that formed the red sandstone zone initiated the local processes of movement and redeposition of calcite and uranium, vanadium, manganese, and iron minerals.

ORIGIN OF DEPOSITS AND COLOR FEATURES OF WASATCH FORMATION

No single cause for intralens accretion can now be proved. However, the relations that suggest this mechanism of concentration are: the apparent redistribution of limy material within sandstone lenses; the epigenetic color change, drab to red, or dehydration of hydrated iron oxides associated with uranium deposits in sandstone lenses; the general unaltered condition of clay and the low uranium content of coal and carbonaceous shale between sandstone lenses; and the lack of faults, shears, and widespread sandstone units that would serve as channels for inter- or intraformational distribution of mineralizing water.

The abundance of calcite, limy sediments, and well and spring water with a pH range of 7 to 9 indicates that water in the sandstone lenses in the Pumpkin Buttes area has always been generally alkaline and rich in carbonates, chiefly calcium carbonate. Presumably an acidic condition may have existed for a time at places, and locally at or near carbonaceous shale and coal beds.

Also, the widespread red sandstone is a good indicator of general oxidizing conditions. As the red color in sandstone seems to have formed generally earlier than the concentrations of manganese, uranium minerals, and calcite, it is likely that any large zones with a negative redox potential existed during deposition of the various types of concretions or disseminated uranium minerals. Local small zones of low redox potential were and are present, as indicated by the presence of pyrite, uraninite, paramontroseite, and coffinite at places around coalified wood and pyrite and uranite in sandstone rich in plant material. These zones may be the results of pockets of the H_2S-rich water or gases that come from decomposing organic matter in the sandstone or, more likely, from the carbonaceous shale and coal.

NATURE OF THE MINERALIZING SOLUTIONS

The limy character of the Wasatch sedimentary rocks, abundance of epigenetic calcite and its apparent local control of much uranium deposition suggest that the mineralizing solutions had a high carbonate and bicarbonate ion content. The relative amounts of carbonate and bicarbonate ions, and consequently the pH of the rock fluids, are a function of the partial pressure of CO_2 dissolved in the fluids. At depths of several thousand feet, CO_2 could exceed the solubility in water, giving rise to a separate CO_2 fluid phase (Garrels and Richter, 1955). Despite the lack of useful information on CO_2 at high pressures, data resulting from the investigations of using carbonate leaching methods on uranium ore (Bullwinkel, 1954) provide an adequate explanation for the solution, migration, and precipitation of the principal elements in the uranium deposits of the Pumpkin Buttes area.

Uranium is readily taken into solution as uranyl carbonate complexes according to the reactions below (Bullwinkel, 1952; 1954).

$$UO_3.2H_2O+2HCO_3^{-}\rightleftarrows UO_2(CO_3)_2(H_2O)_2^{-2}+2H_2O$$

$$UO_2(CO_3)_2(H_2O)_2^{-2}+CO_3^{-2}\rightleftarrows UO_2(CO_3)_3^{-4}+2H_2O$$

The resulting solutions at equilibrium are nearly neutral; however, equilibrium probably is not attained in the natural environment, so the reactions would continually move to the right. These complexes are extremely stable in the intermediate pH range but are destroyed by the addition of either H^+ or OH^- (Garrels and Christ, 1959, p. 86) :

$$UO_2(CO_3)_3^{-4}+2H_2O+H^+ \rightleftarrows UO_2(CO_3)_2(H_2O)_2^{-2}+HCO_3^-$$

$$UO_2(CO_3)_2(H_2O)_2^{-2}+2H^+ \rightleftarrows UO_2^{+2}+2H_2O+2HCO_3^-$$

$$UO_2(CO_3)_3^{-4}+4OH^-+M^{+2} \rightleftarrows MUO_4+2H_2O+3CO_3^{-2}$$

In slightly acid solutions the uranyl ion forms, and it is free to form other complexes, which in nature are generally the insoluble vanadates, phosphates, or arsenates. The stability or uranyl carbonate complexes is evident from adsorption studies by Watson (1952). After testing many commercially available activated chars, gels, hydroxides, complexing agents, and chelating agents, he concluded "* * * test work to date has provided no indication that a uranium or vanadium complex ion can be formed in carbonate leach solution which would be extractable from solution by adsorption." A soluble uranous carbonate complex with the probable formula $U(CO_3)_3^{-2}$ (Bullwinkel, 1952) is stable only in solutions with excess CO_3^{-2} and HCO_3^-. The HCO_3^- acts as a buffer and removes OH^-. Uranium, therefore, in any of its natural states of oxidation may be taken into solution in an environment high in bicarbonate ion content, and in a carbonate complex it may be free to migrate long distances even in the presence of vanadium.

Vanadium has compounds over a wide range in valence, ranging from +2 to +5; and compounds in which the valence is +3, +4, or +5 are common nature. Most of the lower-valent compounds are insoluble in alkaline solutions but soluble in acid solutions. Minerals of mixed V^{+4} and V^{+5}, such as corvusite, are relatively insoluble. Vanadium pentoxide, V_2O_5, however, is strongly amphoteric and dissolves readily in both acid and alkaline solutions. It would seem then that vanadium is transported in the fully oxidized form (V^{+5}) under acid or weakly alkaline conditions. Because there are no minerals that contain U^{+4} or U^{+6} in combination with vanadium with a valence less than +5, and because the Eh stability range of vanadium +4 compounds overlaps the stability range of the uranyl ion (U^{+6}) (Garrels, 1955, p. 1017), it is reasonable to conclude that uranium may be free to migrate even in an environment where vanadium is present (Garrels, 1960, p. 186 and 189) ; also, it would seem that the formation of uranyl vanadates probably is a relatively late feature of uranium mineralization, even when vanadates may be primary minerals. Uranium with a valence of +6 may therefore migrate, concentrate, or precipitate in an Eh and pH range that would essentially preclude vanadium from being in solution. Then with an increase in Eh, V^{+5}, which is readily soluble, exists and is free to migrate until it meets U^{+6} compounds.

690-454 O—64——4

Carbonate- and bicarbonate-rich solutions also provide a means for the solution, migration, and precipitation of manganese. Manganese, sparsely distributed in rocks, is readily taken into bicarbonate solutions, and it may be transported considerable distances even in slightly alkaline water under certain conditions of low oxygen content. Experiments by Savage (1936, p. 281–283) show that syenite containing 62 ppm MnO is leached of manganese by carbonated water more readily than by either oxygenated water or peat water. The nodules of manganese oxides that are found on a gravel bottom in quiet lake water 2 to 6 feet deep also attest to the fact that manganese can be leached from rock with a low manganese concentration, carried in solution at low concentration, and deposited as nodules containing about 35 percent MnO_2 (Kindle, 1932). The high concentration of manganese in nodules is explained in much the same manner as large crystals in dilute solution tend to grow larger and small crystals grow smaller. Savage (1936, p. 291) describes the process as a cumulative catalytic effect. The sandstone in the Wasatch formation generally contains about 20 ppm MnO, an adequate amount to have supplied the material that is presently found in the nodular concretions.

Though iron will react in much the same way as manganese, presumably its oxides do not have the cumulative catalytic tendencies of manganese. Furthermore, the concentration of iron (2–3 percent) in the Wasatch formation may be high enough to saturate readily any solvent that passes over the iron minerals.

Several processes may have functioned to convert the original hydrated iron oxides or other compounds of iron to predominantly hematite in the zone of red sandstone. The detailed mechanism is not clearly understood; however, some solution of iron is probable in a CO_2-rich environment (Garrels and Richter, 1955, p. 454). Reprecipitation as hematite of the small amount of iron dissolved would be likely to take place on undissolved particles or partially altered hydrated iron oxide.

In summary, the carbonate and, at times, high bicarbonate environment of the Wasatch sediments seems adequate to explain the solution, migration, and precipitation of all the major elements in the uranium deposits in the Pumpkin Buttes area.

MECHANISM OF DISTRIBUTION

The distribution of uranium deposits, the lack of interformational permeable channels such as faults and shear zones, the lack of fracturing and the discontinuity of the permeable sandstones within the Wasatch formation present a problem of origin not uncommon for sandstone-type uranium deposits. Field evidence suggests that the elements were intrinsic to the sandstone lenses. Analysis of the possible chemistry required to concentrate the intrinsic elements supports the possibility of intralens accretion rather than opposes it.

The following sequence of conditions and reactions is proposed as the mode of intralens accretion:

1. An increase in CO_2 partial pressure occurred as a result of an addition of CO_2. The increase in CO_2 would cause a high concentration of carbonate and particularly of bicarbonate ions and appreciably increase the hydrogen ion concentration. Because of a change in pressure due to lithostatic and hydrostatic load, some of the amount of CO_2 exceeded the solubility in H_2O and a dense fluid phase developed. The density of CO_2 increases rapidly with small changes in pressure, consequently the density of the gas may have approached that of water. A lithostatic load of 1,000 feet is equivalent to about 50 atmospheres pressure at which CO_2 has a density of about 0.6 (Garrels and Richter, 1955, figs. 1, 5). The density of CO_2 in a sandstone lens would not everywhere be the same, because of small differences in porosity and permeability and the original calcite content. Very likely some zones (hereafter called CO_2 zones) would be much richer in CO_2 than the surrounding rock. Consequently the intensity of the various reactions of bicarbonate and carbonate ions with uranium, vanadium, iron, and manganese would be different in the CO_2 zones than elsewhere. The boundary of the CO_2 zones would be an interface of liquids of different compositions. A simplified analogy is the interface between alcohol and water when they are not mixed. Although the two liquids are miscible, each of them may act as a solvent for some compounds that are soluble in both liquids.
2. The CO_2 zones thus formed are believed to be the site of chiefly three processes:
   a. The red of the sandstone would develop in the zones of highest CO_2 concentration. Because of the low solubility of ferric oxide hydrate and relatively high concentration of iron in the Wasatch formation, iron would probably go into solution last as CO_2 pressure increased and would reprecipitate first as CO_2 pressure decreased.
   b. As the total gas pressure in a sandstone lens, both within and without CO_2 zones, decreased, calcite would precipitate first outside of the CO_2 zones because of initially lower CO_2 partial pressure. As the calcite crystallized the concentration of bicarbonate, hydrogen, and carbonate ion content within the CO_2-zone would increase greatly relative to that in the rest of the sandstone lens. This condition would tend to cause the remaining carbonate, bicarbonate, complex uranium, and complex vanadium ions to migrate toward zones of lower concen-

tration; that is, toward the rim of the CO_2 zone. The ultimate result would be a small concentration of calcite rimming the CO_2 zone, and a concentration of uranium and vanadium compounds against and within this rim. The calcareous concretions and the accompanying disseminated deposits of uranium that are the major ore zones in the Pumpkin Buttes area may have formed in this manner.

Parts of the CO_2 zone undoubtedly had segments where partial pressure of H_2S or the concentration of other reducing agents from organic matter was high. In such environments reduced forms of iron, uranium, and vanadium precipitate with rising pH.

c. Manganese nodules formed and continued growing during and after the deposition of calcite and of uranium and vanadium minerals.

It is unlikely that a single sequence of deposition can be developed with uranium vanadates and silicate, and such easily dissolved compounds as manganese oxides and calcite. All could be deposited under similar conditions. It appears that the components of the manganese nodules are more or less contemporaneous. The present $CaCO_3$ and uranium vanadates at places could be the initial material. Manganese oxides could then collect in the common nodular form and be very stable in such an environment. The subsequent replacement of quartz by manganese oxides in forming the nodular casings would release silica to join with available uranium, not held as vanadates, to form uranophane. The system after being enclosed by a tight shell of manganese oxide would be extremely stable in oxidizing environments. Although perhaps not all uranium minerals were enclosed within the manganese shell, any oxidized uranium minerals in the porous sandstone outside the protective casing of manganese oxide could have been carried away with the dissolved $CaCO_3$ cement, when at or very near the surface of the ground, until little or none remained.

Irregular-shaped masses of manganese oxide mixed with uranium minerals without concentric arrangement of components are found at many places. These masses almost never are exposed at the surface, and if found very close to the surface they are generally in hard calcareous sandstone which offers protection for the other components involved. Without the manganese oxide envelope, the mixture seems to fall apart easily when exposed to weathering for a year or so; failure seems to be due to loss of calcite. Both the relation of manganese oxides and oxidized uranium minerals and their concentric arrangement in concretions were controlled by similar conditions of Eh and pH. The nodular forms, manganese oxides enclosing uranium minerals—always found exposed or very near the surface—are recent modifications by weathering of a system of minerals set up initially by approximately contemporaneous deposition.

AGE OF DEPOSITS

A sequence of events leading to accumulations of uranium in the Powder River Basin was postulated in the preceding section. For the deposits to be formed by the processes described, certain geologic requirements must be met, and in them may be found evidence for a more specific geologic dating than Tertiary for the ore accumulations. The beginnings of redistribution and concentration of the uranium disseminated throughout the sandstone lenses were more likely during deepest burial of the Wasatch formation. This time is judged to be post-early Oligocene, perhaps as recent as middle Miocene time. Very likely, Miocene rocks covered the Powder River Basin (Darton, 1905, pl. 44), and although not now present they are well represented in adjoining areas to the southeast. With the erosion of much of the Miocene(?) and Oligocene rocks, probably in Pliocene time, the lithostatic load on the Wasatch formation was removed and the principal processes of redistribution and accumulation of uranium were no longer effective.

This hypothetical geologic dating is supported by age determinations made of several samples of uranium-bearing materials by Loren Stieff and others in the U.S. Geological Survey laboratory. An age determination was made using uranophane-rich material in a manganese oxide nodule from a surface exposure, an initial use of uranophane in such work. Uraninite in sandstone and the minerals from the oxidation halo around the uraninite from the Blowout deposit were also analyzed and their age dated. The ages determined from lead: uranium ratios (Pb^{206}/U^{238} and Pb^{207}/U^{235}) for the 3 samples range from 4.5 to 13 million years (L. R. Stieff, written communication, 1960). The youngest age was given by the uranophane, but lead: uranium ratios from all the specimens indicate a very young age for the uranium deposits of the Powder River Basin.

Lead: lead (Pb^{207}/Pb^{206}) ratios from the same materials, however, present a different and less consistent pattern. The best age estimate for the uranophane by this ratio was 33 million years, in general the same order of magnitude as with the lead: uranium ratio, but both the uraninite and its oxidation halo were dated by this method at about 425 million years. This different character of lead and apparently younger lead: uranium age, relative to the uraninite, for the uranophane in the manganese oxide masses supports the geologic inference that uranium minerals in these nodules are more recently developed than that in the principal deposits, and the nodules may be closely related to the present topography. It appears then that relatively little common lead or old radiogenic lead was carried along with the uranium deposited as uranophane with the manganese oxides. The Pb^{207}/Pb^{206} ratio of the radiogenetic lead is, within limits of error, that of modern radiogenetic lead. However, according to Stieff, in the uraninite and its oxidation halo minerals, some common lead as well as some older radiogenetic lead was carried to the present site along with the uranium. The anomalously high Pb^{207}/Pb^{206} ratios reflect the age of the source material of the uranium and the older radiogenetic lead.

The analytical data and calculated ages for uranium ores in the Pumpkin Buttes area are listed in table 4.

Radon loss may be discounted as an important factor in developing the high Pb^{207}/Pb^{206} ratios inasmuch as the loss, if significant, would be less in the buried unoxidized uraninite than in the exposed uranophane mineral—a condition that would tend to give an age relation opposite to that found to exist.

It appears then by both geologic inference and isotopic ratios that the uranium deposits in the Wasatch formation of Powder River Basin were formed during middle and possibly late Tertiary time. The lead isotope ratios also suggest that the uranium is from a much older original site where rocks were comparable in age to the crystalline rocks of the Laramie Mountains, the apparent source of most of the Wasatch clastic material.

SUMMARY OF ORIGIN OF URANIUM DEPOSITS IN THE WASATCH FORMATION

Oxidized uranium and vanadium minerals and manganese oxides precipitate in an alkaline oxidizing environment; these minerals are both later than and contemporaneous with calcite in the Wasatch formation. Paramontroseite, uraninite, and pyrite form in alkaline zones of low redox potential; these minerals developed before and probably contemporaneously with calcite.

Mineralization—the solution and subsequent precipitation of uranium, vanadium, manganese, and iron minerals—and the change from drab to red color in sandstone are inferred to be related to the same factors that caused the solution and redistribution of limy material and deposition of calcite. The mineralization could have begun by a differential increase in the partial pressure of CO_2 to form CO_2-rich zones, in which the processes of mineral redistribution worked. The deposits achieved a high degree of stability with a decrease in CO_2 content in the rocks, brought about by the utilization of CO_2 in reactions and escape of CO_2 as erosion decreased the lithostatic load.

TABLE 4.—*Analytical data and calculated ages for uranium ores, Pumpkin Buttes area, Powder River Basin, Wyo.*

Sample		Pb (percent)	U (percent)	Atom abundance of lead isotopes (percent)				Calculated ages in 10^6 years		
No.	Source and type of material			Pb^{204}	Pb^{206}	Pb^{207}	Pb^{208}	Pb^{206}/U^{238}	Pb^{207}/U^{235}	Pb^{207}/Pb^{206}
GS–140 [1]	Uranophane-rich material from manganese nodule, loc. 81, pl. 2.	0.008_4	12.86	0.05_2	94.1_4	4.79_8	1.01+	4.5	4.6	33
GS–419 [2]	Uraninite in sandstone, black core of nodular mass, loc. 246, pl. 2.	.021	22.15	.05	92.2_6	5.69_0	1.99_9	[3] 7.0	[3] 8.0	[3] 357
GS–420 [2]	Yellow secondary uranium minerals, surrounding black core of GS–419.	.017	9.85	$.121_6$	88.6_2	6.37_3	4.88_7	[3] 11.0	[3] 13.0	[3] 240
Composite: GS–419, 420										425

[1] Isotopic analysis by Carbide and Carbon Chemical Co., Oak Ridge, Tenn.
[2] Isotopic analysis by U.S. Geological Survey, Washington, D.C.
[3] These calculated ages obtained by using age tables of Stieff and others, 1959, U.S. Geol. Survey Prof. Paper 334–A.
Pb^{208} was used as the index isotope, with a common lead of the following isotopic composition: $Pb^{204}/Pb^{208}=0.0262_2$; $Pb^{206}/Pb^{208}=0.482_7$; $Pb^{207}/Pb^{205}=0.407_3$

DESCRIPTION OF DEPOSITS

Several deposits in the Pumpkin Buttes area have been selected for detailed description. Most of these represent large and well-developed bodies of ore-grade material. Some, on the other hand, are only occurrences, but they are included because they exhibit some particular feature or mode of occurrence of uranium not conspicuous in other deposits. The deposits described include the Jeannette 1, the Craney Draw area, the Blowout (Anomaly 119), "Channel," Moe 14, "Brown," North School Section, South School Section, and a paramontroseite occurrence. Most of the other occurrences of uranium minerals known in the area are briefly described in table 5.

JEANNETTE 1 DEPOSIT

The Jeannette deposit is about 3 miles west of Savageton in sec. 22, T. 45 N., R. 75 W., Campbell County, Wyo. The deposit is in the sandstone designated "5" on plate 11. This sandstone unit, 20 to 30 feet thick, caps a low ridge between tributary drainage of Pumpkin Creek.

An airborne radioactivity survey by the U. S. Geological Survey early in 1952 showed high radioactivity at several places along this low ridge. Ground examination disclosed several occurrences of uranium minerals associated with manganese oxide concretions. An area of general high surface radioactivity prompted a private company to do exploratory drilling in this area in April 1953. This drilling indicated a discontinuous zone of disseminated uranium minerals principally at and near the base of the sandstone. Late in 1952, 6 to 10 feet of soil and sandstone was removed from the drilled area by Kerr-McGee Industries of Oklahoma City to expose the ore-grade material. Figure 101 shows the geologic relations in this cut. In early 1954, ore was mined to a depth of almost 20 feet in this cut. Subsequently, the pit was partially filled in.

Uranium at the Jeannette mine is in grayish-yellow to pale-yellowish-orange sandstone at or near the contact with light-red sandstone. All habits of uranium are found in this deposit: disseminated minerals in sandstone, oxidized minerals with concretionary manganese oxides, and uraninite.

Mining exposed red sandstone and drab sandstone; the contact of these color variations crossed the pit irregularly from southeast to northwest. The border of the red sandstone in general is accented by a narrow band of calcareous sandstone several inches thick. Calcareous sandstone concretions are in both red and gray sandstone, but they seem to be more common in the areas of red sandstone. Near the center of the pit, where the coloring is more irregular, greenish-yellow

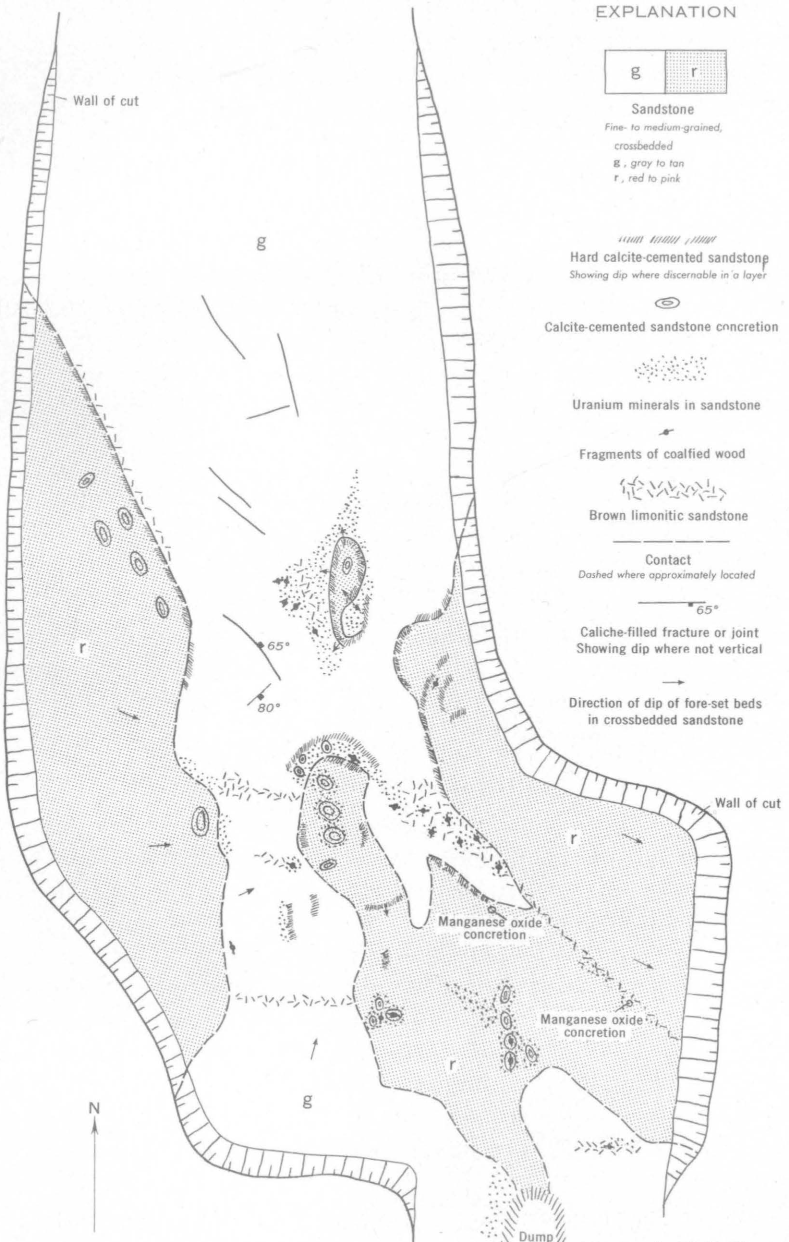

FIGURE 101.—Geologic sketch map, Jeannette 1 mine cut.

uranium minerals are disseminated in soft, grayish-yellow, fine- to medium-grained sandstone at the color change. The fine-grained, light-green uranium mineral is probably tyuyamunite, but it has not been identified by optical or X-ray means.

Some of the sandstone is ferruginous and yellow brown and contains generally distributed small pieces of coalified wood. At such places yellow to greenish-yellow uranium minerals, principally carnotite and tyuyamunite, are concentrated around the coaly pieces.

Within the red sandstone zone, calcareous sandstone concretions are dark red, almost maroon. Disseminated uranium minerals may surround these concretions in a thin belt of gray sandstone. These concretions seem to be clustered around centers in the sandstone (fig. 101). Certain mineral relations are found in the concretions: (a) nodules of pyrite cementing sand grains are enclosed in carnotite- and tyuyamunite-rich sand; and (b) black uraninite cements sand grains in irregular masses as much as 1 foot across. The masses commonly are associated with pieces of coaly material and generally enclose a core of pyrite or randomly spaced specks of pyrite. The uraninite everywhere is enclosed in a thick layer or halo of yellow secondary uranium minerals, mostly carnotite.

Manganese oxides are common principally as small black specks and masses dispersed in red sandstone in the concretionary zone. One manganese oxide nodule showing concentric structure with a core rich in uranophane was found several feet below the surface and isolated from the zones rich in uranium.

CRANEY DRAW AREA

The Craney Draw area includes approximately 1 square mile that covers part of the Craney Draw drainage area, about 5 miles northwest of the Christensen North Ranch in secs. 5 and 8, To. 45 N., R. 76 W., Johnson County, Wyo. (pl. 11).

The topography is semibadland. Undulating grassland is cut by many deep draws, leaving narrow ridges and some tablelike remnants of the more gentle surface. Uranium minerals occur in two thick partly red sandstone units that are exposed in steep cutbanks along Craney Draw. This area includes almost all the typical features of lithology and uranium deposits in the Pumpkin Buttes area. Relations of color of sandstone to uranium deposits are particularly well exposed in the area (pl. 15).

Radioactivity anomalies were first logged over this area by the U.S. Geological Survey airborne equipment in 1952. The exposed occurrences of uranium were then sampled by the Survey, and later in the same year a private company did some shallow drilling on the northwest side of the draw. A minor amount of ore-grade material was mined near the surface. In 1954 the Atomic Energy Commission drilled a series of wide-spaced, air-drilled, plug-bit holes on the southeast side of the draw.

A section of about 250 feet of the red sandstone interval in the Wasatch formation is well exposed in Craney Draw. Two thick partly red sandstone units (3c and 8b of pl. 12) are included in this exposed section. They are separated by about 100 feet of siltstone, claystone, and carbonaceous shale, and each is underlain by claystone. The sandstone at Craney Draw is typical of most of the sandstone lenses in the zone of red sandstone in the Powder River Basin. It is generally poorly sorted, changing from predominantly coarse grained to predominantly fine grained with short distances. At places, sets of crossbedded structures have abundant granules and small pebbles; at other places, biotite mica is concentrated along the crossbedding. Clay fragments and galls are common and may form thin conglomeratic layers. One such layer is shown cutting across the middle of the sandstone in figure 102. Other clay zones rich in calcite and shells of *Unio* and *Goniobasis* form resistant ledges along the banks of the draw. The sandstone has several conspicuous claystone lenses 5 to 10 feet thick toward the upper end of the draw.

Crossbedding is the principal sedimentary structural feature. In the lower sandstone, the crossbedding indicates a current direction north to slightly east of north. In the upper sandstone, the trend is northwestward.

Round calcareous "cannonball" concretions as much as 2 feet in diameter are abundant at places in the red sandstone. Elongate cigar-shaped concretions as much at 2 feet across and 10 feet long are also common. The axes commonly point northwest, even where local crossbedding may trend north to east of north.

Calcite concretions of irregular form are locally abundant along the contact of red and drab sandstone (fig. 102). Elsewhere along the color contact, accretionary calcite cements the sand grains in a thin resistant layer a few inches to 1 foot thick in the drab sandstone. This apparent localization of calcite in drab sandstone at the red color margin is not continuous. Most of the boundary between red and drab sandstone has no variation in physical properties, such as friability, texture, cementation, and iron content.

In the lower sandstone at Craney Draw, the red color is in the central part of the lens and follows the long axis of this channel sand in a northeasterly direction (section *A–A′*, pl. 15). This red component of the sandstone lens has irregular margins in both plan and cross section (pl. 15) but is continuous; isolated red patches have not been found.

The upper sandstone, remnants of which cap the crests of the divides, changes from yellowish gray to red on both sides of the draw

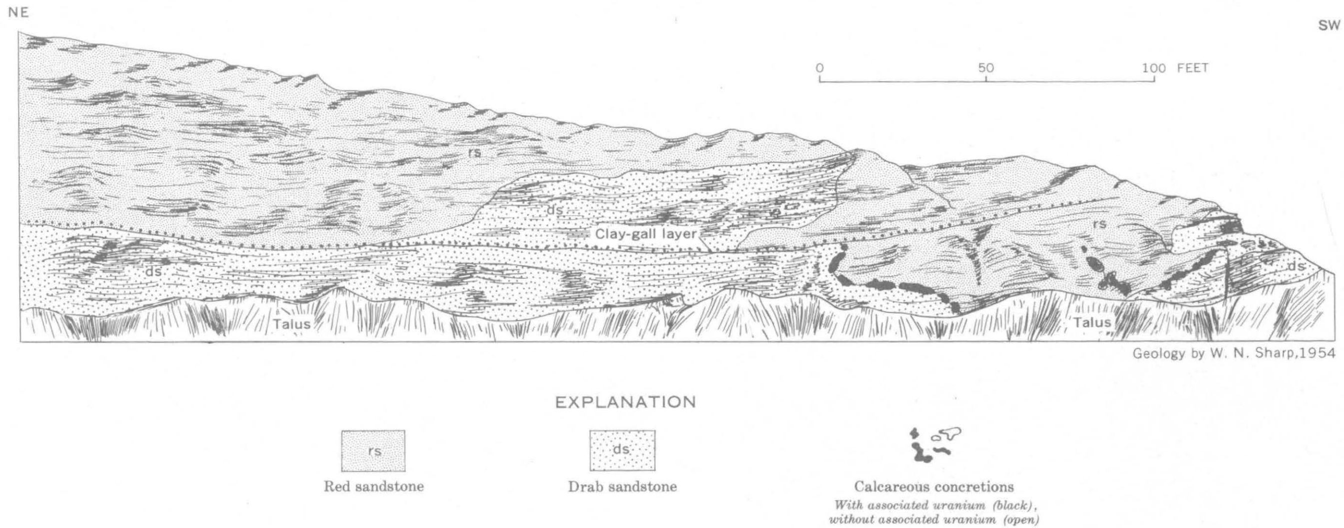

FIGURE 102.—Color change and associated uranium in sandstone cutbank of Craney Draw.

(pl. 15). The margins of the red color trend in the same direction as in the lower sandstone. Other than this general similarity in trend of the red color, there seems to be no connection in the color pattern between the two sandstones.

Uranium minerals, principally carnotite and tyuyamunite, at Craney Draw are almost entirely disseminated and are confined to the drab sandstone in the color contact zone. One nodule of manganese oxide with associated uranium was found in the red sandstone.

The locations of the principal occurrences are shown on plate 15. In the lower sandstone, the uranium is localized at some places around irregular calcareous concretions and hard calcareous layers along the color contact. Uranium minerals may also be concentrated throughout the sandstone between closely spaced calcite concretions (fig. 102). On the northwest side of the draw in the lower sandstone, uranium is disseminated in soft, friable, drab sandstone as much as 4 feet from the color contact and with no apparent concentration of calcite.

A notable feature about these discontinuous occurrences of uranium along the red boundary is their close association with abrupt irregularities in the color contact. Where this contact is regular or smoothly pitching, uranium is not present. Where small wedges or arms of one color penetrate the other, uranium is almost always present.

In the upper sandstone, yellow uranium minerals are also in drab sandstone bordering the red color margin. Some of this concentration of uranium minerals is in hard calcareous sandstone layers and rounded masses; some is in soft and friable sandstone, particularly on the northwest side of the draw.

A small concentration of black manganese oxide cementing sand grains was found in dark reddish-brown sandstone in a northward-trending gully from Craney Draw (near the center of the area shown on pl. 15). Within the core of this nodule were greenish-yellow uranium minerals, principally uranophane, mixed with specks of manganese oxides. No other occurrences of manganese with uranium were found in this area.

BLOWOUT (ANOMALY 119) DEPOSIT

The Blowout deposit (or Anomaly 119 as termed by the Atomic Energy Commission and the company mining the deposit, Kerr-McGee Industries) is about 4 miles northwest of Savageton in sec. 11, T. 45 N., R. 75 W. The sandstone unit (No. 5 on pl. 11), which ranges from 30 to at least 60 feet in thickness, forms a broad ridge in the upper drainage of the middle prong of Pumpkin Creek. The sandstone unit is about 1 mile long and 1,000 to 1,500 feet wide. The long axis of the outcrop and the sedimentary structures both trend northwestward. Several large wind blowouts are conspicuous features on this sandstone.

Radioactivity in the "Blowout" sandstone was first detected by an airborne survey by the U.S. Geological Survey early in 1952. The ground area was checked later, and surface areas 200 to 300 feet across were noted to have abnormally high radioactivity. Localities 36 and 37 (pl. 11) were drilled by the U.S. Geological Survey with a power auger to depths of 10 feet or less. Disseminated uranium minerals were brought up at locality 37. The area of the present mine was drilled in 1953 by Kerr-McGee Industries of Oklahoma City, and ore-grade material was blocked out. Open-pit mining was begun in the summer of 1954 and continued into 1955. Plate 16 is a geologic map of this mine as of April 1955.

The sandstone at the Blowout mine, like other sandstone units of the Pumpkin Buttes area, is poorly sorted, fine- to very coarse-grained, and has small potholes or zones of granule conglomerate 5 to 10 feet across. Clay pellets are common locally and may be arranged along crossbedded laminae. Coalified wood fragments are common but tend to be localized where poor sorting and lack of regular crossbedding indicate turbulent water and eddies in a former stream channel. Calcite "cannonball" concretions are not common in this sandstone, but large irregular to elongate and flaggy masses of calcite-cemented sandstone are plentiful in the blowouts. The sandstone is predominantly grayish yellow to pale yellowish orange and at blowout exposures is spotted and streaked with brown limonitic coloring. The sandstone is pale red to grayish red at the mined area (pl. 16) and along the lower part of the sandstone to the south. The trend of the red color appears to be toward the north or northwest.

Ore material at the Blowout deposit includes uranium minerals disseminated in grayish and yellowish gray sandstone, masses of uraninite in red sandstone, and less commonly, uranium minerals associated with manganese oxides.

The disseminated uranium is spatially related to two distinct lobes of red sandstone that trend north and northwest in the general direction of the long axis of the sandstone unit. The minerals, principally carnotite, tyuyamunite, and some uranophane, were in yellowish to grayish yellow, fine to very coarse sand at places along the boundary of the red color (pl. 16). In two mine cuts, this ore material overlay and followed the sloping boundary of the red sandstone to the base of the sandstone unit. Ore was abundant, particularly at the lobe ends and at irregularities in the color boundary. This layer of uranium-bearing sandstone was locally 3 to 4 feet thick.

Uraninite, cementing sandstone in irregular masses as much as 6 or 8 inches across, was in the red sandstone near the color contact at a depth of less than 10 feet, and also near the base of the sandstone at a depth of about 30 feet. The greatest amount of this uranium mineral was in the short shallow east cut where uraninite and pyrite, always surrounded by secondary oxidized minerals, were closely associated with coalified wood. The coalified wood is without doubt the component that has kept this local environment—so close to the surface—in a partially unoxidized state. The color of the sandstone in this shallow cut is not continuously red but is mottled with dark-red patches in a light-gray very coarse grained sandstone or grit. The light-gray color is due to the abundant white clay interstitial to the sand grains. Elsewhere in the Blowout mine a similar light-gray sandstone overlies the red sandstone. It seems apparent that by some mechanism, local spots of sandstone have their feldspar component much altered whereas, in general, feldspar shows little or no alteration.

In the deepest part of the northwest cut, the sandstone which overlay the red part and which contained disseminated uranium was very limonitic and heavily mottled with dark-brown markings. The overall color was a dark yellowish orange with a greenish cast at places. This ore material gave off a strong odor like a mercaptan or sewer gas when moved. Qualitative tests run on the odorous ore material showed an unusually high percentage of selenium. The red sandstone was analyzed by G. T. Burrow and Wayne Mountjoy for both selenium and arsenic, and the results are compared below to those from the gray sandstone from the same cut:

Laboratory No.	Field No.	Color	Se (percent)	As (percent)
230405	PR-253-3	Red	0. 05	0. 001
230407	PR-253-5	Gray	. 001	. 001

"CHANNEL" DEPOSIT

The Channel deposit (loc. 220, pl. 11) is on a south-trending gully of Heldt Draw, which is a tributary of Willow Creek about 4 miles north-northwest of the Christensen Ranch, in sec. 29, T. 45 N., R. 76 W., Johnson County, Wyo. The sandstone unit in which this deposit is located is labeled 3e on plate 11 and is 25 to 30 feet thick. The sedimentary structures trend N. 50° to 60° W.

A section through the lensing sandstone unit is exposed where the unit is cut by the draw. On the east side the color of the sandstone is continuously red; on the west side the sandstone is partly yellowish gray to yellowish orange and partly red. A narrow arm of red sandstone trending northwest crosses to the west side at the deposit.

Disseminated uranium minerals, principally carnotite, were visible in outcrop at the color contact on the west side of the draw near the base of the sandstone. Several manganese oxide nodules with yellow uranium minerals were exposed on the surface in the red sandstone on the east side.

In the summer of 1953, the sandstone was explored by Kerr-McGee Industries by shallow noncore drilling adjacent to the outcropping uranium minerals on both sides of the draw. During the summer of 1954, about 4,000 cubic yards of the west bank of the draw were cut away; this moved the cutface back about 30 feet. The exposure on this new face is sketched on figure 103. The northwest-trending red color in the sandstone exposed by this cut is about 300 feet wide; both the upper and lower contacts slope to the south. The color boundary shows no control by crossbedding or bedding in the sandstone, for it transects these primary sedimentary features. Below the sandstone is a greenish-gray claystone that contains finely divided pyrite. Near the base of the sandstone at each side of the red zone, where the color boundary crosses a zone rich in coalified wood fragments and trashy carbonaceous material (fig. 103), uranium minerals, principally yellow carnotite, are irregularly disseminated in drab sandstone. Locally they are concentrated at pieces of coaly wood fragments in red sandstone.

The red part of the sandstone yielded several 3-foot-thick zones rich in manganese oxides with abundant yellow and greenish yellow uranium minerals on both sides of the draw. These occurrences were at or very near the surface.

About 1,500 feet southward from the Channel deposit another occurrence of uranium was found on the east side of the draw. A 2-inch-thick layer of pyrite cementing the sand grains crops out for a distance of 8 to 10 feet at the base of the red sandstone, between the sandstone and the underlying greenish-gray carbonaceous claystone. A thin layer of yellow uranium minerals one-eighth inch thick occurs between the pyrite and the red sandstone.

MOE 14 DEPOSIT

The Moe 14 deposit (loc. 222, pl. 11), mined by the Kerr-McGee Industries, is about 5½ miles southwest of the Christensen North Ranch, and about 1¾ miles northwest of the Channel deposit, in sec. 19, T. 45 N., R. 76 W., Johnson County, Wyo.

Anomalous surface radioactivity was discovered over a considerable area by Kerr-McGee fieldmen, and the area was explored by drilling in 1953. An irregular-shaped opencut 10 to 20 feet deep and approximately 200 feet long was made in October 1953, and some ore-grade

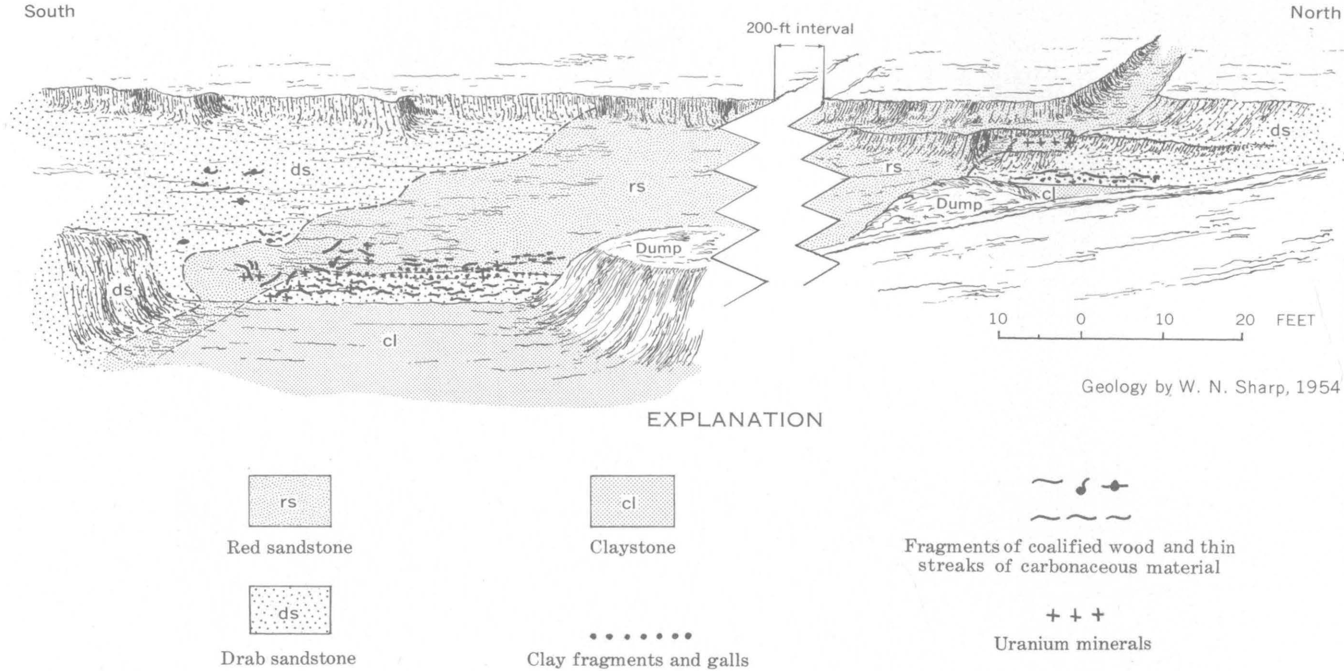

FIGURE 103.—Color change and associated uranium in sandstone cutbank, "Channel" deposit.

material was removed. During the winter of 1953, the mined pit was partly filled in with blown sand and slope wash.

The sandstone at Moe 14, labeled 2f on plate 11, is stratigraphically low in the red sandstone interval of the Wasatch formation. It is coarse grained to fine grained, poorly sorted, and at places contains abundant woody fragments, some of which are coalified and some partly replaced by iron oxides. Some dark carbonaceous clay seams also occur.

A color change in the sandstone from red to gray and grayish yellow is exposed in the northeast-trending pit. The part of the sandstone unit to the south is moderate red to reddish brown; the part to the north seems to be all drab to gray, although this color boundary has not been traced out.

The occurrence of uranium at Moe 14 is similar to the other exposed deposits in the Pumpkin Buttes area, with the exception that uraninite was not noted. Finely disseminated greenish-yellow tyuyamunite and yellow carnotite are in a zone in gray to drab sandstone at the red sandstone boundary, particularly where this contact is irregular. At several places these finely disseminated uranium minerals surround elongate zones of hard gray calcite-cemented sandstone; elsewhere, the sandstone is relatively friable and noncalcareous. Scattered limonitic zones with abundant trash and coalified wood fragments occur near the color contact. Yellow uranium minerals, principally carnotite, were concentrated near and around this carbonaceous material. Some of the black carbonaceous clay seams gave relatively high uranium analyses, although no uranium minerals were visible. Pascoite, a bright-orange vanadium mineral, was found coating sandstone on the dump at this pit. The mineral was probably formed by solution and redeposition of vanadium by snowmelt and rainwater.

Manganese oxide nodules containing uranophane and carnotite were found in the red sandstone near the surface at this locality.

Most of the ore-grade material was taken from 10 to 15 feet below the surface—a few feet above the base of the sandstone.

"BROWN" DEPOSITS

The "Brown" deposits (loc. 16, 17, 18, and 31, pl. 11) are on the north side of Cottonwood Creek, principally in sec. 22, T. 43 N., R. 76 W., about 1 mile northwest of the Rolling Pin Ranch.

An area of many exposures of uranium minerals (pl. 17) was explored in 1952 by the U.S. Geological Survey by bulldozing and auger drilling. The occurrences are in a friable, generally massive, fine- to coarse-grained crossbedded sandstone unit, predominantly reddish, that does not show a conspicuous areal color change as do the sandstone units of the previously described uranium localities. The sandstone, lettered 2p on plate 11, and in this report called the "Brown" sandstone, has an east-west width of slightly more than 3 miles. Correlation of this sandstone with other sandstones occupying the same stratigraphic interval, principally the sandstone labeled 2r on plate 11 along Seventeen Mile Creek, gives a probable north-south length of more than 7 miles for the unit. The thickness of the sandstone ranges from 30 to 60 feet, but in most places it is about 35 feet thick.

The overall homogeneity of this unit breaks down only near the east and west margins. Within the main body claystone lenses are not present and individual sandstone lenses are not discernible, although changes in sandstone texture along curving planes indicate scour-and-fill, foreset bedding, and festoon bedding. The base of the sandstone unit contains reworked claystone and carbonaceous shale locally, but it is generally conformable to an underlying carbonaceous shale bed throughout the area. The sandstone fills shallow channel scours in the underlying carbonaceous shale in only a few places near the east and west margins. Generally in the top 2 to 5 feet the sandstone unit grades to fine-grained clayey sandstone and siltstone.

Intertonguing of sandstone lenses and gray claystone is common on the flanks of the "Brown" sandstone. Reworked zones an inch to several feet thick, which include coarse-grained sandstone or claystone pebble conglomerate or both, are found in places.

The orientation of sedimentary structure in the sandstone ranges from northeast to northwest. Structural features include crossbedding, festoons, and limy sandstone concretions as well as channel fillings. These features and the trend of the "Brown" sandstone suggest that braided northward-flowing streams deposited the sandstone.

Uranium is associated predominantly with manganese oxides, as a cement in concretions, and in irregular flat bodies of sandstone. Bulldozing at the "Brown" deposits (pl. 17) exposed small zones of disseminated uranium minerals peripheral to calcareous sandstone. In the immediate vicinity of some of the uranium-manganese occurrences, the sandstone is stained a dark reddish brown for distances of less than an inch to tens of feet; near disseminated minerals the sandstone is mottled grayish, yellowish, grayish red, reddish brown, dark brown, and black, in halos several feet thick. Away from uranium-manganese occurrences light shades of red and yellow predominate in the sandstone. Regularly spaced color banding is common in the sandstone in the vicinity of, as well as away from, uranium-manganese occurrences. At places several systems of these color bands overlie one another; some bands parallel the bedding and others cross it.

Joints as much as a quarter of an inch wide, containing white limy material, cut the sandstone and all color bands. Several red sandstone dikes 1 to 6 inches thick strike N. 40° to 60° E. and extend from the top of the "Brown" sandstone upward as much as 5 feet into overlying gray, thin-bedded siltstone and claystone.

Uranium occurrences are erratic in their association with sedimentary features such as crossbedding, festoon bedding, channel-fill sandstone beds, reworked claystone lenses, changes in sandstone texture, and fossil woody material; in places some of these features are associated with uranium but many more are barren.

Most of the uranium occurrences in the "Brown" sandstone are found in the "Brown" deposit area (pl. 17). Here the occurrences are similar to those elsewhere in the sandstone, but in aggregate they are large enough to be worked as a deposit. The greater number and size of the uranium-manganese oxide concretions in the "Brown" deposit area are probably related spatially to their position near the east margin of the "Brown" sandstone, rather than to small sedimentary structure features that are common inside as well as outside the "Brown" deposit area. An easterly dip of 16° on the top of the sandstone and in overlying claystone and carbonaceous shale beds at the northeast exposure of the "Brown" sandstone suggests that the deposits are related to a wedge-edge of the sandstone, and that this relation influenced ore deposition in the area of the "Brown" deposit.

No obvious control for the ore deposits as a whole could be found. Local sedimentary features that appear to concentrate the ore are also present in barren sandstone. Color changes are more varied in and around ore bodies than in barren sandstone, probably because of greater abundance of iron and manganese in these places. In a few places uranium apparently has been leached from deposits in the basal sandstone and redeposited in the top of the underlying carbonaceous shale bed.

NORTH SCHOOL SECTION DEPOSITS

The North School Section deposits are on a ridge that trends north from Dome Butte at the north end of North Butte. They are about 3 miles south of the Christensen North ranch in sec. 36, T. 45 N., R. 76 W. The sandstone that caps the ridge is an extension of unit 9 (pl. 11), and it can be traced southward to North Middle Butte, where the same sandstone contains several occurrences of uranium minerals similar to those at North School Section. The occurrences are significant because of the unusually good outcrops of manganese oxide concretions, most of which enclose or otherwise are associated with secondary uranium minerals.

The sandstone at this locality is coarse grained to medium grained and predominantly red. Calcite-cemented sandstone concretions or "cannonballs" are abundant, but the form is more irregular than round. This may be a reflection of turbulent conditions during deposition of the sandstone. Fossil wood fragments and logs are also common.

The individual manganese-oxide nodules exposed in this sandstone range in size from 1 inch to 1 foot across. At places several irregular-shaped nodules are grouped or clustered in an area 2 to 3 feet across; at other places they form an elongate zone 20 to 30 feet long and 1 to 2 feet wide. Most of the nodules, however, are scattered individuals.

The association of manganese oxide cement in sandstone with fossil wood is general in the North School Section area. Many of the irregular-shaped masses of manganese oxide enclose or are contiguous to fossil wood. At places irregular accretionary masses of manganese oxide are along the remains of a fossil log, and, in part, they preserve the shape of the log for 20 feet or so.

Yellow uranophane, tyuyamunite, and amber-orange carnotite are enclosed in and mixed with manganese oxide in the masses and nodules. This association in most nodules has a concentric arrangement. The uranium-bearing sandstone, speckled with manganese oxide, is enclosed in a casing as much as 2 inches thick of nearly nonradioactive manganese oxide. The irregularly shaped masses of manganese oxide and uranium minerals have no such orderly arrangement of components. Uranium minerals mixed with manganese oxide specks fill pores in sandstone at places around the principal mass of barren manganese oxide. The mixed minerals and fragments of fossil wood form the largest masses, which may amount individually to several cubic feet of ore material. The cores of these nodules and the mixed manganese-uranium rock are high in uranium content. Samples of this material have contained as much as 25 percent uranium.

The semiclustered to random distribution of the nodules of manganese oxide and uranium at North School Section is shown in figure 104. The area was drilled in 1952, but no uranium minerals disseminated in sandstone were found nor was a color change to drab sandstone found. The sandstone at this locality is continuously red or mottled red and grayish-white, an alteration color of red sandstone.

SOUTH SCHOOL SECTION DEPOSIT

Another significant deposit of uranium associated with manganese oxide is about 2⅓ miles southeast of the Rolling Pin Ranch in sec. 36, T. 43 N., R. 76 W. The deposit is in an extensive predominantly red sandstone, labeled 3w on plate 11. At the locality a small north-trending spur is capped by 30 to 40 feet of this sandstone.

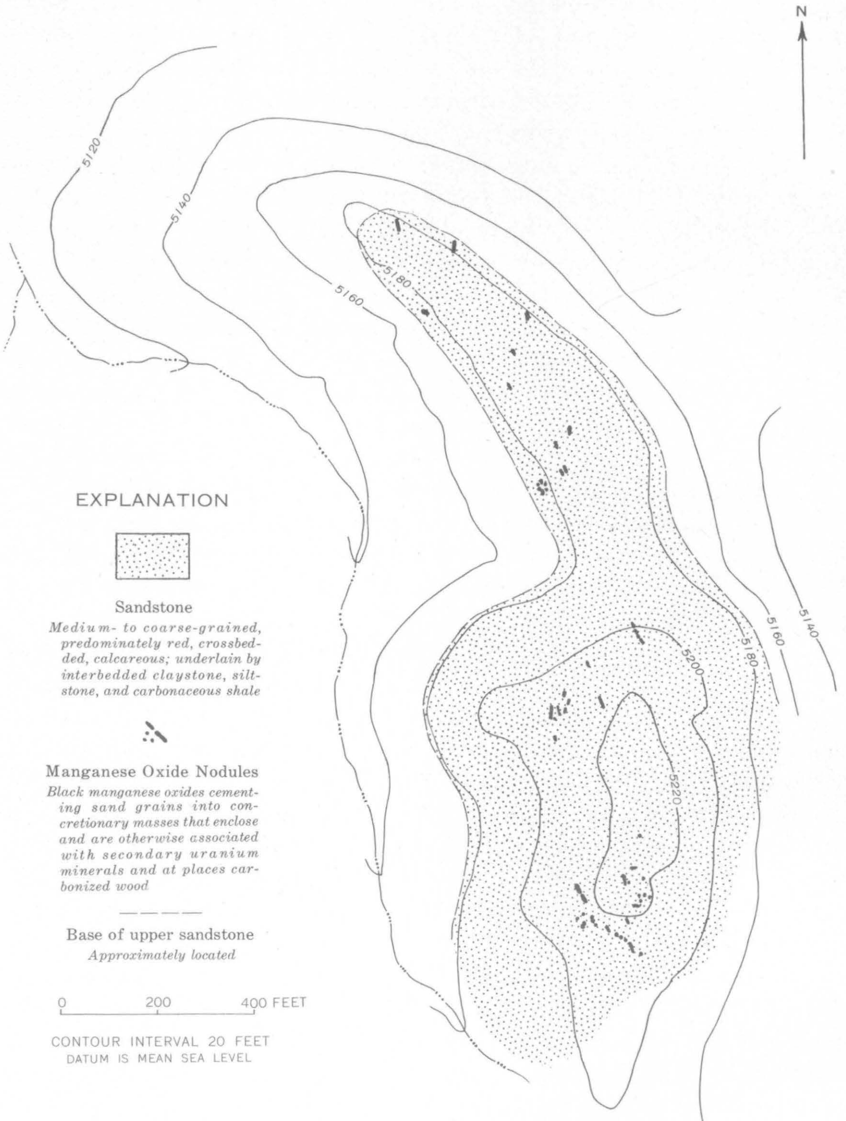

FIGURE 104.—Distribution of manganese oxide nodules, North School Section ridge.

Two distinct zones in the sandstone are rich in manganese oxide: one, a few feet above the base, and another 25 to 30 feet above the base. These two zones crop out along the west side of the spur for 100 to 125 feet. The more prominent upper zone averages about 8 feet in thickness and has an exposed width on the surface of about 10 feet. The lower zone, related to a persistent dark-red band 6 inches to 5 feet thick, is less continuous but may be more widespread under the ridge. The spur of the exposed mineralized zones was drilled by power auger in 1952. All holes bottomed in a hard calcareous layer at approximately the position of the lower ore zone without cutting through it.

There are many individual manganese oxide nodules here, but the bulk of the manganese-rich sandstone occurs in a flat-lying mass composed of coalescing spheroidal forms. This mass in part formed a "cobble" capping on a narrow ledge running along the flank of the ridge. Most of this material contains intermixed yellow to greenish-yellow uranium minerals, principally uranophane with some carnotite and tyuyamunite.

The deposit was mined in 1954, and approximately 20 tons of ore was produced that contained 4 to 5 percent uranium.

In the lower part of the sandstone a sharp, red-to-drab color change cuts nearly vertically through the sandstone and passes through a round calcareous sandstone concretion. This "cannonball" concretion, about 15 inches across, was approximately half dark red and half yellowish gray. The relation supports the idea that the color change (or the agent that effected the color change) in the sandstone was probably early, at least before some of the concretions were formed.

PARAMONTROSEITE OCCURRENCE

Paramontroseite, a black vanadium mineral (V_2O_4), was found in outcrop at locality 247 (pl. 11) on the Van Irvine Ranch in sec. 36, T. 44 N., R. 77 W. Like the occurrence of uraninite, paramontroseite is associated with sulfides in red sandstone near a color change in the sandstone.

The exposure of paramontroseite-bearing sandstone is about 5 feet wide at the bottom of a steeply dissected gully. Eastward, toward the drainage source, the gray sandstone outcrop makes up the bottom of the gully for about 60 feet. Westward, the sandstone thickens abruptly; the top rises about 30 feet in a distance of about 50 feet, and the lens becomes about 40 feet thick. Projection eastward of the relatively flat base of the thicker part of the sandstone indicates that the sandstone is about 5 feet thick at the paramontroseite locality. Interpretation of bedding structure and sandstone texture in the thick and thin parts of the unit indicates that the unit is a northward-trending channel that thins laterally. The thick channel sandstone is brick red. The thinning edges of the sandstone are gray and contain irregular pyrite concretions. Some of these pyrite concretions have cores of fossil wood fragments.

A color change from red to gray occurs in a zone about 3 feet wide in the thinning edge of the sandstone. It is in this zone of color change that black paramontroseite cements sand grains into nodular masses which enclose smaller masses of pyrite (figs. 105, 106). On exposed surfaces these masses have a green coating that is probably composed of vanadium salts. Halos of light-gray, bleached sandstone as much as 1 inch across separate the black mineralized sandstone from the surrounding red sandstone. A hard envelope of calcareous sandstone as much as 1 foot thick encloses the mineralized rock and part of the red sandstone.

The paramontroseite masses are anomalously radioactive though not comparable in radioactivity to deposits of predominantly uranium minerals; and the sandstone surrounding the paramontroseite and pyrite in the zone of color change is weakly radioactive. Most of this radioactivity comes from minute scattered specks of coffinite in the paramontroseite, which were identified in heavy mineral fractions separated from the bulk concretionary mass.

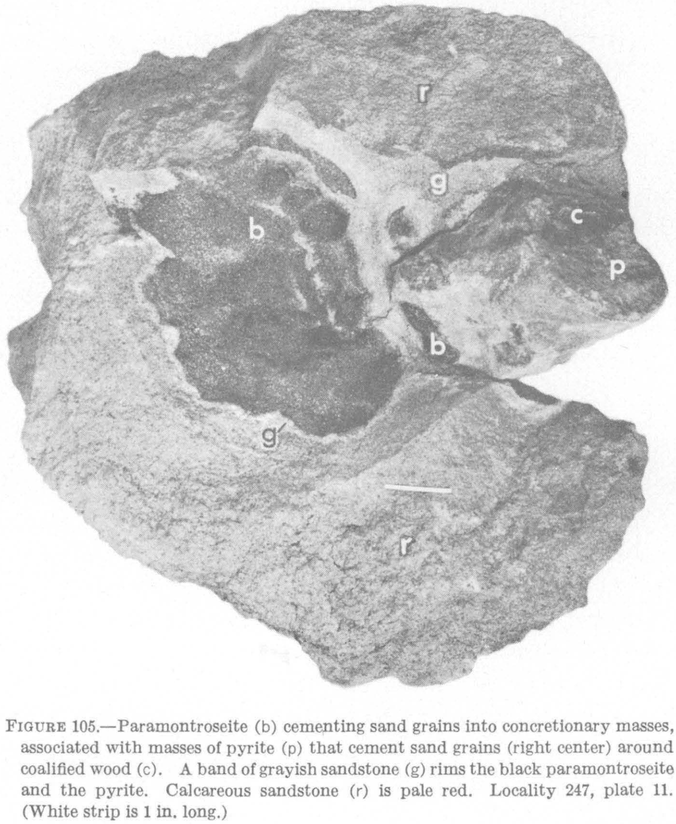

FIGURE 105.—Paramontroseite (b) cementing sand grains into concretionary masses, associated with masses of pyrite (p) that cement sand grains (right center) around coalified wood (c). A band of grayish sandstone (g) rims the black paramontroseite and the pyrite. Calcareous sandstone (r) is pale red. Locality 247, plate 11. (White strip is 1 in. long.)

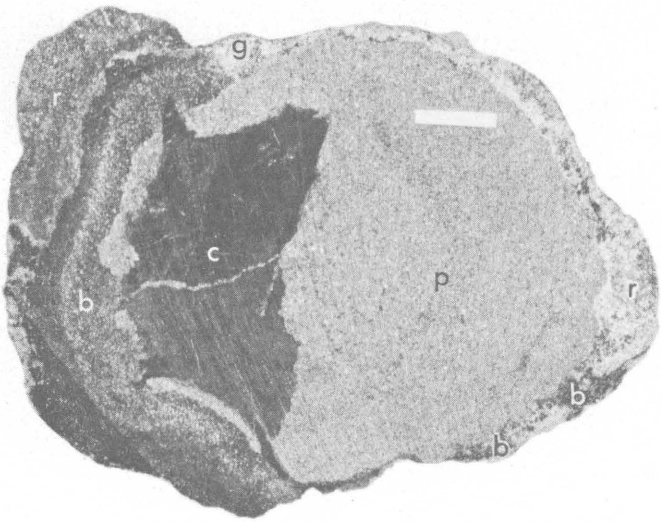

FIGURE 106.—Section across pyrite mass shown in figure 105. Black coalified wood (c) is surrounded by pyrite (p). Paramontroseite (b) cements sand grains in contact with pyrite at left side of wood fragment. A thin band of gray sandstone (g) separates the unoxidized material from the red sandstone (r). (White strip is ½ in. long.)

TABLE 5.—*Summary of uranium localities in Pumpkin Buttes and adjacent areas (pls. 11, 14), and analytical data of samples*

[Analyses by U.S. Geological Survey. Radioactivity analyses by S. P. Furman and B. A. McCall. Chemical analyses by I. H. Barlow, H. E. Bivèns, G. W. Boyes, Jr., G. T. Burrow, R. P. Cox, R. F. Dufour, R. N. Eccher, Mary Finch, W. D. Goss, E. C. Mallory, Jr., J. W. T. Meadows, Wayne Mountjoy, W. W. Niles, J. W. Patton, H. P. I. Peterson, D. L. Schafer, J. P. Schuch, D. L. Skinner, D. L. Stockwell, R. C. Tripp, J. S. Wahlberg, and J. E. Wilson]

Locality—					Sample—								
No.	Land division			Description	No.	Analytical data (percent)							Description and type
	Sec.	T.	R.			eU	U	V_2O_5	Mn	$CaCO_3$	CO_2	Fe_2O_3	
1	15	45	75	Uranium minerals associated with manganese oxide concretions in red to grayish-red sandstone which becomes drab downward. Fossil woody material is present. 300 yds north is another zone of uranium with manganese oxide concretions and fossil wood. Area between the two occurrences has been drilled.	TW-65	3.7	3.85	0.80	1.19				Yellow uranium-minerals with manganese oxide in red sandstone; selected sample.
2	22	45	75	Yellow uranium minerals disseminated in pink sandstone adjacent to drab sandstone; exposed in bulldozed cut. The mineralized sandstone is about 2 in. thick, and the adjacent buff sandstone is calcareous.	64	.24	.21	.26	.25		10.83		Pink sandstone with disseminated yellow uranium minerals; selected sample.
3	22	45	75	Uranium minerals in manganese oxide concretions on surface in red to gray red sandstone. Area about 200 by 300 ft has been drilled on 25-ft centers. Most holes show 1–3 ft of disseminated uranium minerals in drab sandstone near base of sandstone. See locality 246.	63	9.1	14.62	3.32	.50				Yellow uranium minerals disseminated in drab sandstone; selected sample.
4	29	45	75	Uranium minerals in outcrops of generally moderate red sandstone over an area of about 225 sq ft. Manganese oxide concretions with uranium minerals as large as 1 by 2 ft. Yellow uranium minerals disseminated in pink to drab sand-	7	14.2	17.08	.38	1.17				Core of manganese oxide concretion, rich in manganese oxide and yellow uranium minerals; selected sample.

				stone with bedding highly contorted.									
5	28	45	75	Uranium minerals in manganese oxide concretions scattered in thin red conglomeratic sandstone outcrops on top and shoulders of hill.	21	10	8.43	1.51	7.4	--------	--------	--------	Manganese oxide concretion rich in yellow uranium minerals; selected sample.
6	27	45	75	Yellow uranium minerals in manganese oxide concretions in outcrops of medium- to coarse-grained, crossbedded, moderate red sandstone. Disseminated yellow minerals in drab sandstone along red color boundary. Area has been bulldozed.	5	3.2	3.98	1.96	7.56	--------	--------	--------	Concretionary manganese oxide with yellow uranium minerals in coarse grained sandstone; selected sample.
7	33	45	75	Yellow uranium minerals associated with manganese oxide principally along bedding in calcareous concretions of yellowish-brown coarse-grained sandstone.	6	6.7	7.7	2.69	.63	--------	--------	--------	Yellow uranium minerals in red conglomeratic sandstone with manganese oxide; selected sample.
8	34	45	75	Bulldozed cut in red and pink sandstone exposing manganese oxide nodules containing yellow uranium minerals. Bulldozed and auger drilled by U.S. Geological Survey in 1952.	--------	--------	--------	--------	--------	--------	--------	--------	
9	36	45	76	North School Section deposit. Abundant manganese oxide concretions, many containing yellow uranium minerals; located on a ridge capped by red sandstone underlain by carbonaceous shale. A thin red sandstone below the shale shows some uranium minerals at northwest end of ridge. The manganese oxide concretions are exposed in a surface area about 2,200 by 150 ft.	LW-86	5.7	6.34	.47	1.1	--------	--------	--------	Manganese oxide concretion with yellow uranium minerals, from southern part of locality; selected sample.
					87	4.2	4.72	1.75	5.7	--------	--------	--------	Manganese oxide concretion with yellow uranium minerals, from northern part of locality; selected sample.
10	35	45	76	Yellow uranium minerals in manganese oxide concretions, many of which are associated with fossil logs. Some red sandstone units, as at locality 9, cap and underlie ridge. Some concretions follow bedding, others lie along ironstone casts of fossil logs.	82	1.9	2.97	1.21	.63	--------	--------	--------	Pink, ferruginous sandstone with yellow uranium minerals, from iron-manganese rich concretionary mass; selected samples; North end of locality.
					83	2.1	2.30	.55	5.8	--------	--------	--------	Yellow uranium minerals with manganese oxide in red sandstone; selected sample.
					84	2.3	2.43	.92	5.3	--------	--------	--------	Yellow uranium minerals with manganese oxide in dark-red sandstone; selected sample.
					85	5.2	5.62	.64	2.5	--------	--------	--------	Yellow uranium minerals with manganese oxide in red sandstone; selected sample. South end of locality.

TABLE 5.—*Summary of uranium localities in Pumpkin Buttes and adjacent areas (pls. 11, 14), and analytical data of samples*—Continued

Locality—					Sample—								
No.	Land division			Description	No.	Analytical data (percent)							Description and type
	Sec.	T.	R.			eU	U	V_2O_5	Mn	$CaCO_3$	CO_2	Fe_2O_3	
11	1	44	76	Yellow uranium minerals with manganese oxide associated with fossil wood in dark-red sandstone. Disseminated greenish-yellow minerals in drab sandstone. Mined in 1954.	121	20	23.6	0.18	0.36	--------	--------	--------	Elongate concretionary masses, grayish-green, iron-rich sandstone. Sample of most radioactive part.
12	17	44	75	Prominent outcrop of large cannonball sandstone concretions in otherwise friable sandstone. Locally sandstone is red. Yellow uranium ore associated with manganese oxide concretions and black bands along bedding. Underlain by clay and carbonaceous shale.	TW-3	.44	.55	1.54	.07	--------	--------	--------	Pink, limy sandstone with trace of powdery yellow mineral.
					4	.004	.003	.32	.10	--------	--------	--------	Ferruginous, slightly radioactive sandstone.
13	9	43	75	Several manganese oxide concretions with uranium minerals exposed on ridge capped with red sandstone about 18 ft thick. Sandstone underlain by carbonaceous shale.	LW-100	8.5	12.85	1.79	3.6	--------	--------	--------	Manganese oxide concretion with yellow uranium minerals; selected sample.
					104	6.5	9.46	1.24	.19	--------	--------	--------	Selected from concretionary mass of manganese oxide.
					105	.06	.079	.1	.12	--------	--------	--------	Sandstone from around manganese oxide concretion.
14	15	43	76	"Brown" deposits. Yellow uranium minerals associated with manganese oxide concretions in pink to red sandstone. Thin coal bed at base of sandstone.	56	1.7	1.77	1.31	--------	--------	--------	--------	Red-pink sand with yellow uranium minerals.
					57	.006	.004	.05	--------	--------	--------	--------	Pink sandstone; no visible uranium minerals.
15	22	43	76	"Brown" deposits. Pink to red sandstone above coaly layer; slightly radioactive but no uranium minerals visible.	51	.036	.025	.07	--------	--------	--------	--------	Pink sandstone; channel cut of lower 3 ft of sandstone.
16	22	43	76	"Brown" deposits. Abundant yellow uranium minerals in manganese oxide concretions in pink to red sandstone. Auger drilled in 1952.	54	5.5	5.42	2.44	--------	--------	--------	--------	Manganese oxide concretion with yellow uranium minerals.
					55	.018	.013	,04	--------	--------	--------	--------	Pink sandstone, 4-ft channel, 10 ft more above base.
					59	.003	.002	.06	--------	--------	--------	--------	Pink sandstone, 1 ft channel, 2 ft above base.

					60	0.009	0.010	0.04	--------	--------	--------	--------	Pink sandstone, 6-in. sample, 3 ft above base.
					61	.26	.19	.86	--------	--------	--------	--------	Concretionary manganese oxide cementing sandstone; selected sample.
					62	4.6	4.57	1.72	--------	--------	--------	--------	Yellow uranium minerals in sandstone with manganese oxides; selected sample.
					TW-41	.007	.004	.06	.147	--------	--------	--------	Pink sandstone, radioactive, drill hole BH-45.
					42	.45	.48	.35	.945	--------	6.75	--------	Pink sandstone, limy, some yellow uranium minerals; drill hole BH-50; 9.5 to 10 ft.
					46	.13	.12	.19	.468	--------	7.19	--------	Pink limy sandstone, some yellow uranium minerals, drill hole BH-59; 24 to 24.5 ft.
					LRP-E52-1	.68	.85	--------	--------	--------	--------	--------	Gray coarse-grained sandstone with scattered masses of manganese oxide and uranium minerals.
17	22	43	76	"Brown" deposit. Abundant yellow uranium minerals in manganese oxide concretions in pink sandstone along edge of draw.	LW-52	1.2	1.38	.96	--------	--------	--------	--------	Manganese oxide concretion with yellow uranium minerals in pink sandstone; 15 ft above base of pink sandstone.
					53	.006	.004	.07	--------	--------	--------	--------	
18	22	43	76	"Brown" deposit. Yellow uranium minerals in manganese oxide concretions and in pink to red sandstone. Coal underlying sandstone slightly radioactive.	63	.079	.10	.06	--------	--------	--------	--------	Coal; upper part of bed.
					64	.037	.008	.10	--------	--------	--------	--------	Pink sandstone; basal part.
					LRP-C52-1	1.2	1.22	.81	.219	--------	--------	--------	Concretionary manganese oxide with uranium minerals in gray sandstone.
19	22	43	76	"Brown" deposit. Abundant yellow uranium minerals in manganese oxide concretions in pink sandstone overlying slightly radioactive coal.	LW-48	.027	.024	.06	--------	--------	--------	--------	Coal; upper 6 in. of bed.
					49	.004	.001	.06	--------	--------	--------	--------	Pink sandstone.
					50	7.4	7.27	1.63	--------	--------	--------	--------	Manganese oxide concretion with yellow uranium minerals, in pink sandstone.
					LRP-D52-2A	.27	.29	--------	--------	--------	--------	--------	Coarse-grained pink sandstone with clay pellets and yellow uranium minerals.
20	19	43	75	Yellow uranium minerals associated with manganese oxide concretions in pink sandstone along cliff exposure. Two groups of concretions about 75 ft apart, underlain by 5-ft coaly seam.	TW-38	.34	.34	1.02	6.70	--------	4.15	--------	Manganese oxide concretion with small amount of uranium minerals.
					LW-120	5.8	6.59	2.09	6.00	--------	--------	--------	Selected from 1 ton of manganese oxide ore.
21	30	43	75	Yellow uranium minerals associated with manganese oxide concretions in pink limy sandstone capping hill. Uranium minerals associated with fossil woody material.	110	3.8	4.02	.46	17.88	--------	--------	--------	Manganese oxide concretion.

TABLE 5.—*Summary of uranium localities in Pumpkin Buttes and adjacent areas (pls. 11, 14), and analytical data of samples*—Continued

Locality—					Sample—								
No.	Land division			Description	No.	Analytical data (percent)							Description and type
	Sec.	T.	R.			eU	U	V_2O_5	Mn	$CaCO_3$	CO_2	Fe_2O_3	
22	25	43	76	Yellow, greenish-yellow, and orange uranium minerals associated with manganese oxide and calcareous zones in very coarse to medium-grained gray to red sandstone; underlain by silty claystone and carbonaceous shale.	66	0.98	1.87	0.67	----	----	----	----	Concretionary manganese oxide with uranium minerals.
					67	.021	.020	.04	----	----	----	----	Pink sandstone, basal part.
					68	.008	.007	.08	----	----	----	----	Gray silty claystone underlying sandstone.
					69	.31	.53	.53	----	----	----	----	Coarse limy pink sandstone with yellow uranium minerals.
23	36	43	76	Thick red to dark-red sandstone; two zones, 300 ft apart, have scattered manganese oxide concretions and yellow uranium minerals associated with manganese and fractures in sandstone. Uranium minerals exposed 27.4 ft above base of sandstone. Coal underlies sandstone.	107	.10	.026	.08	1.09	----	----	----	Manganese oxide and uranium minerals in pink sandstone; channel of 1-ft zone.
					108	.023	.003	.05	1.11	----	----	----	Manganese oxides and uranium minerals in sandstone, sample of 2-ft zone, 4 ft above coal.
					109	.31	.025	.07	.76	----	----	----	Manganese oxides and uranium minerals in red sandstone; east end of locality; sample of 1-ft zone.
24	31	43	76	Small amount of yellow uranium minerals in sandstone rich in iron and manganese.	----	----	----	----	----	----	----	----	
25	34	43	76	Yellow uranium minerals associated with narrow manganese oxide seam in red sandstone. Underlain by slightly radioactive siltstone.	TW-10	.62	.63	.61	4.0	----	2.69	----	Manganese oxide concretion with small amount of associated uranium minerals.
26	4	42	76	Yellow uranium minerals in scattered manganese oxide concretions in red sandstone, exposed in cutbank. Auger drilled in 1952.	LW-88	7.6	9.7	0.68	1.2	----	----	----	Manganese oxide with uranium minerals; 10 ft above base of sandstone; composite of several grades.
27	4	42	76	Yellow uranium minerals in large manganese oxide concretions in cutbank exposure of pink sandstone.	----	----	----	----	----	----	----	----	
28	4	42	76	Yellow uranium minerals scattered in dark-brown zone in orange sandstone. Manganese oxide present.	TW-40	.042	.030	.08	.60	----	8.72	----	Dark-brown sandstone with scattered yellow uranium minerals and manganese oxide; representative of zone.
29	4	42	76	Yellow uranium minerals in fractures in red and yellowish-brown sandstone and associated with manganese oxide concretions and seams. Flu-	LW-112	1.1	.085	.15	.17	----	----	----	Red sandstone including manganese oxide and uranium minerals, 6-in. cut.
					113	.21	.005	.05	2.29	----	----	----	Yellowish-brown sandstone with manganese oxide along bedding;

				orescent minerals, liebigite and bayleyite as encrustations on wet sandstone at base, overlying coal.	111	0.054	0.095	20.6 percent ash .44 percent uranium in ash		--------	--------	--------	uranium minerals as encrustation. Lignite below mineralized sandstone.
					TW-25	--------	.04 ppm	.05 ppm selenium		--------	--------	--------	Water sample from seep at base of sandstone.
30	2	42	76	Yellow uranium minerals principally as bloom on outcrop at base of red sandstone overlying coaly shale.	9	1.1	1.27	1.57	.41	--------	--------	--------	Yellowish-brown sandstone with coating of uranium minerals.
					39	.98	.99	1.15	2.42	--------	--------	--------	
31	22	43	76	"Brown" deposits, bulldozed area where many occurrences of uranium minerals and manganese oxide concretions were exposed. Uranium minerals are also disseminated in sandstone at places around calcareous concretions and zones. Bulldozed and mapped 1952. Several tons of rock rich in manganese oxide and uranium stockpiled.	LW-44	4.2	3.92	1.97	--------	--------	--------	--------	Manganese oxide concretions from several places in area.
					45	.54	.54	.35	--------	--------	--------	--------	Pink sandstone with manganese oxide and uranium minerals; 1-ft sample.
					46	.20	.15	.14	--------	--------	--------	--------	Pink sandstone; basal 3 ft.
					47	.009	.007	.10	--------	--------	--------	--------	Pink sandstone from several places in area.
					LRP-F52-1	.012	.010	.13	.415	--------	--------	--------	Manganese oxide concretion.
					H52-1	.044	.023	--------	--------	--------	--------	--------	Gray sandstone from around manganese oxide concretion.
					AEC-171	6.9	6.79	2.96	2.33	10.7	--------	5.40	Grab of rock rich in manganese oxide and uranium minerals from dump; 50-lb sample.
					172	2.5	2.5	1.29	1.98	13.0	--------	4.97	Grab of average of "ore" dump; 50-lb sample.
36	11	45	75	Surface area on ridge is abnormally radioactive. Auger drilling showed 4-5 ft of fine- to medium-grained buff sandstone underlain by clay and silt. No visible uranium minerals.	--------	--------	--------	--------	--------	--------	--------	--------	
37	11	45	75	Auger drilling showed yellow uranium minerals in red sandstone in area of generally high radioactivity.	TW-106	1.7	2.27	1.00	.237	--------	--------	--------	Yellow uranium minerals in red sandstone from auger hole.
					107	.061	.03	.04	.028	--------	--------	--------	Red sandstone from 8-ft auger hole
38	11	45	75	Yellow uranium mineral found in loose sand 6 in. below surface in red sandstone exposed on ridge.	110	.024	.003	.05	.037	--------	--------	--------	Yellow uranium minerals in loose brown sand at surface.
39	15	45	75	Red to mottled red-drab sandstone capping broad ridge. Several zones where manganese oxide concretions exposed with uranium minerals.	--------	--------	--------	--------	--------	--------	--------	--------	
43	33	45	75	Manganese oxide concretions scattered on surface of red sandstone, in zones conformable to bedding at two places, several hundred feet apart. Red sandstone caps most of peaked ridge.	TW-114	1	.92	.50	12.85	--------	--------	--------	Concretionary manganese oxides and uranium minerals in red sandstone.

TABLE 5.—*Summary of uranium localities in Pumpkin Buttes and adjacent areas (pls. 11, 14), and analytical data of samples*—Continued

Locality—					Sample—								
No.	Land division			Description	No.	Analytical data (percent)							Description and type
	Sec.	T.	R.			eU	U	V_2O_5	Mn	$CaCO_3$	CO_2	Fe_2O_3	
45	31	45	75	Yellow uranium minerals with manganese oxide concretions in red sandstone about 20 ft from color change to white sandstone. Adjacent blowout in white sandstone contain a few barren manganese oxide concretions and wood fragments. Several radioactive soil zones in vicinity.									
46	8-9	45	76	Upper sandstone at Craney Draw. Upper part red, lower part yellowish orange. Along color contact yellowish orange sandstone is calcareous and generally radioactive. Yellow uranium minerals thinly disseminated at places.									
48	36	45	76	Yellow uranium minerals with manganese oxide concretions in red sandstone.									
49	29-30	46	76	Small knob capped with red sandstone underlain by coal bed. Greenish-yellow uranium minerals in thin seam at base of sandstone in southern part. In northern part of outcrop greenish-yellow uranium minerals associated with MnO_2.	TW-78	1.2	1.84	1.53	0.98				Greenish-yellow uranium minerals in pink sandstone.
					79	.13	.084	.13	.05				Greenish-yellow minerals in soil overlying core.
					80	.72	.95	.75	1.36				Manganese oxide with uranium minerals.
					81	.20	.032	.58	.27				Greenish-yellow uranium minerals in red sandstone.
50	5	45	76	Yellow uranium minerals disseminated in gray sandstone along pink-red color boundary, 5-15 ft above base of sandstone. Abundant fragments of wood replaced by iron.									
51	8	45	76	Craney Draw area; disseminated yellow uranium minerals in buff sandstone along color contact from drab to red sandstone, and around calcareous sandstone concretions in drab sandstone.	TW-66	.54	.90	.93	.13				Yellow uranium minerals in yellowish sandstone.
					67	.063	.064	.25	.10				Do.
					68	.008	.008	.07	.11				Yellow uranium minerals in yellowish sandstone, channel of 5 ft.
					124	.27	.47	1.24	.027		0.14	2.95	Yellow uranium minerals in yellowish sandstone, representative sample.

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					164	0.91	0.95						Yellow uranium minerals in yellowish sandstone, grab sample.
					165	.71	1.26						Do.
52	9	45	76	Thick sandstone, grayish-yellow to red, exposed in ravine cut. Yellow uranium minerals in drab sandstone along bedding planes on south side. Radioactive zone on north side.	89	.068	.027	0.14	0.15				Yellow uranium minerals in drab sandstone from south side of draw.
					90	.22	.19	.11	.37				Yellowish-brown to red sandstone radioactive.
53	5	45	76	Several occurrences of yellow uranium minerals disseminated in drab sandstone and around calcite concretions along red color contact. At eastern edge of Craney Draw area.									
54	16	45	76	Strong anomaly, but no visible uranium mineral.									
55	15	45	76	Yellow uranium minerals in manganese oxide concretions in red to gray sandstone.	TW–28	3	3.10	.78	7.14				Manganese oxides with uranium minerals in red sandstone.
56	21	45	76	Yellow uranium minerals in manganese oxide concretions in dark-red sandstone.	71	1.3	2.42	2.59	.28				Concretionary manganese oxides with uranium minerals in red sandstone
					72	.036	.013	.16	.14				Red sandstone; 6-ft channel.
57	22	45	76	Yellow uranium minerals in manganese oxide concretions in red sandstone.	35	.023	.014	.19	.258				Red sandstone with manganese oxides and yellow uranium minerals.
58	22	45	76	Yellow uranium minerals in manganese oxide concretions in red sandstone.	34	.21	.17	.29	7.05				Manganese oxide concretion.
59	22	45	76	Brown sandstone capping ridge. Auger drilling showed 8 ft of brown sandstone underlain by carbonaceous shale and siltstone. One small sandstone concretion with uranium minerals was found in gray medium- to coarse-grained sandstone.	112	.06	.023	.08	.277				Gray, micaceous sandstone, slightly radioactive.
60	27	45	76	A zone of anomalous radioactivity, 40 ft long, in red sandstone; no visible uranium minerals.									
61	26	45	76	Area of radioactivity anomalies; no visible uranium minerals. Area has been auger drilled.	TW–27	.018	.006	.06	.028				Brownish-gray sandstone.
62	26	45	76	Yellow uranium minerals in friable white sandstone; very little manganese oxides. Small red zones are nearby. On north side of ravine uranium minerals are associated with carbonaceous material.	87	.14	.13	.26	.16				Yellow uranium minerals in white sandstone.
					88	.18	.17	.46	.07				Yellow uranium minerals in brown sandstone with carbonaceous material.

TABLE 5.—*Summary of uranium localities in Pumpkin Buttes and adjacent areas (pls. 11, 14), and analytical data of samples*—Continued

Locality—					Sample—								
No.	Land division			Description	No.	Analytical data (percent)							Description and type
	Sec.	T.	R.			eU	U	V_2O_5	Mn	$CaCO_3$	CO_2	Fe_2O_3	
63	23	45	76	Radioactivity anomaly on crest of ridge of white to buff sandstone. No visible uranium minerals.	--------	--------	--------	--------	--------	--------	--------	--------	
64	24	45	76	Yellowish-green uranium minerals in small concretion in white to reddish friable sandstone.	--------	--------	--------	--------	--------	--------	--------	--------	
65	33	45	76	Yellowish-green uranium minerals disseminated in gray calcareous sandstone zones in red sandstone.	--------	--------	--------	--------	--------	--------	--------	--------	
66	35	45	76	Brown, red, and buff sandstone exposure in small canyon with no visible uranium minerals; however, one boulder, not in place, has yellow uranium minerals in manganese oxide concretions.	--------	--------	--------	--------	--------	--------	--------	--------	
67	35	45	76	Yellow uranium minerals in sandy soil fill in small canyon. Thick gray to light-brown sandstone is 15 ft above valley floor. No visible uranium minerals in the sandstone.	TW-8	6	9.35	1.54	0.02	--------	--------	--------	Grayish-yellow sand with yellow uranium minerals.
68	4	44	76	Yellowish-green uranium minerals in the calcareous basal zone of thick sandstone. No manganese observed.	--------	--------	--------	--------	--------	--------	--------	--------	
69	7	44	76	Disseminated yellow uranium minerals exposed in bulldozer cut in gray, pink, and brown sandstone. Uranium minerals are apparently restricted to gray carbonaceous zone of the sandstone. Drilled in 1953.	SU-13	.32	.57	.92	MnO .290	18.0	--------	2.33	Gray sandstone with yellow uranium minerals, in upper 10 ft of sandstone unit.
70	10	44	76	Yellow uranium minerals with manganese oxide concretions in brown to pink sandstone, in a zone about 10 ft thick. Similar occurrence at base of	LW-123	9.2	11.6	.37	7.60	--------	--------	--------	Concretionary manganese oxide with uranium minerals in brown sandstone.

				sandstone 100 yds to northwest.									
71------	3	44	75	Yellow uranium minerals in manganese oxide concretions in red sandstone. Concretions occur over a distance of about 100 yds.	TW-82----------	2.4	2.84	0.42	2.25	--------	--------	--------	Concretionary manganese oxides with uranium minerals in red sandstone.
72------	3	44	75	Yellow uranium minerals in concretions of manganese oxide in mottled red sandstone, in sandstone blowout.	83----------	.84	1.03	.64	1.25	--------	--------	--------	Concretionary manganese oxide with uranium minerals in red sandstone.
73------	3	44	75	Yellow uranium minerals in yellowish sandstone at contact between red sandstone and white sandstone. Adjacent drab sandstone has slight radioactivity.	85----------	.067	.038	.17	.14	--------	--------	--------	Drab sandstone, slightly radioactive.
74------	10	44	75	Yellow uranium minerals in manganese oxide concretions along bedding in red sandstone. Zone of concretions is about 4 ft thick.	84----------	2.7	2.94	.92	6.40	--------	9.07	--------	Concretionary manganese oxide with uranium minerals in red sandstone.
75------	10	44	75	Anomalous radioactivity at several places in buff sandstone, with no visible uranium minerals. About 275 yds south of loc. 75, yellow uranium minerals exposed in red sandstone. See loc. 195.	86----------	.19	.085	.22	.32	--------	--------	--------	Drab sandstone, slightly radioactive.
77------	13	44	77	Yellowish-green disseminated uranium minerals in brownish-red sandstone adjacent to gray sandstone. Mineralized zone is near the base of the sandstone.	33----------	.39	.28	.38	.173	--------	--------	--------	Yellow uranium minerals in brownish-red sandstone.
78------	18	44	76	Yellowish-gray, pink, and pinkish-brown sandstone exposed with no uranium minerals visible. Anomalous radioactivity.	----------	--------	--------	--------	--------	--------	--------	--------	
79------	18	44	76	Small gray calcareous zone is slightly radioactive. In bank of deep gully two radioactive zones: yellow-brown sandstone with no uranium minerals visible; another, 40 ft to south, yellow uranium minerals visible in dark-red to brown sandstone.	----------	--------	--------	--------	--------	--------	--------	--------	
80------	19	44	76	Gray sandstone above thick section of shales; slightly radioactive but no uranium minerals visible.	----------	--------	--------	--------	--------	--------	--------	--------	

TABLE 5.—*Summary of uranium localities in Pumpkin Buttes and adjacent areas (pls. 11, 14), and analytical data of samples*—Continued

Locality—					Sample—								
No.	Land division			Description	No.	Analytical data (percent)							Description and type
	Sec.	T.	R.			eU	U	V_2O_5	Mn	$CaCO_3$	CO_2	Fe_2O_3	
81	24	44	76	"Discovery Roll." Yellow uranium minerals in a large manganese oxide concretion, 10 ft above base of a yellowish-brown sandstone about 25 ft thick, underlain by thin coaly bed.	LW-18	0.005	0.004	-----	-----	-----	-----	-----	Coal and carbonaceous shale from below sandstone.
					19	14	15.14	-----	-----	-----	-----	-----	Concretionary manganese oxide in brown sandstone with abundant uranium minerals.
					20	.022	.026	-----	-----	-----	-----	-----	Siltstone, grayish-green, from near deposit.
83	22	44	75	Yellow uranium minerals in manganese oxide concretion along bedding plane in thin red sandstone capping of small peak.	-----	-----	-----	-----	-----	-----	-----	-----	
85	28	44	75	Thin red sandstone capping north-trending ridge in which are exposed several occurrences of concretionary manganese oxide with uranium minerals.	TW-2	.029	.18	0.47	0.54	-----	-----	-----	Red platy sandstone; radioactive and manganiferous.
					73	2.4	2.61	1.48	3.60	-----	-----	-----	Yellow uranium minerals and manganese oxide in red sandstone.
86	28	44	75	Locality 86 is 200–300 yds east of loc. 85; yellow uranium minerals associated with manganese oxides, as a coating on bedding planes of thin red sandstone capping.	-----	-----	-----	-----	-----	-----	-----	-----	
87	32	44	76	Radioactivity anomaly on ridge underlain by thick sandstone unit; a few outcrops of clay and limestone overlie sandstone; no visible uranium minerals.	-----	-----	-----	-----	-----	-----	-----	-----	
88	4	43	75	Gray and yellow sandstone underlain by coaly carbonaceous shale; exploration in 1953 uncovered yellow uranium minerals disseminated in the gray sandstone.	LW-26	.021	.015	.05	-----	-----	-----	-----	Coal and carbonaceous shale.
89	3	43	75	Radioactivity anomaly in poorly exposed pink sandstone; no visible uranium minerals.	-----	-----	-----	-----	-----	-----	-----	-----	
90	12	44	78	Radioactivity anomaly in area of white and yellow sandstone.	AEC-25399	.18	-----	-----	-----	-----	-----	-----	Fine-grained, friable, carbonaceous, yellow sandstone with disseminated yellow minerals(?).
91	28	43	75	Zone of anomalous radioactivity in drab sandy soil. Area underlain by thick partly red sandstone.	-----	-----	-----	-----	-----	-----	-----	-----	

92	28	43	75	Yellow uranium minerals associated with manganese-oxide concretions in red clay pebble. Conglomerate and sandstone near base of sandstone units.									
93	28	43	75	Yellow uranium minerals disseminated in fine-grained gray calcareous sandstone, with a few woody fragments. Several small areas near by are anomalously radioactive.	AEC-25302	0.53	0.87	0.62					Yellow uranium minerals in grayish-yellow sandstone.
94	29	43	75	Radioactivity anomaly in zone of gray to light-brown sandstone.									
95	30	43	76	Small area of yellow uranium minerals in reddish sandstone with abundant "ironstone" float on outcrops.									
96	30	43	76	Small area of yellow uranium minerals in sandstone.									
97	34	43	75	High radioactivity anomaly in red sandstone about 200 ft east of color change from red to gray.									
98	23	42	75	Radioactivity anomaly in area about 100 ft square.									
99	21	42	75	Radioactivity anomaly on ridge of white sandstone.	TW-74 AEC-1079	.034 .14	.006 .12	.03 .10	0.04				Channel sample of white sandstone. Selected sample of white sandstone with disseminated yellow minerals.
100	1	44	76	Radioactivity anomaly in white sandstone with no visible uranium minerals.									
101	1	44	76	Radioactivity anomaly in white sandstone. No visible uranium minerals.									
102	29	45	75	Yellow uranium minerals in small concretions of manganese oxide in two thin red sandstone lenses. Bulldozed cut exposes one lens.									
103	8	45	76	Yellow uranium minerals disseminated in gray calcareous sandstone adjacent to color change to red sandstone. Craney Draw area.	TW-69 AEC-173	.048 .31	.045 .54	.24 .92	.17 .041	 1.5		 2.09	Carbonaceous shale. Yellow uranium minerals in drab sandstone with carbonized wood fragments; representative sample.
104	21	45	76	Yellowish-green uranium minerals in a calcite concretion of gray to buff sandstone, in a bed of mottled red to buff sandstone exposed in deep draw. Mineralized zone trends N. 45° W. across draw.									
106	17	45	74	One occurrence of yellow uranium minerals in manganese-oxide concretions in calcareous red sandstone exposed near ridge top.	TW-102	3.4	4.60	.28	.305				Manganese oxide with uranium minerals in calcareous red sandstone.

TABLE 5.—*Summary of uranium localities in Pumpkin Buttes and adjacent areas (pls. 11, 14), and analytical data of samples*—Continued

Locality— No.	Land division Sec.	T.	R.	Description	Sample— No.	Analytical data (percent) eU	U	V_2O_5	Mn	$CaCO_3$	CO_2	Fe_2O_3	Description and type
107	13	44	77	Frank 3 claim. Radioactivity anomaly in thin-bedded gray sandstone exposed in steep-sided gully; no visible uranium minerals.	-----	-----	-----	-----	-----	-----	-----	-----	
108	13	44	77	Several radioactivity anomalies in an area underlain by red slabby sandstone; no visible uranium minerals.	TW-36	0.073	0.016	0.09	0.378	-----	-----	-----	Red calcareous sandstone; slightly radioactive.
109	24	44	77	Area with several radioactivity anomalies. Bulldozer cut exposed variegated reddish- and yellowish-brown sandstone; no visible uranium minerals.	-----	-----	-----	-----	-----	-----	-----	-----	
111	9–10	43	77	Several radioactivity anomalies in area of reddish-brown sandstone overlying white sandstone; one small occurrence of yellowish-green uranium minerals disseminated in mica-rich red sandstone. Area drilled in 1953 by Atomic Energy Commission.	AEC-25393	-----	.017	.01	-----	-----	-----	-----	Sandstone, slightly radioactive.
					7	-----	.008	.02	-----	-----	-----	-----	Sandstone, mottled gray and red, slightly radioactive.
					5	-----	.017	.05	-----	-----	-----	-----	Sandstone, slightly radioactive.
					6	.32	.52	.69	-----	-----	-----	-----	Greenish-yellow uranium minerals in gray sandstone.
112	20	43	77	Radioactive red sandstone with ferruginous concretions.	TW-75	.10	.07	.26	.92	-----	-----	-----	Selected samples of ferruginous radioactive sandstone.
					13	.09	.06	.98	.83	-----	-----	-----	
115	16	43	77	Radioactivity anomaly in yellow sandstone in lower part of predominantly pink sandstone; no visible uranium minerals.	11	.29	.49	.51	.07	-----	-----	-----	Yellow sandstone, radioactive.
116	8	43	77	Red sandstone that contains much ferruginous material caps ridge for more than 1 mile. Radioactivity anomaly is one of many associated more specifically with areas of ferruginous sandstone. (See locs. 186, 211, 193, 156 and 210.)	-----	-----	-----	-----	-----	-----	-----	-----	
117	5	42	76	Radioactivity anomaly in coal which underlies coarse-grained pink sandstone; no visible uranium minerals.	LW-90	.052	.081	.17	.03	-----	-----	-----	Carbonaceous shale and coal.
119	36	43	76	South School Section deposit; yellow uranium minerals asso-	114	.014	.008	.42	20.48	-----	-----	-----	Manganese oxide concretion.
					115	4.8	5.33	.66	2.05	-----	-----	-----	Concretionary manganese oxide with

				ciated with abundant concretionary manganese oxide in dominantly red sandstone; sandstone about 30 ft thick at top of hill. Drilled in 1952; mined in 1954.									uranium minerals from near base of sandstone.
					116	0.025	0.018	0.07	0.17	--	--	--	Red sandstone; 1-ft channel from base of unit.
					117	.012	.003	.05	1.18	--	--	--	Sandstone; 1-ft channel; spotted with manganese oxides.
					118	14.0	22.4	.87	.35	--	--	--	Yellow uranium minerals with manganese oxide; selected sample.
					119	.088	.084	.05	.08	--	--	--	Brown sandstone; 3.2-ft channel including some manganese oxides.
					TW-43	.033	.020	.35	17.9	--	--	--	Manganese oxide concretions.
120	36	43	76	Radioactivity anomaly in area of red sandstone on hill immediately west of loc. 119; no visible uranium minerals.	--	--	--	--	--	--	--	--	
121	25	43	76	Radioactive anomaly in reddish-brown sandstone; no visible uranium minerals.	LW-70	.033	.112	.53	--	--	--	--	Greenish yellow sandstone from base of unit.
122	33	44	76	Gray calcareous sandstone, concretionary mass approximately 140 ft long, trending north-south, in dominantly pink sandstone; no visible uranium minerals but significantly radioactive all along zone.	29	.003	.002	.06	--	--	--	--	
					30	.019	.003	.17	--	--	--	--	
					31	.36	.009	.18	--	--	--	--	
					32	.014	.003	.05	--	--	--	--	Gray calcareous sandstone, slightly radioactive; samples taken at intervals along concretionary mass from north to south.
					33	.092	.008	.07	--	--	--	--	
					34	.027	.003	.20	--	--	--	--	
					35	.032	.010	.06	--	--	--	--	
					36	.007	.006	.07	--	--	--	--	
123	4	43	76	Radioactive calcareous gray sandstone in dominantly pink sandstone similar to loc. 122; no visible uranium minerals.	28	.020	.022	.13	--	--	--	--	Red sandstone, slightly radioactive.
					37	.015	.004	.08	--	--	--	--	
					38	.10	.053	.24	--	--	--	--	
					39	.031	.026	.12	--	--	--	--	Gray calcareous sandstone, slightly radioactive; samples taken at intervals along concretionary mass from north to south.
					40	.029	.004	.12	--	--	--	--	
					41	.023	.002	.07	--	--	--	--	
					42	.015	.004	.19	--	--	--	--	
125	6	43	75	Radioactivity anomaly in covered area probably underlain by gray sandstone; no uranium minerals visible.	65	.013	.006	.06	--	--	--	--	Gray friable sandstone, slightly radioactive.
127	30	42	75	Yellow uranium minerals in coarse-grained brown sandstone.	TW-104	8.5	11.24	1.99	.031	--	--	--	Selected sample of brown sandstone with concentrated yellow uranium minerals.
128	35	42	77	Radioactivity anomaly in area or red calcareous sandstone.	103	.02	.003	.04	.54	--	--	--	Selected sample of calcareous red sandstone.
130	7	44	75	Yellow uranium minerals disseminated in dominantly red sandstone and also associated with manganese oxide concretions in locally gray sandstone zones.	AEC-1066	.306	.026	.05	--	--	--	--	Yellow uranium minerals in grayish yellow to red sandstone.
					TW-125	.44	.03	.14	.553	--	--	--	Yellow uranium minerals with manganese oxide in gray sandstone.
131	1	42	76	Radioactivity anomaly in red sandstone.	--	--	--	--	--	--	--	--	

TABLE 5.—*Summary of uranium localities in Pumpkin Buttes and adjacent areas (pls. 11, 14), and analytical data of samples*—Continued

Locality—					Sample—								
No.	Land division			Description	No.	Analytical data (percent)							Description and type
	Sec.	T.	R.			eU	U	V_2O_5	Mn	$CaCO_3$	CO_2	Fe_2O_3	
132	29	43	75	Radioactivity anomaly in area of no sandstone outcrops and no visible uranium minerals.									
133	23	43	76	Radioactivity anomaly in area of no outcrops and no visible uranium minerals.	LW-106	0.036	0.009	0.1	0.02	----	----	----	Sandy soil; slightly radioactive.
134	34	43	76	Radioactivity anomaly in thick sandstone along top of ridge.	----	----	----	----	----	----	----	----	
135	34	43	76	Radioactivity anomaly near top of prominent butte in red sandstone.	----	----	----	----	----	----	----	----	
136	34	43	76	Radioactivity anomaly in red sandstone.	----	----	----	----	----	----	----	----	
137	27	43	76	Yellow uranium minerals disseminated in pink sandstone, associated with manganese oxides at places near base of the sandstone for 500 ft. along outcrop.	SU-12	3.4	3.93	1.65	1.608	15.0	----	3.59	Uranium minerals disseminated in pink, calcareous sandstone with manganese oxide; composite of several zones.
138	14	43	76	Radioactivity anomaly in red sandstone.									
139	4	42	76	Yellowish-green uranium minerals disseminated in grayish-yellow sandstone underlain by thin carbonaceous zone which also is slightly radioactive.	AEC-25313	.068	.043	.03	----	32.8	----	----	Greenish-yellow uranium minerals in gray calcareous sandstone.
140	20	42	76	Yellow uranium minerals disseminated in gray and yellow-brown sandstone.	----	----	----	----	----	----	----	----	
141	28	42	76	Radioactivity anomaly in area of red sandy soil underlain by carbonaceous clay and shale.	AEC-25314	.02	.02	.05	----	----	----	----	Brown carbonaceous shale at base of red sandstone.
144	34	43	75	Radioactivity anomaly in sandstone blowout; no visible uranium minerals.	----	----	----	----	----	----	----	----	
145	34	43	75	Radioactivity anomaly in red sandstone. No visible uranium minerals.	----	----	----	----	----	----	----	----	
146	34	43	75	Radioactivity anomaly in red sandstone. No visible uranium minerals.	----	----	----	----	----	----	----	----	
147	33	44	76	Yellow uranium minerals associated with manganese oxide in red sandstone.	TW-121	.23	.40	.76	.169	----	----	----	Yellow uranium minerals with manganese oxides in red sandstone.

					AEC-1067	1.207	1.632	1.67	--------	--------	--------	--------	Uranium minerals in red sandstone; selected high grade.
148	28	44	76	Radioactivity anomaly in mottled red and gray sandstone; no visible uranium minerals.	1073	.051	.034	.12	--------	--------	--------	--------	Sandstone, slightly radioactive.
149	34	43	75	Radioactivity anomaly in red sandstone; no visible uranium minerals.	--------	--------	--------	--------	--------	--------	--------	--------	
150	36	43	76	Yellow uranium minerals with manganese-oxide concretions in calcareous red sandstone exposed on small prominent butte.	LW-99	.64	.66	2.71	6.5	--------	5.93	--------	Uranium minerals with manganese oxides in red sandstone.
151	4	42	76	Yellow uranium minerals in manganese-oxide concretion in red sandstone.	89	.12	.15	.1	1.4	--------	--------	--------	Red sandstone; radioactive.
152	36	45	76	Manganese-oxide concretions in red sandstone; no visible uranium minerals, but concretions are radioactive.	--------	--------	--------	--------	--------	--------	--------	--------	
153	34	45	76	Yellow uranium minerals disseminated at base of red sandstone, above contact with carbonaceous shale.	--------	--------	--------	--------	--------	--------	--------	--------	
154	6	43	74	Radioactivity anomaly in gray sandstone; no visible uranium minerals.	--------	--------	--------	--------	--------	--------	--------	--------	
156	8	43	77	Radioactivity anomaly in area of ferruginous sandstone and siltstone.	--------	--------	--------	--------	--------	--------	--------	--------	
157	5	43	77	Yellow uranium minerals in red sandstone with sparse manganese oxide concretions.	TW-99	.12	.08	.18	.34	--------	--------	--------	Selected sample of red sandstone containing yellow uranium minerals.
158	12	42	76	Disseminated yellow uranium minerals at places in thick, dominantly red sandstone exposed along draw. Sandstone underlain by shaly coal bed. Basal part of sandstone is wet with water seep at one place.	LW-91	.058	.063	.21	.11	--------	--------	--------	Pink sandstone, radioactive; 2-ft channel from southwest of seep.
					92	.27	.43	.72	.13	--------	--------	--------	Red sandstone and carbonaceous material with yellow uranium minerals from 200 ft north of seep.
					93	.16	.16	.75	.03	--------	--------	--------	Red sandstone with uranium minerals composite of sandstone near base.
					94	.10	.16	.10	.06	--------	--------	--------	Red sandstone, basal 2 ft.
					95	1.3	.73	.75	.13	--------	--------	--------	Yellow uranium minerals in sandstone; channel sample of 3 ft.
					96	2.8	1.68	.1	.05	--------	--------	--------	Gray sandstone with disseminated uranium minerals overlying coal seam.
					102	--------	22 (ppm)		1.0 (ppm)		--------	--------	Water sample from seep.
159	12	42	76	Disseminated yellow uranium minerals in calcareous zone in red sandstone exposed in small draw. Sandstone underlain by shaly coal.	--------	--------	--------	--------	--------	--------	--------	--------	
160	13	43	76	A small amount of yellow uranium minerals in base of pink silty sandstone.	--------	--------	--------	--------	--------	--------	--------	--------	

TABLE 5.—*Summary of uranium localities in Pumpkin Buttes and adjacent areas (pls. 11, 14), and analytical data of samples*—Continued

Locality—					Sample—								
No.	Land division			Description	No.	Analytical data (percent)							Description and type
	Sec.	T.	R.			eU	U	V_2O_5	Mn	$CaCO_3$	CO_2	Fe_2O_3	
161	8	43	76	Yellow uranium minerals in manganese oxide concretions in red sandstone.	--------	--------	--------	--------	--------	--------	--------	--------	
164	5	43	77	Radioactivity anomaly in ferruginous sandstone with manganese oxide concretions.	TW-100	0.06	0.03	0.05	0.79	--------	--------	--------	Selected sample of ferruginous and manganiferous sandstone.
166	4	43	75	Yellow uranium mineral disseminated in soft grayish-yellow sandstone; containing abundant coaly fragments. Area mined in 1953.	119	.22	.010	.05	.628	--------	--------	--------	Gray sandstone with yellow uranium minerals from exploratory pit; carbonaceous material.
					LW-25	.051	.004	.04	--------	--------	--------	--------	Gray, soft, silty sandstone; radioactive.
167	11	45	76	Yellow uranium minerals with manganese oxide in thin red sandstone poorly exposed on small knob.	--------	--------	--------	--------	--------	--------	--------	--------	
168	11	45	75	Yellow uranium minerals in manganese oxide concretions in red sandstone; area drilled with auger in 1952.	TW-108	.009	.001	.03	.029	--------	--------	--------	Yellowish-brown and red sandstone; auger cuttings; slightly radioactive.
					109	.74	.84	.35	.445	--------	--------	--------	Red sandstone with manganese oxides and uranium minerals.
169	6	43	74	Radioactivity anomaly in gray sandstone; no visible uranium minerals.	AEC-1085	.06	.068	.10	--------	--------	--------	--------	Gray sandstone, radioactive.
170	6	43	74	Radioactivity anomaly in gray sandstone; no visible uranium minerals.	--------	--------	--------	--------	--------	--------	--------	--------	
171	12	42	75	Radioactivity anomaly in gray sandstone; no visible uranium minerals.	72	.017	.017	.03	--------	--------	--------	--------	Gray sandstone, slightly radioactive.
172	12	42	75	Radioactivity anomaly in surface area apparently below thick gray sandstone; no visible uranium minerals.	--------	--------	--------	--------	--------	--------	--------	--------	
173	3	43	75	Yellowish-green uranium minerals within iron and manganese oxide concretions in pink sandstone.	--------	--------	--------	--------	--------	--------	--------	--------	
174	16	45	74	Small amounts of yellow uranium minerals disseminated in red sandstone.	AEC-25380	.43	.45	.37	--------	--------	--------	--------	Yellow uranium minerals in gray sandstone.
175	16	45	74	Yellow uranium minerals disseminated in brown limonitic sandstone adjacent to red sandstone.	25384	.15	.111	.13	--------	--------	--------	--------	Yellow uranium minerals in limonitic sandstone.

176	16	42	75	Radioactivity anomaly in sandstone.	1080	0.01 1.05	Tr. 1.01	0.03 .47					Selected sample of radioactive sandstone.
177	29	42	75	do	1065	.05	.008	.03					Do.
178	29	42	75	do	1068	1.37	1.95	1.42					Do.
179	33	44	76	Yellow uranium minerals in manganese oxide concretions in red sandstone that caps knob.									
180	23	44	76	Slightly radioactive manganese oxide concretions in brown sandstone that caps spur; underlain by thick carbonaceous shale.									
181	21	42	75	Radioactivity anomaly on ridge.									
182	14	44	77	Radioactivity anomaly in red sandstone overlying coal bed; no visible uranium minerals.									
183	14	44	77	Radioactivity anomaly in red sandstone exposed in deep gully; no visible uranium minerals.									
184	14	44	77	Radioactivity anomaly in area of red soil; no outcrops and no visible uranium minerals.									
185	23	42	77	Area of thin-bedded brown sandstone underlain by red and light-brown sandstone.									
186	8	43	77	Radioactivity anomaly in area of ferruginous sandstone.									
187	35	42	77	Radioactivity anomaly on sandstone ridge.									
188	25	45	76	Radioactivity anomaly in area of drab sandstone exposed on low ridge; no visible uranium minerals.									
189	5	41	76	Radioactivity anomaly in area of drab calcareous sandstone.	AEC-25401	.026	.009	Tr.					Selected sample of drab calcareous sandstone.
190	12	42	75	Radioactivity anomaly in area of calcareous friable gray and brown sandstone.	25402	.02	.10	Tr.					Sandstone, gray to brown.
191	8	41	75	Radioactivity anomaly in area of gypsiferous clay at base of sandstone.	25400	.009	Tr.	.006					Gray, gypsiferous clay.
192	11	44	75	Radioactivity anomaly on low knoll in fine-grained calcareous grayish-yellow to brown sandstone.									
193	8	43	77	Radioactivity anomaly in area of ferruginous sandstone.									
195	10	44	75	Yellow uranium minerals in manganese oxide concretions scattered in thin red sandstone that caps ridge; disseminated uranium minerals in gray sandstone near the color change to red sandstone.									

TABLE 5.—*Summary of uranium localities in Pumpkin Buttes and adjacent areas (pls. 11, 14), and analytical data of samples*—Continued

Locality— No.	Land division Sec.	T.	R.	Description	Sample— No.	Analytical data (percent) eU	U	V_2O_5	Mn	$CaCO_3$	CO_2	Fe_2O_3	Description and type
196	10	44	75	Yellow uranium minerals in manganese oxide concretions scattered in red sandstone.									
198	12	44	77	Radioactivity anomaly in area of red, grayish-yellow, and gray sandstone exposed in gully; no visible uranium minerals.									
201	32	43	75	Radioactvity anomaly in area of gray sandstone; no visible uranium minerals.									
202	29	43	75	do									
203	25	43	76	do									
205	28	43	75	Radioactivity anomaly in area covered by drab, coarse-grained sand and soil; underlain by thick sandstone; no visible uranium minerals.									
206	28	43	75	Radioactivity anomaly in area of brown sandy soil with no outcrops; no visible uranium minerals.									
207	28	43	75	Radioactivity anomaly in area of drab sandstone; no visible uranium minerals.									
208	21	43	77	Radioactivity anomaly in reddish-brown sandstone that caps ridge. Much "ironstone" float; area drilled by Atomic Energy Commission.									
209	10	43	77	Radioactivity anomaly in area of reddish-brown and white sandstone. Much "ironstone" float.									
210	17	43	77	Radioactivity anomaly in area of ferruginous sandstone.									
211	8	43	77	Radioactivity anomaly in area of ferruginous sandstone.									
212	21	44	76	Yellow uranium minerals disseminated in carbonaceous yellowish-gray sandstone overlying pink sandstone in cutbank.									

213	20	45	76	Yellow uranium minerals disseminated in crossbedded pink and brownish-red sandstone exposed in gully.	----------	-------	-------	-------	-------	-------	-------	-------	
214	16	45	76	Yellow uranium minerals disseminated along bedding in yellowish-brown sandstone and carbonaceous grayish-pink sandstone, at the color change. Area drilled in 1953.	SU-3A	0.70	1.21	1.83	0.009	0.7	-------	4.99	Uranium minerals in yellowish-brown sandstone from 12 ft above base; selected sample.
					3B	.82	1.27	3.23	.014	1.0	-------	8.32	Uranium minerals in grayish-red sandstone from contiguous zone; selected sample.
215	17	45	76	Yellow uranium minerals disseminated in small area of red sandstone in dominantly yellowish-gray sandstone, near top of cliff exposure.	----------	-------	-------	-------	-------	-------	-------	-------	
216	8	45	76	Small amount of yellow uranium minerals disseminated in thin-bedded, shale carbonaceous sandstone containing coalified woody material.	----------	-------	-------	-------	-------	-------	-------	-------	
217	6	45	76	Yellow uranium minerals disseminated in reddish-brown sandstone that caps a small hill.	6	.52	.68	.28	*MnO* 1.187	78.0	-------	.19	Uranium minerals in reddish-brown sandstone.
218	29	45	76	Yellow uranium minerals disseminated in pink sandstone; mineralized zone trends N. 5° E. and extends horizontally for about 60 ft; area has been drilled.	----------	-------	-------	-------	-------	-------	-------	-------	
220	29	45	76	Channel deposit. Abundant yellow uranium minerals disseminated in yellowish-brown sandstone near color change to pink sandstone; carbonaceous material is abundant in lower part of sandstone. Some uranium minerals concentrate around fragments of coalified wood. Area was drilled and mined, 1953 and 1954.	----------	-------	-------	-------	-------	-------	-------	-------	
221	12	44	77	Radioactivity anomaly in gray to pink sandstone. Area drilled in 1953.	----------	-------	-------	-------	-------	-------	-------	-------	
222	19	45	76	Moe 14 Deposit. Yellow uranium minerals disseminated in fine- to medium-grained gray carbonaceous, calcareous sandstone at color change to pink sandstone. Area was drilled and mined in 1953. Yellow uranium minerals disseminated near base of red sandstone; area drilled in 1953.	15A	.18	.28	.46	.027	2.3	-------	2.29	Uranium minerals in gray sandstone.
					15B	.028	.012	.46	.061	.30	-------	7.11	Carbonaceous material surrounded by limonitic sandstone.
					PR-222-B1	.59	1.04	2.48	.14	15.8	-------	3.13	Black carbonaceous clayey material from mine pit.
					B2	1.2	1.79	5.99	.18	10.7	-------	3.50	Radioactive.

TABLE 5.—*Summary of uranium localities in Pumpkin Buttes and adjacent areas (pls. 11, 14), and analytical data of samples*—Continued

Locality					Sample—								
No.	Land division			Description	No.	Analytical data (percent)							Description and type
	Sec.	T.	R.			eU	U	V_2O_5	Mn	$CaCO_3$	CO_2	Fe_2O_3	
223	19	45	76	Red sandstone containing uranium minerals in exposure 5 ft above base. South extension of Moe 14 sandstone. Area drilled in 1953.	------	------	------	------	------	------	------	------	
224	21	44	76	Yellow uranium minerals disseminated in coarse- to medium-grained gray carbonaceous sandstone, locally pink, about 5 ft above base of sandstone; exposed in cutbank; area drilled in 1954 by Atomic Energy Commission.	SU-17	3.3	4.53	3.19	0.09	2.4	------	7.54	Uranium minerals in limonitic sandstone from 5 ft above base; selected sample.
225	13	44	77	Yellow uranium minerals disseminated in pink zone in yellowish-gray sandstone, about 2 ft above base of the sandstone; sandstone is about 15 ft thick; similar minerals occur 50 ft south, where the same sandstone is highly carbonaceous and limonitic.	18	.27	.39	.56	.152	7.5	------	2.61	Uranium minerals in yellowish-gray sandstone from 2 ft above base; selected sample.
226	13	44	77	Yellow-green uranium minerals associated with pyrite nodules, disseminated in limonitic zone in yellowish-gray sandstone above pink sandstone.	19	.63	.56	1.22	.119	4.7	------	7.28	Uranium minerals in gray sandstone with pyrite and limonitic material.
227	7	44	75	Yellow uranium minerals disseminated in gray fine-grained sandstone, and also encased in manganese-oxide concretions in the sandstone, associated with fossil woody material; part of area has been drilled.	------	------	------	------	------	------	------	------	
228	29	45	75	Yellow uranium minerals in manganese-oxide concretions in variegated, fine- to coarse-grained sandstone, more red toward the base; mineralized zone is about 20 ft above base.	------	------	------	------	------	------	------	------	
229	28	45	75	Yellow uranium minerals associated with limonitic zone in large calcareous concretions in	------	------	------	------	------	------	------	------	

				a white to yellow sandstone which is pink at base; sandstone is underlain by sandy silt rich in pelecypod shells.									
230	33	45	75	Yellow uranium minerals in manganese oxide concretions 6 ft above base of a crossbedded white to red sandstone 23 ft thick in measured section.	...	...	...	...	...	...	...	...	
231	21	45	75	Yellow uranium minerals in manganese oxide concretions, in white to pink and red sandstone; fossil wood or bone are in close spatial relation with the uranium minerals.	...	...	...	...	...	...	...	...	
232	33	44	75	Yellow uranium minerals associated with manganese oxide concretions in red to pink, medium- to fine-grained sandstone capping narrow ridge; woody material is abundant.	...	...	...	...	...	...	...	...	
233	16	45	76	Yellow uranium minerals associated with manganese oxide concretions in pink to gray sandstone that caps ridge.	...	...	...	...	...	...	...	...	
234	22	43	76	Yellow uranium minerals in manganese oxide concretions in red sandstone; some disseminated minerals also.	...	...	...	...	...	...	...	...	
235	21	43	76	Greenish-yellow uranium minerals disseminated in red sandstone, surrounded by bleached zone.	MS-6d	0.28	0.50	0.37	0.51	...	...	2.92	Uranium minerals in varicolored calcareous sandstone.
236	28	43	76	Yellow uranium minerals in manganese oxide concretion in red sandstone.	...	...	...	...	...	...	...	...	
237	9	43	76	Yellow uranium minerals in manganese oxide concretions in red sandstone.	...	...	...	...	...	...	...	...	
238	22	43	76	Yellow uranium minerals in manganese oxide concretion in red sandstone.	...	...	...	...	...	...	...	...	
239	15	43	76	Yellow uranium minerals in manganese oxide concretions that are elongate with bedding of red sandstone in a zone about 25 ft long.	...	...	...	...	...	...	...	...	
240	21	43	76	Yellow uranium minerals in manganese oxide concretions that are as much as 10 in. in diameter in red sandstone.	...	...	...	...	...	...	...	...	

TABLE 5.—*Summary of uranium localities in Pumpkin Buttes and adjacent areas (pls. 11, 14), and analytical data of samples*—Continued

Locality					Sample—								
No.	Land division			Description	No.	Analytical data (percent)							Description and type
	Sec.	T.	R.			eU	U	V_2O_5	Mn	$CaCO_3$	CO_2	Fe_2O_3	
241	16	43	76	Yellow uranium minerals in small irregular manganese oxide concretions in red sandstone.	MS-8a	0.098	0.66	0.13	1.27	--------	--------	5.71	Manganese oxide concretions with yellow uranium minerals.
242	15	44	75	Yellow uranium minerals in manganese oxide concretions in a gray zone in a pink to white sandstone that caps a ridge. Area has been drilled.	--------	--------	--------	--------	--------	--------	--------	--------	
243	26	44	75	Yellow uranium minerals in manganese oxide concretions in red to yellow, medium- to coarse-grained sandstone that caps ridge; woody material abundant at south end of sandstone; area has been mined.	--------	--------	--------	--------	--------	--------	--------	--------	
244	26	44	75	Yellow uranium minerals associated with manganese oxide concretions in dark red zone at base of sandstone; upper part of sandstone is pink to white; uranium minerals associated with woody material.	--------	--------	--------	--------	--------	--------	--------	--------	
245	29	46	76	Yellow uranium minerals disseminated in narrow band in limonite-stained gray sandstone that underlies red sandstone; uranium minerals seem most abundant below darkest red sandstone.	--------	--------	--------	--------	--------	--------	--------	--------	
246	22	45	75	Mined area at Jeannette 1 claim; carnotite-tyuyamunite and uranophane disseminated in drab sandstone at red color contact, associated with manganese oxide concretions and fossil woody material in red sandstone; uraninite cements sand grains into concretionary masses in red sandstone.	PR-246-J2	.35	.37	.25	.02	0.6	--------	2.91	Greenish-yellow uranium minerals finely disseminated in fine-grained gray sandstone; representative of 3-ft zone.
					J3	.13	.10	.14	.02	1.2	--------	2.73	Same as above, from different zone.
					J7	.007	.003	.1	.03	.3	--------	3.58	Gray sandstone, nonradioactive.
					J8	.002	--------	--------	--------	--------	--------	--------	Red limy sandstone.

247	36	44	77	Van 1 deposit. Black vanadium minerals associated with concretionary pyrite and coalified wood fragments, in poorly exposed medium-grained red sandstone at color boundary.	PR-247-M2	0.13	0.14	3.86	0.18	11.9	15.57	Black paramontroseite-cemented sandstone.
					M2a	.006	.0002	.1	.03	20.7	2.89	Red sandstone from around black concretion of vanadium minerals.
248	33	43	77	Radioactivity anomaly in area of gray sandstone underlain by red, grayish red, and brown sandstone; no uranium minerals visible.								
249	8	45	75	Yellow uranium minerals in manganese oxide concretions in red sandstone that caps hill; sandstone is 6–8 ft thick.								
250	8	45	75	Yellow uranium minerals in manganese oxide concretions associated with woody material near base of reddish-brown and pink sandstone.								
251	10	44	75	Uranium minerals in silty red sandstone; area explored by pits in 1954.								
252	3	44	75	Yellow uranium minerals associated with manganese oxide concretions in red sandstone, locally ferruginous.								
									Se (ppm)	*As*		
253	11	45	75	"Blowout" (anomaly 119) deposit. Oxidized and unoxidized uranium minerals in gray and red sandstone, predominantly in color contact zone. Area mined in 1954–55.	PR-253-1	.036	.002		13	.003		Sandstone mottled red and white, with scattered manganese oxides.
					2	.03	.12		3	.004		Limonitic sandstone.
					3	.042	.045		500	.001		Red sandstone, selenium rich.
					4	.13	.078		13	.090		Greenish-brown sandstone.
						.014	.002		10	.001		White sandstone. (Samples are all nonore sandstone components from mine pit.)
254	33	46	74	Yellow uranium minerals in manganese oxide concretions in pink sandstone. Area drilled by Atomic Energy Commission in 1954.								
255	32	45	76	Yellow uranium minerals in thin band that overlies thin pyrite zone at base of red sandstone. Pyrite zone separates red sandstone from underlying gray clay.								

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