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Geology and Uranium Mineralization In the East Gas Hills, Wyoming

by

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GEOLOGY AND URANIUM MINERALIZATION
IN THE EAST GAS HILLS, WYOMING

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L I S T O F I L L U S T R A T I O N S

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ABSTRACT

The East Gas Hills comprises an area of approximately 36 square miles between the Dutton Basin anticline and the Rattlesnake Hills in central Wyoming. It has become an important uranium producing area.

Exposed sedimentary rocks of this area include Paleozoic and Mesozoic formations which were folded, dissected into hogsbacks, and then buried by Tertiary sediments, and are now once again exposed.

The important uranium horizons are in Eocene strata, often subdivided into the Lower Eocene or Wind River formation, and the Middle and Upper Eocene. Uranium was discovered in 1954 touching off extensive government and private exploration. Discoveries of various quantities and grades have been made ranging from near surface depths up to 630 feet below the surface.

Subsurface geologic methods were employed to trace channels, important stratigraphic controls, structural features, and ground water occurrances, all of which play important roles in the concentration and control of uranium ore bodies.

Trace elements have been found useful in subsurface exploration. Halos of these elements exist around nearly every ore body. Oxidation of the uranium ore bodies may result from the heat and loss of oxygen occurring in the disintegration of uranium.

The production now being maintained by several mines demonstrates the economic importance of the area. In the less than 10 per cent of the area drilled, more than 1,500,000 tons of commercial ore have been discovered.

INTRODUCTION

PURPOSE AND SCOPE

Uranium was first discovered in the Gas Hills area in the summer of 1954 by a prospector from Riverton, Wyoming. This discovery touched off extensive prospecting in the southern Wind River Basin, of which the Gas Hills area is a part. This first discovery is now known as the Lucky Mac Mine, which is managed and operated by Utah Construction Company.

Since 1948, geologic studies of the region containing the Gas Hills have been made by the United States Geological Survey as part of a program of the Department of Interior for the development of the Missouri River Basin. During the summer of 1954, topographic crews mapped the region. In the fall of 1954, the Atomic Energy Commission, evaluating the uranium occurrances, drilled 15,000 feet of exploratory holes. They discovered several ore bodies. New prospectors entered the area during the winter of 1954 and 1955. Ore bodies were discovered in undifferentiated Eocene sediments, generally designated as the Wind River formation.

After an appraisal of the area during the winter and spring of 1954 and 1955, the writer obtained the cooperation of several companies in a drilling program to give special attention to geochemical aspects of the area, and to evaluate the stratigraphic, structural, and ground water controls for the localization of uranium ore bodies.

As a result of this study, ten uranium ore bodies of variable size, one in excess of 300,000 tons, were discovered. This thesis describes exploration techniques, general geology, economic geology, and methods of development work. Some aspects of the problem of the origins of the uranium are considered. Other problems connected with the ore bodies are defined.

LOCATION AND ACCESSIBILITY

The area described in this paper comprises about 36 square miles of eastern Fremont County and western Natrona County, in central Wyoming. Nearly all of the area is contained in Township 33 North, Range 89 West. The nearest post office is at Moneta, Wyoming, 20 miles north of the area on combined U. S. Highways 20 and 26. The main supply center for the area is Riverton, Wyoming, 54 miles to the west. Split Rock, the site of a new uranium mill, lies 35 miles to the south. Casper, Wyoming, is 75 miles to the east. All of the roads are good and are constantly being improved.

The nearest railroad station is at Lysite, on the Chicago, Burlington and Quincy Railroad, 34 miles to the north. Frontier Airlines serve Riverton and Casper, Wyoming twice daily. There are two landing strips in the area capable of accommodating most small aircraft.

The East Gas Hills area lies in the southeastern sector of the Wind River Basin, north of the Beaver Divide, east of the Dutton Basin anticline, and west of the Rattlesnake Hills.

PHYSICAL FEATURES

The East Gas Hills are bordered on the south by the Beaver Divide, a high sinuous northfacing escarpment. This geomorphic feature forms the northern limit of the Sweetwater Plateau. The Dutton Basin anticline forms a series of hogsbacks of Paleozoic and Cretaceous rocks, locally called the Gas Hills, on the western border. The most prominent of the anticlines in the region forms the Rattlesnake Hills on the eastern border. The Muskrat anticline and the Conant Creek anticlines are features of the West Gas Hills, and lie in the ore trend of which the area studied is a part.

The conspicuous eastward trending escarpement of the Beaver Divide rises 7,600 feet above sea level. This divide separates steep-gradient northward-draining tributaries of the Wind River from the low-gradient southward-flowing tributaries of the Sweetwater River. The East Gas Hills have been dissected by the Canyon Creek Drainage System.

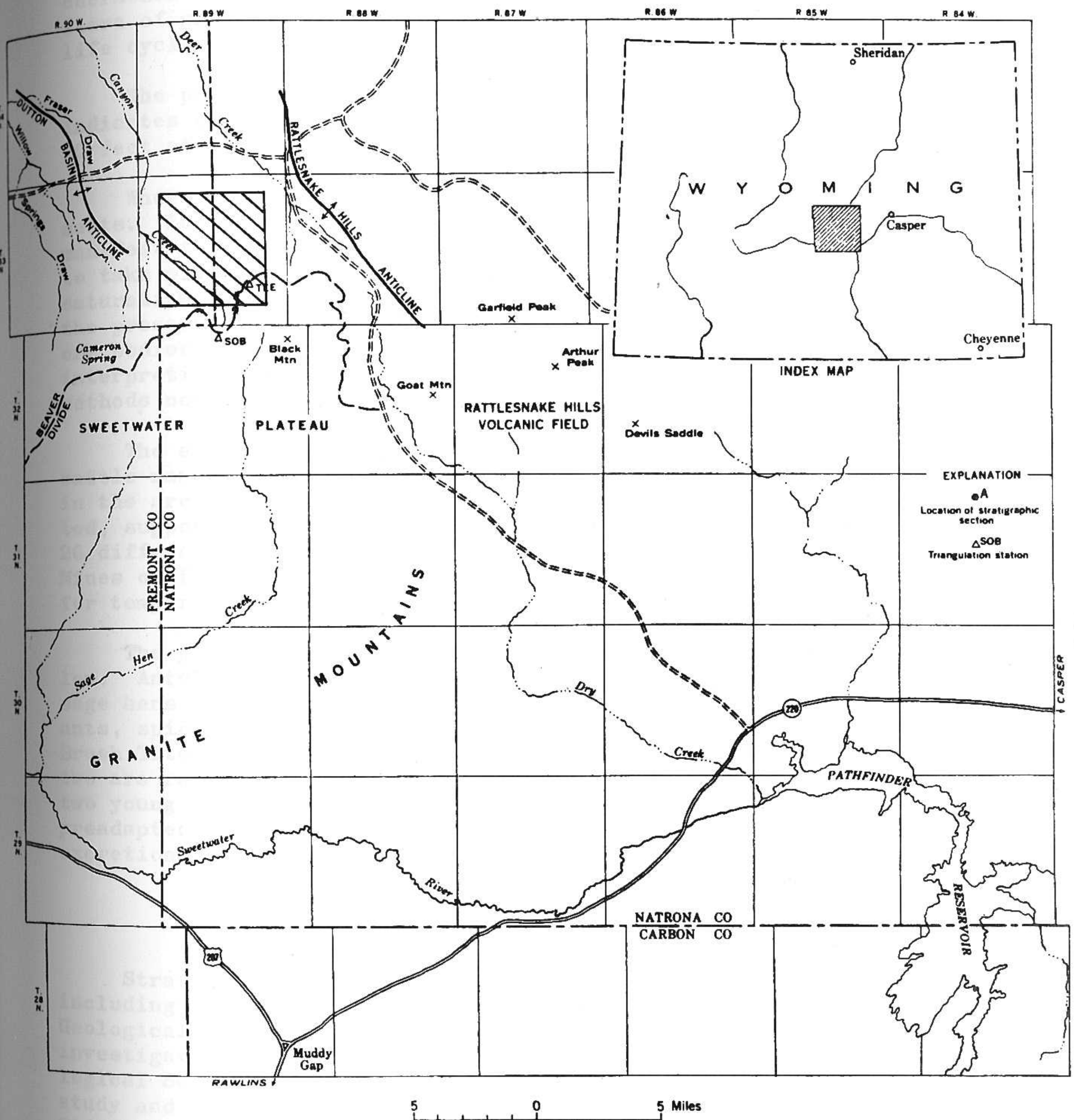
The Wind River Basin has been eroded in basin-fill deposits of Tertiary age, exposing folded Mesozoic and Paleozoic strata. The topographic expression and relief is not great. The lowest point in the area is 6,700 feet above sea level.

The climate of the area, in common with the High Plains of Wyoming, is considered to be semi-arid to arid with precipitation amounting to less than 14 inches per year in the higher altitudes. There are approximately 130 days of frost annually. May and September are the months of greatest precipitation. At a mean elevation of 6,900 feet thunderstorms are not infrequent. Snowfall in the winter is often quite deep and temperatures drop to -32° F. The wind blows incessantly in the region, and unless open pits are aimed directly towards the prevailing winds, great snow drifts will fill them. The summer months have an average temperature of 90° F. While some adverse winter conditions do exist, all year operations can be maintained.

The distinctive biota of the area includes 19 species of the Juniper-Pinion biome association. The plants are hardy and survive under extreme water and temperature flucuations. Sparse growths are supported only where soil and moisture conditions prevail.

During early stages in the field study for this thesis, attention was given to possible geobotanical aids for prospecting such as the selenium-indicator and uranium-accumulator plants. Selenium occurrences in the area have been observed but plants absorbing the element have not been identified. While preliminary work did not indicate that the geobotanical possibilities were of any value, future trace element work may find them to be so.

INDEX MAP



After Van Houten, et al, 1955

The soils were found to be intermediate between podzol and chernozem types. During brief wet periods a surprisingly rich flora of grasses and herbs appear, most of them completing their life cycle in a few weeks.

The presence of shad scale biotics and the sagebrush community indicates that the surface and substrata are permeable to depths of 70 feet at least and that the sediments are saline free.

Where shad scale is present the sediments are high in mineral salts. Locally the evaporative processes of the sediments are more manifest than the leaching processes. Any leaching would have had to take place in water saturated sediments. Where evidence of saturation exists near the surface, or if found during drilling, the presence of water tables is indicated and the possibilities of ore bodies are increased. More time could profitably be spent on interpreting the geology from ecological and botanical viewpoints, methods not often applied in the field by geologists.

The area has no permanent residents. Limited sheep and cattle ranching are the only industries. Ground water is plentiful in the area and may, after all mining activities have been terminated, support a resurgence of ranching. At this writing there are 26 different mining companies maintaining camps in the region. Mines on full scale operating status have provided living facilities for temporary workers.

The population density of animals in the area is generally low. Antelope predominate in the area; some deer, rabbits, and sage hens are also observed. Small life includes lizards, rodents, ants, spiders, and beetles. The Pinion Jay, Gray Titmouse, and Brush Tite are characteristic permanent resident birds. The first two are restricted to the Juniper-pinion biome. From dill holes two young reptiles emerged of the uric-acid type. They are preadapted to desert biomes by impervious integuments and dry excretions. Hetermoyidae members of the rodents were observed.

PREVIOUS WORK

Stratigraphic and structural studies of the Wind River Basin, including the Gas Hills, have been in progress by the U. S. Geological Survey since 1944 as part of a regional oil and gas investigations program. In 1951, J. D. Love of the U. S. Geological Survey made a Geiger survey in portions of the area under study and noted high radioactive anomalies. Field men of the Oak Ridge Laboratory of the Atomic Energy Commission (AEC) sent in water samples collected in the Gas Hills area for analysis because of a high uranium content. The Pumpkin Buttes and Miller Hill radiometric surveys by the U. S. Geological Survey in 1952 and 1953 resulted in recommendations for regional surveys to be made which include the Gas Hills. This survey was begun on September 27, 1953. On September 9, 1953, Mr. Neil McNeice of Riverton, Wyoming, discovered uranium in the Wind River formation in section 22, Township 33 North, Range 90 West. With this discovery the AEC began detailed studies of the uranium deposits and possibilities in the area.

In 1913 and 1914, C. J. Hares of the U. S. Geological Survey mapped the Rattlesnake Hills region as part of a geological examination of central Wyoming. In 1944, J. D. Love collected the first fossil mammals recovered from the White River formation of Oligocene age, establishing the relative stratigraphy and geochronology in the area. In 1950, Mr. Love discovered the first plant and mammalian fossils in the Tertiary deposits of the Canyon Creek area. Subsequently J. F. Rachou found larger collections which form the basis of present age assignments. The Department of the Interior project for development of the Missouri River Basin has been underway since 1948. In 1951, the Tertiary formations west of the Rattlesnake Hills were mapped and studied by Colin C. McAneny. In 1954, B. D. Carey, Jr. made a detailed study of the Rattlesnake Hills Tertiary volcanic field. Stratigraphic sections were measured by hand level and elevations were established by aneroid barometer readings based on triangulation stations of the Survey. This data was then adjusted to the U. S. Geological Survey topographic survey program conducted during 1953 and 1956.

In December, 1954, J. D. Love published Geological Survey Circular 352, Preliminary report on Uranium in the Gas Hills Area, Fremont and Natrona Counties, Wyoming. In late 1955, Geological Survey Professional Paper 274-A by F. B. Van Houten, "Volcanic-Rich Middle and Upper Eocene Sedimentary Rocks Northwest of Rattlesnake Hills Central Wyoming," was published.

In late 1956, Oil and Gas Investigations Map OM 180 by F. B. Van Houten and J. L. Weitz became available. Other investigations are as yet unpublished.

S T R A T I G R A P H Y

GENERAL FEATURES

The rocks exposed in the mapped area range in age from Cambrian to Upper Eocene. In the eastern part of the area hogsbacks of the northeast flank of the Dutton Basin anticline include the Cambrian, Mississippian, Pennsylvanian, Permian, and Triassic systems. These Paleozoic and Mesozoic rocks are partially buried and surrounded by Eocene strata. Quaternary and Recent valley fill occupies most of the drainage basins.

SEDIMENTARY ROCKS

Cambrian System

Gros Ventre Formation

This stratigraphic unit crops out in hogsbacks in the eroded anticlines of an anticlinorium developed in the southern part of the Wind River Basin. The Gros Ventre formation is essentially siltstone and sandstone, gray to reddish-brown. Some of the lower part which is exposed includes flat-pebble limestone conglomerate. The base of the Cambrian is not exposed.

Gallatin Limestone

The Gallatin limestone is composed of flat-pebble conglomerate with a sandy limestone matrix and ranges in color from gray to red. It crops out in the eroded hogsbacks of the regional anticlines. In some areas of Wyoming this formation is part of an undifferentiated Cambrian series, especially in the southwest and northwest areas of the state. The Gallatin limestone is 200 feet thick in the East Gas Hills.

Mississippian System

Madison Limestone

This is the most prominent lithologic unit exposed in the hogsbacks of the eroded anticlines of the Wind River basin. It lies unconformably over the Cambrian strata. The Madison limestone is limey in the upper part and dolomitic in the lower part and varies in color from light-gray to gray-brown and is 340 feet thick in the area mapped.

Pennsylvanian System

Amsden Formation

The Amsden formation is composed of red and gray sandstones and shales, and in some areas cherty gray limestones, dolomitic in part. The Amsden is correlated with the Darwin sandstone of the Wind River Mountains to the west and with the Lower Tensleep sandstone elsewhere in Wyoming and is 188 feet thick in the area mapped.

Permian System

Phosphoria Formation

The Phosphoria formation is a dolomitic siltstone and dolomite, gray to brown in color, with bedded chert and thin phosphatic zones. The Phosphoria formation is extremely thick and massive in the southwest part of Wyoming, but thins towards the northwest. To the southeast and northeast it becomes a cherty, gray and lavender dolomite with intercalated beds of red shale and gypsum. The Phosphoria formation is 348 feet thick in the Gas Hills area.

Triassic System

Dinwoody Formation

The Dinwoody formation is composed of gray to tan shale and sandstone. It is calcareous in the upper half and shaly and silty dolomite in the lower half. The Dinwoody formation has not been fully identified and in places may have been included as basal Chugwater. The Dinwoody formation is 60 feet thick.

Chugwater Formation

The characteristic dark-red appearance of this formation sets it off prominently from the other formations of the area mapped. The Chugwater formation is a sandstone and siltstone, shaly in part and dark red in color. It has only been fully identified in the southeast part of Wyoming. In other areas the Chugwater is included in undifferentiated Triassic rocks. In the area mapped the Chugwater was not fully exposed.

Tertiary System

Eocene

The Wind River foramtion of Lower Eocene age is the chief uranium ore host in the Gas Hills. It is difficult to subdivide because of the rapid lateral changes in facies. Some general characteristics have permitted the tentative subdivision of the Wind River into the following five units:

1. Lower: Red and green beds of intercalated sands and silts with silts predominating. It is marked by the absence of conglomerates, and is shaly in part. This unit is 100 to 400 feet thick. The thickness variation is due to the irregular topography buried by the Eocene sediments.

2. Upper Lower: This is a zone of intercalated arkoses, and lenses of conglomerates, uncemented for the most part. It is 100 to 180 feet thick.

3. Lower Middle: This is also a zone of intercalated arkoses, bentonitic beds, silts, conglomerates, and sandstones. Dark colored units are absent. The thickness is 100 to 150 feet.

4. Upper Middle: A zone of intercalated arkoses, sands, conglomerates, silts, and clayey beds. Blue and dark units are abundant. It is 100 to 150 feet thick.

5. Upper: This is a zone of mudstone, intercalated lenses of sandstone, arkoses, and calcareous units. Yellow-orange and white colors predominate. This zone is 100 to 150 feet thick.

Middle and Upper Eocene

This is an unnamed sequence of mudstone, siltstone, and sandstone in the upper part; sandstone, mudstone, and volcanic conglomerate in the middle part; and mudstone and siltstone in the lower part. The units are often tuffaceous in part. The sequence is greenish-yellow, gray, olive, and white in color. The Middle and Upper Eocene has not been fully differentiated from the Wind River formation in all parts of the Basin, thus causing stratigraphic misidentifications. This sequence is 150 to 600 feet thick (Van Houten, 1956).

Oligocene

The Oligocene is represented by the White River formation. The upper part of which formation is a mudstone. It is tuffaceous in character, but not devitrified. It is white to pale-orange.

There are intercalated lenses of arkose and conglomerate, some bentonitic material, and clayey lenses. A vertebrate fauna occurs in this formation (Love, 1955).

Miocene

The Miocene epoch is an unnamed sequence of conglomerate, sandstone and fine-grained to silty sandstone. It is gray to pale-orange of variable thickness with local areas of friable white sandstone (Love, et al, 1955-56).

Quaternary System

The Quaternary alluvium varies in thickness up to 120 feet. It is mostly silts, sandy clay and soil and slope wash.

Generalized section of Sedimentary Rocks in the East Gas Hills

Age	Formation, member of constituent units	Thickness (Feet)	Character
Quaternary	Alluvium	variable up to 120 feet	Soil and slope wash locally. Sandy clay, sand but mostly silts.
	Unconformity		
Miocene	Unnamed sequence	variable	Conglomerate and sandstone, yellowish-gray to pale-orange, local areas of soft white sandstone.
	Unconformity		
Oligocene	White River	100-500	Upper part mudstone, tuffaceous, white to pale-orange. Intercalated lenses of arkose and conglomerate bentonitic. Vertebrate fauna.
	Unconformity		
Upper and Middle Eocene	Middle and Upper unnamed sequence	150-550	Mudstone, siltstone, and sandstone in upper part; sandstone, mudstone, and volcanic conglomerate in central part; mudstone in lower part. Greenish-yellow, gray, olive, white; Tuffaceous.
Lower Eocene	Wind River Upper	100-150	Mudstone, intercalated sandstone, arkoses, and bentonitic beds; calcareous. Oxidized. Yellow, orange, white beds.
	Upper Middle	100-150	Intercalated arkoses, sands, conglomerate, some silts, very little calcareous beds. Reduced. Blue beds.
	Lower Middle	100-150	Intercalated arkoses, bentonitic beds, silts, conglomerates. Some reduced beds, essentially oxidized.

Age	Formation, member of constituent units	Thickness (Feet)	Character
Lower Eocene	Wind River Upper lower	100-180	Intercalated arkoses, conglomerates. Upper part oxidized, lower part reduced. Conglomerates well cemented.
	Lower	100-300	Silts, sands, red beds, green beds, no conglomerates.
Unconformity			
Triassic	Chugwater formation.	1000-1250	Sandstone, dark-red, shaly and silty in upper part. Limestone, gray, hard, forms ridges. Sandstone and siltstone, dark red. Calcareous.
	Dinwoody formation.	62	Shale and sandstone, gray to tan. Calcareous. Silty, dolomitic in lower part.
Unconformity			
Permian	Phosphoria formation	348	Dolomitic siltstone and dolomite. Gray to brown with some bedded chert and thin phosphatic zones.
Pennsylvanian	Tensleep Sandstone.	200-300	Sandstone, gray to rusty. Calcareous, cross-bedded, some white dolomite and cherty dolomite.
	Amsden formation	180-190	Sandstone and shale, red to gray, silty near top. Cherty gray limestone and dolomite in middle. Sandstone near base rusty to reddish, thick bedded, calcareous.

Age	Formation, member of constituent units	Thickness (Feet)	Character
Mississippian	Madison Limestone	300-400	Limestone, and dolomite. Light gray to gray-brown, cherty in part.
	Unconformity		
Cambrian	Undifferentiated	300-500	Limestone, pebble conglomerate, gray to red, sandy. Siltstone and sandstone, gray to reddish brown, glauconitic. Sandstone, reddish brown, quartzitic in part, cross-bedded.

IGNEOUS ROCKS

No outcrops of igneous rocks exist in the mapped area, but about ten miles southeast and east of the area is a late Eocene volcanic field, the rocks of which were intruded through Precambrian, Paleozoic, and Mesozoic rocks. Volcanic debris in the middle and upper Eocene sediments in the Gas Hills were probably derived from this source.

A great deal of the Tertiary sediments are composed of debris that has been derived from paleo-sources of granitic and metamorphic rocks. The Granite Mountains some twenty miles south of the area are composed of Precambrian igneous complexes and must have supplied much of the materials for the Tertiary sediments. The intercalation of fine detritus and numerous conglomerate beds, some with three foot boulders, indicates flucuations in the elevation of the source area as well as other orogenic activities.

During the early stages of exploration in the area, personnel of several mining companies believed that the underlying basin was intruded by hidden igneous bodies. Drilling was conducted to check this, but proved to be negative. Deep drilling by oil companies has not encountered, as yet, any underlying igneous rocks. A basement complex of igneous and metamorphic rocks no doubt exists but is not associated with the uranium occurrences in the area. Igneous rocks, except for their contribution to the sediments, are not considered important.

STRUCTURAL GEOLOGY

GENERAL STATEMENT

The important structural deformation of the area had its beginnings during the Laramide revolution. Northeast-southwest forces converged in central Wyoming to form a northwest trending anticlinorium. There was attendent faulting with this folding activity, but this older faulting apparantly has not played a significant part in the economic geology of the uranium deposits. South of the area the Granite Mountains were tremendously uplifted during the later stages of the Laramide revolution. These sturctures were deformed and deeply eroded. This period of diastrophic and tectonic activities extended over a considerable period of time in central Wyoming. Thrust faulting from the north in Wasatchian time was extant along the southern margin of the Big Horn Mountains and the south side of the Owl Creek Mountains. The development of the great anticlinorium was accompanied by folding, after the close of Bridgerian time, in the Big Horn Mountains. A resurgent uplift occurred in the Granite Mountains and the Rattlesnake Hills just prior to the Eocene epoch. This structural activity introduced prolonged aggradation of the Wind River Basin and the lower Eocene Wind River formation was deposited, deriving most of their detritus from the Granite Mountains. The nature of the sediments indicates that this sediment source was periodically uplifted and eroded.

Normal faulting occurred during and after Oligocene time. Great northwest faults in the Granite Mountains became filled with hornblenditic dikes. Volcanism occurred to the east of the area mapped during Oligocene epoch. In all, 30 volcanoes have been counted. Igneous rocks were intruded into the surrounding area.

FOLDING

The Laramide revolution introduced regional and local folding. An anticlinorium of regional proportions was developed. Largest of the associated northwest-southeast trending anticlines is the Rattlesnake Hills. The Gas Hills or Dutton Basin anticline, just west of the Rattlesnake Hills, is the next most prominent structure. To the northwest a large synclinorium developed and provided a depositional basin from Paleocene to Miocene times and was part of a system of folding and deformation that extended to the Montana border. It may be, however, that this anticlinorium is but a series of flanking folds of Paleocene age formed as part of the major deformation of the Sweetwater Uplift.

The Laramide folding deformed Paleozoic and Mesozoic rocks. The west flanks of the anticlines are steeper than the east flanks. The predominant forces appear to have originated to the northeast with a hedreocraton somewhere to the southwest. Late Miocene compressional faulting occurred in the Tertiary sediments as they compacted and adjusted to the underlying irregular topography they had buried. In probably what can be considered Pliocene or early Pliestocene time, compressional forces developed a northeast-southwest trending anticline. The axis of this anticline is traceable for over 20 miles. There are many indications that this last structure has played a very important role in the control of uranium ore bodies in the area. The northeast nose of this anticline is in part covered by the area studied. This late Tertiary deformation is very gentle. The dip does not exceed seven degrees and is not easily observed since the area has been dissected and eroded.

FAULTING

Thrust faulting that occurred during Wasatchian time is not apparent in the area mapped. Normal faulting during or after Oligocene time occurred as the Tertiary sediments adjusted compactionally to the underlying irregular topography. Compactional faulting of small displacement occurred during Eocene time also with the development of small monoclines in younger sediments. Important faulting has occurred in the East Gas Hills, during late Pliocene or early Pliestocene time. Displacements of one foot to 175 feet have been noted. These faults are more or less parallel to the anticlinorium axis and are probably compactional and adjustmental in origin. They are high-angle normal faults with down-thrown blocks on the south. Some previously described faults in the area are now considered to be joint systems in older consolidated rocks.

Except where folding and faulting has materially interferred with the ground water or water tables, there appears to be no intimate connection between them and ore deposits.

SUMMARY OF GEOLOGIC HISTORY

During the Archeozoic and Proterozoic eras the paleogeography and tectonic history of the region was essentially hedreocratonic in character margined by deeper, sinking miogeosynclines. Farther to the west there may have been eugeosynclinal belts. During the early Paleozoic Era the area was a stable interior of the continent which received locally less than 5000 feet of sediments. An emergent zone formed to the north of the area supplying sediments. During early Cambrian time the area was part of the elongated shelf zone. During upper Cambrian it was a vast sandy coastal plain. The area received sediments during Ordovician time but probably lost these during a period of uplift in the Silurian.

During Devonian time, the Utah-Wyoming shelf developed west of the area. The area to the east was epeirogenically uplifted and subjected to erosion as the Trans-Continental Arch. The Gas Hills was in the intermediate zone between the shelf of the Nevada-Idaho Basin and the Cambridge Arch. The area received no sediments during this time.

Gentle subsidence occurred in Mississippian time developing the Madison Basin east of the area with local orogenic zones. The Gas Hills was, during this time, part of the Wyoming Shelf that received less than 1000 feet of sediments. There was little change during early Pennsylvanian time. Some 1000 feet of sediments were deposited in late Pennsylvanian time where the area subsided as the Central Colorado Basin surrounded by epeirogenic uplifts, principally the Uncompahgre-San Luis comples. The same areas were emergent during Permian time, but the basin had migrated southward. However, the area was still a deposition site, and less than 1000 feet of sediments were laid down as the Phosphoria formation. During the Triassic similar conditions prevailed in the local areas as had been extant in the Permian period, and again less than 1000 feet of sediments of the Chugwater and Dinwoody formations were deposited.

This area became emergent in the Jurassic and was part of a vast epeirogenic uplift that was subjected to erosion. At the end of the Jurassic period a basin developed as a part of the Shelf area of the Utah Trough and less than 500 feet of shales and sandstones were deposited in Cretaceous time when the area was part of a subsided region adjacent to the parallel syncline developed east of the Cordilleran Geanticline.

A long succession of dynamic events persisted through late Mesozoic and Tertiary time. These vast compressional disturbances and orogenic activities are considered to be the Laramide Revolution. In the region studied, great asymmetric anticlinal ranges were formed. Numerous small intrusive bodies are present in the compressional belts. Large and small thrust faults of low-angle character were developed. These thrust sheets later became folded by compressional movements. The entire orogeny is characterized by a lack of metamorphism. The area studied is part of the shelf zone where the sediments were deposited.

After Mesozoic times the central Wyoming region became depressed and received sediments from the surrounding highlands. The major deformation of the Sweetwater uplift and its flanking folds probably occurred in late Paleocene time. As a result of uplift the Granite Mountains and other structures formed during the Laramide revolution became deeply eroded and prolonged aggradation of the Wind River Basin began.

The early Eocene deposition buried the rugged topography cut from the folded Paleozoic and Mesozoic rocks by deep erosion. Arkosic arenites and rudites accumulated in stream channels and pre-Eocene valleys between hogbacks of the older rocks. As these valleys filled, flood plains developed, depositing variegated argillites and lutites. As the lowlands and basins filled, the deposits which were essentially derived from the Granite Mountains spread marginward across truncated older formations of the Rattlesnake Hills and Dutton Basin anticlines. During Eocene time the Yellowstone-Absaroka volcanic field developed and introduced tuff and pyroclastic debris west of the area, but no volcanic debris is recognized from the Wind River in the Canyon Creek area. But, in late Eocene time, volcanic activity in the Rattlesnake Hills to the east supplied abundant pyroclastic and detrital volcanic debris.

The earlier Wind River formation of arkoses, conglomerates, and silts were followed without significant interruption by the mud and felsic ash of the Middle and Upper Eocene formations. Scattered patches of volcanic conglomerate and poorly sorted arkose, containing volcanic pebbles, occur in these late Eocene beds. Uplift and erosion interrupted aggradation of the region for a short period of time, but not before widespread sheets of arkosic sand and gravel from Precambrian rocks of the Granite Mountains and the erosion of volcanic debris from the Rattlesnake Hills had covered the area.

An episode of deformation and uplift developed an unconformity between the Eocene sediments and the younger Oligocene sediments. This activity may have been a result of, or part of, the volcanic activity in the vicinity of the Rattlesnake Hills which intricately faulted and deformed adjacent areas. When deposition was renewed with Oligocene strata being deposited on the erosional surface of the Eocene sediments, considerable amounts of vitric tuff and detrital volcanic materials were laid down. Renewed uplift to the east and south permitted the development of high stream gradients which were powerful enough to transport coarse volcanic gravel many miles. Mudflows of course volcanic debris suggests that steep gradients were maintained in the source area.

Widespread aggradation was renewed with the White River formation accumulating on the erosional surface. The deposition of mud and local gravel lenses was accompanied by variable thickness of felsic ash and fine-grained volcanic materials. Considerable amounts of vitric tuff were deposited during Oligocene, Miocene, and Pliocene times.

A broad regional uplift accompanied by downfaulting of the Sweetwater uplift produced the superimposed anticline and the reversal of dip to the north and south of the area. This broad regional uplift initiated the present cycle of erosion and introduced adjustments and forces which produced some of the faults in the area which have acted as barriers to ground water and provided sites for uranium precipitation.

The present physiographic and geomorphic character of the area is the result of erosion through the Pleistocene period to recent times. The old anticlines are again exposed and much of the original character of the Wind River Basin is exhibited.

E C O N O M I C   G E O L O G Y

GENERAL STATEMENT

In 1951, a geiger counter survey was made in the Gas Hills by J. D. Love which indicated the presence of many radioactive anomalies. Water samples analyzed by the Oak Ridge Laboratory of the AEC indicated the presence of uranium in abnormal amounts in the ground water of the area. A detailed scintillation counter survey was recommended for the area by the United States Geologyical Survey in 1952 and 1953. This survey began in September, 1953. On September 9, 1954, Mr. Neil McNeice of Riverton, Wyoming, discovered radioactive sandstone in section 22, Township 33 North, Range 90 West. A drilling program under the auspices of the AEC commenced soon afterwards. Other ore bodies on the Aljob mining properties and other grounds were discovered. Extensive prospecting and staking soon resulted in other discoveries, principally in the West Gas Hills.

Uranium was found to occur in the Thermopolis shale of early Cretaceous age, in the Wind River formation and other rocks of Eocene age, and in Oligocene rocks. However, the most abundant occurrences were found to be in the poorly consolidated sandstones and arkoses of the Wind River formation.

The original McNeice find resulted in a large open pit mine now known as the Lucky Mac Mine. Much of their ore was of a lignite type. However, some oxidized and reduced types of ores have been mined also. Occurrences of uranium in asphalt deposits in commerical quantities were also found.

Most of the uranium deposits have been found in arkosic sandstone lenses, clayey beds below leached arkoses, in reduced sands and silts below cemented conglomerates, in water table zones and fault traps, and in carbonaceous lenses. The deposits are varied in character, form, and possible origins, and range up to 500,000 tons in volume. Ore bodies of about 25,000 tons are characteristic of the area. A number of different uranium minerals have been identified in the various ore bodies.

Fifty mines have produced in the area. During 1955, Vitro Chemical Corporation performed most of the activity in the area, but in 1956, with the discovery of the Globe Uranium deposits in the West Gas Hills and the Two States Uranium Corporation ore body in the East Gas Hills, an intensive prospecting and drilling program has been carried out by many operators. Not more than 15 per cent of the favorable ground in the Gas Hills has yet been drilled. Future prospects for discoveries are excellent and the area is beginning to assume major importance as a producer of uranium.

In 1956, Lost Creek Uranium and Lucky Mac received permission to build uranium mills with 400 and 750 tons per day capacity respectively. There are four additional mill applications before the Atomic Energy Commission at this writing. A reserve of 900,000 tons has to be proved to qualify for a 350 ton a day mill. From this information an idea of the total reserves in the area can be imagined. Lucky Mac and Vitro alone represent a reserve in excess of 3,000,000 tons.

New discoveries are being made each week. Some companies report ore bodies at depths of 630 feet ranging from 10 to 110 feet thick and in grade from .07 to 8 per cent. The Gas Hills area of Wyoming will increase in importance as a uranium source area and may be second only to Ambrosia Lake, New Mexico, in national reserves.

CLASSIFICATION OF ORE BODIES

A classification of the ore bodies in the Gas Hills could be based on any, or a combination of, characteristic features such as size, grade, mineralogy, type of host material, age, or origin. Some geologists in the area who approach a classification from the ground water controls classify the near surface deposits that have formed by evaporation or uraniferous ground water as: (1) Surficial, ore which have formed within or below a large disseminated source; (2) Vadose, ores formed at or above the water table; and (3) Hydrodynamic, those ore bodies which occur adjacent to permeable rock units, part of a hydrodynamic system through which ground water circulates and where there is an absence of excess oxygen, and which may be magmaticly fed, and are later leached and laterally disseminated through secretion and accretion. Since less than 15 per cent of the favorable ore area in the Gas Hills has been drilled, only tentative classification is possible.

Another classification puts the ores into two catagories, the oxidized ore bodies and the reduced ore bodies. This has been current for some time, but many problems are involved. Oxidized ores are considered to be those that have a yellow-white, orange-red appearance or any color but blue or black. The reduced ores are those that are blue or black. This use of oxidization and reduction refers to the physical color appearance and not to the chemistry of the deposits because chemically the light colored ores may be reduced, and the dark colored ores may be oxidized. This problem is considered later.

CHARACTER OF THE ORE BODIES

In the East Gas Hills most of the ore bodies so far discovered have fairly uniform characteristics. The main host rocks are fine to coarse grained arkosic sandstones and grits, conglomerates, and carbonaceous lenses. Some ore bodies are 75 per cent conglomerates with boulders nearly one foot in diameter. There is very little sorting of sediments, and they are consistantly angular. There is very little clay and silt in the ores, though lutite zones exist above and below them in many instances. The sedimentary features such as current bedding and normal bedding are quite visible when the ore bodies are opened up and indicate that most, if not all, of the ore bodies are occurring in intercalated interchannel deposits of sand and conglomerate.

In the immediate vicinity of the ore bodies very little, if any, red colored rocks are found, though in certain altered ore bodies the ores are very red. The ores vary in color from white to black, running the entire color range.

The ore bodies have every conceivable shape, varying from nearly circular to elongate, sinuous patterns. In size, the ore bodies range from as little as 30 tons to ore bodies in excess of 500,000 tons. The ores are controlled in size by sedimentary features, which in turn are controlled by the variations in channel flow and deposition.

Deep drilling has not been performed in the East Gas Hills as yet, but from all information available larger ore bodies are found in the lower zones of the Wind River. Ore bodies have been reported by Amarad Oil in the West Gas Hills to be as thick as 110 feet and to contain more than 500,000 tons. The unique feature about these large ore bodies is that the centers of the ore bodies have the high grade as if a slow migration and accretion from the center outwards has been taking place. New data obtained during the last period of this study indicates that there may be greater importance attached to horst blocks than has been in the past, probably because this physical feature has not been identified in many instances and has no surface expression. The thicker ore bodies have been recently found in horsts. This may also indicate important fault controls.

The usual ore body has approximately the following petrograhpic features:

Arkosic Sediments: (Vine, 1955, et al) angular to moderately spherical.

1. Quartz: 30-70 per cent

2. Feldspar: 15-30 per cent
   Potassic-orthoclase, and/or, microcline
   some sub-albite.

3. Rock Fragments:
   A. Granite
   B. Granite gneiss
   C. Schist-common
   D. Volcanic rocks

4. Varietal Minerals:
   A. Micas-common
   B. Chlorite-rare
   C. Biotite-rare

5. Oligoclase, clays, montmorillonite and kaolinite-rare

6. Texture: Coarse grained
   A. Much conglomerate
   B. Size-sorting very poor

7. Accessories: unidentified

8. Cements: rare
   A. SiO_2-rare
   B. CO_3^{2}-locally abundant

9. Color: not characteristic
   Generally gray to blue, often white, yellow, orange, and red

MINERALOGY

The secondary uranium minerals fall into three groups (Katz and Rabinowitch, 1951):

1. Uranates, silicates, carbonates, sulfates

2. Uranium "micas," or the type:
   $$M\ (II)\ (UO_2)_2\ (XO_4)_2 \cdot n\ H_2O$$
   where M is Ca, Cu, Fe, Pb, Mn, or UO_2, and X is P, W. or As.

3. Carbonaceous uranium-bearing substances.

The secondary minerals identified in the Gas Hills are autunite, phosphuranylite, uraninite, liebigite, becquerelite, an unnamed silicate of the phosphates, and zuernnerite. Some geologists report as many as twelve different uranium minerals for the area.

The principle ore mineral in the East Gas Hills is sabugalite, a secondary uranium mineral, identified by J. W. Gruner as a result of a study conducted in the Gas Hills during 1956, as yet unpublished. It has the reported formula:

$$HAl(U_2O)_4 \cdot 16\ H_2O$$

This formula is not balanced and should be considered as follows:

$$H_2Al_2(U_2O)_4 \cdot H_2O$$

This mineral is probably a hydrogen urano-aluminous hydrate. The ore mineral contains variable amounts of moisture up to 12 per cent, often more. The ores are dried for some time before they can be shipped. Sabugalite is the green-gray mineral observed in the 32 foot thick ore body of the Valley Dean Corporation. The mineral weathers yellow and red on exposure.

Another uranium mineral intimately associated with sabugalite is metasippeite, a hydrated uranium sulphate with the following formula:

$$2UO_3 \cdot SO_3 \cdot n\ H_2O$$

. It has been reported as $(UO_2)\ (SO_4)\ (OH)_2 \cdot n\ H_2O$ which is probably the meta- or altered variety.

Where zones of supersaturation are encountered, the characteristic mineral is ilsemannite. Ilsemannite is a secondary mineral formed by the oxidation of molybdenite or other molybdenum minerals. It is always associated intimately with the uranium ores. Associated with iron and aluminum sulfates in the capillary zone above the water table, ilsemannite gives a deep blue and black color to the ores, water, and material in the saturated zone. In this case oxidization yields a dark color that might be mistaken as a reduced ore zone.

The formula for ilsemannite is variable before it is peptized by water and is probably of the character:

$$MoO_3SO_3 \cdot 5H_2O$$

but after peptization it becomes a deep blue hydrous oxide:

$$Mo_3O_8 \cdot n\ H_2O$$

The genesis of some ore bodies is intimately associated with the geochemistry of this mineral. At present the study of this mineral is incomplete.

Peptization assists in the formation of a colloidal solution, especially a sol-gel transformation. When a supersaturated water zone becomes colloidal in nature an increased precipitation of uranium occurs. This colloidalization occurs when turbulant ground waters become impeded, when waters become supersaturated (Trask, 1950), and when H_2S or carbonates are encountered by the waters in their movement through the sediments. In the Rex pit the supersaturated waters encountered a 20 per cent $CaCO_2$ lense which neutralized the acidic solutions and contributed to the peptization of minerals in solution.

Ilsemannite is most important in the Gas Hills as a guide to exploration because of its frequent association with fault traps, supersaturated water zones, and precipitation zones. Wherever it has been found an associated uranium ore body has also been discovered.

GEOCHEMICAL FEATURES

Feldspar is abundant in most of the ore bodies. The fact that in some of them the feldspar is still relatively little altered would indicate that the ores have not been subjected to any great amount of post-depositional alteration. Organic matter west of the Gas Hills exists in amounts up to seven per cent, but in the East Gas Hills the carbonaceous material is less than .2 per cent, often too fine grained to be visible. There is little or no calcite, though there is some primary gypsum. Mica is abundant, but no secondary quartz was observed. Microscopically fine-grained pyrite contributes to the blue and gray color of some of the ores. There is very little vanadium present. Some apatite exists as coatings on sand grains. Microscopically fine-grained uranitnite has not been identified as yet, but some geologists assume that it does occur. In ore bodies associated with faults, gypsum fills most cracks and fissures and forms thin layers of satin spar parallel to structural features. Wherever pyrite has been oxidized and associated with gypsum, jarosite was noted. This oxidation may have been brought about by the action of microorganisms (Bryner, et al, 1954).

The gangue constituents of the blue-black "reduced" ores are the common minerals of sandstone, silts, and shales. In the East Gas Hills the host rocks, or sediments, for uranium ore bodies are arkosic and micaceous regardless of their stratigraphic position. The coarse, angular texture of the sediments illustrate their porous and permeable character. An ore body occurring in a fully cemented and consolidated condition has not as yet been observed. A limited amount of carbonates in some ore bodies might indicate some original clastic calcite. The highest quantitative analysis of carbonates did not exceed 3.4 per cent. Finely divided pyrite, where found, occurs in the darker colored ore bodies and appears to have been authegenic in origin.

The occurrance of uranium-vanadium minerals in the East Gas Hills as yet has not been observed. Some low valence vanadium minerals probably do occur, however, The low percentage of that element in the ores is conspicuous. The content is less than .03 per cent. This small amount of vanadium might be associated with the mica roscoelite as several mica varities seem to be extant in the ores.

Copper occurs in amounts less than .008 per cent and does not contribute to the mineral suite. The copper probably occurs as a dissemmanation in igneous rock fragments. In some other uranium areas copper has played an important role.

The arsenic minerals have been found in close proximity to uranium mineralization. Arsenic occurs in larger relative proportions in a halo around large ore bodies, sometimes as much as 300 feet from the main ore limits. Drilling conducted in the area seeks to find these halos in the course of subsurface exploration and to drill in the direction of an arsenic increase. Lithium, yttrium, and phosphorous are also useful in the same manner. An ordinary spectographic assay which indicates these minerals in combination or alone provides assistance for directing drilling.

Urano-orane minerals have not been discovered in the East Gas Hills though they do occur in the West Gas Hills where complex pyrobitumens have been identified; thucholite is typical.

The essential uranium mineral occurring in the ore bodies of this area is subugalite. Whereas it is blue to black in appearance in hand samples, under the microscope it is dark green. After exposure to the air, it oxidizes to a deep green and then further alters to an opaque yellow color.

Carbonation

Carbonation plays an important part in the alteration of some ores. Carbon dioxide, derived from the air or subsurface chemical activity, enters chemical combination with water to form carbonic acid. If there are available alkalies H_2CO_3 will react to form "bound" ($-CO_3$) and "half-bound" ($-HCO_3$) carbonates. These radicals would have kept the hydrogen ion concentration of any solution near the neutral point. Carbonates have not developed except in local zones not considered important. In some of the oxidized zones the highest grades of ore have been found. That may be due to the depletion of oxygen during oxidation and an increase in CO_2 concentration which, if there is more interstitial solution movement, will precipitate uranium. This precipitation of uranium by CO_2 in oxidized zones could account for local zones of high grade ores which are extremely out of equilibrium and gamma deficient. Disequilibrium suggests in most instances recent deposition, weathering, and migration of the dissolved ions. However, disequilibrium does not presuppose any great distance of transport. Only that distance necessary to remove the dissolved ions of uranium from their daughter elements is required. This may be as little as twelve inches.

Microorganism Activity

Soluable copper and iron in the ground waters of the area are the products of biological oxidation of sulfide minerals. Practically all leaching by sulphuric acids would be controlled by microorganisms (Bryner, 1954).

Uranium Content of Rock Forming Minerals

The following minerals associated in the Eocene sediments have been found to contain uranium (Von Houten, et al, 1956):

Derived from Tertiary Volcanic rock:	Uranium PPM
Augite	T
Clinopyroxene	T
Hypersthene	3.2
Oxyhornblende	10.
Dark brown hornblende	10.
Dark green-brown hornblende	10.
Dark green hornblende	10.
Amber biotite	5.1
Brown biotite	5.1
Greenish-brown biotite	5.1
Apatite	47.
Sphene	T
Magnetite	3.

Derived from Precambrian igneous and metamorphic rocks:	Uranium PPM
Muscovite	8.
Grayish-brown biotite	5.1
Blue-green hornblende	10.
Amphibole	43.
Epidote	T
Garnet	5.8
Tourmaline	T

These minerals could yield up their uranium content under chemical weathering to ground waters. In addition they could supply considerable amounts of indigenous uranium to the sediments in which they were originally deposited. In the region east of the mining area the ground waters could have dissolved much of the indigenous mineral suite in the sediments. But the essential fact is that the minerals listed above constitute the Eocene sediments, and in the younger sediments which are supposed to have supplied the dissolved uranium there is a marked absence of most of these minerals.

If the uranium was derived from a source area through the decomposition of minerals containing minute amounts of uranium and transported by ground water, the younger sediments above the Eocene Wind River cannot be considered to have been the source. If the uranium was so derived, at all, the source must be the actual host sediments themselves, and not the lean and sterile overlying sediment derived from other sources than those which contributed detritus to the lower Eocene sediments.

It appears reasonable that the ground water in the area has carried minute amounts of uranium dissolved from sediments containing uranium bearing minerals and that the uranium has been precipitated in favorable structural and stratigraphic features.

Importance of Trace Elements

The concentration of differentiations, particularly the hydrogen ion, plays an important role in the area. The main mineral identified in the East Gas Hills is sabugalite, a hydrogen alumina of uranium. The presence of changing amounts of certain elements affects the solubility relations of uranium (Brown, 1958). Of these, thorium, cesium, niobium, ytrrium, lithium, lanthanum, arsenic, and molybdenum ions appear to play a role. More important for exploration, an above normal occurrence of these elements has always been found to exist in a halo in the vicinity of the ore bodies, sometimes as much as 300 feet from the limits of commercial grade ores. These elements appear to accompany uranium through various stages of its mobile history from the very late stages of rock crystallization, through any subsequent hydrothermal or metamorphic episode, and then during the eventual weathering of the rocks which finally supplied the sediments for the area.

Provided the conservation of charge is met, ions of uranium will interchange in crystals and compounds of other ions whose radii differ by not more than 15 per cent (Katz Rabinowitch, 1951). The U (IV) ion has a radius of 1.05 (Rankama, 1955). This can be compared with the radii of the following elements of common occurrance in the East Gas Hills uranium minerals:

	Å
Th (IV)	1.10
Er (III)	1.02
Yb (III)	1.00
U (III)	1.06
Ca (III)	1.06
U (IV)	1.05

All minerals containing appreciable amounts of rare earth elements or the above trace elements are likely to contain uranium. An unusual concentration of any of these above may indicate the presence of an uranium ore body in the vicinity.

Effect of Structure

Early in the study of the Gas Hills it was discovered that the uranium occurrances were associated with channels. Subsequent studies in the East Gas Hills have similarly shown that nearly all ore bodies are associated with channels. These paleo channels are now being subjected to geophysical and other means of study, including the new thermal study. The channels assume great proportions. The channel which appears to control the East Gas Hills area is approximately two miles wide and of unknown extent. It has been traced for four miles. Explorations and drilling conducted in the channel area reveal that the uranium concentrations occur in the sites and channel areas where a heavy mineral concentration would be expected. The meander scours, downstream from meander scours, slip-off slopes of meanders, natural levies formed in the stream banks, filled-in oxbows, conglomerate zones, carbon trash zones, scour pools in the channels, and shallow areas are where precipitation has developed.

The channel course was consequent to the shape and determined by the degree and nature of the dissection of the old formations which formed the hogsbacks in the area and were buried by the sediments. The channel in the East Gas Hills has an east-west trend. Important ore occurrences have been made where the channels have meandered around the old hogsbacks, and where faults have intersected the channel. Wherever faults have cut surface features, the displacements are so small that even when fully exposed in open pits they are hard to distinguish. The clayey gouge developed on the faults usually creates an impermeable barrier for water and creates the desired environment which favors the development of an ore body. The Bengal Fault, however, has a displacement of some 20 feet and brings beds of varying composition against each other, forming an impermeable barrier. However, the ore body has been displaced. In this case, ore had been deposited prior to faulting under a sedimentary control and then the north side of the fault became the loci for enrichment.

Only about eight per cent of the channel area in the East Gas Hills has been explored. Other features not now known may be found to control the ores as more geological tools are being employed in searching out the controls and occurrances of ore bodies. Whatever may be found will probably demonstrate more specifically the intimate relationships between the sediment chemistry and the composition of sediments, the channeled nature of the sediments, and the importance of structural features where they occur in the channel.

It was observed that where faults occur in the channels they act as barriers to ground water movements. The impediment of water movement, and the tendency for the water to evaporate up along the fault changes the concentration of dissolved ions and thus the equilibrium relationships. Wherever supersaturated ground waters meet these conditions, mineralization may develop. The chief mineral resulting from this type of concentration is the carbonate ilsemannite, which imports a black and blue color to the water and the ores.

Observers in the area are just beginning to learn the significance of ground water in the distribution and localization of uranium in the Gas Hills. The distribution of water in the ground affects the oxidation-reduction potential. Materials above the water become more oxidized than corresponding materials lying below. With changes of the water level, significant chemical reactions take place. In the Tee Basin of the East Gas Hills, the ground water level has dropped four feet in the past years with the development of a disequilibrium layer of uranium in the former pore space the water once occupied. Slow movement of water through pore space favors the development of a relatively high degree of saturation of dissolved substances. By drilling, the sediments of the East Gas Hills have been found to have smaller pore space and finer detritus than those found east of the producing areas. Waters originating in the regions east of the mining area appear to flow more quickly through larger mineral grains and detritus, but are impeded and appreciably slowed down upon reaching the East Gas Hills, and in many places are trapped by faults. A convergence of ground waters and a slowed rate of movement appears to contribute to the abundance and ease of precipitation of uranium when the chemical environment is conductive to precipitation.

If the movement of the waters are slow, the water becomes saturated to the extent no further material can be dissolved. It may be concluded, then, that any materials introduced into the East Gas Hills may have been dissolved at a distance, or in some way introduced to the ground waters that are moving into the known production area (Gruner, 1956).

In the course of geologic history, some of the earlier precipitated ore bodies have been redissolved and redistributed. It may also be that in the adjoining regions supplying the ground waters, hydrothermal and pneumatolitic contributions are being and have been made.

Oxidation and Reduction

Oxidation depends on access of air, or oxygen, to the ore. Oxidation generally is a condition that occurs above the water table. Reduction is a condition that occurs below a saturated zone, or in a zone where surface and near surface oxygen is not available. However, oxidation and reduction must always occur together. In the surficial ore bodies, evaporation is high and where continuous permeable zones exist above water tables, oxidation can readily take place. Oxidation is retarded by water when the water is held in the pore spaces, unless microorganisms are specifically active. Uranium often precipitates in high concentration in a reducing environment. The RanRex Mining Company's Rex Pit is an excellent example of this. In the Rex Pit carbonaceous zones developed abiotic substances which contributed to uranium precipitation. After a given time determined by chemical saturation, the abiotic influence became insignificant, and the uranium concentration increased only as long as the organic material acted as a filter.

Reduced ores may have become oxidized and thus formed into the yellow-white ore bodies. Some of the oxidized ore bodies are residual deposits having been leached and flushed by ground waters. Others may have been derived from an older deposit and were redeposited in their oxidized state. No oxidized ore body has been observed that was in radioactive equilibrium as yet. It takes 1,000,000 years for any given quantity of uranium to develop radioactive equilibrium. This would mean that all of the oxidized ore bodies are younger than the Pliestocene. Their degree of equilibrium will be proportional to their age. A relative geochronology might be developed through a complete understanding of the equilibrium data. The equilibrium characteristic of the ore bodies indicate whether or not they are residual ore bodies or newly migrated ore bodies. Essentially, if the ore body assays chemically higher than the radiometric, the ore body is residual. Both ore bodies could be oxidized. In the first case insufficient time has elapsed to permit the development of the daughter elements created during the disintegration of uranium into lead. In the second case the developed daughter elements, usually insoluable, remain behind after the more easily dissolved uranium ions have been removed. Intercalated zones of sediments that have an indigenous uranium content of less than .03 per cent are usually in full equilibrium. This fact suggests that low grade zones have not been seriously altered and that vertical and lateral leaching of the sediments is not the source of uranium.

While it is known that solutions of a PH_4, or lower, moving through sediments will oxidize the ores and transport dissolved uranyl ions, the evidence observed in some ore bodies does not support this idea of transportation (Bain, 1952). There is no evidence of large amounts of solution movement as yet. The physical aspects of the ore body must exercise an influence not yet observed. The abruptness of the change in large ore bodies between what has been called reduced and oxidized zones suggests that the chemical nature of the ore bodies bear a great deal on the idea of oxidation. The role played by microorganisms may be very important in this respect (Bryner, et al, 1954).

In the radioactive disintegration of uranium to lead many gross chemical phenomena occur. One of these is illustrated by the equation:

$$UO_2 \ \text{---} PbO + O + \ (6He) \ + \text{heat}$$

In the process above, oxygen is liberated within the mineral and frequently made accessible to the surrounding minerals. The amount of oxygen liberated by radioactive disintegration and bound in the mineral has been found experimentally to correspond very closely to the amount of PbO (RaG Oxide) formed. The general matamict character of uranium minerals contributes to this idea also (Katz and Rabinowitch, 1951). It may be that black and iron gray ores are only altered, or oxidized, by this process. Portions of an ore body buried deep in sediments, inaccessible by surface oxygen or circulating ground waters may become oxidized in this manner. It is only when this type of alteration and oxidation continues that the minerals receive their characteristic coatings of scarlet, orange, yellow, green, gray, and brown decomposition products. It may be that many of the uranium minerals identified currently as oxidization are not so. Oxidization may take place anywhere in any environment due to the liberation of oxygen through disintegration processes. It may be that the so called "primary" minerals are all secondary, and the only primary uranium ore would be uranium dioxide (Goldschmidt and Thomassen, 1923). Immediately upon the formation of uranium dioxide, disintegration would oxidize the mineral into a composition between UO_2 and $UO_2 67(U_3O_8)$ with the tetravalent uranium usually predominant (Katz and Rabinawitch, 1951).

Reduced ores may merely be oxidized ores in a different degree of phase of transition from UO_2 to the end product usually called secondary minerals. This would mean a revaluation of the process of oxidization and would require quite a different treatment of ores in the East Gas Hills than describing them as oxidized or unoxidized ores.

The writer observed ores of a so-called oxidized type existing in the midst of reduced ores. The liberation of oxygen as above described could account for this. The low grade ores would liberate less oxygen and therefore be less oxidized. High grade ores would liberate more oxygen and be, therefore, more oxidized. Decomposition colors would depend on the indigenous content of water contained in the sediments which is a diagenetic problem and compactional problem. The zone of oxidization in the Gas Hills accessible to surface oxygen has been determined by the AEC as 30 feet. The writer, during his study of the area, would prefer 70 feet as the limit, but when white and yellow ores are encountered, to depths of 200 feet or more, intimately associated with darker ones in a reduced environment, some other explanation appears necessary; the simplest is that the ores supply their own source of oxygen, or the highly speculative possibility of a flucuating water table which does not appear probable since reduction is nearly complete in the non-uraniferous sediments.

RADIOACTIVITY

The role that radioactivity plays in the ore bodies should receive considerable attention. In the Gas Hills nearly every ore body has some degree of disequilibrium.

When uranium ore is in equilibrium, a certain fixed proportion of each of its daughter elements, of which there are 14, is present, whether the ore contains .01 per cent uranium or five per cent uranium. At equilibrium, each daughter element that is a gamma ray emitter, of which there are five, is present in its normal amount and the radioactivity measured by a detector or counter is dependent on the amount of uranium present. A counter is capable of only providing an indication of the amount of equilibrium in the material and not its actual uranium content.

If uranium in a purified state is separated from its radioactive daughter elements, it immediately starts to decay and to produce its daughter elements. As these progressively decay, all the elements normally in the series gradually accumulate. But it take one million years for the uranium ion to reach equilibrium with its daughter products. Each element is then present and in such amounts that it decays at the same rate as it is produced. Thereafter, no further change takes place in the proportion of any daughter element of the radiation series. This is equilibrium.

Lack of equilibrium results from the separation of uranium from its daughter elements within the last one million years. Because the ores in the East Gas Hills vary in equilibrium, the ores are much younger than the host sediments which are of Eocene age. Some ore bodies in full equilibrium may yet be found, however.

Lack of equilibrium can be brought about in several ways, but probably most particularly by the attack upon uranium minerals by solutions such as ground water. Many secondary uranium minerals such as autunite, are deposited by ground water. Most such deposits are out of equilibrium. The minerals were deposited less than one million years ago. The gamma emitting daughter elements have not yet accumulated in their equilibrium amounts and more uranium may be present, or less may be present, than is suggested by counter readings. Probing drill holes may yield information which can lead to costly and bitter results. Operators in the area have opened up large pits to mine lenses of high radiation only to find that the lenses carry very little uranium. In actual mining, lenses of very low count have yielded ores of very high grade. Radiation becomes a key to the amount and degree of transportation of uranium ion. The same radiation or lack of it is also a key to the age of the deposits. Radiation in the East Gas Hills is a very necessary tool and knowledge of it may determine field results.

Ore bodies much older than one million years have been dissolved by ground waters. Left behind in the ore site are the insoluable daughter elements. They continue to emitt gamma rays and will for many years. When these lenses are found, the possibilities of an ore body are good if the new place of precipitation and deposition of the uranium is close by. But the new ore body will be low in radiation. Chemical assays are always necessary and are the only criteria for identification of an ore body or a sterile zone.

The use of trace elements again assumes importance. An ordinary spectographic assay which shows the trace element suite indicates that quantitative assaying for uranium should be made. The use of the mass spectographic assay has been found to be of major importance in exploration in the East Gas Hills.

GENESIS OF ORES

The genesis of uranium ore bodies in the Gas Hills is not clearly demonstrated. The ore is epigenetic in origin in some cases. In such situations the uranium would have to be slowly deposited from dilute, moderate to low temperature aqueous solutions that pass through pore and fracture spaces in the strata and deposit uranium in or near paths of ground water flow. Deposition probably results from chemical reactions or delicate changes in the physical and chemical environments. The source of the original uranium, however, is not clearly demonstrated or known. More research in the area will be required to arrive at a proper conclusion. Various aspects of the problem will be reviewed here because, no doubt, the ultimate conclusions on origins may be found to be a composite of explanations involving a cycle with a magmatic parent distantly related. Emanations, volcanic leaching, lateral secretion, penecontemporaneous deposition, and other contributing factors may all play a role in the emplacement and deployment of the uranium throughout the Eocene sediments of the Gas Hills region.

Elements present in a liquid parent magma, but not required in the crystal structure of the common igneous rock-forming minerals, tend to concentrate in the residual magmatic fluids, and as cooling and crystallization of the magma progresses become more concentrated. These fluids are expelled under various conditions and react with the surrounding cooler rocks. Close spatial relations between the deposits and igneous intrusions, coincidence of the time of intrusion and formation of the deposits; or hypogene zoning of the deposits away from an igneous center, can be used as evidence of a genetic relation. All uranium, as is the case for most minerals, probably has its ultimate origin in the parent magma. In waters issuing from volcanic beds, uranium, phosphorous, arsenic, selenium, molybdenum, lead, copper, nickel, cobalt, zinc, and vanadium are constantly and continuously being dissolved and carried into solution. Thus it might not be too much to presume that a large proportion of the uranium and its associated elements are not found locked in crystal structures of discrete minerals but are free and available to leaching by ground water.

Quantitatively there is enough indigenous uranium in any large volume of magmatically derived rocks to supply, through a process of leaching and concentration, the known ore bodies of uranium. During the late erosion cycles in the Wind River basin this would have been the case and made available to ground water uranium in vast quantities. It is the thinking of many observers in the Gas Hills that the uranium has been derived from overlying sediments rich in soluable amounts of indigenous uranium. If the sediments younger than the Eocene formation containing such uranium were subjected to leaching as suggested, the UO_2 originally deposited would have to be altered to UO_3 and perhaps partially into uranosic oxide. The sediments were supposed to contribute an acidic condition to leaching solutions which would dissolve the U-ion. To do so one third of the oxygen would be replaced by an acid radical. The removal of the uranium then would leave a residual condition where the sediments would be alpha deficient, gamma abundant, and exhibit the results of oxidized altered material. Sediments observed in the area do not show the features. The sediments are alpha abundant, only slightly gamma deficient, which is opposite of what they should be. The removal os uranium ions from the sediments that have been deposited for upwards of 10 to 50 million years would demand that daughter products of an insoluable nature would remain behind as resistates and give the sediments a high gamma ratio to chemical assays. Since this is not the case, the indigenous uranium content in the sediments is still normal and as originally deposited and laid down with only slight changes found locally but with accompanying chemical features to explain them. In the East Gas Hills another source of uranium than that of overlying sediments is required.

To return to the nature of the ore bodies themselves, some criteria might give a clue in that direction. The ore bodies show a deficiency of gamma radiation which indicates the ores have not been in place for more than one million years. The relative age of the ore bodies can often be determined by the degree of alpha radiation, the absence of beta radiation, and the amount of gamma radiation. The greater the alpha radiation, the younger is the deposit. The greater the gamma radiation, the older is the deposit. If the ore body is in equilibrium, the ore body is older than one million years. As yet the writer has not encountered an ore body in the East Gas Hills that was in equilibrium. This would tend to the conclusion that the ores are Pleistocene or younger in age.

However, a number of highly oxidized and leached zones have been encountered where the radiation was gamma abundant and the material yielded a chemical assay for uranium of .021 per cent U_3O_8, but the radiometric assay was .34 per cent eU. The ore body is of an older origin and has been leached of its uranium content. The relative age can be arrived at by determining the amounts of the first seven of the thirteen of the uranium disintegration products. If they are present the deposit was of Pliocene age, if they are absent the deposit is much older, Oligocene of Eocene in age. Abundant beta radiation, or the presence of beta emitters, would indicate similar data.

An investigation of the radiation characteristics of the ore bodies leads one to conclude that ore bodies have been in the making since the sediments were first deposited. A multiple migration accretion action may have taken place. The present ore bodies may only reflect the redistribution of uranium that had previously been present, or that is being continuously introduced from an extraneous source into the area.

Probably the most likely of geologic features which would exist throughout the Tertiary history of the basin would be the ground water. Ground water levels would tend to shift as the area was subjected to various agencies in the course of its history. All of the ore bodies are associated with zones which at one time or another may have been zones of water movement. The water table and the waters in the sediments thus have probably played a most important role in the distribution and concentration of uranium in the East Gas Hills.

Some uranium would have been introduced into the sediments when they were first deposited. Stream channels, playa lakes, small oxbow areas, and other features formed favorable loci for materials and solutions to unload elements and minerals that would, at a later date, contribute to some ore body. Drainage would always be from higher ground toward these areas. The areas may have been barren of uranium or may have contained uranium from earlier deposition activities undergoing oxidation, precipitation, and erosion. There would be a gradual accumulation where organic matter occurred in abundance or other chemical environments developed through the alteration of the sediments.

As the Wind River Basin was a poorly drained area, accumulations of uranium could have increased considerably over the millions of years provided. The extraction of the uranium, probably in the form of $Ca_2UO_2(CO_3)_3$ from weathering granitic material in the sweetwater uplift and the Granite Mountains, and from tuffaceous terraine, including the detrital material derived from the granites, would have been the earliest contributors to ore bodies. The fact that the lower parts of the Wind River are barren, and that the contact zone of the Wind River with the underlying irregular topography yield no ore bodies establishes the fact that the paleogeographic source during the first stages of erosion contributed only Paleozoic and Mesozoic rocks, and it was not until later on, during subsequent periods, that the granitic and volcanic materials became available through exposure and erosion. If leaching was the main method of uranium distribution and concentration, there would be no better loci for accumulations than on the old irregular contact area between the Tertiary unconsolidated sediments and the consolidated older rocks. But ore bodies are not found there. They occur essentially in sedimentary lenses marked by the abundance of arkosic materials which have favorable chemical characteristics.

Where the arkosic sediments were rich in vanadates, phosphates, or organic material, waters coming into them would yield their soluable uranium ions. These first accumulations were probably low in tenor but increased as precipitation continued, and would account for the variations in radiations in a single ore body. The various small accumulations may have been reworked, eroded, redissolved, oxidized, carried to new loci of precipitation, but each progressing stage would give rise to greater accumulations, and the undisturbed ore bodies would become larger and richer, but with a variable change in radiation characteristics in the direction of enrichment.

One difficulty is the fact that the ore bodies have less permeability than surrounding sediments. The permeable zones, when enriched, do not have impervious bottoms, and often do not have impervious roofs. The ores of certain localities are not filled with coarse and heterogeneous materials, but are remarkably uniform. These are physical features that reflect the importance of sedimentary characteristics as factors in uranium concentration and precipitation.

Considerable quantities of uranium appear to have been leached from the arkosic and granitic beds and tuffs that comprise the Eocene sediments of the area, and then reprecipitated within the host formation. The ore deposits are relatively recent in many instances, and structurally less involved, and the paths which the solutions took would be less complicated than might be the case in such areas as the Colorado Plateau. Drilling in the area has revealed that the lower sediments are supersaturated with ground waters and dissolved minerals. When the subsurface waters are undersaturated they can dissolve material; but if oversaturated they precipitate material (Trask, 1950). The principle factors are ionic concentrations, temperature, oxidation-reduction potential, amount of water, and rate at which conditions change. In the unconsolidated sediments pressure may be a factor, but as yet has not been demonstrated. The annual variations in moisture and temperature from one year to another may strongly influence chemical reactions because of their effects upon equilibrium conditions and the degree of saturation of dissolved substances.

Nearly all of the uranium occurrences in the East Gas Hills are associated with coarse grained granitic detritus, including many giant conglomerate beds. Only a few occurrances of uranium are in the highly complicated Mesozoic and Paleozoic structures and then only as shallow veneer where the element which descended ari passu when the erosion of the Tertiary rocks was arrested in its downward travel because it abruptly found itself in an unsuitable environment.

The essential sedimentary characteristic of the ore bodies is that the host material is arkosic sands associated with channels which appear to have been rather quickly buried after original deposition.

Erosion, ground water activity, leaching, and other factors and agencies have all operated most abundantly during the Pliocene and Pleistocene time, but the point of loci and the size of the ore bodies appear to be related to original deposition features which have controlled ground waters, and not to the areas of more or less erosion of the overlying sediments. The sedimentary features are the original controls, the ground waters which have persisted throughout the Tertiary history, the main agents, the physical and structural features introduced during geologic activities, and the intersedimentary changes in chemistry have all contributed to the present size and distribution of the uranium ore bodies in the East Gas Hills.

ORE DEPOSITS

MINING

Underground mining methods have been found to be impractical in the Gas Hills area because the sediments of Eocene age are unconsolidated; whereas, open pit operations have been found to be practical and very economical. Pits have been excavated to depths up to 160 feet, and deeper pits are in the planning state of various companies.

Nearly all mining in the area is done by contractors. Bids received from various contractors in the Wyoming area to remove overburden are on a cubic-yard cost basis. The bids range from $.25 to $.35 per cubic yard. The ores are then mined by renting equipment on an hourly basis. A uniform ore body can be mined for as little as $.15 per ton. As much as $1.00 per ton has been paid for mining difficult ores which need rigid chemical control.

Drilling costs vary depending on the type of approach made by the field geologist and engineers. Some companies amortize drilling costs for as much as $1.10 per ton. Others using different techniques have only a $.12 to $.30 per ton cost. Methods have been developed in assaying and mining which reduce the cost of assaying per ton to as little as $.01. Larger companies spend as much as $.30 per ton.

The $.06 per ton mile shipping allowance paid by the government covers all shipping costs. Thus, depending on the depth of the ores, various mining operators can expect as much as 85 per cent of the gross as their net profit. Seldom has any mine in the area that has been managed properly concluded an operation for less than 50 per cent of the gross value of the ore as their profit. Deeper ores now being discovered will probably yield less profit. Profit is proportionate to the thickness of the ore body at any given depth.

RANREX MINING CO.

The RanRex Mining Company operates an open pit known as the Rex Pit in sections 14, 15, 22, and 23 of Township 33 North, Range 89 West, in the Gas Hills. The Rex Pit is accessible by dirt roads from all important areas in the East Gas Hills and is 37 miles from the buying station at Split Rock, Wyoming.

The properties of RanRex Mining Co. consist of four claims, staked in an east-west direction and are contiguous north and south along their side lines. They are unpatented lode claims. The claims were acquired from the Brush-Smith group of Lander, Wyoming, in December, 1955. The writer was in charge of the initial drilling program. Exploratory drilling was concerned strictly with the water table which was known to be at a depth of 44 feet or less and to be saturated with the molybdenum carbonate ilsemmanite. The fourth hole drilled encountered ore at a depth of ten feet. Blocking out drilling was conducted on approximately 40 foot centers. The ores recovered from drilling indicated an ore body eight feet above the water table and extending an unknown depth into the water table. The uranium assayed an average of .19 per cent U_3O_8.

The ore was found in the lower Eocene strata, the Wind River formation, and in the upper zone of that formation, and was found to be controlled by a fault that had intersected a water table, or perched ground water zone. The ground waters had been trapped by converging faults, became supersaturated and precipitated their mineral content. Three faults were found to occur which influenced the areas of higher concentration.

These faults all have an east-west trend. The northernmost of these three faults has an undetermined displacement. The intermediate fault has been displaced nearly a foot, and the south fault nearly 18 inches. Essentially the ore body is contained in a horst.

The ore body is 180 feet long and 110 feet wide on the east end but only 40 feet wide on the west end where the north and south faults converge. At the present time the ore body has been proven to a depth of 60 feet on the east end where a knob rises above the area, to 22 feet on the west end where the knob slopes away to level ground. The average thickness of the ore body is 14 feet. The center of the ore body is lean material below commercial grade. The high grade ores exist associated with the fault trends and where the ground water flow was interferred with.

The chief ore mineral is sabugalite. The chief gangue mineral is the molybdenum carbonate ilsemmanite. The ore occurs in channel arkosics and fine-grained sand with lenses of intercalated conglomerate. A few pieces of petrified wood occur, but the silica had replaced the wood before the ground waters had become saturated with uranium minerals.

The ore body was originally sampled by assaying each two foot material recovered during rotary drilling. Assays from this sampling gave returns from .14 5o .19 per cent U_3O_8. When the ore was mined, each eight ton pile was grab sampled and some of the material assayed as high as 4.5 per cent. The ores are mixed so the average grade that is shipped is about .17 per cent.

The ore body was considered to have 10,000 tons of ore reserves. Due to the water problem, tonnages below the water table have not been calculated. An inferred tonnage has not been arrived at. Ore reserves are not always calculated on the basis of measured material but on the basis of pounds of U_3O_8 at an average of 3.5 pounds per ton. In other words, this ore body is considered to have 35,000 pounds of U_3O_8.

The ore is mined by drag line at the rate of 1,000 tons of material per day. Then it is stockpiled for assaying and drying. Shipments are made on the basis of an AEC quota which, for the Rex Pit, is 300 tons per month. A few days of mining usually provided adequate tonnages for months ahead.

The cost of mining units of 3.5 pounds of U_3O_8 is only approximated until the last unit has been sold. The operating costs are, however, considered to be $3.50 per unit, or $1.00 per pound of U_3O_8. Operations of the RanRex variety at shallow depth usually net approximately 60 per cent of the gross value of the ore body.

Three additional ore bodies have been discovered on the RanRex Mining Co. claims. The total reserves are considered in excess of 35,000 tons of material with an average U_3O_8 content of 3.5 pounds. The company has on the planning board the opening up of one of these which will require the removal of 130,000 cubic yards of overburden to a depth of 80 feet to recover ores which, when the operation is complete, will have net the company 71 per cent of the gross value.

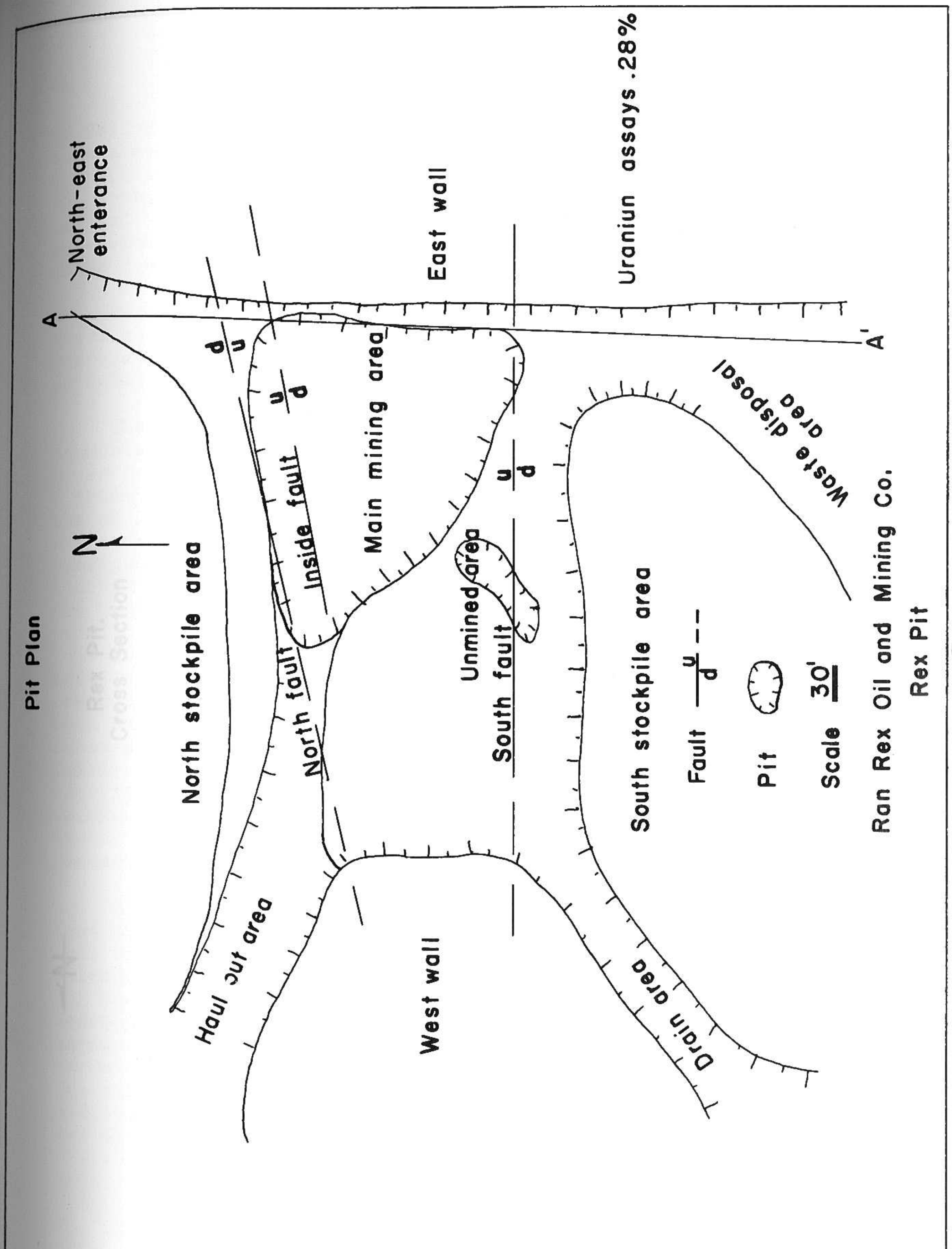

Pit Plan
N
North stockpile area
Haul ɔut area
West wall
North fault
Inside fault
Main mining area
Unmined area
South fault
South stockpile area
Drain area
Waste disposal area
East wall
North-east enterance
Uraniun assays .28%
A
A'
u
d
Fault
Pit
Scale 30'
Ran Rex Oil and Mining Co.
Rex Pit

Figure 2

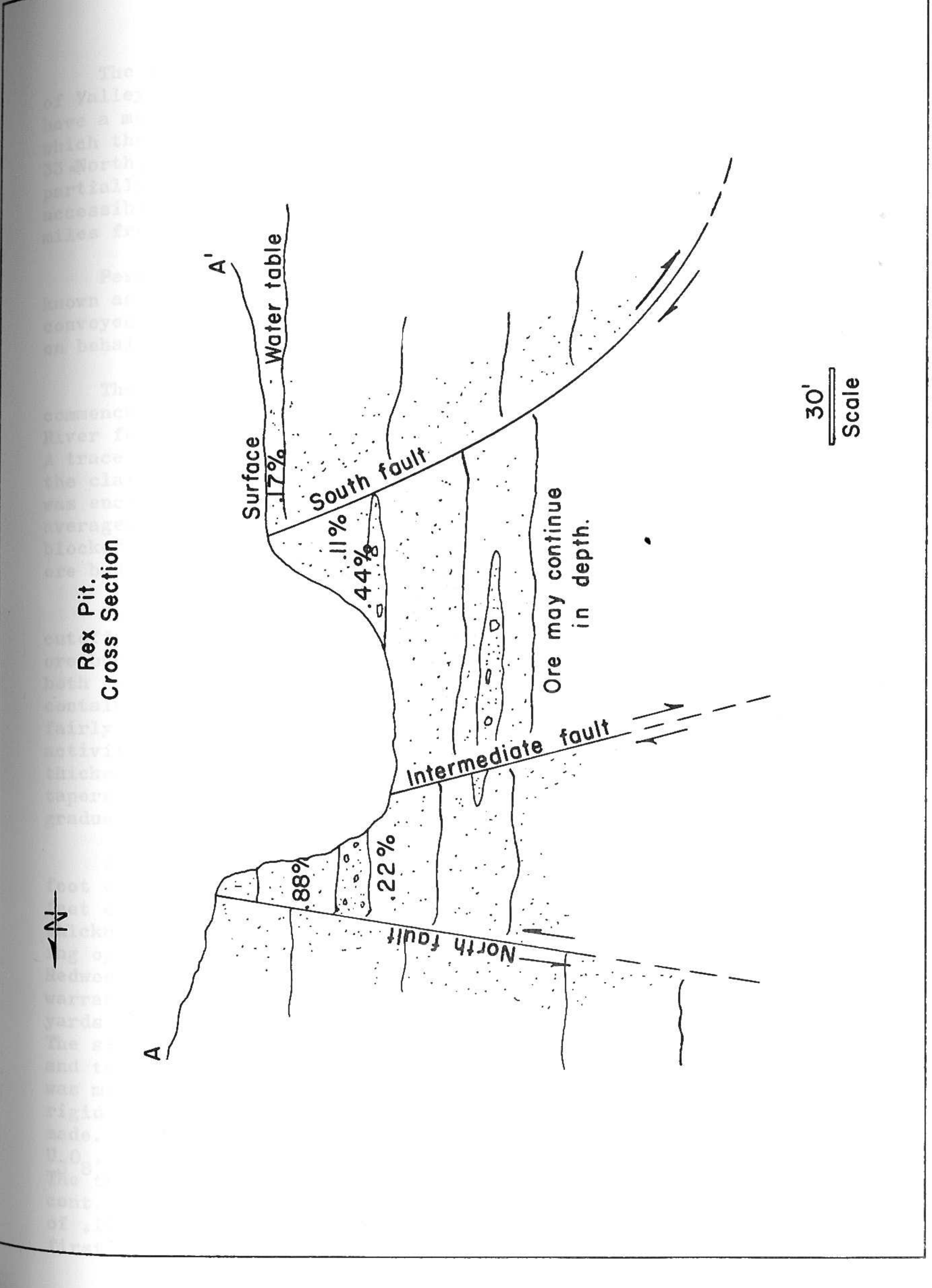

Rex Pit.
Cross Section
N
A
A'
Surface
Water table
.17%
South fault
.11%
.44%
.88%
.22%
Ore may continue
in depth.
Intermediate fault
North fault
30'
Scale

Figure 3

TWO STATES URANIUM CO.

The Two States Uranium Company operates an open pit on behalf of Valley Dean Corporation and Hughes Mining Co., and in which they have a major interest, known as the Redwood Pit. The claim upon which the ore was found is located in sections 27 and 28 of Township 33 North, Range 89 West, in the East Gas Hills. The claim lies partially in Natrona and Fremont Counties. The Redwood Pit is accessible by dirt roads from all parts of the Gas Hills and is 35 miles from the buying station at Split Rock, Wyoming.

Personnel of Two States Uranium Company obtained the claim known as Bountiful No. 1 from Hughes Mining Co. The claim was then conveyed to Valley Dean Corporation. Two States operates the mine on behalf of the various interest holders.

The writer was in charge of the exploratory program which commenced in August, 1955. Drilling was restricted to the Wind River formation and to a zone 200 feet thick above the water table. A trace element suite was obtained in a hole near the center of the claim. An offset hole was drilled 250 feet away. The ore body was encountered. Thirty-two feet was drilled through which averaged .32 per cent U_3O_8. A fifty foot grid drilling program blocked out a reserve in excess of 200,000 tons in the contiguous ore body.

The ore occurred in what appears to be a sand and silt filled cutoff ox bow of a large channel. No faults were observed. The ore body is not connected to a ground water control. The ores were both oxidized and reduced, white and blue in color, and were contained in a reduced sedimentary environment. The ore was fairly uniform sand and silts, unconsolidated, and of low radioactivity. The top of the ore occurred at a depth of 102 feet. The thickest portion of the ore body exceeds 50 feet. The ore body tapers in all directions to a fine edge. Protores thin out more gradually away from the ore body and terminate irregularly.

A rule of thumb for ore recovery demands that at least one foot of ore of at least .17 per cent or better exists for each ten feet of depth. For 100 feet of depth, an ore body of ten foot thickness could be profitably recovered in the Gas Hills by stripping operations. Since more than 30 feet of ore existed in the Redwood Ore Body, the value of the ore body was considerable and warranted a stripping operation. To remove the ore, 425,000 cubic yards of overburden were removed to expose 30,000 tons of ore. The stripping was performed during winter and in adverse circumstance and took five months. The ore was removed with heavy equipment and was mined in 15 days. Chemical controls on the ores permitted rigid assay control for stockpiling so three stockpiles could be made. One stockpile received all ores assaying .05 to .10 per cent U_3O_8. Another received all ores from .10 to .17 per cent U_3O_8. The third stockpile received all ores assaying in excess of .17 per cent. Shipments then were so mixed as to provide a constant assay of .17 per cent average. Every ton of material mined from the first opening was shipped.

The first opening of the pit required a larger ration of overburden to be removed to ores mined. This ration was 15:1. The ore body is now programmed to remove each additioanl 30,000 ton block on a ration of 1 ton to 5 cubic yards of overburden.

A small kidney of ore was discovered during excavations which yielded approximately 100 tons of ore. This small body was entirely out of equilibrium. The uranium had been leached from it leaving behind the radioactive daughter elements. Radiation exceeded the uranium content. Ten feet above the ore body a meander channel of ore in nearly full equilibrium was also discovered which yielded several hundred tons of ore. Another deposit of several hundred tons of boulder filled ore with carbonaceous trash occurred 30 feet above the main ore body. This ore body exhibited various degrees of equilibrium. The ores assayed from .09 to .32 per cent.

Redwood Ore Reserves

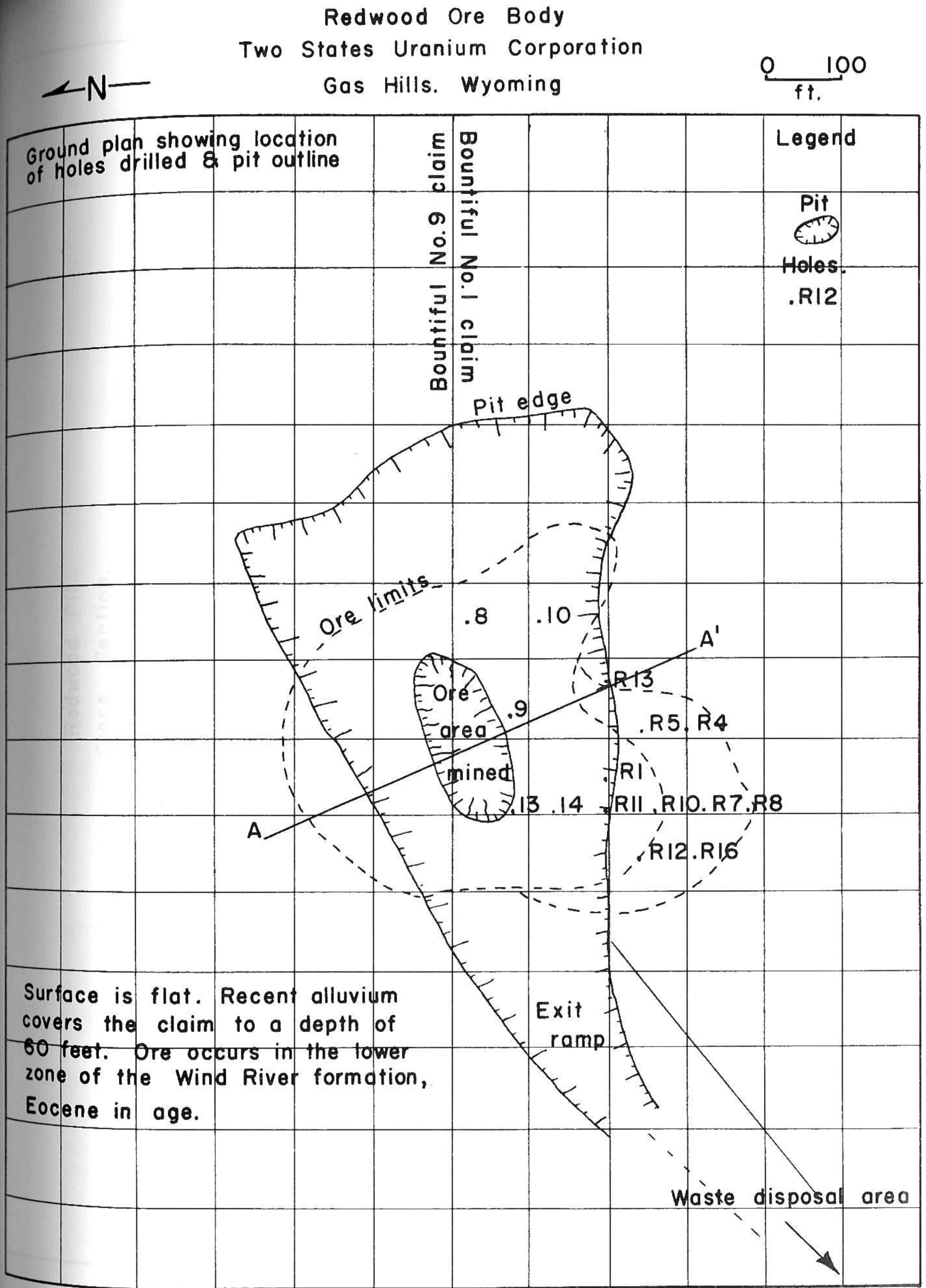
To obtain the amount of the proven ore reserves for the Two States Uranium Company's Redwood Ore Body, the Area of Influence Method of obtaining ore reserves was applied.

This method assumes that the assay value of an ore body varies at a uniform rate from point to point, or hole to hole, the persistence of any particular individual sample may be taken as extending halfway from the point tested and assayed to all adjacent points assayed. This agrees with the basic assumption that each sample must continue to be considered as representative of the ore body until it is relieved of that responsibility by another assayed sample at another point.

The area of influence, for irregular drilling, of any sample is, therefore, a polygon bounded midway to all surrounding sample points; for any point within such a polygon is within the area of influence of the sample assayed which is in question, since it is nearer to that point than to any other point. This equally applied to thickness data.

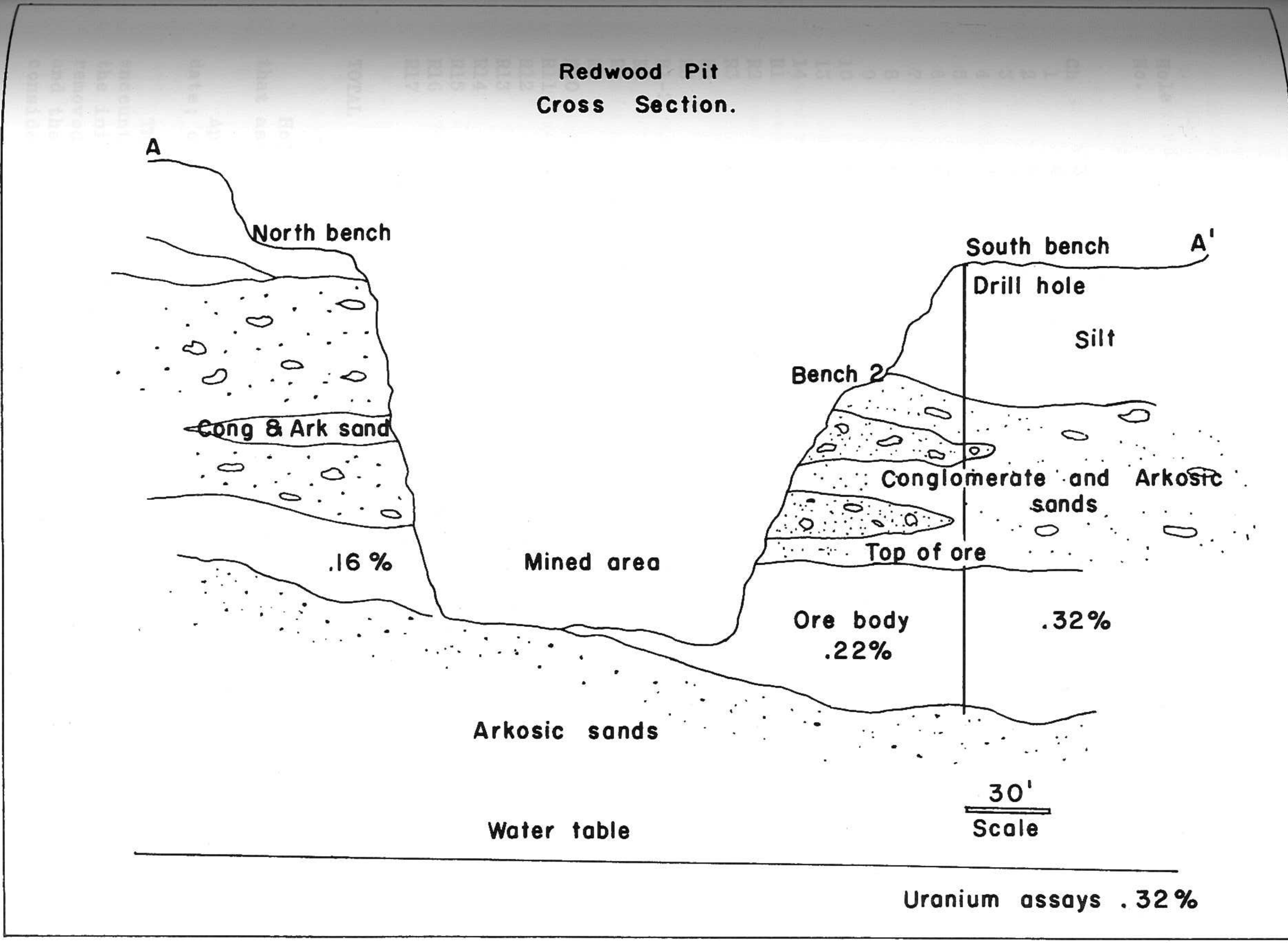
In combining the group of assays and thickness data, as well as volume data, each is given its due area-of-influence weight by multiplying its area of influence by both the sample length, thickness, and the assay value to give a volume-assay product, thus providing a more accurate average value.

The area of influence method was applied because it permits treatment of irregularly spaced assays and drill sites. A scale map showing the location of the drill sites permits the determination of the area fairly accurately. The assays are normally taken every two feet and then averaged for the assay length. The assayed length is the ore thickness. For opening up a pit, only the proven reserves can be considered. Inferred and possible reserves may occur to increase tonnage but an established tonnage is necessary to warrant stripping and mining operations.



Redwood Ore Body
Two States Uranium Corporation
Gas Hills. Wyoming
N
0 100
ft.
Ground plan showing location of holes drilled & pit outline
Legend
Pit
Holes.
.R12
Bountiful No.9 claim
Bountiful No.1 claim
Pit edge
Ore limits
.8
.10
A'
R13
Ore area mined
.9
.R5. R4
.R1
.13 .14
.R11 .R10. R7. R8
A
.R12.R16
Surface is flat. Recent alluvium covers the claim to a depth of 60 feet. Ore occurs in the lower zone of the Wind River formation, Eocene in age.
Exit ramp
Waste disposal area

Figure 4



Redwood Pit
Cross Section.
A
North bench
Cong & Ark sand
.16 %
Mined area
South bench
A'
Drill hole
Silt
Bench 2
Conglomerate and Arkosic sands
Top of ore
Ore body .22%
.32%
Arkosic sands
30'
Scale
Water table
Uranium assays .32%

Figure 5

Tabulations

Hole No.	Sp. Ft. Area of Influence	Thickness Ft.	Volume Factor	Assay U_3O_8	Volume-Assay Factor
Ch	3,325	44	146,300	.247	36,106
1	4,622	30	138,600	.125	17,333
2	2,284	36	82,224	.30	24,667
3	2,974	36	107,064	.134	14,347
4	4,497	20	89,940	.071	6,347
5	2,270	26	59,020	.17	10,044
6	3,208	34	109,072	.18	19,633
7	3,200	36	115,200	.36	41,472
8	6,845	20	136,900	.08	10,952
9	5,926	30	177,780	.10	17,778
10	9,555	20	191,100	.142	27,136
13	2,777	30	83,310	.21	17,495
14	2,786	20	55,720	.32	17,831
R1	4,694	28	131,432	.072	9,463
R2	2,818	40	112,720	.137	15,443
R3	2,820	20	56,400	.04	2,256
R4	2,815	15	42,325	.06	2,440
R5	Inconclusive				
B1-2	5,460	20	109,200	.06	6,542
R7	2,340	20	46,800	.05	2,340
R8	2,341	20	46,820	.085	3,980
R9	4,720	10	47,200	.08	3,776
R10	2,450	34	83,300	.16	13,328
R11	2,340	50	117,000	.24	28,080
R12	1,950	20	39,000	.06	2,340
R13	7,410	40	296,400	.07	20,748
R14	Poor recovery				
R15	Not drilled				
R16	Poor recovery				
R17	Poor recovery				
TOTAL	97,437		2,619,887		370,926

Holes that were inconclusive, or had poor recovery, such that assays were not taken, are included in the probable reserves.

Approximately 4,500 feet of drilling has been conducted to date; of this approximately 1,000 feet were in ore.

The above figures do not include the smaller ore bodies encountered at shallow depths. In the removal of the overburden in the initial open pit, about 1,000 tons of .34 per cent ore were removed from three ore bodies at the 30 foot level, the 62 foot level, and the 83 foot level. These are in meandering channels and are considered to have extension to the south.

The ore channel at the 84 foot level is particularly of importance because it yielded considerable ore of excellent grade and had a north-south trend. These ores are considered in the inferred ore possibilities.

Using the above figures obtained in the tabulation, the average thickness of the ore body is obtained by dividing the total of the volume factor by the total of the area of influence:

$$2,619,887 \div 97,437 = 27 \text{ feet, average thickness.}$$

The average assay per ton of the unadjusted assay, not having as yet been correct for the loss in fines or the differences in actual ore when mined, is the volume-assay factor divided by the Volume factor:

$$370,926 \div 2,619,887 = .142 \text{ per cent } U_3O_8.$$

Assuming that 12 cubic feet, which by direct measurement appears to be the figure to use in the ore body under consideration, is equal to one ton of ore, the total proven tonnage would be the volume factor divided by 12:

$$2,619,887 \div 12 = 218,322 \text{ tons.}$$

However, from the open pit operation previously conducted, 17,500 tons have been removed from the Bountiful No. 1 side, of claim and additional 7,500 tons have been removed from Bountiful No. 9, adjoining on the north. Adjusting this total tonnage then by subtracting 17,500 from 218,322 tons, gives a total ore proven reserve of: 200,822 tons.

BENGAL URANIUM COMPANY

This company has opened up a pit exposing an ore body at a depth of 90 to 120 feet. This ore body occurs in what appears to be a cut off oxbow on the southern extremity of the channel area. A fault has displaced the ore body approximately 20 feet. Tonnage estimates exceed 10,000 tons of uranium ore. The pit is not as yet complete.

HUGHES MINING CO.

This company opened up a small ore body at a depth of 25 feet. The ore occurs in a conglomerate and silt filled channel scour area. Tonnage estimates are not available. Faults occur in the pit area but are not associated with the ore body.

VACA MINERALS CO.

This company has opened up an ore body that occurs in a boulder deposit in the main channel area. The ore is in the matrix material surrounding the boulders. The ore body occurs at a depth of 40 feet. Tonnage estimates are not available, but the ores will probably exceed 10,000 tons.

ALJOB MINING CO.

Most of the ore discoveries on this group of holdings are associated with trash and carbonaceous zones and vary in depth from 30 to 120 feet. The ore estimates exceed 75,000 tons. Extensive exploration is under way on the properties.

P. C. CORPORATION

The ore body is the result of trapped ground water in a braben created by faults of as yet unknown displacement Ore estimates exceed 5,000 tons. The ore is at a depth of 70 feet. Water is associated with the ores.

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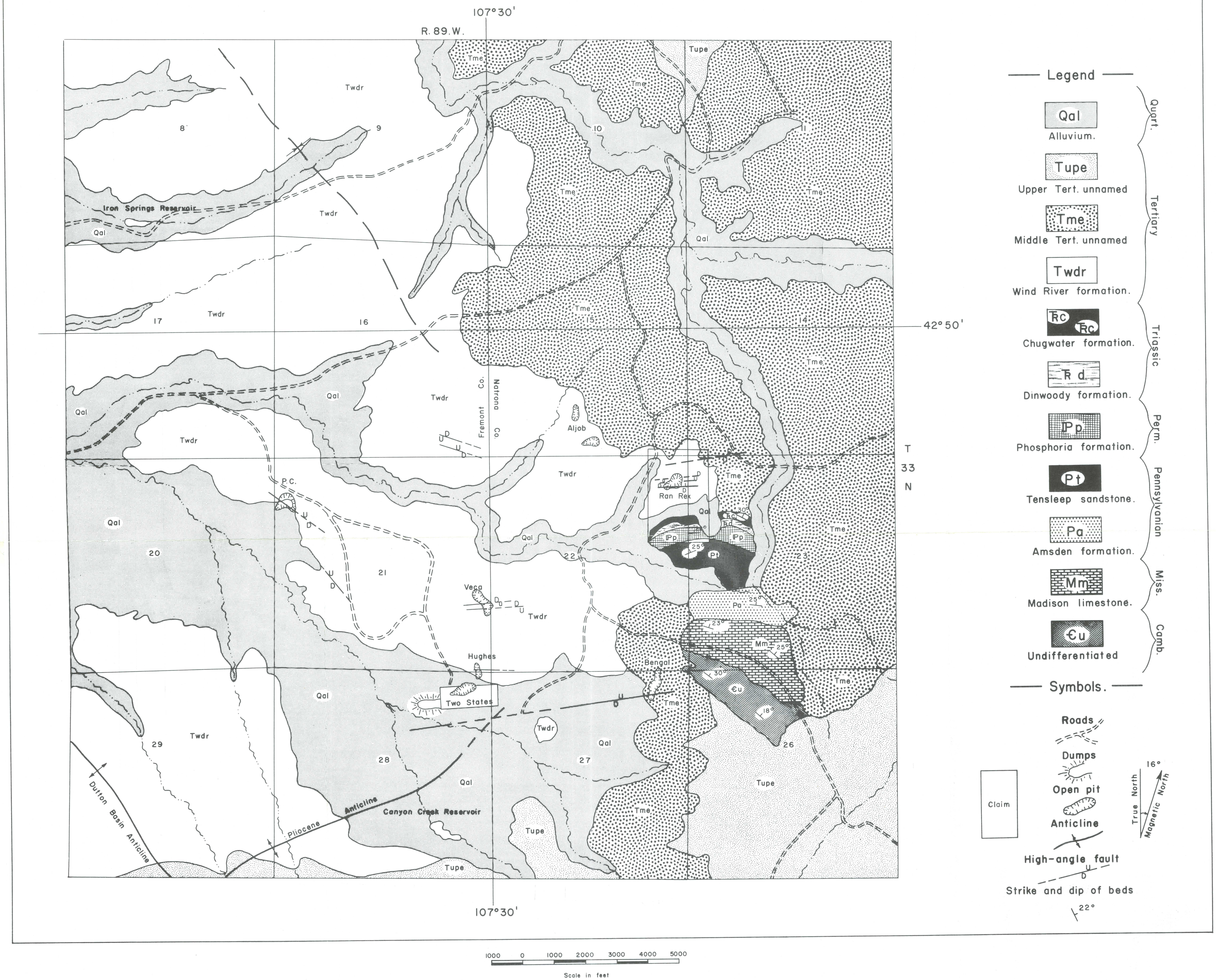

A Geologic Map of the East Gas Hills Area, Wyoming.

by

Einar C Erickson.

1957