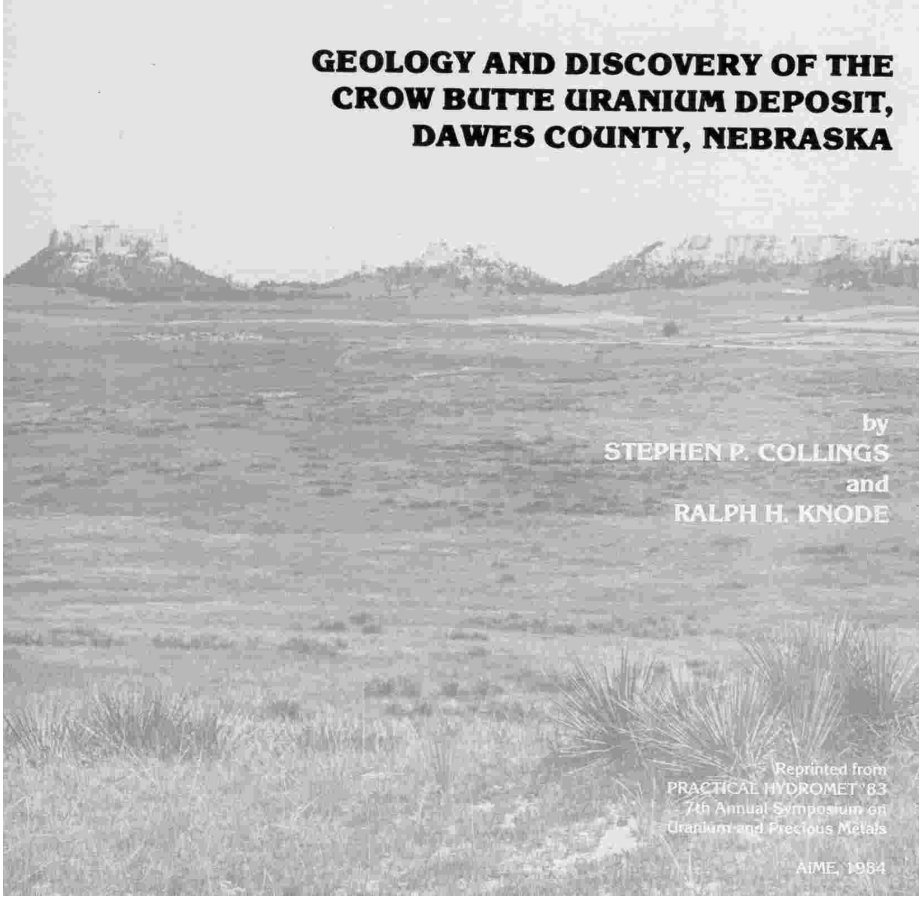
WFC
WYOMING FUEL COMPANY
Lakewood, Colorado
Crawford, Nebraska



GEOLOGY AND DISCOVERY OF THE CROW BUTTE URANIUM DEPOSIT, DAWES COUNTY, NEBRASKA

STEPHEN F. COLLINGS AND RALPH H. KNODE

Wyoming Fuel Company, Lakewood, Colorado and Crawford, Nebraska

INTRODUCTION

The Crow Butte uranium deposit is located in northwest Nebraska near the Town of Crawford (Figure 1). The deposit was discovered during the fall of 1980 by Wyoming Fuel Company, operator of the Crow Butte Joint Venture. The Crow Butte Joint Venture is owned 50 percent by Wyoming Fuel Company, a subsidiary of KN Energy, Inc.; formerly Kansas-Nebraska Natural Gas Company, Inc., 40 percent by Ferret Exploration Company, Inc., and 10 percent by First Exploration Company. A preliminary announcement made in January 1981 indicated a "probable potential" reserve in excess of 25,000, 000 pounds U308. Drilling during 1981 and 1982 confirmed these reserves and indicated the presence of more than 30,000,000 pounds U308 having an average grade in excess of 0.25 percent U308.

Wyoming Fuel Company was initially attracted to the area in 1978 by favorable regional geology for sandstone uranium deposits and weak radioactivity noted in regional oil and gas holes. Exploration drilling began in 1979 following the formation of the Crow Butte Joint Venture. Drilling has continued up to the present, at which time the Joint Venture is ready to proceed with a pilot scale solution mine. Environmental baseline data have been acquired and the permit applications for the pilot scale mine have been submitted to the Nuclear Regulatory Commission and to the applicable state agencies in Nebraska.

GEOLOGICAL SETTING

The Crow Butte deposit is in the Pine Ridge country of northwest Nebraska. The main portion of the deposit lies north of the Pine Ridge escarpment on gradual sloping terrain with local relief of less than 100 feet. The Pine Ridge escarpment surrounds the main deposit on three sides and is about 500 feet higher in elevation than the northward sloping plain (Figure 2). The Pine Ridge is covered with ponderosa pine and is formed by a major sandstone unit.

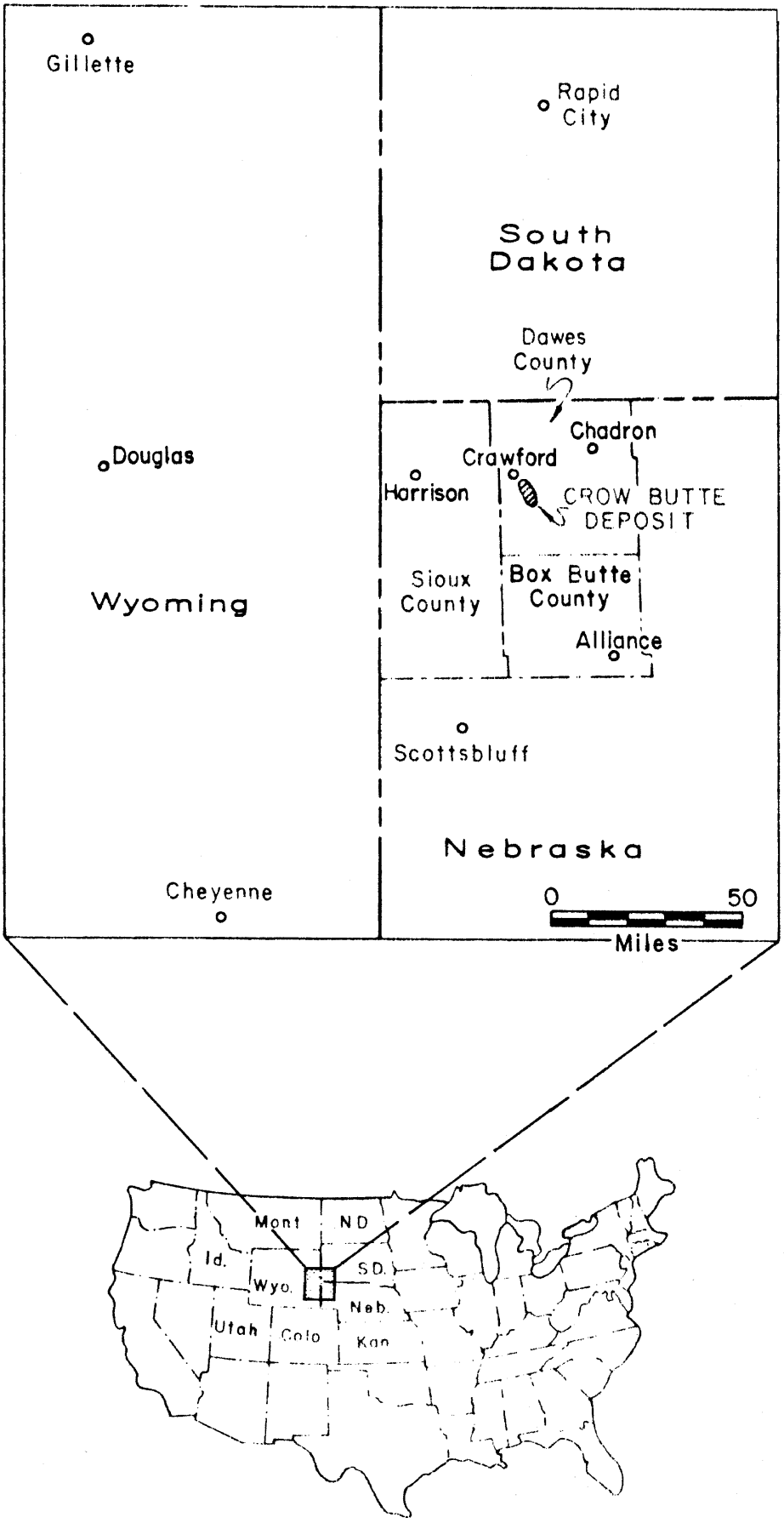


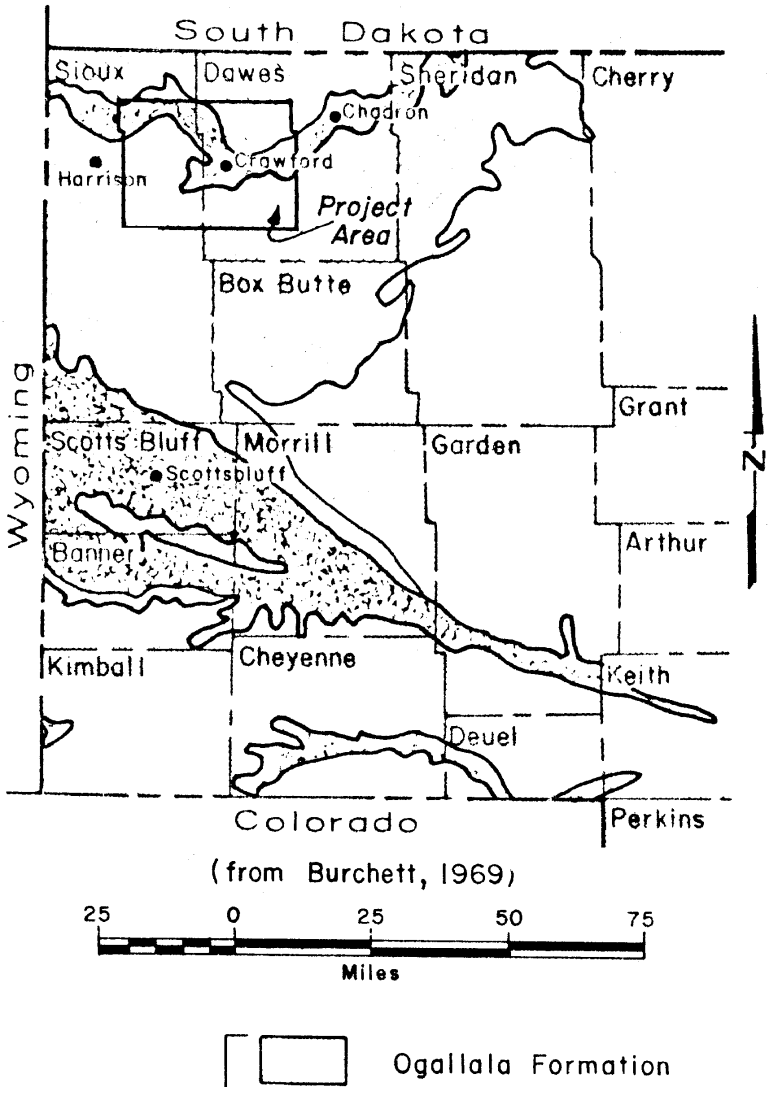
FIGURE 1. Location Map: Crow Butte Deposit

Figure 2. Pine Ridge - Crow Butte on left. View looking northeast. Crow Butte Deposit is in the middle distance. Gering and Monroe Creek Formations form the Pine Ridge.

The climate, typical of a semi-arid continental climate is characterized by warm summers, cold winters, light precipitation and frequent changes in the weather. The average precipitation is 15.5 inches distributed mostly during the spring and summer. Average temperature ranges from 23 degrees F in January to 74 degrees F in July, with extremes ranging from -29 degrees F to 110 degrees F

The land in the area of the deposit is largely privately owned and used for agriculture with a population density of about 12 persons per square mile. Winter wheat and hay are the principal crops and cattle are the principal livestock.

Nearby Crawford is a town of 1320 people whose economy is based on agriculture and tourism. Fort Robinson State Park is located immediately west of the town; other nearby points of interest are the Nebraska National Forest to the southeast and the Black Hills, 90 miles to the north. Chadron, with a population of 5933, the largest community in the immediate area, is 25 miles to the east. Scottsbluff, located 75 miles to the south, is the largest community and the principal trade center



for northwest Nebraska and east-central Wyoming.

GENERAL STRATIGRAPHY

Sedimentary strata ranging from late Cretaceous through Tertiary age exposed throughout the project area (Figure 3). Pleistocene alluvial and colluvial material are abundant along the north slope of the Pine Ridge. Figure 4 is a generalized stratigraphic column for the area.

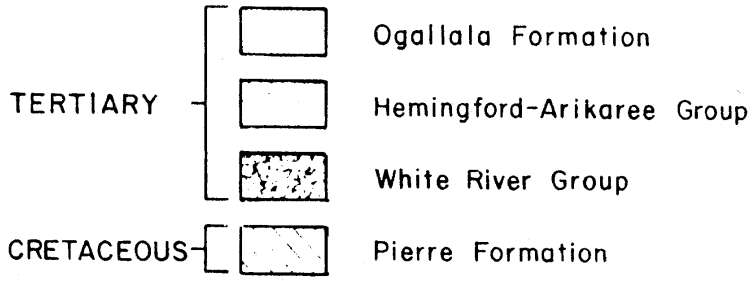


FIGURE 3. Regional Geology: Western Nebraska

Pierre Shale

The Pierre Shale of Late Cretaceous age is the oldest formation encountered in WFC's test holes. The Pierre is a widespread dark gray to black marine shale, with relatively uniform composition throughout. The Pierre outcrops extensively in Dawes County north of the project area, (Figure 3). The Pierre is essentially impermeable to the degree that in areas of outcropping Pierre, water for domestic and agricultural needs is piped in from wells from other formations.

Although the Pierre is up to 5,000 feet thick in other areas, in Dawes County deep oil tests have indicated thicknesses of 1,200 to 1,500 feet. Aerial exposure and subsequent erosion greatly reduced the vertical thickness of the Pierre prior to Oligocene sedimentation. Consequently, the top of the present day Pierre contact marks a major unconformity and exhibits a paleotopography with considerable relief (DeGraw, 1969).

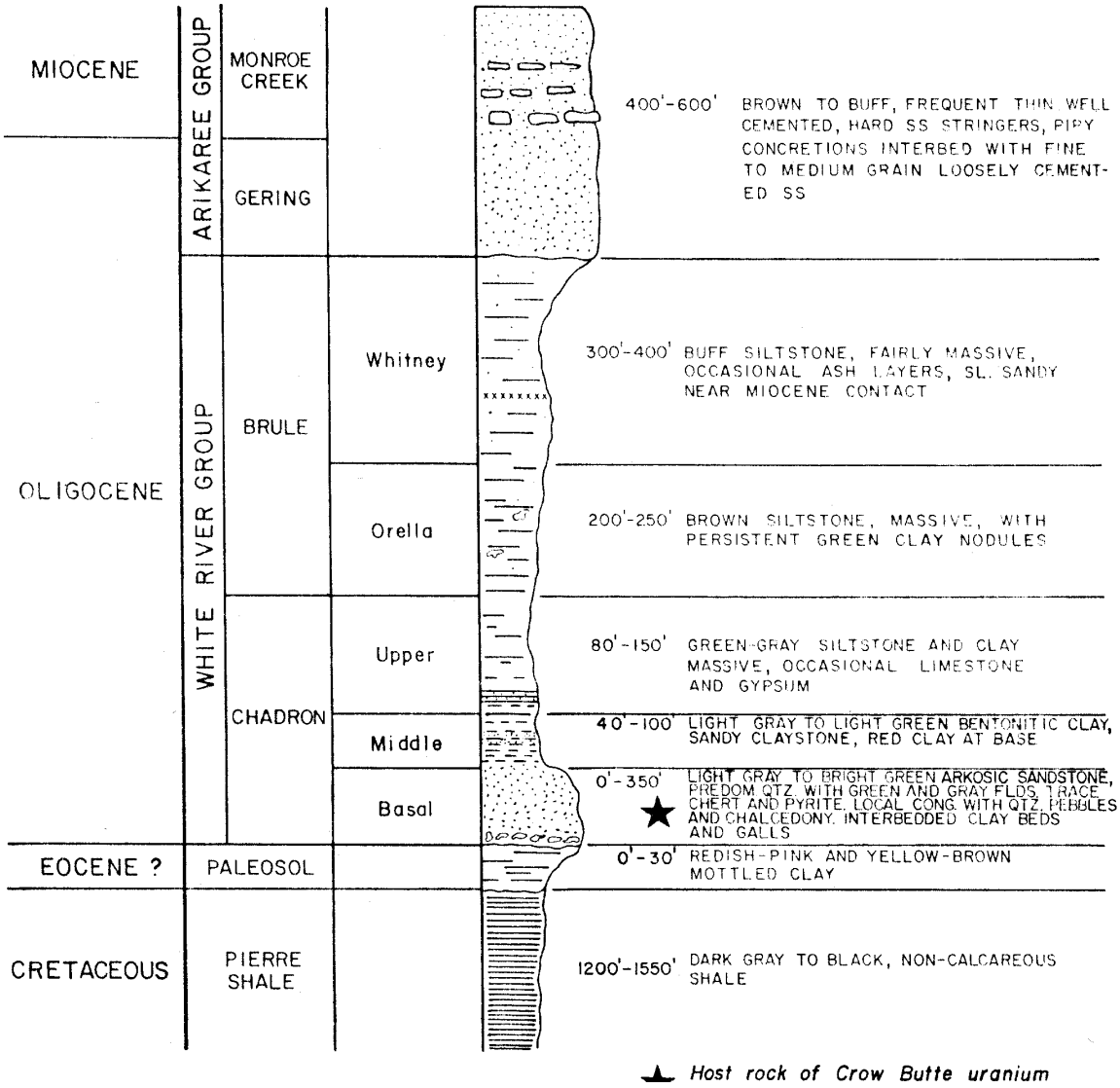


FIGURE 4. Stratigraphic Column: Crow Butte Project Area

As a result of the extended exposure to atmospheric weathering, an ancient soil horizon or Paleosol was formed on the surface of the Pierre Shale. It is known as the "Interior Paleosol Complex" of the Pierre Shale (Shultz and Stout, 1955, p.24) and is readily observed in certain outcrop exposures. The Paleosol is generally absent in areas of Chadron Sandstone channels.

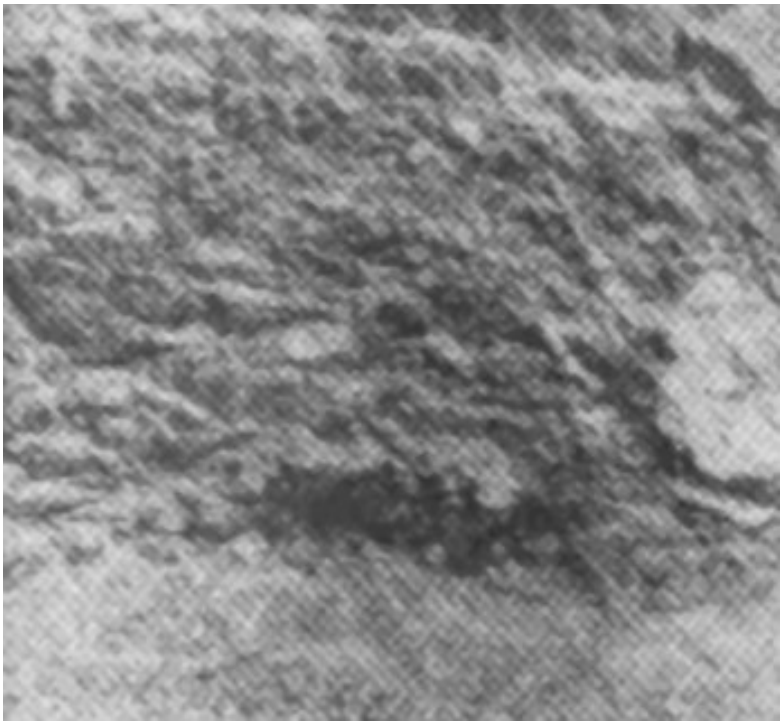
The Pierre Shale is the confining bed below the Basal Chadron Sandstone member which is the host for uranium mineralization (Figure 5). The black marine shale is an ideal confining bed with measured permeabilities of less than 0.0001 millidarcies. The log characteristics of the Pierre Shale are shown on Figure 6 and illustrate its impermeable nature.

White River Group

The White River Group is Oligocene in age and consists of the Chadron and Brule Formations. The Chadron is the oldest Tertiary Formation of record in northwest Nebraska. It lies with marked unconformity on top of the Pierre Shale (Figure 5). Regionally, the vertical thickness of the Chadron Formation varies greatly. This is attributed to the extreme variability of the Basal Sand unit of this formation. The Chadron Formation is comprised of three distinct members.

Basal Sandstone Member: The Basal Sandstone is the depositional product of a large, vigorous braided stream system which occurred during early Oligocene (approximately 36 to 36 million years before present). Regionally, the Basal Sandstone ranges in thickness from 0 to 350 feet.

Uranium mineralization occurs exclusively within the Basal Chadron Sandstone Member, a coarse grained arkosic sandstone with frequent interbedded thin clay beds and clay galls (Figures 5 and 6). Occasionally the lower portion of the Basal Member is a very coarse, poorly sorted conglomerate (Figure 7). Thickness of the Basal Chadron within the ore trend is about 40 feet.



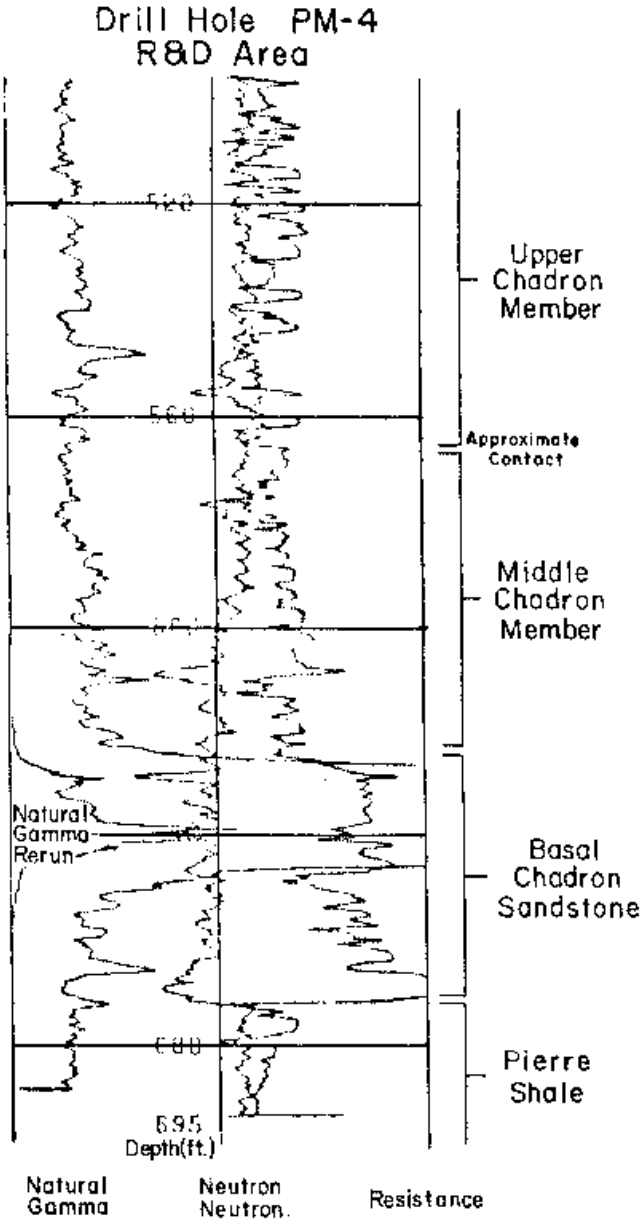
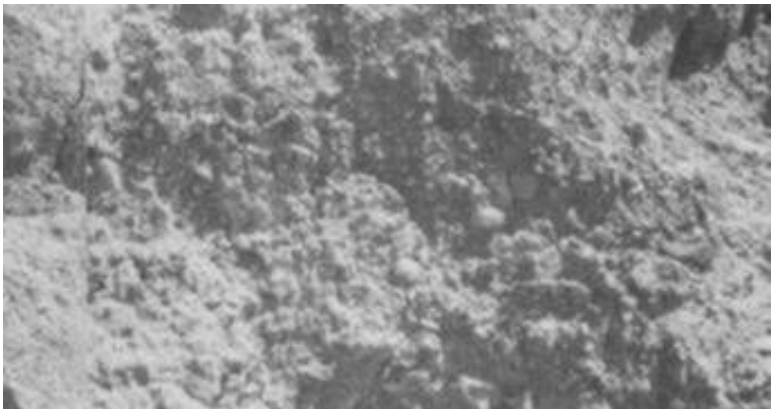
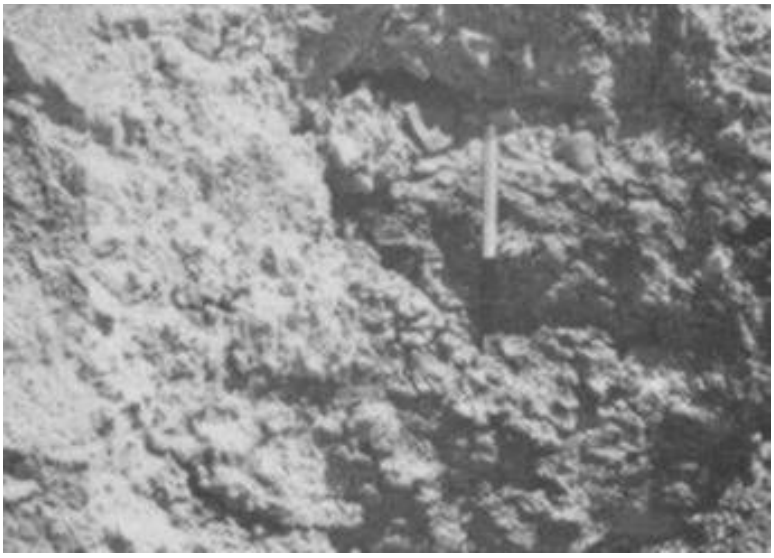


FIGURE 6. Log Characteristics: Crow Butte Project Area.

Figure 5. Pierre Shale - Basal Chadron Sandstone Contact, Whitehead Creek, Section 36, T34N, R54W, Sioux County



Thin section examination of the Basal Chadron Sandstone reveals its composition to be 50% monocrystalline quartz, 30 to 40% undifferentiated feldspar, plagioclase feldspar, and microcline feldspar. The remainder includes polycrystalline quartz, chert, chalcedonic quartz, various heavy minerals and pyrite.



Core samples of the Basal Chadron exhibit numerous clay galls up to a few inches in diameter. In addition, the Basal Member contains frequent thin silt and clay lenses of varying thickness and continuity. These represent flood plain, or low velocity, deposits which normally occur during fluvial sedimentation. These lenses vary in thickness from several inches to one or two feet. Within the ore trend, clay beds one to two feet thick separate the Chadron Sandstone into two or more subunits. X-ray diffraction of the Basal Sandstone has identified the following clay minerals: illite, smectite, expandable mixed layer illite-smectite, and minor amounts of Kaolinite.

Figure 7: Close-up Pierre Shale - Basal Chadron Sandstone Contact. Note pebbles and heterogenity of Chadron Sandstone, Whitehead Creek, Sec. 36, T34N, R54W, Sioux County.

Middle Chadron Member: The Middle Chadron Member represents a distinct and rapid facies change from the underlying Basal Sandstone. The lower portion of the Middle Chadron is characterized by brick red clay (Figure 8). The brick red clay can be observed on outcrop in northern Dawes and Sioux Counties and serves as an excellent marker bed in drill hole cuttings. The Middle Chadron Member has been observed in virtually all drill holes along the mineral trend. Thickness of the Middle Chadron Member ranges from 40 to 100 feet throughout the project area.

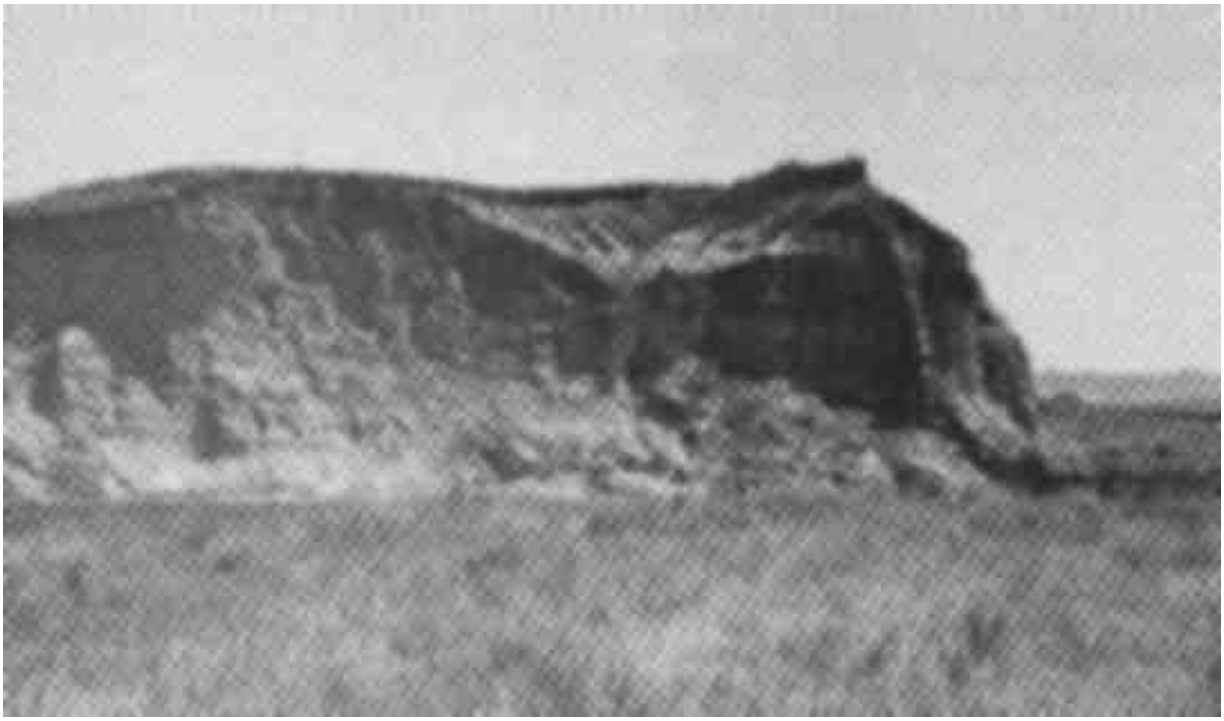


Figure 8. Basal Chadron Sandstone - Middle Chadron Member. Red clay at base of Middle Chadron is dark band overlying light colored sandstone. Whitehead Creek, Sec. 36, T34N, R54W, Sioux County

The Middle Chadron Member is the upper confining bed overlying the Basal Sandstone Member. This can be observed by the epigenetic occurrence of the uranium mineralization, which is strictly confined to the Basal Chadron Sandstone Member. The lower part of the Middle Member is a brick red clay with occasional interbedded gray-green clay. The brick red clay grades upward to a light green-gray sandy claystone. The upper part of the Middle Member is a light gray bentonitic clay. Upper Chadron Member: The Upper Chadron consists of massive claystones and siltstones (Figure 9). These range in color from a dark bluegreen to greenish-brown. The sequence of green siltstones and mudstones are generally considered fluvial channel and flood plain deposits, with limited lacustrine and eolian material present (Vondra, 1958, p.41). Well developed sand channels in the Upper Chadron are rarely encountered in test holes, and of very limited lateral extent when observed. The Upper Chadron Member averages 100 feet thick throughout the project area.

Figure 9. Upper Chadron Member. Claystones and Siltstones. Sugar Loaf Butte Sec. 27, T34N, R53W, Sioux County.

Brule Formation

The Brule Formation lies conformably on top of the Chadron Formation and combined with the Chadron comprises the White River Group. The Brule outcrops throughout the main ore trend. It is made up almost entirely of siltstones with minor sand channels (Figure 10). The contact between the Upper Chadron Member and the overlying Brule Formation is a gradational one. In drill cuttings and geophysical logs the formation boundary can only be approximated. The Brule Formation can generally be identified by its buff to medium brown color in contrast to the greens of the underlying Chadron.

The Brule has been subdivided into two separate members (Shultz and stout, 1938) the Orella and the Whitney. Differentiation of the two members in drill hole cuttings or with geophysical logs is very difficult.

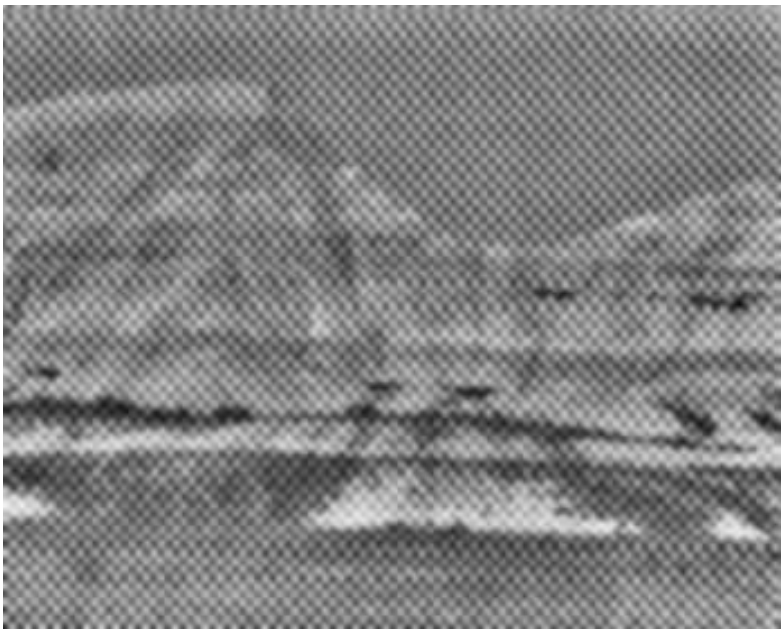


Figure 10. Brule Formation, Siltstones, Toadstool Park, Sec. 5, T33N, R53W, Sioux County.

The Orella lies directly on the Chadron Formation and an approximate Brule-Chadron contact can generally be estimated with drill cuttings but usually not on geophysical logs. The Orella is composed of buff to brown siltstones, with persistent spotty green nodules as it grades into the green clays of the Chadron.

The Whitney Member of the Brule is comprised of fairly massive buff to brown siltstones, in part probably eolian in origin (Vondra, 1958, p.19). Several volcanic ash horizons have been reported in outcrops. They are rarely distinguishable in drill hole cuttings, but are occasionally identified on geophysical logs. The Whitney Member frequently becomes coarser grained upward near the Gering Formation contact. This is marked by an increase in grain size which is difficult to detect in drill hole cuttings but usually can be observed on geophysical logs. Some moderate to well defined channel sands can be observed in both drill holes and on outcrops. These upper Brule channels are limited in lateral extent and continuity but may occasionally be water saturated in the otherwise generally impermeable Brule.
Within the pilot mine area occasional sand units are encountered in the upper 250 feet of the drill hole. These represent small Brule channel sands known to occur intermittently in the Whitney Member. The small sand units have very limited lateral continuity and although water bearing, little water can be produced. Thus, these units do not meet a strict definition of an aquifer. This has been

demonstrated in WFC drill holes and can be observed in cross sections throughout the R and D permit area.

Arikaree Group

The Arikaree Group includes three sandstone Formations which are present locally and regionally but in the main ore trend are absent due to erosion. The Gering Formation (Figure 2) is the oldest formation of the Arikaree Group. The Gering Formation is Oligocene in age (Souders, 1981) and lies unconformably on the Brule Formation. The Gering is predominantly buff to brown, fine grained sandstones and siltstones. These repre sent channel and flood plain deposits of higher velocity than the underlying Brule. The Gering Formation also includes some eolian material. Thickness of the Gering Formation ranges from 100 to 200 feet (Witzel, 1974, p.50).

The Monroe Creek Formation is Miocene in age and overlies the Gering Formation (Figure 2). The Monroe Creek is lithologically similar to the Gering with buff to brown, fine grained sandstone. The unique characteristics of the Monroe Creek is the presence of large "pipy" concretions. These concretions consist of fine grained sand similar to the rest of the formation with calcium carbonate cement and are extremely hard and resistent to weathering.

The reported thickness of the Monroe Creek Formation is 280 to 360 feet (Lugan, 1938 from Witzel, 1974, p.53).
The Harrison Formation is the youngest member of the Arikaree Group. To date, this formation has rarely been penetrated in WFC drill holes, thus little first hand information is available. It is described as lithologically similar to the Gering and Monroe Creek Formations, with fine grained unconsolidated buff to light gray sands. The Harrison Formation is also noted for its abundance of fossil remains (Witzel, 1974, p.55)

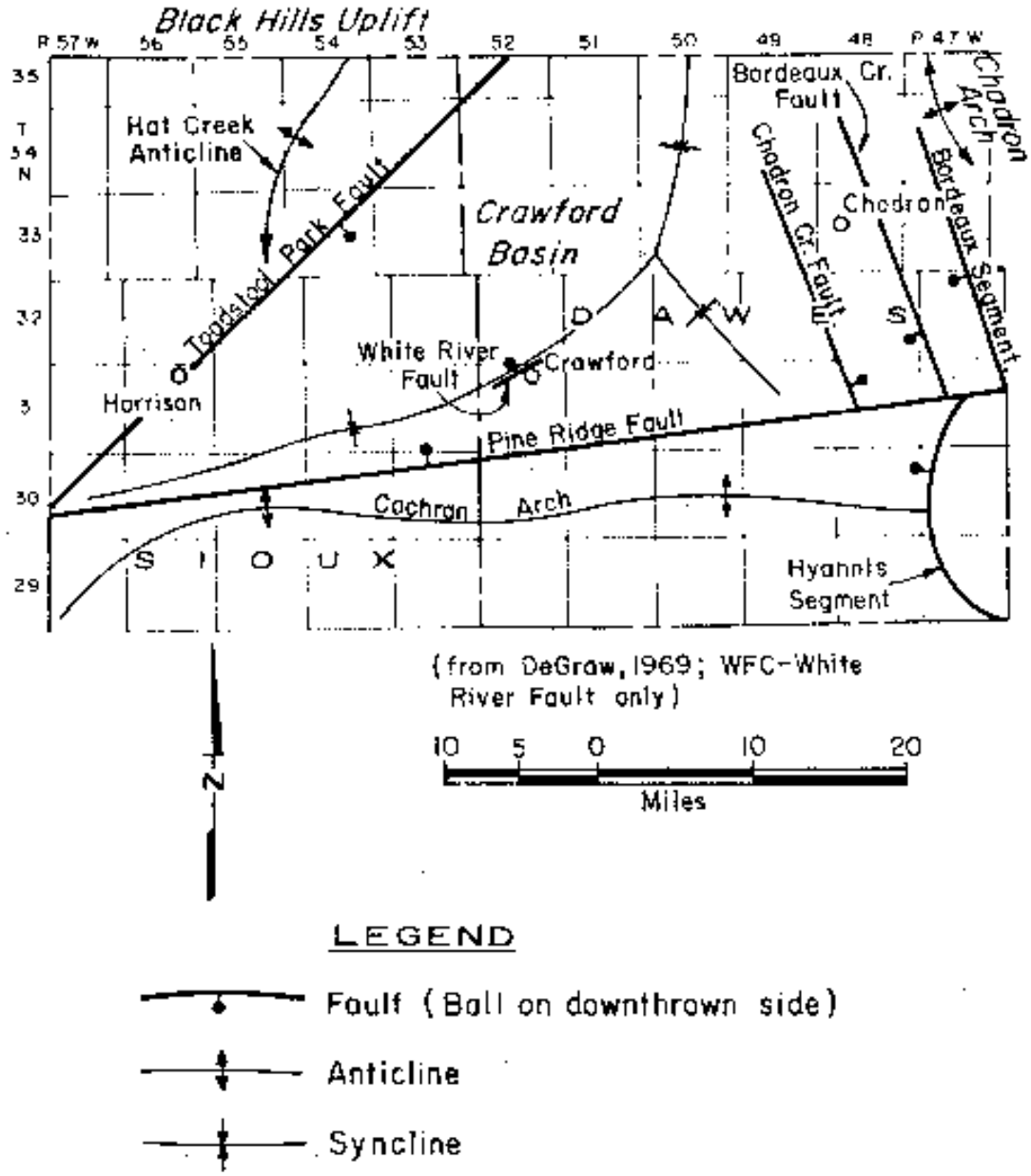
Quarternary Alluvium

Quarternary alluvial and colluvial material are present in the permit area ranging in depth from 0 to 40 feet. The material consists of OligoceneMiocene rock fragments, silt, sand and gravel.

REGIONAL STRUCTURE

The most prominent structural expression in northwest Nebraska is the Chadron Arch (Figure 11). This anticlinal feature strikes roughly northwestsoutheast along the northeastern boundary of Dawes County. The only surficial expression of the Chadron Arch is in the northeastern corner of Dawes County, as well as small portions of Sheridan County and Shannon County, South Dakota.

The Black Hills lie north of Sioux and Dawes Counties in southwestern South Dakota (Figure 11). Together with the Chadron Arch, the Black Hills Uplift has produced many of the prominent structural features presently observed in the area. As a result of the uplift, formations underlying the project area dip gently to the south. The Tertiary deposits dip slightly less than the older Mesozoic and Paleozoic Formation (Witzel, 1974, p.18).



LEGEND

Fault (Ball on downthrown side)

Anticline

Syncline

FIGURE 11. Regional Structure: Northwest Nebraska

The Crow Butte ore body lies in what has been named the Crawford Basin (DeGraw, 1969). DeGraw made detailed studies of the preTertiary subsurface in western Nebraska using primarily deep oil well test information. DeGraw substantiated known structural features and proposed several structures not earlier recognized. The Crawford Basin was defined by DeGraw as being a triangular, asymmetrical basin bounded by the Toadstool Park Fault on the northwest, the Chadron Arch and Bordeaux Fault to the west, the Cochran Arch and Pine Ridge Fault to the south (Figure 11).

The Toadstool Park Fault, the Bordeaux Fault and other faults occur outside WFC's project area and are assumed to exist as described by DeGraw and others. The Pine Ridge Fault has also been inferred from subsurface data and proposed by DeGraw

(1969, p.36). This fault trends east-west across Sioux and Dawes Counties. This fault is subparallel to the Cochran Arch and has a reported displacement of about 300 feet with the south side upthrown.

The Cochran Arch was also proposed by DeGraw (1969, p.36) on the basis of subsurface data. The Cochran Arch trends east-west through Sioux and Dawes Counties, parallel to the aforementioned Pine Ridge Fault. Structural features subparallel to the Cochran Arch have also been observed in drill hole data. The existence of the Cochran Arch alone is probably enough to explain the structural high south of Crawford.
The synclinal axis of the Crawford Basin trends roughly eastwest and plunges west into what is informally referred to as the Inner Crawford Basin by WFC. The Inner Basin is characterized by a rather sharp paleotopographic change in the Pierre Shale with dramatic increase in the thickness of the Basal Chadron Sandstone.

The single most prominent structural feature within the Crawford Basin is the previously unnamed White River Fault (Figure 11). It is located directly north of Crawford, and strikes northeastsouthwest with the upthrown side to the south. The total vertical displacement is 200 to 400 feet; no strike-slip movement has been detected. The disturbance of the Chadron and Brule Formations date the fault as post-Oligocene.

HISTORY OF DISCOVERY
A review of the regional geology indicated that northwest Nebraska was favorable for the occurrence of sandstone uranium mineralization. H.M. DeGraw of the Nebraska Geological Survey reviewed several thousand oil and gas logs in the Nebraska Panhandle and outlined several major fluvial systems within the basal Tertiary, the Oligocene Chadron Formation (DeGraw, 1969). A major fluvial system from Wyoming and South Dakota trends through northern Sioux County and southeastward across Dawes and Box Butte Counties (Figure 12). Another major system trends southeastward along the present day course of the North Platte River near Scottsbluff (Figure 12).

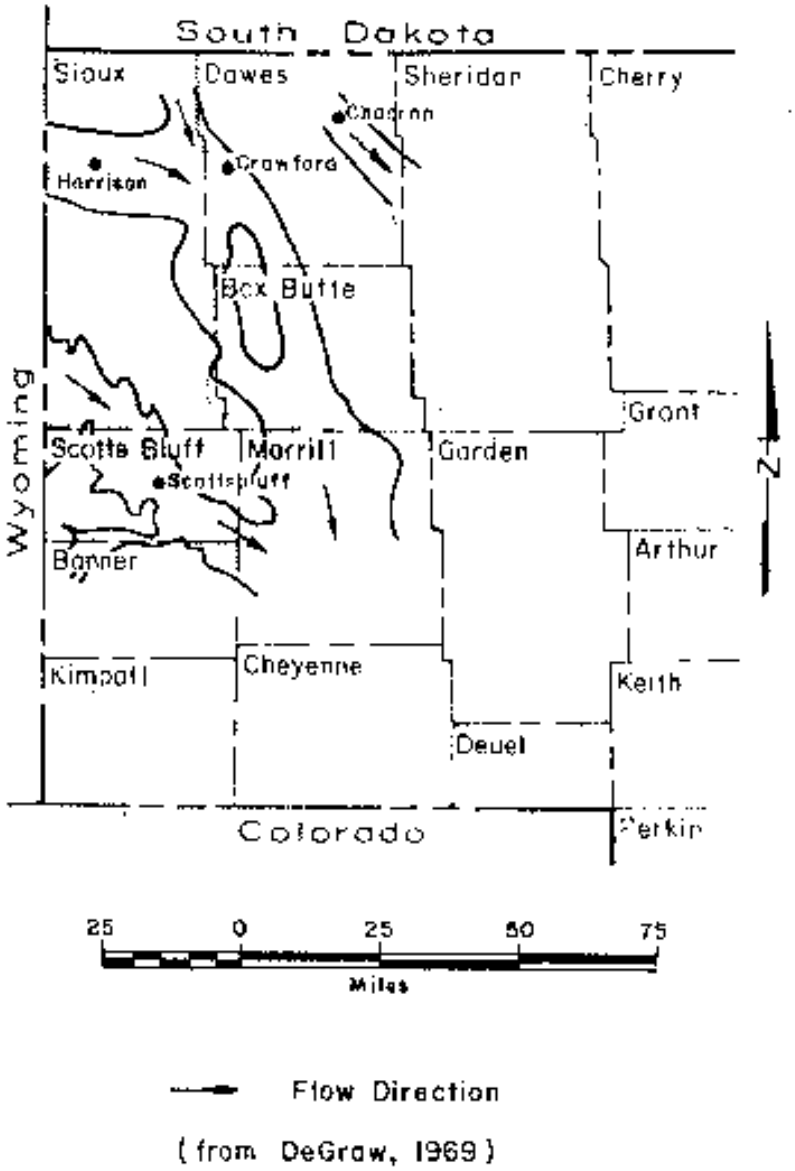


FIGURE 12. Regional Chadron Sandstone Channels: Western Nebraska

Wyoming Fuel Company reviewed the DeGraw study and reinterpreted the logs and developed a Chadron sandstone isopach (Figure 13) based on the widely spaced oil and gas exploration holes, 0 to 5 holes per township. The logs indicate an extensive fluvial sandstone system at the base of the Tertiary overlying the Cretaceous Pierre Shale. This fluvial sandstone is the Basal Sandstone Member of the Chadron Formation of Oligocene age. In the Crawford area it was noted that five oil and gas holes had gamma spikes in the sandstone indicating approximately .005 to .025 percent eU308. (In this context, eU308 refers to estimation by means of radiometric measurement.) In addition, methane gas shows had been reported from several oil and gas holes and water wells in the Crawford area. There was also some evidence of oxidation-reduction interfaces based on a lithologic log of one of the

oil and gas holes.

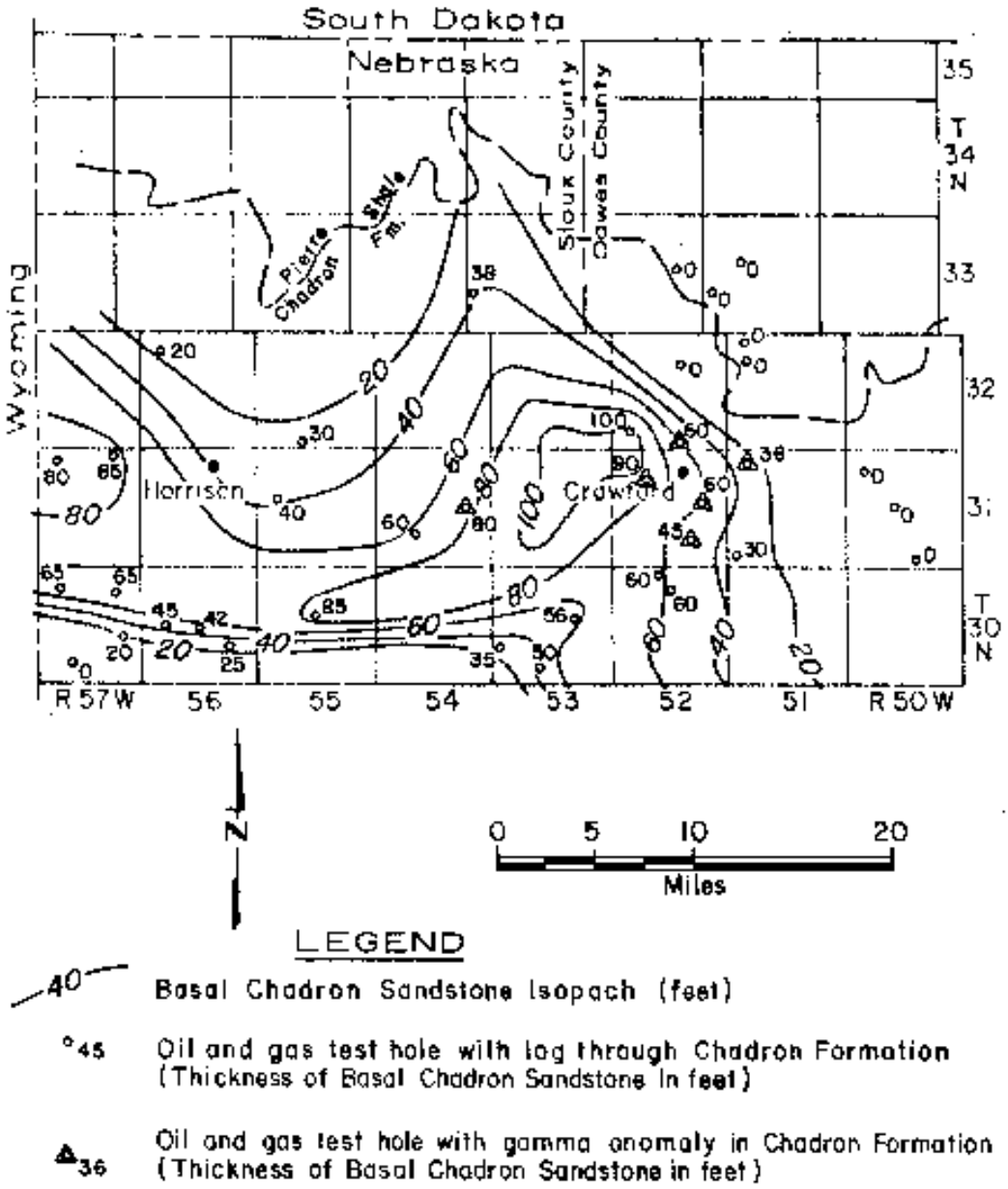


FIGURE 13. Chadron Sandstone Isopach: Northwest Nebraska

Based on this information Wyoming Fuel Company acquired a regional lease position from Sioux Minerals, Ltd. and Wulf Oil Corporation of about 64,000 acres along the Chadron Formation outcrop (Figure 3) of northwest Nebraska in the spring of 1978. The lease position extended from north of Harrison to southeast of Crawford, a distance of about 30 miles.

Wyoming Fuel Company and Ferret Exploration Company formed a joint venture during the late summer of 1979. Wyoming Fuel Company, designated as project operator, undertook a regional exploration drilling program. Property evaluation began during

1979 and 95 exploration drill holes totaling approximately 50,000 feet were completed (Figure 14). The holes were widely spaced on one or two mile centers. In areas of encouragement, a few holes were drilled on a one-fourth to one-half mile spacing. Two areas of encouragement were encountered during this drilling (Figure 14). An area north of Crawford was identified as having considerable weak uranium mineralization associated with vague oxidation-reduction boundaries adjacent to the White River Fault. This was in the same general area of weakly radioactive oil and gas holes and methane gas shows.

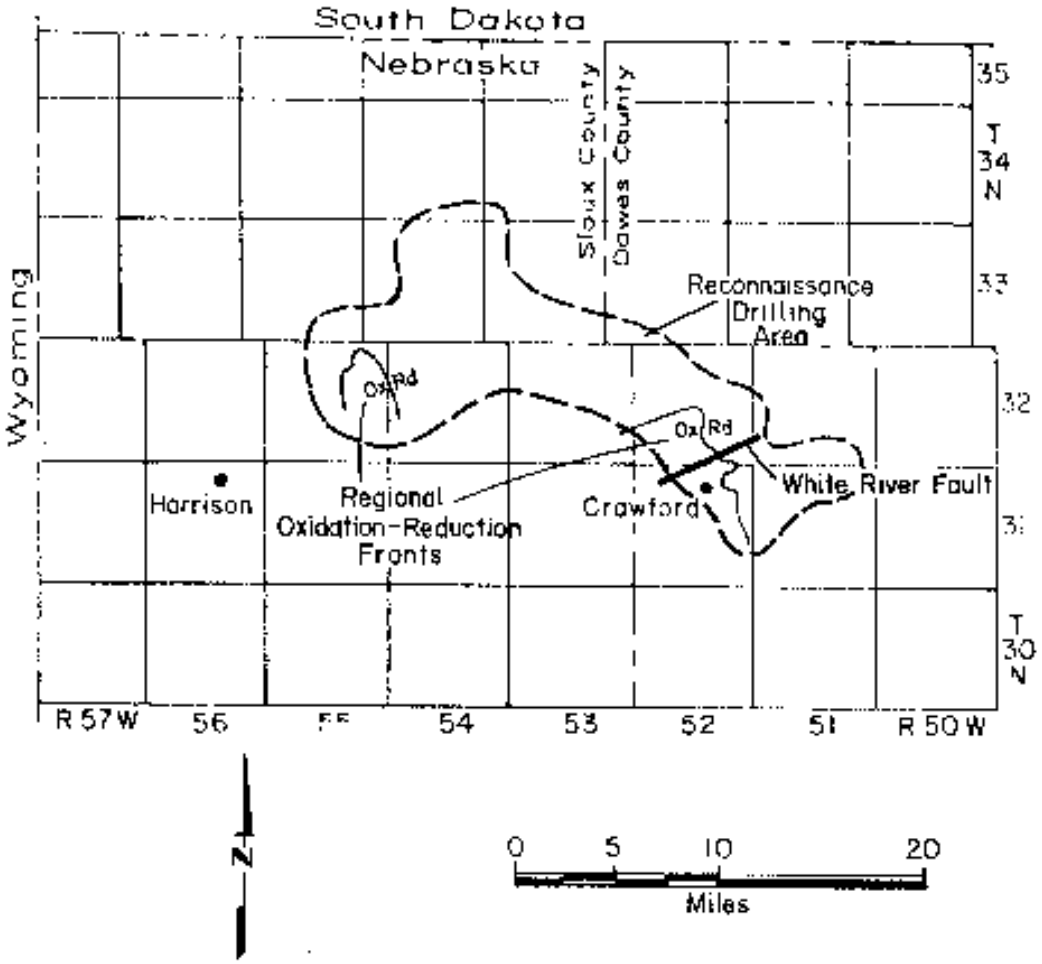


FIGURE 14. Reconnaissance Drill Results: Crow Butte Project

Following the 1979 drilling, the lease position was consolidated and additional acreage was leased in the areas of encouragement. Amore extensive drill program was planned for the next phase of project evaluation.

During 1980, reconnaissance drilling continued within the lease block and follow-up drilling continued in areas with encouraging results. The 100th hole of the 1980 drill program intersected the first ore grade mineralization (0.1% eU308). After an additional 65 holes, a mineralized trend based on three additional holes was indicated to extend about six miles southeast of Crawford.

Following additional lease acquisition, Wyoming Fuel increased the pace of close-

spaced drilling. An additional 148 holes were drilled during 1980 to define the mineralized trend (Figure 15) which was named Crow Butte for a prominent butte of the Pine Ridge southeast of Crawford (Figure 2). A total of 408 drill holes had been drilled to date.

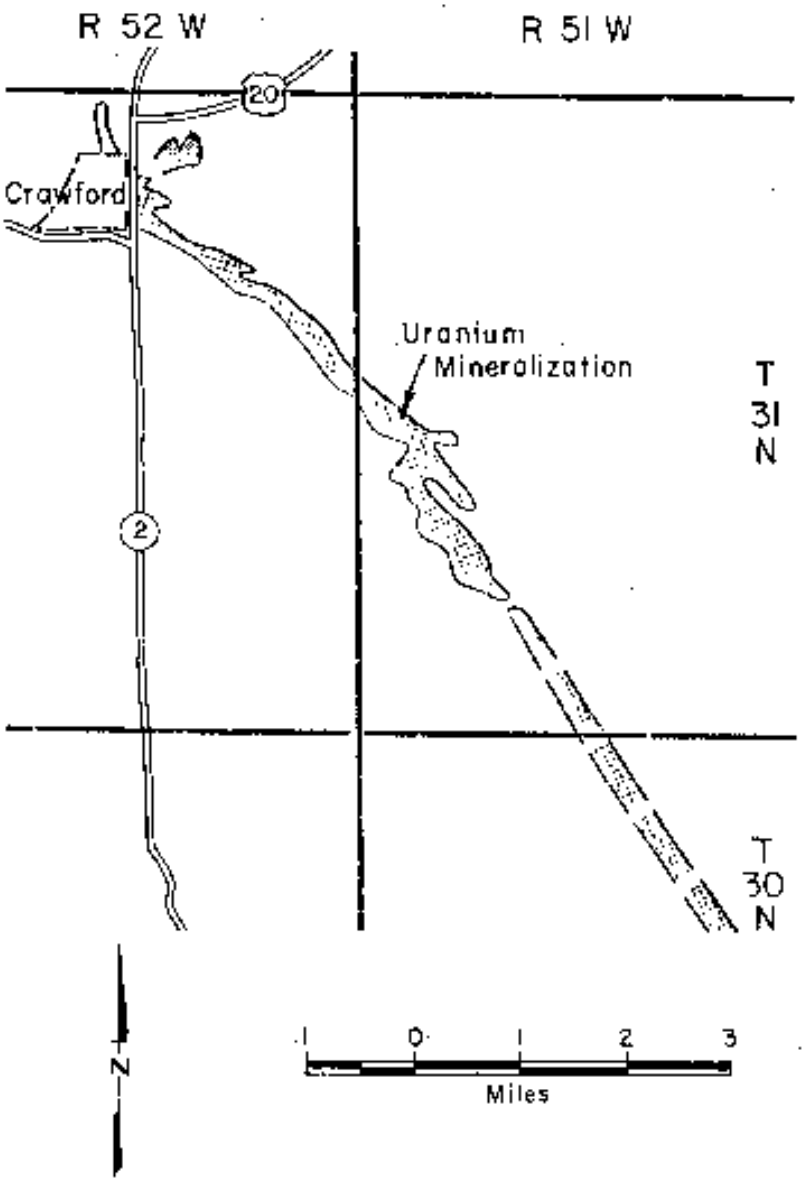


FIGURE 15. Crow Butte Mineralized Trend

At this point, the Crow Butte mineralized trend was determined to be about six miles long and up to 3000 feet wide as defined by a drill hole spacing of 400 feet by 1000 feet in the shallower northern part and 400 feet by 2500 feet along the deeper southern part. Depths to mineralization varied from 275 to 820 feet. Based on 127 holes drilled within the Crow Butte mineralized trend, a news release of January 12, 1981 stated that "probable potential" reserves at the Crow Butte prospect exceeded 25 million pounds U308.

An additional 850 holes drilled during 1981 further defined the grade, thickness and extent of the Crow Butte mineralized trend. The trend was drilled on a 200 foot by 200 foot grid. Ore reserves of the Crow Butte Deposit (Figure 15) calculated following the 1981 drilling indicated over 30 million pounds eU308 in place with an average grade in excess of 0.25% eU308. In addition, chemical analyses of a large number of samples from core holes throughout the deposit indicated that the ratio of chemical uranium to equivalent uranium exceeds 1.20. The only uranium mineral that has been identified to date is coffinite, a uranium silicate.

Reconnaissance drilling during 1982 doubled the known length of the Crow Butte trend; however, drill hole spacing is too wide to calculate additional reserves. Detailed drilling on a 50 to 100 foot spacing confirmed that the 200 foot grid was adequate for reserve calculations and defined an area for a pilot solution mining operation. Baseline environmental data were also gathered during 1982 for research and development permits to operate the pilot solution mine. Permit applications were submitted during February and April of 1983 to the Nuclear Regulatory Commission and the Nebraska Department of Environmental Control respectively.

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Home Uranium Back