2.4 REGIONAL HISTORIC, ARCHEOLOGICAL, ARCHITECTURAL, SCENIC AND NATURAL LANDMARKS

2.4.1 Historic, Archeological, and Cultural Resources

Previous cultural resource investigations in the general area surrounding Crawford indicate that a variety of prehistoric and historic resources of potential significance exist in the vicinity. Resources include the Hudson-Meng prehistoric bison kill to the north of the area, several prehistoric camps and artifact scatters in the general areas, fur-trade period sites associated with the early history of Chadron, Fort Robinson to the west of Crawford, the Sidney-Deadwood Trail, the two historic railroads that cross where the town of Crawford emerged, and the town of Crawford itself. There has been extensive farming around Crawford, which may have disturbed many earlier sites, but has also created historic farming sites and features.

The proposed North Trend Expansion Area is on private lands north of the town of Crawford. An architectural and structural properties search was completed at the Nebraska State Historic Preservation Office and an archaeological site search was completed at the Archaeology Division of the Nebraska State Historical Society in July 2004. No previous cultural resources inventories have been documented for this area and the State Historic Preservation Office has no record of documented standing structures in the area. Two sites, one historic (25DW501) and one prehistoric (25DW73), in the general vicinity were identified in the archeological site search. The historic site is the ruins of the Hall Brothers Mill near the southeast edge of the Expansion Area along the White River. The prehistoric site is a reported Indian camp, also southeast of the Expansion Area. Information on the prehistoric site is scanty. Both of these sites were reported as being outside the assessment area. There are no reported National Register Properties or National Natural Landmarks in the vicinity of the project.

On April 30, 2004 letters identifying the nature and location of the proposed project were sent to the Nebraska Commission on Indian Affairs and the following 13 tribes: the Apache Tribe of Oklahoma; the Cheyenne River Sioux Tribe; the Cheyenne and Arapaho Tribes of Oklahoma; the Crow Creek Sioux Tribe; the Crow Nation; the Kiowa Tribe of Oklahoma; the Lower Brule Sioux Tribe; the Northern Arapaho Tribe; the Northern Cheyenne Tribe; the Oglala Sioux Tribe; the Pawnee Nation of Oklahoma; the Rosebud Sioux Tribe; and the Standing Rock Sioux Tribe. Follow up telephone calls were made in June to verify that the information had reached the appropriate persons in each tribe and to ask whether the tribes had any concerns about the project or were aware of any traditional concerns in the immediate vicinity of the project. Harvey Whitewoman of the Oglala Sioux called before the follow up calls were begun to ask what effect the proposed project might have on water quality. No other tribal concerns were identified.

The identification and assessment of cultural resources within the North Trend Expansion Area involved a single cultural resource inventory of a 1,190-acre area of anticipated development. This area was inventoried by Greystone (now ARCADIS) archaeologists from August 16 through August 18, 2004 (Späth 2006). A 2,680-acre license area was defined, and a 1,190-acre archaeological review area was defined within that license boundary. (The size of the proposed license area has been reduced since 2004 to approximately 2,110 acres.) The archaeological review area was surveyed for the presence of cultural resources that may be impacted by the proposed mine development. Three historic sites and three isolated prehistoric artifacts were located and identified. The historic sites are the ruins of an abandoned farm complex (25DW296), an occupied farm complex (25DW297), and a refuse disposal area (25DW298). The individual artifacts are an early historic (1860s to 1870s) metal trade point (25DW299), a chert core (25DW300), and a Plains Archaic chert point fragment (25DW301). These resources are not likely to yield information important in prehistory or history and are considered not eligible for the National Register of Historic Places. Because these resources are considered not eligible, they are not historic properties. The proposed North Trend Expansion will have no effect on historic properties, and no further cultural resource work is recommended. The Nebraska State Historic Preservation Officer (SHPO) has concurred that the reported resources are not eligible for the National Register of Historic Places and that the proposed project will not affect archaeological, architectural, or historic context properties (Steinacher and Puschendorf 2006).

Appendix A to this application contains a copy of the Cultural Resource Inventory Report and supporting correspondence including the Nebraska SHPO concurrence letter and the correspondence to the tribal authorities. Appendix B, Site Location Map and Appendix C, Site Forms from the Cultural Resource Inventory Report contain information that falls under the confidentiality requirement for archeological resources under the National Historic Preservation Act, Section 304 (16 U.S.C. 470w-3(a)). Additionally, disclosure of this information is protected under Nebraska State Statute Section 84-712.05 (13 and 14). Accordingly, disclosure is specifically exempted by statute as specified in 10 CFR §2.390(a)(3). Therefore, CBR requests that all portions of Appendices B and C remain "CONFIDENTIAL" for the purpose of Public Disclosure of this application. Each page of the protected cultural resource information has been marked as follows:

Confidential Information Submitted under 10 CFR 2.390

The cover pages for each of these appendices have been marked with a more detailed statement, as follows:

Confidential Information Submitted under 10 CFR 2.390
Disclosure is Limited Under the National Historic Preservation Act, Section 304 (16 U.S.C. 470w-3(a)), and under the Nebraska Public Records Statutes (Neb. Rev. Stat. 84-712.05(13)).

All addenda are included in Volume II of this Technical Report and must be kept confidential.

2.4.2 Scenic Resources

2.4.2.1 Introduction

The North Trend Expansion Area is on private land that is not managed to protect scenic quality by any public agency. However, it is located in scenic landscape of the Pine Ridge area of northwestern Nebraska and is visible from sensitive viewing areas. The existing landscape and the visual effect of the proposed facilities have been inventoried and assessed for the proposed project using the Bureau of Land Management (BLM) Visual Resource Management (VRM) system.

2.4.2.2 Methods

The VRM system is the basic tool used by the BLM to inventory and manage visual resources on public lands. The VRM inventory process involves rating the visual appeal of a tract of land, measuring public concern for scenic quality, and determining whether the tract of land is visible from travel routes or observation points.

The scenic quality inventory was based on methods provided in BLM Manual 8410 – *Visual Resource Inventory*. The key factors of landform, vegetation, water, color, influence of adjacent scenery, scarcity, and cultural modifications were evaluated according to the rating criteria, and provided with a score for each key factor. The criteria for each key factor ranged from high to moderate to low quality based on the variety of line, form, color, texture, and scale of the factor within the landscape. A score was associated with each rating criteria, with a higher score applied to greater complexity and variety for each factor in the landscape. The results of the inventory and the associated score for each key factor are summarized in Table 2.4-1. According to NUREG-1569; 2.4.3(7), if the visual resource evaluation rating is 19 or less, no further evaluation is required. The total score of the scenic quality inventory is 13; however, an analysis was prepared to reflect the growing concern some residents may have for the scenic resource, as Dawes County is expected to continue to develop tourism in the region.

TABLE 2.4-1
SCENIC QUALITY INVENTORY AND EVALUATION FOR THE NORTH TREND EXPANSION AREA

Key Factor	Rating Criteria	Score
Landform	Flat to rolling terrain with no interesting landscape features	1
Vegetation	Some variety of vegetation; cropland, range, riparian	3
Water	Water is present, but not evident as viewed from residences and roads	0
Color	Some variety in colors and contrasts with vegetation and soil.	3
Influence of adjacent scenery	Buttes of Fort Robinson State Park provide a scenic backdrop	5
Scarcity	Landscape is common for the region	1
Cultural modifications	Existing modifications are agricultural, and introduce no discordant elements.	0
	Total Score	13

Visual Resource Management Classes

The elements used to determine the visual resource inventory class are the scenic quality, sensitivity levels, variety classes, and distance zones. Each of the elements used to identify the VRM Class is defined below:

Scenic Quality - Scenic quality is a measure of the visual appeal of a tract of land. In the visual resource inventory process, public lands are assigned an A, B, or C rating based on the apparent scenic quality, which is determined using seven key factors: landform, vegetation, water, color, adjacent scenery, scarcity, and cultural modifications. During the rating process, each of these factors is ranked comparatively against similar features within the physiographic province.

Sensitivity Level – A degree or measure of viewer interest in the scenic qualities of the landscape. Factors to consider include 1) type of users; 2) amount of use; 3) public interest; 4) adjacent land uses; and 5) special areas. Three levels of sensitivity have been defined:

- Sensitivity Level 1 – The highest sensitivity level, referring to areas seen from travel routes and use areas with moderate to high use.

- Sensitivity Level 2 – An average sensitivity level, referring to areas seen from travel routes and use areas with low to moderate use.

- Sensitivity Level 3 – The lowest sensitivity level, referring to areas seen from travel routes and use areas with low use.

Distance Zones – Areas of landscapes denoted by specified distances from the observer, particularly on roads, trails, concentrated-use areas, rivers, etc. The three categories are foreground-middleground, background, and seldom seen.

- Foreground-Middleground – The area visible from a travel route, use area, or other observer position to a distance of 3 to 5 miles. The outer boundary of this zone is defined as the point where the texture and form of individual plants are no longer apparent in the landscape and vegetation is apparent only in pattern or outline.

- Background - The viewing area of a distance zone that lies beyond the foreground and middleground. This area usually measures from a minimum of 3 to 5 miles to a maximum of about 15 miles from a travel route, use area, or other observer position. Atmospheric conditions in some areas may limit the maximum to about 8 miles or increase it beyond 15 miles.

- Seldom Seen – The area is screened from view by landforms, buildings, other landscape elements, or distance.

The visual resource inventory classes are used to develop visual resource management classes, which are generally assigned by the BLM through the resource management plan process. VRM objectives are developed to protect scenic public lands, especially those lands that receive the greatest amount of public viewing. The following VRM classes are objectives that outline the amount of disturbance an area can tolerate before it no longer meets the visual quality of that class.

- Class I Objective: To preserve the existing character of the landscape. The level of change to the characteristic landscape should be very low and must not attract attention.

- Class II Objective: To retain the existing character of the landscape. The level of change to the characteristic landscape should be low.

- Class III Objective: To partially retain the existing character of the landscape. The level of change to the characteristic landscape should be moderate.

- Class IV Objective: To provide for management activities which require major modification of the existing character of the landscape. The level of change to the characteristic landscape can be high.

The Scenic Quality, Sensitivity Level, and Distance Zone inventory levels are combined to assign the VRM Class to inventoried lands as shown in the following matrix:

Determining BLM Visual Resource Inventory Classes							
Visual Sensitivity		**High**			**Medium**			**Low**
Special Areas		I	I	I	I	I	I	I
Scenic Quality	A	II	II	II	II	II	II	II
	B	II	III	III/IV	III	IV	IV	IV
	C	III	IV	IV	IV	IV	IV	IV
Distance Zones		f/m	b	ss	f/m	b	ss	ss

f/m = foreground-middleground
b = background
ss – seldom seen

2.4.2.3 Affected Environment

The Pine Ridge country that surrounds the North Trend Expansion Area features diverse and beautiful scenery that provides a setting for a variety of recreational activities as well as agricultural and other land uses. Rugged, white buttes rise up to 1,000 feet over stands of deep green Ponderosa Pine. The buttes are surrounded by flat to rolling plains dissected by the White River and its various tributaries. Riparian vegetation along waterways includes a large variety of trees, shrubs, and grasses.

The North Trend Expansion Area is located on rolling plains with a backdrop of the spectacular buttes of Fort Robinson State Park located west of the project area. The North Trend Expansion Area landscape is rural and agricultural in character, and is composed primarily of scenery that is common for the region. The landscape colors are dominated by tan, gold, and green vegetation; and the tan soils. Riparian vegetation along the White River and Spring Creek exhibits considerable variety in form, texture, and color. Dark to light green colors and a variety of forms and textures of the riparian vegetation provide

pleasing contrasts to the flat, horizontal lines of the surrounding agricultural land in the project area.

Land use in the project area is dominated by crop production, primarily wheat. Grazing occurs on all lands not cultivated for crops, including riparian areas.

2.4.2.4 North Trend Visual Inventory

Most of the North Trend Expansion Area is characterized by the low, rolling plains and agricultural land uses that are typical of the Pine Ridge area in northwestern Nebraska. The scenic quality of the project area is common, or Class B. Class A landscapes consisting of the rugged buttes of the Fort Robinson State Park are visible to the west and southwest of the project area. The buttes provide a scenic backdrop to the project area that is visible to travelers on Nebraska State Highway (SH) 2/71, which forms the east boundary of the project area.

2.4.2.4.1 Sensitive Viewing Areas

There are sensitive viewing areas on SH 2/71 and in the Crawford Cemetery. The entire project area is within 5 miles of views from SH 2 and the cemetery, which places the area in the foreground – middleground distance zone. In general, residents and other users of the region are accustomed to viewing human modification in the rural landscape, but could be sensitive to increased levels of development.

The greatest number of viewers of the proposed facilities would be traveling on SH 2/71. The annual average daily traffic (AADT) on SH 2/71 north of Crawford for the year 2002 was 635 vehicles. Travelers on SH 2/71 include local traffic, vehicles traveling through the region, and visitors to local scenic, historic, and recreational attractions. The highway provides access to nearby Fort Robinson State Park, as well as other destination sites in the region (see discussion of local recreation in section 2.2.2, Land Use). Some motorists exposed to the landscape would have a concern for scenic quality, and would be sensitive to modifications to the landscape.

Most of the project area is screened from views of motorists by the terrain. The rolling terrain consists of gentle ridges that trend in an east-west direction, which is approximately perpendicular to SH 2/71. The ridges block much of the interior of the project area from SH 2/71 north of the project area. In addition, the project area is at a higher elevation than the highway to the south, so that it is not visible to northbound travelers south of the highway until they reach the project area boundary. Most of the project area is in the seldom-seen distance zone of viewers on SH 2/71 to the north and south of the project area. However, a short segment of highway located at the southbound

lane on the downside of a high point of elevation about 3,200 feet north of the Crawford Cemetery provides a panoramic view of the interior project area. This highway segment has a large area of unimpeded views with the greatest potential for extended viewing times.

The Crawford Cemetery, which is located at the east-central boundary of the project area, provides views of the central interior of the project area to cemetery visitors. Unimpeded views of the project area span from the west boundary of the Crawford Cemetery, approximately midway between the north and south boundaries. The viewpoint provides a panoramic view of the project area that would be seen by visitors who are in the west side of the cemetery. Views from the central and eastern portions of the cemetery would be blocked to some degree by trees that are distributed throughout the cemetery.

The level of use at these viewing areas is low to moderate, or a Sensitivity Level 2. Viewers at isolated rural residences with views of the project area are few compared with viewers at other sensitive viewing areas, but these residents would generally have a strong level of concern for changes in the viewshed.

2.4.2.4.2 VRM Class

Based on the project area Class B scenic quality, the Sensitivity Level 2 as viewed from SH 2/71 and the Crawford Cemetery, and the location of the project area in the foreground-middleground distance zone as seen from the sensitive viewing areas, the North Trend Expansion Area has been assigned Class III for both the visual resource inventory and the VRM objective.

2.4.2.5 Environmental Consequences

The visible surface structures proposed for the North Trend Expansion Area include wellhead covers, wellhouses, electrical distribution lines, and one satellite processing plant. The project will use existing and new roads to access each wellhouse and the satellite plant.

Each wellhead cover would consist of a weatherproof structure placed over each well. Each structure would be approximately 3 feet high and 2 feet in diameter. Each wellhouse consists of a small shed. The plant building would be approximately 100 feet by 130 feet in size. A permanent disturbance area around each wellhouse would be sized to provide an adequate vehicle turn-around. There would be an estimated 10 to 12 wellhouses on the new site.

Electric distribution lines would connect wellhouses to existing electric distribution lines. The distribution poles would be approximately 20 feet high. The poles would be wooden so that their natural color harmonizes with the landscape.

2.4.2.5.1 Short-term Effects

Temporary and short-term effects during the construction period to the visual character of the landscape at each well pad would result from wellhouse construction, well drilling, and associated construction of ancillary facilities, such as access roads and electric distribution lines. Drilling and other construction activities would typically occur 8 to 12 hours per day during the regular work week.

Following completion of facility installation, temporary disturbance areas would be reclaimed to pre-construction conditions. Only permanent disturbances associated with operations and maintenance of the facilities will remain following post-construction restoration.

2.4.2.5.2 Long-term Effects

Long-term effects for the project would result from the addition of structures to the landscape, such as the satellite plant, wellhouses, wellhead covers, and associated access roads and electric distribution lines. Effects from long-term activities would occur over the production life of the project.

Project development would alter the physical setting and visual quality of portions of the landscape, which would affect the overall landscape to some degree, as viewed from sensitive viewing areas. The proposed facilities would introduce new elements into the landscape and would alter the existing form, line, color, and texture, which characterize the existing landscape. The project would primarily affect croplands.

In foreground-middleground views, the satellite plant, wellhouses, and associated access road clearings would be the most obvious features of development. Clearings and access roads would be visible as light-tan exposed soils in geometrically-shaped areas with straight, linear edges that provide some textural and color contrasts with the surrounding cropland. The satellite plant, wellhouses, and wellhead covers would be painted to harmonize with the surrounding soil and vegetation cover. These facilities would be visible from SH 2 and the Crawford Cemetery, but would be subordinate to the rural landscape. Most of the occupied housing units are located near the south end of the project area, and would be screened from views of the facilities by riparian vegetation along the White River.

The electric distribution line poles would be an estimated 20 feet tall, and would be located throughout the project area to connect wellhouses with existing lines. The distribution lines are similar in appearance to those typical of the rural landscape, but would occur at a higher density than on adjacent lands. The lines would be obvious to viewers at the sensitive viewing areas, but would not change the rural character of the existing landscape.

Wellhead covers would be difficult to discern in the landscape from any sensitive viewing area. The form and textural contrast would be very weak because the relatively low profile (3 feet high) and small size of the facilities would disappear into the surrounding textures of soil and vegetation. Generally, color contrasts are most likely to be visible in foreground-middleground distance zone. However, the wellhead covers would be painted a tan color that would harmonize with the surrounding vegetation and soil colors. Therefore, contrast of line, form, texture, and color would be low. The facilities would not be noticeable to the casual observer. Wellhead covers would be visually subordinate to the landscape in foreground-middleground distance zone.

The objective of VRM Class III is to partially retain the existing character of the landscape. The level of change to the characteristic landscape should be moderate. The existing rural/agricultural landscape would be retained, but would be modified with a noticeable, but minor, industrial component. Line and textural contrasts of the well houses, the plant, and associated access roads and distribution lines would be visible from sensitive viewing areas; however, contrasts would be low to moderate. The VRM Class III objectives would be met by proposed long-term project facilities.

2.4.2.6 Mitigation

Mitigation measures are meant to minimize adverse contrasts of project facilities with the existing landscape. The measures should be applied to all facilities, even those that meet VRM objectives. Mitigation would enable proposed project facilities to harmonize with the surrounding landscape to the extent feasible.

In addition to selecting paint colors that harmonize with the surrounding landscape, several other measures would minimize adverse effects of project facilities in the landscape.

- Using existing vegetation and topographic features to screen wells, facilities, and roads;

- Painting facilities with non-reflective paint that harmonizes with the surrounding landscape;

- Avoiding straight line-of-sight road construction;

- Aligning roads with the contours of the topography rather than cutting straight across contours to well houses, although this method of aligning the roads may result in a greater area of disturbance;

- Constructing clearings to appear as natural clearings by rounding corners and feathering the vegetation interface between the clearing and the surrounding grasses and shrubs (In those areas where the existing vegetation is dense, clearings should be irregular in shape); and

- Removing construction debris immediately because it creates undesirable textural contrasts with the landscape.

In general, resource protection measures proposed for erosion control, road construction, rehabilitation and revegetation, and wildlife protection would mitigate effects to visual quality.

2.4.2.7 References

Späth, Dr. Carl. 2006. *Crow Butte Resources North Trend Expansion Area Class III Cultural Resource Inventory, Dawes County, Nebraska*, February 2006,

Steinacher, Terry, and L. Robert Puschendorf. 2006. *Crow Butte Resources North Trend Expansion, Dawes Co., NE, H.P. #0603-040-01*. Letter to Dr. Carl Spath from the Nebraska State Historical Society, 21 March 2006.

U.S.D.I., Bureau of Land Management (BLM). 1986. *Visual Resource Contrast Rating*. BLM Manual Handbook 8431-1.

U.S.D.I., Bureau of Land Management (BLM). 1986. *Visual Resource Inventory*. BLM Manual Handbook 8410-1.

Nebraska Department of Roads, 2003. *2002 NE Highway Traffic Flow Map*. [web page] located at: http://www.nebraskatransportation.org/maps/#traffvol Accessed: 6/15/04.

2.5 METEOROLOGY

2.5.1 Introduction

This section describes the meteorological conditions in the region surrounding the Crow Butte Project and the North Trend Expansion Area. The data presented in this section were used to determine the effect of the local climate on the development area. The joint frequency data can be used to assess the atmospheric dispersion characteristics present in the region.

Data sources for the meteorological conditions used for this report come from the High Plains Regional Climatic Center (HPRCC) for a site located in Chadron, Nebraska (HPRCC 2004) and from an on-site monitoring station near the Crow Butte facility. The period of record for the HPRCC data covers 56 years of observation between 1948 and 2003. The on-site monitoring data were collected between May 1982 and April 1984, and include temperature, precipitation, evaporation, wind speed, and wind direction. Data are also included from the National Weather Service Stations in Scottsbluff, Nebraska and Rapid City, South Dakota.

The North Trend Expansion Area is located in Dawes County (in the north central portion of the Nebraska panhandle), which shares its northern border with South Dakota. The weather patterns are typical of a semi-arid, continental climate. This climate is characterized by warm summers, cold winters, light precipitation, and frequent changes in the weather.

The Rocky Mountains, located to the west of the site, and the Black Hills, located to the north, effectively block moisture from these directions, while moisture from the south is directed eastward by a plateau south of the region. As a result of this topography, the project area is generally drier than the rest of the panhandle.

The HPRCC data were collected at the Chadron 1 NW site (latitude 42° 50' north, longitude 103° 01' west with a ground elevation of 1021 m [3350 ft] above mean sea level). The monitor is 1.4 km (0.9 miles) west northwest of Chadron, 37 km (23 miles) east northeast of Crawford, and 35 km (22 miles) east northeast of the proposed license area.

2.5.2 Temperature

Table 2.5-1 shows the mean daily maximum and minimum temperatures as well as the mean monthly temperatures. The months of November through March all have mean daily minimum temperatures below freezing, with January as the coldest month.

December, January, and February all have monthly mean temperatures below freezing. The warmest months are July and August. The mean yearly temperature is 8.9°C (48.0°F).

The temperature extremes for the period of record are also given in Table 2.5-1, along with the year of occurrence. These data show that temperatures can exceed 100°F (38°C), and freezing or near-freezing temperatures can occur throughout the year.

Table 2.5-1 summarizes Mean Daily Maximum and Minimum and Mean Monthly Temperature Data for Chadron, Nebraska (From 1948 to 2003).

Table 2.5-2 lists the mean number of days per month with temperatures above or below selected values.

TABLE 2.5-1
MEAN DAILY MAXIMUM AND MINIMUM AND MEAN MONTHLY TEMPERATURE DATA FOR CHADRON, NEBRASKA

Month	Mean Daily Maximum	Mean Daily Minimum	Mean Monthly	Record High		Record Low	
	(°C)	(°C)	(°C)	(°C)	Year	(°C)	Year
Jan	2.0	-11.8	-4.9	21.1	1989	-33.9	1949
Feb	5.0	-9.2	-2.1	24.4	1982	-32.8	1982
Mar	8.9	-5.4	1.8	28.3	1967	-32.2	1989
Apr	15.1	0.2	7.7	33.9	1989	-23.9	1975
May	20.9	6.3	13.6	36.7	1969	-8.9	1954
June	27.1	11.6	19.3	41.7	1989	-3.3	1969
July	31.8	15.2	23.5	43.3	1954	3.3	1971
Aug	31.3	14.3	22.8	42.2	1980	2.2	1962
Sept	25.3	8.1	16.7	40.0	1978	-8.3	1984
Oct	18.2	1.3	9.7	34.4	1953	-21.7	1991
Nov	8.9	-5.4	1.8	27.2	1999	-27.8	1959
Dec	3.6	-10.1	-3.3	22.2	1980	-40.0	1989
Year	16.5	1.2	8.9	43.3	Jul-54	-40.0	Dec-89

Source: HPRCC

TABLE 2.5-2
TEMPERATURE OCCURRENCES FOR CHADRON, NEBRASKA
(FROM 1948 TO 2003)

Month	Mean Number of Days with Maximum Temperatures		Mean Number of Days with Minimum Temperatures	
	> 32.2°C	< 0°C	< 0°C	< -17.8°C
Jan	0.0	11.4	30.1	7.5
Feb	0.0	7.8	26.7	4.3
Mar	0.0	4.7	26.2	1.7
Apr	0.1	0.8	15.4	0.0
May	0.9	0.0	2.9	0.0
June	6.0	0.0	0.1	0.0
July	15.9	0.0	0.0	0.0
Aug	15.6	0.0	0.0	0.0
Sept	5.6	0.0	1.9	0.0
Oct	0.3	0.5	12.4	0.1
Nov	0.0	4.5	25.6	1.0
Dec	0.0	9.1	29.6	4.7
Year	44.3	38.7	170.8	19.3

Source: HPRCC

The average date of the last yearly 0°C (32°F) temperature is May 18 while the first fall freeze is expected on September 18. The average growing season is 120 to 130 days long (USDA 1981). These are average values, and the exact occurrence of freezing temperatures depends on exposure.

2.5.3 Precipitation

Precipitation in the region is generally light, with the heaviest occurrences in the spring and summer. Table 2.5-3 lists the monthly precipitation totals for the period of record. May has the heaviest precipitation, with good precipitation occurring through July. The driest months are November through February. The mean yearly precipitation is 40.79 cm (16.06 in). The maximum 24-hour precipitation events are also listed in Table 2.5-3.

The monthly mean and maximum snowfalls for the period of record are listed in Table 2.5-3. The mean annual snowfall is 107.44 cm (42.30 in). July and August are the only two months without a reported snowfall. The maximum mean monthly snowfall occurred in March.

Precipitation data from the National Oceanic and Atmospheric Administration (NOAA) was also reviewed. The site in Scottsbluff, Nebraska is 98 km (60.9 mi) south of the license area and the site in Rapid City, South Dakota is 158 km (98.2 mi) north of the license area. These data indicate that precipitation in excess of 0.03 cm (.01 in) can be expected on an average of 91 and 96 days per year, respectively. These data are listed in Table 2.5-4.

Tornadoes are rare. In the USNRC, "Draft Generic Environmental Impact Statement on Uranium Milling", (USNRC 1979) the authors calculated a mean annual frequency of 0.6 for tornadoes in intensity Category I at Rapid City. The annual probability of occurrence at this location is 4.8 x 10^{-4}. A tornado in intensity Category I has a rotational speed of 134 meters per second (m/s) and a translational speed of 26 m/s.

TABLE 2.5-3
MEAN AND MAXIMUM PRECIPITATION DATA FOR CHADRON, NEBRASKA (FROM 1948 TO 2003)

Month	Water Equivalent		Snow Fall	
	Mean	Maximum 24-Hour	Mean	Maximum Monthly
	(cm)	(cm)	(cm)	(cm)
Jan	1.12	2.72	16.51	88.14
Feb	1.17	3.81	16.51	59.69
Mar	2.16	3.51	21.84	88.14
Apr	4.47	6.22	13.21	49.28
May	7.52	6.50	1.52	23.62
June	7.14	5.38	0.00	3.05
July	5.41	5.08	0.00	0.00
Aug	3.48	4.62	0.00	0.00
Sept	3.66	11.18	0.76	25.40
Oct	2.36	3.81	5.59	28.45
Nov	1.24	1.78	13.21	42.93
Dec	1.04	1.80	17.78	46.99
Year	40.79	11.18	107.44	196.85

Source: HPRCC

TABLE 2.5-4
PRECIPITATION EVENTS (1982 - 1990)

Month	Mean Number of Days with Precipitation	
	Scottsbluff, NE	Rapid City SD
January	5.4	5.4
February	5.4	6.2
March	7.3	9.2
April	9.2	8.0
May	12.0	10.8
June	9.2	11.3
July	8.6	8.3
August	8.2	8.6
September	8.0	8.3
October	5.3	6.6
November	6.6	6.2
December	6.2	6.8
Year	91.4	95.7
Period of Record (years)	9	9

Source: NOAA 1993

2.5.4 Humidity

Relative percent humidity at the Scottsbluff and Rapid City weather stations is given in Table 2.5-5. The humidity at 0500, 1100, 1700, and 2300 hours is listed. Both locations have about the same humidity during the night; but in the early morning, Scottsbluff is slightly more humid. By noon and throughout the afternoon, Scottsbluff becomes less humid than Rapid City. These data indicate that humidity differences are slight and the humidity at the license area can be expected to be similar to these locations.

TABLE 2.5-5
PERCENT RELATIVE HUMIDITY DATA (FROM 1982 - 1990)

Month	0500 Hours		1100 Hours		1700 Hours		2300 Hours	
	NE[a]	SD[b]	NE	SD	NE	SD	NE	SD
January	72.0	67.7	54.3	55.7	53.4	61.0	68.3	67.0
February	75.0	71.0	52.6	54.8	47.6	56.1	70.0	70.0
March	76.0	76.2	50.9	56.3	44.1	54.9	68.4	73.7
April	75.3	70.6	42.9	44.9	39.1	43.2	65.0	65.1
May	80.3	75.4	44.4	49.2	41.2	47.5	68.8	70.8
June	80.0	77.0	43.0	49.8	38.4	46.1	66.8	71.3
July	81.1	72.3	40.7	41.3	35.1	37.8	65.4	62.8
August	82.6	73.4	42.6	41.3	37.2	36.8	69.2	64.7
September	79.5	71.9	42.7	44.1	37.8	42.0	68.0	65.8
October	76.6	69.7	43.4	45.2	40.9	48.2	67.6	66.4
November	76.2	72.3	51.2	54.3	53.9	60.5	71.3	70.9
December	76.1	69.1	57.4	56.6	59.6	63.3	73.4	68.1
Year	77.6	72.2	47.2	49.5	44.0	49.8	68.5	68.1
Period of Record (years)	9	9	9	9	9	9	9	9

Source: NOAA 1993
a Scottsbluff, NE
b Rapid City, SD

2.5.5 Winds

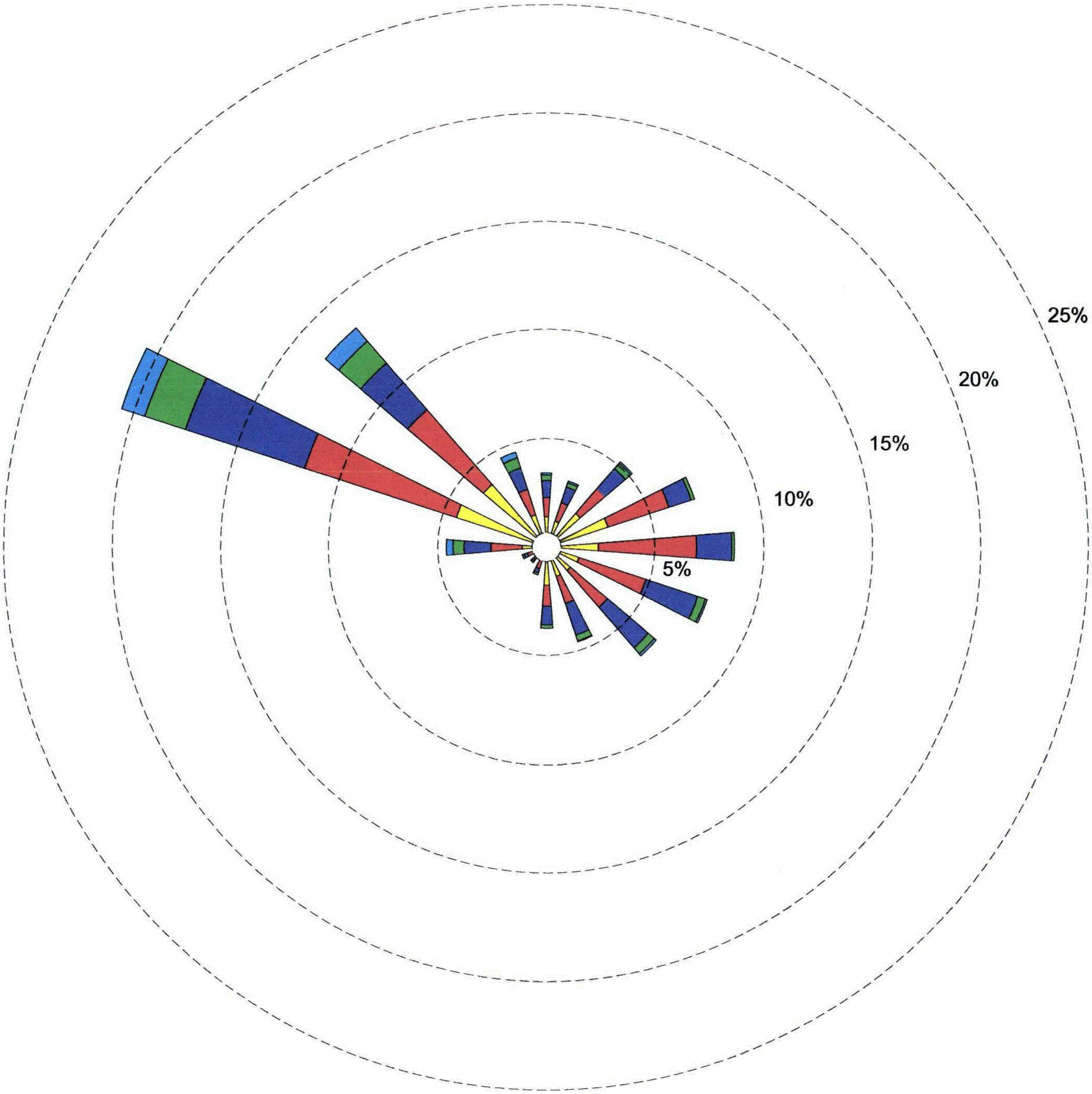
Figure 2.5-1 and Figure 2.5-2 are the wind roses for Scottsbluff, Nebraska and Rapid City, South Dakota, respectively. These figures show predominant wind patterns that are similar; however, the finer details are greatly influenced by the local topography. Rapid City has a predominant wind from the north-northwest while Scottsbluff has a slightly bimodal distribution with the predominant winds from the west-northwest and the east-southeast. The least prevalent wind direction at Scottsbluff and Rapid City is from the southwest.

As shown by the wind rose for the license area in Figure 2.5-3, the predominant air pollutant dispersion would be towards the north to northeast. The next most common directions would be towards the southwest to south-southwest.

Local terrain will have a significant influence on the wind patterns in a given area. Because of this, a meteorological station was installed on the current Crow Butte project

site. This station was capable of measuring wind speed, direction, and the standard deviation of the wind direction. Joint frequency data was compiled from this information. Figure 2.5-3 exhibits the wind rose that was identified for the site and Table 2.5-5 through Table 2.5-12 shows the frequency of winds by direction and speed for the six stability classes. Table 2.5-13 shows the annual relative joint frequency distribution. As shown on Figure 2.5-3, the predominant wind direction of the site is from a south-southwest direction approximately 45 percent of the time. Because of the differences among the site, Rapid City, and Scottsbluff, the two-year Crow Butte site wind record is considered the most representative.

Precipitation was also recorded at the station with a heated tipping bucket rain gauge. Evaporation was measured using a 48" evaporation pan and an evaporation gauge with analog output. The air temperature was also recorded using a precision linear thermistor and fan-aspirated radiation shield. All of the information was recorded on strip chart recorders. In addition, the information was run through a microprocessor and recorded on magnetic tape. The information from the tape was transferred to a computer and then verified by comparison from the strip charts and from visual observation records.



Source: Greystone

Wind Speed (Knots)

- >21
- 17-21
- 11-16
- 7-10
- 4-6
- 1-3

Station: 24028 Scottsbluff, Nebraska		
Avg. Wind Speed	9.69	knots
Percent Calm Winds	3.2	percent
Wind Direction	Blowing From	
Years	1984 - 1990	

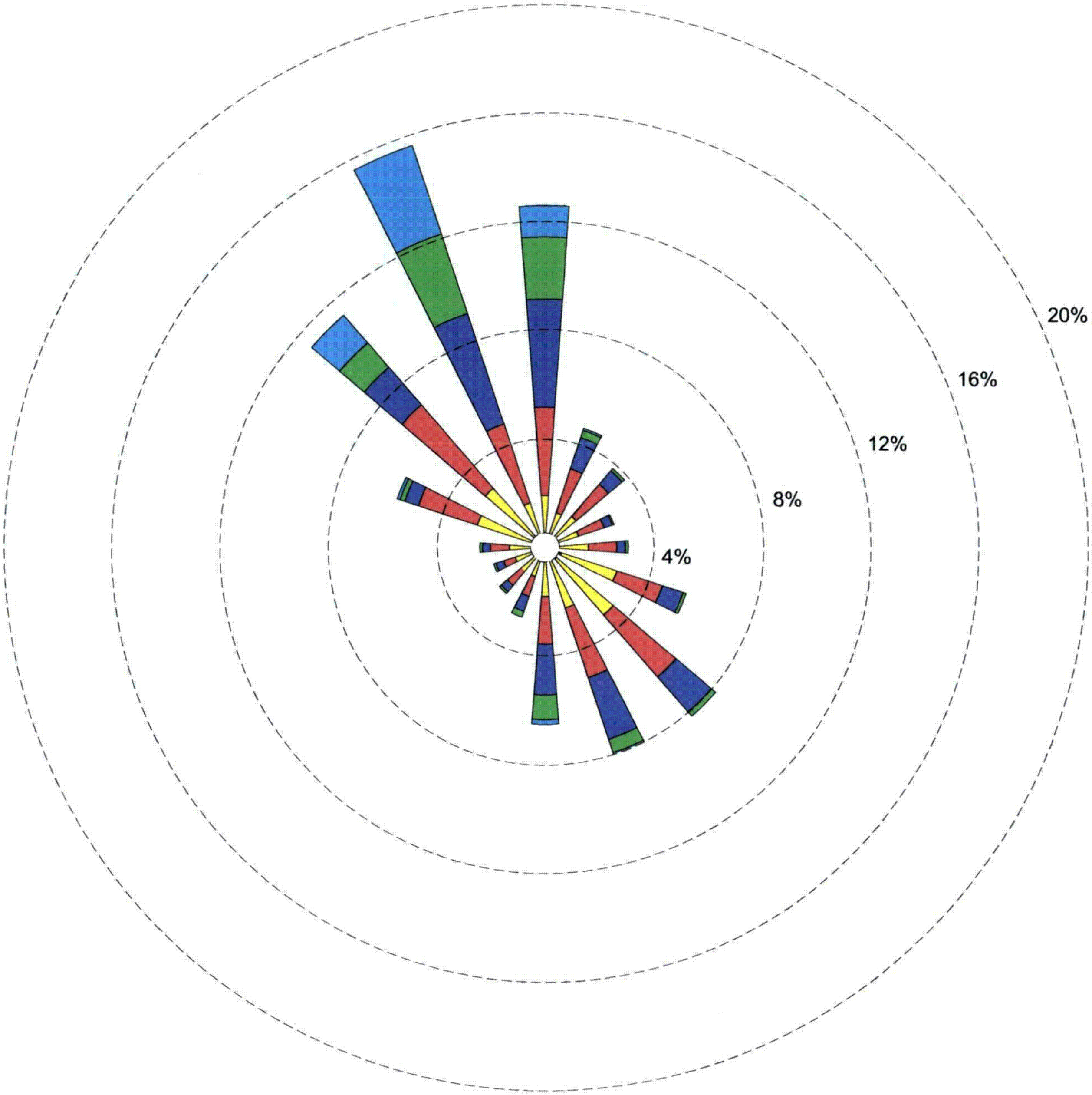
1711-04 cb-wind-rose.dwg

CROW BUTTE PROJECT

DAWES & SIOUX COUNTIES, NEBRASKA

FIGURE 2.5-1
SCOTTSBLUFF SURFACE WINDS

Date: **06/01/04** *Drawn:* **ETC** *Fig.* **2-5-1**



Source: Greystone

Wind Speed (Knots)

- >21
- 17-21
- 11-16
- 7-10
- 4-6
- 1-3

Station: 27090 Rapid City, South Dakota
Avg. Wind Speed 10.49 knots
Percent Calm Winds 2.88 percent
Wind Direction Blowing From
Years 1984 - 1990

1711-04 cb-wind-rose.dwg

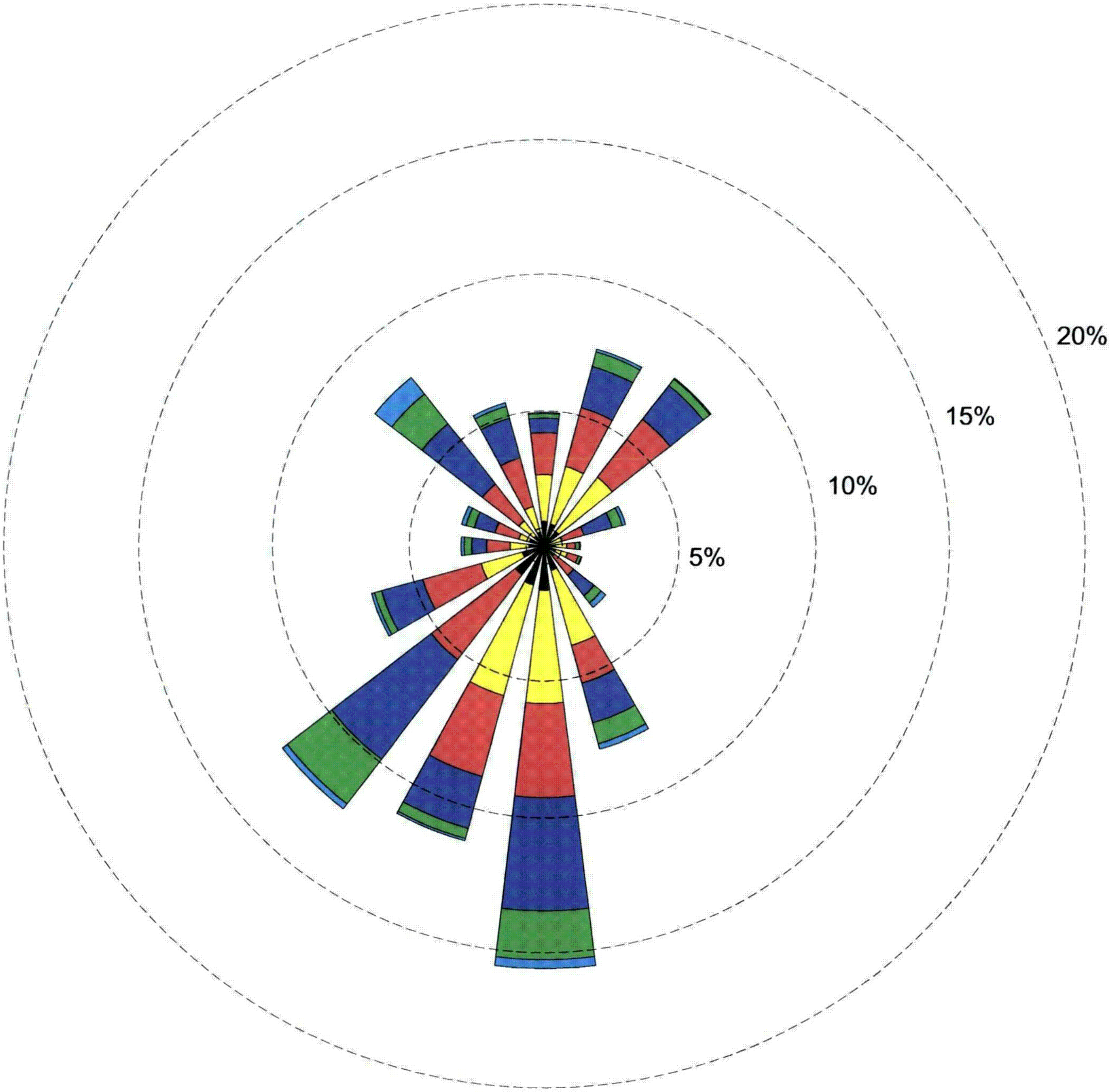
CROW BUTTE PROJECT

DAWES & SIOUX COUNTIES, NEBRASKA

FIGURE 2.5-2 RAPID CITY SURFACE WINDS

NEBRASKA

Date: **06/01/04** *Drawn:* **ETC** *Fig.* **2-5-2**



Source: Greystone

Wind Speed (Knots)

- >21
- 17-21
- 11-16
- 7-10
- 4-6
- 1-3

Avg. Wind Speed	8.40	knots
Percent Calm Winds	0.3	percent
Wind Direction	Blowing From	
Years	May 1982 - April 1984	

CROW BUTTE PROJECT

DAWES & SIOUX COUNTIES, NEBRASKA

FIGURE 2.5-3 CROW BUTTE SURFACE WINDS

NEBRASKA

Date: ***06/01/04*** *Drawn:* ***ETC*** *Fig.* **2-5-3**

1711-04 cb-wind-rose.dwg

TABLE 2.5-6
FREQUENCY OF WINDS BY DIRECTION AND SPEED
(STABILITY A)

Wind Direction	Speed Class Intervals (Knots)							
	1 - 3	3 - 6	6 - 10	10 – 16	16 - 21	>21	All	Mean Speed
N	0.98	8.63	2.62	0.11	0.00	0.00	12.34	4.90
NNE	2.61	8.74	2.95	0.11	0.00	0.00	14.31	4.60
NE	1.64	8.52	1.31	0.00	0.00	0.00	11.47	4.50
ENE	0.66	4.37	0.55	0.00	0.00	0.00	5.58	4.40
E	1.20	1.97	0.77	0.00	0.00	0.00	3.94	4.40
ESE	0.33	0.87	0.22	0.00	0.00	0.00	1.42	4.00
SE	0.98	1.75	1.64	0.00	0.00	0.00	4.37	5.10
SSE	0.44	2.61	1.64	0.11	0.00	0.00	4.70	5.30
S	0.98	3.72	1.53	0.00	0.00	0.00	6.23	5.00
SSW	0.55	1.97	2.08	0.22	0.00	0.00	4.82	6.00
SW	0.77	3.72	1.53	0.00	0.00	0.00	6.02	5.00
WSW	0.66	2.08	1.53	0.00	0.00	0.00	4.27	5.30
W	0.66	1.75	1.75	0.11	0.00	0.00	4.27	5.50
WNW	0.77	1.42	0.98	0.44	0.00	0.00	3.61	5.70
NW	0.66	2.30	1.53	0.11	0.00	0.00	4.60	5.50
NNW	1.53	3.93	1.86	0.44	0.00	0.00	7.76	5.30
ALL	15.32	58.25	24.49	1.65	0.00	0.00	99.71	5.00

Stability Class A
Data Recorded between May 1982 and April 1984
Crow Butte Uranium Project Site, Nebraska
Calm (less than one knot) = 0.3%
Period mean wind speed = 5.0 knots
Percent occurrence for A stability class = 5.6%

TABLE 2.5-7
FREQUENCY OF WINDS BY DIRECTION AND SPEED
(STABILITY B)

Wind Direction	Speed Class Intervals (Knots)							
	1 - 3	3 - 6	6 - 10	10 – 16	16 - 21	>21	All	Mean Speed
N	1.01	2.68	5.53	0.67	0.00	0.00	9.89	6.40
NNE	1.34	3.52	3.77	0.34	0.00	0.00	8.97	5.70
NE	0.92	5.28	5.45	0.50	0.00	0.00	12.15	6.00
ENE	0.84	1.76	2.85	0.25	0.00	0.00	5.70	6.00
E	0.17	0.84	0.75	0.08	0.00	0.00	1.84	6.00
ESE	0.59	0.59	1.09	0.00	0.00	0.00	2.27	5.80
SE	0.08	1.26	2.26	0.25	0.00	0.00	3.85	6.90
SSE	0.67	1.17	2.43	0.50	0.00	0.00	4.77	6.50
S	1.09	1.01	4.02	0.92	0.00	0.00	7.04	7.00
SSW	1.01	2.01	2.26	0.75	0.00	0.00	6.03	6.30
SW	0.92	3.19	2.61	0.59	0.00	0.00	7.21	6.10
WSW	0.59	2.01	2.60	0.84	0.08	0.00	6.12	6.90
W	0.42	1.34	2.35	0.42	0.08	0.00	4.61	7.20
WNW	0.67	1.09	2.10	0.34	0.00	0.00	4.20	6.60
NW	0.25	1.09	4.02	1.09	0.08	0.00	6.53	7.80
NNW	0.42	1.51	4.95	1.68	0.08	0.00	8.64	7.80
ALL	10.99	30.35	48.94	9.22	0.32	0.00	99.82	6.60

Stability Class B
Data Recorded between May 1982 and April 1984
Crow Butte Uranium Project Site, Nebraska
Calm (less than one knot) = 0.2%
Period mean wind speed = 6.5 knots
Percent occurrence for B stability class = 7.4%

TABLE 2.5-8
FREQUENCY OF WINDS BY DIRECTION AND SPEED
(STABILITY C)

Wind Direction	Speed Class Intervals (Knots)							
	1 - 3	3 - 6	6 - 10	10 – 16	16 - 21	>21	All	Mean Speed
N	0.74	1.54	2.68	0.74	0.00	0.00	5.70	6.70
NNE	0.63	2.62	2.90	0.85	0.00	0.00	7.00	6.60
NE	0.91	2.28	5.69	1.20	0.00	0.00	10.08	7.00
ENE	0.46	1.03	2.96	0.97	0.00	0.00	5.42	7.30
E	0.00	0.57	0.74	0.28	0.00	0.00	1.59	7.60
ESE	0.23	0.34	0.91	0.23	0.00	0.00	1.71	7.00
SE	0.17	0.68	1.82	0.74	0.00	0.00	3.41	7.70
SSE	0.46	0.74	2.22	1.48	0.00	0.00	4.90	8.00
S	0.97	1.65	5.30	2.28	0.00	0.00	10.20	7.70
SSW	1.14	3.02	3.93	0.97	0.00	0.00	9.06	6.60
SW	1.03	3.36	4.67	1.14	0.11	0.00	10.31	6.80
WSW	0.97	3.02	3.59	1.14	0.06	0.06	8.84	6.80
W	0.11	0.91	1.99	1.03	0.11	0.00	4.15	8.40
WNW	0.17	0.51	1.03	1.25	0.06	0.00	3.02	9.10
NW	0.40	0.74	3.70	2.22	0.06	0.00	7.12	8.70
NNW	0.40	1.42	3.42	2.11	0.00	0.00	7.35	8.20
ALL	8.79	24.43	47.55	18.63	0.40	0.06	99.86	7.40

Stability Class C
Data Recorded between May 1982 and April 1984
Crow Butte Uranium Project Site, Nebraska
Calm (less than one knot) = 0.2%
Period mean wind speed = 7.4 knots
Percent occurrence for C stability class = 10.8%

TABLE 2.5-9
FREQUENCY OF WINDS BY DIRECTION AND SPEED
(STABILITY D)

Wind Direction	Speed Class Intervals (Knots)							
	1 - 3	3 - 6	6 - 10	10 – 16	16 - 21	>21	All	Mean Speed
N	0.17	0.52	1.14	0.83	0.20	0.02	2.88	9.20
NNE	0.16	1.12	2.34	2.90	0.89	0.19	7.60	10.70
NE	0.13	1.53	2.65	2.72	0.46	0.08	7.47	9.80
ENE	0.04	0.47	0.79	0.50	0.06	0.00	1.86	8.30
E	0.02	0.06	0.28	0.22	0.04	0.00	0.62	9.50
ESE	0.01	0.25	0.35	0.13	0.00	0.00	0.74	7.40
SE	0.06	0.42	0.71	0.52	0.18	0.01	1.90	9.50
SSE	0.13	1.78	1.50	2.60	1.21	0.34	7.56	11.10
S	0.34	1.67	3.58	7.77	3.57	0.58	17.51	12.40
SSW	0.22	1.37	3.82	3.60	0.76	0.12	9.89	10.00
SW	0.17	2.11	5.80	3.80	0.29	0.02	12.19	8.80
WSW	0.17	0.61	2.28	2.74	0.54	0.16	6.50	10.70
W	0.10	0.20	0.64	1.03	0.47	0.19	2.63	12.60
WNW	0.05	0.17	0.91	1.39	0.66	0.28	3.46	13.20
NW	0.05	0.31	1.60	5.13	2.68	1.55	11.32	15.00
NNW	0.04	0.49	1.80	2.34	0.90	0.20	5.77	11.90
ALL	1.86	13.08	30.09	38.22	12.91	3.74	99.90	11.20

Stability Class D
Data Recorded between May 1982 and April 1984
Crow Butte Uranium Project Site, Nebraska
Calm (less than one knot) = 0.1%
Period mean wind speed = 11.2 knots
Percent occurrence for D stability class = 51.3%

TABLE 2.5-10
FREQUENCY OF WINDS BY DIRECTION AND SPEED
(STABILITY E)

Wind Direction	Speed Class Intervals (Knots)							
	1 - 3	3 - 6	6 - 10	10 – 16	16 - 21	>21	All	Mean Speed
N	0.85	2.92	0.65	0.04	0.00	0.00	4.46	4.60
NNE	0.97	2.80	1.82	0.00	0.00	0.00	5.59	5.20
NE	0.97	3.32	1.90	0.08	0.00	0.00	6.27	5.10
ENE	0.45	1.26	0.73	0.00	0.00	0.00	2.44	5.10
E	0.16	0.73	0.20	0.00	0.00	0.00	1.09	4.70
ESE	0.28	0.65	0.45	0.00	0.00	0.00	1.38	4.80
SE	0.49	1.82	0.85	0.12	0.00	0.00	3.28	5.10
SSE	1.70	7.62	1.05	0.08	0.00	0.00	10.45	4.40
S	2.23	11.06	4.34	0.16	0.00	0.00	17.79	5.00
SSW	2.11	10.53	2.80	0.04	0.00	0.00	15.48	4.70
SW	1.78	8.18	5.67	0.12	0.04	0.00	15.79	5.50
WSW	1.05	2.88	2.47	0.04	0.00	0.00	6.44	5.40
W	0.65	0.97	0.36	0.04	0.00	0.00	2.02	4.30
WNW	0.36	0.97	0.81	0.00	0.00	0.00	2.14	5.50
NW	0.45	1.18	0.85	0.20	0.00	0.00	2.68	5.70
NNW	0.61	1.34	0.49	0.00	0.00	0.00	2.44	4.50
ALL	15.11	58.23	25.44	0.92	0.04	0.00	99.74	5.00

Stability Class E
Data Recorded between May 1982 and April 1984
Crow Butte Uranium Project Site, Nebraska
Calm (less than one knot) = 0.2%
Period mean wind speed = 5.0 knots
Percent occurrence for E stability class = 15.2%

TABLE 2.5-11
FREQUENCY OF WINDS BY DIRECTION AND SPEED
(STABILITY F)

Wind Direction	Speed Class Intervals (Knots)							
	1 - 3	3 - 6	6 - 10	10 – 16	16 - 21	>21	All	Mean Speed
N	3.30	1.65	0.00	0.00	0.00	0.00	4.95	2.80
NNE	1.65	1.33	0.00	0.00	0.00	0.00	2.98	3.00
NE	0.95	1.40	0.00	0.00	0.00	0.00	2.35	3.10
ENE	1.40	0.76	0.00	0.00	0.00	0.00	2.16	2.80
E	1.27	0.44	0.00	0.00	0.00	0.00	1.71	2.80
ESE	1.78	1.02	0.00	0.00	0.00	0.00	2.80	2.60
SE	1.72	1.78	0.00	0.00	0.00	0.00	3.50	3.00
SSE	3.75	4.76	0.00	0.00	0.00	0.00	8.51	3.10
S	7.50	12.07	0.00	0.00	0.00	0.00	19.57	3.30
SSW	7.24	13.15	0.00	0.00	0.00	0.00	20.39	3.30
SW	6.48	8.01	0.00	0.00	0.00	0.00	14.49	3.20
WSW	2.73	2.60	0.00	0.00	0.00	0.00	5.33	3.00
W	1.78	1.46	0.00	0.00	0.00	0.00	3.24	2.90
WNW	0.83	0.95	0.00	0.00	0.00	0.00	1.78	3.00
NW	1.33	1.21	0.00	0.00	0.00	0.00	2.64	3.00
NNW	1.33	0.51	0.00	0.00	0.00	0.00	1.84	2.60
ALL	45.04	53.10	0.00	0.00	0.00	0.00	98.14	3.10

Stability Class F
Data Recorded between May 1982 and April 1984
Crow Butte Uranium Project Site, Nebraska
Calm (less than one knot) = 1.8%
Period mean wind speed = 3.1 knots
Percent occurrence for F stability class = 9.7%

TABLE 2.5-12
FREQUENCY OF WINDS BY DIRECTION AND SPEED
(ALL STABILITIES)

Wind Direction	Speed Class Intervals (Knots)							
	1 – 3	3 – 6	6 - 10	10 – 16	16 - 21	>21	All	Mean Speed
N	0.75	1.72	1.53	0.57	0.10	0.01	4.68	6.50
NNE	0.70	2.16	2.24	1.61	0.46	0.10	7.27	8.20
NE	0.57	2.64	2.69	1.57	0.23	0.04	7.64	7.70
ENE	0.37	0.99	1.08	0.38	0.03	0.00	2.85	6.50
E	0.24	0.42	0.35	0.15	0.02	0.00	1.18	6.20
ESE	0.31	0.46	0.44	0.09	0.00	0.00	1.30	5.50
SE	0.35	0.93	0.95	0.38	0.09	0.01	2.71	7.00
SSE	0.81	2.84	1.44	1.55	0.62	0.17	7.43	8.20
S	1.48	4.17	3.45	4.33	1.83	0.30	15.56	9.30
SSW	1.36	4.17	3.09	2.03	0.39	0.06	11.10	7.20
SW	1.21	3.91	4.62	2.13	0.17	0.01	12.05	7.10
WSW	0.70	1.60	2.21	1.60	0.29	0.09	6.49	8.20
W	0.40	0.69	0.87	0.68	0.26	0.10	3.00	8.90
WNW	0.27	0.54	0.91	0.90	0.35	0.14	3.11	10.20
NW	0.32	0.75	1.73	2.99	1.39	0.79	7.97	12.80
NNW	0.40	0.99	1.84	1.58	0.47	0.10	5.38	9.50
ALL	10.24	28.88	29.44	22.64	6.70	1.92	99.72	8.40

Stability Class All
Data Recorded between May 1982 and April 1984
Crow Butte Uranium Project Site, Nebraska
Calm (less than one knot) = 0.3%
Period mean wind speed = 8.4 knots
Percent occurrence for A stability class = 100.0%

Table 2.5-13 Joint Frequency Distribution

Stability Class A					
0.00056	0.00488	0.00148	0.00006	0.00000	0.00000
0.00142	0.00495	0.00167	0.00006	0.00000	0.00000
0.00093	0.00482	0.00074	0.00000	0.00000	0.00000
0.00037	0.00247	0.00031	0.00000	0.00000	0.00000
0.00068	0.00111	0.00043	0.00000	0.00000	0.00000
0.00019	0.00049	0.00012	0.00000	0.00000	0.00000
0.00056	0.00099	0.00093	0.00000	0.00000	0.00000
0.00025	0.00142	0.00093	0.00006	0.00000	0.00000
0.00056	0.00210	0.00087	0.00000	0.00000	0.00000
0.00031	0.00111	0.00117	0.00012	0.00000	0.00000
0.00043	0.00210	0.00087	0.00000	0.00000	0.00000
0.00037	0.00117	0.00087	0.00000	0.00000	0.00000
0.00037	0.00099	0.00099	0.00006	0.00000	0.00000
0.00043	0.00080	0.00056	0.00025	0.00000	0.00000
0.00037	0.00130	0.00087	0.00006	0.00000	0.00000
0.00087	0.00223	0.00105	0.00025	0.00000	0.00000
Stability Class B					
0.00074	0.00198	0.00408	0.00049	0.00000	0.00000
0.00099	0.00260	0.00278	0.00025	0.00000	0.00000
0.00068	0.00389	0.00402	0.00037	0.00000	0.00000
0.00062	0.00130	0.00210	0.00019	0.00000	0.00000
0.00012	0.00062	0.00056	0.00006	0.00000	0.00000
0.00043	0.00043	0.00080	0.00000	0.00000	0.00000
0.00006	0.00093	0.00167	0.00019	0.00000	0.00000
0.00049	0.00087	0.00179	0.00037	0.00000	0.00000
0.00080	0.00074	0.00297	0.00068	0.00000	0.00000
0.00074	0.00148	0.00167	0.00056	0.00000	0.00000

Table 2.5-13 Joint Frequency Distribution

0.00068	0.00235	0.00185	0.00043	0.00000	0.00000
0.00043	0.00148	0.00192	0.00062	0.00006	0.00000
0.00031	0.00099	0.00173	0.00031	0.00006	0.00000
0.00049	0.00080	0.00155	0.00025	0.00000	0.00000
0.00019	0.00080	0.00297	0.00080	0.00006	0.00000
0.00031	0.00111	0.00365	0.00124	0.00006	0.00000
Stability Class C					
0.00080	0.00167	0.00291	0.00080	0.00080	0.00000
0.00068	0.00284	0.00315	0.00093	0.00093	0.00000
0.00099	0.00247	0.00618	0.00130	0.00130	0.00000
0.00049	0.00111	0.00321	0.00105	0.00105	0.00000
0.00000	0.00062	0.00080	0.00031	0.00031	0.00000
0.00025	0.00037	0.00099	0.00025	0.00025	0.00000
0.00019	0.00074	0.00198	0.00080	0.00080	0.00000
0.00049	0.00080	0.00241	0.00161	0.00161	0.00000
0.00105	0.00179	0.00575	0.00080	0.00000	0.00000
0.00124	0.00328	0.00427	0.00093	0.00000	0.00000
0.00111	0.00365	0.00507	0.00130	0.00012	0.00000
0.00105	0.00328	0.00389	0.00105	0.00006	0.00006
0.00012	0.00099	0.00216	0.00031	0.00012	0.00000
0.00019	0.00056	0.00111	0.00025	0.00006	0.00000
0.00043	0.00080	0.00402	0.00080	0.00006	0.00000
0.00043	0.00155	0.00371	0.00161	0.00000	0.00000
Stability Class D					
0.00087	0.00266	0.00587	0.00427	0.00105	0.00012
0.0008	0.00575	0.01205	0.0149	0.00457	0.00099
0.00068	0.00785	0.01311	0.01397	0.00235	0.00043
0.00019	0.00241	0.00408	0.0026	0.00031	0.00000

Table 2.5-13 Joint Frequency Distribution

0.00012	0.00031	0.00142	0.00111	0.00019	0.00000
0.00006	0.0013	0.00179	0.00068	0.00000	0.00000
0.00031	0.00216	0.00365	0.00266	0.00093	0.00006
0.00068	0.00915	0.00773	0.01335	0.00624	0.00173
0.00173	0.00859	0.01842	0.04	0.01836	0.00297
0.00111	0.00705	0.01966	0.01854	0.00389	0.00062
0.00087	0.01088	0.02986	0.01953	0.00148	0.00012
0.00087	0.00315	0.01175	0.01409	0.00278	0.0008
0.00049	0.00105	0.00328	0.00532	0.00241	0.00099
0.00025	0.00087	0.0047	0.00717	0.0034	0.00142
0.00025	0.00161	0.00822	0.0264	0.01379	0.00797
0.00019	0.00253	0.00927	0.01205	0.00464	0.00105
Stability Class E					
0.00130	0.00445	0.00099	0.00006	0.00000	0.00000
0.00148	0.00427	0.00278	0.00000	0.00000	0.00000
0.00148	0.00507	0.00291	0.00012	0.00000	0.00000
0.00068	0.00192	0.00111	0.00000	0.00000	0.00000
0.00025	0.00111	0.00031	0.00000	0.00000	0.00000
0.00043	0.00099	0.00068	0.00000	0.00000	0.00000
0.00074	0.00278	0.00130	0.00019	0.00000	0.00000
0.00260	0.01162	0.00161	0.00012	0.00000	0.00000
0.00340	0.01688	0.00661	0.00025	0.00000	0.00000
0.00321	0.01607	0.00427	0.00006	0.00000	0.00000
0.00272	0.01249	0.00865	0.00019	0.00006	0.00000
0.00161	0.00439	0.00377	0.00006	0.00000	0.00000
0.00099	0.00148	0.00056	0.00006	0.00000	0.00000
0.00056	0.00148	0.00124	0.00000	0.00000	0.00000
0.00068	0.00179	0.00130	0.00031	0.00000	0.00000

Table 2.5-13 Joint Frequency Distribution

0.00093	0.00204	0.00074	0.00000	0.00000	0.00000
Stability Class F					
0.00321	0.00161	0.00000	0.00000	0.00000	0.00000
0.00161	0.00130	0.00000	0.00000	0.00000	0.00000
0.00093	0.00136	0.00000	0.00000	0.00000	0.00000
0.00136	0.00074	0.00000	0.00000	0.00000	0.00000
0.00124	0.00043	0.00000	0.00000	0.00000	0.00000
0.00173	0.00099	0.00000	0.00000	0.00000	0.00000
0.00167	0.00173	0.00000	0.00000	0.00000	0.00000
0.00365	0.00464	0.00000	0.00000	0.00000	0.00000
0.00729	0.01175	0.00000	0.00000	0.00000	0.00000
0.00705	0.01280	0.00000	0.00000	0.00000	0.00000
0.00631	0.00779	0.00000	0.00000	0.00000	0.00000
0.00266	0.00253	0.00000	0.00000	0.00000	0.00000
0.00173	0.00142	0.00000	0.00000	0.00000	0.00000
0.00080	0.00093	0.00000	0.00000	0.00000	0.00000
0.00130	0.00117	0.00000	0.00000	0.00000	0.00000
0.00130	0.00049	0.00000	0.00000	0.00000	0.00000

2.5.6 Air Quality

The air dispersion of radiological pollutants will not be an issue because there will be no sources of radiological air emissions other than radon gas at the North Trend Expansion Area.

The primary new emission source of non-radiological pollutants will be tailpipe emissions of nitrogen oxides (NO_x), carbon monoxide (CO), sulfur dioxide (SO_2), non-methane-ethane volatile organic compounds (VOC), and particulate matter with a diameter less than ten micrometers (PM_{10}) resulting from vehicle traffic within the North Trend Expansion Area. Approximately 6-8 vehicle trips per day (VTPD) are anticipated as part of regular operations. These vehicles are expected to be light duty pick-up style trucks. Heavy equipment in the form of drill rigs, equipment haulers, or water trucks will be used as necessary and are anticipated to average less than one VTPD. These emissions are expected to be minor and should not affect the local ambient air quality.

Although there are no ambient air quality monitoring data for these non-radiological pollutants in the license area, PM_{10} concentrations have been measured in Rapid City, South Dakota and Badlands National Park in South Dakota. Both locations are geographically similar to the license area.

The Rapid City data were collected at the National Guard Camp Armory site about 2 miles west of the city. This are is classified as suburban. The Badlands data were collected in an area classified as rural. Because of the degree of urbanization, the air quality at the license area would probably fall somewhere between the air quality at these two locations. These data were obtained from the United States Environmental Protection Agency (USEPA) air quality monitoring database (USEPA 2007), and are presented in Table 2.5-14.

The National Ambient Air Quality Standards (NAAQS) for PM_{10} are 150 micrograms per cubic meter (24-hour average), and 50 micrograms per cubic meter (annual average). All counties within the 80-km radius or the project are in attainment of NAAQS.

TABLE 2.5-14
PM_{10} MONITORING SUMMARY
(MICROGRAMS PER CUBIC METER)

Year	Maximum 24-hr Average		Annual Average	
	Black Hills, SD	Rapid City, SD	Black Hills, SD	Rapid City, SD
1998	-	87.4	-	30.7
1999	-	116.9	-	28.2
2000	38.5	97.4	12.0	31.3
2001	47.9	81.5	12.6	34.6
2002	26.0	104.7	9.9	34.9
2003	74.4	91.8	16.3	36.2
2004	24.0	72.0	10.0	30.0
2005	40.0	94.00	9.0	27.0
2006	30.0	124.0	10.0	29.0

2.5.7 References

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2.6 GEOLOGY AND SEISMOLOGY

This section describes the regional and local geology and seismology related to the Crow Butte Project and the North Trend Area. In this regard, discussion of the geology of the Crow Butte Project, and the current NRC-licensed area (also referred to as the commercial study area [CSA]), in particular, has been presented in previous reports (Wyoming Fuel, 1983; Ferret Exploration of Nebraska, 1987). Detailed information contained in these reports (e.g., laboratory results and field data that describe formation characteristics [mineralogy, permeability, etc.] for the Pierre Shale, Brule Formation, Chadron Formation, and the Basal Chadron Sandstone in the CSA), also applies in a general sense to the North Trend Area. These data, in addition to new information from exploratory drilling/logging activities within the North Trend Area, are used to describe the geology and seismology in this section.

2.6.1 Regional Setting

The Crow Butte Project is in Dawes County in northwestern Nebraska. Crawford is the principal town in the area and lies approximately four miles northwest of the current NRC-licensed area. The proposed North Trend license area lies approximately 5.5 miles northwest of the current NRC-licensed area.

Crawford is 25 miles west of Chadron, Nebraska and 70 miles north of Scottsbluff, Nebraska. Crawford is 21 miles south of the South Dakota state line and 33 miles east of the Wyoming state line. The topography consists of low rolling hills dominated by the Pine Ridge south and west of the project area.

2.6.1.1 Regional Stratigraphy

Sedimentary strata ranging from late Cretaceous through Tertiary are exposed throughout northwest Nebraska. Pleistocene alluvial-colluvial material are abundant along the north slope of the Pine Ridge. Table 2.6-1 is a generalized stratigraphic chart for the region. Figure 2.6-1 shows a geological bedrock map of the northwest portion of the State of Nebraska (Burchett, 1986). Figures 2.6-2a, 2.6.2b, and 2.6-2c are a cross section location map and regional cross sections through the area, showing the configuration of major stratigraphic units in the region. Figures are included at the end of this section.

Table 2.6-1: General Stratigraphic Chart for Northwest Nebraska

System	Series	Formation or Group	Rock Types	Thickness
Miocene		Ogallala	SS, Slt	1560*
		Arikaree	SS, Slt	1070*
Oligocene/Eocene		White River	SS, Slt, Cly	1450*
Cretaceous	Upper	Pierre	Sh	1500
		Niobrara	Chalk, Ls, Sh	300
		Carlile	Sh	200-250
		Greenhorn	Ls	30
		Graneros	Sh	250-280
		D Sand	SS	5-30
		D Shale	Sh	60
		G Sand	SS	10-45
		Huntsman	Sh	60-80
	Lower	J Sand	SS	10-30
		Skull Creek	Sh	220
		Dakota	SS, Sh	180
Jurassic	Upper	Morrison	Sh, SS	300
		Sundance	SS, Sh, Ls	300
Permian	Guadalupe	Satanka	Ls, Sh, Anhy	450
	Leonard	Upper	Ls, Anhy	150
		Lower	Sh	150
	Wolfcamp	Chase	Anhy	80
		Council Grove	Anhy, Sh	300
		Admire	Dolo, Ls	70
Pennsylvanian	Virgil	Shawnee	Ls	80
	Missouri	Kansas City	Ls, Sh	80
	Des Moines	Marmaton/ Cherokee	Ls, Sh	130
	Atoka	Upper/Lower	Ls, Sh	200
Mississippian	Lower	Lower	Ls, Sh	30
Pre-Cambrian			Granite	

Notes: * Maximum thickness based on Swinehart, et. al, 1985.

2.6.1.2 Pre-Pierre Shale Stratigraphy

Formations older than the Cretaceous Pierre Shale are listed on the General Stratigraphic Chart shown in Table 2.6-1. This chart has been developed from the published literature and nearby oil and gas test holes. The Upper Cretaceous Niobrara, Carlile, and Greenhorn-Graneros Formations outcrop in the Chadron Arch about 30 miles northeast of Crawford.

2.6.1.3 Pierre Shale

The Pierre Shale of Cretaceous age is the oldest formation of interest for the Crow Butte area since it is the lower confining unit. Typically, Crow Butte Resources (CBR) test holes have been terminated in the top of the Pierre Shale. Therefore, descriptions of the full Pierre section included herein are based on data obtained from other sources, and data from the CBR Class I disposal well located at the current NRC-licensed area.

The Pierre is a dark gray to black marine shale, with relatively uniform composition. The Pierre outcrops extensively in Dawes and Sioux Counties along the South Dakota boundary north of the proposed North Trend Permit Area (Witzel, 1974). The Pierre generally consists of black to dusty gray and brownish claystones that include thin layers of bentonite, shaley limes, concretionary zones, and an occasional thin sandstone. While the Pierre can be as much as 5,000 feet thick, it is approximately 1,500 to 2,000 feet thick in Dawes County, and has been regionally divided into six members based on lithology, sequence, and fossil content. Two members, the Sharon Springs Member and Gregory Member were recognized by Witzel (1974) in Pierre outcrops in Dawes County. Fossils present in the Pierre include numerous pelecypods and ammonoids, as well as baculites, a straight ammonoid.

Although the Pierre Shale is up to 5,000 feet thick regionally, in Dawes County deep oil tests have indicated thicknesses of 1,200 to 1,500 feet. Figure 2.6-3 presents a regional isopach of the Pierre Shale. Exposure and subsequent erosion greatly reduced the vertical thicknesses of the Pierre prior to Oligocene/Eocene sedimentation. Consequently, the top of the present day Pierre contact marks a major unconformity and exhibits a paleotopography with considerable relief (DeGraw, 1969). As a result of the extended exposure to atmospheric weathering, an ancient lateritic paleo 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) and is readily observed in certain outcrop exposures. Because the paleosol profile shows enrichment in iron and alumina, low calcium, but insignificant leaching of silica, Witzel speculated that the zone underwent less intensive weathering than that produced by typical laterites. Thus, the soil probably developed under subtropical rather than intensive tropical conditions. It should

also be noted that the Pierre-Oligocene contact is also characterized by erosion via overlying Oligocene (Chadron) sandstones, resulting in deeply-incised channels at some locations (Witzel, 1974).

2.6.1.4 White River Group

The White River Group is Oligocene/Eocene in age and consists of the Chadron and Brule Formations. Geologic maps (e.g., Figure 2.6-1) show this unit to be present as bedrock in the general CBR and North Trend area, noting that members of the White River Group outcrop as a band at the base of the Pine Ridge, which occurs about six miles southeast of Crawford, Nebraska.

2.6.1.5 Chadron Formation

The Chadron is the oldest Tertiary Formation in northwest Nebraska and lies with marked regional unconformity on top of the Pierre Shale. Swinehart et al (1985) indicate that the Basal Chadron Sandstone contains sandstone and conglomerate with some interbedded clay and is the depositional product of a large, vigorous braided stream system which occurred during early Oligocene/Eocene (approximately 36 to 40 million years before present). Witzel (1974) describes the Chadron as representing a variety of depositional facies including channel, flood plain, pond and upland environments, characterized regionally by lateral and vertical heterogeneity. Typically, the Chadron Formation has a sandstone and conglomerate at the base with overlying siltstone, mudstone, and claystone, which is green-hued (Singler and Picard, 1980). Regionally, the vertical thickness of the Chadron Formation varies greatly. On outcrop, the Chadron Formation varies in thickness from 135 to 205 feet (Singler and Picard, 1980). More recently, the maximum thickness of the Chadron Formation has been estimated at 300 feet (Swinehart et al, 1985). Based on CBR data, the Chadron Formation thickness in the CSA ranges from 300 to 600 feet. At North Trend, the Chadron Formation thickness is approximately 500 feet.

Witzel (1974) identified the Chadron Formation as consisting of three general stratigraphic divisions he called A (lower), B (middle) and C (upper) units. The lower portion of the Chadron is a very coarse, very poorly sorted conglomerate that occurs, where present, at the base of the Chadron. This conglomerate consists of well rounded, predominantly quartz and chalcedony cobbles ranging up to six inches across. The basal conglomerate occurs primarily in deeper entrenched valleys upon the Pierre and sometimes has cement with pyretic matrix. The Basal unit grades upward into 20 to 40 feet of porous, coarse to fine-grained, limonite-stained sandstone.

The B (middle) unit is predominantly green to pinkish in color and was deposited by two main types of depositional lithologies: channel and flood plain, with occasional localized ponds. Channel fills consist of greenish-brown sandstone composed of quartz and feldspar, cemented with calcium carbonate or silica. Finer-grained materials (siltstone, claystones) may occur adjacent to the channel sand deposits. Witzel states that the *"bulk of the Middle Chadron sediments are of floodplain type, grading laterally into the channel fills."* Maximum thickness of the Middle Chadron varies from about 114 to126 feet.

The Middle and Upper Chadron are sometimes difficult to distinguish in the field (Wetzel, 1974), with the presence of [occasional] sandstones within the Middle unit being the predominant differentiator. The upper part of the Chadron represents a distinct and rapid facies change from the underlying sediments. The Chadron above the Upper/Middle Chadron sand is a light green-gray bentonitic claystone at the top, grading downward to green and frequently red claystone often containing gray-white bentonitic clay interbeds.

2.6.1.6 Brule Formation

The Brule Formation lies conformably on top of the Chadron Formation and consists of interbedded siltstone, mudstone, and claystone with occasional sandstone. The Brule Formation is reported to range in thickness from 130 to 530 feet (Singler and Picard, 1980). Witzel (1974) indicates that the Brule, in Dawes County, has a maximum thickness of 480 feet. The Brule had previously been subdivided into two separate members, the lower Orella (middle Oligocene) and the upper Whitney (upper Oligocene) (Schultz and Stout, 1938; Witzel, 1974). More recently, the maximum thickness of the Brule Formation has been described as 1,150 feet. This is due to the inclusion of the Brown Siltstone beds (Swinehart et al, 1985).

The Orella is composed of interbedded siltstone, mudstone, and claystone with occasional sandstones. The color of the Orella grades from green-blue and green-browns upward to buff and browns. The Orella was deposited in a fluvial setting with some eolian activity (Singler and Picard, 1980). Witzel states that the Orella member is about 200 feet thick in Dawes County, and can be subdivided further into 3 subunits. The Lower Orella is about 90 feet thick at a maximum, and is characterized by greenish to brownish buff silty clay with abundant fossil remains. Nodular sandy siltstone occurs at the base. The Middle Orella occurs unconformably atop the lower, and is about 146 feet thick at a maximum. This subunit is characterized by channel deposits in its lower portions, consisting of coarse, cross-bedded arkosic sands (Witzel, 1974). The middle Orella is capped by a major paleosol complex. The Upper Orella varies in thickness from 34 to 53 feet, and contains channel and floodplain facies.

The Whitney Member of the Brule is comprised of fairly massive buff to brown siltstones, primarily eolian in origin (Singler and Picard, 1980). Several volcanic ash horizons have been reported in outcrops (Swinehart et al, 1985). Some moderate to well-defined channel sands are present in the upper part of the Whitney Member. These Brule channels are commonly water-bearing in the otherwise generally impermeable Brule. Witzel states that the Whitney attains a maximum thickness of about 270 feet in Dawes County, and is more uniform in lithology than the underlying Orella Member. As with the Orella, the Whitney can also be subdivided into upper, middle, and lower subunits, distinguished by intervening volcanic ash layers. The Lower Whitney is about 90 feet thick and is described as a massive sandstone unit; it is capped by about 8 feet of Lower Ash. The Middle Whitney is lithologically similar to the lower and is about 76 feet thick. The Middle Whitney is capped by about a three-foot thick Upper Ash unit.

The Brown Siltstone beds have been recognized by Swinehart and others in northwest Nebraska (Swinehart et al, 1985). This informal member has been added to the upper part of the Brule Formation. This unit is described as volcanic sandy siltstones and very fine-grained sandstones. Fine to medium-grained sandstones occur locally at or near the base.

2.6.1.7 Arikaree Group

The Arikaree-Ogallala Groups are absent in the immediate North Trend project area. However, a general description for each group follows because they do occur on a regional scale.

The Miocene Arikaree Group includes three sandstone formations that form the Pine Ridge escarpment, which trends from west to east across northwest Nebraska.

2.6.1.8 Gering Formation

The Miocene Gering Sandstone is the oldest formation of the Arikaree Group, and lies unconformably on the Brule Formation. The Gering is predominantly buff to brown, fine-grained sandstones and siltstones. These represent channel and flood plain deposits. Thickness of the Gering Formation ranges from 100 to 200 feet (Witzel, 1974).

2.6.1.9 Monroe Creek Formation

The Monroe Creek Formation overlies the Gering and is the middle unit of the Arikaree Group. The Monroe Creek Formation is lithologically similar to the Gering with buff to brown fine-grained sandstone. The unique characteristic 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 resistant to weathering. The reported thickness of the Monroe Creek Formation is 280 to 360 feet (Lugn, 1938, in Witzel, 1974).

2.6.1.10 Harrison Formation

The Harrison Formation is the youngest unit of the Arikaree Group. It is described as lithologically similar to the Gering and Monroe Creek Formations, with fine-grained unconsolidated sands, buff to light gray in color. The Harrison Formation is also noted for its abundance of fossil remains (Witzel, 1974).

2.6.1.11 Ogallala Group

The Miocene Ogallala Group overlies the Arikaree Group and is the outcropping unit south of the Pine Ridge. The Ogallala Group is composed primarily of sandstones that are coarser-grained, poorly sorted and contain only small amounts of volcanic material compared to the underlying Arikaree Group rocks (Souders, 1981). Some siltstone and mudstone is interbedded with the sandstones and gravels.

The Ogallala Group is the principal aquifer where it is present in northwest Nebraska. The Arikaree Group is the principal water-bearing geologic unit in Sioux, Dawes, and Box Butte Counties.

2.6.1.12 Regional Structure

Figure 2.6-1 presents structural features identified on the bedrock geology map and Figure 2.6-4 is a regional structural feature map. The most prominent structural expression in northwest Nebraska is the Chadron Arch. This anticlinal feature strikes roughly northwest-southeast along the northeastern boundary of Dawes County. The only surficial expression of the Chadron Arch is the outcropping of pre-Pierre Cretaceous rocks in the northeastern corner of Dawes County (Figure 2.6-1), as well as small portions of Sheridan County, Nebraska, and Shannon County, South Dakota.

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

The Crow Butte Basal Chadron ore body lies in what has been named the Crawford Basin (DeGraw, 1969). DeGraw made detailed studies of the pre-Tertiary subsurface in western Nebraska using primarily deep oil test hole information. He was able to substantiate known structural features and propose 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 east and the Cochran Arch and Pine Ridge Fault to the south (DeGraw, 1969). The town of Crawford is located near the axis of the Crawford Basin which is about 50 miles long in an east-west direction and about 25 to 30 miles wide at Crawford.

Figure 2.6-5 presents structural features identified previously by others and also new features proposed by DeGraw associated with the Crawford Basin. The geologic map of northwest Nebraska reproduced from the State Geologic Map, Figure 2.6-1 illustrates the recognized faulting in northwest Nebraska, but the Bordeaux Fault, Pine Ridge Fault, and Toadstool Park Fault proposed by DeGraw (1969) are not presented on the State Geologic Map. The Toadstool Park Fault has been noted on outcrop at one location in T33N, R53W, to have a displacement of about 60 feet (Singler and Picard, 1980).

Six northeast trending faults are identified or proposed in Sioux and Dawes Counties (Figure 2.6-5). All of these faults are downthrown to the north. One of these faults, the White River Fault, follows the White River north of Crawford and was postulated during the exploration drilling phase of the Crow Butte Project (Collings and Knode, 1984). The only other fault illustrated, the White Clay Fault, terminates the Arikaree Group rocks on the east from White Clay to about six miles east of Gordon (Nebraska Geological Survey, 1986).

The Cochran Arch was also proposed by DeGraw (1969) on the basis of subsurface data. The Cochran Arch trends east-west through Sioux and Dawes Counties, parallel to the Pine Ridge Fault proposed by DeGraw. Structural features subparallel to the Cochran Arch have been recognized based on CBR drill hole data. The existence of the Cochran Arch may explain the structural high south of Crawford.

The synclinal axis of the Crawford Basin trends roughly east-west and plunges to the west into what CBR informally calls the Inner Crawford Basin located west of the CSA (Collings and Knode, 1984). The Inner Crawford Basin is characterized by an increase in the thickness of the Chadron Sandstone.

2.6.2 North Trend Area Geology

2.6.2.1 Introduction

A local stratigraphic column, representative of both the North Trend and the Commercial Study Area (CSA), has been prepared and is shown as Table 2.6-2. The stratigraphic nomenclature of Swinehart et al (1985) and Crow Butte Resources are shown on the column.

The general stratigraphy underlying the North Trend site, based on data from well CPW-2, is summarized in Table 2.6-2. Note that the nomenclature differs somewhat from that used by Witzel (1974) and has been modified consistent with the units used by CBR for the Crow Butte area, including North Trend. All maps and figures generated specific to the North Trend area are based upon data provided by CBR. The database used to construct figures and cross-sections extends approximately one section beyond the North Trend Expansion Area boundaries, but geologic picks are not consistently available for all locations.

Specific to the North Trend area, the stratigraphic sequence of interest, in descending order is as follows: alluvial sediments with occasional perched water, Brule Formation (including a sandy clay that is considered the shallowest overlying aquifer), Upper Chadron (upper confining layer), Upper/Middle Chadron sand (overlying sand, where present), Middle Chadron (upper confining layer), Basal Chadron Sandstone (production zone), and Pierre Shale (underlying confining layer). Because no sands occur for over 1,000 feet below the top of the Pierre Shale, site-specific analysis of these deeper intervals is not presented.

Table 2.6-2: Stratigraphic Chart for North Trend Expansion Area

Depth (feet; bgs)	Description
0 – 25	Topsoil and alluvial deposits; no wells
25 – 110	Brule Formation (interbedded silt and sandstone); BOW wells
110 - 290	Upper Chadron (silt and clay); no wells
Approx. 290-390	Upper/Middle Chadron Sand; MCOW wells
390 – 615	Middle Chadron (interbedded clay, claystone, and siltstone); no wells
615 – 659	Basal Chadron Sandstone (interbedded sandstone and clay); CPW and COW wells
659 +	Pierre Shale; no wells

The locations of 14 geologic cross-sections through the North Trend area are depicted on Figure 2.6-6. Of these 14 cross-sections that were constructed to assess site geology, nine are included as representative sections of the North Trend Area, constructed both parallel and perpendicular to local dip. Figures 2.6-7 through 2.6-15 (Cross-sections A-A', B-B', C-C', D1-D1', D2-D2' and E-E', I-I', K-K', and M-M', respectively) show the geological cross-sections in detail. The cross-sections demonstrate that the Basal Chadron production zone is stratigraphically isolated from the overlying Upper/Middle Chadron sand and the water-bearing portion of the Brule Formation by a low permeability-confining unit (and the Upper/Middle Chadron). These sections also demonstrate the continuity of the Basal Chadron Sandstone and the excellent confinement provided by not only the overlying Chadron and Brule Formations, but the underlying Pierre Shale. The cross-sections, isopach and structure maps were generated with the PETRA software package using select drill hole data, geologic picks and logs provided by CBR. Figures 2.6-16 through 2.6-20 present 3-D views of the Brule, Upper/Middle Chadron sand, Basal Chadron Sandstone, and Pierre Shale and the relationship between those units. The geology of the Pierre, Chadron and Brule specific to the North Trend area is discussed below.

2.6.2.2 Pierre Shale - Lower Confinement

The Pierre Shale is a black marine shale and is the oldest formation typically encountered in CBR test holes associated with Class III operations. The Pierre Shale is the confining bed below the Chadron Sandstone which is the host for uranium mineralization (Figures

2.6-7 through 2.6-15.) The description provided under regional stratigraphy also describes the Pierre Shale within the North Trend area. The ancient soil horizon known as the Interior Paleosol has been scoured away by the overlying Chadron Sandstone throughout most of the North Trend Expansion Area. Figure 2.6-21 is a structure contour map constructed at the top of the Pierre for the North Trend Area.

The character of the entire Pierre Shale can be observed in nearby oil and gas well geophysical logs, from two wells, the Heckman No. 1 and Soester No. 1. The Heckman No.1 hole is about six miles southeast (Section 24, T31N, R52W) of the North Trend area. The log from Heckman No. 1 is believed to be representative of the Pierre Shale within the Crow Butte Area, including North Trend. At the location of Heckman No. 1, the base of the Chadron Formation is at a depth of 525 feet. The Pierre Shale is 1,565 feet thick and rests on the Niobrara Formation at 2,090 feet. The spontaneous potential and resistivity curves for this hole qualitatively indicate a lack of permeable, water-bearing zones within the Pierre Shale. The Soester No. 1 well is located within the North Trend Permit Area, in Section 34, T32N, R52W. At this location, the Pierre is 1,265 feet thick and also shows no indication of permeable (water bearing) zones. At the Soester No. 1 well location, the top of the Pierre occurs at a depth of 645 feet, and the base is encountered 1,910 feet below ground surface.

X-ray diffraction analyses of two core samples from the CSA indicate that the Pierre Shale is primarily comprised of quartz and montmorillonite with minor kaolinite-chlorite and mica illite (Table 2.6-3). The black marine shale is an ideal confining bed with measured vertical hydraulic conductivity in the CSA of less than 10^{-10} cm/sec. The electric log characteristics of the Pierre Shale and overlying units are shown on logs included on the cross sections, and illustrate the impermeable nature of the Pierre Shale.

2.6.2.3 Basal Chadron Sandstone - Mining Unit

The Basal Chadron production zone lies upon a marked regional unconformity on the top of the Pierre Shale in the North Trend area. Regionally, deposition of the Basal Chadron has been assigned to large, high-energy braided streams and this appears to also be characteristic of the North Trend area. In this regard, the Basal Chadron is lenticular with numerous facies changes occurring within short distances. A similar, but lower-energy depositional environment appears to account for the spatial variability of the intermittent Upper/Middle Chadron sand.

The Basal Chadron Sandstone is generally present at the bottom of the Chadron Formation and is a coarse-grained arkosic sandstone with frequent interbedded thin clay beds and clay galls. Occasionally, the Basal Chadron Sandstone grades upward to fine grained sandstone containing varying amounts of interstitial clay material and persistent

clay interbeds. A persistent clay horizon, typically brick red in color, generally marks the upper limit of the Basal Chadron Sandstone. The Basal Chadron Sandstone is the host member and mining unit of the Crow Butte ore deposit; no other commercial uranium mineralization has been identified in the overlying units.

The vertical thickness of the Basal Chadron Sandstone within the North Trend area averages about 20 to 60 feet, although the unit is up to 170 feet thick west of the North Trend property boundary. An isopach map of the Basal Chadron Sandstone is presented in Figure 2.6-22. The top of Pierre Shale and Basal Chadron Sandstone structure is shown on Figures 2.6-21 and 2.6-23.

Thin section examination of Basal Chadron Sandstone samples collected in the CSA indicates a composition of 50% monocrystalline quartz, 30 to 40% undifferentiated feldspar, plagioclase feldspar and microcline feldspar (Table 2.6-3). The remainder includes polycrystalline quartz, chert, chalcedonic quartz, various heavy minerals and pyrite. X-ray diffraction analyses indicate that the Basal Chadron Sandstone is 75% quartz with the remainder K-feldspar and plagioclase.

Table 2.6-3: Estimated Weight Percent as Determined by X-Ray Diffraction

Phase	Upper Part Chadron Formation (2) Upper Confinement	Chadron Sandstone (4) (Mining Unit)	Pierre Shale (2) Lower Confinement
Quartz	22.5	75.5	26
K Feldspar	2	13	4
Plagioclase	1	9.5	1
Kaolinite-Chlorite	--	<1	9
Montmorillonite	44	<1	32
Mica-Illite	1	<1	15
Calcite	22	--	1.5
Fluorite	0.5	--	--
Amorphous	7	1	10.5
Unidentified	--	<1	1
TOTAL	**100**	**100**	**100**

CBR has collected mineralogical samples from the Chadron Formation in the North Trend area, and is currently assembling and evaluating this information.

Core samples and outcrops of the Basal Chadron Sandstone exhibit numerous clay galls up to a few inches in diameter, frequent thin silt and clay lenses of varying thickness and continuity, and occasionally a sequence of upward fining sand. These probably represent flood plain or low velocity deposits which normally occur during fluvial sedimentation. Within the North Trend Area, varying thicknesses of clay beds and lenses often separate the Basal Chadron Sandstone into fairly distinct subunits.

2.6.2.3.1 Geochemical Description of the Mineralized Zone

Hansley, et al (1989) conducted detailed geochemical analysis of the Crow Butte uranium ore to assess both ore genesis and composition. The Crow Butte deposits, including North Trend, are roll-type deposits with coffinite being the predominant uranium mineral species present. The origin of the uranium is in-situ rhyolitic ash material within the Basal Chadron. Coffinite is associated with pyrite, and high silica activity due to dissolution of the rhyolitic ash which favored formation of coffinite over uraninite in most parts of this sandstone. In addition, smectite is present in the samples examined, with the most common minerals in the sandstone being quartz, plagioclase, K-feldspar, coffinite, pyrite, marcasite, calcite, illite/smectite and tyuyamunite. The heavy mineral portion of the samples contained several minerals including those above as well as garnet, magnetite, marcasite, and illmenite. Vanadium was detected in the samples primarily as an amorphous species presumed to have originated from the in-situ ash. Hansley et al state that at least some uranium and vanadium remain bound to amorphous volcanic material and/or smectite rather than as discrete mineral phases.

Petrographic data obtained and examined by Hansley et al (1989) suggest that uranium mineralization occurred before lithification of the Basal Chadron. Hansley states: *"Dissolution of abundant rhyolitic volcanic ash produced U- and Si- rich ground waters that were channeled through permeable sandstone at the base of the Chadron by relatively impermeable overlying and underlying beds. The precipitation of early authigenic pyrite created a reducing environment favorable for precipitation and accumulation of U in the basal sandstone. The U has remained in a reduced state, as evidenced by the fact that the unoxidized minerals, coffinite and uraninite, comprise the bulk of the ore."*

The ore body ranges in grade from less than 0.05% to greater than 0.5%U_3O_8, with an average grade estimated at 0.26% equivalent U_3O_8 and 0.31% chemical U_3O_8. Table 2.6-3 presents the mineralogical composition of the Chadron Sandstone interval.

2.6.2.4 Middle Chadron and Upper/Middle Chadron Sand

The Middle Chadron confining layer occurs above the Basal Chadron Sandstone, and is described as a clay-rich interval that grades from brick red to grey in color with interbedded bentonitic clay. The Middle Chadron is about 250 to 300 feet thick in the North Trend Expansion Area. An isopach of the Middle Chadron confining unit is presented in Figure 2.6-24.

The Upper/Middle Chadron sand occurs above the Middle Chadron confining interval. It was created by a depositional environment similar to the Basal Chadron sandstone, but of lower-energy that would appear to account for the spatial variability of the Upper/Middle Chadron sand. The available data suggest that the Upper/Middle Chadron sand may be continuous across the site (see Figure 2.6-25), yet the regional depositional model suggests that the sand may occur intermittently. The continuity of this Upper/Middle Chadron sand, with regard to justification for detailed monitoring, is questionable. However, the sand does occur with sufficient frequency to justify its identification as a mappable stratigraphic marker. The Upper/Middle Chadron Sandstone is similar in appearance to the rest of the Chadron Sandstone, and is typically a very fine to fine grained, well sorted, poorly cemented sandstone.

The available data, maps and figures included herein indicate that the Middle Chadron is approximately 200 to 300 feet thick, while the Upper/Middle Chadron sand is approximately 10-70 feet thick in the North Trend Permit Area.

2.6.2.5 Upper Chadron and Brule Formations, Upper Confinement

The Upper Chadron confining unit represents a distinct and rapid facies change from the underlying portions of the Chadron, and is continuous across the North Trend Permit Area. An isopach map of the Upper Chadron is presented in Figure 2.6-26, and shows that this portion of the Chadron Formation can be from about 100 to 250 feet thick in the North Trend Permit Area. The upper part of the Chadron Formation is a light green-gray bentonitic clay grading downward to green and frequently red clay. X-ray diffraction analyses of the red clay indicate that it is primarily comprised of montmorillonite and calcite (Table 2.6-3). This portion of the Chadron often contains gray-white bentonitic clay interbeds. The light green-gray "sticky" clay of the Chadron serves as an excellent marker bed in drill cuttings and has been observed in virtually all drill holes within the Crow Butte Area, including North Trend. Based on data from the CSA, the vertical hydraulic conductivity of the upper confining intervals at Crow Butte is less than 1.0×10^{-10} cm/sec.

The Brule Formation lies conformably on top of the Chadron Formation. The Brule Formation is the outcropping formation throughout most of the Crow Butte Area. The Brule, including the uppermost portion discussed in Section 2.6.2.6 below, is about 50 to 100 feet thick in the North Trend Area. The lower part of the Brule Formation consists primarily of siltstones and claystones. Infrequent fine-to-medium-grained sandstone channels have been observed in the lower part of the Brule Formation. When observed, these sandstone channels have very limited lateral extent.

The Brule-Chadron contact is sometimes difficult to ascertain, as the contact between the two formations is gradational and cannot be consistently picked in drill cuttings or electric logs. Therefore, the Upper Chadron/Lower Brule may be considered a single confining interval.

2.6.2.6 Upper Part of the Brule Formation - Upper Monitoring Unit

The upper part of the Brule Formation is primarily composed of buff to brown siltstones which have a larger grain size than the lower part of the Brule Formation. Occasional sandstone units are encountered in the upper part of the Brule Formation. The small sand units have limited lateral continuity and, although water bearing, do not always produce usable amounts of water. These sandstones have been included in the upper part of the Brule Formation and are illustrated on the series of cross-sections as overlying the upper confinement (Figures 2.6-7 through 2.6-12). The lowest of these water bearing sandstones would be monitored by shallow monitor wells during mining. This unit may correlate with the Brown Siltstone beds recognized by Swinehart et al (1985).

2.6.2.7 North Trend Area Structure

Figures 2.6-21 and 2.6-23 present the structure on top of the Pierre and Basal Chadron, respectively, in the North Trend Area. Cross-sections presented in Figures 2.6-7 through 2.6-15 illustrate local structural trends across the North Trend Area (see Figure 2.6-6 for cross-section locations). The structure at the top of the Pierre dips to the south in the North Trend Permit Area through Sections 22 and 27, with dip changing and steepening to the northwest in southern portions of Section 34.

Previous drilling identified a structural feature referred to as the White River Fault located between the current permit area and the proposed North Trend permit area. The feature is oriented NE-SW generally along the drainage of the White River (Figure 2.6-5). The general location of the feature is shown on Figures 2.6-21 and 2.6-23. Deep data are limited, but suggest that the vertical movement along the feature appears to be approximately 200 feet, upthrown to the south-southeast. Drilling and logging data in the North Trend Area suggest that, while this fault may occur at depth, it may not continue

upsection through the Pierre into and through the Chadron and Brule Formations in the North Trend Area. Therefore, based on the data available to date and presented herein, it is possible that the referenced structural feature is a fault at depth, movement along which is expressed upsection in the Pierre, Chadron and Brule as a fold (e.g., a monocline), as discussed below.

Cross sections presented in Figures 2.6-7 through 2.6-15 show a definite structural high in the southeastern portion of the North Trend Area, specifically in the southeast corner of Section 34, T32N, R52W. This is verified by structure contour maps constructed at the top of the Pierre and Basal Chadron Sandstone (Figures 2.6-21 and 2.6-23). Previous maps by CBR and others show the White River Fault to transect the Chadron and Upper units, suggesting that faulting transected both the Pierre surface and overlying Chadron post-depositionally. However, cross-section correlations are readily made without showing that the fault explicitly transects these upper units. While structure contour maps clearly show the presence of a feature in the southeast portion of Section 34, the data does not mandate that contouring reflect a fault in this location. As a result, the presence of the White River Fault through the Chadron and Brule, as previously mapped, is not explicitly verified in new cross-sections, although there is definite evidence that a structural feature is present that impacted both the paleotopographic Pierre surface and thickness of overlying units.

Previous interpretations have indicated that the White River Fault transected through the Chadron and Brule Formations post-depositionally. If this had been the case, then isopach variations within the Chadron would not be readily apparent, or at least would not likely be associated with the fault. The cross-sections show that the Basal Chadron Sandstone is pervasive and correlatable throughout the area and does not appear to exhibit thickness changes across the White River Fault/fold, suggesting that movement along this feature did not impact deposition of the Basal Chadron Sandstone. However, in the area where the White River Fault is suspected to occur (Figures 2.6-5 and 2.6-25), the Middle/Upper Chadron (or Chadron/Lower Brule, depending upon interpretation) notably thins across the mapped fault suggesting that movement along the monocline/fold may have impacted deposition of the Middle/Upper Chadron (assuming that the Brule/Chadron picks are correct). This portion of the Chadron appears to thicken to the west and north of the fault area, and intermittent sandstones of the Middle Chadron are more readily identifiable in these thicker areas, based on available data. Structure contour maps of the Pierre surface show there to be lows in areas of the Chadron thickening, and highs where the Chadron thins. This is consistent with historical interpretations in the CBR permitting documents that suggest (1) an erosional paleotopographic surface of the Pierre Shale prior to deposition of the Chadron Formation, and (2) structural movement which occurred prior to or during deposition of the Middle/Upper Chadron which affected the depositional patterns of this unit in the area.

In summary, current data suggest that the White River Fault may be present at depth and movement along this feature impacted the deposition of the Middle/Upper Chadron. However, data do not clearly require that this fault transect the Middle/Upper Chadron or Brule, and mapped data suggest that movement along the structure occurred during deposition of the Chadron/Brule via uplift of a monocline or fold in this area. Crow Butte is committed to conduct additional exploratory drilling to better define the nature of the feature before commencing mining operations.

2.6.2.8 Conclusions- Site Geology and Confining Strata

The North Trend ore body represents a situation favorable for in-situ mining of uranium; the successful historic and continuing mining operations in the current Class III Permit area immediately southeast of North Trend within the same geologic setting further verifies this conclusion. Figures 2.6-7 through 2.6-15 and 2.6-22 present the location and lateral continuity of the Basal Chadron Sandstone mined interval, showing that this interval is laterally continuous throughout the North Trend Area, with thick portions occurring along a North-South trend in Sections 22, 27, and 34, as well as in Sections 28 and 33 west of the North Trend property boundary. The lower confining bed is the Pierre Shale and is over 1,000 feet in thickness. The Pierre Shale is a thick, homogenous black shale with very low permeability and is one of the most laterally extensive formations of northwest Nebraska.

The upper confinement is composed of the Middle Chadron Formation above the Basal Chadron Sandstone and that portion of the Upper Chadron and Brule Formation underlying the intermittent Brule sandstones. The Middle Chadron confining unit includes a clay-rich interval that grades from brick red to grey in color with interbedded bentonitic clay. The upper part of the Chadron Formation is an impermeable clay grading upward into several hundred feet of siltstones and claystones of the Brule Formation. These units separate the mining zone (Basal Chadron Sandstone) from the nearest overlying water bearing unit with several hundred feet of clay and siltstones. The Middle and Upper Chadron Formation clays also have a large lateral extent and have been observed in all holes within the North Trend Area. The thickness of the upper confinement ranges from approximately 250 to over 500 feet within the North Trend Area.

From Table 2.6-3, it is evident that the upper and lower confining beds (the Middle Chadron through Brule Formation and Pierre Shale) contain significant percentages of montmorillonite clay and other clays and/or calcite. These two analyses would indicate the presence of clay minerals with very fine grain sizes. Size distribution analyses of these beds verify that the material is quite fine grained. These two facts indicate that both the upper and lower confinement are significantly less permeable than the ore zone and

essentially impermeable. Further, core and hydrologic data from the CSA indicate that the vertical hydraulic conductivity of the confining shales and clays overlying and underlying the Basal Chadron Sandstone are on the order of 10^{-10} cm/sec, or lower. The geologic information presented in this application clearly demonstrates the lateral continuity of the overlying and underlying confining zones on both regional and local scales, as well as the lateral occurrence and distribution of the Basal Chadron Sandstone mined interval.

2.6.3 Seismology

The Crow Butte Project Area, including the North Trend area, is in northwest Nebraska within the Stable Interior of the United States. The project area along with most of Nebraska and the surrounding region is in seismic risk Zone 1 on the Seismic Risk Map for the United States, and is therefore in an area of low Seismic Hazard (Figure 2.6-27) as presented by the USGS. Most of the central United States is within seismic risk Zone 1 and only minor damage is expected from earthquakes which occur within this area. The closest Zone 2 area is in the southeastern part of Nebraska within the eastern part of the central Nebraska Basin (Burchett, 1990) about 300 miles southeast from the proposed North Trend Expansion Area.

Although the project area is within an area of low seismic risk, occasional earthquakes have been reported. Over 1100 earthquakes have been catalogued within the Stable Interior of the U.S. since 1699 by Docekal (1970). This study noted several earthquake epicenters within northwest Nebraska. All but two of these earthquakes were classified within the lowest category, Intensity I-IV, on the Modified Mercalli Intensity Scale of 1931.

Figure 2.6-28 is a seismicity map of Nebraska prepared by the USGS for the 1990-2001 time period. (http://earthquake.usgs.gov/regional/states/nebraska/seismicity.php). The location of the principal structural features of Nebraska including the Chadron and Cambridge Arches are shown in Figure 2.6-5. The earthquakes which have been recorded along these two structural features are tabulated in Table 2.6-4.

The strongest earthquake in northwest Nebraska (No. 21) occurred July 30, 1934 with an intensity of VI and was centered near Chadron. This earthquake resulted in damaged chimneys, plaster, and china. Earthquake No. 26 occurred on March 24, 1938 near Fort Robinson. This earthquake had an intensity of IV; no additional information is available. An Intensity IV earthquake should be felt indoors by many and cause dishes, windows, and doors to be disturbed. Earthquake No. 30 occurred on March 9, 1963 near Chadron. This earthquake was reported to last about a second and was not accompanied by any damage or noise and was not even noticed by many of the residents of Chadron.

Earthquake No. 32 occurred on March 28, 1964 near Merriman. The vibrations from this earthquake lasted about a minute and caused much alarm but no major damage occurred. Books were knocked off shelves and closet and cupboard doors swung open. On May 7, 1978 an earthquake (No. 40) with Intensity V occurred in southwestern Cherry County, also near the Chadron Arch. No major damage was reported from this earthquake.

Although the risk of major earthquakes in Nebraska is slight (Burchett, 1990), some low to moderate tectonic activity has occurred (Rothe, 1981). This tectonic movement is also suggested by geomorphic and sedimentation patterns during the Pleistocene (Rothe, 1981), which reflect such movement. Recent seismicity on the Cambridge Arch appears to be related to secondary recovery in the Sleepy Hollow oil field (Rothe et al, 1981). Deeper events, however, suggest current low level tectonic activity on the Chadron and Cambridge Arches. This activity is not expected to affect the mining operations in the North Trend Area.

The most recent earthquake recorded in Nebraska occurred February 1, 2006. The epicenter was about 20 miles east-northeast of Ainsworth, Nebraska, and was therefore over 200 miles east of Crawford. This earthquake had a recorded magnitude of 2.9, but was not felt at Crawford or the Crow Butte/North Trend area. According to the USGS (http://folkworm.ceri.memphis.edu/recenteqs/) no earthquakes have been felt in Nebraska since the February 1, 2006 event.

Table 2.6-4: Earthquakes in Nebraska

Date	Central Standard Time	Locality	Latitude Degrees North	Longitude Degrees West	Modified Mercalli (MM) Intensity	Source
March 17, 1884	14:00	North Platte	41.133	100.75	IV	A
Dec. 16, 1916	-----	Stapleton	41.55	100.467	II-III	A
Sept. 24, 1924	5:00	Gothenburg	40.95	100.133	IV	A
Aug. 8, 1933	-----	Scottsbluff	41.867	103.667	IV-V	A
30-Jul-34	1:20	Chadron	42.85	103	VI	A
24-Mar-38	7:11	Fort Robinson	42.683	103.417	IV	A
9-Mar-63	9:25	Chadron	42.85	103	II-III	A
28-Mar-64	4:21	Merriman	42.8	101.667	VII	A
7-May-78	10:06	SW Cherry County	42.26	101.95	V	B
6-May-83	0:15	NE Sheridan County	42.96	102.2	III	B
1-Jan-87	2:02	Crawford	42.79	103.48	III	B
8-Feb-89	23:16	Merriman	42.8	101.6	IV	B

Sources: A = Docekal, 1970
B = National Earthquake Information Service

2.6.4 Inventory of Economically Significant and Energy Related Deposits and Artificial Penetrations Inventory

According to the Nebraska Department of Economic Development website (www.neded.org) there has been no oil and gas production from Dawes County from 1994-2004. The only non-fuel mineral produced in Dawes County is sand and gravel. Based on data up to 2005, coal is not produced anywhere in Nebraska (http://tonto.eia.doe.gov/FTPROOT/coal/05842005.pdf).

Other than the monitoring wells installed by CBR and discussed in Section 2.7 (see Figure 2.7-11), there is only one deep penetration well that transects the Brule and Chadron in the North Trend Permit Area. This well, the Soester No. 1, is located in Section 34, Township 32 North, Range 52 West. Plugging information for this well shows that the well reached total depth (TD) on September 3, 1977 with a total depth of 2006 feet. The well was subsequently abandoned, with the borehole filled with mud-laden fluid and cement emplaced from 124 ft to ground surface. This information shows that appropriate action was taken to properly abandon this well in accordance with regulatory requirements and common practice in place at the time of abandonment.

2.6.5 Soils

The Crow Butte North Trend Project Area is located in the semiarid west-central portion of Dawes County, Nebraska, just north of the city of Crawford. For the proposed project, an investigation was made of the local soils. Soils data for the North Trend Project Area was obtained from the United States Department of Agriculture (USDA), Natural Resource Conservation Service (NRCS), Soil Survey of Dawes County, Nebraska, published in February 1977.

The project area is bounded on the south by the White River and is located in the White River watershed. The terrain is generally flat with gentle rolling hills. Natural vegetation is dominated by drought tolerant short-grass prairie and large areas of mixed-grass prairie, but they have been largely replaced by agricultural crops within the project area.

Dawes County soils were formed by weathering of materials of the underlying geologic formations or of materials deposited by wind and water. The Brule Formation is widely exposed on lower slopes, is soft and weathered rapidly producing the Epping, Kadoka, Deota, Schamber and Mitchell soils. As this material weathered, it produced the Epping, Kadoka variant, Keota, and Mitchell soils. Overlying Tertiary-age bedrock at higher elevations is the Arikaree Group. This massive sandstone contains layers of compacted silt and clay. Soils formed from this fine grained material are Alliance, Busher, Canyon,

Oglala, Tassel and Rosebud. Sandstone mixed with loess formed soils such as Bayard, Bridget and Vetal formed in colluvial and alluvial materials.

Soil association is a landscape that has a distinctive proportional pattern of soils, consisting of one or more major soils and at least one minor soil. Three soil associations exist within the Project Area: Kadoka-Keith-Mitchell, Busher-Tassel-Vetal, and Tripp-Haverson-Glenberg.

The Kadoka-Keith-Mitchell soils are deep, nearly level to steep, well drained silty soils that formed in loess and in material weathered from siltstones, on uplands and foot slopes. Typically this association consists of undulating to rolling uplands that are dissected by many spring-fed creeks. Areas of this association are mostly west of the project area. Approximate percentages of soils in this association are Kadoka at 28 percent, Keith 23 percent and Mitchell at 18 percent. Minor soils and land types make up the remaining 31 percent. Minor soils in this series are Bridget, Duroc, Epping, Ulysses, Keota, and Schamber series, and areas of loamy alluvial land and badland.

The Busher-Tassel-Vetal soils are deep and shallow, very gently sloping to steep, well drained to somewhat excessively drained sandy soils that formed in colluvium and in material weathered from sandstone. These sandy soils are found on undulating to hilly uplands which are crossed by numerous creeks and intermittent drainageways. Approximate percentages of soils in this association are Busher 35 percent, Tassel 32 percent and Vetal 15 percent. Minor soils and land types make up the remaining 18 percent. These include the Bayard, Jayem and Sarben soil types and sandy alluvial land.

The Tripp-Haverson-Glenberg soils are deep and shallow, very gently sloping to steep, well-drained to somewhat excessively-drained sandy soils that formed in colluvium and in material weathered from sandstone on uplands and foot slopes. These soils are found in undulating and hilly uplands that are crossed by numerous creeks and intermittent drainageways. Approximate percentages of soils in this association area: Busher soils at 35 percent, Tassel soils at 32 percent, and Vetal soils at 15 percent. Minor soils and land types make up the remaining 18 percent. Minor soils in this association are soils in the Bayard, Jayem, and Sarben series and areas of sandy alluvial land and rock outcrop.

In certain areas, the soil material is so rocky, shallow, severely eroded or variable that it has not been classified by soil series. These areas are called land types and are given descriptive names. An example of this is "sandy alluvial land" found within the Busher-Tassel-Vetal association.

Certain of the mapping units are composed of soil complexes or undifferentiated soil groups. A soil complex consists of areas of two or more soils so intricately mixed or so small in size that they cannot be shown separately on the soil map. Undifferentiated soil

groups are made up of two or more soils that could be delineated individually but are shown as one unit because, for the purpose of the soil survey, there is little value in separating them. The name given uses the two dominant soil series represented in the group. Four of the mapping units within the restricted area belong to this category, where the names of dominant soils are joined by "and".

Soils Mapping Unit Descriptions

Table 2.6-5 summarizes those soils found within the North Trend Project Area. The first capital letter is the initial one of the soil name. The lower case letter that follows separates mapping units having names that begin with the same letter except that it does not separate sloping or eroded phases. The second capital letter indicates the class of the slope. Symbols without a slope letter are for soils that have a slope range of 0 to 2 percent or miscellaneous land types that have a wide range of slopes. A final number 2 in the symbol indicates that the soil is eroded. Those soils are also shown on Figure 2.6-29.

Table 2.6-5: Summary of Soil Resources within the Project Area

Map Unit	Map Unit Name	% of Project Area
Bg	Bridget silt loam, 0 to 1 percent slopes	1.22%
BgB	Bridget silt loam, 1 to 3 percent slopes	0.30%
BuD	Busher loamy very fine sand, 5 to 9 percent slopes	0.00%
BuD2	Busher loamy very fine sand, 5 to 9 percent slopes, eroded	0.11%
DuB	Duroc very fine sandy loam, 1 to 3 percent slopes	6.30%
GoB	Glenberg loamy very fine sand, occasionally flooded, 0 to 3 percent slopes	0.35%
HbB	Haverson silt loam, occasionally flooded, 0 to 3 percent slopes	0.27%
JmC	Jayem loamy very fine sand, 1 to 5 percent slopes	9.15%
JvD	Jayem and Vetal loamy very fine sands, 5 to 9 percent slopes	0.22%
KaD	Kadoka silt loam, deep variant, 3 to 9 percent slopes	5.27%
KaD2	Kadoka silt loam, deep variant, 3 to 9 percent slopes, eroded	1.04%
KeB	Keith silt loam, 1 to 3 percent slopes	29.43%
KeD	Keith silt loam, 3 to 9 percent slopes	1.68%
KfD	Keith and Ulysses silt loams, 3 to 9 percent slopes	9.79%
KoB	Keota silt loam, 1 to 3 percent slopes	0.44%
KpD	Keota-Epping silt loams, 3 to 9 percent slopes	3.05%
Lo	Loamy alluvial land	0.69%
OgF	Oglala loam, 9 to 30 percent slopes	0.50%
OhF	Oglala-Canyon loams, 9 to 20 percent slopes	0.26%
Sn	Sandy alluvial land	0.92%
SrC	Sarben fine sandy loam, 1 to 5 percent slopes	11.47%
SrD	Sarben fine sandy loam, 5 to 9 percent slopes	0.91%
SrF	Sarben fine sandy loam, 9 to 30 percent slopes	0.08%
SvF	Sarben and Vetal loamy very fine sands, 9 to 30 percent slopes	4.01%
VeC	Vetal and Bayard soils, 1 to 5 percent slopes	12.55%

Bg - Bridget silt loam, 0 to 1 percent slopes

The Bridget component makes up 100 percent of the map unit. Slopes are 0 to 1 percent. This component is on hillslopes on uplands. The parent material consists of loamy colluvium. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is very high. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. This component is in the R064XY036NE Loamy 17 - 20" P.z. ecological site. Nonirrigated land capability classification is 2c. Irrigated land capability classification is 1. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 6 percent.

Soil blowing can be a hazard in cultivated areas. A large acreage of this soil is cultivated and is dryfarmed with wheat and alfalfa being the principal crops.

BgB - Bridget silt loam, 1 to 3 percent slopes

The Bridget component makes up 99 percent of the map unit. Slopes are 1 to 3 percent. This component is on hillslopes on uplands. The parent material consists of loamy colluvium. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is very high. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. This component is in the R064XY036NE Loamy 17 - 20" P.z. ecological site. Nonirrigated land capability classification is 2e. Irrigated land capability classification is 2e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 6 percent.

Water and wind erosion are hazards in areas where the soil surface is unprotected. Nearly all areas of this soil are dryfarmed to wheat, oats, or alfalfa. Native grass areas are used for grazing and hay.

BuD - Busher loamy very fine sand, 5 to 9 percent slopes

The Busher component makes up 100 percent of the map unit. Slopes are 5 to 9 percent. This component is on hillslopes on uplands. The parent material consists of residuum weathered from sandstone. Depth to a root restrictive layer, bedrock, paralithic, is 40 to 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. This component is in the R064XY032NE Sandy 17-20" P.z. ecological site. Nonirrigated land capability classification is 4e. Irrigated land capability classification is 4e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 3 percent.

Water and wind erosion are hazards in areas where the soil surface is unprotected. Most areas of this soil are native grass used for grazing and hay production. A few areas are dryfarmed to wheat, alfalfa, and oats.

BuD2 - Busher loamy very fine sand, 5 to 9 percent slopes, eroded

The Busher component makes up 99 percent of the map unit. Slopes are 5 to 9 percent. This component is on hillslopes on uplands. The parent material consists of residuum weathered from sandstone. Depth to a root restrictive layer, bedrock, paralithic, is 40 to 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. This component is in the R064XY032NE Sandy 17-20" P.z. ecological site. Nonirrigated land capability classification is 4e. Irrigated land capability classification is 4e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 3 percent.

Water and wind erosion are serious hazards where the soil surface is unprotected. Nearly all areas of this soil are dryfarmed to wheat, alfalfa, and oats. A few areas are seeded to grass and used for grazing or hay production.

DuB - Duroc very fine sandy loam, 1 to 3 percent slopes

The Duroc component makes up 99 percent of the map unit. Slopes are 1 to 3 percent. This component is on swales on uplands. The parent material consists of alluvium. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is high. Shrink-swell potential is moderate. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. This component is in the R064XY036NE Loamy 17 - 20" P.z. ecological site. Nonirrigated land capability classification is 2e. Irrigated land capability classification is 2e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 5 percent.

Much of the soil is suited for irrigation and cultivated; however, the area is mostly dryfarmed to wheat, oats, or alfalfa. The rest of the acreage is in native and tame grasses used for grazing or hay production.

GoB - Glenberg loamy very fine sand, occasionally flooded, 0 to 3 percent slopes

The Glenberg component makes up 100 percent of the map unit. Slopes are 0 to 3 percent. This component is on flood plains on valleys. The parent material consists of stratified calcareous alluvium. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer

is high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. This soil is occasionally flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 1 percent. This component is in the R064XY029NE Sandy Lowland ecological site. Nonirrigated land capability classification is 4w. Irrigated land capability classification is 3w. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 6 percent.

Soil blowing is a hazard if the soil is cultivated and the surface is not protected. Small areas of this soil are cultivated with Alfalfa being the main dryfarmed crop. The rest of the area is in native or tame grasses used for grazing or hay production.

HbB - Haverson silt loam, occasionally flooded, 0 to 3 percent slopes

The Haverson component makes up 100 percent of the map unit. Slopes are 0 to 3 percent. This component is on flood plains on valleys. The parent material consists of stratified calcareous alluvium. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is high. Shrink-swell potential is low. This soil is occasionally flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 1 percent. This component is in the R064XY026NE Loamy Overflow ecological site. Nonirrigated land capability classification is 2w. Irrigated land capability classification is 2w. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 6 percent.

Approximately half the acreage of this soil is in crops with the other half in range. Alfalfa is the main crop. Trees and shrubs cover some areas.

JmC - Jayem loamy very fine sand, 1 to 5 percent slopes

The Jayem component makes up 99 percent of the map unit. Slopes are 1 to 5 percent. This component is on hillslopes on uplands. The parent material consists of sandy and silty eolian deposits. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. This component is in the R064XY032NE Sandy 17 - 20" P.z. ecological site. Nonirrigated land capability classification is 3e. Irrigated land capability classification is 3e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 1 percent.

Soil blowing is a hazard if the soil surface is left unprotected. Most of the acreage of this soil is in native grass, which is used for grazing or hay. The rest of the acreage is cultivated with wheat or alfalfa being the main crops.

JvD - Jayem and Vetal loamy very fine sands, 5 to 9 percent slopes

The Vetal component makes up 50 percent of the map unit. Slopes are 5 to 9 percent. This component is on hillslopes on uplands. The parent material consists of loamy alluvium over eolian deposits. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. This component is in the R064XY032NE Sandy 17 - 20" P.z. ecological site. Nonirrigated land capability classification is 4e. Irrigated land capability classification is 4e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 3 percent.

Water and wind erosion are hazards in cultivated areas where the soil surface is left unprotected. Most areas are in native grasses used for grazing and hay production. A small acreage is cultivated to wheat, alfalfa, and oats.

KaD - Kadoka silt loam, deep variant, 3 to 9 percent slopes

The Thirtynine component makes up 99 percent of the map unit. Slopes are 3 to 9 percent. This component is on hillslopes on uplands. The parent material consists of alluvium derived from siltstone. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is very high. Shrink-swell potential is moderate. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 3 percent. This component is in the R064XY036NE Loamy 17-20" P.z. ecological site. Nonirrigated land capability classification is 3e. Irrigated land capability classification is 3e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 8 percent.

Water and wind erosion are hazards in cultivated areas where the soil surface is left unprotected. Most acreage of this soil is used for range with small areas used for hay production.

KaD2 - Kadoka silt loam, deep variant, 3 to 9 percent slopes, eroded

The Thirtynine component makes up 99 percent of the map unit. Slopes are 3 to 9 percent. This component is on hillslopes on uplands. The parent material consists of alluvium derived from siltstone. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is very high. Shrink-swell potential is moderate. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 3 percent. This component is in the R064XY036NE Loamy 17-20" P.z. ecological site. Nonirrigated land capability classification is 3e. Irrigated land capability classification is 3e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 8 percent.

Water erosion is the main hazard. Nearly all the acreage of this soil is cultivated to wheat, alfalfa, or oats. A few areas are seeded to grass, which is used for grazing or hay production.

KeB - Keith silt loam, 1 to 3 percent slopes

The Keith component makes up 99 percent of the map unit. Slopes are 1 to 3 percent. This component is on plains on uplands. The parent material consists of loess. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is very high. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. This component is in the R064XY036NE Loamy 17 - 20" P.z. ecological site. Nonirrigated land capability classification is 2e. Irrigated land capability classification is 2e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 6 percent.

Soil erosion is the main hazard with modest water erosion potential in some areas. This soil is used for both crops and range. Winter wheat, alfalfa, and oats are the principal dryfarmed crops. Some areas are in grass and are used for grazing or hay production.

KeD - Keith silt loam, 3 to 9 percent slopes

The Keith component makes up 99 percent of the map unit. Slopes are 3 to 9 percent. This component is on hillslopes on uplands. The parent material consists of loess. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available

water to a depth of 60 inches is very high. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. This component is in the R064XY036NE Loamy 17 - 20" P.z. ecological site. Nonirrigated land capability classification is 3e. Irrigated land capability classification is 3e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 6 percent.

Water erosion is the main hazard, with soil erosion a concern of management. A small acreage of this soil is used for crops, but most areas are in native grass and are used for grazing or hay production.

KfD - Keith and Ulysses silt loams, 3 to 9 percent slopes

The Keith component makes up 50 percent of the map unit. Slopes are 3 to 9 percent. This component is on hillslopes on uplands. The parent material consists of loess. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is very high. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. This component is in the R064XY036NE Loamy 17 - 20" P.z. ecological site. Nonirrigated land capability classification is 3e. Irrigated land capability classification is 3e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 6 percent.

The Ulysses component makes up 49 percent of the map unit. Slopes are 3 to 6 percent. This component is on hillslopes on uplands. The parent material consists of calcareous loess. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is high. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. This component is in the R064XY036NE Loamy 17 - 20" P.z. ecological site. Nonirrigated land capability classification is 3e. Irrigated land capability classification is 3e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 8 percent.

Water erosion is a hazard, along with the controlling of soil blowing. Nearly all of the acreage of this soil is used for crops such as wheat, alfalfa, and oats. Only a few areas are irrigated and a small acreage is seeded to tame grasses used for grazing or hay production.

KoB - Keota silt loam, 1 to 3 percent slopes

The Keota component makes up 99 percent of the map unit. Slopes are 1 to 3 percent. This component is on interfluves on uplands. The parent material consists of calcareous loamy residuum weathered from siltstone. Depth to a root restrictive layer, bedrock, paralithic, is 20 to 40 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is low. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 1 percent. This component is in the R064XY037NE Thin Upland ecological site. Nonirrigated land capability classification is 3e. Irrigated land capability classification is 3e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 5 percent.

Soil blowing and water erosion are hazards. Much of the acreage of this soil is cultivated or has been seeded to grass. Wheat is the principal dryfarmed crop. Areas of grass are used for grazing or hay production.

KpD - Keota-Epping silt loams, 3 to 9 percent slopes

The Keota component makes up 70 percent of the map unit. Slopes are 3 to 6 percent. This component is on hillslopes on uplands. The parent material consists of calcareous loamy residuum weathered from siltstone. Depth to a root restrictive layer, bedrock, paralithic, is 20 to 40 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is low. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 1 percent. This component is in the R064XY037NE Thin Upland ecological site. Nonirrigated land capability classification is 4e. Irrigated land capability classification is 4e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 5 percent.

The Epping component makes up 29 percent of the map unit. Slopes are 3 to 9 percent. This component is on ridges on uplands. The parent material consists of loamy residuum weathered from siltstone. Depth to a root restrictive layer, bedrock, paralithic, is 10 to 20 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is very low. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 1 percent. This component is in the R064XY040NE Shallow ecological site. Nonirrigated land capability classification is 6s. This soil does not meet hydric

criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 6 percent.

Water erosion and soil blowing are hazards. Most of the acreage of this mapping unit is used for dryfarmed crops such as wheat, oats or alfalfa. The rest of the acreage is in native tame grasses, which are used for grazing or hay production.

Lo - Loamy alluvial land

The Haverson component makes up 98 percent of the map unit. Slopes are 0 to 3 percent. This component is on flood plains on valleys. The parent material consists of stratified calcareous alluvium. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is high. Shrink-swell potential is low. This soil is frequently flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 1 percent. This component is in the R064XY026NE Loamy Overflow ecological site. Nonirrigated land capability classification is 6w. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 6 percent.

Most areas of this land type are used for grazing but grass in a few areas is cut for hay. The hazard of flooding and deposition of sediment generally makes this land type unsuited to cultivation. The native vegetation is mostly grasses, and some areas support trees or shrubs. Most areas provide good food and cover for wildlife.

OgF - Oglala loam, 9 to 30 percent slopes

The Oglala component makes up 100 percent of the map unit. Slopes are 9 to 30 percent. This component is on hillslopes on uplands. The parent material consists of loamy residuum weathered from soft, fine-grained sandstone. Depth to a root restrictive layer, bedrock, paralithic, is 40 to 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is low. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. This component is in the R064XY036NE Loamy 17 - 20" P.z. ecological site. Nonirrigated land capability classification is 6e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 3 percent.

Soil blowing and water erosion are hazards if the soil surface is not protected. Nearly all the acreage of this soil is in native grass. A few areas are seeded to tame grasses. This soil is unsuited to cultivation because of the steepness of the slopes.

OhF - Oglala-Canyon loams, 9 to 20 percent slopes

The Oglala component makes up 70 percent of the map unit. Slopes are 9 to 20 percent. This component is on hillslopes on uplands. The parent material consists of loamy residuum weathered from soft fine grained sandstone. Depth to a root restrictive layer, bedrock, paralithic, is 40 to 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is low. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. This component is in the R064XY036NE Loamy 17 - 20" P.z. ecological site. Nonirrigated land capability classification is 6e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 3 percent.

The Canyon component makes up 30 percent of the map unit. Slopes are 9 to 20 percent. This component is on ridges on uplands. The parent material consists of calcareous loamy residuum weathered from limestone and sandstone. Depth to a root restrictive layer, bedrock, paralithic, is 6 to 20 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is moderately high. Available water to a depth of 60 inches is very low. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. This component is in the R064XY040NE Shallow ecological site. Nonirrigated land capability classification is 6s. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 6 percent.

Water erosion is a hazard if the cover of native grass is removed from these soils. Nearly all the acreage of this unit is in native grass and is used mostly for grazing. Nearly all of the areas that were cultivated have been seeded to grass. These soils are not suited to cultivation.

SrC - Sarben fine sandy loam, 1 to 5 percent slopes

The Sarben component makes up 100 percent of the map unit. Slopes are 1 to 5 percent. This component is on hillslopes on uplands. The parent material consists of sandy and loamy eolian deposits. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 1 percent. This component is in the R064XY032NE Sandy 17 - 20"

P.z. ecological site. Nonirrigated land capability classification is 3e. Irrigated land capability classification is 2e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 6 percent.

Water erosion is a hazard in some areas but wind erosion is the main hazard. Nearly all the acreage of this soil is in cultivated crops such as wheat, alfalfa, and oats. Some areas are seeded to tame grass used for grazing or hay production.

SrD - Sarben fine sandy loam, 5 to 9 percent slopes

The Sarben component makes up 99 percent of the map unit. Slopes are 5 to 9 percent. This component is on hillslopes on uplands. The parent material consists of sandy and loamy eolian deposits. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 1 percent. This component is in the R064XY032NE Sandy 17 - 20" P.z. ecological site. Nonirrigated land capability classification is 4e. Irrigated land capability classification is 4e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 6 percent.

Water and wind erosion is a hazard in areas with disturbed surface. Nearly all the acreage of this soil is in cultivated crops; wheat, alfalfa, or oats. Some areas are seeded to tame grass used for grazing or hay production.

SrF - Sarben fine sandy loam, 9 to 30 percent slopes

The Sarben component makes up 100 percent of the map unit. Slopes are 9 to 30 percent. This component is on hillslopes on uplands. The parent material consists of sandy and loamy eolian deposits. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 1 percent. This component is in the R064XY032NE Sandy 17 - 20" P.z. ecological site. Nonirrigated land capability classification is 6e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 6 percent.

Water erosion and soil blowing are major hazards if the soil surface is left unprotected. This soil is generally too steep and too erodible for cultivation but where it occurs in

areas with soils that are suited to crops, it is cultivated along with those soils. Some areas are seeded to tame grass used for grazing or hay production.

SvF - Sarben and Vetal loamy very fine sands, 9 to 30 percent slopes

The Sarben component makes up 70 percent of the map unit. Slopes are 9 to 30 percent. This component is on hillslopes on uplands. The parent material consists of sandy and loamy eolian deposits. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 1 percent. This component is in the R064XY032NE Sandy 17 - 20" P.z. ecological site. Nonirrigated land capability classification is 6e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 6 percent.

The Vetal component makes up 30 percent of the map unit. Slopes are 9 to 10 percent. This component is on hillslopes on uplands. The parent material consists of loamy alluvium over eolian deposits. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. This component is in the R064XY032NE Sandy 17 - 20" P.z. ecological site. Nonirrigated land capability classification is 4e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 3 percent.

Water erosion and soil blowing are hazards if the soil surface is not protected. All the acreage of this mapping unit is in native grass used for grazing or hay production. This unit is too steep for the commonly grown crops.

VeC - Vetal and Bayard soils, 1 to 5 percent slopes

The Vetal component makes up 50 percent of the map unit. Slopes are 1 to 5 percent. This component is on stream terraces on valleys. The parent material consists of loamy alluvium over eolian deposits. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is high. Available water to a depth of 60 inches is moderate. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. This component is in the R064XY032NE Sandy 17 - 20" P.z. ecological site. Nonirrigated land capability classification is 3e. Irrigated land capability classification is

3e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 3 percent.

The Bayard component makes up 49 percent of the map unit. Slopes are 1 to 5 percent. This component is on stream terraces on valleys. The parent material consists of colluvial-alluvial sediments from calcareous sandstone. Depth to a root restrictive layer is greater than 60 inches. The natural drainage class is well drained. Water movement in the most restrictive layer is high. Available water to a depth of 60 inches is high. Shrink-swell potential is low. This soil is not flooded. It is not ponded. There is no zone of water saturation within a depth of 72 inches. Organic matter content in the surface horizon is about 2 percent. This component is in the R064XY032NE Sandy 17 - 20" P.z. ecological site. Nonirrigated land capability classification is 3e. Irrigated land capability classification is 3e. This soil does not meet hydric criteria. The calcium carbonate equivalent within 40 inches, typically, does not exceed 6 percent.

Soil blowing is a hazard if the soil surface is not protected. About half the acreage of these soils is in crops and half is in range. Wheat, alfalfa and oats are the principal crops. Some areas are seeded to tame grasses used for hay production. Areas of native grass are used for grazing or the grass is cut for hay production.

2.6.6 References

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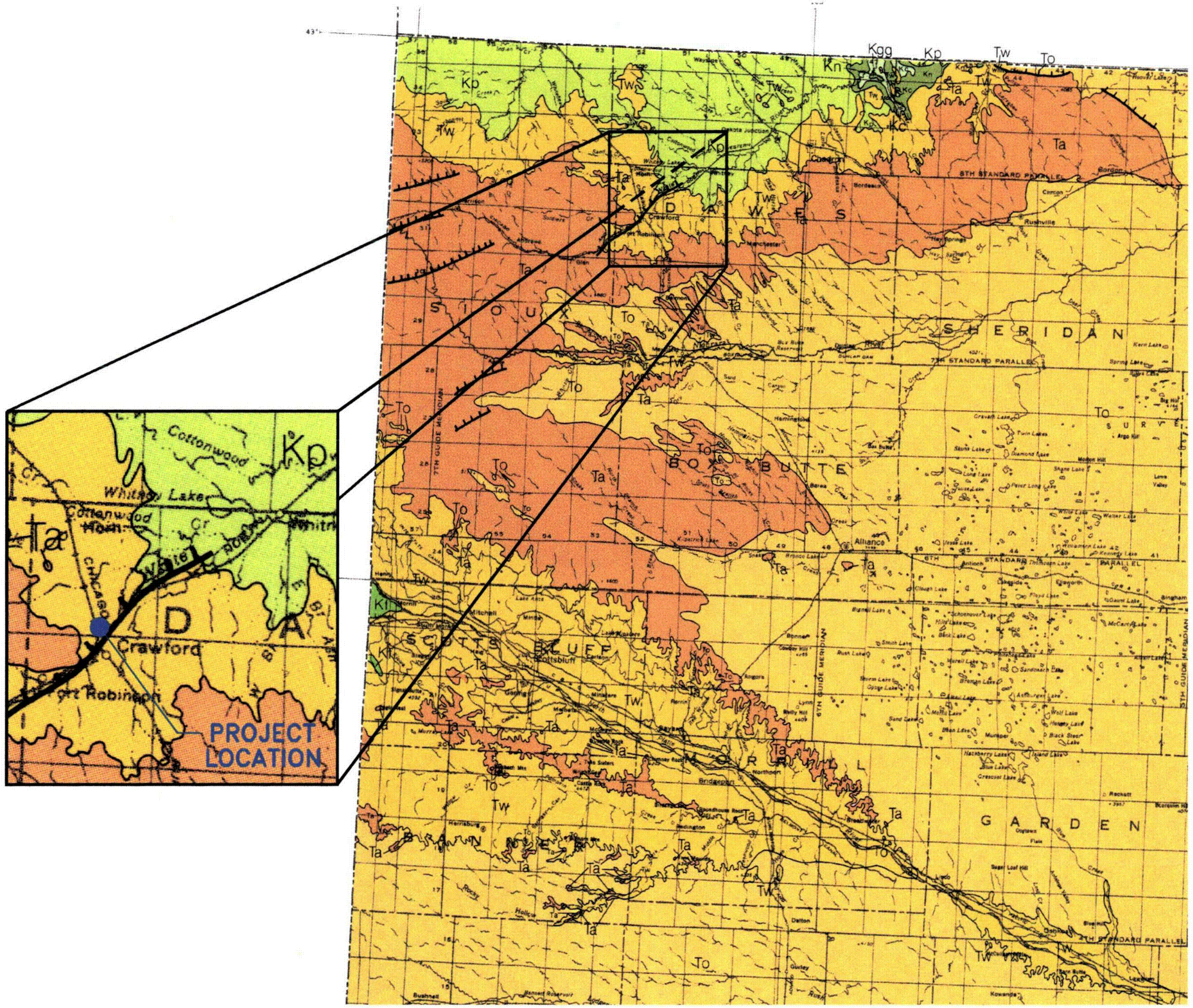
Oil and Gas Test Wells in the Vicinity of the CSA and North Trend

Bunch No. 1, Section 5, Township 31 North, Range 51 West
Heckman No. 1, Section 24, Township 31 North, Range 52 West
Arner No. 1, Section 26, Township 31 North, Range 52 West
Roby No. 1, Section 31, Township 31 North, Range 51 West
Soester No.1, Section 34, Township 32 North, Range 52 West
True State, Section 36, Township 32 North, Range 52 West
San Jacinto No. 1 Federal, Section 17, Township 31 North, Range 52 West
CBR Deep Disposal Well, Section 19, Township 31 North, Range 51 West

Figures 2.6-1 Through 2.6-29 are Located on the Following Pages of Section 2.6



LEGEND

SYSTEM	SERIES	GROUP OR FORMATION	SYMBOL
T TERTIARY	MIOCENE	OGALLALA	To
		ARIKAREE	Ta
	OLIGOCENE	WHITE RIVER	Tw
K CRETACEOUS	UPPER CRETACEOUS	MONTANA: Fox Hills	Kf
		MONTANA: Pierre	Kp
		COLORADO: Niobrara	Kn
		COLORADO: Carlile	Kc
		COLORADO: Greenhorn-Graneros	Kgg
	LOWER CRETACEOUS	DAKOTA	Kd
Jr JURASSIC			
P PERMIAN	BIG BLUE	CHASE	Pc
		COUNCIL GROVE	Pcg
		ADMIRE	Pa
IP PENNSYLVANIAN	VIRGIL	WABAUNSEE	IPw
		SHAWNEE	IPs
		DOUGLAS	IPd
	MISSOURI	LANSING	IPl
		KANSAS CITY	IPkc
	DES MOINES	MARMATON	IPm
M MISSISSIPPIAN			
D DEVONIAN			
S SILURIAN			
O ORDOVICIAN (Middle & Upper)			
CO CAMBRIAN & ORDOVICIAN (Lower)			
PC PRECAMBRIAN			

(PLIOCENE AND QUATERNARY deposits not shown)

Source: Nebraska Geological Survey

CROW BUTTE RESOURCES, INC.

FIGURE 2.6–1
BEDROCK GEOLOGY MAP, DAWES COUNTY

PROJECT: 223–37	DATE: MARCH 2007	
NTLAAFig2.6–1.dwg	BY: KRS	CHECKED: HPD

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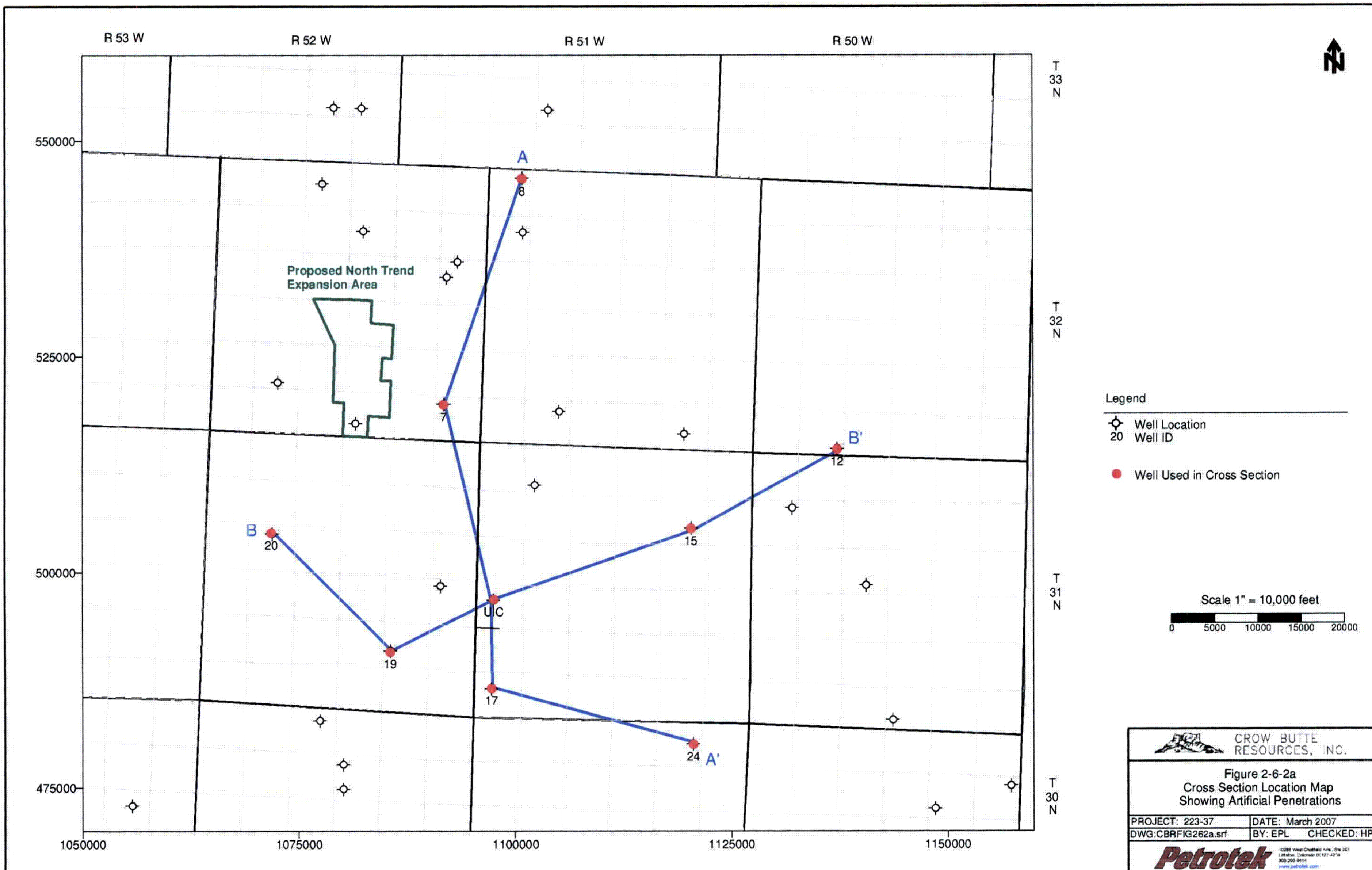
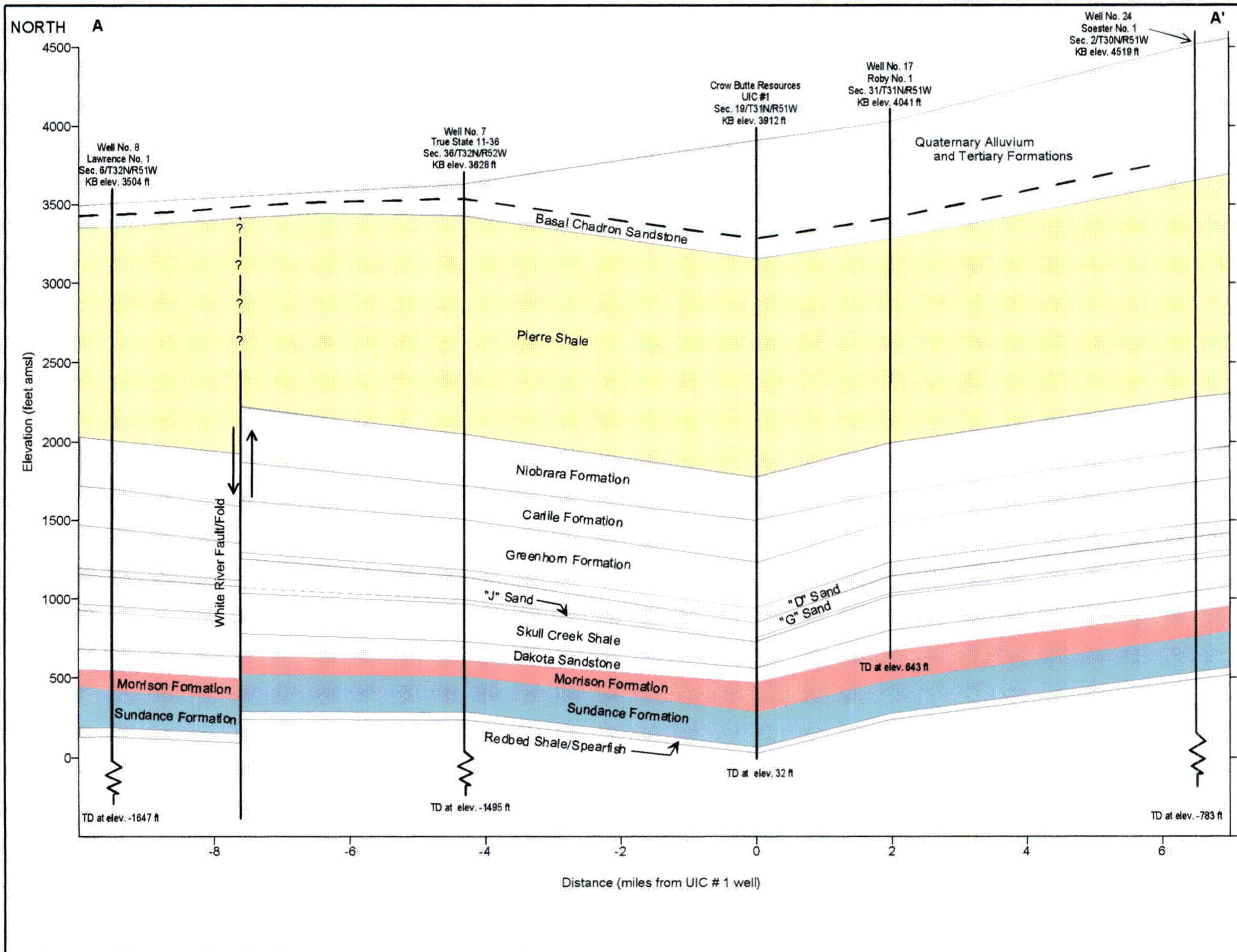


Figure 2-6-2a
Cross Section Location Map
Showing Artificial Penetrations



Orientation of Cross Section A-A' is indicated on Figure 2.6-2a

Vertical Scale 1" = 600 feet
Horizontal Scale 1" = 1.4 miles

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Figure 2.6-2b
N.S Regional Cross Section

PROJECT: CBR04-01	DATE: MARCH 2007	
DWG: CBRFIG262b	BY: EPL	CHECKED: HPD

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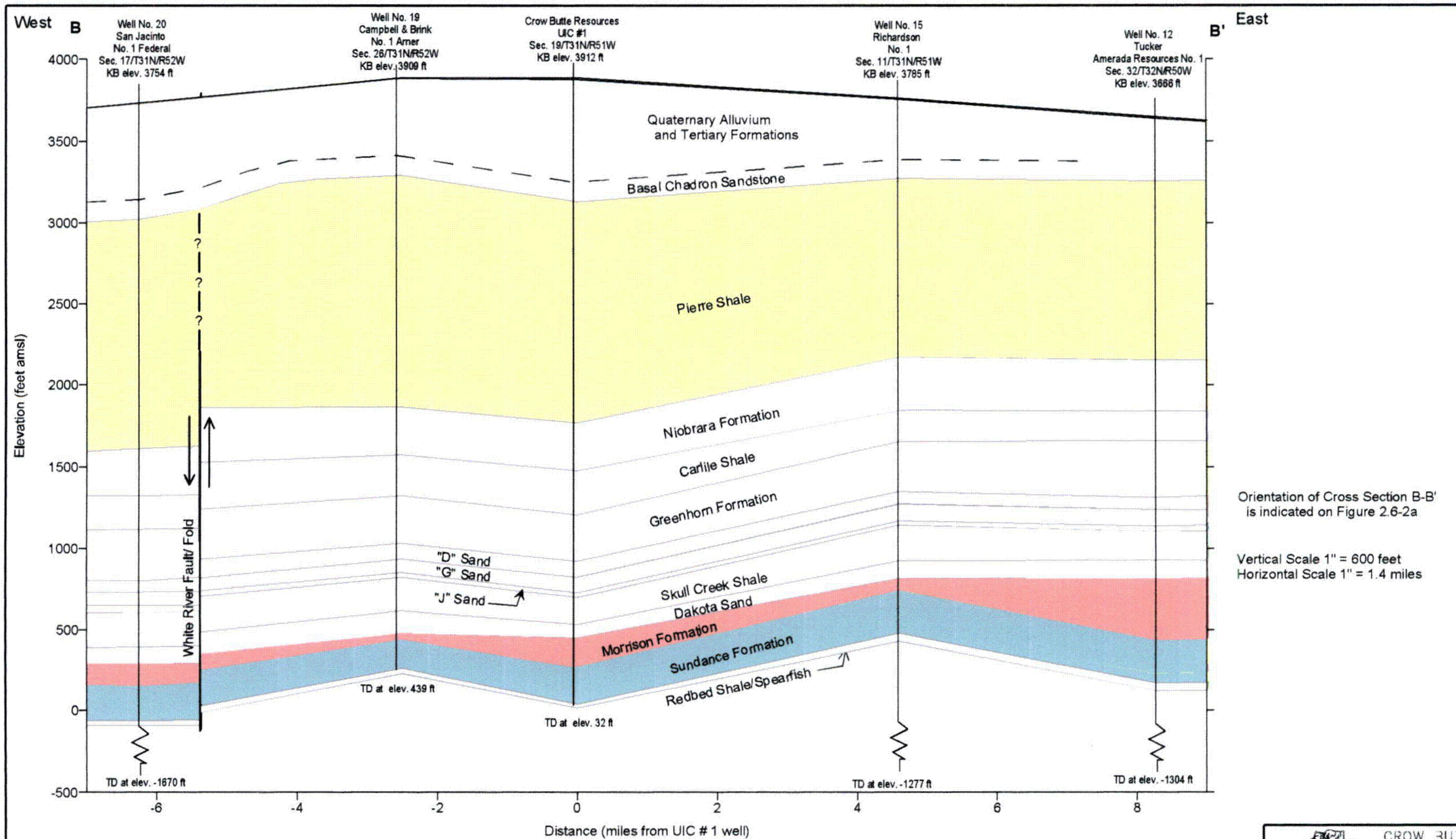

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Figure 2.6-2c
E-W Regional Cross Section

PROJECT: CBR04-01	DATE: MARCH 2007
DWG: CBRFIG262c.SRF	BY: EPL

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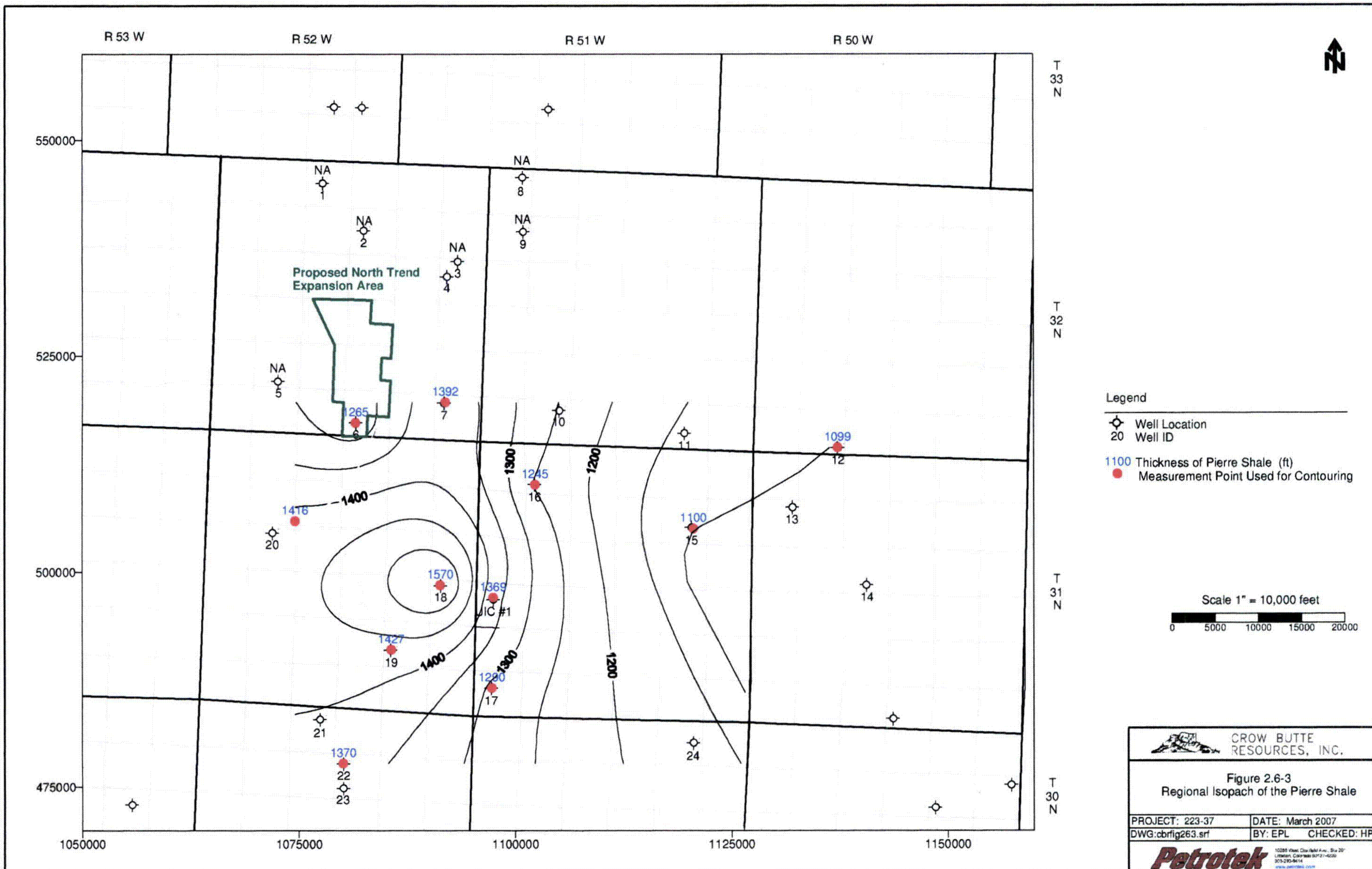


Figure 2.6-3
Regional Isopach of the Pierre Shale

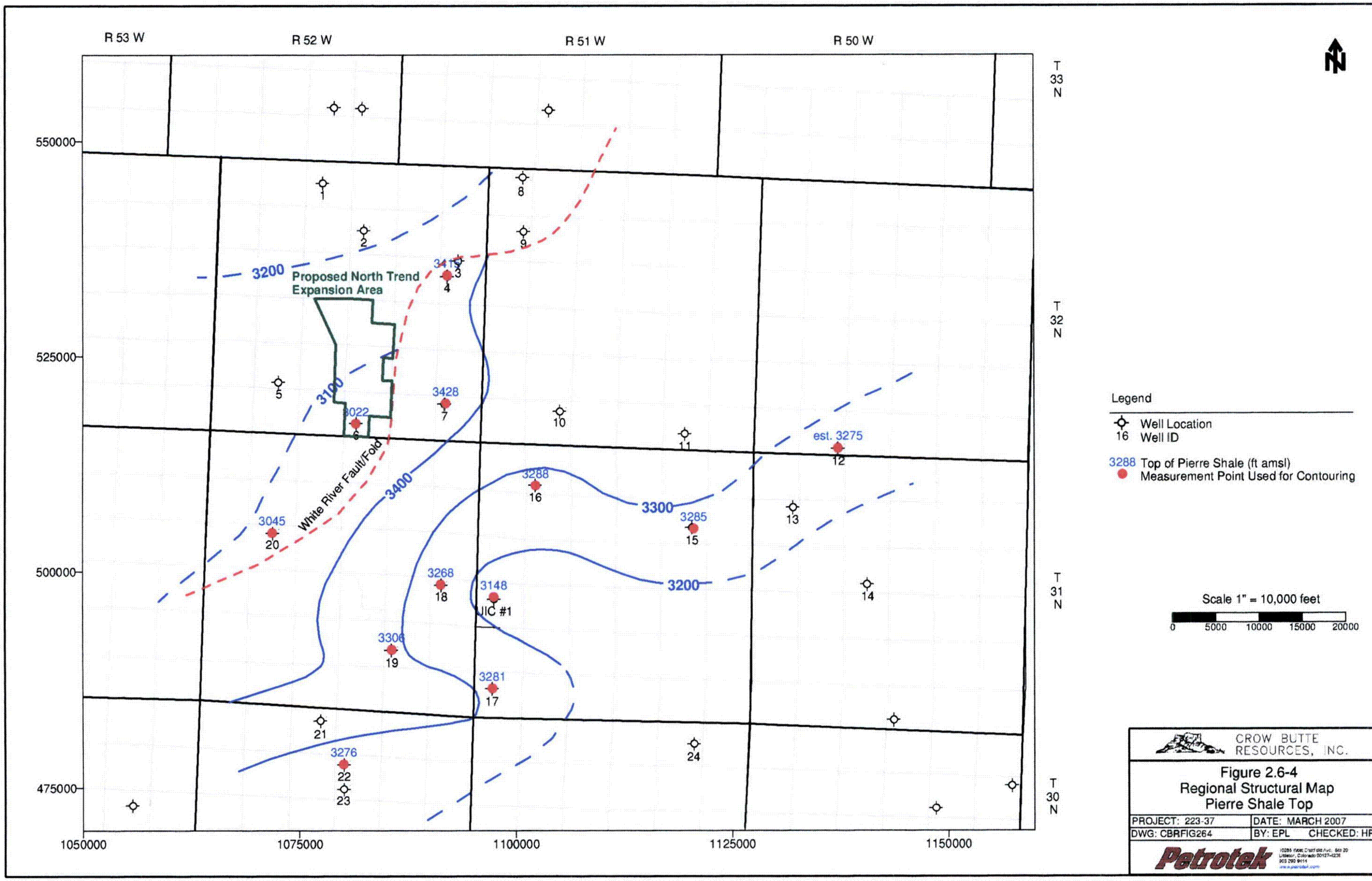
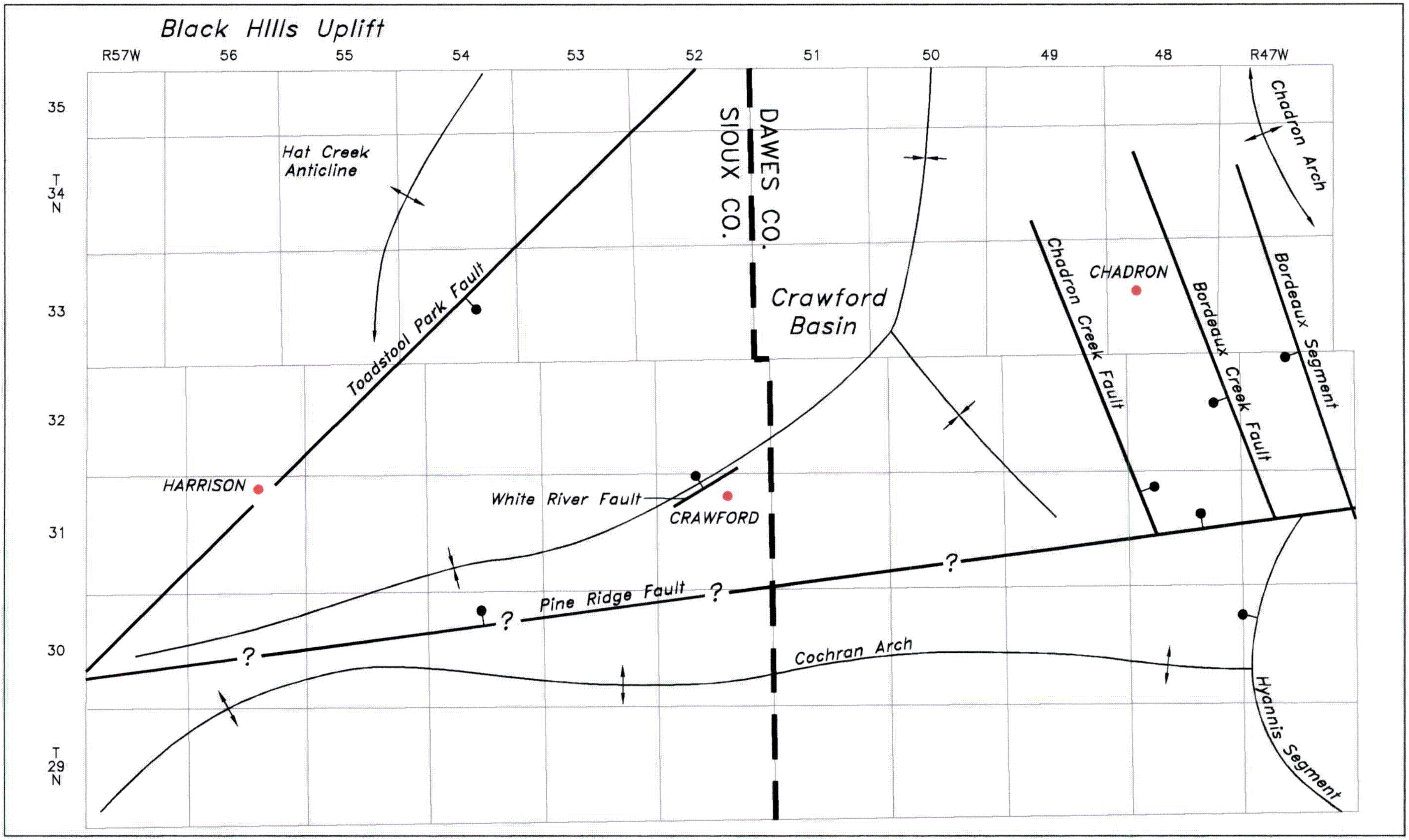


Figure 2.6-4
Regional Structural Map
Pierre Shale Top



LEGEND

Fault (Ball on downthrown side)

Anticline

Syncline

Modified from DeGraw, 1969; WFC–White River Fault only

0 5 10 20

SCALE IN MILES

N

W E

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FIGURE 2.6–5
STRUCTURAL FEATURES MAP
OF THE CRAWFORD BASIN

PROJECT: 223–37	DATE: MARCH 2007	
NTLAAFig2.6–5.dwg	BY: KRS	CHECKED: HPD

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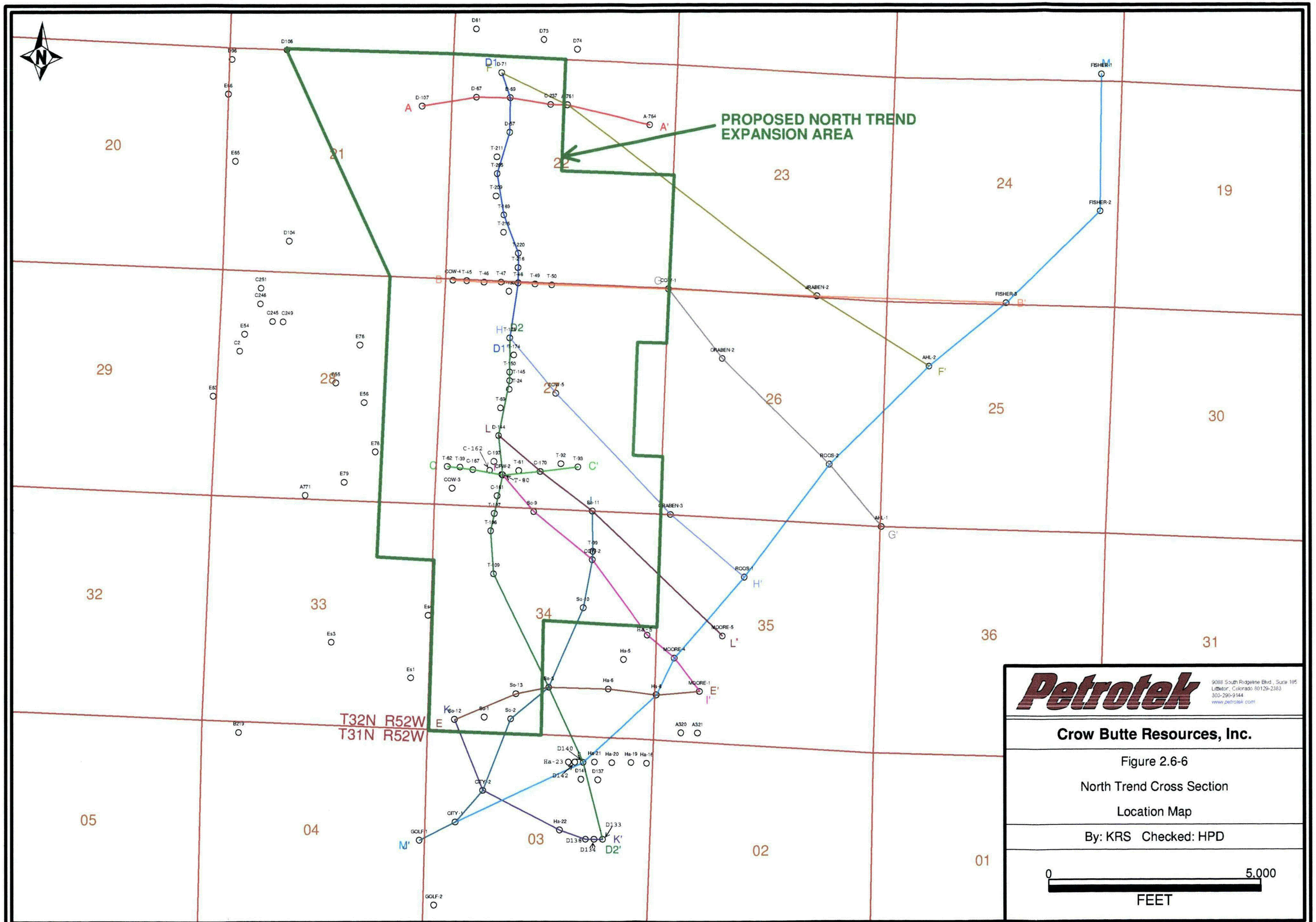

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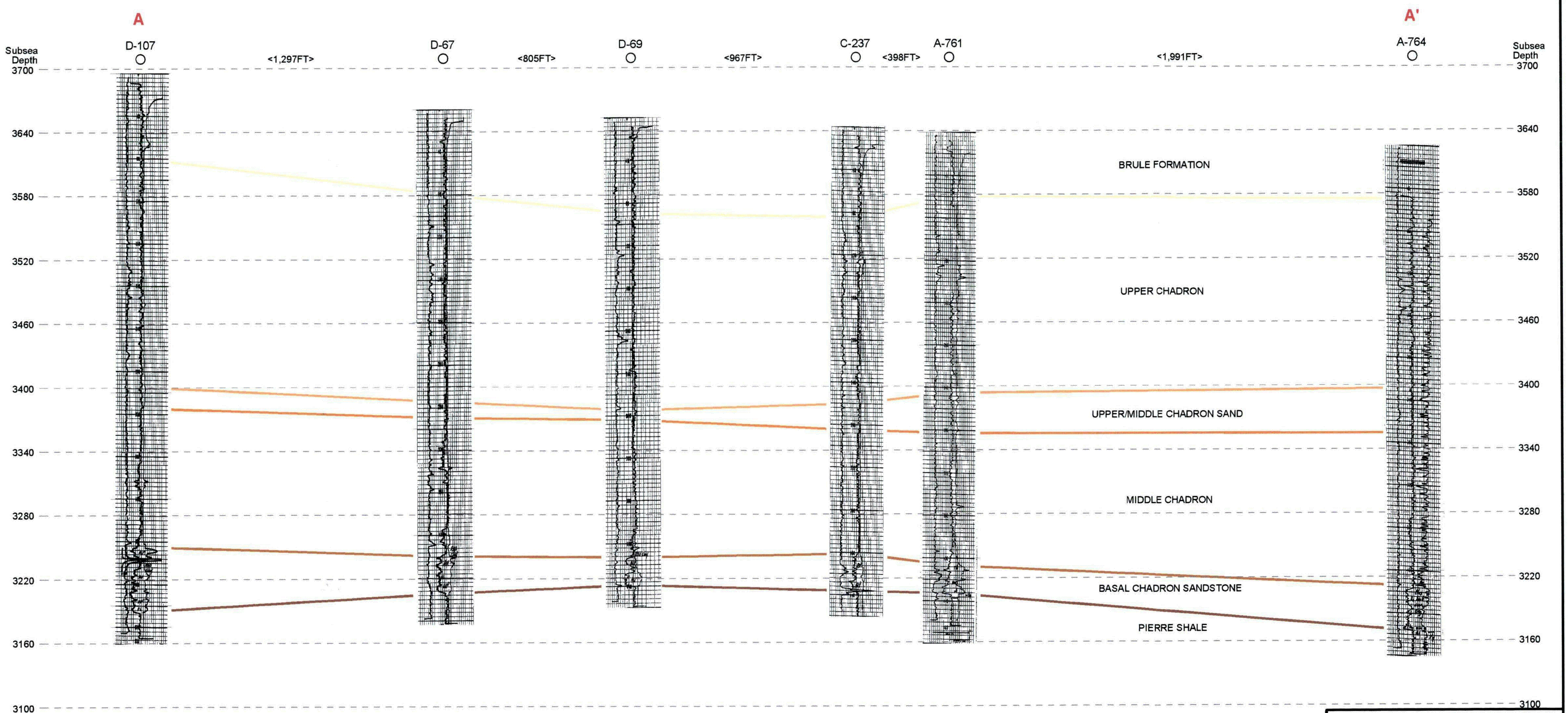

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North Trend Structural

Cross Section: A - A'

TOPS AND MARKERS

- TOP_UPPER_CHADRON_FORMATION
- TOP_UPPER/MIDDLE_CHADRON_SAND
- TOP_MIDDLE_CHADRON_FORMATION
- TOP_BASAL_CHADRON
- TOP_PIERRE

Figure 2.6-7

By: KRS Checked: HPD/WB

March 12,2007 11:45 AM

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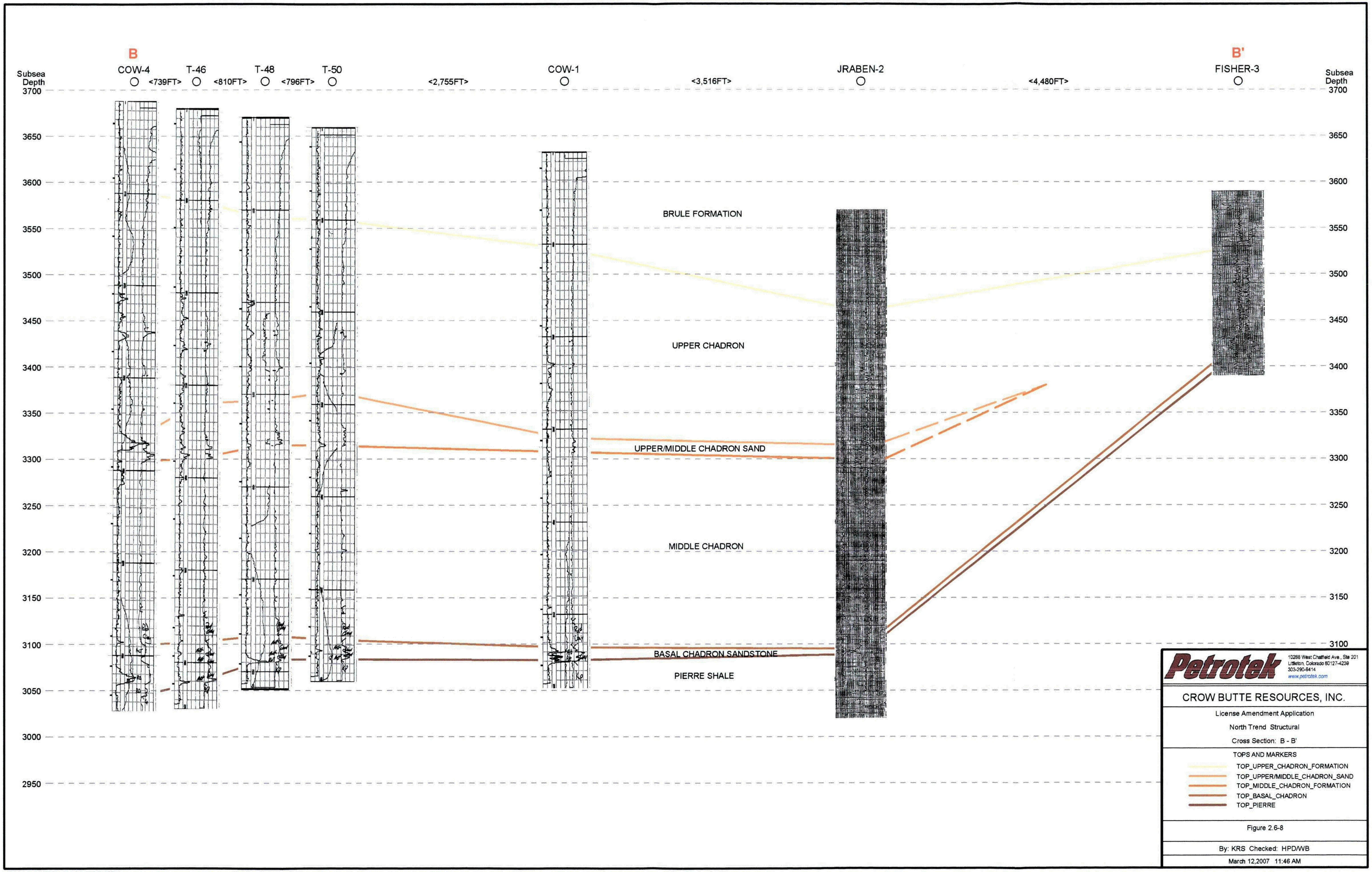

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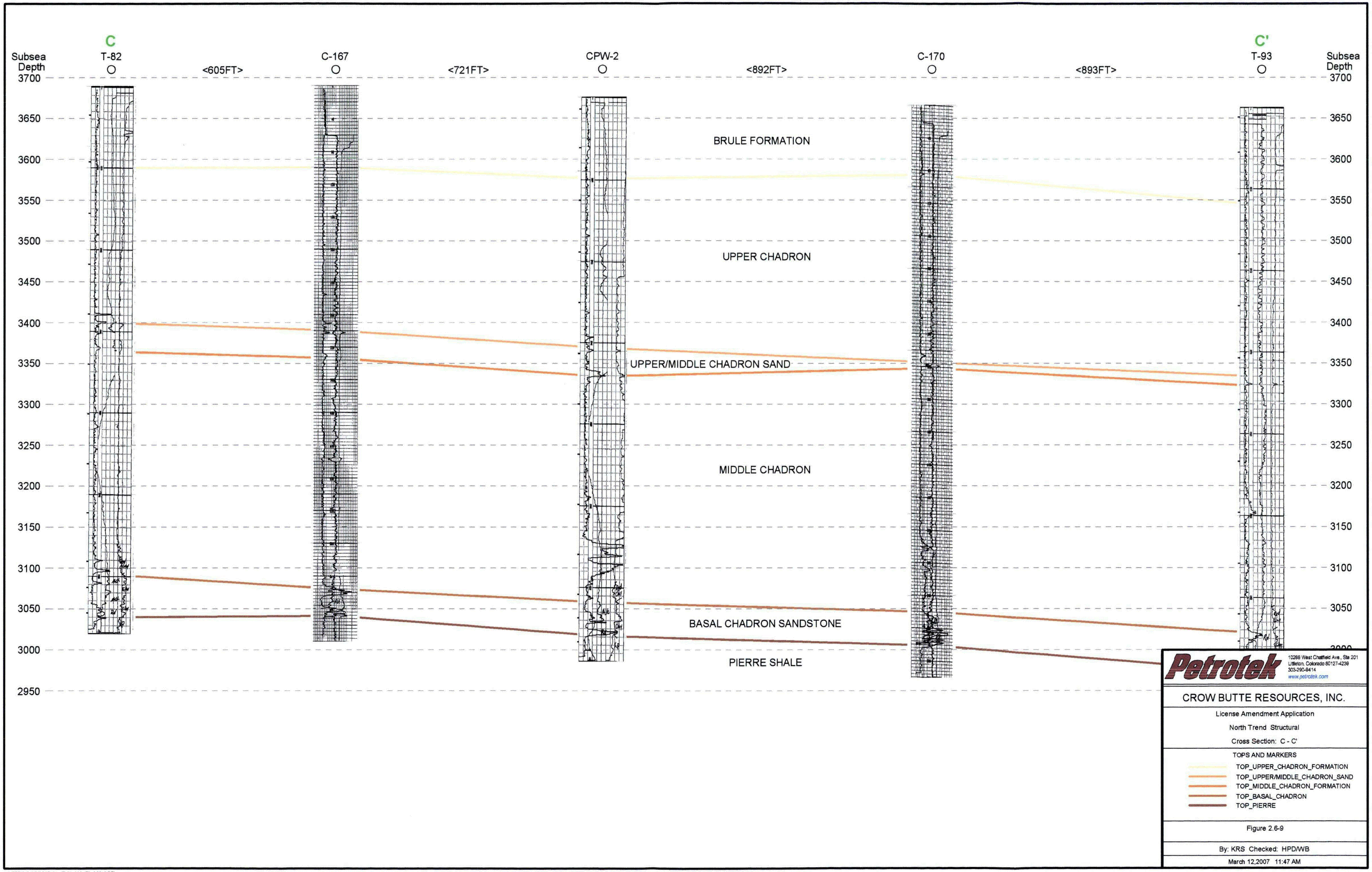

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North Trend Structural

Cross Section: C - C'

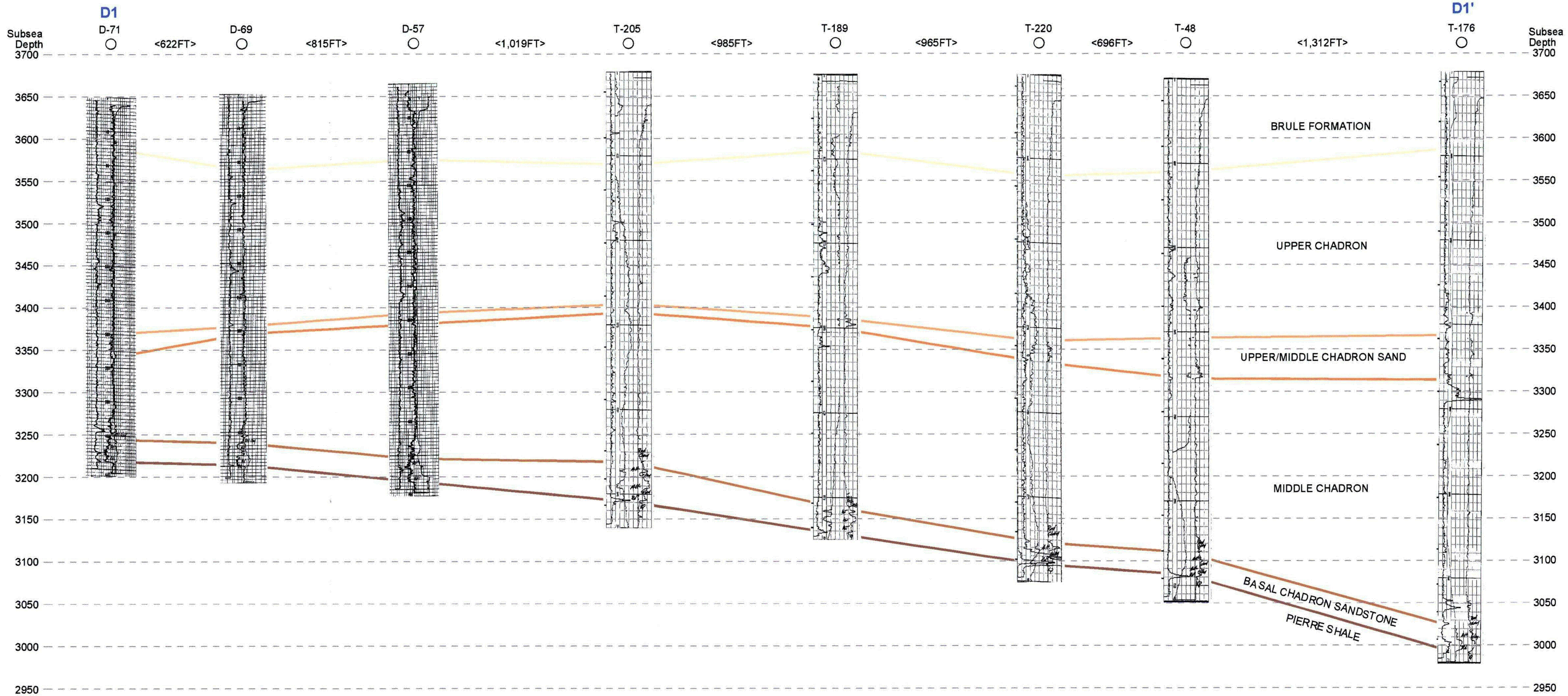
TOPS AND MARKERS
- TOP_UPPER_CHADRON_FORMATION
- TOP_UPPER/MIDDLE_CHADRON_SAND
- TOP_MIDDLE_CHADRON_FORMATION
- TOP_BASAL_CHADRON
- TOP_PIERRE

Figure 2.6-9

By: KRS Checked: HPD/WB

March 12,2007 11:47 AM

PETRA 3/12/2007 11:47:29 AM (Fig269.CSP)



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Cross Section: D1 - D1'

TOPS AND MARKERS

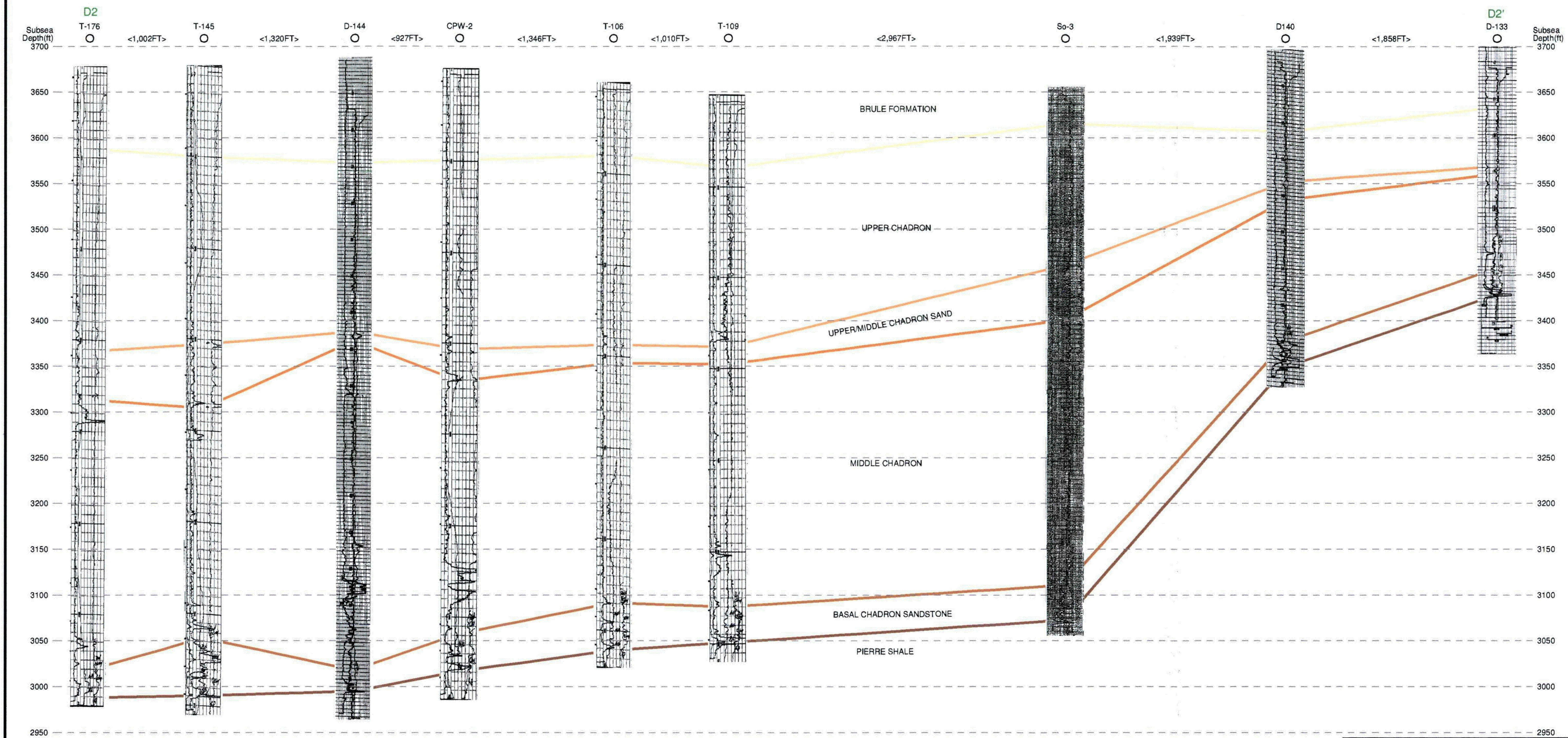
- TOP_UPPER_CHADRON_FORMATION
- TOP_UPPER/MIDDLE_CHADRON_SAND
- TOP_MIDDLE_CHADRON_FORMATION
- TOP_BASAL_CHADRON
- TOP_PIERRE

Figure 2.6-10

By: KRS Checked: HPD/WB

March 13,2007 4:38 PM

PETRA 3/13/2007 4:38:42 PM (Fig2610.CSP)



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Cross Section: D2 - D2'

TOPS AND MARKERS

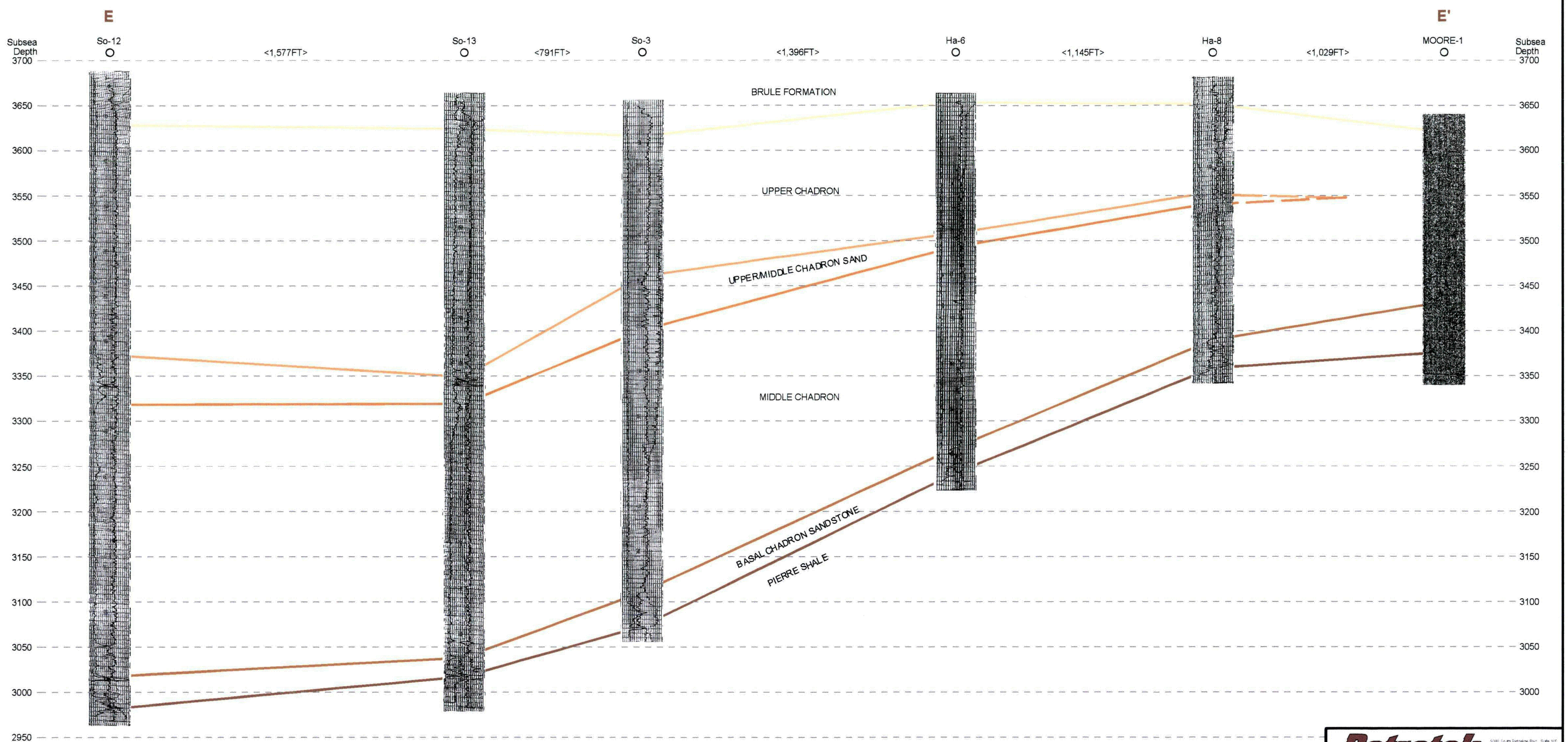
- TOP_UPPER_CHADRON_FORMATION
- TOP_UPPER/MIDDLE_CHADRON_SAND
- TOP_MIDDLE_CHADRON_FORMATION
- TOP_BASAL_CHADRON
- TOP_PIERRE

Figure 2.6-11

By: KRS Checked: HPD/WB

April 2,2007 3:47 PM

PETRA 4/2/2007 3:47:42 PM (Fig2611.CSP)



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Cross Section: E - E'

TOPS AND MARKERS

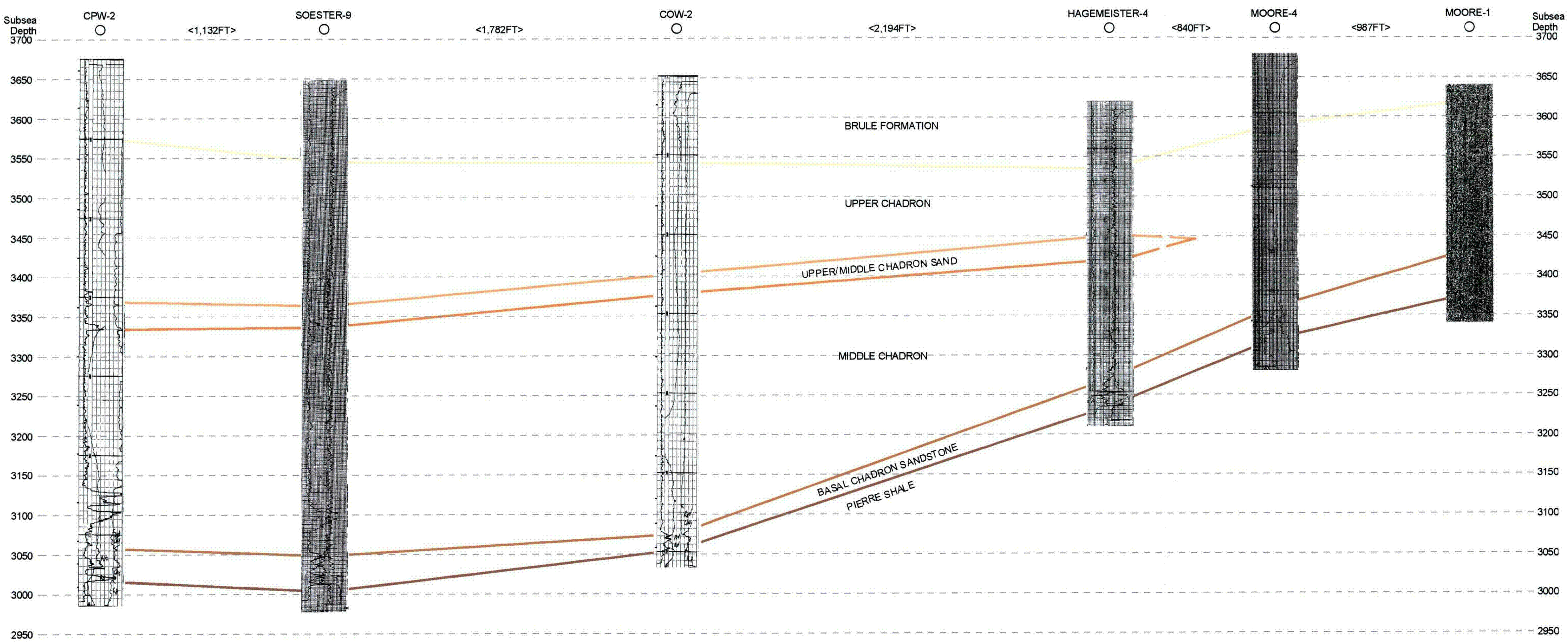
- TOP_UPPER_CHADRON_FORMATION
- TOP_UPPER/MIDDLE_CHADRON_SAND
- TOP_MIDDLE_CHADRON_FORMATION
- TOP_BASAL_CHADRON
- TOP_PIERRE

Figure 2.6-12

By: KRS Checked: HPD/WB

March 13,2007 4:44 PM

PETRA 3/13/2007 4:44:52 PM (Fig2612.CSP)



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Cross Section: I - I'

TOPS AND MARKERS

- TOP_UPPER_CHADRON_FORMATION
- TOP_UPPER/MIDDLE_CHADRON_SAND
- TOP_MIDDLE_CHADRON_FORMATION
- TOP_BASAL_CHADRON
- TOP_PIERRE

Figure 2.6-13

By: KRS Checked: HPD/WB

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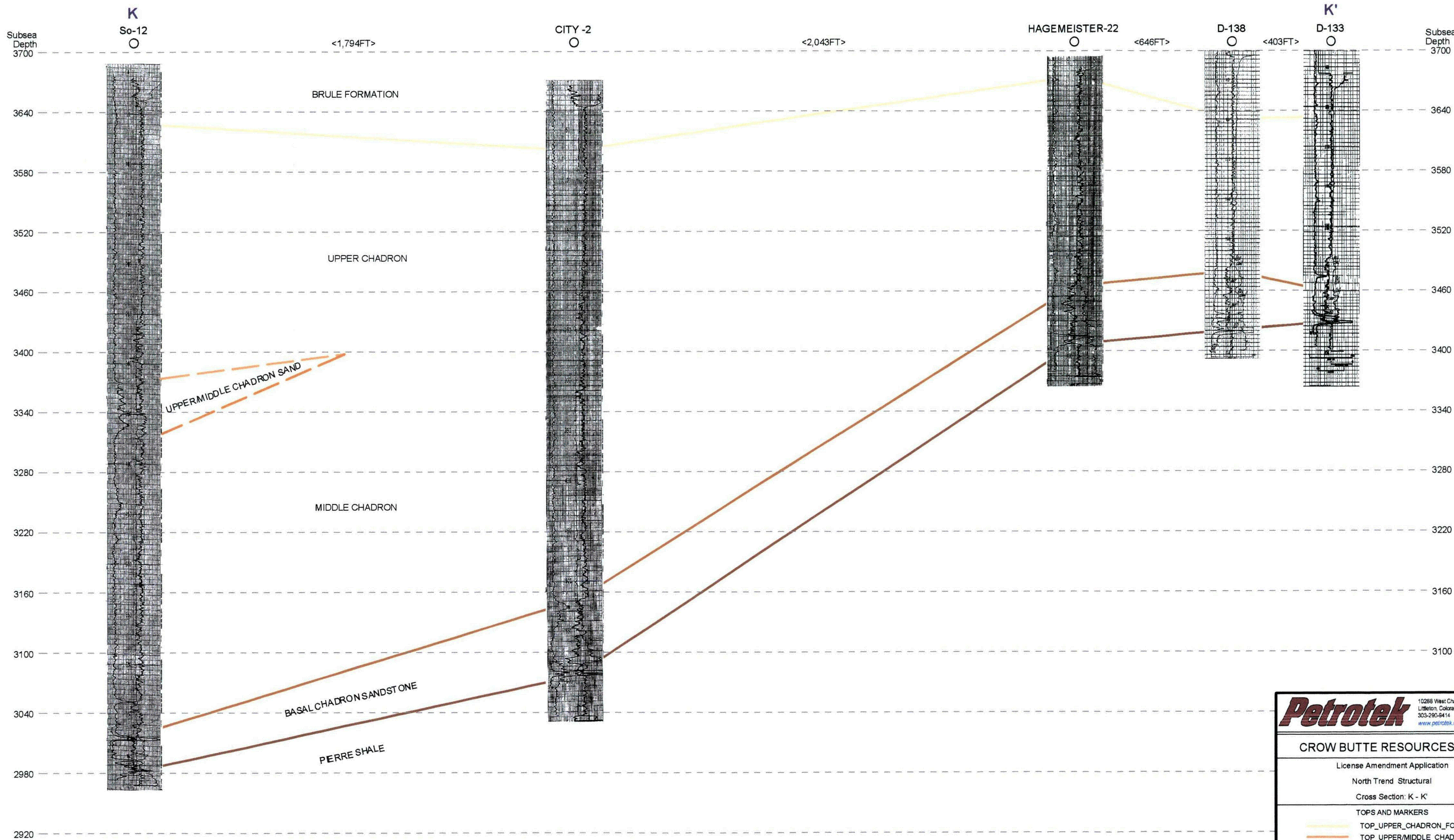

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Cross Section: K - K'

TOPS AND MARKERS
- TOP_UPPER_CHADRON_FORMATION
- TOP_UPPER/MIDDLE_CHADRON_SAND
- TOP_MIDDLE_CHADRON_FORMATION
- TOP_BASAL_CHADRON
- TOP_PIERRE

Figure 2.6-14

By: KRS Checked: HPD/WB

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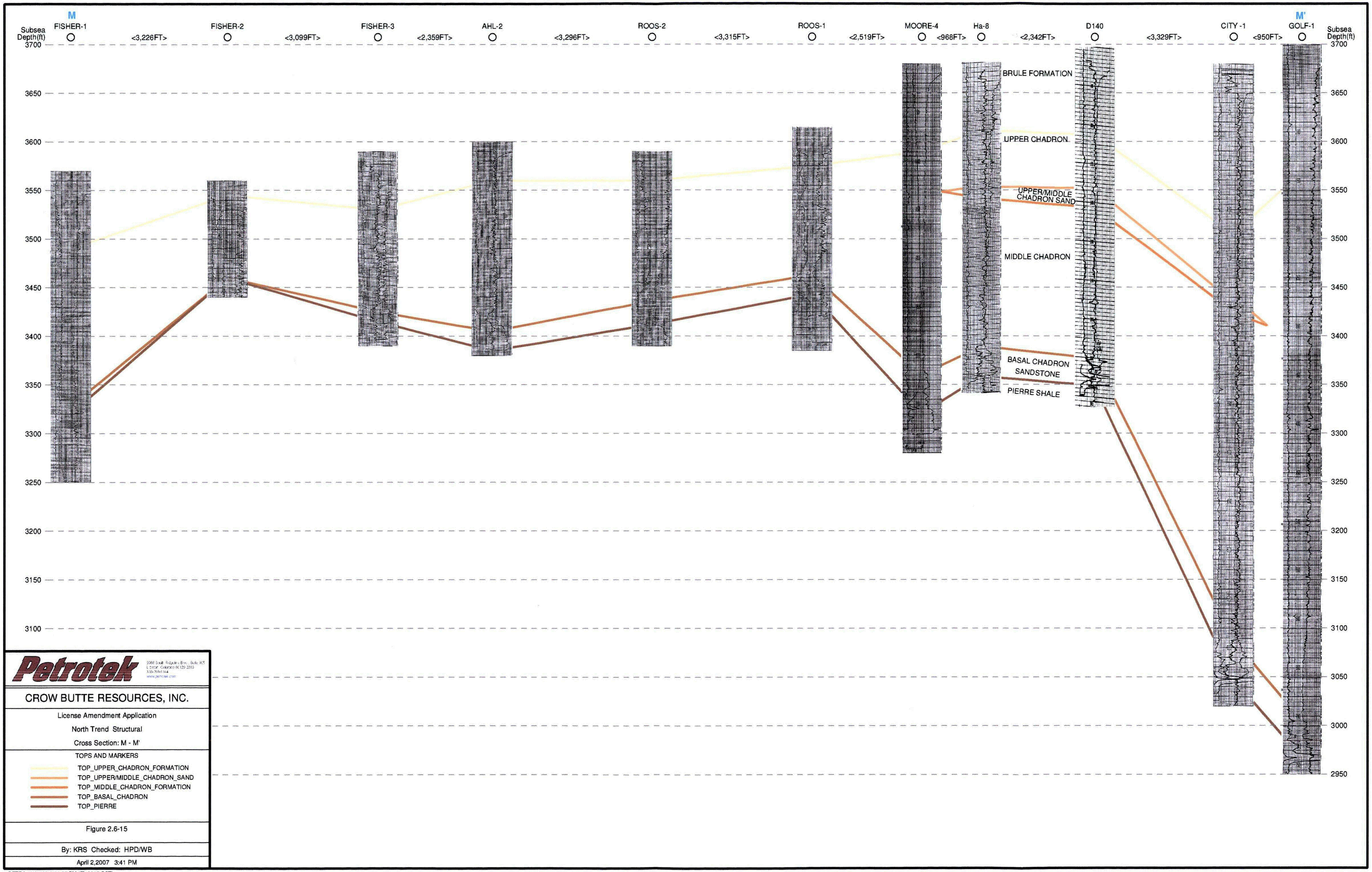
M
M'
Subsea Depth(ft)
FISHER-1
<3,226FT>
FISHER-2
<3,099FT>
FISHER-3
<2,359FT>
AHL-2
<3,296FT>
ROOS-2
<3,315FT>
ROOS-1
<2,519FT>
MOORE-4
<968FT>
Ha-8
<2,342FT>
D140
<3,329FT>
CITY -1
<950FT>
GOLF-1
3700
3650
3600
3550
3500
3450
3400
3350
3300
3250
3200
3150
3100
3050
3000
2950
BRULE FORMATION
UPPER CHADRON
UPPER/MIDDLE CHADRON SAND
MIDDLE CHADRON
BASAL CHADRON SANDSTONE
PIERRE SHALE
Petrotek
CROW BUTTE RESOURCES, INC.
License Amendment Application
North Trend Structural
Cross Section: M - M'
TOPS AND MARKERS
TOP_UPPER_CHADRON_FORMATION
TOP_UPPER/MIDDLE_CHADRON_SAND
TOP_MIDDLE_CHADRON_FORMATION
TOP_BASAL_CHADRON
TOP_PIERRE
By: KRS Checked: HPD/WB
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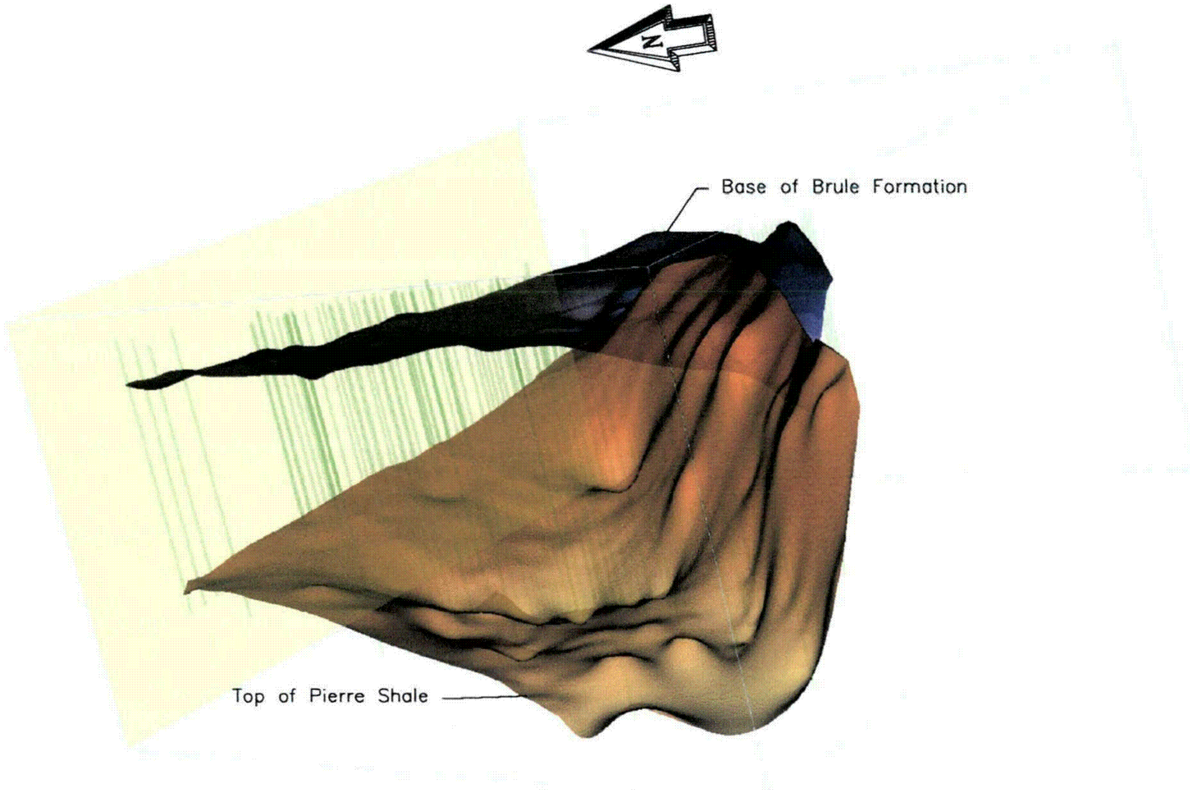
Figure 2.6-15



VERTICAL EXAGGERATION = 15x

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-16
BASE OF BRULE & TOP OF PIERRE
3-D VIEW LOOKING NORTHEAST

PROJECT: 223-37	DATE: MARCH 2007
DWG: Figure 2.6-16.dwg	BY: KRS CHECKED: HPD

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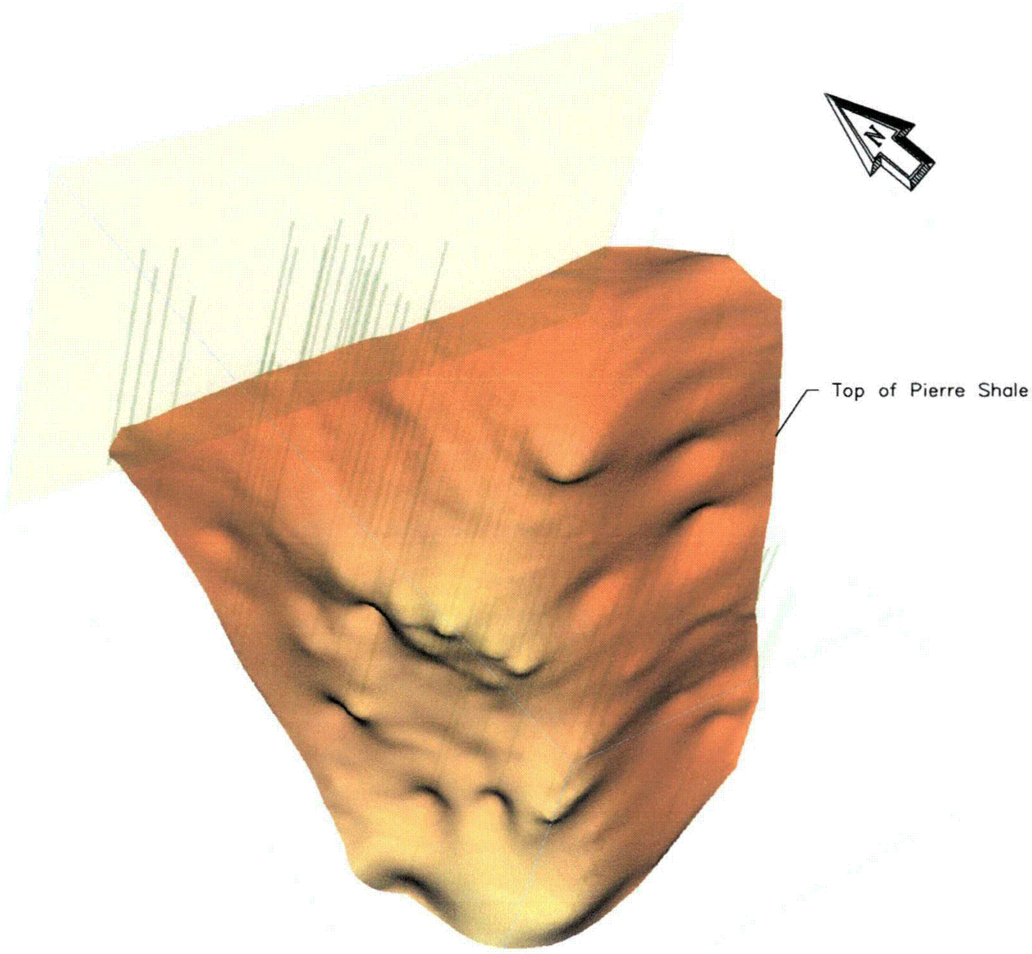

VERTICAL EXAGGERATION = 15x

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-17
TOP OF PIERRE
3-D VIEW LOOKING NORTHEAST

PROJECT: 223-37	DATE: MARCH 2007
DWG: Figure 2.6-17.dwg	BY: KRS CHECKED: HPD

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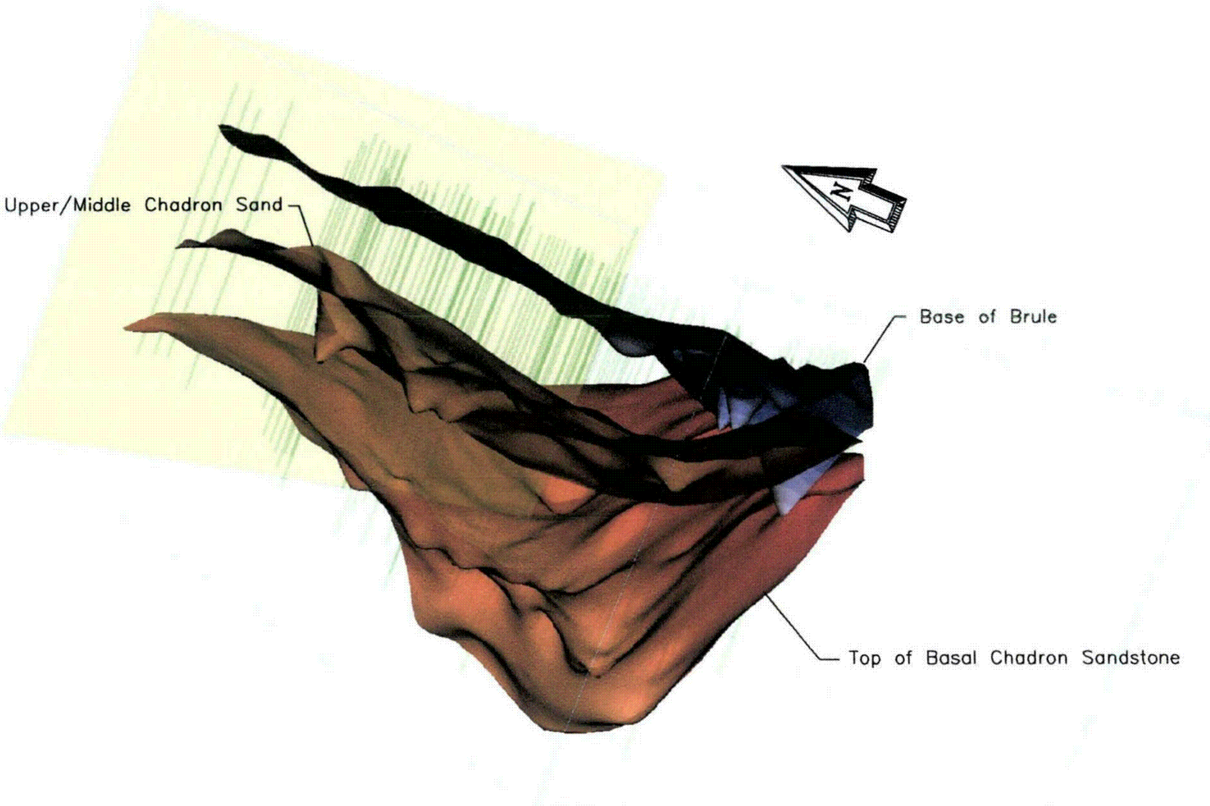

VERTICAL EXAGGERATION = 15x

CROW BUTTE RESOURCES, INC.

FIGURE 2.6–18
BASE OF BRULE, UPPER/MID CHADRON SAND AND TOP OF BASAL CHADRON SANDSTONE 3–D VIEW LOOKING NORTHEAST

PROJECT: 223–37	DATE: MARCH 2007
DWG: Figure 2.6–18.dwg	BY: KRS CHECKED: HPD

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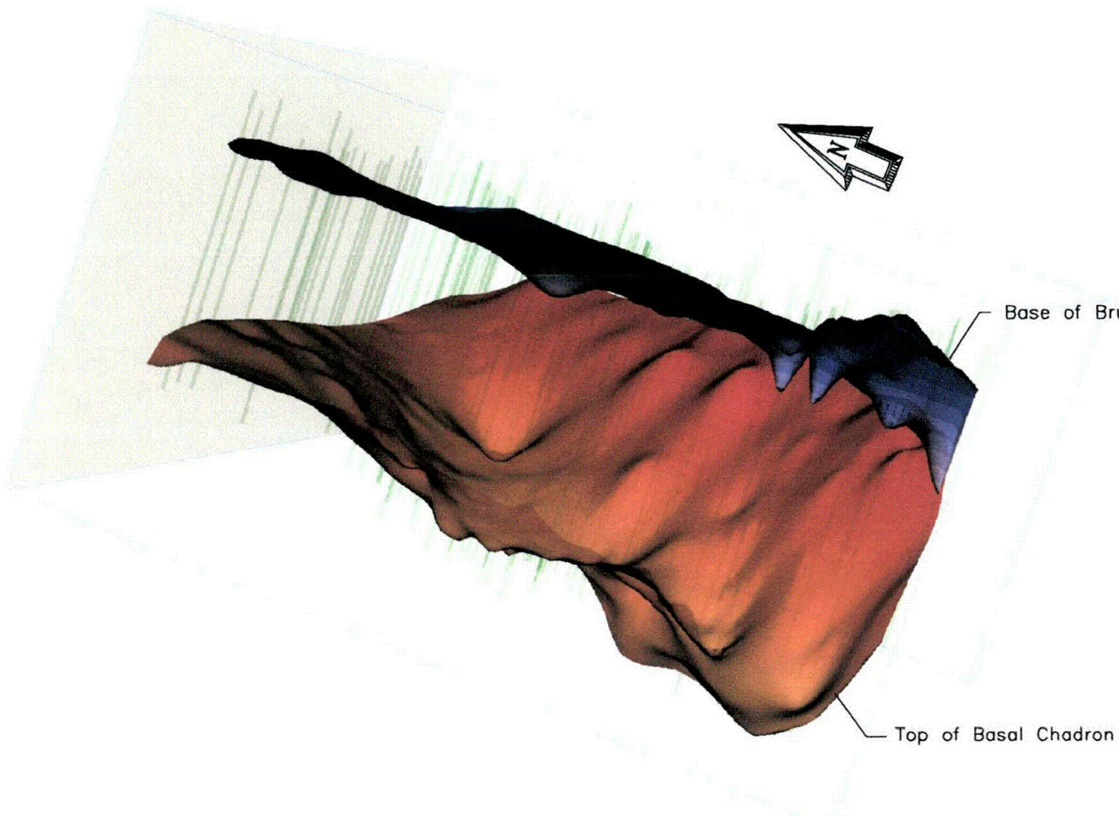

VERTICAL EXAGGERATION = 15x

CROW BUTTE RESOURCES, INC.	
FIGURE 2.6–19 BASE OF BRULE AND TOP OF BASAL CHADRON SANDSTONE 3–D VIEW LOOKING NORTHEAST	
PROJECT: 223–37	DATE: MARCH 2007
DWG: Figure 2.6–19.dwg	BY: KRS CHECKED: HPD

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VERTICAL EXAGGERATION = 15x

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FIGURE 2.6–20
TOP OF UPPER/MID CHADRON SAND
3–D VIEW LOOKING NORTHEAST

PROJECT: 223–37	DATE: MARCH 2007
DWG: Figure 2.6–20.dwg	BY: KRS CHECKED: HPD

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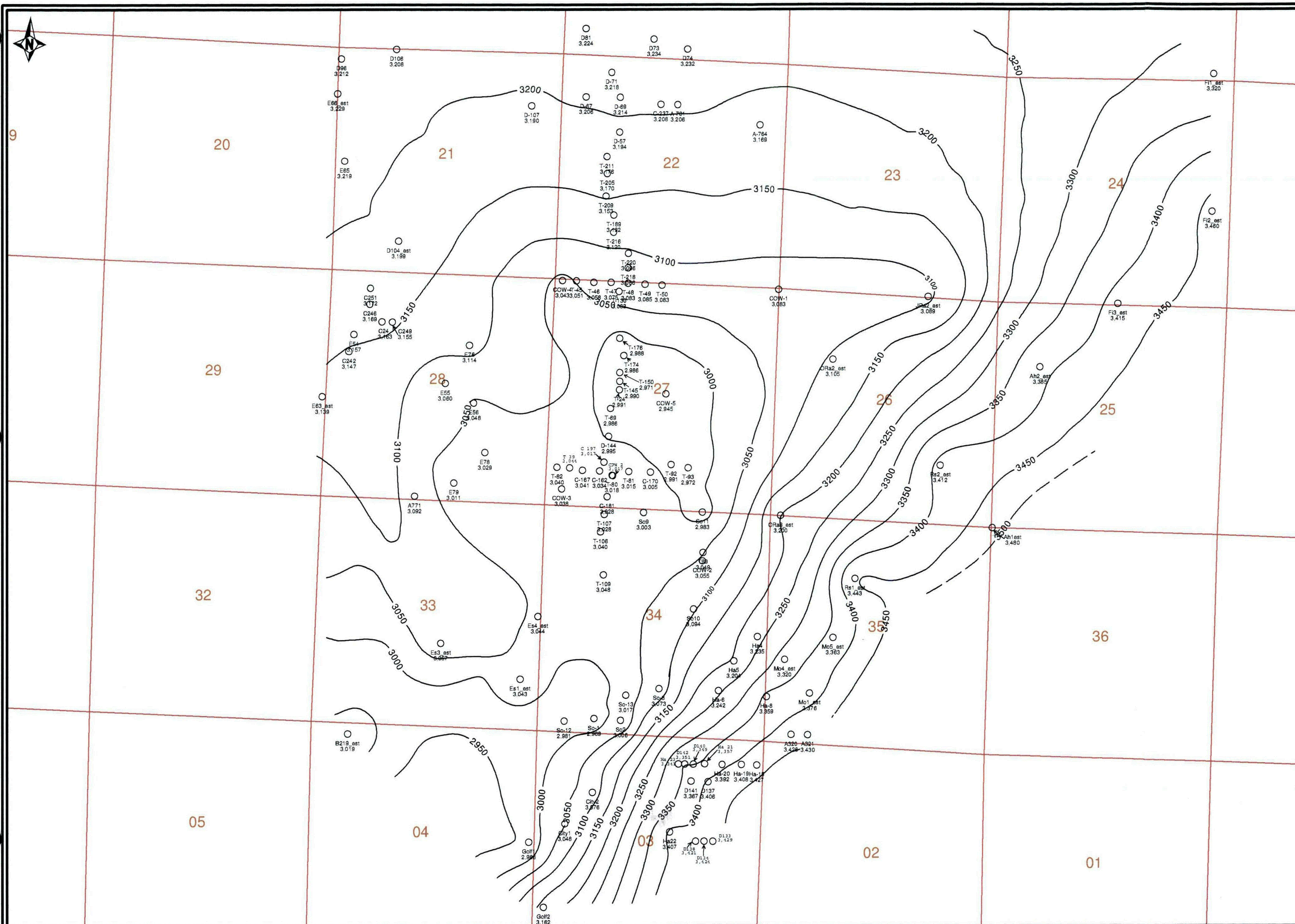

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Crow Butte Resources, Inc.

Figure 2.6-21

North Trend Structure Map

Top of Pierre

REMARKS
Countour Interval = 50' (AMSL)

By: KRS Checked: HPD

0 2,500
FEET

PETRA 3/14/2007 4:07:26 PM

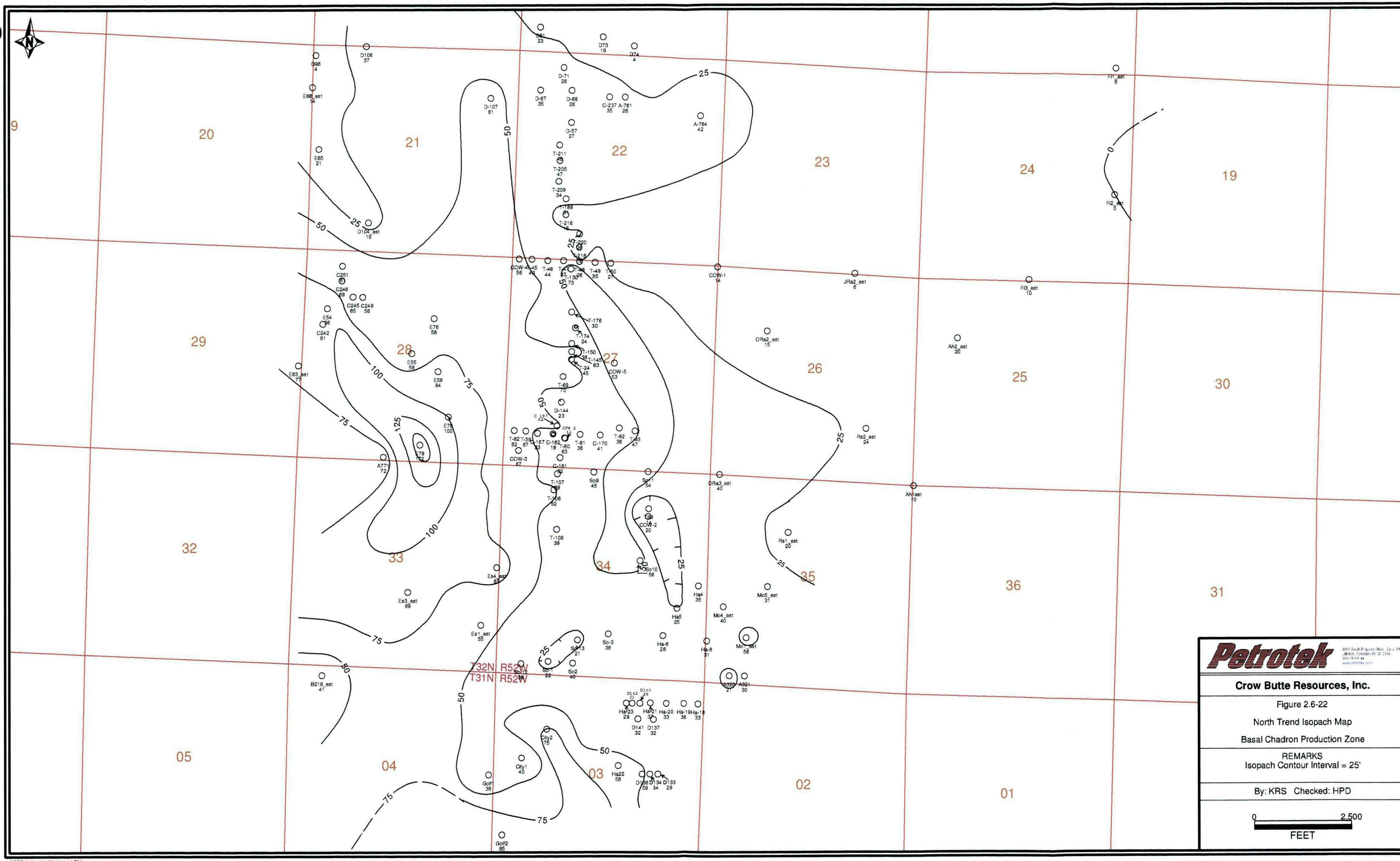

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Figure 2.6-22

North Trend Isopach Map

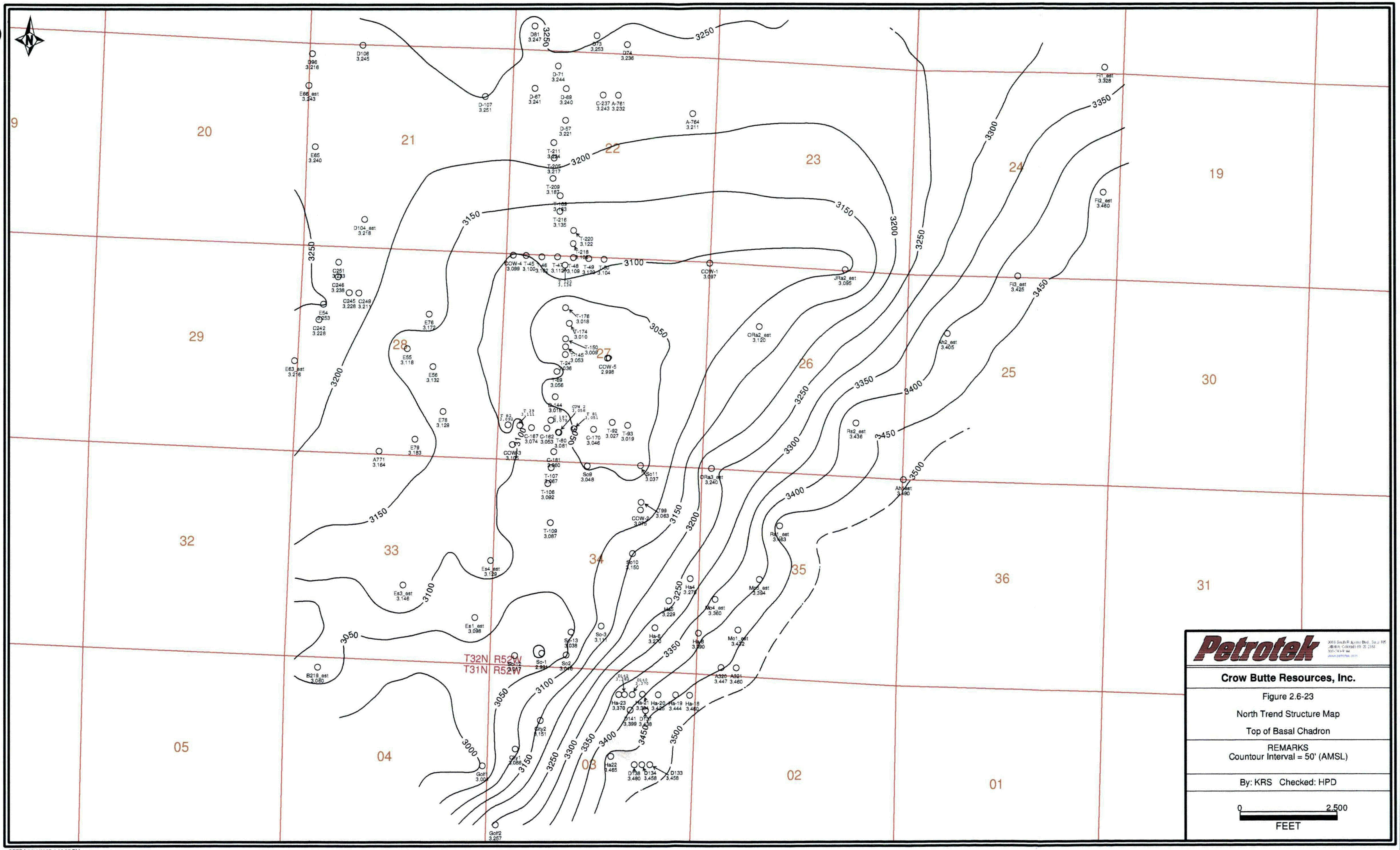
Basal Chadron Production Zone

REMARKS
Isopach Contour Interval = 25'

By: KRS Checked: HPD

0 2,500
FEET

PETRA 3/14/2007 4:21:21 PM



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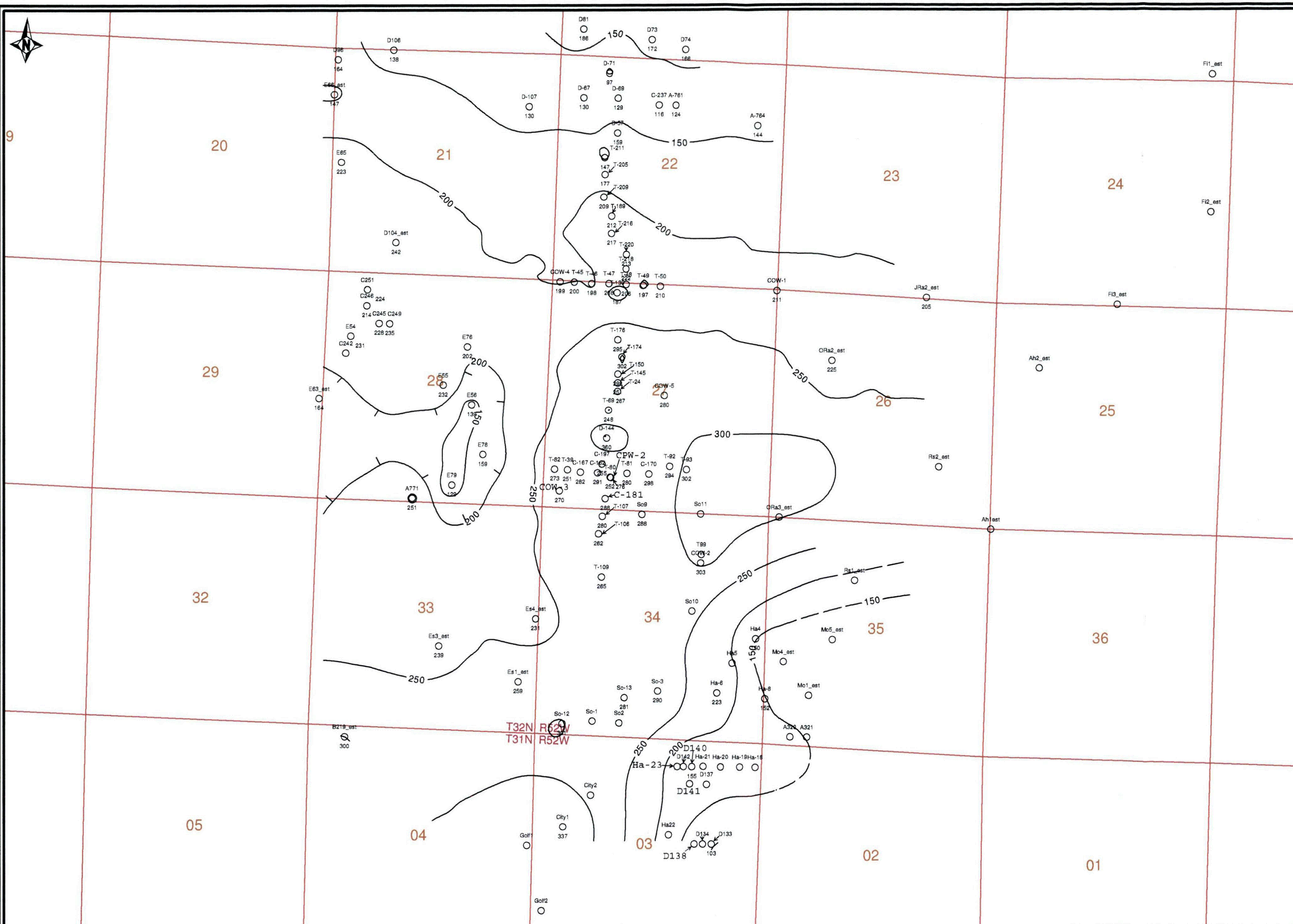

Crow Butte Resources, Inc.

Figure 2.6-24

North Trend Isopach Map

Middle Chadron Confining Unit

REMARKS
Isopach Contour Interval = 50'

By: KRS Checked: HPD

0 2,500
FEET

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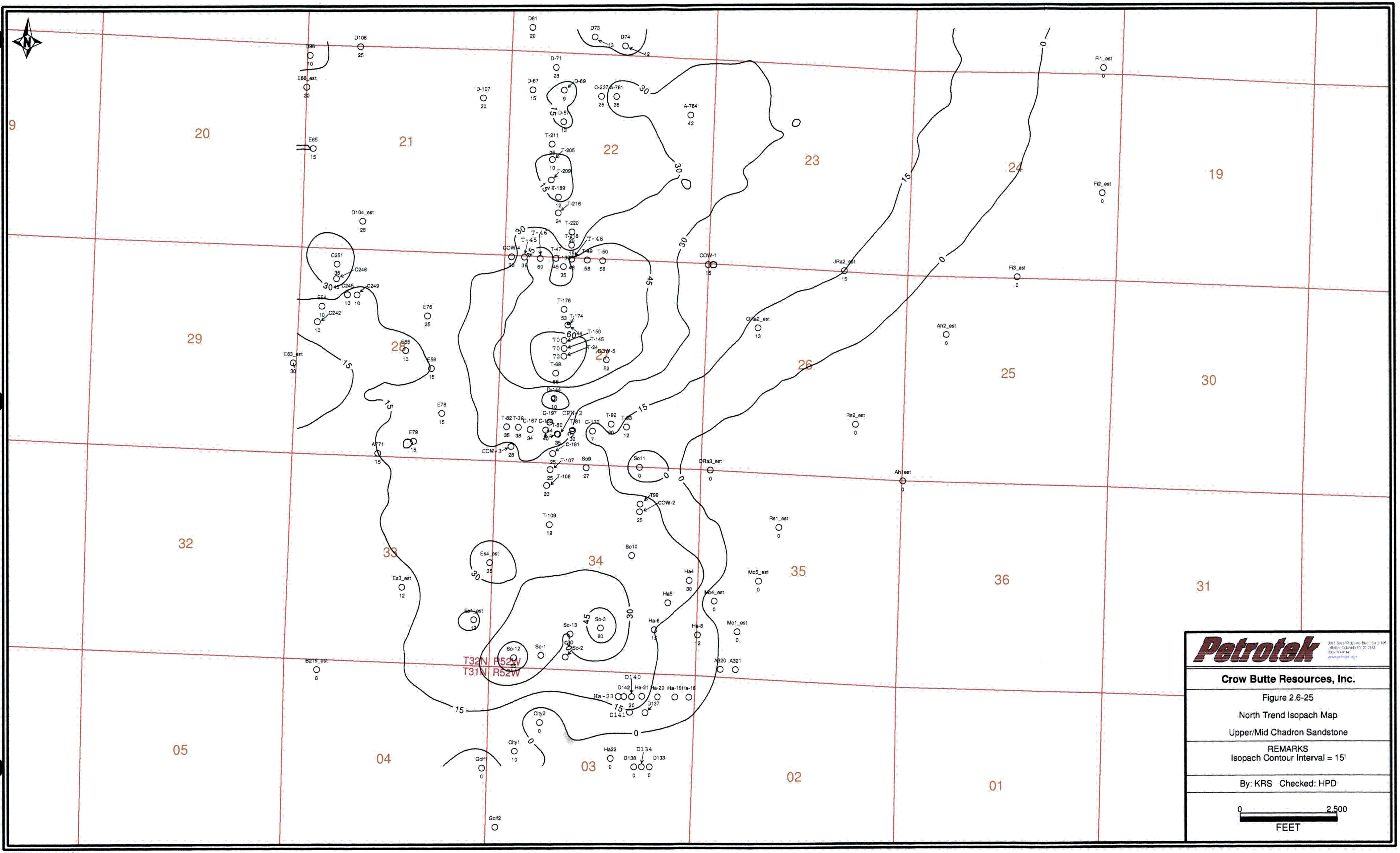

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Figure 2.6-25

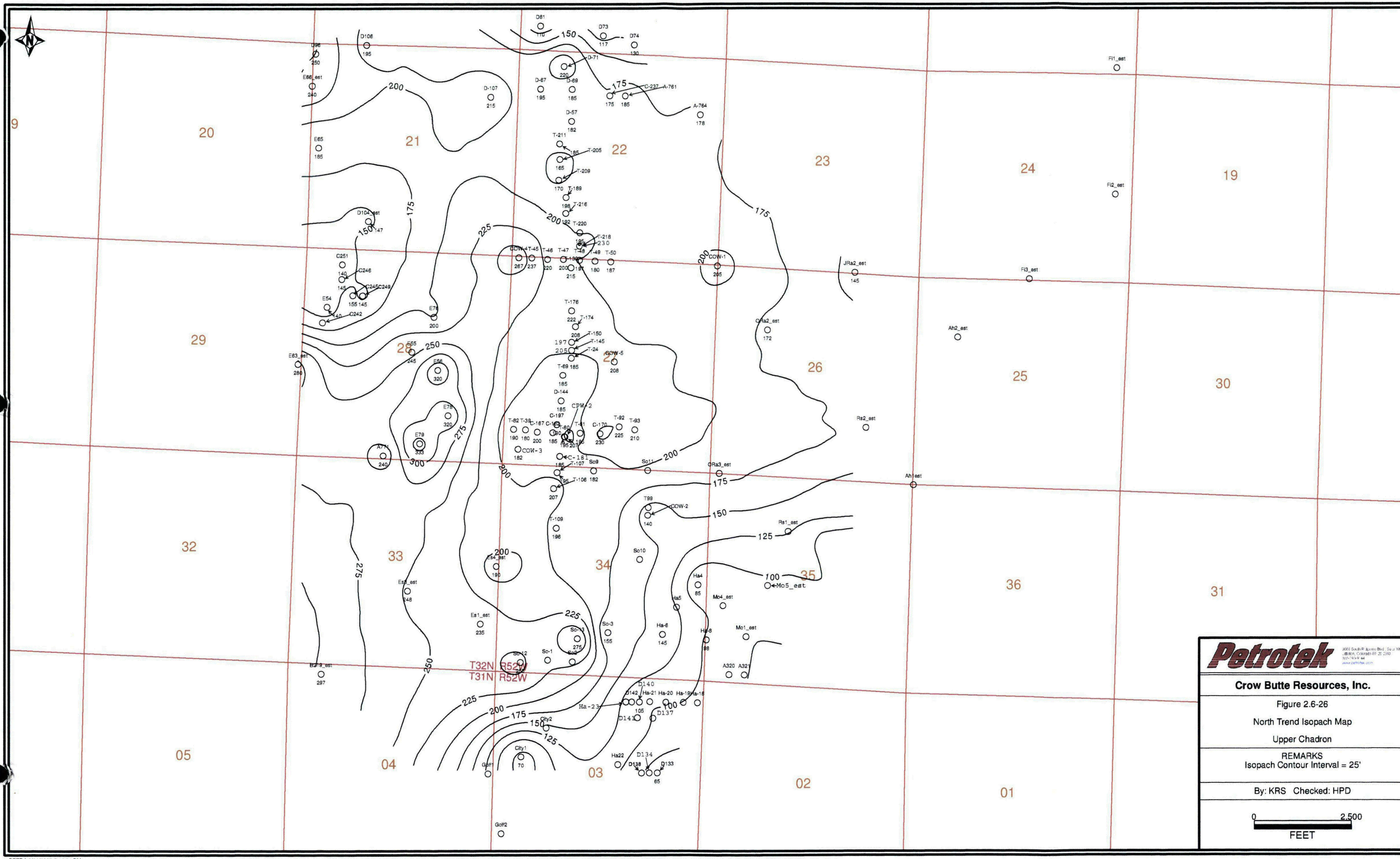
North Trend Isopach Map

Upper/Mid Chadron Sandstone

REMARKS
Isopach Contour Interval = 15'

By: KRS Checked: HPD

PETRA 3/14/2007 5:16:58 PM



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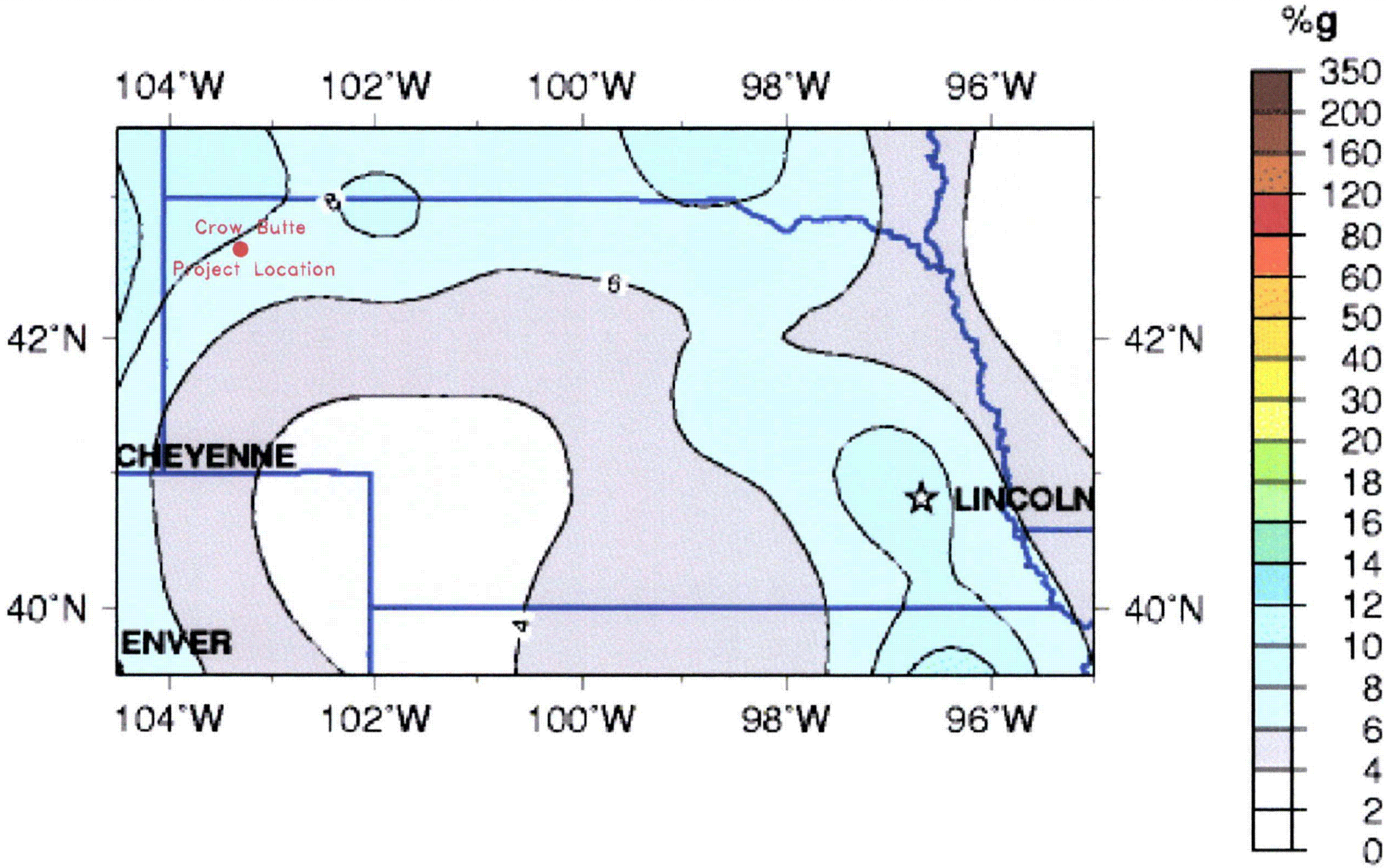

LEGEND

Peak Acceleration (%g) with 2% Probabilty if Exceeedance in 50 Years
Site: NEHRP B-C boundary
National Seismic Hazard Mapping Project

Source: USGS National Seismic Hazard Maps

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-27
SEISMIC HAZARD MAP FOR NEBRASKA

PROJECT: 223-37	DATE: MARCH 2007
NTLAAFig2.6-27.dwg	BY: KRS / CHECKED: HPD

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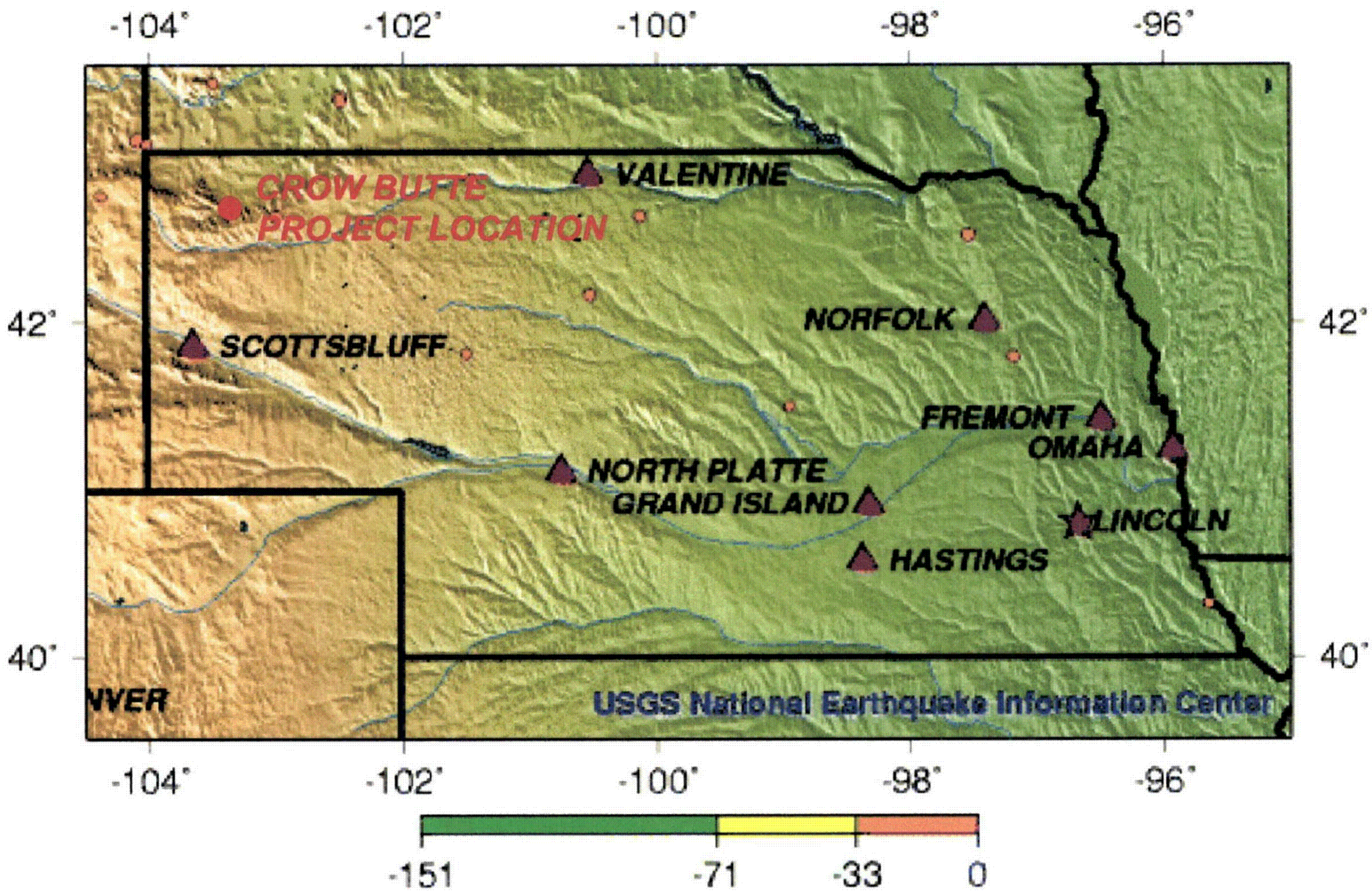

LEGEND

Purple Triangles towns; orange circles seismic events

Source: USGS National Earthquake Information Center

N
W — E

CROW BUTTE RESOURCES, INC.

FIGURE 2.6-28
SEISMICITY OF NEBRASKA 1990 – 2001

PROJECT: 223-37	DATE: MARCH 2007	
NTLAAFig2.6-28.dwg	BY: KRS	CHECKED: HPD

Petrotek

Source: NRCS, Soil Survey of Dawes County, Nebraska, 1977.

LEGEND

SrF MAP UNIT ID

MAP UNIT BOUNDARY

2000 0 1000 2000 3000 Feet

CROW BUTTE PROJECT

REGIONAL AREA BASE MAP

DAWES & SIOUX COUNTIES, NEBRASKA

FIGURE 2.6-29 NORTH TREND SOILS

NEBRASKA

N

Date: 3/7/07 | Drawn: PBE | Fig. 2.6-29

I:\CO001223\ACAD:1223 Figure 2.6-29.dwg