

White River Group Paleosols as Source Rocks for Uranium Mineralization in Western Nebraska¹

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ABSTRACT

The Crow Butte in situ recovery uranium mine in Dawes County, Nebraska has produced approximately 15 million pounds (lbs) of U₃O₈ since 1991. In January 1981, Wyoming Fuel Company announced the discovery of at least 25 million lbs of U₃O₈ at a grade of 0.25 percent or greater near Crawford, Nebraska (historic numbers; not 43-101 compliant). At the time of discovery, it was thought that the uranium mineralization was in the basal sands of the Oligocene Chadron Formation in the White River Group. This paper presents evidence that recent revision of the White River Group stratigraphy places the Crow Butte deposit in the Eocene Chamberlain Pass Formation, which is unconformably overlain by the Chadron Formation.

The uranium mineralization at Crow Butte occurs in roll-front deposits similar to the classic roll-front deposits found in the Tertiary basins of Wyoming. These roll-front deposits occur along the margins of the Chamberlain Pass Formation paleovalleys located in western Dawes County, Nebraska. The Chamberlain Pass Formation consists of interbedded subarkosic sandstones and green bentonitic mudstones overlain by the well-developed Interior Paleosol Equivalent. The Interior Paleosol Equivalent is a significant sequence-bounding paleosol associated with the Chamberlain Pass Formation – Chadron Formation unconformity. The overlying Chadron Formation consists of green bentonitic mudstones, and minor lacustrine limestones. The Ahearn Member of the Chadron Formation is an arkosic sandstone and conglomerate found in an incised paleovalley in South Dakota.

The Interior Paleosol Equivalent of the Chamberlain Pass Formation and the paleosols of the Peanut Peak Member of the Chadron Formation are possible uranium source rocks. Determining which stratigraphic units acted as the source of the uranium has implications for the exploration of similar deposits in the Great Plains. Exploration along the margins of the Chamberlain Pass paleovalleys should encounter additional uranium mineralization. If the Peanut Peak Member of the Chadron Formation acted as a source rock, then the Ahearn Member of the Chadron Formation becomes an attractive exploration target.

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INTRODUCTION

Since 1991, the Crow Butte in situ recovery uranium mine near Crawford, Nebraska (Fig. 1) has produced approximately 15 million pounds (lbs) of U_3O_8 (Wade Beins, 2010, Cameco Resources, pers. comm.). At the time of discovery in 1980, the basal sandstones and conglomerates of the White River Group in northwestern Nebraska were considered to be part of the Oligocene Chadron Formation (Collings and Knode, 1984; Gjelsteen and Collings, 1988; Gjelsteen, 1988). Extensive field work in the 1990s in western South Dakota and northwestern Nebraska led to a significant revision of the White River Group stratigraphy (Evans and Terry, 1994; Terry and Evans, 1994; Terry, 1998). Presently, the White River Group in Nebraska and South Dakota is divided into three formations, in ascending order: Chamberlain Pass, Chadron, and Brule formations (Fig. 2).

During the last 30 years, there has been a considerable amount of detailed study of the paleosols of the Tertiary section in Nebraska and South Dakota which has resulted in a reinterpretation of the stratigraphic framework of the White River Group. The purpose of this paper is to review the changes in the interpretation of the geology of the White River Group and its implications for uranium exploration.

GEOLOGY

The Eocene-Oligocene White River Group of the northern Great Plains and central Rocky Mountains is a thick sequence of largely volcanoclastic sediments deposited in fluvial, eolian, and lacustrine environments. The large amounts of volcanoclasts in the White River Group were first recognized by Darton (1899). Larson and Evanoff (1998) determined that the source of the volcanic material was from the caldera eruptions in the Great Basin in eastern Nevada and western Utah. The ultimate source of the uranium in the Crow Butte deposit is thought to be from the volcanic glass shards that were ejected from these calderas (Zielinski, 1983).

In the Great Plains, the White River Group sediments are well known for their vertebrate fossils and have been studied extensively for 150 years (Terry, 1998). The revised stratigraphic framework for this paper (Fig. 2) is from Terry (1998) and is applied to the interpretation of the uranium deposits. In South Dakota and Nebraska, the White River Group is divided into the following three formations (in descending order): Brule, Chadron, and Chamberlain Pass formations.

The Brule Formation consists of up to 600 feet (ft) of interbedded brown siltstone and mudstones, with local lenses of fluvial sandstones. In contrast, the Chadron For-



Figure 1. Location Map of the Crow Butte uranium deposit in northwestern Nebraska and outcrops of the White River Group formations near Whitehead Creek and Badlands National Park, South Dakota.

CRETACEOUS	TERTIARY		SYSTEM
	EOCENE	OLIGOCENE	SERIES
	WHITE RIVER FORMATION (GROUP)		MEEK AND HAYDEN (1857)
PIERRE SHALE	CHADRON FM	BRULE CLAY	DARTON (1899)
PIERRE SHALE	CHADRON FM	BRULE FM ORELLA AND WHITNEY MBRS	SWINEHART AND OTHERS (1985) Nebraska
PIERRE SHALE YELLOW MOUNDS PALEOSOL SERIES	CHADRON FM CHAMBERLAIN PASS FM AHEARN MBR CRAZY JOHNSON MBR PEANUT PEAK MBR	BRULE FM SCENIC MBR POLESLIDE MBR	EVANS AND TERRY (1994) South Dakota
PIERRE SHALE YELLOW MOUNDS PALEOSOL SERIES EQUIVALENT	CHADRON FM CHAMBERLAIN PASS FM BIG COTTONWOOD CREEK MBR PEANUT PEAK MBR	BRULE FM ORELLA MBR WHITNEY MBR	TERRY et al. (1995) Nebraska

Figure 2. Abbreviated history of stratigraphic nomenclature of the White River Group in South Dakota and Nebraska. Modified from Terry et al., 1995.

mation is composed largely of interbedded green-gray bentonitic mudstones and clays with thin lacustrine limestone beds in the upper part. The Peanut Peak Member of the Chadron Formation is a blue-green to dark olive-green bentonitic mudstone originally deposited as a hummocky-bedded airfall tuff and is widespread in both western Nebraska and southwestern South Dakota (Terry, 1998). The Ahearn Member of the Chadron Formation is an arkosic sandstone and conglomerate only found in the Paleo-Red River Valley of South Dakota (Clark et al., 1967). The Paleo-Red River Valley (Fig. 1) is a west-to-east oriented incised valley located in the southern part of Badlands National Park. This incised paleovalley is approximately six miles wide and was eroded down through the Chamberlain Pass Formation and the Yellow Mounds paleosol to the underlying unweathered Cretaceous Pierre Shale. The Chamberlain Pass Formation is

also found in paleovalleys incised into the underlying Cretaceous Pierre Shale. The complex stratigraphic relationships of the basal sands of the White River Group formations are summarized in Figure 3. The incised Chamberlain Pass Formation paleovalleys are found primarily in Nebraska.

The Chamberlain Pass Formation is composed of fluvial subarkosic sandstones and conglomerates interbedded with light green bentonitic mudstones. The Chamberlain Pass conglomerate clasts include quartz, quartzite, and chert which are much more resistant to weathering than the distinctly different lithology of the overlying Ahearn Member of the Chadron Formation. The clasts of the conglomeratic sandstones of the Ahearn Member of the Chadron Formation include granite and metamorphic rocks derived from the Precambrian core of the Black Hills uplift.

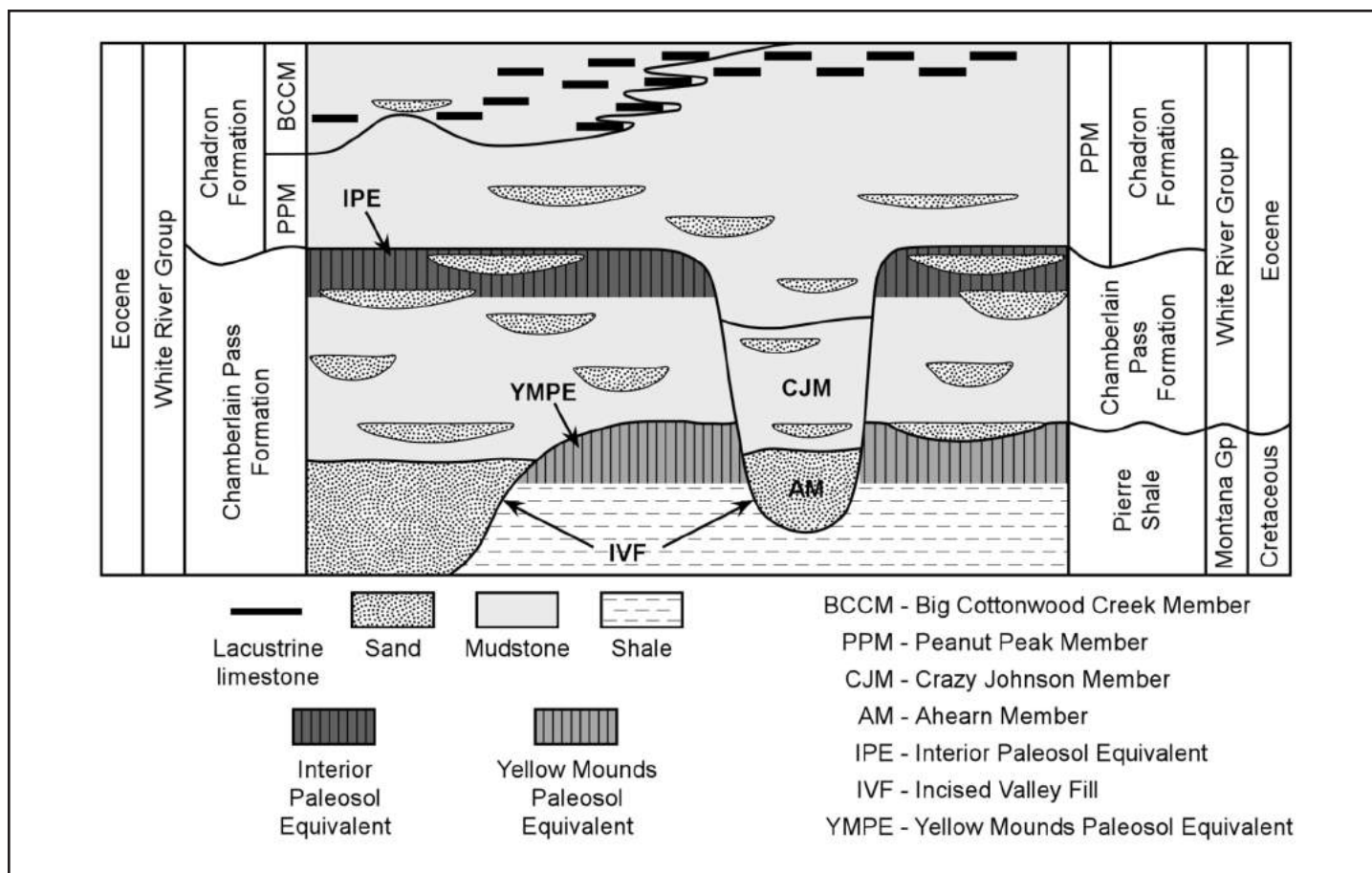


Figure 3. Diagram showing the stratigraphic relationships between the Chadron and Chamberlain Pass formations in northwest Nebraska and southwest South Dakota. Adapted from Terry (1998).

The Chamberlain Pass Formation sandstones can be distinguished from the sandstones of the Chadron and Brule formations by the higher percentage of stable minerals such as quartz. White or bleached lenses of crossbedded basal sandstones and conglomerates of the Chamberlain Pass Formation are found in isolated outcrops in South Dakota at the base of the White River Group. In the subsurface in Nebraska, the Chamberlain Pass sandstones are much thicker, reaching a maximum thickness of 350 ft west of the Crow Butte mine. The Chamberlain Pass sandstone is usually only 40 to 60 ft thick in the Crow Butte mine (Collings and Knode, 1984).

DeGraw (1969) originally mapped the basal sandstone of the White River Group in western Nebraska as the Chadron Formation sandstone. Until recently, the White River Group was divided into only the Brule and the Chadron formations (Swinehart et al., 1985). The recent recognition of the significance of the widespread, well-developed paleosols within the lower part of this volcanoclastic sequence has refined the stratigraphic interpretation of the White River Group.

PALEOPEDOLOGY

As early as the 1890s, geologists and paleontologists working in the badlands of Nebraska and South Dakota have recognized the existence of fossil soil zones (Retallack, 1983). Schultz and Stout (1955) suggested the term "Interior Paleosol Complex" for the prominent red and yellow paleosol that developed on the Pierre Shale (Upper Cretaceous) in northwestern Nebraska. Pettyjohn (1966) considered the age of the Interior Paleosol Complex to be Late Eocene based on field evidence.

The first detailed study of White River Group paleosols was conducted by Retallack (1983) in the Badlands National Park of South Dakota. In the Pinnacles area of Badlands National Park, Retallack studied 70 fossil soil zones within a 380 ft section of the White River Group. Retallack (1983) recognized that the bulk of the White River Group sediments consisted of paleosols that developed in an alluvial floodplain environment. Retallack (1983) also determined that the "Interior Paleosol Complex" of Schultz and Stout (1955) consisted of two separate

and distinct laterally extensive well-developed paleosols or geosols.

A geosol is a paleosol or series of paleosols that is mappable, and typically develops over a long period of time. A geosol can develop on different parent materials and at different positions within a relatively large area. This results in a geosol that is composed of multiple paleosols (Retallack, 1988). Geosols occur at a consistent stratigraphic position and reflect a consistent paleoenvironmental condition, typically paleoclimate. The very thick (up to 80 ft) yellow paleosol (or geosol) that developed on the underlying Cretaceous rocks (usually the Pierre Shale) was named the Yellow Mounds paleosol by Retallack (1983). The overlying well-developed red paleosol was named the Interior Paleosol.

REINTERPRETATION OF WHITE RIVER STRATIGRAPHY

In a major revision to the White River Group stratigraphy, Evans and Terry (1994) recognized that the “blazing white” (Terry, 1998) quartz and kaolinite-rich zone at the top of the basal sandstones of the White River Group was a highly-developed paleosol (Fig. 4). This paleosol is later-

ally equivalent to the red Interior Paleosol series of Retallack (1983) and is part of the geosol named “Interior Paleosol Equivalent” by Terry (1998). The kaolinite-rich zone was formed by the destruction of feldspar, and possibly volcanic ash, by acidic soil conditions due to abundant rainfall in a humid climate. Translocation of the clays from the surface has also enriched this soil zone with kaolinite. This “blazing white” zone of intense pedogenic alteration is similar to the “bleached” zone described by Odland et al. (1988) in the Cretaceous Muddy Formation at the Amos Draw Field in the Powder River Basin of Wyoming. In both cases, bleaching may have been due to reduction of ferric iron (Fe^{+3}) to more soluble ferrous iron (Fe^{+2}), transport of the ferrous iron (Fe^{+2}), and either precipitation of iron as pyrite or incorporation of iron in minerals such as chlorite or ferroan carbonate (Parry et al., 2009).

The contact immediately above the highly weathered paleosols in both the Cretaceous Muddy Formation (Amos Draw Field) and in the Tertiary White River Group is unconformable. Evans and Terry (1994) suggested that the Chamberlain Pass-Chadron unconformity developed when the Paleo-Red River Valley described by Clark et al. (1967) developed in response to faulting. This new outlet for White River sediment lowered base level and soil development continued in the upland areas until the valley filled



Figure 4. Bleached outcrop of highly weathered sandstone, the Interior Paleosol Equivalent, at the Chamberlain Pass Formation – Chadron Formation unconformity. Peanut Peak Member of the Chadron Formation is the overlying stratigraphic unit. Location is approximately 1/2 mile west of Whitehead Creek, Nebraska. Shovel is approximately 3 ft.

and the paleosols were covered by the clays and mudstones of the younger Chadron Formation.

Catuneanu (2006) used the term “sequence-bounding paleosol” to describe the paleosols associated with unconformities. When compared to paleosols that formed within sequences, sequence-bounding paleosols are more strongly developed, develop during a longer period of time, and are associated with a lower water table. These characteristics of sequence bounding paleosols are positive factors when evaluating potential source rocks for roll-front uranium mineralization.

Subsurface Evidence for the Chamberlain Pass Formation in Nebraska Paleovalleys

At the time of discovery of the Crow Butte deposit, the basal sandstones of the White River Group in the paleovalleys of Nebraska were considered to be part of the Chadron Formation. Collings and Knode (1984) correlated a brick red clay marker bed from the mine area to outcrops along Whitehead Creek in northern Sioux County, Nebraska (Fig. 5). The red clay marker bed had been observed in “virtually all drill holes along the mineral trend.” The marker bed and the overlying light green bentonitic mudstones were designated “Middle Chadron” by Collings and Knode (1984). Terry (1998) examined the same outcrops and found that well-developed Weta Paleosol Series (part of the Interior Paleosol Equivalent geosol) was present in the light green bentonitic mudstones above the red marker bed. The chert, quartz, and quartzite pebbles in the conglomeratic sandstones below the red clay marker were also typical of the Chamberlain Pass Formation. This places the uranium bearing sandstones found at the Crow Butte Mine in the Chamberlain Pass Formation.

Further evidence for the presence of the Chamberlain Pass Formation in the paleovalleys of Nebraska comes from the author’s observation of siliceous cement, probably from silcrete, in drill cuttings from a monitoring well drilled to the base of the White River Group in Scotts Bluff County, Nebraska. Terry (1991) has described silcrete from the type locality of the Chamberlain Pass Formation in South Dakota. Carbonate cements were observed by the author in outcrops of the Ahearn Member of the Chadron Formation near Red Shirt, South Dakota. Core is needed of the paleosols overlying the uranium bearing sandstones at the Crow Butte Mine in order to confirm the interpretation presented in this paper.

URANIUM MINERALIZATION

An announcement in January, 1981 reported a “probable potential reserve” (historic reserve; not 43-101 compli-

ant) of 25 million lbs of U_3O_8 at an average grade of 0.25 percent U_3O_8 (Collings and Knode, 1984). The original lease position was acquired based on a favorable review of regional geology that indicated the presence of extensive fluvial system underlying potential source rocks of the White River Group. Collings and Knode (1984) also reported there was evidence of an oxidation-reduction front found in a description of samples from one of the oil and gas test holes. In addition, gamma spikes were noted on wireline logs run in oil and gas tests that indicated the presence of radioactive minerals.

Uranium is found along the boundary between oxidized and reduced sediments similar to the uranium roll-front deposits of Wyoming. Reduced sediments contain only small amounts of organic carbon (0.02 to 0.2 percent) while pyrite concentrations can be as high as 10 percent. Hansley et al. (1989) reported that coffinite, the major uranium mineral, is intimately associated with pyrite. Coffinite is precipitated when silica activity is high due to the dissolution of rhyolitic ash. Corrosion textures of the pyrite suggest that pyrite acted as the reductant. Pyrite replaced organic material during sulfate reduction (Hansley et al., 1989).

The oxidized sediments contain neither pyrite nor organic matter; iron oxides (both hematite and limonite) are found as coatings on sediment grains (Gjelsteen and Collings, 1988). Oxidation-reduction fronts developed along the margins of the incised Chamberlain Pass Formation paleovalleys. Oxidation-reduction boundaries in the Chamberlain Pass Formation near the Crow Butte area are shown in Figure 6. Groundwater flow direction at the time of mineralization was from the northwest to the southeast. Additional exploration efforts along the margins of the paleovalleys mapped by DeGraw (1969) should result in further discoveries (Fig. 7). The Chamberlain Pass Formation sandstones and conglomerates in the Whitehead Creek area contain carbonaceous material (Fig. 8) with no detectable uranium mineralization. This lack of mineralization has negative implications for the uranium potential of the Chamberlain Pass Formation paleovalleys originating in South Dakota.

WHITE RIVER GROUP: URANIUM SOURCE ROCKS

Walton et al. (1981) considered the weakest link in the exploration model for sandstone uranium deposits to be the inability to recognize potential uranium source rocks. Based on the work of Walton et al. (1981), a functional uranium source rock should be a well-developed paleosol where a large quantity of rhyolitic ashfall glass has been weathered to clay (typically montmorillonite or kaolinite) under oxidizing conditions in the vadose zone. This potential uranium source should overlie a relatively large, permeable aquifer where a groundwater flow system can



Figure 5. Chamberlain Pass Formation outcrop in Whitehead Creek area, Sioux County, Nebraska. Red clay marker bed overlies white “bleached” sandstones. Quaternary alluvial material is at the top of the exposure.

deliver a sufficient quantity of uranium over a period of time to form a uranium deposit large enough to be of economic interest.

Silicic igneous rocks (rhyolite and granite) have high uranium content and are often considered potential sources of uranium deposits. Both Precambrian granite and tuffaceous rocks of the White River Group have been considered as potential uranium sources for the roll-front uranium deposits found in the Tertiary basins of Wyoming. Studies by Harshman (1972) and Zielinski (1983) in the Shirley and Powder River basins of Wyoming have established the tuffaceous White River Group to be the most probable source of the uranium in these basins. Gjølsteen (1988) and Gjølsteen and Collings (1988) consider the tuffaceous sediments of the White River Group be the source of the uranium at the Crow Butte deposit.

Walton et al. (1981) studied the release of uranium from volcanic glass from the Tertiary Tascotal and Catahoula formations of Texas and found that while uranium was released from glass in both formations, uranium was only released for long distance migration during pedogenic alteration in the vadose zone. Uranium released from glass below the water table in the open meteoric flow system was only redistributed locally. The only samples in Walton’s study that exhibited significant loss of uranium were highly weathered paleosols of the Catahoula Formation. Some of these paleosols contained abundant kaolinite, indicating acidic conditions. Average uranium concentration was 2 parts per million (ppm) for the paleosols, while average uranium content was 9 ppm from relatively unaltered lake margin sediments. Walton et al. (1981) considered the intensity and duration of the pedogenic process to

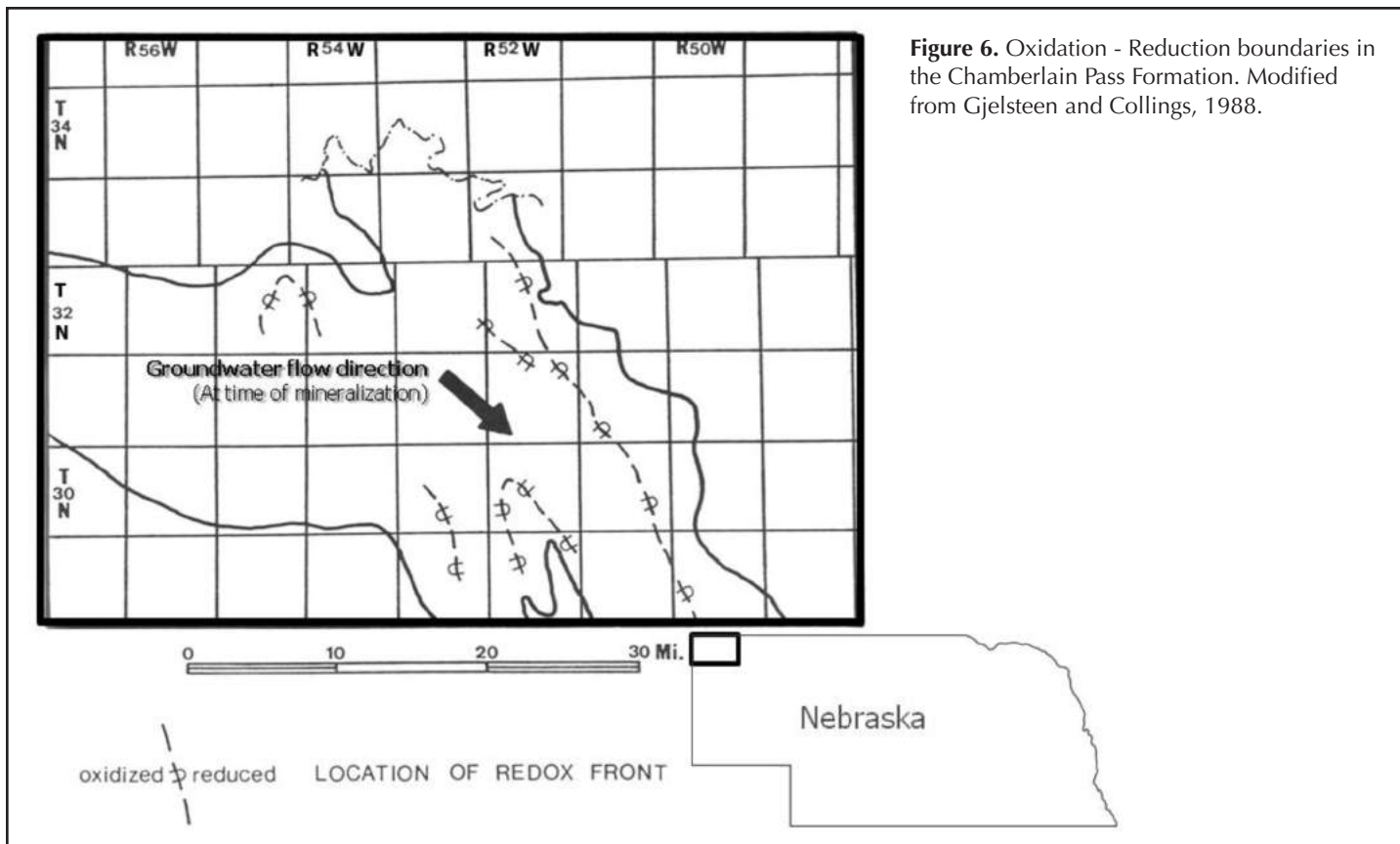


Figure 6. Oxidation - Reduction boundaries in the Chamberlain Pass Formation. Modified from Gjelsteen and Collings, 1988.

be factors in determining if a paleosol was a functional source rock.

Zielinski (1983) conducted a detailed evaluation of the tuffaceous sediments of the White River Group in Wyoming as the potential source of uranium using Thorium/Uranium (Th/U) ratios. Since U^{+4} and Th^{+4} have similar large ionic size and behave similarly in the igneous environment, Th/U ratios should be relatively constant from a given volcanic source even though individual eruptions may show variations in igneous differentiation. In the sedimentary environment, thorium is always insoluble while uranium can be leached in an oxidizing environment. White River Group ash beds vary in composition from andesite to rhyolite (Larson and Evanoff, 1998), and the only way to accurately determine if an altered potential source rock is depleted in uranium is to use Th/U ratios.

Zielinski (1983) found that montmorillonite separates showed an average loss of 41 percent uranium when compared to the volcanic glass separates. A release of 41 percent of the uranium from the huge volume of tuffaceous sediment would release a very large amount of uranium. In contrast, whole rock samples of White River Group siltstone from Wyoming showed little alteration of volcanic glass to montmorillonite, and an average loss of only 0.4 ppm $\pm$ 0.4 ppm uranium. It is the author's opinion that

Zielinski's White River Group siltstone samples may have been from the Brule Formation rather than from the more clay-rich older formations of the White River Group.

The White River Group in Wyoming is not separated into formations rather it is lumped together as the White River Formation. The Brule Formation paleosols are relatively weakly developed and contain abundant glass shards (Swinehart et al., 1985; Retallack, 1983; Meehan, 1994). Instead of relying on a model with large amounts of water moving through a massive amount of relatively low permeability siltstones of the Brule Formation, a more effective model for the genesis of the uranium deposits would involve source rocks where there is almost complete alteration of rhyolitic ashfall glass to montmorillonite or kaolinite. The Chadron and Chamberlain Pass formations both contain clay-rich paleosols that could have been effective source rocks.

The paleosols in the upper part of the Chadron Formation are only weakly-to-moderately well developed (Retallack, 1983; LaGarry, 1998; and Terry, 2001). In addition, the presence of lacustrine carbonates, evaporites, tufas, and travertines indicate that the vadose zone was very shallow (Evans, 1999). Galloway et al. (1979) favored regional groundwater flow systems that existed for a long time for the efficient transport of uranium. A shallow water

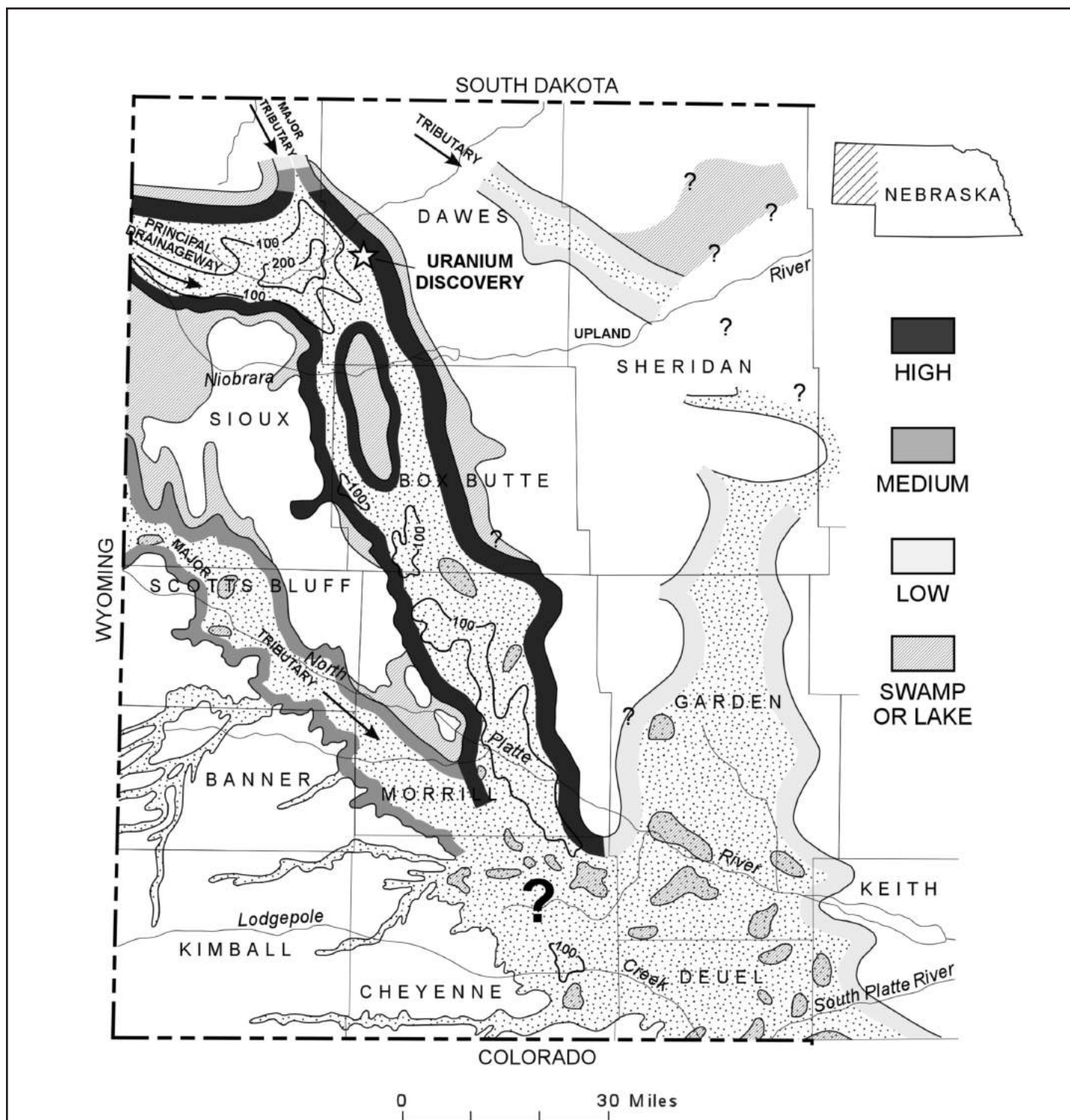


Figure 7. Chamberlain Pass Paleovalleys as mapped by DeGraw (1969). Exploration potential is considered highest in the paleovalley where uranium has already been discovered. Medium potential has been assigned to the paleovalley originating from Wyoming southwest of the main paleovalley. Paleovalleys originating in South Dakota are considered low potential.



Figure 8. Carbonaceous material at the base of the Chamberlain Pass Formation. No uranium mineralization is present. Light colored material at the base of the pick is weathered Pierre Shale, Yellow Mounds Paleosol Equivalent. Location is Whitehead Creek, Nebraska.

table system with a low gradient can transport uranium to a nearby stream or lacustrine environment, with less uranium entering the underlying aquifer. Uranium transported to a stream is more than likely lost while uranium transported to the lacustrine environment could be concentrated in relatively small, low-grade calcrete-type deposit. Dickinson (1991) has described small, low-grade uranium calcrete-type mineralization in evaporitic lacustrine mudstones of the upper part of the Chadron Formation. The Chadron Formation carbonates and gypsum deposits are thin and are very limited in extent (Evans, 1999; Spellman, 1976). It is doubtful that the groundwater flow systems feeding these evaporitic lakes operated long enough to form any deposits of commercial interest. Further limiting the potential role of the paleosols of the upper part of the Chadron Formation as a uranium source rock is the confining nature of the bentonitic clays of the Peanut Peak Member of the Chadron Formation.

The bentonitic clays of the Peanut Peak Member of the Chadron Formation were derived from the pedogenic alteration of rhyolitic glass shards (Terry, 1998). Retallack (1983) determined that the initial soil conditions were well drained and oxidizing due to the lack of preserved organic material and the presence of vertical root traces.

These characteristics qualify the Peanut Peak Member as a possible uranium source. However, the blue-green to dark olive-green color may indicate reducing conditions developed below the water table or during diagenesis. Retallack (1983) estimated the depth to the water table to be on the order of 3 to 6 ft during the development of these paleosols. This is consistent with a rise in base level after the filling of the Paleo-Red River Valley. The lack of uranium mineralization in the carbonaceous material accumulated at the Whitehead Creek outcrop is also not consistent with the Peanut Peak Member paleosols as a source rock. Peanut Peak Member paleosols are widespread and overlie this outcrop. Whole rock analysis of Peanut Peak Member paleosols for Th/U ratios are needed to determine if uranium was mobilized during pedogenesis.

The most likely source rock for uranium mineralization is the Interior Paleosol Equivalent geosol. This very well-developed, sequence-bounding paleosol formed during a relatively long period of time during the faulting, erosion, and filling of the Paleo-Red River Valley (Evans and Terry, 1994). The dropping of base level during the development of this paleovalley resulted in a deep oxidizing vadose zone. The three parent materials of the Interior Paleosol

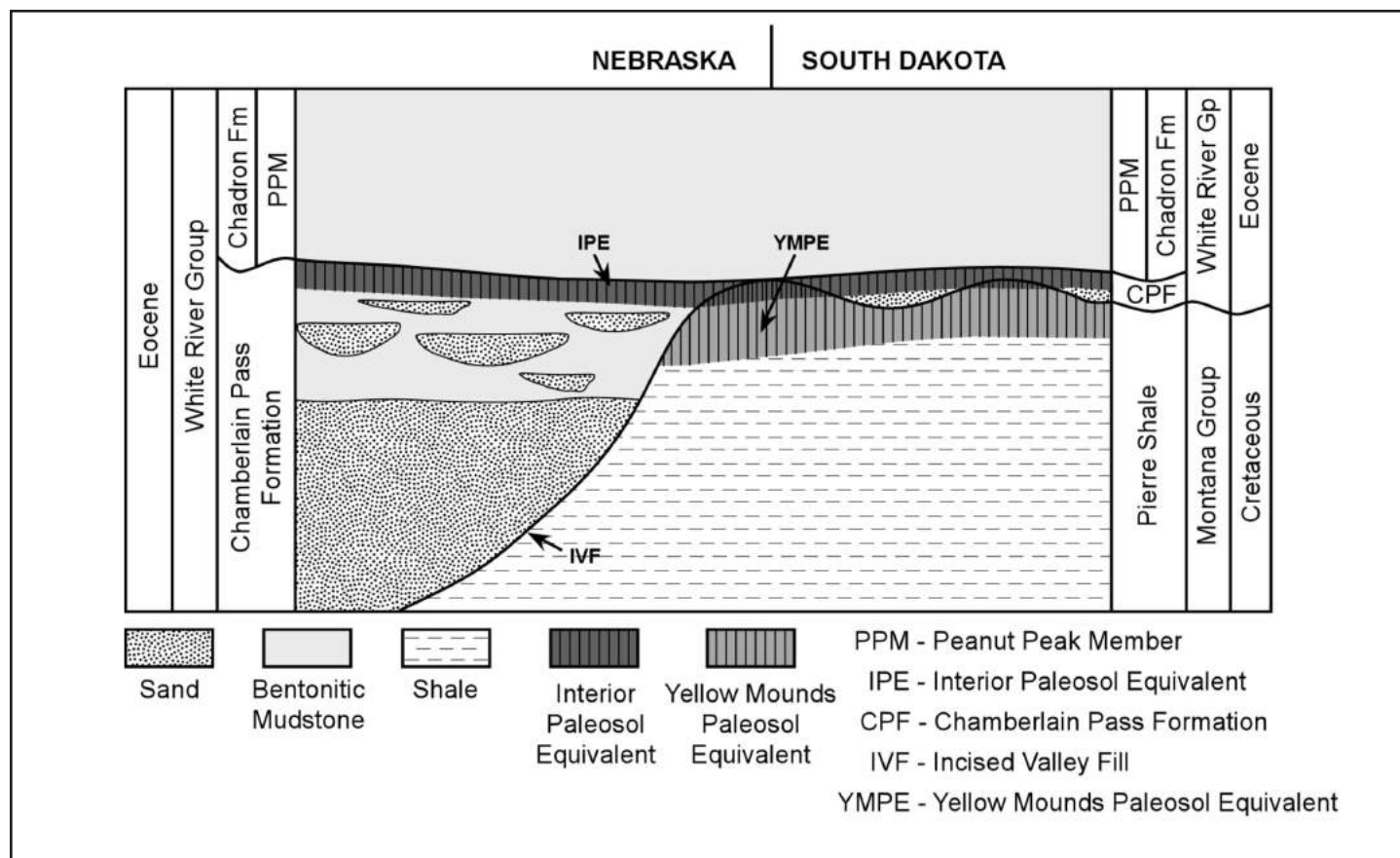


Figure 9. Diagram showing the stratigraphic relationships between the Chamberlain Pass Formation and the Chadron Formation between Nebraska and South Dakota (excluding the Paleo-Red River Valley of Clark et al., 1967). Notice that the parent material of the Interior Paleosol Equivalent in South Dakota includes large areas of Yellow Mounds Paleosol Equivalent which is expected to be low in uranium. Modified from Terry (1998).

Equivalent in South Dakota were the Yellow Mounds Paleosol, Paleozoic sediments eroded from the Black Hills, and volcanic ash (Retallack, 1983). The first two parent materials are not considered potential sources of uranium. In most outcrops in South Dakota, the red Interior Paleosol Equivalent sits directly on top of the Yellow Mounds Paleosol Equivalent (Fig. 9). The volume of volcanic ash weathered during the development of the Interior Paleosol Equivalent in South Dakota could be relatively small which may explain the lack of uranium mineralization at Whitehead Creek. Swinehart et al. (1985) have noted that ash beds in the White River Group are thicker to the south and west and thin to the north and east. This indicates that the parent material of the Interior Paleosol Equivalent was more tuffaceous in Wyoming and Nebraska, and is a more likely source rock for uranium. Chamberlain Pass Formation sediments derived from South Dakota are less attractive exploration targets than those derived from Wyoming and Nebraska (Fig. 7).

CONCLUSIONS

The geologic history of the uranium bearing White River Group sediments in western Nebraska and western South Dakota has been greatly enhanced by the detailed paleopedologic and stratigraphic studies of the last 30 years. Two distinctly different basal sandstone and conglomerates are now recognized as comprising two different stratigraphic units separated by a previously unrecognized unconformity. Evidence that the uranium deposit at the Crow Butte mine occurs in the older formation, the Chamberlain Pass Formation, is outlined in this paper. Uranium mineralization occurs as roll-front deposits along the margins of the paleovalleys developed at the base of the White River Group.

Review of the detailed studies of the paleosols of the White River Group has identified two potential source rocks for the uranium found in western Nebraska. The oldest likely source rock is in the Interior Paleosol Equivalent

which developed over a long period of time and is linked to the development of the Paleo-Red River Valley in South Dakota. Due to a significant lowering of base level, this paleosol developed a deep oxidizing weathering profile and could generate significant amounts of uranium given a tuffaceous parent material. In South Dakota, where there was low uranium parent material (Yellow Mounds Paleosol Equivalent and reworked Paleozoic rocks derived from the Black Hills) combined with a limited supply of high uranium rhyolitic glass shards, there was little uranium generated. In contrast, the amount of volcanic material was greater to the south and west in Nebraska and Wyoming. The margins of the Chamberlain Pass Formation paleovalleys in these areas are considered more attractive exploration targets.

The other potential source rocks of uranium would be the paleosols of the Peanut Peak Member of the Chadron Formation. These bentonitic paleosols are well developed but the water table was fairly high and it is possible that reducing conditions prevailed under the vadose zone. This may have limited mobility of uranium released in the oxidizing vadose zone. As shown by the work of Zielinski (1983), Th/U whole rock analysis can be used to identify uranium source rocks in weathered volcanoclastic sequences with variable initial compositions. If the Peanut Peak Member paleosols were source rocks, then the younger Ahearn Member of the Chadron Formation in South Dakota becomes an attractive exploration target.

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