EXPERT OPINION REGARDING ISL MINING IN DAWES COUNTY, NEBRASKA

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INTRODUCTION

In 2007, Chadron Creek, a stream that supplies water to the city of Chadron, Nebraska, went dry for the first time in the citys' history. Subsequent study of the creek's water flow rates by Chadron State College students suggested that normal amounts of water are flowing from the springs, but the water is disappearing into deeper alluvium or into fractures in the rock (Balmat & others 2008, Butterfield & others 2008). Following these observations, a Chadron State College graduate student began studying the widespread faults and lineaments of northwestern Nebraska using data collected by high-flying aircraft, satellites, and the space shuttle (Balmat & Leite 2008). These data, along with contributions from scientists from the Nebraska Geological Survey, the United States Geological Survey, the University of Nebraska School of Natural Resources, and the Upper Niobrara-White Natural Resource District, were presented in May 2008, at "Our Water, Our Future: a Town Hall Meeting." The consensus opinion of the presenters was that water shortages and declining water quality are real and worsening problems in northwestern Nebraska.

In January 2008 I was contacted by the Western Nebraska Resource Council for information about the geology and hydrology of northwestern Nebraska, and how uranium contamination might spread from an ISL mine site into surrounding areas. I was shown documentation reporting spills of mine waste water, and asked if there was any way that this waste could have made it's way northward 30 miles (see below). The uranium mine is situated along the same aquifers and fault zones as Chadron Creek. If faults and joints are draining the flow of Chadron Creek, they could also be allowing mine waste waters to migrate through faulted and jointed confining layers. A review of the scientific literature showed that faults and joints are well-known in some areas, but especially along the Pine Ridge near Chadron and Crawford (Swinehart & others 1985), and along the southern border of the Pine Ridge Reservation near the towns of Whiteclay, Nebraska, and Pine Ridge, South Dakota (Fielding & others 2007). Faults are also common in the vicinity of Taodstool Park on northeastern Sioux County and northwestern Dawes County (LaGarry & LaGarry 1997).

I am offering this expert opinion regarding ISL uranium mining near Crawford because I am concerned that unmapped and unmonitored faults may be transmitting lixiviant and waste water through confining layers and into the White River, the alluvium within the White River Valley, and into the secondary porosity of the Brule Formation. I am not against uranium mining in fact or principle. Since arriving in Chadron three years ago, my spouse (also a geologist) and I have sought employment at Crow Butte Resources. Crow Butte employs many of Chadron State College's recent graduates, This issue isn't even about the uranium. It's about protecting the region's water supply, and the future inhabitability of northwestern Nebraska and southwestern South Dakota. In this document, I will briefly explain the basis for my concerns, and propose a series of studies that should clarify whether or not Crow Butte Resources is contaminating the region's water, and if so, how much.

PROFESSIONAL BACKGROUND

I have 20 years experience studying the rocks and fossils of northwestern Nebraska. From 1988-1991 I collected fossils from northern Sioux County for my dissertation work. From 1991-1996 I led field parties from the University of Nebraska State Museum while mapping the fossils and geology of the Oglala National Grassland in Sioux and Dawes Counties. From 1996-2006 I led a team of geologists from the Nebraska Geological Survey that mapped in detail the surficial geology of most of northwestern Nebraska (a total of 80 1:24,000 quadrangles). This mapping included the entire Pine Ridge area and the area between Crawford, Nebraska and Pine Ridge, South Dakota. These maps, including digital versions (ArcInfo) and supporting field notes, are available from the University of Nebraska-Lincoln School of Natural Resources (contact James B. Swinehart). As a direct consequence of this mapping, I have published peer-reviewed articles on the Chadron Formation (Terry & LaGarry 1998), the Brule Formation (LaGarry 1998), the mapping of surficial deposits (Wysocki & others 2000, 2005), and local faults (Fielding & others 2007). Based on this mapping, we also intend to revise and reclassify the remaining rocks and surficial sediments of northwestern Nebraska.

STRATIGRAPHY OF WATER-BEARING ROCKS IN NORTHWESTERN NEBRASKA

The rocks of northwestern Nebraska range from Cretaceous to Pleistocene in age, and consist entirely of sedimentary rocks. These rocks vary in thickness and geographic extent, and are described as follows (see LaGarry & LaGarry 1997, Terry 1998).

Pierre Shale (aquiclude 1) - underlies all other units, generally 1000'-2000' thick. Contributes small amounts of sulfer and arsenic to overlying surface aquifers (e.g. modern White River alluvium) and water in streams and impoundments. Joints and faults within this unit contain minerals deposited by water movement in the geological past,

Chamberlain Pass Formation (aquifer 1) - formerly 'basal Chadron sandstone,' base of White River Group, overlies Pierre Shale, underlies Chadron Formation and modern river alluvium. Channel sandstones within this unit are a local aquifer and are mined for uranium. Water from this unit is typically used for residential and livestock supplies. Unit was deposited in an ancient paleovalley oriented generally from Crawford in the N-NW and Bayard to the S-SE. Joints and faults within this unit contain minerals deposited by water movement in the geological past,

Chadron Formation (aquitard 1) - middle of White River Group, overlies Chamberlain Pass Formation, underlies Brule Formation and modern river alluvium. Generally impermeable, except where fractured. Many faults and joints contain minerals deposited by water movement in the geologic past.

Brule Formation (aquitard 2) - top of White River Group, overlies Chadron Formation, underlies Arikaree and Ogallala groups (High Plains Aquifer) and modern river alluvium. Generally impermeable, except where fractured. Where fractured, has enough water to be included with overlying High Plains Aquifer. Used locally for residential and low-intensity agricultural supplies. Secondary porosity in Brule can transmit water up to 1500' day. Many faults and joints contain minerals deposited by water movement in the geologic past.

Arikaree Group (aquifer 3, lower part) - base of High Plains Aquifer, overlies Brule Formation of the White River Group, underlies Ogallala Group and modern river alluvium. Consists of moderately porous and permeable sandstones and silty sandstones. Coarser sandstone beds deposited along preexisting fault traces. Unit highly faulted and jointed along Pine Ridge Escarpment. Water supplies springs that feed local creeks, and is used for high-capacity irrigation wells.

Ogallala Group (aquifer 3, upper part) - upper part of High Plains Aquifer, overlies Arikaree Group, underlies modern rever alluvium and sand dunes. Consists of highly porous and permeable sandstones and conglomerates, Coarser sandstone beds deposited along preexisting fault traces. Unit highly faulted and jointed along Pine Ridge Escarpment. Water is used for high-capacity irrigation wells.

Modern river alluvium (aquifer 4) - overlies all bedrock units at one place or another. Consists of layers of silt and sand and lens-shaped ribbons of coarse gravel. Unit also overlies major fault zones. Unit is used as aquifer, and supplies water to residences, livestock, and in the case of the

White River, supplies water to the cities of Crawford, Nebraska and Pine Ridge, South Dakota, among others. Crow Butte Resources surface operations all occur on this unit.

The recent mapping of the geology of northwestern Nebraska has shown that the simplified, "layer cake" concept applied by pre-1990's workers is incorrect, and overestimates the thickness and areal extent of many units by 40-60%. Many units' distributions are heavily influenced by the contours of the ancient landscapes onto which they were deposited. For example, when considered to be the 'basal Chadron sandstone,' the Chamberlain Pass Formation was assumed to have a distribution equal to that of the overling Chadron Formation. However, the Chamberlain Pass Formation is 1-1.5 million years (Ma) older than the Chadron Formation, and has a distribution determined by the ancient topography weathered into the Pierre Shale prior to deposition of the Chamberlain Pass Formation.

SECONDARY POROSITY IN NORTHWESTERN NEBRASKA

Secondary porosity, in the form of intersecting faults and joints, is common in northwestern Nebraska, especially along the Pine Ridge Escarpment (see Swinehart & others 1985). These faults and joints are generally oriented NW-SE and SW-NE, and are most likely a result of the uplift of the Black Hills of southwestern South Dakota. The Black Hills have been tectonically active since the late Eocene (Evans & Terry 1994), and continued to fault, fracture, and fold the rocks of northwestern Nebraska and southwestern South Dakota into the middle Miocene (Fielding & others 2007). These faults and fractures transect all major bedrock units listed above. These faults could potentially connect the uranium-bearing Chamberlain Pass Formation to modern river alluvium, and connect the uranium-bearing Chamberlain Pass Formation to the overlying secondary porosity of the Brule Formation.

In addition to allowing contaminated water to move vertically, it can also transmit water horizontally. Many of the faults in northwestern Nebraska persist for tens of miles (Diffendal 1994, Fielding & others 2007). Also, many of the ancient river deposits of the Arikaree and Ogallala Groups, along with the alluvium deposited by modern rivers, follow the faults zones because fractured rock erodes more easily. Swinehart & others (1985) and Diffendal (1994) reported faults that could transmit contaminants from Crawford to Chadron, and from Crawford to Pine Ridge, South Dakota. In its license amendment for the North trend expansion, Crow Butte Resources reports a fault along the White River that could transport contaminants from the ISL mine to the White River, and from the river directly to Pine Ridge, South Dakota.

CONTAMINANT PATHWAYS

There are two principal pathways through which contaminated water could migrate away from Crow Butte Resources well fields and into adjacent areas: 1) along the White River alluvium (modern river alluvium); and 2) along faults. The White River alluvium can receive contaminants from three sources: a) from surface spills at the Crow Butte mine site; b) from waters transmitted through the Chamberlain Pass Formation where it is exposed at the land surface; and c) through faults. Contaminants within the White River can be transmitted into the areas where the alluvium intersects faults downstream from Crawford. Once into the White River alluvium, every rain event will push the contaminants a little bit downstream. In the case of the White River, downstream is to the N-NE and directly onto the Pine Ridge Reservation. Residential users, agricultural users, wildlife, and the City of Crawford all receive water supplies from the White River alluvium.

The second pathway is through faults. These faults can receive contaminants from three sources: a) from surface spills into the White River alluvium; b) from waters transmitted through the Chamberlain Pass Formation; and c) from underground excursions, which can of either lixiviant or uranium-laden water. Once into the faults, contaminants could migrate along the groundwater gradiant (which is generally eastwards) northeastward towards the Pine Ridge Reservation or southeastward toward Chadron and the majority of the remaining High Plains Aquifer. Uranium could also be drawn upwards into parts of the High Plains Aquifer by high-capacity irrigation wells, some of which are known to be within major fault zones (northernmost Sheridan County, Nebraska).

In May of 2008, I was asked to evaluate the importance of a "whistleblower letter" from Mr. John Peterson, a mining geologist, to Mr. Gary Konwinski of the Nuclear Regulatory Commission. This letter is dated 4 April 1989, and expresses Mr. Petersons concern that information pertaining to faults was being suppressed so that that Crow Butte Resources (CBR) could mine in an unsafe area. Mr. Peterson's main contention is that <u>the uranium mined by CBR occurs within the faults themselves,</u> and is not a roll-front deposit as CBR maintains. This would be the worst possible situation. If there are minerals within faults, they are there because flowing water brought them there and deposited them there. If there are minerals along the faults and CBR is mining them, then they (CBR) are progressively "uncorking" the flow pathways along these faults. If this is the true situation, the risk of spilling contaminants into these faults increases with additional mining, and contamination by chemically altered waters is a virtual certainty. Also, mining the Chamberlain Pass Formation could cause these faults to move again. This could create new, unforeseen pathways for contaminants spread through.

THE PROBLEM OF ARTESIAN WATER

Artesian flow occurs along the Pine Ridge of Nebraska when there is a hydrologic connection, through faults or highly permeable strata, between the Chamberlain PassFormation and the High Plains Aquifer. The weight of water in the topographically higher High Plains Aquifer exerts pressure downward into the Chamberlain Pass Formation, which can be released as artesian water flow where the topographically lower Chamberlain Pass Formation is exposed at the surface, or where it is punctured by drilling. Artesian flow was predicted by NDEQ in their evaluation of CBR's petition for an aquifer exemption, and was observed by a local landowner as CBR did test drilling for the North Trend Expansion. Artesian flow could transmit the most mineral-laden of waters onto the land surface (and into White River alluvium) and discharge large amounts of contaminants into aquifers or faults in a very short time.

CONCLUDING REMARKS

Based on the arguments presented above, it is my expert opinion that ISL mining in the Crawford, Nebraska area should not be allowed to continue until the potential contaminant pathways of the White River alluvium and the SW-NE and NW-SE trending fault zones are examined and monitored. To this end, I suggest:

1. establishing a GIS database for the mapping of existing geologic units and features (e.g., faults). This would allow computer modeling of the region geology, hydrology, and structure, and would present the most complete picture of the data for final evaluation. Data acquired during the following investigations would be incorporated to the database.

2. map the White River alluvium in order to characterize its potential as a conduit for radioactive contaminants.

3. sample water from the White River at regular intervals (e.g., 2 miles) between Crawford and Pine Ridge to locate a plume of contaminated water or sediments, if present.

4. if contaminants are detected, convert sample wells to monitoring wells.

5. map the network of faults present in northwestern Nebraska and southwestern South Dakota.

6. pump test the faults to determine their permeability and the rate of water flow along them.

7. if water flow is detected along the faults, the convert selected sampling wells into monitoring wells.

8. color the water used in all underground stages of production. This will allow future leaks to be detected even if they manifest far from the mined area.

If these steps were taken, and the threat of uranium contamination were to be disproven, then Crow Butte Resources can proceed to mine uranium, but with renewed confidence, public trust, and regulatory credibility. If these steps were taken, and the threat of uranium contamination were to be confirmed, then it may be possible to mitigate the situation such that water supplies are protected and preserved as much as possible following the early detection of contaminants.

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