ADDITIONAL TESTIMONY REGARDING LINEAMENTS, JOINTS, AND FAULTS AS CONTAMINANT PATHWAYS NEAR CRAWFORD, NEBRASKA (CROW BUTTE RESOURCES ISL FACILITY)

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INTRODUCTION

Beginning in 2008 and again in 2015 I have provided expert opinions to the Western Nebraska Resources Council and Owe Aku (among others) regarding Crow Butte Resources' ISL uranium mining near Crawford, Nebraska. I have also offered expert opinions on Crow Butte Resources' proposed expansions, and initiated or participated in several scientific studies intended to further clarify the issues I raised in those written opinions. I am offering this additional expert testimony on lineaments, joints, and faults in support of the Consolidated Interveners' new and revised contentions regarding the license renewal of the Crow Butte Resources ISL uranium mine near Crawford, Nebraska. I am concerned that issues regarding the lack of lixiviant containment raised in earlier opinions have not been addressed and also apply to the Consolidated Petitioners' contentions in this particular case. My goal in offering this additional testimony is not to protest uranium mining, but rather to express my concerns regarding threats to the region's diminishing water supplies and the future inhabitability of northwestern Nebraska and adjacent southwestern South Dakota. In earlier documents I have expressed the basis for my concerns. In this document I will describe recently acquired research reports and their bearing on this case.

PROFESSIONAL BACKGROUND

I have 25 years' experience studying the geology of northwestern Nebraska and adjacent South Dakota. Following dissertation work on the regional geology from 1988-1995, from 1996-2006 I led teams of geologists from the Nebraska Geological Survey that mapped in detail the geology of most of northwestern Nebraska (a total of 80 1:24,000 quadrangles). The completion of this work frequently required detailed study of equivalent strata in adjacent Fall River, Shannon, and Todd counties in 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 Dr. Matthew Joeckel, Director). 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). From 2006-2008 I continued this work as an Adjunct Professor of Geology at Chadron State College (CSC) in Chadron, Nebraska. During this time I worked with and advised students studying the region's groundwater, surface water, and faults (Balmat & Leite 2008, Balmat & others 2008, Butterfield & others 2008). Since 2008 I have worked as an Instructor and Researcher in the Department of Math, Science, & Technology at Oglala Lakota College (OLC MST), serving the department as Co-Chair from 2009-2012 and Chair from 2012-2013. Since 2013 I have resumed my duties as a full-time instructor and researcher.

In addition to my ongoing geological work in Nebraska, I have been working with students and faculty to study the geology, groundwater, surface water, and heavy metal contaminants of southwestern South Dakota and the Pine Ridge Reservation. For the past 6 years our research has been funded by the National Science Foundation's Tribal Colleges and Universities Program and Experimental Program for Stimulating Competitive Research, and the USDA National Institute for Food and Agriculture Tribal College Equity Program. We have formed and maintained partnerships with Chadron State College, the South Dakota Geological Survey, the South Dakota School of Mines and Technology, South Dakota State University, the University of Illinois Urbana-Champaign, the University of Illinois Center for Advanced Materials Purification of Water Systems, the Department of Health Physics at the University of Michigan School of Nuclear Engineering, the University of Washington Native American Research Center for Health, and the Technological University of Darmstadt, Germany. I have authored or co-authored reports detailing the preliminary results of studies describing toxic heavy metal contamination of drinking water (Salvatore & others 2010, Botzum & others 2011), characteristics of local aquifers (Gaddie & LaGarry 2010, LaGarry & others 2012), potential uranium contamination risk to communities on the Pine Ridge Reservation (LaGarry & Yellow Thunder 2012), and the transmission of uranium-contaminated water along regional faults (Bhattacharyya & others 2012).

THE RECENTLY ACQUIRED RESEARCH REPORTS

My expert opinions in this case are based largely on my extensive fieldwork and detailed knowledge of past research in the region (mentioned above). As is the case with any scientific enterprise, whether its academic research or industrial mineral extraction, these practices are the basis of sound science, allow the best informed decisions to be made, and provide a basis for informing the affected public whose interests are to be protected. Furthermore, central to my expert opinions in this case is the prevalence of faults and joints that could plausible serve as contaminant pathways for unconfined lixiviant. Previously mentioned research on lineaments (Diffendal 1994), when combined with recently acquired research reports describing faults and joints by Balmat (2011) and Maher (2012), and a water use map by the Wyoming Fuels Company (1982), allows a clearer understanding of the prevalence of faults and joints than was available earlier (2008, 2015).

Lineaments

Lineaments are any unexplained, straight-line topographic feature in remotely sensed imagery (Peter & others 1988). Some lineaments represent fence lines and roads, but many represent faults and joints, which are most obvious when forming parallel sets. Recognition of lineaments is vital as faults and joints are primary pathways for surface and groundwater transmission of contamination away from historically mined areas into adjacent regions. Such pathways must also be considered when evaluating mining activity that requires the containment of contaminant-bearing liquids.

Diffendal (1994) described and mapped multiple sets of parallel lineaments oriented generally NW-SE and SW-NE throughout northwestern Nebraska (Fig. 1). These lineaments may or may not represent faults and joints. Such a determination would require extensive fieldwork to check each lineament. However, in field checking and statistically analyzing lineaments south of

Chadron, Nebraska, Balmat (2011, page 53) concluded that in this part of northwestern Nebraska, lineaments visible from Earth's orbit do, in fact, represent faults and joints identifiable on the ground.

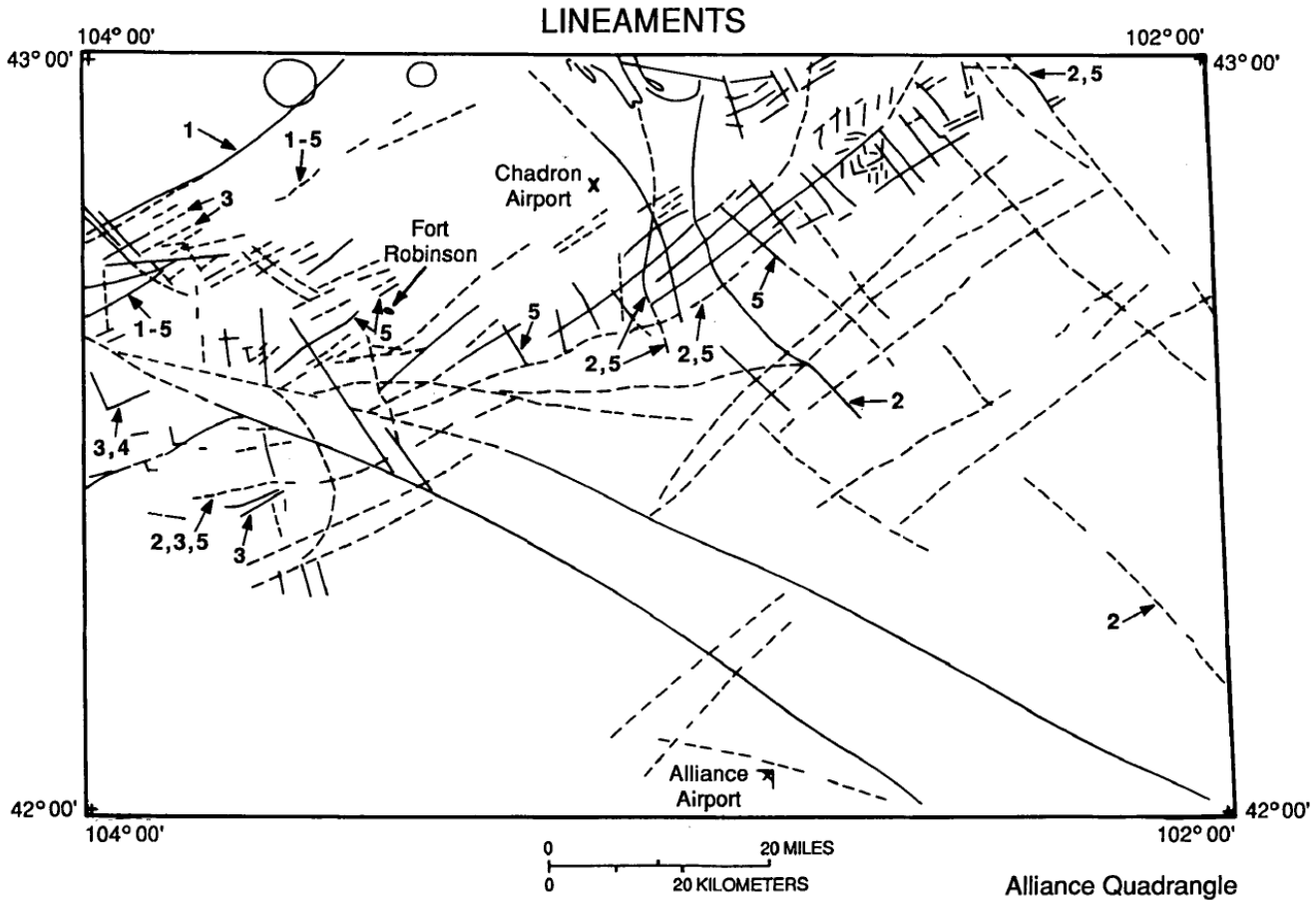

Figure 1. Diffendal's (1994) map of lineaments visible from space in northwestern Nebraska (Sioux, Dawes, and Sheridan counties). The locations of Ft. Robinson, the Chadron airport, and the Alliance airport allow relative positions to be determined on this map.

Faults and joints

Based on my earlier opinions, I consider faults and joints to be the primary concern for the migration of unconfined lixiviant away from the Crow Butte Resources site. Faults and joints can plausibly allow contaminants to flow vertically and come into contact with drinking water in overlying alluvial aquifers or react chemically with carbon, arsenic, and selenium in the subjacent Pierre Shale. Faults and joints also could plausibly allow mining fluids to migrate laterally into adjacent areas. Also, faults and joints in this region are frequently mineralized, showing conclusively that such mineral deposits (potentially uranium minerals) do occur (see discussion in Sibray & Carlson 2010).

While working with a student on a related research project in March 2015, a detailed literature search uncovered a poster presentation by Maher and Schuster (2012). This poster presentation used extensive detailed fieldwork in northwestern Nebraska and southwestern South Dakota to describe the regional structural fabric (a term used to describe faults and joints, as well as other

structural features, on a regional scale. Maher and Schuster (2012) mapped faults and joints in: 1) the vicinities of Toadstool Park (Crawford) and Whitney, Nebraska, 2) along the Nebraska-South Dakota border near Whiteclay, Nebraska and Pine Ridge, South Dakota, 3) at Badlands National Park in South Dakota, and 4) in Harding County South Dakota. In each location the found faults and joints were ubiquitous and pervasive and generally followed an ESE trend. This corresponds to the NW-SE trend (just in a different way) described by Diffendal (1994), supporting his assertions about the structural origins of the lineaments he observed from orbital photography. Their observations also support by expert opinions based on detailed geological mapping in northwestern Nebraska (2008, 2015) in which my field crews and I observed countless faults and joints having the same NW-SE, SW-NE, and ESE trends.

In April 2015 I was asked to help locate copies of my open-file 1:24,000 geological maps of northwestern Nebraska (see the list in my recent 2015 CBR opinion). After learning that these are no longer available from the repository at the University of Nebraska-Lincoln School of Natural Resources, I began searching through my own professional effects for paper copies still in my possession. While I was unable to turn up any of those maps, I did locate a map I acquired in 2004 from Vernon Souders of the Nebraska Geological Survey at about the time of his retirement. This water resources map (Wyoming Fuels Company 1982) shows the distribution of the potential ore area for the Crow Butte Project (Fig. 2). The wells marked on the map may be useful in other contexts. However, what caught my attention was that the area marked as the potential ore body is a generally NW-SE trending lineament similar to the trend noted by Diffendal (1994). Also, the depiction of the ore body shows two closely spaced variations ("kinks") in the linear trend that offset it in opposite directions as if by two closely spaced SW-NE trending faults (red). Such faults were observed by Diffendal (1994) and are portrayed on his map due east of Fort Robinson. If these offsets are the result of faulting, then they confirm the observations first made by Balmat & Leite (2008), confirms the assertion by Balmat (2011) that lineaments observed from orbit are in fact faults, and supports my earlier assertions that the uranium being mined at Crow Butte Resources may be from mineralizations in faults as described in the "whistleblower letter" (2008, 2015).

SUMMARY

The research described herein supports the consolidated interveners' contentions regarding the plausibility of unconfined lixiviant in that: 1) it establishes that SW-NE and SW-NE trending lineaments are pervasive in northwestern Nebraska in the areas in which Crow Butte Resources is currently mining or intends to expand into (Diffendal 1994), 2) there is a high degree of statistical probability that these lineaments represent faults along which unconfined lixiviant could plausibly migrate (Balmat 2011), 3) detailed field work in northwestern Nebraska and adjacent South Dakota supports my earlier (2008, 2015) assertions that faults and joints are ubiquitous throughout the region, and that 4) my previous assertions that faults visible from space directly impact the mined area are supported by the configuration of the mined uranium deposits (Wyoming Fuels Company 1982). I herein reiterate my earlier (2008, 2015) assertions that Crow Butte Resources' complete and continued reliance on modeling based on outdated and incomplete parameters will never be sufficient to satisfy concerns based on actual mapping and recent published studies. It is incumbent upon potential ISL operators, as it is with any natural resource extractors, to seek out the most recent research and expert opinions on the geological settings in which they propose to operate.

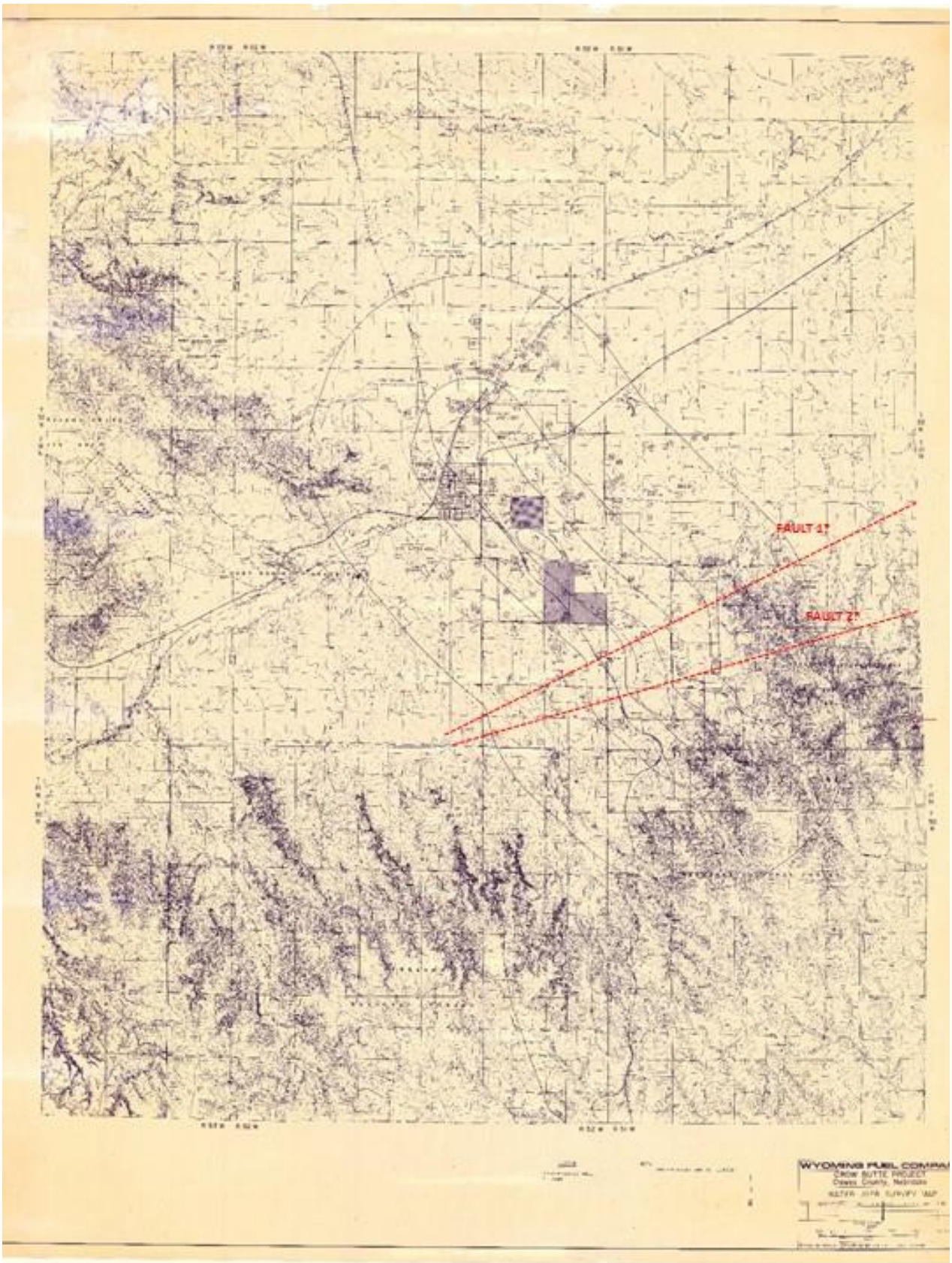

Figure 2. Wyoming Fuels Company (1982) map of Crow Butte Resources showing possible faults (red lines).

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