APPENDIX E

Clarification of Breccia Pipes

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF PLATES

LIST OF PHOTOS

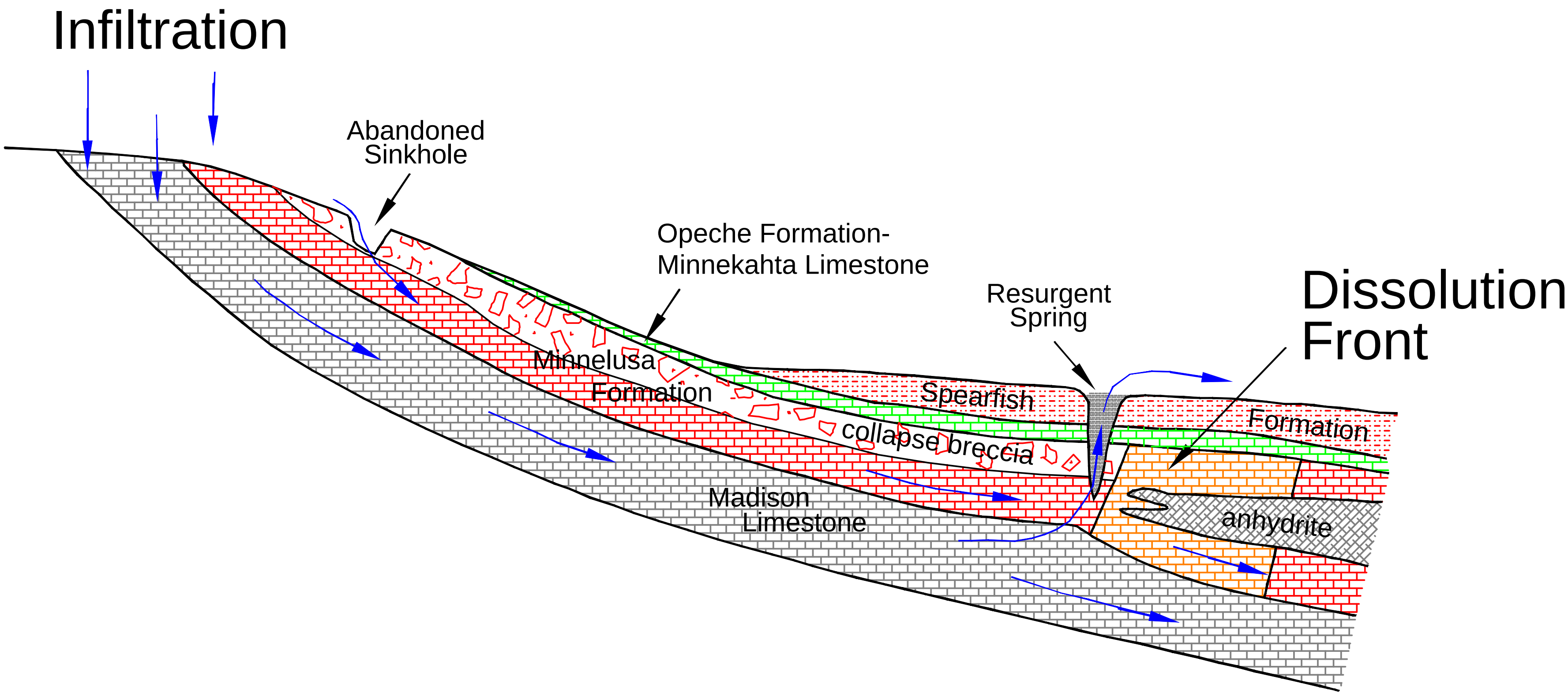
1.0 INTRODUCTION

USGS Professional Paper 763 (Gott et al., 1974) describes the stratigraphy of the Inyan Kara Group along the southern flank of the Black Hills Uplift and presents a working theory on the localization of uranium deposits. The geologic mapping and stratigraphic descriptions contained in that report are comprehensive and provide an important source of information on the stratigraphy and depositional environment of Inyan Kara sediments in this region. However, theories presented in that report on uranium mineralization emplacement that are centered on and related to the presence of breccia pipes penetrating the Inyan Kara Group have not been proven and have been replaced by the classic "roll front" theory of uranium emplacement. Moreover, there appears to be no credible basis to support the theory that collapse features are acting as "conduits" for large volumes of ascending water to recharge the Inyan Kara Group. Powertech evaluated the potential for breccia pipes in and around the project area and concluded that there is no evidence of breccia pipes. Following are the results of the evaluation.

2.0 REGIONAL SETTING

Breccia pipes and collapse breccias were mapped in the southern Black Hills by Darton (1909). Gott et al. (1974) state that these collapse features originate in anhydrite and gypsum sequences within the upper portion of the Minnelusa Formation of Pennsylvanian age. Dissolution of these evaporite sequences by underlying Minnelusa and/or Madison artesian water created solution cavities into which overlying Permian sediments collapsed. On Plate 4 of Gott et al. (1974), locations of classic Black Hills collapse breccias occurring within Paleozoic sediments were identified. In addition, many other more speculative features occurring higher in the stratigraphic column were mapped. All breccia pipes or collapse structures located by Gott et al. (1974) and labeled as occurring in the Minnelusa Formation, Opeche Shale, Minnekahta Limestone or basal Spearfish Formation may be considered to be "documented" breccia pipe locations. All of these Paleozoic breccias pipes are located 8-25 miles north and east of the project area, and none occur within the project area.

Geologic mapping and water resource reports have set limits on the expected areal extent of Minnelusa-based collapse breccias. As an example, Figure 1 is based on an illustration in an article by Jack B. Epstein published in USGS Water-Resource Investigation Report 01-4011 (2001) and describes the maximum down-dip limit of a dissolution front within the evaporite sequence of the upper Minnelusa Formation. In the Black Hills region, extensive dissolution of gypsum and anhydrite beds of the upper Minnelusa has taken place in the surface or near-surface environment. Up to 150 feet of these highly soluble sediments have been removed from the upper Minnelusa through a dissolution process. As illustrated in Photo A, behind (up-gradient of)



Source: USGS Water-Resources Report 01-401, 2001, Jack B. Epstein, pp. 30-37

Figure 1

Minnelusa Dissolution Front
Southern Black Hills
South Dakota
Dewey-Burdock Project

DRAWN BY	J. Bonner
DATE	17-Jul-2012
FILENAME	MinnDissFront.dwg

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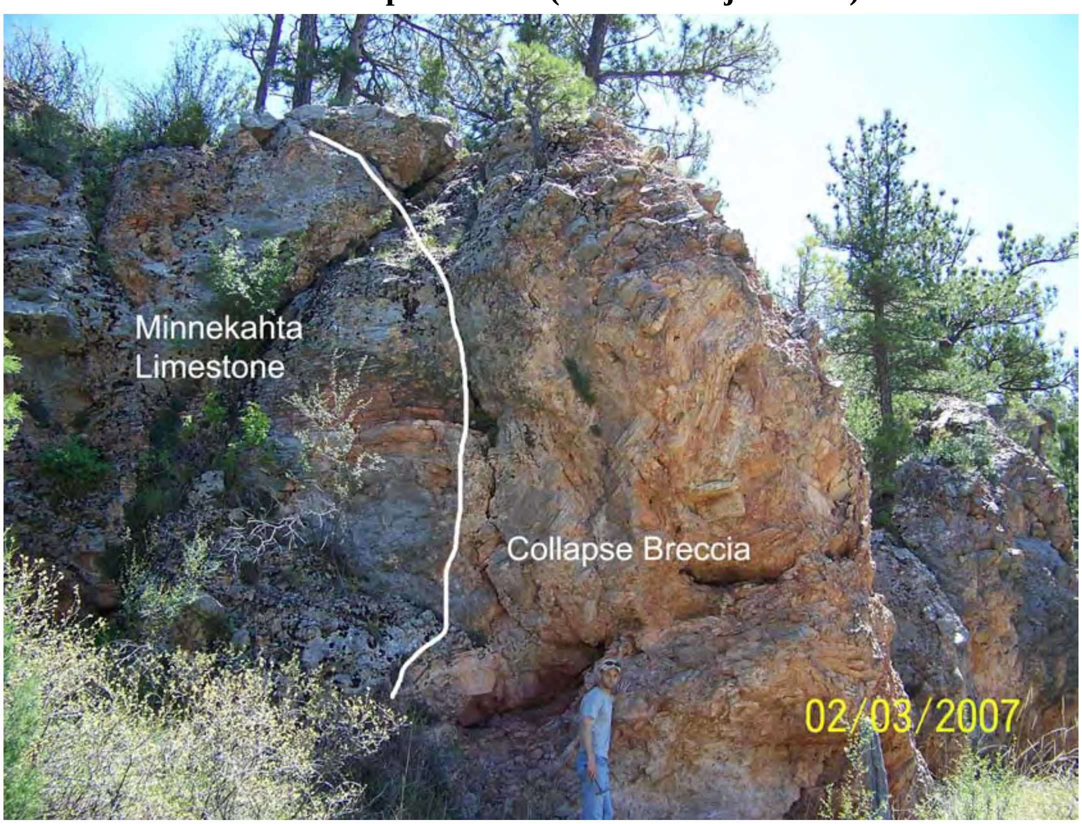
the dissolution front the upper Minnelusa has a distinctive appearance at the outcrop. In addition to an obvious lack of anhydrite and gypsum, its appearance indicates oxidation and weathering. The remaining sediments are extremely distorted, cavernous, brecciated and exhibit numerous flow features. The subsidence within this unit, due to the dissolution process, results in down-dropping of, and collapse breccias within, overlying sediments. Epstein shows that this dissolution extends only a few miles down-gradient in the subsurface, where he shows it stopping at a dissolution front. Down-dip from this front, no dissolution occurs and the evaporite sequences within the upper Minnelusa are intact. With no dissolution, no subsidence, collapse or brecciation can take place.

The presence of a dissolution front within the upper Minnelusa has been recognized for more than a half century. In 1955-56, the USGS mapping team of Braddock, Carter and Bridge compiled the geologic mapping for the Jewel Cave SW 7 ½ minute quadrangle map (Plate 6.23). This mapping included the upper Minnelusa Formation in the area of Hell Canyon, in which extensive dissolution has taken place. Within the sediments overlying the upper Minnelusa in this area, there are many collapse breccia features. In fact, this area of lower Hell Canyon (not within the project area) is one of the best locations to view classic Black Hills breccia pipes. Photo B shows a small collapse breccia developed in the Minnekahta Limestone within Hell Canyon. Disoriented blocks of Minnekahta Limestone and smaller breccia material can be seen in this collapse structure. Less than 2 miles down-gradient from the location of this breccia pipe, the USGS mapping team annotated on the geologic map "Probable limit of collapse breccias in Minnelusa Formation" – showing the down-dip extent of the dissolution front. This boundary for Minnelusa breccia pipes is some 6 miles northeast of the Dewey-Burdock project area.

Plate 6.24 is based on Plate 4 of Gott et al. (1974) and shows all suggested locations for the three categories of collapse features. It also illustrates the outcrop areas of the Minnelusa Formation and the Inyan Kara Group. The "red line" on this exhibit corresponds to locations where the down-dip limit of the dissolution front in the upper Minnelusa has been mapped or projected. North of this line classic Black Hills breccia pipes have been mapped and identified. South of this line suggested locations of collapse features are more speculative and many features are identified as "structures of possible solution origin" and "topographic depressions." The identification and mapping of a solution front within the upper Minnelusa is critical to confirming the absence of breccia pipes at the Dewey-Burdock project area. As previously described, dissolution of the anhydrites and gypsum within the upper Minnelusa is essential for subsequent collapse brecciation and breccia pipe formation in overlying sediments. In areas where there has been no dissolution, there is no geologic foundation for the creation of breccia

Photo A: Upper Minnelusa Outcrop (Outside Project Area)

Photo B: Minnekahta Collapse Breccia (Outside Project Area)



pipes in overlying sediments. Also shown on Plate 6.24 is the outline of the Jewel Cave SW 7½ minute quadrangle map (Plate 6.23) and the locations of all photographs.

3.0 SITE-SPECIFIC EVALUATION

Figure 2 shows the Mesozoic and a portion of the Paleozoic stratigraphy below the project site. This electric log is from an abandoned oil & gas test well (the Darrow well) in Section 2, T7S, R1E that penetrated the Minnelusa Formation. The character of the upper Minnelusa Formation under the project area is extremely important because all Black Hills breccia pipes are "rooted" in this unit. Three observations from Figure 2 are of major significance to this matter.

1) As discussed above, the dissolution front in the upper Minnelusa has been mapped north of the project area. This test well is located approximately 7 miles farther down-gradient from and beyond the dissolution front. The electric log signature shows thick sequences of evaporites. There has been no dissolution within the upper Minnelusa under the project area.
2) The thickness of the upper Minnelusa in the Darrow test well also supports the fact that this test hole is located well in advance of a dissolution front. Hayes (1999) discusses the collapse brecciation at Cascade Springs and provides stratigraphic descriptions of the upper Minnelusa. He describes this interval as beginning at a red, mudstone-rich marker bed, locally known as the Red Marker and continuing upward to the Opeche Shale. He states that a 300-foot thickness of the upper Minnelusa is common in areas where anhydrite has been removed by solution and breccia pipes occur. Basinward (down-dip), the upper Minnelusa is 150 feet thicker in the subsurface where dissolution of anhydrite beds has not taken place. The thickness of the upper Minnelusa in the Darrow test well is 442 feet, again indicating that there has been no dissolution under the project area.
3) As shown in the left margin of Figure 2, the stratigraphic horizons that host classic Black Hills breccia pipes are the upper Minnelusa Formation, Opeche Shale, Minnekahta Limestone and the lower 200 feet of the Spearfish Formation. These geologic units are fully intact and over 1,000 feet below the ground surface at the Dewey-Burdock project area.

The following Powertech geological evaluations and environmental baseline analyses present additional evidence demonstrating that breccia pipes are not present at the Dewey-Burdock site.

1) Exploration Drilling - The large number of exploration drill holes (more than 4,000) completed within the project area without any indication of solution collapses bolsters the hypothesis that no breccia pipes have penetrated the Inyan Kara Group. If such an event had occurred, evidence of solution collapses would be observed in the correlation of the electric logs or from the structure maps developed on top of the Morrison Formation, Chilson Member, Fuson Shale or Fall River Formation. Any subsidence, collapse features

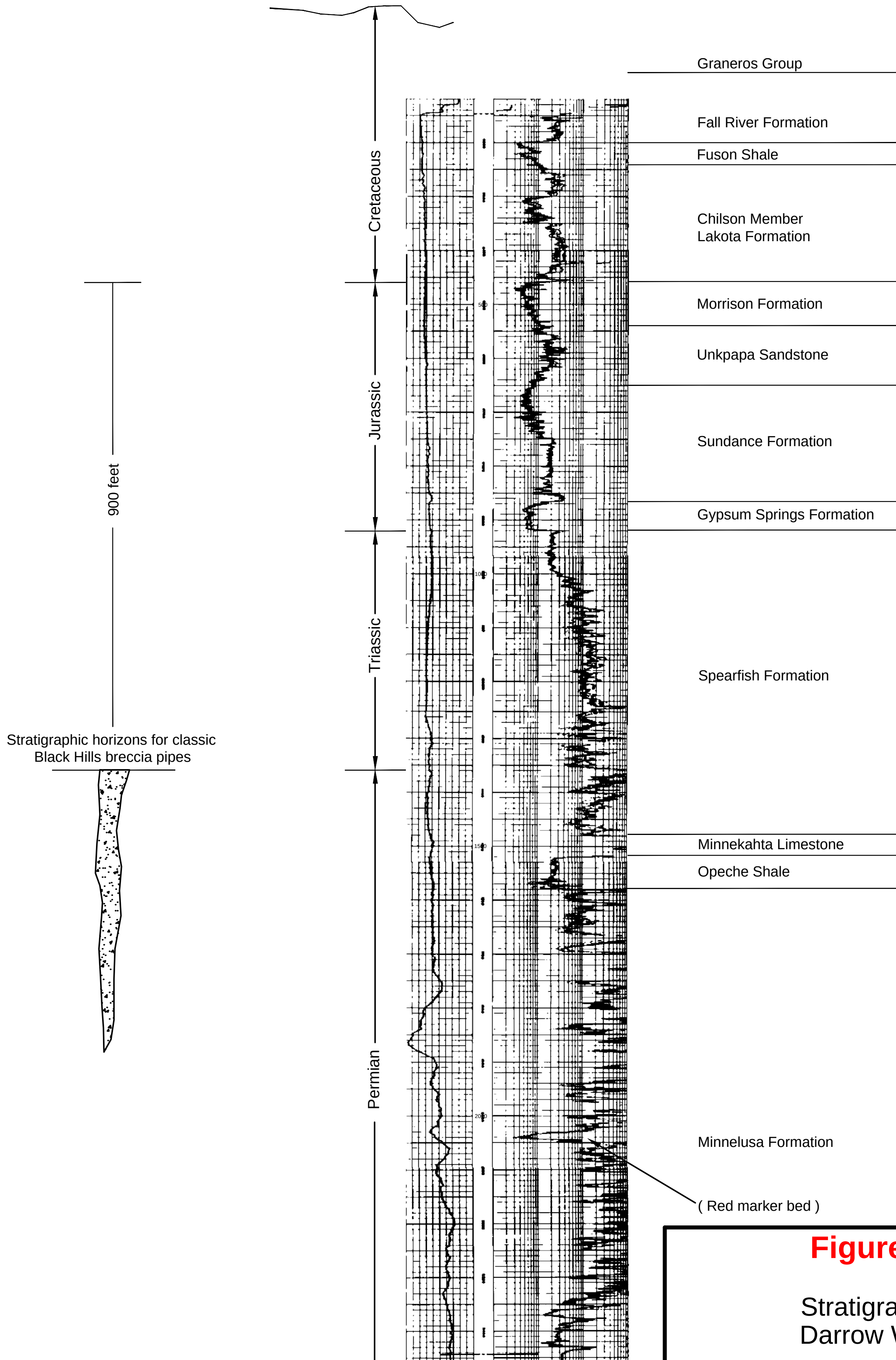


Figure 2

Stratigraphy
Darrow Well

Dewey-Burdock Project

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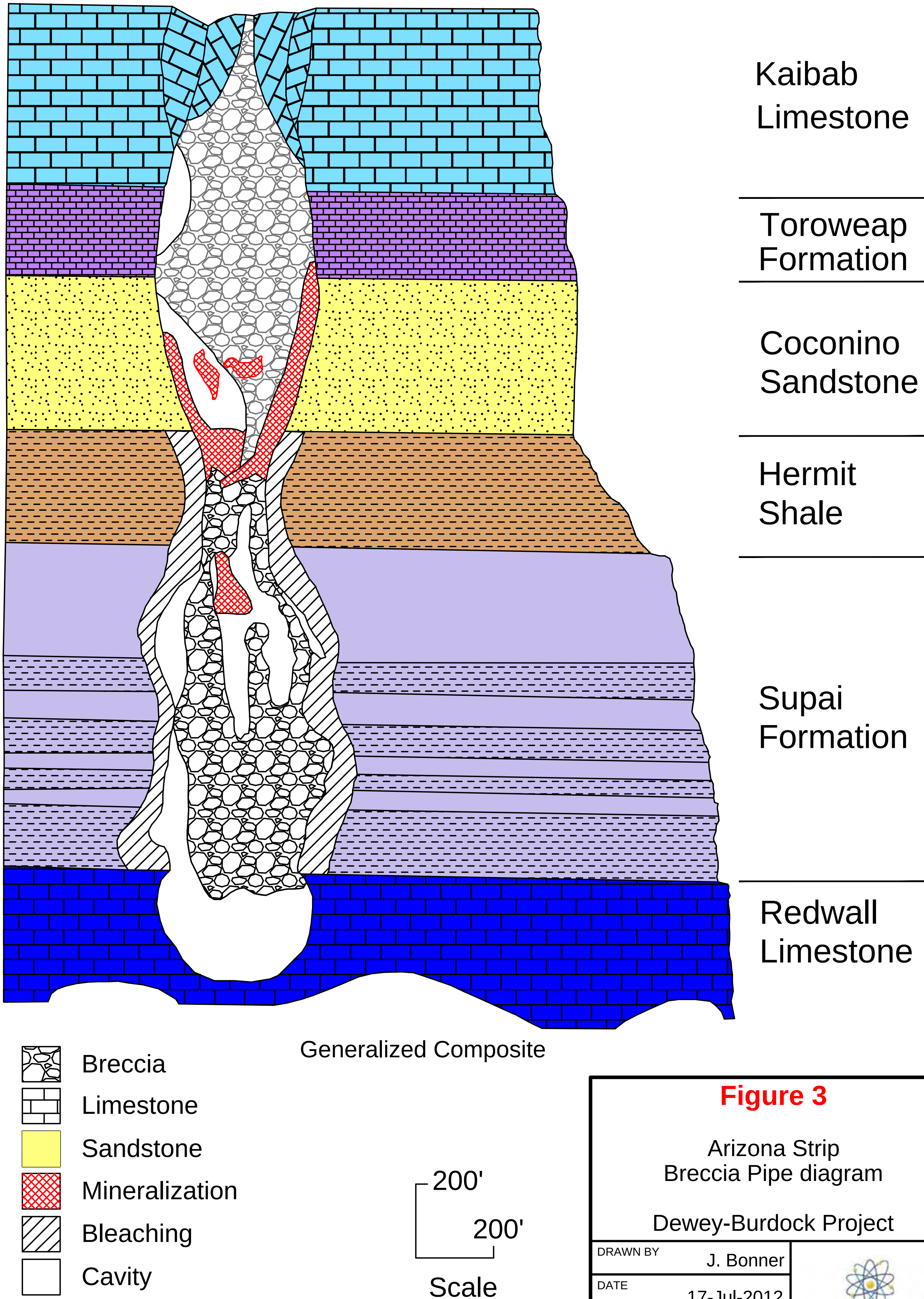
or down-dropped sediments would have been evident while preparing cross sections or structure contour maps.

2) Field Investigations for Breccia Pipes - In Professional Paper 763, Gott et al. presented the theory that breccia pipes may extend upward into the Inyan Kara sediments. While there were no features identified within the project boundary, Powertech's field investigation focused on "proposed" collapse features within Jurassic and Cretaceous sediments northeast of the project. Due to the high-grade uranium deposits that have been mined within breccia pipes in the Arizona Strip of northwest Arizona, the uranium industry has extensive experience in surface exploration techniques for these features (Figure 3). As a comparison, Arizona Strip evaluation criteria were applied to the proposed Black Hills features. These criteria consisted of displaced sediments, brecciation, dip changes of surface beds, fracture patterns and alteration patterns. In addition, due to the Gott et al. theory that breccia pipes were conduits for high volumes of ascending groundwater as recharge to the Inyan Kara aquifer, the Powertech geologic team specifically searched for evidence of solution movement at these sites. Investigation sites correspond to photo locations shown on Plate 6.24.

    A. The first site examined was Cascade Springs, a classic Black Hills breccia pipe located south of Hot Springs, South Dakota. This breccia pipe area was the subject of the previously mentioned USGS Water-Resource Investigation Report 99-4168 (Hayes, 1999). Powertech staff believed it was important to examine a verified collapse breccia feature and collect "ground truth" before investigating other sites. At the subject site, the surface Minnekahta Limestone met several of the Arizona Strip evaluation criteria, including major fracture patterns, brecciation within the limestone, dip changes of surface beds in the fractured areas and obvious evidence of solution movement. Also of major importance, this feature is located upgradient or updip of the mapped upper Minnelusa dissolution front. Photos C and D illustrate some of these observed evaluation criteria.

    B. The second site focused on "breccia pipes" mapped by Gott et al. within Jurassic sediments approximately 2 miles north of the project area. This area is located 2 miles down-gradient from the mapped down-dip limit of the dissolution front and no evidence of collapse or brecciation was observed. Instead, these features were found to be small, normal faults within the Dewey Fault Zone. As shown in Photos E and F, the sediments were subject to high compressional forces within the fault zone, resulting in folding and normal faulting. The area met none of the Arizona Strip evaluation criteria.

    C. The third and fourth sites examined were areas where Gott et al. mapped "breccia pipes" within Inyan Kara sediments approximately 2-3 miles northeast of the project area. These features were of primary interest because they had purportedly penetrated the Morrison Formation and Inyan Kara sediments. Powertech geologists spent two days investigating these features. These features were located in Sections 21 and 24, T6S, R2E and were 2 miles down-gradient from the mapped dissolution front. These features were found in the bottoms of deep canyons with Chilson Member sandstones forming steep cliffs



Source: Rocky Mountain Energy Company

Figure 3

Arizona Strip
Breccia Pipe diagram

Dewey-Burdock Project

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Photo C: Cascade Springs Breccia Pipe (Outside Project Area)

Photo D: Cascade Springs Breccia Pipe (Outside Project Area)

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Photo E: Sundance Formation Fault (Outside Project Area)

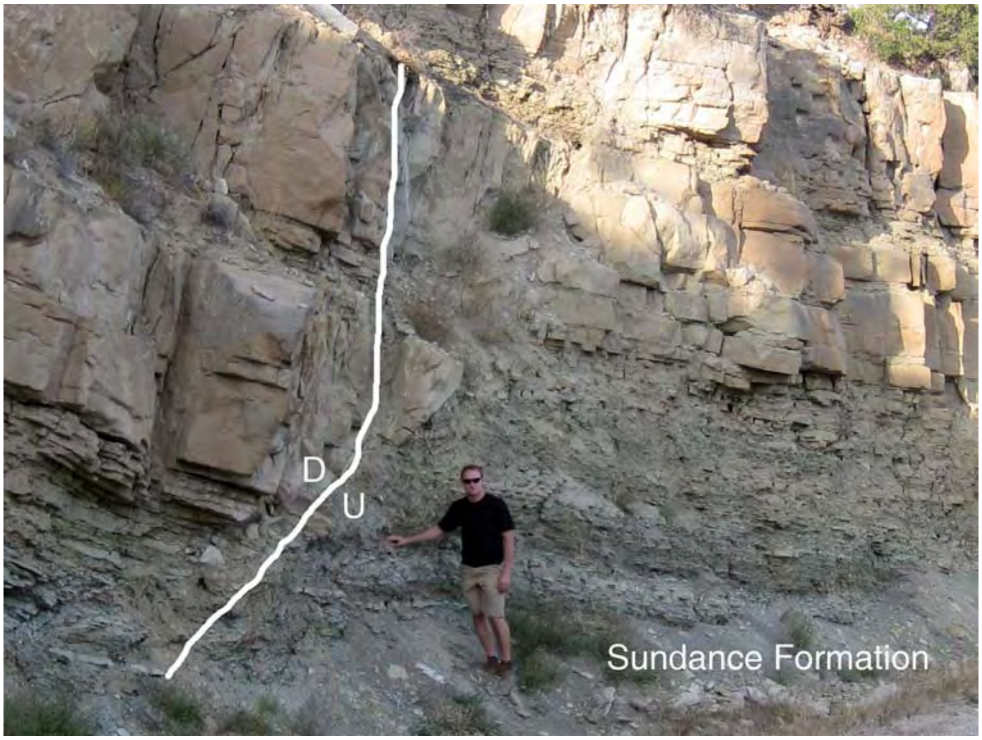

Photo F: Sundance Formation Fault (Outside Project Area)

along the canyon walls. There was no evidence of collapse or brecciation and, as shown in Photos G and H, it appears the features were the result of surface erosion and slump blocks caving off the steep canyon walls. The area met none of the Arizona Strip evaluation criteria.

In addition to the above sites, other "structures of possible solution origin" were investigated. All of these sites were located down-gradient of the mapped down-dip limit of the dissolution front and met none of the Arizona Strip criteria. Further, there was no evidence of springs to indicate flow of ascending groundwater into the Inyan Kara aquifer. The signature surface expressions for breccia pipes are lacking in all areas examined; no surface geologic evidence could be found to support the presence of breccia pipes on or adjacent to the project area.

4) Inyan Kara Water Temperatures - Gott et al. also theorized that the rapidly ascending groundwater from the deeper Minnelusa Formation would have a higher temperature than the water in the Inyan Kara aquifer. This theory proposes that "water probably has been heated in deeper aquifers and then has ascended to the Inyan Kara Group" through breccia pipes. As supporting evidence of this theory, Gott et al. cite the presence of high geothermal gradients within Inyan Kara wells averaging 1.5º C per 100 feet, as opposed to an average geothermal gradient of 0.9º C per 100 feet for pre-Cretaceous rocks in the Black Hills area.

   As part of Powertech's environmental baseline analyses, field parameters were collected at each sampled well (Appendix N). Water temperature measurements from 16 wells completed within the Inyan Kara aquifer were used to estimate geothermal gradients within the Inyan Kara aquifer at the Dewey-Burdock Project. In addition to these field measurements, Powertech also has accurate information on the screened interval for each of these wells, which provides reliable depths to groundwater (top of screened intervals).

   Depths to groundwater in the 16 Inyan Kara wells ranged from 30 to 715 feet below ground surface. Water temperatures ranged from 11.55º C (in the shallowest well) to 15.39º C (in the deepest well). The average geothermal gradient of these 16 wells was calculated to be 0.42º C per 100 feet – well below one-half the gradient cited by Gott et al. for the Inyan Kara aquifer. Based on Powertech's more accurate and concentrated water sampling results within the Dewey-Burdock project area, all evidence indicates the presence of a normal geothermal gradient within the Inyan Kara aquifer – not an elevated gradient due to rapidly ascending, heated groundwater from underlying aquifers as theorized by Gott et al.

5) Regional Pumping Tests - The pumping tests conducted by TVA in the late 1970s and early 1980s (Appendix I) and by Powertech in 2008 (Appendix J) were "regional tests" aimed specifically at evaluating hydraulic transmission and storage characteristics of the mineralized zones within the Fall River Formation and the Chilson Member of the Lakota Formation and the intervening Fuson Shale confining unit.

Photo G: Mapped "Breccia Pipes" (Outside Project Area)

Photo H: Mapped "Breccia Pipes" (Outside Project Area)

Based on the results of the regional pumping tests that have been conducted within the project area, the Fuson Shale, which is the confining unit between the overlying Fall River Formation and the underlying Chilson Member, may locally be "leaky"; that is, the observed aquifer response in the Fall River and Chilson suggests possible hydraulic communication between these units. In none of the aquifer tests conducted to date, however, has a "recharge boundary" been observed which would suggest the existence of a significant source of water such as postulated by Gott et al. (1974). In other areas of the Black Hills, the surface discharge through breccia pipes is on the order of several cubic feet per second.

6) Color Infrared (CIR) Imagery - 2010 CIR satellite imagery was obtained for an approximately 10-square-mile area, including the project area and surrounding vicinity. The imagery obtained through the National Agriculture Imagery Program (NAIP) of the USDA Farm Services Agency has a resolution of one meter.

The imagery was examined visually for any anomalies that may suggest groundwater discharge at or near surface, such as from upward flow through a breccia pipe, an open borehole or a natural spring. Using a combination of CIR and field investigations, all surface water features within the project area were identified and no surface water features or groundwater flow sources were found within the project area indicative of a breccia pipe flowing to the surface.