2.E NAME AND DEPTH OF USDWs

For Class II Wells (Not Applicable to this Application)

2.F MAPS AND CROSS SECTIONS OF GEOLOGIC STRUCTURE

Submit maps and cross sections detailing the geologic structure of the local area (including the lithology of injection and confining intervals) and generalized maps and cross sections illustrating the regional geologic setting.

RESPONSE

Regional Setting

The Dewey-Burdock Project area is located on the southwestern flanks of the Black Hills Uplift. As shown on Figure F-1, the Black Hills are within the Great Plains physiographic province. A generalized geologic cross-section through the Black Hills is included as Figure D-2.

The Black Hills area of South Dakota and Wyoming is the principal recharge area for the regional bedrock aquifer systems and strongly influences the hydrology of western South Dakota and northeastern Wyoming. Because of its higher elevation, the Black Hills area receives greater precipitation than the surrounding areas. The average annual precipitation increases from 16 to 17 inches in the Dewey-Burdock area to greater than 28 inches in the northern Black Hills near the town of Lead. Many streams in western South Dakota originate in the Black Hills.

Geologic Setting

The present-day structural features of the Northern Great Plains are directly related to the geologic history of the Cordilleran platform, which is a part of the stable interior of the North American Continent. The present-day structure probably was controlled by the pre-existing structural grain in the Precambrian basement and modified during the Laramide orogeny (Downey, 1984).

During Paleozoic time, the area generally was a broad, flat plain, covered by shallow warm seas. Numerous disconformities during Paleozoic time indicate intermittent transgressions and regressions when seas advanced from west to east in response to tectonic activity. Deposits generally were beach, shallow marine, carbonate, and evaporite units (Redden and Lisenbee, 1996).

During Cretaceous time, the area was covered by a north-south trending sea, which extended from the Gulf of Mexico to the Arctic Ocean (Downey, 1986). During Late Cretaceous time, this sea was at its widest extent; marine deposition, however, was interrupted by frequent east-west regressions (Anna, 1986).

The Northern Great Plains area was part of the Cordilleran platform through most of Paleozoic time. The Williston Basin, which covers parts of North Dakota, South Dakota, southern Saskatchewan, southwestern Manitoba, and eastern Montana, began to take shape during Ordovician time. Other major Jurassic and Cretaceous (pre-Laramide) paleostructural elements include the Powder River Basin, the Central Montana trough and uplift, the Cedar Creek anticline, and the Alberta shelf (Anna, 1986) (Figure F-1).

The Laramide orogeny, which affected the eastern Rocky Mountains, began during Late Cretaceous time and continued in the Eocene period (Redden and Lisenbee, 1996). The Laramide orogeny was characterized by large-scale warping, deep erosion of uplifts and deposition of orogenic sediments in the major basins (Tweto, 1975). Most, if not all, pre-Laramide structural features were reactivated and became more prominent during the Laramide orogeny (Anna, 1986). During the Laramide orogeny, the Bighorn and Laramie Mountains, the Black Hills, and the Central

Montana uplifts formed, and the Williston and Powder River Basins were downwarped into essentially their present configuration (Anna, 1986).

The Black Hills Uplift forms a northwest trending dome about 125 miles long by 60 miles wide. The formation of the uplift deformed the entire sedimentary sequence from Cambrian to late Cretaceous. Subsequent erosion of the dome has exposed the rock units which dip radially outward in successive elliptical outcrops surrounding the central Precambrian granitic core. Differential weathering has further resulted in the present day topography of concentric ellipsoids of valleys under softer rocks and ridges held up by more competent units (R.B. Smith & Assoc., Inc., 2005).

Superimposed on the Black Hills Uplift are numerous folds plunging radially outward. Local structures of this type include the Chilson Anticline and Sheep Canyon Monocline east of the community of Edgemont, and the Cottonwood Creek Anticline trending southwest from the community of Edgemont (Figures D-8 and D-15).

Two major structural zones, Dewey and Long Mountain, are conspicuous within the project area and consist principally of a series of en echelon faults. The Barker Dome Anticline, which forms a productive oil field in the Minnelusa, is located approximately 3 miles to the northeast of the Project (Figure D-19).

As noted, the uranium mineralization within the Dewey-Burdock deposit occurs in the Lower Cretaceous Fall River and Lakota Formations as a classic roll front deposit.

Topography and Elevation

In the southern and western portion of the Dewey-Burdock Project area, the terrain is undulating to moderately incised. The eastern and northern portions of the project area, being further into the uplift, are cut by narrow canyons. Only four or five significant drainages likely exist within the project area (R.B. Smith & Assoc., Inc., 2005).

The change in elevation across the project area is approximately 200 feet. The lower elevation of 3,600 feet above mean sea level (amsl) occurs on the south and west sides of the project area; the highest elevation of approximately 3,800 feet amsl is in the northeast portion.

Stratigraphy

The geologic section in the southwestern portion of South Dakota is shown in Table F-1 and described in the following sections from oldest to youngest rocks. Note that rocks deposited after the Skull Creek Shale are not generally present in the Dewey-Burdock Project area. Specific details regarding the geologic column are provided here from deepest (oldest) to surface.

Precambrian

Precambrian rocks form the basement in the northern Great Plains and are exposed in the central core of many of the mountain ranges including the Black Hills Uplift, but lie greater than 15,000 feet below land surface at the center of the Williston Basin to the north of the Black Hills.

The oldest stratigraphic units in the Dewey-Burdock project area are Precambrian igneous and metamorphic rocks, composed primarily of metasediments, including schists and graywackes. The Precambrian rock surface was eroded to a gentle undulating plain at the beginning of the Paleozoic Era and the overlying Paleozoic and Mesozoic strata were deposited on the Precambrian surface as nearly horizontal beds. Subsequent uplift during the Laramide orogeny and erosion have

exposed the Precambrian rocks in the central core of the Black Hills, with the Paleozoic and Mesozoic sedimentary rocks, as noted, exposed in roughly concentric rings around the uplifted Precambrian core (Driscoll et al., 2002). The Precambrian basement forms the lower confinement below the Deadwood Formation.

Deadwood Formation (Cambrian)

The Cambrian-age Deadwood Formation consists of massive to thinly-bedded, brown to light-gray sandstone; greenish glauconitic shale; flaggy dolomite; and flat-pebble limestone conglomerate. Sandstone with conglomerate occurs locally at the base of the formation. Regionally, the Deadwood ranges in thickness from 0 to 500 feet (Carter et al., 2003). Locally the Deadwood is estimated to be approximately 100' thick (Figure A-4) and has approximately 85' of 11% porosity. Limited data are available, and no wells penetrate to basement through the Cambrian section on site.

In the northern and central Black Hills, the Deadwood Formation is disconformably overlain by Ordovician rocks, which include the Whitewood and Winnipeg Formations. The Winnipeg Formation is absent in the southern Black Hills and the Whitewood Formation has been eroded and is not present south of Rapid City. In the southern Black Hills, the Deadwood Formation is unconformably overlain by the Devonian- and Mississippian-age Englewood Formation, which in turn, is overlain by the Madison Limestone (Driscoll et al., 2002).

Winnipeg and Whitewood (Red River) Formations (Ordovician)

As noted, the Ordovician Winnipeg and Whitewood (Red River) Formations are absent in the Dewey-Burdock Project area. Elsewhere these formations consist of green shale with siltstone (Carter et al., 2003).

Englewood Formation (Devonian - Mississippian)

The Englewood Formation consists of pink to buff limestone with shale at its base and ranges from about 30 to 60 feet thick (Carter et al., 2003). Locally, the Englewood is projected to be approximately 34' thick and is the upper confining layer above the Deadwood Formation (Figure A-4).

Madison (Pahasapa) Limestone (Mississippian)

The Mississippian-age Madison Limestone consists of a sequence of marine carbonates and evaporites deposited mainly in a shallow, warm-water environment. It is a massive, gray to buff limestone, and locally dolomitic. The Madison Limestone was exposed at land surface for approximately 50 million years. During this period, significant erosion, soil development, and karstification occurred, resulting in the formation of numerous caves and fractures within the upper part of the formation. The thickness of the Madison increases from south to north in the Black Hills area and ranges from almost zero on the southeastern flank of the Black Hills Uplift to 1,000 feet of thickness east of Belle Fourche. Locally, the Madison is approximately 295' thick (Figure A-4). Because the Madison Limestone was exposed to erosion and karstification for millions of years, its contact with the overlying Minnelusa Formation is unconformable. Collapse features within the Madison and Minnelusa Formations may hydraulically interconnect the two formations (Driscoll et al., 2002) at some locations near the outcrop of the Black Hills. However, local data suggest that these two formations are hydrologically isolated in the Project area.

Minnelusa Formation (Permian - Pennsylvanian)

The Pennsylvanian- and Permian-age Minnelusa Formation consists of yellow to red, cross-stratified sandstone, limestone, dolomite, and shale. The middle and lower parts of the formation consists of shale and anhydrite. The upper portion of the Minnelusa may also contain anhydrite, which generally has been removed by dissolution in or near the outcrop areas, occasionally forming collapse features filled with breccia.

The Minnelusa Formation was deposited in a coastal environment; dune structures at the top of the formation may represent beach sediments. The thickness of the Minnelusa increases from north to south and ranges from 375 feet near Belle Fourche to 1,175 feet near Edgemont. In the northeastern part of the central Black Hills, little anhydrite occurs in the subsurface due to a change in depositional environment. On the south and southwest sides of the Black Hills Uplift, the thickness of clastic units increases and a thick section of anhydrite occurs. In the southern Black Hills, the upper part of the Minnelusa Formation is disconformably overlain by the Permian-age Opeche Shale, which, in turn, is overlain by the Minnekahta Limestone (Driscoll et al., 2002; Carter et al., 2003).

Locally, the Minnelusa is 1,150' thick. The upper portion of the formation has three lobes that total approximately 164' of 21% porosity. The lower 560' appear to have relatively lower porosity and serve as lower confinement (Figure A-3).

Opeche Shale (Permian)

The Opeche Shale consists of red shale and sandstone and ranges in thickness from 25 to 150 feet (Carter et al., 2003). Locally, the Opeche Shale is approximately 95' thick (Figure A-2) and forms the upper confinement above the Minnelusa.

Minnekahta Limestone (Permian)

The Permian-age Minnekahta Limestone is a thin to medium-bedded, fine-grained, purple to gray laminated limestone, which ranges in thickness from 25 to 65 feet. The Minnekahta is overlain by the Spearfish Formation of Triassic- and Permian-age (Driscoll et al., 2002). Locally, the Minnekahta is approximately 40' thick (Figure A-2).

Spearfish Formation (Triassic/Permian)

The Spearfish Formation consists of red silty shale, soft red sandstone, and siltstone with gypsum and thin limestone layers near its base and ranges from about 375 to 800 feet thick (Carter et al., 2003). Locally, the Spearfish is approximately 320' thick (Figure A-2).

Gypsum Springs Formation (Jurassic)

The Gypsum Springs Formation of Jurassic age consists of red siltstone, gypsum, and limestone and is 0 to 45 feet thick (Carter et al., 2003).

Unkpapa/Sundance Formation

Some authors differentiate geologically between the Unkpapa and Sundance Formations, but they are thought to be connected hydrogeologically. As such, they are referenced as one formation elsewhere in this document in regard to hydrogeology and discussion of the lowermost USDW locally.

Sundance Formation (Jurassic)

The Sundance Formation consists of greenish gray shale with thin limestone lenses; glauconitic sandstone, with red sandstone near the middle of the formation. The Sundance ranges from 250 to 450 feet thick (Carter et al., 2003). Locally, the Sundance is approximately 280' thick (Figure A-2).

Unkpapa Sandstone (Jurassic)

The Unkpapa Sandstone is a massive fine-grained sandstone, 0 to 225 feet thick (Carter et al., 2003). Locally, the Unkpapa is approximately 80' thick (Figure A-2).

Morrison Formation (Jurassic)

The Morrison Formation ranges from 0 to 220 feet thick and consists of green to maroon shale with thin sandstone beds (Carter et al., 2003). Locally, the Morrison is approximately 135' thick (Figure A-2).

Inyan Kara Group (Cretaceous)

The Inyan Kara Group includes the Lakota and Fall River Formations. In aggregate, the Inyan Kara Group ranges from 135 to 900 feet thick in the Black Hills area (Driscoll et al., 2002) and is the host rock for the uranium mineralization in the Dewey-Burdock Project area. Locally, the Inyan Kara is approximately 235' thick (Figures D-16 – D-18).

The basal Lakota Formation consists of yellow, brown, and reddish-brown, massive to thinly bedded sandstone, pebble conglomerate, siltstone, and claystone of fluvial origin. Locally, the formation contains fine-grained limestone and coal and ranges in thickness from 35 to 700 feet (Carter et al., 2003). The basal Chilson Member of the Lakota Formation is a fluvial sequence which grades upward into marginal marine sediments. The upper Fuson Member of the Lakota Formation is composed of shale with minor beds of fine-grained sandstone and siltstone.

The overlying Fall River Formation consists of massive to thin-bedded, brown to reddish-brown sandstone, 10 to 200 feet thick. The formation is thinly bedded at the top and massive at the bottom (Carter et al., 2003).

Graneros Group (Cretaceous)

The Graneros Group includes the Skull Creek Shale, Muddy/Newcastle Sandstone, Mowry Shale, and Belle Fourche Shale, which outcrop as a series of concentric rings outward from the Precambrian core of the Black Hills uplift. The Skull Creek Shale consists of dark-gray to black siliceous shale, 150 to 270 feet thick (Carter et al., 2003).The Muddy/Newcastle Sandstone is a brown to light-yellow and white sandstone, 0 to 150 feet thick (Carter et al., 2003) and is present regionally but not over the project area. The Newcastle Sandstone is not present over the project area. The Mowry Shale is a light-gray siliceous shale with fish scales and thin layers of bentonite, and ranges from 125 to 230 feet thick (Carter et al., 2003).The Belle Fourche Shale is a gray shale with scattered limestone concretions and clay-spur bentonite at the base and is approximately 150 to 850 feet thick (Carter et al., 2003). Locally, the Skull Creek and Mowry are present and range in thickness from approximately 60' to 525' across the Dewey-Burdock Project area. The Graneros Group is bedrock regionally; some limited alluvium is found along drainages.

Regional Structure

As described previously, the Black Hills Uplift is a dome structure with the rock units dipping outward, away from the central core. In detail, subsequent and attendant local doming caused by local intrusions disrupts the general dip of the units. Tensional stress created fault zones with considerable displacement from one side of the zone to the other, often a distance of three or four miles. The Dewey fault zone is a zone of major displacement. The faulting drops the uranium host units of the Inyan Kara several hundred feet where the oxidation reduction contact that formed the Dewey-Burdock mineralization is terminated (R.B. Smith & Assoc., Inc., 2005). Some authors (Carter et al., 1999, Figure D-8) show this fault continuing to depth. However, others (SDGS, Figure F-2) do not show deep displacement. In addition, there is little if any displacement shown on the Minnelusa structure contour map (Figure D-12). Even if some offset is present at the Minnelusa depth, this fault system is far enough from the proposed wells such that the impact of the fault on reservoir behavior is considered minimal.

Table F-1 presents a USGS stratigraphic column in the Black Hills area. Table F-2 presents a listing of projected depths (BGS) to top of major formations below the Dewey-Burdock Disposal Wells sites, based on tops and thicknesses determined from the Type Logs (#1 West Mule Creek [T39N, R61W, Section 2], the Sun Lance- Nelson Estate #1 [T7S, R1E, Section 21], the Earl Darrow #1 Well [T7S R1E, Section 2]), and uranium exploration wells across the project area.

Note that all depths are projections based on regional data, and may vary from site-specific conditions. Therefore, actual formation top depths below ground surface may vary from those presented in Table F-2 and will be evaluated during well installation and testing.

This permit application requests injection into two zones: the Deadwood and granite wash (if present) and the Minnelusa. It is anticipated that each injection zone will be accessed via a separate well.

Precambrian and Cambrian Units (Lower Confining Zone and Injection Zone)

Precambrian

The oldest stratigraphic units in the Dewey-Burdock project area are the Precambrian igneous and metamorphic rocks, composed primarily of metasediments, including schists and graywackes. The Precambrian rock surface was eroded to a gentle undulating plain at the beginning of the Paleozoic Era and the overlying Paleozoic and Mesozoic strata were deposited on the Precambrian surface as nearly horizontal beds. Subsequent uplift during the Laramide orogeny and erosion exposed the Precambrian rocks in the central core of the Black Hills, with the Paleozoic and Mesozoic sedimentary rocks, as noted, exposed in roughly concentric rings around the uplifted Precambrian core (Driscoll et al., 2002). The Precambrian basement is estimated to occur at about 3,195' (Site 1) – 3,530' (Site 2) below ground surface at the Dewey-Burdock Disposal Well sites, and would serve as a lower confining zone. A structure contour map of the Precambrian is included as Figure F-2.

Cambrian

The Cambrian-age Deadwood Formation consists of massive to thinly-bedded, brown to light-gray sandstone; greenish glauconitic shale; flaggy dolomite; and flat-pebble limestone conglomerate. Sandstone with conglomerate occurs locally at the base of the formation. The Deadwood, along with the granite wash below should it be present, is the proposed Injection Zone for DW Nos. 2 and 4. It is expected to be approximately 100' thick below the Dewey-Burdock Project and is expected to occur at about 3,095' below Site 1 and 3,430' below Site 2. Injection would occur from

approximately 3,100' - 3,195' at Site 1 and 3,435' - 3,530' at Site 2 (Figures M-2 and M-4). Based on Type Log #3, the effective porosity of the Deadwood is estimated to be approximately 85' thick at about 11% porosity (Figure A-4). Due to the fact that there are little local data available for the Deadwood, the assumed formation parameters and estimated depths and thicknesses will be confirmed during the drilling of DW No. 1. A regional isopach map of the Deadwood is included as Figure D-5.

Devonian - Mississippian Unit (Upper Confining Zone)

The Englewood Formation consists of pink to buff limestone with shale at its base and ranges from about 30 to 60 feet thick (Carter et al., 2003). The Englewood is estimated to occur from 3,060' – 3,095' below Site 1 and 3,395' – 3,430' below Site 2. As shown on the lower portion of Type Log #3 from northeastern Wyoming, the upper 6' of the Deadwood and the approximately 34' thick Englewood Formation (Figure A-4) would provide approximately 40' of confining zone below the over-pressured Madison Formation.

Pennsylvanian – Permian Units (Lower Confining Zone, Injection Zone, and Upper Confining Zone)

The Pennsylvanian- and Permian-age Minnelusa Formation consists of yellow to red, cross-stratified sandstone, limestone, dolomite, and shale. The middle and lower parts of the formation consists of shale and anhydrite. In the southern Black Hills, the upper part of the Minnelusa Formation is disconformably overlain by the Permian-age Opeche Shale. (Driscoll et al., 2002; Carter et al., 2003). Structure and isopach maps are presented as Figures D-12 and D-13, respectively.

Lower Confining Zone

Based on correlation of the Type Log #1 and Type Log #2 (Figures A-2 and A-3), the Minnelusa Formation is expected to occur at approximately 1,615' below Site 1 and 1,950' below Site 2 and expected to be approximately 1,150' thick. Based on type logs, the lower 560' appears to consist of interbedded tight sand and shale layers. Due to an apparent lack of porosity and permeability, this lower interval would not be targeted for injection but would serve as the lower confining zone above the Madison. Formation testing during the drilling process of DW No. 1 would be used to confirm the suitability of this section as a confining zone.

Injection Zone

The upper portion of the Minnelusa, the targeted zone for injection, is expected to occur from 1,615' - 2,205' below Site 1 and from 1,950' - 2,540' below Site 2 (Figures M-1 and M-3). The Type Logs indicate that there are three porous zones that total 164' in the upper 590' of the formation that range in porosity from approximately 21 to 33% (Figures A-2 and A-3). For the purpose of calculating the AORs, a conservative estimate of 21% was used. Depths, thicknesses and other parameters will be confirmed through formation testing during the drilling of DW No. 1.

Upper Confining Zone

The Opeche Shale consists of red shale and sandstone and ranges in thickness from 25 to 150 feet (Carter et al., 2003). As shown on Type Log #1 located within the Dewey-Burdock Project (Figure A-2), the formation is approximately 95' thick. The Opeche Shale is expected to occur at 1,520' below Site 1 and 1,855' below Site 2 and would serve and the upper confining zone above the Minnelusa Formation. The regional extent of the Opeche Shale is shown on Figures D-21 and D-22.

Structural Geology and Faulting

As described previously, the Black Hills Uplift is a dome structure with the rock units dipping outward, away from the central core. Subsequent local doming caused by local intrusions disrupts the general dip of the units. Tensional stress created fault zones with considerable displacement from one side of the zone to the other, often a distance of three or four miles. The strata below the Dewey-Burdock Project dips 2–6 degrees to the southwest away from the domal uplift.

The northeast to southwest trending Dewey fault zone, a few miles to the north of the town of Dewey, is a zone of major displacement. It is a steeply dipping to vertical normal fault with the north side uplifted approximately 500'. Some authors (USGS, 1999) show this fault continuing to depth. However, others (SDGS, Figure F-2) do not show displacement. In addition, there is little if any displacement shown on the Minnelusa structure contour map (Figure D-12). Even if some offset is present at the Minnelusa depth, this fault system is far enough from the proposed wells such that the impact of the fault on reservoir behavior would be minimal.

The Long Mountain Structural Zone is located 7 miles southwest of the project area. It trends northeast – southwest and contains several small surface faults in the Inyan Kara. No faults were identified in the area on structure maps of the underlying Minnelusa or Deadwood Formations. There are no identified faults that occur within the AORs or the Dewey-Burdock Project area.

Seismic Activity

The Dewey-Burdock area of southwestern South Dakota has been designated as a relatively minor seismic risk area by the USGS (http://earthquake.usgs.gov/earthquakes/states/south_dakota/hazards.php). The proposed area has a peak acceleration of 10-12 percent g. While South Dakota does have a comparatively higher rate of seismicity than other northern plains states, earthquakes tend to be relatively rare and of low to moderate magnitude, and no active faults have been mapped in the vicinity. No data are available to suggest that seismic activity presents a risk for injection at the Dewey-Burdock Project. Figures F-3 and F-4 present seismic and peak ground acceleration maps of South Dakota.

TABLE F-1 Stratigraphic Section – Black Hills Area, South Dakota

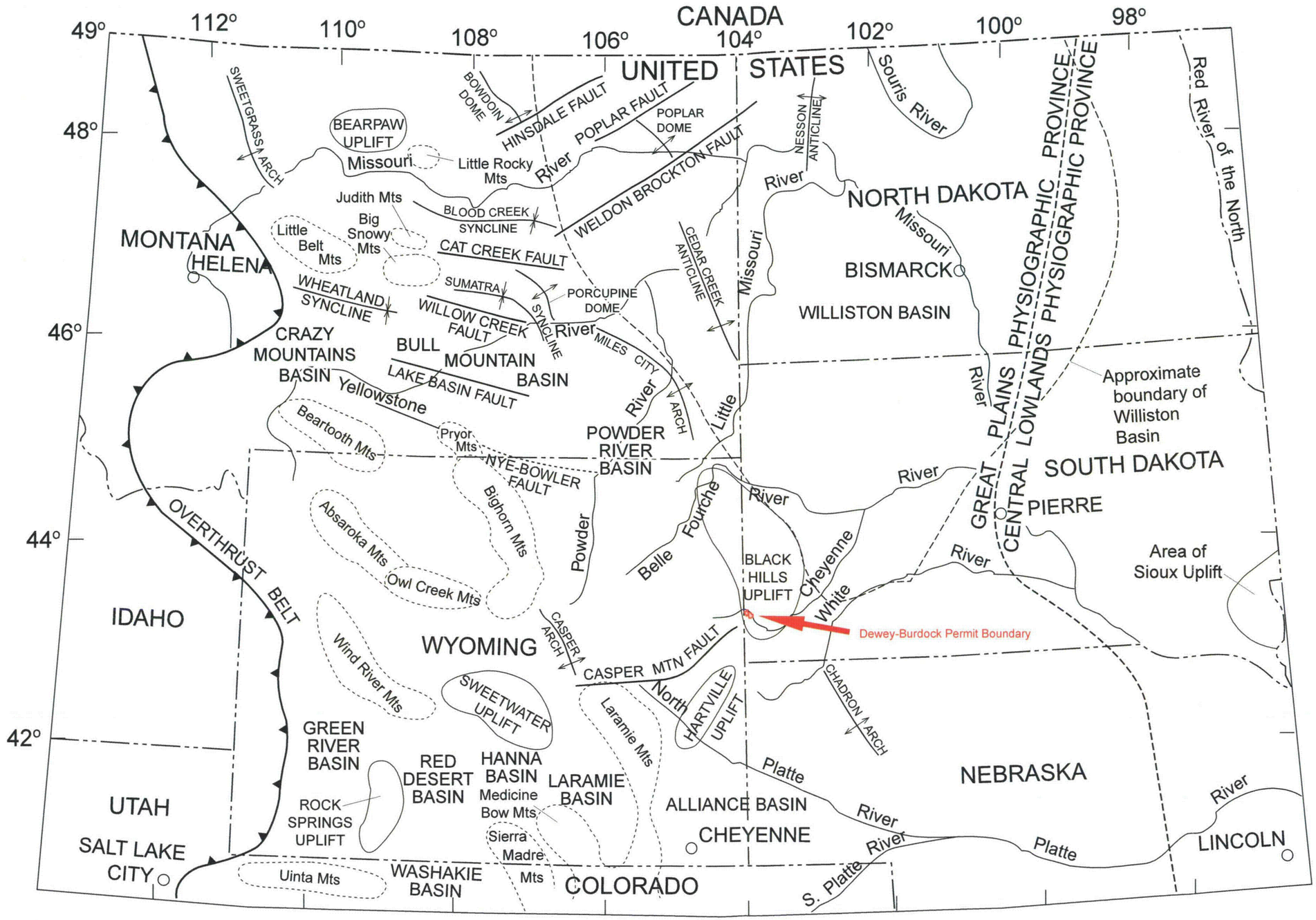
ERA	SYSTEM	STRATIGRAPHIC UNIT		THICK-NESS IN FEET	DESCRIPTION
CENOZOIC	Quaternary & Tertiary (?)	Undifferentiated alluvium, terraces, and colluvium		0-50	Sand, gravel, boulders, & clay
	Tertiary	White River Group		0-300	Light colored clays with sandstone channel fillings & local sandstone lenses
		Intrusive Igneous Rocks		--	Includes rhyolite, latite, trachyte & phonolite
MESOZOIC	Cretaceous	Pierre Shale		1,200-2,700	Principal horizon of limestone lenses giving teepee buttes
					Dark gray shale containing concretions
					Widely scattered limestone masses, giving small teepee buttes.
					Black fissile shale with concretions
		Niobrara Formation		80-300	Impure chalk & calcareous shale
		Carlile Shale	Turner Sandy Member	350-750	Light-gray shale with numerous large concretions & sandy layers
			Wall Creek Member		Dark-gray shale
		Greenhorn Formation		225-380	Impure slabby limestone. Weathers buff
					Dark-gray calcareous shale with thin Oman Lake limestone at base.
		Graneros Group	Belle Fourche Shale	150-850	Gray shale with scattered limestone concretions
					Clay spur bentonite at base
			Mowry Shale	125-230	Light-gray siliceous shale. Fish scales and thin layers of bentonite.
			Muddy/New-castle Sandstone	0-150	Brown to light-yellow and white sandstone
			Skull Creek Shale	150-270	Dark-gray to black siliceous shale
		Inyan Kara	Fall River Formation	10-200	Massive to thin-bedded, slabby, brown to reddish-brown sandstone
			Lakota Formation	35-700	thinly bedded sandstone, pebble conglomerate, siltstone, and claystone. Locale fine-grained limestone and coal
	Jurassic	Morrison Formation		0-220	Green to maroon shale. Thin sandstone
		Unkpapa Sandstone		0-225	Massive fine-grained sandstone
		Sundance Formation		250-450	Greenish-gray shale, thin limestone lenses
					Glauconitic sandstone; red sandstone near middle
		Gypsum Spring Formation		0-45	Red siltstone, gypsum, & limestone
	Triassic	Spearfish Formation		375-800	Red sandy shale, soft red sandstone & siltstone with gypsum and thin limestone layers; Gypsum locally near base.
PALEOZOIC	Permian	Minnekahta Limestone		25-65	Thin to medium bedded, fine-crystalline, purplish-gray, laminated limestone
		Opeche Shale		25-150	Red shale & sandstone
		Minnelusa Formation		375-1,175	Yellow to red cross-bedded sandstone, limestone, & anhydrite locally at top.
					Interbedded sandstone, limestone, dolomite, shale, and anhydrite
	Pennsylvanian				Red shale with interbedded limestone & sandstone at base.
	Mississippian	Madison (Pahasapa) Limestone		250-1,000	Massive light-colored limestone, Dolomite in part. Cavernous in upper part
	Devonian	Englewood Formation		30-60	Pink to buff limestone. Shale locally at base
	Ordovician	Whitewood (Red River) Formation		0-225	Buff dolomite & limestone
		Winnipeg Formation		0-150	Green shale with siltstone
	Cambrian	Deadwood Formation		0-500	Massive to thin-bedded brown to light-gray sandstone. Greenish glauconitic shale, flaggy dolomite, limestone, & flat-pebble limestone conglomerate. Sandstone with conglomerate locally at base.
PRE-CAMBRIAN		Undifferentiated Igneous & Metamorphic Rocks		--	Schist, slate, quartzite, and arkosic grit. Intruded by diorite, metamorphosed to amphibolite, and by granite & pegmatite

Source: Carter, J.M., and D.G. Driscoll, 2003. *Ground-Water Resources in the Black Hills Area,* South Dakota. U.S. Geological Survey Water-Resources Investigations Report 03-4049.

TABLE F-2 Proposed Dewey-Burdock Disposal Wells Projected Formation Depth Summary

	DW Nos. 1 and 2 (Based on Well FBS170 and Typelogs)			DW Nos. 3 and 4 (Based on Well DWA140 and Typelogs)		
Formation	Depth of Top (ft) AMSL	Depth of Top (ft) BGS	Est. Thickness (ft)	Depth of Top (ft) AMSL	Depth of Top (ft) BGS	Est. Thickness (ft)
Skull Creek Shale	3710	0	190	3650	0	525
Fall River	3520	190	125	3125	525	125
Lakota	3395	315	110	3000	650	110
Morrison	3285	425	135	2890	760	135
Unkpapa	3150	560	80	2755	895	80
Sundance	3070	640	280	2675	975	280
Spearfish	2790	920	320	2395	1255	320
Goose Egg	2470	1240	240	2075	1575	240
Minnekahta Limestone	2230	1480	40	1835	1815	40
Opeche Shale	2190	1520	95	1795	1855	95
Minnelusa	2095	1615	1150	1700	1950	1150
Madison (Pahasapa)	945	2765	295	550	3100	295
Englewood	650	3060	35	255	3395	35
Deadwood	615	3095	100	220	3430	100
Granite Wash	TBD	TBD	TBD	TBD	TBD	TBD
Precambrian	515	3195	N/A	120	3530	N/A

Note: Estimates Based on Powertech Cross-sections (Class III application), the #1West Mule Creek Well (API: 4902705978, T39N R61W Sec 2) the Lance-Nelson Estate #1 Well (API:4004705089, T7S R1E Sec 21), and the Earl Darrow #1 Well (API: 4004705095, T7S R1E Sec 2)



From:
Water-Resources Investigations Report 02-4094
(after Peterson, 1981 and Busby et al., 1995,
modified by Driscoll et al., 2002)

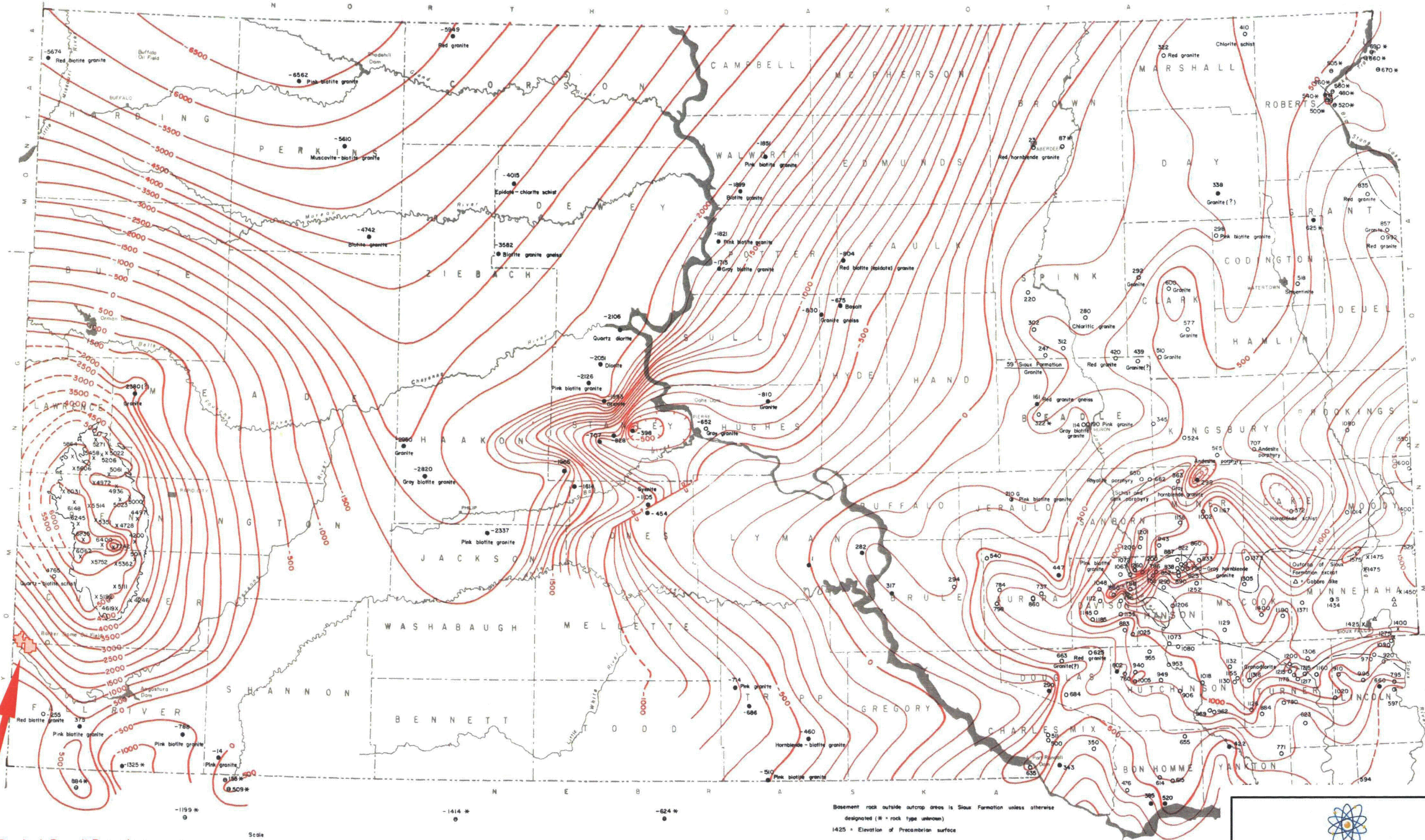
POWERTECH (USA) INC.

Figure F-1
Regional Geologic Structure Map

2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010
2010_DB_Class_V_Fig_F-01.ai	By: JLM Checked: HD

Petrotek
10288 West Chatfield Ave., Suite 201
Littleton, Colorado 80127-4239 USA
303-290-9414
www.petrotek.com



Scale

10 5 0 10 20 30 Miles

"Data in Black Hills modified from Darton and Paige, 1926"

Nebraska wells from 1957 Precambrian map by Reed and Svoboda

Minnesota wells from Minnesota Geological Survey Bulletins 22 and 31

Compiled and drafted by Fred V. Steece

From:
Fred V. Steece, 1961

Basement rock outside outcrop areas is Sioux Formation unless otherwise designated (* = rock type unknown)

1425 = Elevation of Precambrian surface

- ● Oil test
- ○ Water well
- ◑ Stratigraphic test (G = U.S.G.S., S = S.D.G.S.)
- ⊖ Purpose of test unknown
- X Elevation of Precambrian outcrop
- Inferred fault (D = downthrown side, U = upthrown side)
- Area of Precambrian outcrop and sub-glacial drift outcrop
- -1000 Contour line showing elevation of Precambrian surface. Interval = 100 feet except below -2000 and near Black Hills

N

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Figure F-2
Structure Contour Map - Precambrian
2010 Dewey-Burdock Class V Permit

Scale: See Bar Scale	Date: March 2010	
2010_DB_Class_V_Fig_F-02.ai	By: JLM	Checked: HD

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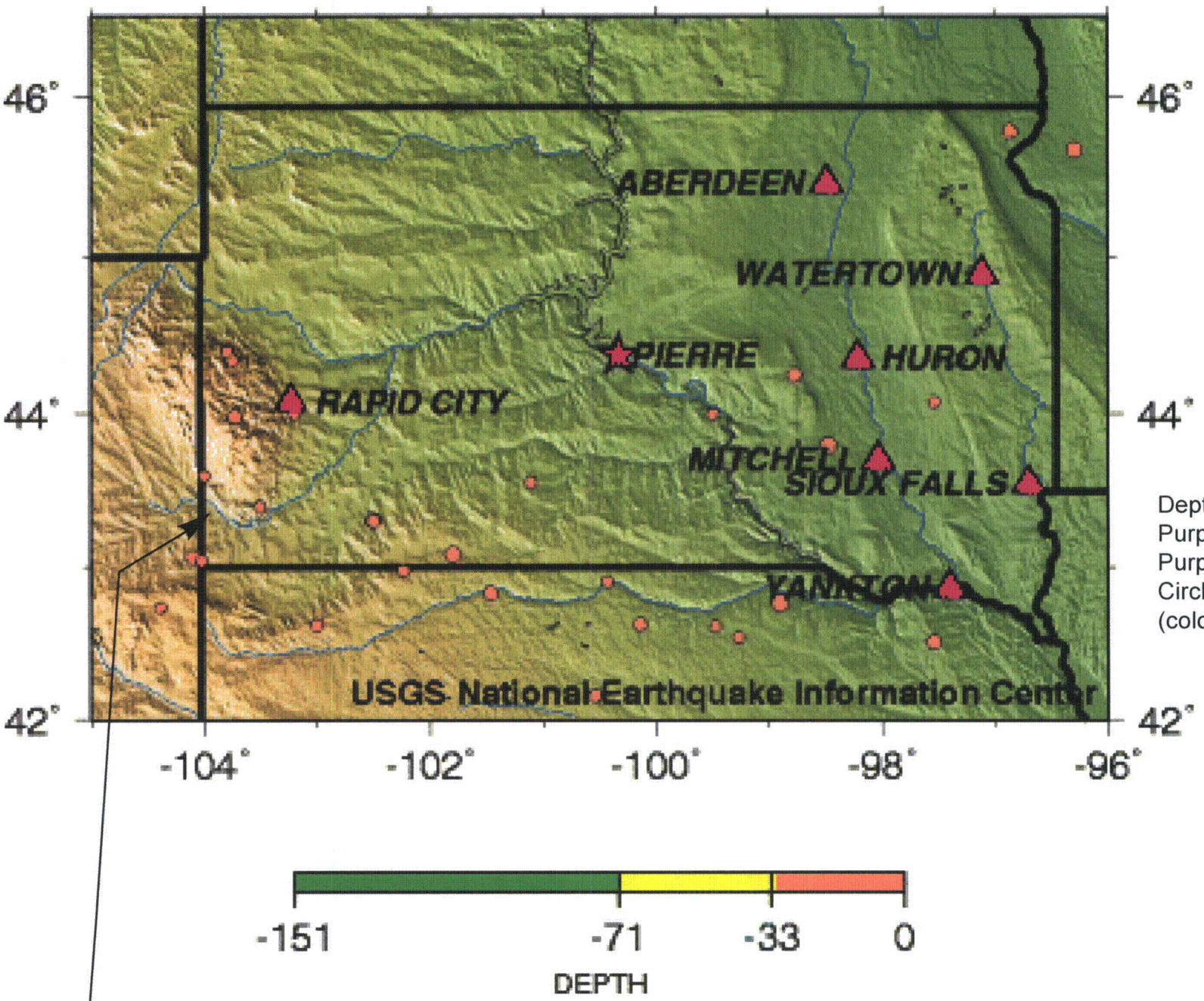
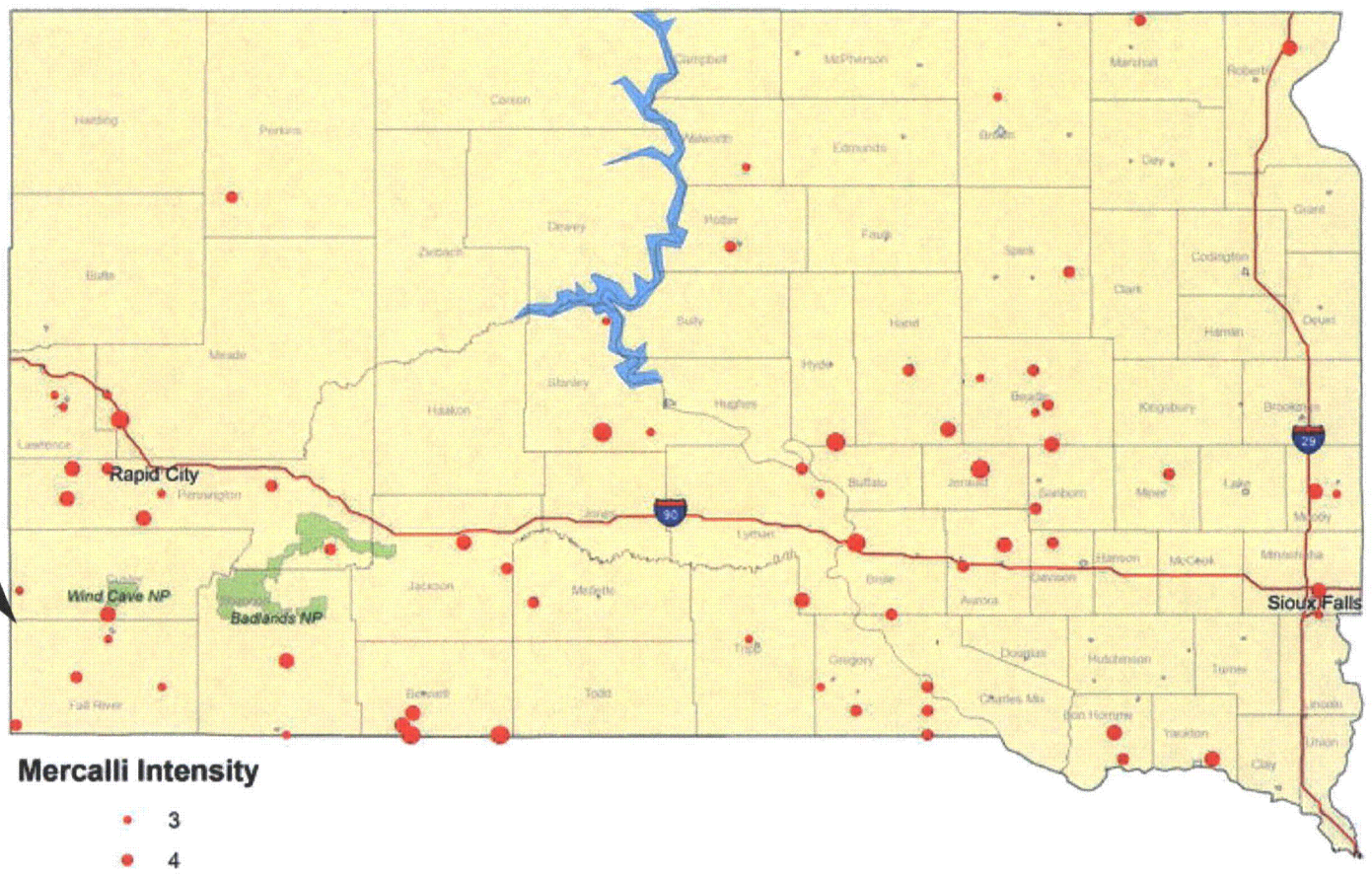
Seismicity of South Dakota
1990 - 2006



Depth is in kilometers.
Purple Triangles: Cities
Purple Star: Capital City
Circles: Earthquakes
(color represents depth range)

Dewey Burdock
Project Location

Earthquakes in South Dakota (1872 - 2007)



Map Source: USGS website
Earthquake locations are from the USGS/NEIC PDE catalog.

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Figure F-3
Seismicity of South Dakota, 1990-2006; and
Earthquakes in South Dakota, 1872-2007
2010 Dewey-Burdock Class V Permit

Scale: NTS	Date: March 2010	
2010_DB_Class_V_Fig_F-03.ai	By: JLM	Checked: HD

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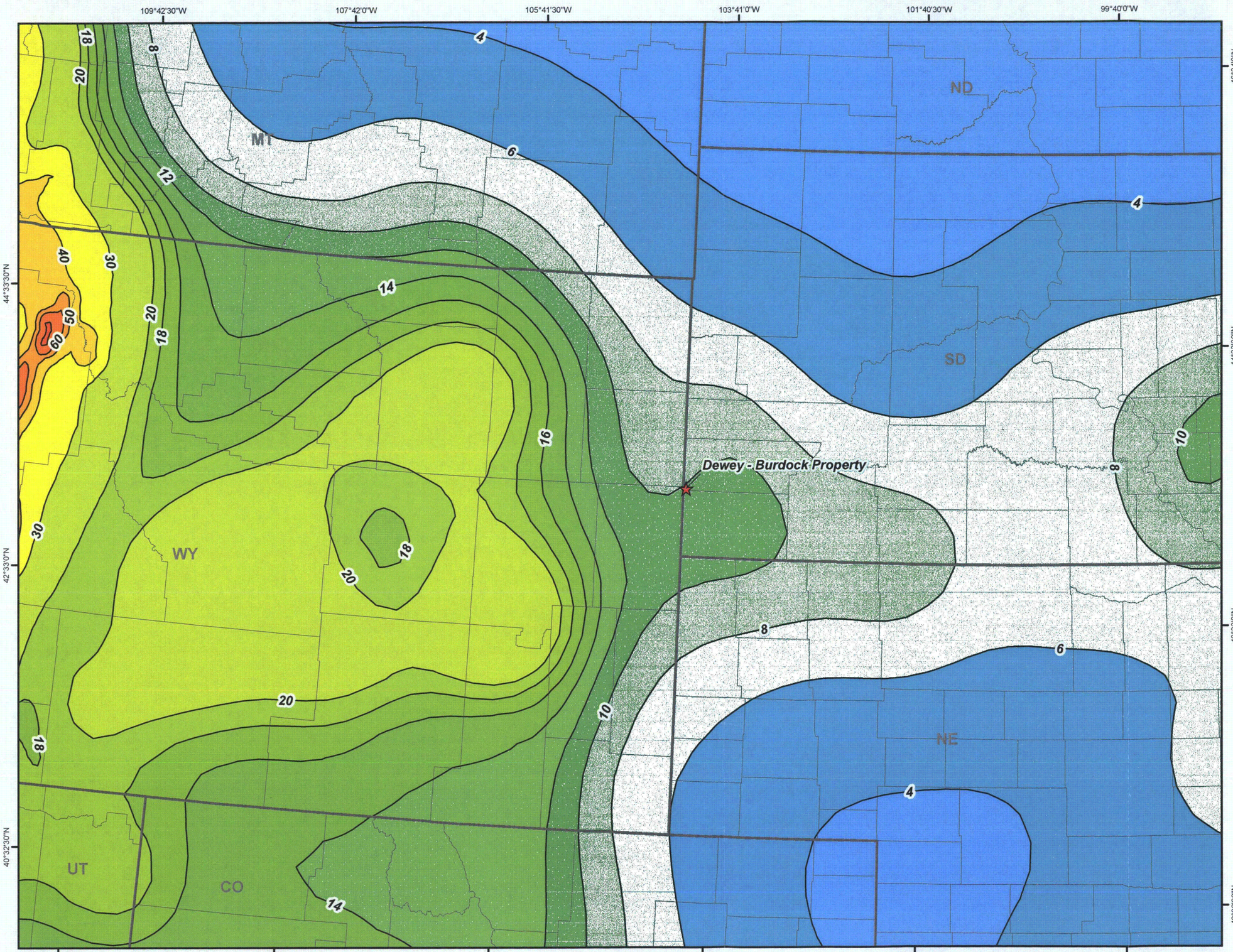

Legend

% G

- 160-200
- 120-160
- 80-120
- 60-80
- 50-60
- 40-50
- 30-40
- 20-30
- 18-20
- 16-18
- 14-16
- 12-14
- 10-12
- 8-10
- 6-8
- 4-6
- 2-4
- 0-2

Contour Data from: USGS,
National Seismic Hazard Maps - 2002

N

0 25 50 75 100 Miles

Projection: South Dakota State Plane South, NAD83 (feet)

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Figure F-4
Peak Ground Acceleration (PGA),
Illustrating 2% Probability of Exceedance
in the Next 50 Years
2010 Dewey-Burdock Class V Permit

Scale: 1:3,000,000	Date: March 2010	
2010_DB_Class_V_Fig_F-04.mxd	By: JLM	Checked: HD

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