U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

PRECAMBRIAN BASEMENT MAP OF THE TRANS-HUDSON OROGEN AND ADJACENT TERRANES, NORTHERN GREAT PLAINS, U.S.A.

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Prepared in cooperation with the
Geological Surveys of Minnesota, Montana,
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Pamphlet to accompany
MISCELLANEOUS INVESTIGATIONS SERIES MAP
I–2214

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INTRODUCTION

The Trans-Hudson orogen (Hoffman, 1981) is a deformed, generally north-trending orogenic belt of Early Proterozoic age that extends from outcrop areas in the Canadian Shield southward beneath Phanerozoic strata into the subsurface of the Northern Great Plains, U.S.A. It consists of Early Proterozoic, mainly arc related rocks (Lewry and others, 1985; Green, Weber, and Hajnal, 1985) and Archean rocks. The orogen separates two major Archean cratons, the Superior on the east and the Wyoming on the west, and represents a major constructional phase in the assembly of Laurentia (Hoffman, 1988), the North American craton. It terminates against the younger Early Proterozoic Central Plains orogen in southern South Dakota (Sims and Peterman, 1986; Bickford and others, 1986).

This Precambrian basement map was prepared as a companion to the basement map of the northern midcontinent region (Sims, 1990), in order to provide a better geologic framework of the Precambrian basement in north-central United States (fig. 1). It was compiled from drill-hole data and magnetic and gravity data as part of a cooperative Federal-State project with the State Geological Surveys of Minnesota, Montana, Nebraska, North Dakota, South Dakota, and Wyoming. The states submitted 1:1,000,000-scale maps or other records showing basement drill holes and lithotypes; in addition, the Nebraska and North Dakota Geological Surveys submitted maps at the 1:1,000,000 scale showing basement topography, contoured at 200-ft (60.96-m) intervals. J.S. Klasner submitted a map and a report on the basement rocks of North Dakota and South Dakota, prepared under an earlier Federal-State contract. In addition, the geologic map of that part of eastern South Dakota and Nebraska between lat 42° N. and lat 46° N. and east of long 100° W. was revised because of the availablity of some new drill-hole data and new gravity and aeromagnetic data. This area together with a narrow strip of Minnesota and Iowa was included on the earlier basement map of the midcontinent region (Sims, 1985; 1990). A report by Faircloth (1988) provided petrologic and geochemical data on several basement drill core samples in North Dakota, South Dakota, and Minnesota.

One of us (TGH) compiled digital aeromagnetic and gravity maps of the Northern Great Plains at the compilation scale, and provided a colored map of each at a scale of 1:2,000,000; Lindrith Cordell (U.S. Geological Survey) compiled a potential terrace map (Cordell and McCafferty, 1989) at a scale of 1:2,000,000 for use in the geologic interpretation. These geophysical maps were used to define, insofar as possible, the trend, extent, and boundaries of gross geologic rock units.

All available age data were examined for the purpose of assigning ages to the rock units, and selected published and unpublished age data are included in Appendix A. Well data used for delineating the configuration of the basement surface were compiled from lists supplied by the state geological surveys (App. B). Lithologies of basement samples in the various subsurface terranes are shown in a classification appropriate for reconnaissance mapping (App. C).

The symbols for the age designation used on the geologic map are refinements of the formal nomenclature used by the U.S. Geological Survey. The informal unit Y^1 in the Middle Proterozoic Era has chronologic boundaries at 1,400 and 1,600 Ma, and the informal unit X^2 in the Early Proterozoic Era has chronologic boundaries at 1,800 and 2,100 Ma. It should be noted, however, as an exception that part of unit X^2s in the Black Hills uplift is somewhat older than 2,100 Ma.

PREVIOUS WORK

Delineation of the Trans-Hudson orogen in the subsurface is based largely on the previous work of Green and others (1979), Green, Hajnal, and Weber (1985), and Green, Weber, and Hajnal (1985), who identified discrete magnetic regions in southwestern Manitoba and southern Saskatchewan that they correlated with lithostructural domains exposed in northern Saskatchewan and Manitoba. They extended these magnetic regions southward into the United States. Lewry and others (1986) criticized some of the details of these correlations, particularly the lithologies in the basement domains versus those in the supposedly correlative exposed domains. Green and others (1986) countered with the suggestion that different crustal levels may be present in subcrop along strike, thus explaining the lithologic diversity. Earlier, Dutch (1983) had mapped the Trans-Hudson orogen in the subsurface of the Dakotas on the basis of gravity and magnetic information. Klasner and King (1986) utilized drill-hole data together with gravity and magnetic data to delineate several lithotectonic terranes in the Dakotas; their domains are similar to those suggested by Green, Weber, and Hajnal (1985).

The Trans-Hudson orogen was named by Hoffman (1981) and defined as the Early Proterozoic orogen between the Archean Wyoming and Hearne provinces, on the west, and the Archean Superior province on the east (Hoffman, 1988, fig. 1). The term Trans-Hudson orogen refers to the rocks within the orogenic belt. The Trans-Hudson orogen is attributed to the Early Proterozoic Hudsonian orogeny, an arc-continent collision. Earlier, the orogen as well as the bounding rocks on its

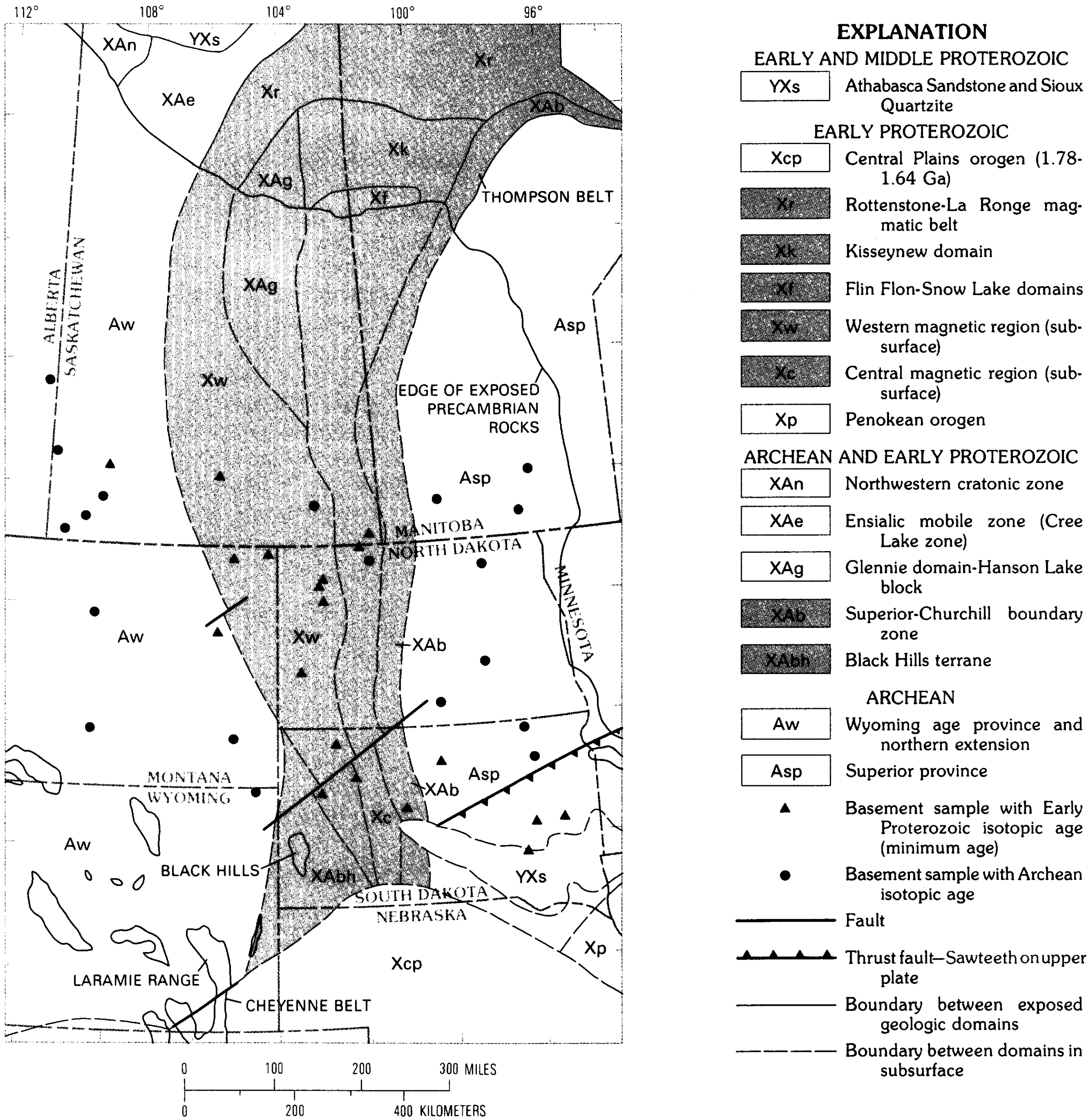

Figure 1. Regional geology of the Trans-Hudson orogen.

northwest margin, now assigned by Hoffman (1988) to the Hearne province, was called the Churchill province (Davidson, 1972).

Earlier geophysical and geochronologic studies extended the Churchill province southward from northern Saskatchewan into the Dakotas with a fairly clear definition of its eastern boundary. Innes (1960) delineated a major gravity high parallel to the Thompson belt in northern Manitoba and named it the Nelson River high. Wilson and Brisbin (1962) traced the high to the southwest beneath Phanerozoic sedimentary cover to the international boundary, and its further extension was evident from gravity data for North Dakota (Muehlberger and others, 1967).

Isotopic age studies also contributed to the delineation of the Trans-Hudson orogen in the subsurface. Gast and others (1958) established the presence of a major Archean terrane in Wyoming and Montana which is now known as the Wyoming province. K–Ar biotite ages were used to delineate the subsurface extent of the "Churchill province" in the basement of western Canada (Burwash and others, 1962), and a comparable study focused on the basement of the Dakotas (Peterman and Hedge, 1964). We now know that these early K–Ar and Rb-Sr biotite ages register anorogenic heating and uplift followed by cooling (cratonization) rather than orogenesis (magmatism, tectonism, and metamorphism). However, the ages did clearly identify some of the major tectonic boundaries such as the Superior-Churchill boundary zone in North Dakota, a term we retain in this report.

GEOLOGIC TERRANES

Six major tectono-stratigraphic terranes are delineated in the map area (see fig. 2, on map), from oldest to youngest:

(1) Archean gneiss terrane of Superior craton (3,600–2,600 Ma);
(2) Archean gneiss terrane of Wyoming craton (3,400–2,500 Ma);
(3) Archean greenstone-granite terrane of Superior craton (2,750–2,600 Ma);
(4) Wisconsin magmatic terranes of Penokean orogen (1,890–1,840 Ma);
(5) Trans-Hudson orogen (1,910–1,800 Ma) (exclusive of older continental margin rocks); and
(6) Central Plains orogen (1,800–1,630 Ma).

In addition, the Sioux Quartzite forms a coherent, platform sedimentary body unconformably overlying Early Proterozoic and Archean rocks in eastern South Dakota and a small adjacent part of Nebraska and Iowa.

A terrane, as defined in the northern midcontinental region, has a unique stratigraphy, structure, and age, and is fault bounded. It is analogous to the tectonostratigraphic (or suspect) terranes (Jones and others, 1977) in the North American cordillera, and is a useful concept for deciphering accretionary tectonics.

ARCHEAN GNEISS TERRANE OF SUPERIOR CRATON (3,600–2,600 MA)

The Archean gneiss terrane is exposed in the Minnesota River Valley (Grant, 1972), about 12.5 mi (20 km) east of the map area. It is a complex migmatitic terrane consisting of granite gneiss, schistose to gneissic amphibolite, garnet-, cordierite-, and sillimanite-bearing metasedimentary gneisses, and metagabbro of granulite or amphibolite metamorphic grade (Himmelberg and Phinney, 1967). Late tectonic granite (≈2,600 Ma) plutons locally intrude the gneisses. Most of the rocks are older than 3,000 Ma and have undergone a long and complex history of multiple deformation and metamorphism, which culminated at or before 2,600 Ma (Goldich and Wooden, 1980). The exposed rocks are folded into large-scale, moderately open and gently plunging antiforms and synforms that trend easterly (Bauer, 1980). The gneisses can be traced in the subsurface into eastern South Dakota by drill-hole and geophysical data. The northern margin of the gneiss terrane, the Great Lakes tectonic zone (fig. 2; Morey and Sims, 1976; Sims and others, 1980), is marked by a steep magnetic gradient (down to north) that trends about N. 60° E. The southeast margin of the gneiss terrane, in southeastern South Dakota, also is expressed by a steep magnetic gradient (down to southeast) that trends about N. 50° E., but in detail is complicated (see geologic map). It abuts the Early Proterozoic Penokean orogen, and probably is a major fault. The Archean gneiss terrane is truncated on the southwest by the Early Proterozoic Central Plains orogen (Sims and Peterman, 1986). Geophysically, this margin of the craton is partly expressed by a moderate gravity gradient; gravity values increase southward over presumably denser metamorphic rocks of the Central Plains orogen.

The Great Lakes tectonic zone (GLTZ) is an Archean crustal boundary of subcontinental length (Sims and others, 1980) that separates the Archean greenstone-granite terrane of the Superior craton on the north from the Archean gneiss terrane of the Superior craton. It extends into the map area (this study) as well as into adjacent areas of Minnesota beneath Pleistocene glacial deposits, but its position and characteristics have been determined by geophysical data. COCORP seismic-reflection profiling in central Minnesota indicates that the GLTZ probably dips 25°–30° N. beneath the greenstone-granite terrane (Gibbs and others, 1984). Two-dimensional aeromagnetic and gravity models, calculated with physical properties from rocks recovered from drill holes along the COCORP line, also suggest that the GLTZ is a north-dipping structure (see Southwick and Sims, in press, and references given therein). Gibbs and others (1984) interpreted the structure as a probable thrust fault, but they did not infer the direction of vergence. Recent mapping of an exposed segment of the GLTZ in northern Michigan (Sims, in press, b) indicates, however, that the GLTZ is a northward-verging thrust fault that resulted from oblique collision of the Archean gneiss terrane with the Archean greenstone-granite terrane (Superior province). Northward-verging tectonic imbrication has resulted in overriding of the greenstone-granite terrane by the gneiss terrane. In east-central Minnesota and Upper Peninsula of Michigan, the GLTZ is largely covered by Proterozoic rocks of the Animikie basin. The structural style (Penokean orogen) in the Proterozoic cover indicates north-verging tectonism. Some geologic and seismic evidence indicates that the GLTZ has been sporadically active in post-Penokean (post-1840 Ma) time. In Upper Peninsula of Michigan, many Keweenawan diabase dikes are oriented parallel to the zone (Sims, in press, a) suggesting crustal extension along this old line of weakness. In western Minnesota, the thickness of Upper Cretaceous marine sedimentary rocks increases at the GLTZ (Schurr, 1980) as does the elevation of the sub-Cretaceous unconformity (Dutch, 1981). Finally, the recent seismic history of Minnesota suggests that the GLTZ presently is the locus of low-level stress release (Mooney, 1979; Chandler and Morey, 1989).

ARCHEAN TERRANE OF WYOMING CRATON (3,400–2,500 MA)

Rocks of the Wyoming craton are exposed in the northern half of the Laramie Range and the Hartville uplift, in eastern Wyoming, and have been penetrated by drilling at a few places in eastern Wyoming, eastern Montana, and adjacent South Dakota (Butte County). Except for the exposed areas, the rocks are designated on the geologic map as one unit (Agn) because of the sparse subsurface data.

The northern part of the Laramie Range is underlain mainly by granite of the Laramie batholith (Wg), which forms a sharply discordant, nearly horizontal contact with older metamorphic rocks (Johnson and Hills, 1976). The granite has a Rb-Sr whole-rock age of 2.51±0.03 Ga and an initial $a^{87}Sr/^{86}Sr$ ratio of 0.7026. The metamorphic rocks (Wgg) are mainly gray granite gneiss (2.70±0.15 Ga) and leucogranite (2.72±0.04 Ga), but include sillimanite-bearing migmatitic gneiss (2.96±0.22 Ga), amphibolite, and ultramafic rocks, which are interlayered with or form pods and stringers in the granite gneiss and leucogranite. The ultramafic pods range from 6.5 ft (2 m) long and 3.3 ft (1 m) wide to 650 ft (200 m) long and 330 ft (100 m) wide; they are dominantly actinolite-rich schist containing serpentine, talc, magnetite, biotite, and chlorite. Three south-verging thrust faults transect the northern part of the range (Johnson and Hills, 1976). Supracrustal greenstone (Wgs) and associated granite crop out sparsely along the northern tip of the Laramie Mountains (Gable, 1987). The greenstone sequence is composed of mafic-ultramafic units, including amphibolite and hornblende schist, interlayered with a metasedimentary unit consisting of high alumina, low potassium gneiss and schist, quartzite, iron-banded quartzite and, locally, metaconglomerate. Folding on older northwest-trending and younger northeast-trending axes is presumed to be related to the regional deformation that has been dated at 2.86±0.08 Ga (Peterman and Hildreth, 1978). Northward-verging thrust faults, with locally associated serpentine, thrust the Precambrian rocks over Cretaceous rock at the northern tip of the Laramie Range (Gable, 1987). These thrusts appear to be segments of a major thrust fault—here named the Douglas fault—that trends northeastward from the Laramie Range towards the Black Hills uplift (Stone, 1969; Blackstone, 1989), and which forms the southern margin of the Powder River basin.

A sequence of amphibolite grade metavolcanic and metasedimentary rocks crops out in the central Laramie Range immediately north of the Middle Proterozoic intrusive complexes (Snyder and others, 1988). Collectively, these units are called the metamorphic suite of Bluegrass Creek (Snyder, 1984), and their lithostructural belt is called the Elmers Rock greenstone belt (Graff and others, 1982). These supracrustal rocks are intruded by and associated with members of the igneous and metamorphic complex of the Laramie River (Snyder, 1984) comprising granite, granitic gneiss, migmatite, and deformed dikes of diabase and peridotite. The supracrustal sequence consists of massive and pillowed metabasalts intruded by mafic sills and metasedimentary rocks derived from graywacke, iron-formation, conglomerate, quartzite, and limestone. Isotopic ages indicate that the bedded rocks and most of the granitoids are Late Archean (Snyder and others, 1988; Z.E. Peterman and K.L. Ludwig, unpub. data). U–Pb zircon ages for two felsic volcanic rocks are 2.73±0.06 Ga and 2.64±0.01 Ga. Twenty-two samples of massive to foliated granitoids define a whole-rock Rb-Sr isochron of 2.56±0.03 Ga. A zircon age of 2.62±0.03 Ga has been determined for a pluton of gneissic granite that intrudes the supracrustal sequence. Older ages are inferred from whole-rock Rb-Sr data for granitic gneisses on the east side of the Laramie Range, but these await further verification.

Supracrustal rocks assigned to the Late Archean Whalen Group and associated granite constitute most of the exposed rocks in the Hartville uplift (Snyder, 1980; Peterman, 1982; Snyder and others, 1988). The supracrustal rocks include metabasalt, metagraywacke, metapelite, quartzite, calc-silicates, and dolomite. These are intruded by the Late Archean granite of

Rawhide Buttes (2.57±0.07 Ga), the strongly deformed gneissic granite of Flattop Butte (1.98±0.10 Ga), and by much younger, undeformed diorite of the Twin Hills (1.74±0.01 Ma) and granite of the Haystack Range (1.72±0.04 Ga) plutons. Sm-Nd model ages for two older granites range from 3.14 to 2.80 Ga indicating the presence of Middle Archean lower crust in the region (Kiyoto Futa and Z.E. Peterman, unpub. data). The Archean rocks lie on both sides of the major north-trending Hartville-Rawhide fault.

In the subsurface of southeastern Montana and adjacent South Dakota, granite gneiss and cataclastic or mylonitic granite gneiss are the main rock types that have been penetrated by drilling (Muehlberger and others, 1964).

Magnetic anomalies over the gneiss are oriented northerly in northeastern Wyoming and northeasterly in northeastern (Daniels County) Montana, comparable to the dominant structural trends of gneisses in the Laramie Range.

ARCHEAN GREENSTONE-GRANITE TERRANE OF SUPERIOR CRATON (2,750–2,600 MA)

The greenstone-granite terrane is in the buried southern extension of the Superior province of the Canadian Shield (Sims and Peterman, 1981). It consists mainly of greenschist-facies mafic to felsic volcanic and volcanogenic rocks, including graywacke, and intrusive tonalite to granite (Sims, 1976) that are 2,600–2,750 Ma (Peterman, 1979a). The terrane is not exposed in the map area, but gross units can be delineated by diagnostic east- northeast-trending magnetic and gravity anomalies that extend westward from exposed areas in northern Minnesota (Morey and others, 1982). The most prominent magnetic anomalies overlie generally thin, steeply dipping banded iron-formations that are common in metabasaltic units of the greenstone belts (Sims, 1972a). Batholithic plutonic rocks of tonalite-granite composition that are mainly foliated to gneissic generally produce low amplitude, crudely linear or irregular magnetic anomalies that are slightly higher than anomalies over felsic volcanic rocks and graywacke. Metabasalt generally is relatively nonmagnetic because the pervasive retrograde (greenschist-facies) metamorphism has destroyed primary magnetite. The plutonic rocks yield prominent gravity lows, whereas the metabasalt yields gravity highs (Sims, 1972b). The broad positive magnetic and gravity anomaly in Rolette and adjacent Counties, North Dakota, is interpreted from the few drill holes as a felsic to mafic gneiss complex of amphibolite or higher metamorphic grade; such units are atypical of the exposed greenstone-granite terrane in northern Minnesota (Sims, 1976), and possibly resulted from uplift adjacent to the eastern margin of the Trans- Hudson orogen, which truncates the greenstone-granite terrane.

WISCONSIN MAGMATIC TERRANES OF PENOKEAN OROGEN (1890–1,840 MA)

The Early Proterozoic Wisconsin magmatic terranes have been interpreted from sparse drill-hole and isotopic age data, as well as magnetic and gravity anomaly data, to form a northeast-trending belt along the southeast margin of the Archean gneiss of Superior craton extending from south-central Minnesota through northwestern Iowa into northeastern Nebraska (Sims, 1985; 1990). A small part of the belt is shown in the southeastern part of the geologic map. The belt is characterized by moderately high gravity values (commonly 0 to –10 mGals) and alternating linear zones of low and high magnetic values.

Where exposed in Wisconsin (Sims and others, 1989), the Wisconsin magmatic terranes consist of mafic to felsic volcanic rocks and abundant plutonic rocks ranging in composition from gabbro to granite.

TRANS-HUDSON OROGEN (1910–1,800 MA)

Units delineated in the Trans-Hudson orogen on the geologic map are modified from the magnetic units of Green and others (1979), Green, Weber, and Hajnal (1985), and Green, Hajnal, and Weber (1985). These authors projected major rock units exposed in northern Manitoba and Saskatchewan (Lewry and Sibbald, 1980; Lewry, 1981; Hoffman, 1989) southward beneath the Phanerozoic cover into north-central United States on the basis of regional-scale geophysical data, mainly aeromagnetic data. The gross geophysical units recognized by Green, Weber, and Hajnal (1985) provide a satisfactory basis at this time for subdividing the Trans-Hudson orogen in the United States, inasmuch as drill-hole information is not adequate alone to delineate rock units in the orogen.

Isotopic age data

The main igneous and metamorphic events in the Trans-Hudson orogen in the exposed shield areas of northern Saskatchewan and Manitoba are isotopically dated between 1,910 and 1,800 Ma. Metamorphosed calc-alkaline volcanic rocks erupted in island arcs are dated between 1,910 and 1,876 Ma (Baldwin and others, 1985; Van Schmus and others, 1987), and the gigantic Wathaman batholith, between 1,865 and 1,852 Ma (Ray and Wanless, 1980; Van Schmus and others, 1987). More recent work, summarized by Bickford and others (1990), identified orogenic plutons as young as 1,830 Ma with thermotectonic events continuing to about 1,800 Ma. Post-orogenic granites are dated at 1,780 Ma. The Sm-Nd systematics (Chauvel and others, 1987) have been used to identify both juvenile Early Proterozoic material and reworked Archean crust in the Trans-Hudson orogen of northern Saskatchewan.

Isotopic age control for the buried basement is much more limited in scope (fig. 3, on map) and reliability than outcrop areas. However, we assume that the geochronologic framework for the buried basement is comparable to that for the exposed orogen; the sparse isotopic age data for basement cores supports this contention (App. A). With some exceptions, notably in South Dakota, few new basement penetrations have been made in the map area during the past 20 years, and where new drilling has encountered Precambrian rocks, cuttings rather than cores were commonly taken for samples. Consequently, much of the isotopic age information available in the area comes from the early University of Texas/U.S. Geological Survey and University of Alberta basement age studies (Burwash and others, 1962; Peterman and Hedge, 1964; Goldich and others, 1966). These data are analytically sound, and selected ages are included here after recalculation to modern isotopic constants (App. A). Because of large sample requirements at that time, no U–Pb zircon ages were completed. Available core from the older collections even now limits the application of U–Pb geochronology even though modern sample requirements are much smaller.

The older data sets are mainly Rb-Sr and (or) K–Ar determinations on biotite, K-feldspar, hornblende, or whole rock samples. The mineral ages commonly do not date crystallization events in the sense ascribed to U–Pb zircon ages when inherited components can be precluded. Rather, they record times of closure in an environment of declining temperature (Cliff, 1985). For example, the K–Ar and Rb-Sr systems in biotite (Bt) close (cease to lose daughter products) between about 250 and 300 °C. The Rb-Sr system in K-feldspar (KF) closes between 350 and 400 °C, and the K–Ar system in hornblende (Hb) at 500 and 550 °C. Thus, a common pattern in slowly cooled rocks is $T(Hb) > T(KF) > T(Bt)$ where T is isotopic age. Exceptions can sometimes be attributed to excess Ar or to alteration that compromises the integrity of a mineral at temperatures above or below closure.

In recent years, the utility of the Sm-Nd system in granitoid rocks for determining crustal residence times has been convincingly demonstrated (DePaolo, 1981; Patchett and Bridgwater, 1984). Calc-alkaline felsic igneous rocks commonly carry the Sm-Nd age signature of the oldest major component of the crust in which they are emplaced. The implication is that most granitic rocks are probably derived from or incorporate substantial amounts of older crustal material rather than being direct derivatives from the mantle. Because of this, the Sm-Nd system in granitic rocks can be used to map out first-order Precambrian age provinces on the basis of their crustal residence time, that is the time elapsed since a particular crustal domain was extracted from the mantle through various geologic processes. Much of the Canadian Shield is composed of large super terranes that are characterized by a limited age range, for example the Superior province. In this context, the Sm-Nd system in granitic rocks can be particularly valuable for identifying and delineating (mapping) such superterranes in the subsurface and for understanding the tectonic and magmatic reworking of older terranes in younger orogenic belts.

Some conventional geochronology was completed for this study. In addition, a regionally representative suite of core samples was selected for Sm-Nd analyses, and these data are tabulated in Appendix A. One of the more important results from this Sm-Nd study (Peterman and Futa, 1988) is the demonstration that the Superior province and the Wyoming age province are not laterally equivalent as might be expected by simple lateral correlation across the Trans-Hudson orogen. Like much of the western Superior province, the westward basement extension in the eastern Dakotas is juvenile Late Archean crust with Sm-Nd model ages of 2.67 to 2.76 Ga. In contrast, most of the Wyoming age province is composed of crust that was extracted from the mantle in Early and Middle Archean time. Late Archean (2.7 Ga) felsic plutons, for the most part, faithfully carry a Sm-Nd signature of this older continental crust.

Geochronologic studies in the Black Hills bear importantly on the buried basement because this area provides the only exposures of the Trans-Hudson orogen in the United States. Strongly overprinted Archean basement rocks occur in the northeastern and western Black Hills (Gosselin and others, 1988), and key marker zones in the Early Proterozoic cover (mafic sills and metatuffs) establish the presence of at least three discrete stratigraphic packages (2.1–2.5, 1.97, and 1.89 Ga) with metamorphic and tectonic events bracketed between 1.89 and 1.71 Ga, the latter being the age of the Harney Peak Granite (Peterman and Zartman, 1986; Redden and others, in press). The two stratigraphic successions in the Black Hills that are older than the arc rocks of the main events in the exposed shield areas in Canada (Bickford and others, in press) probably are continental margin rocks of pre- or syn-rift origin. Such rocks may be present in the Cree Lake zone in Saskatchewan but have not been recognized in other parts of the Trans-Hudson orogen.

K–Ar and Rb-Sr biotite ages for basement samples from the Trans-Hudson orogen indicate uplift and cooling (cratonization) at 1.66–1.74 Ga (App. A). Ages of granulite-facies rocks near the international boundary indicate the presence of both juvenile Early Proterozoic rocks and reworked Archean rocks. Mafic granulite veined with charnockite in northeastern Montana (MT–1; all sample numbers refer to App. A) crystallized in the Early Proterozoic as shown by a U–Pb zircon concordia intercept age of 1,781±16 Ma and a less precise Rb-Sr isochron age of 1,826±122 Ma. An Archean component was present in the source of these rock or was assimilated during their crustal history as shown by an initial $^{87}Sr/^{86}Sr$ ratio of 0.7053±0.0012 and Sm-Nd model ages of 2.34 Ga (charnockite) and 2.43 Ga (mafic granulite). Similar high-grade rocks in northwestern South Dakota also show isotopic signatures indicating a complex history. Biotite-garnet gneiss from northern Renville County, N. Dak. (ND–5) yielded a Rb-Sr whole-rock age of 1.76±0.10 Ga, which probably reflects metamorphism of Early Proterozoic pelitic rocks. Rb-Sr and U–Pb data for nearby felsic and mafic granulites (ND–6, ND–7) suggest that these are reworked Archean rocks that were metamorphosed to granulite facies during the Hudsonian orogeny. In contrast, charnockite from McKenzie County, N. Dak. (ND–10) is juvenile Early Proterozoic material with whole-rock model ages of 1.81 Ga (Rb-Sr) and 2.17 Ga (Sm-Nd). Collectively, these isotopic data for the northern Trans-Hudson orogen in the United States suggest Hudsonian granulite facies metamorphism imposed on a complex terrane composed of both Archean and Early Proterozoic rocks. This conclusion is supported by similar studies of basement rocks from southern Saskatchewan, which also indicate a large component of reworked Archean rocks (both metamorphically overprinted and magmatically reworked) within the Trans-Hudson orogen (Collerson and others, 1989). In northeastern Montana and adjacent South Dakota, the presence of high-grade Early Proterozoic pelites (ND–5), granulites derived from Archean protoliths (ND–6 and ND–7), Early Proterozoic granulites with a component of Archean material (MT–1), and probable juvenile Early Proterozoic charnockites (ND–10) suggests that the rocks represent a relatively deep level of exposure (the infrastructure) in the Trans-Hudson orogen. Several tens of miles of rock have been removed by erosion from this part of the Trans-Hudson orogen, supporting the contention of Green and others (1986) that some of the lithologic diversity in the Trans-Hudson along strike is a result of the exposure of different crustal levels.

Superior-Churchill boundary zone

The western margin of the Superior craton is marked by two continuous and parallel magnetic features: (1) an abrupt truncation of the east-northeast-trending Late Archean magnetic fabric by anomalies produced by north-south-trending Early Proterozoic structures, and (2) a rather narrow, linear zone of low magnetization. This zone of low magnetization is the boundary zone between the Superior and Churchill provinces (XWb). In the exposed shield, this geophysical zone includes shelf and deeper water metasedimentary rocks, metavolcanic rocks, mafic and ultramafic intrusions, and gneisses of the Thompson nickel belt (Weber and Scoates, 1978; Peredery and others, 1982; Hoffman, 1989), as well as probable Archean basement, the Pikwitonei granulites (Weber and Scoates, 1978). In the United States, drill holes in this zone have penetrated schist, hornblende gneiss, chlorite schist, slate (Dewey County, S. Dak.), tonalite-granite, pyroxene-bearing syenite, and pyroxenite. The pyroxene-rich rocks underlie sharp positive magnetic anomalies, and presumably equate with the mafic-ultramafic intrusions in the Thompson belt, some of which host nickel sulfide deposits (Peredery and others, 1982). The Sioux Quartzite overlies rocks of the Trans-Hudson orogen in south-central South Dakota. South of the quartzite body, geophysical and drill-hole data suggest that granite composes the boundary zone, as shown on the geologic map.

Central magnetic region

The segment of the Trans-Hudson orogen immediately west of the Superior-Churchill boundary zone in the central magnetic region (X^2c) is characterized by high-amplitude, medium-wavelength magnetic anomalies on a moderately low regional background. A subunit (X^2cd) within the region is expressed by a broad positive gravity anomaly of about 25 mGal, which is inferred to be underlain dominantly by moderately dense rocks, such as intermediate-mafic volcanic rocks. Green, Weber, and Hajnal (1985) interpreted the geophysical unit mapped as unit X^2c to be composed dominantly of Early Proterozoic arc-derived rocks. In the United States, the unit contains both Archean and Early Proterozoic rocks at least locally metamorphosed to granulite grade. Gneiss, mylonite, felsite, and granite have been penetrated by drilling in map unit X^2c. In addition, graywacke was intersected in a hole in Perkins County, S. Dak., and high-grade rocks including mafic granulite, cordierite gneiss, and biotite-garnet gneiss were penetrated in Renville Co., N. Dak. near the Canadian border (Peterman and Goldich, 1982). The central magnetic region can be extended on the basis of magnetic anomalies to connect with the Flin Flon-Snow Lake domain in the exposed shield (Green, Hajnal, and Weber, 1985; fig. 1, pamphlet).

Western magnetic region

The westernmost segment of the Trans-Hudson orogen, the western magnetic region (X^2w), is characterized by low magnetic relief and long-wavelength anomalies. A subunit (X^2wd) within it is expressed by a broad positive gravity anomaly and is inferred to be underlain dominantly by intermediate-mafic volcanic rocks. Basalt was reported to have been penetrated in a drill hole in Harding County, S. Dak. Green, Hajnal, and Weber (1985) interpreted this unit to be composed dominantly of back-arc basin deposits, such as exposed in the Rottenstone-LaRonge magmatic belt in the shield. In the United States, sparse drilling has intersected gneiss, granite, mafic granulite, charnockite, and syenite as well as the basalt mentioned earlier. Of 15 core samples from the Saskatchewan portion of this belt, only two are granitoids. The remaining 13 are gneisses or metasedimentary rocks including biotite gneiss, hornblende-biotite gneiss, garnet-biotite gneiss, cordierite gneiss, phyllite, metagraywacke, iron-formation, and marble (Z.E. Peterman, unpub. data).

Black Hills domain

The Black Hills uplift characterizes a wedge-shaped (see geologic map), probably fault-bounded domain (XWbh) in western South Dakota that consists of Early Proterozoic metasedimentary and metavolcanic rocks that overlie reworked Archean basement rocks (Zartman and Stern, 1967; Redden and Norton, 1975; Kleinkopf and Redden, 1975; DeWitt and others, 1986; Gosselin and others, 1988; Redden and others, in press). It provides the only surface exposures of Precambrian rocks within the United States segment of the Trans-Hudson orogen. The Black Hills owes its exposure to Laramide uplift.

The Archean rocks crop out at two localities along the exposed margin of the Proterozoic rocks: (1) the Little Elk terrane along the northeast flank, and (2) the Bear Mountain terrane along the west flank. The Archean Little Elk terrane consists of a supracrustal assemblage dominated by biotite- feldspar gneiss (meta-arkose or metatuff) that was intruded at 2.55±0.01 Ga by the calc-alkaline, I-type Little Elk Granite (Gosselin and others, 1988). The Bear Mountain terrane is dominated by biotite-plagioclase schist that was intruded by the S-type granite at Bear Mountain, which has a badly discordant U–Pb age of 2.39±0.23 Ga and a multiple-event Pb-loss model age of ≈2.5 Ga (Gosselin and others, 1988).

The lowermost Early Proterozoic rocks (Redden and others, in press) are mainly quartzite, metataconite, metaconglomerate, and marble (X^1qt) of miogeoclinal affinity, which are older than 2.17 Ga. These rocks are overlain, apparently unconformably, by another sequence of mica schist, quartzite, metabasalt, meta-iron-formation, and graphitic schist (part of X^2s; Redden and Norton, 1975), which are mainly 1.97–2.17 Ga. These continental margin rocks are overlain by schist, phyllite, and metagraywacke (X^2s), and by an upper unit (X^2qs) of quartzite and sillimanite schist; both units formed in the interval 1.88–1.97 Ga. The layered rocks are intruded by the Harney Peak Granite dated at 1.70±0.03 Ga by Rb-Sr (recalculated from Riley, 1970) and 1,715±3 Ma by a concordant U–Pb monazite age supported by discordant zircon ages (Redden and others, in press). The granite is a coarse-grained to pegmatitic peraluminous granite, about 40 mi^2 (104 km^2) in area, in which hundreds of dikes and sills coalesce into a coherent, but compositionally and texturally variable intrusive body. Its initial $^{87}Sr/^{86}Sr$ ratio of about 0.7157 indicates that the rock was derived by remelting of older upper crustal material (DeWitt and others, 1986).

Both the Archean rocks and epicratonic Early Proterozoic rocks have a north-northwest-oriented structural fabric that is parallel to geophysical anomalies related to the Trans-Hudson orogeny. The Archean rocks were reworked during the Hudsonian orogeny, as indicated by a 1.85 Ga Rb-Sr whole-rock isochron for the Little Elk Creek Granite. Gosselin and others (1988), however, suggested that the most intense metamorphic conditions culminated with the emplacement of the 1,715–Ma Harney Peak Granite.

The Trans-Hudson reworking of the Archean rocks in the Black Hills and the similarity of the Proterozoic assemblages to those in northern Saskatchewan imply that the Black Hills occupies a tectonic position similar to the Cree Lake zone in northern Saskatchewan, as described by Lewry and others (1985).

Isotopic ages and geochemistry of the Archean basement rocks (Gosselin and others, 1988) and the similarity of the continental margin deposits of the Black Hills to those in the Sierra Madre and Medicine Bow Mountains (Karlstrom and others, 1983), to the west of the Laramie Range, suggest that the Black Hills and the Wyoming province had similar tectonic settings during the Trans-Hudson orogeny. The much younger metamorphic event accompanying emplacement of the

1,715–Ma Harney Peak Granite is inferred to be related to the 1,800–1,630 Ga Central Plains orogen (Sims and Peterman, 1986).

Western boundary

The western boundary of the Trans-Hudson orogen in the United States is marked by the Cedar Creek and Hartville-Rawhide faults (see geologic map). Whether or not the Cedar Creek fault exists north of the northeast-trending Brockton-Froid fault zone and forms the boundary in that area is uncertain. The boundary as defined by us is similar to that proposed by Thomas and others (1987).

Both faults on the western boundary are major crustal structures expressed by large-scale steep gravity and magnetic gradients. The Cedar Creek fault, which is the basement subsurface expression of the Cedar Creek or Glendive-Baker anticline (Gilles, 1952), displaces the basement surface at least 900 ft (274 m) vertically, as indicated by isopachs of Phanerozoic strata (Jensen and Mitchell, 1972), and probably displaces it a maximum of about 1,200 ft (366 m) (James Clement, oral commun., 1988); the southwest side moved down relative to the northeast side. Gravity values decrease to the west by 50 to 70 mGals along a steep gradient coincident with the axis of the anticline. The feature is also well displayed by slightly displaced aeromagnetic data, the upthrown side being magnetically low relative to the downthrown side. Preliminary gravity modelling indicates that rock densities differ on each side of the fault (higher on the east) inasmuch as the anomaly cannot be accounted for simply by 1,200 ft (366 m) of vertical offset. Gneisses of the Archean Wyoming craton on the west are less dense than the presumed intermediate-mafic volcanic rocks and high-grade crystalline rocks on the east side of the fault, within the Trans-Hudson orogen.

The Hartville-Rawhide fault, which is exposed in the Hartville uplift (Snyder, 1980), is interpreted as the western boundary of the Trans-Hudson orogen in the area west of the Black Hills. A steep gravity gradient of as much as 30–40 mGals (down to west) coincides with the fault; the magnitude of the gradient decreases to the north, and is no more than 20 mGals between the Black Hills and the presumed juncture of the fault with the Cedar Creek fault, in extreme southwestern North Dakota. The Hartville-Rawhide fault probably marks the boundary between relatively thick Archean crust on the west (Wyoming craton) and much thinner Archean crust overlain by Early Proterozoic arc-related rocks within the Black Hills domain of the Trans-Hudson orogen. This boundary may possibly coincide with the approximate position of the much younger Cheyenne belt (Karlstrom and Houston, 1984; Duebendorfer and Houston, 1987), which has been delineated in the Medicine Bow Mountains and the Sierra Madre and projected into the Laramie Range (see geologic map). If so, the Cheyenne belt may be superposed on a much older, ancestral continental margin that formed before 1,900 Ma and possibly about 2,300 Ma. Such an interpretation of an ancestral Atlantic-type margin of this age could account for the thick sequence of continental shelf (miogeoclinal) rocks, about 2,300 to 2,200 Ma, which predate by about 500 m.y.—a seemingly long time—the continent-island arc collisional orogenesis culminating along the Cheyenne belt about 1,700 Ma (Karlstrom and others, 1983).

North American Central Plains conductive anomaly

A zone of high conductivity in the basement that extends from southeastern Wyoming to north-central Saskatchewan is approximately parallel to and partly coincident with the western boundary of the Trans-Hudson orogen. Camfield and Gough (1977) delineated this zone and named it the North American Central Plains (NACP) conductive anomaly. They interpreted the zone as a possible Proterozoic plate boundary. Handa and Camfield (1984) linked the northern end of the NACP with the Rottenstone-LaRonge magmatic belt in Saskatchewan and Manitoba. The southern end of the NACP swings westward, coincident with the Cheyenne belt. Camfield and Gough (1977) noted that the conductor in the vicinity of the Cheyenne belt is deep, possibly even in the upper mantle, whereas east of the Black Hills it is less than 23.5 mi (38 km) deep. More recently, Jones and Savage (1986) suggested that the NACP along the international boundary lies about 46.5 mi (75 km) east of the position inferred by Camfield and Gough (1977), and thus is well within the Trans-Hudson orogen, as defined here. Thomas and others (1987) have suggested that the NACP anomaly could be the expression of a series of discontinuous conductors that have not been resolved by the coarse spacing of magnetometer stations, because of the lack of parallelism at places between the trend of the NACP and linear gravity-gradient features. We support this suggestion.

Granite batholith(?) in south-central South Dakota

A large gravity low in south-central South Dakota has a west-northwest dimension of 175 mi (280 km) and a width of about 50 mi (80 km). Several drill holes in the gravity low penetrated granite. Accordingly, Klasner and King (1986) interpreted the feature as a granite batholith. The easternmost part of the gravity low has a conspicuous positive magnetic anomaly, and one drill hole on the margin of this positive anomaly penetrated granodiorite.

We also interpret the geophysical anomaly as a probable granitic batholith, likely of Early Proterozoic age. Possibly the granite in Aurora County, S. Dak. (SD–15, App. A), which has an age of ~1.89 Ga, is a part of this body. The granite intrudes presumed Archean gneiss on the east and apparently crosses the southernmost part of the Superior-Churchill boundary zone to intrude rocks of the Trans-Hudson orogen on the west (see geologic map); it is older than the Sioux Quartzite, which partly overlies the batholith(?).

The batholith(?) was intruded into and apparently along a zone of complex northwest-trending faults. One fault in this zone, the Reservation fault (Sims and others, 1987, p. 21), has been reactivated repeatedly since the Archean, and today is the locus of abnormally high temperature ground water in the Upper Cretaceous Dakota Formation (Houser and Gray, 1980). Possibly extensive cataclastic deformation along this and other northwest faults and low-temperature retrogressive alteration minerals contribute to the large gravity low.

CENTRAL PLAINS OROGEN (1,800–1,630 MA)

The Central Plains orogen (Sims and Peterman, 1986; Bickford and others, 1986) is the eastern extension of the Early Proterozoic foldbelt (Colorado province; Reed and others, 1987) exposed in the basement uplifts of Colorado and southern Wyoming. It is an arcuate belt of metamorphic and igneous rocks that truncates, from west to east, the Archean Wyoming craton, the Early Proterozoic Trans-Hudson orogen, the Archean Superior craton, and the Penokean orogen. Its northern boundary, the Cheyenne belt (Karlstrom and Houston, 1984) is projected, on the basis of geology, northeastward through the Laramie Range into northwestern Nebraska and southern South Dakota; this part of the boundary is also marked by a sharp, northeast-trending gravity gradient. From that position eastward, the boundary is placed along the northern edge of a conspicuous west- to northwest-trending gravity high in north-central Nebraska, which reflects lithologic and structural trends of rocks within the Central Plains orogen (Lidiak, 1972). In northeastern Nebraska, the northern boundary sharply truncates the northeast-trending Penokean orogen.

Judged from detailed studies of subsurface samples in Nebraska (Lidiak, 1972; Marvin Carlson, Nebraska Geological Survey, written commun., 1988), the principal lithotypes in the Central Plains orogen are quartz-feldspar gneiss, biotite, hornblende, and quartz-muscovite schist, amphibolite, granofels, micaceous quartzite, and phyllite. The metamorphic rocks are mainly amphibolite facies, but include greenschist facies, and range in texture from granoblastic to mylonitic. Mesozonal syntectonic granitoid rocks ranging in composition from quartz diorite to granite and younger (~1,400 Ma) granitic rocks intrude the metamorphic rocks. Most of the younger intrusions are two-mica granites (Y^1g). U–Pb zircon ages on seven samples of metamorphic and foliated granitoid rocks in Nebraska range from 1.8 to 1.64 Ga (M.E. Bickford and W.R. Van Schmus, written commun., 1990). One dated sample from Keya Paha County constrains the location of the northern boundary.

The Cheyenne belt of southeastern Wyoming is a major shear zone as much as 3.1 mi (5 km) wide that separates Archean gneiss and Early Proterozoic miogeoclinal rocks of the Wyoming craton to the north from 1.8–1.6 Ga arc-related gneisses and calc-alkaline plutons to the south, in the Medicine Bow Mountains (Houston and others, 1979) and the Colorado Front Range. The rocks exposed in these Laramide uplifts are believed to be equivalent to those in the buried Central Plains orogen. The Cheyenne belt consists of several tectonized blocks separated by steeply dipping, northeast-trending mylonite zones (Duebendorfer and Houston, 1987). The mylonite zones contain a steep stretch (elongation) lineation that is interpreted by Deubendorfer and Houston to be subparallel to the tectonic transport direction. COCORP reflection profiling data suggest that the Cheyenne belt dips about 55° SE at depth (Allmendinger and others, 1982), and the steeply dipping structures at the surface are inferred as resulting from northward-directed thrusts that were subsequently rotated to their present vertical orientations during progressive shortening by folding following thrusting (Karlstrom and Houston, 1984).

SIOUX QUARTZITE

The western extension of the Sioux Quartzite, exposed on Sioux Ridge in southwestern Minnesota and adjacent South Dakota, is present in the subsurface in South Dakota. The rock is vitreous pink to red to purple orthoquartzite; it contains local beds of red argillite (pipestone). Mature basal conglomerates are present in outcrop areas (Ojakangas and Weber, 1984; Southwick and Mossler, 1984). A weathering profile about 50 to 65 ft (15 to 20 m) thick developed on Archean basement gneiss prior to deposition of the sandstone protolith of the quartzite. Southwick and Mossler (1984) interpreted the protolith as braided fluvial deposits, which formed on an alluvial plain or a plexus of alluvial fans formed within a subsiding intracratonic trough. The considerable thickness of the quartzite (at least 7,000 ft (2,100 m); Ojakangas and Weber, 1984) suggests that basins of deposition were moderately tectonically unstable, possibly rift-related basins. The protolith of the quartzite has been inferred from a suggested correlation with the Baraboo Quartzite (Dott, 1983) to have been deposited between about 1.63 Ga and 1.76 Ga. A Rb-Sr biotite age of 1.67±0.08 Ga for granodiorite beneath the quartzite (Goldich and others, 1966) is consistent with this age assignment.

The quartzite is mildly folded (Austin, 1972) and extensively deformed by northwest- and northeast-trending faults. Southwick and Mossler (1984) have proposed that northwest-trending faults that border basins of Sioux Quartzite were active during sedimentation, and B.B. Houser (reported in Sims and others, 1987, p. 21) has shown that the Reservation fault has been active intermittently since the sediments were deposited. The northwest-trending faults are part of a family of transcurrent faults in the Superior craton and flanking Proterozoic terranes in north-central United States and Canada (Sims and others, 1987).

NORTHWEST-TRENDING FAULTS

Northwest-trending faults are abundant in the basement rocks of the Northern Great Plains and adjacent areas. These faults transect rocks ranging in age from Archean to Middle Proterozoic. Those in Archean terranes dip steeply and have been shown to be dextral transcurrent (or wrench) faults. An example is the Vermilion fault in northern Minnesota (Sims, 1976); it produces a pronounced magnetic lineament. These faults are ductile to brittle shear zones characterized by mylonite, brecciation, and, locally, by silicification. Hudleston and others (1988) have proposed that this "family" of faults was formed in Late Archean time as part of a continuum of dextral shear of regional extent. They attribute the deformation to transpression: oblique compression between two more rigid crustal blocks to the north and south. Peterman and Day (1989) have shown by Rb-Sr dating of pseudotachylite that two faults in this set near the Canadian border were reactivated in Early Proterozoic (1,947 Ma) time. Further, Southwick and Mossler (1984) have postulated that northwest-trending faults that border basins of Early Proterozoic Sioux Quartzite in southwestern Minnesota were active during sedimentation. B.B. Houser (cited by Sims and others, 1987) has shown that reactivation of the Reservation fault continued, or was renewed, in the Paleozoic. Today, this fault is the locus of abnormally high temperture ground water in the Upper Cretaceous Dakota Formation. The kinematics of faults farther south, such as the Chadron is equivocal, but many of these coincide with known anticlinal structures in overlying Paleozoic rocks, and accordingly, they clearly were active in Paleozoic time.

NORTHEAST-TRENDING FAULTS

The northeast-trending faults are mainly mapped on the basis of magnetic lineaments, but two in central South Dakota, the Philip and Pierre faults, are known to offset the Precambrian basement surface. The Philip fault has at least 600 ft (183 m) of vertical displacement on the Precambrian surface (north side down), as indicated by drill-hole data and shallow seismic profiling (T.C. Nichols, Jr., oral commun., 1989). The seismic data indicated that it is a normal fault that dips about 55° N. The seismic profiling also indicates the presence of several subparallel(?), lesser, normal faults immediately north of the Philip fault, and, at a distance of 3 mi (5 km) the existence of several closely spaced south-dipping normal faults. Nichols and others (1989) have demonstrated that there has been recent faulting in the Upper Cretaceous Pierre Shale along the upward propagation of the Philip fault.

The Pierre fault displaces the Precambrian surface about 600 ft (183 m) (north side down). This fault is aligned with the southwest extension of the Great Lakes tectonic zone. Probably it is a northward-dipping normal fault, comparable to the Philip fault.

TECTONIC EVOLUTION

The geographic and temporal evolution of the major Archean and Early Proterozoic terranes in the Trans-Hudson orogen and adjacent areas can be discussed with respect to the small-scale tectonic map (fig. 2, on map).

During the Late Archean, the two Archean terranes in the Superior craton were juxtaposed to form a composite Archean craton. The two terranes were sutured along the Great Lakes tectonic zone (GLTZ), apparently by thrusting of the gneiss terrane over the northern, greenstone-granite terrane (Sims, in press b). Whether or not the Archean Wyoming craton similarly is a composite of two or more tectono-stratigraphic terranes is not known because of sparse data.

In the Early Proterozoic, rifting of the southeastern segment of the Superior craton before 1,900 Ma led to the development outboard of oceanic crust, subduction (southward), and eventual continent-arc collision at ~1,860 Ma (Sims and others, 1989), to yield the

Penokean orogen. Probably at about the same time or a little earlier, rifting of the western part of the Superior craton on a northerly axis occurred, leading to the development of oceanic crust and eventual collision of oceanic arc systems with the continent, to yield the Trans-Hudson orogen. Active subduction in the Trans-Hudson orogen is dated by calc-alkaline felsic volcanics between 1,910 and 1,875 Ma in Manitoba and 1,886 and 1,875 Ma in Saskatchewan (Bickford and others, 1989). Peterman and Futa (1988) have shown through Nd crustal residence ages that the Superior and Wyoming cratons developed independently and that the Wyoming craton therefore was not rifted from the Superior craton and subsequently returned to its present position. Continent-arc collision occurred at about 1,850 Ma followed by continent-continent collision in the interval 1,830–1,800 Ma (Bickford and others, 1989).

The isotopic age and rock record for the Trans-Hudson orogen in the basement is much less complete than for the exposed shield area. Nonetheless, they contribute importantly to reconstructions of the tectonic history. K–Ar and Rb-Sr biotite ages for basement samples indicate uplift and cooling (cratonization) at 1.74–1.66 Ga (App. A). Ages of granulite-facies rocks near the international boundary indicate the presence of both juvenile Early Proterozoic rocks and reworked Archean. Mafic granulite veined with charnockite in northeastern Montana (MT–1) crystallized in the Late Proterozoic as shown by a U–Pb zircon concordia intercept age of 1,781±16 Ma and a less precise Rb-Sr isochron age of 1,826±122 Ma. An Archean component was present in the source of these rock or was assimilated during their crustal history as shown by an initial $^{87}Sr/^{86}Sr$ ratio of 0.7053±0.0012 and Sm-Nd model ages of 2.34 Ga (charnockite) and 2.43 Ga (mafic graulite). Similar high-grade rocks in northwestern South Dakota also show isotopic signatures indicating a complex history. Biotite-garnet gneiss from northern Renville County, N. Dak. (ND–5) yielded a Rb-Sr whole-rock age of 1.76±0.10 Ga, which probably reflects metamorphism of Early Proterozoic pelitic rocks. Rb-Sr and U–Pb data for nearby felsic and mafic granulites (ND–6, ND–7) suggest that these are reworked Archean rocks that were metamorphosed to granulite facies during the Hudsonian orogeny. In contrast, charnockite from McKenzie County, N. Dak. (ND–10) is genuine juvenile Early Proterozoic material with whole-rock model ages of 1.81 Ga (Rb-Sr) and 2.17 Ga (Sm-Nd). Collectively, these isotopic data for the northern Trans-Hudson orogen in the United States suggest Hudsonian granulite facies metamorphism imposed on a complex terrane composed of both Archean and Early Proterozoic rocks. This conclusion is supported by isotopic studies of basement rocks from southern Saskatchewan, which also indicate a large component of reworked Archean rocks (both metamorphically overprinted and magmatically reworked) within the Trans-Hudson orogen (Collerson and others, 1989; Bickford and others, 1989).

The southward decrease of juvenile Early Proterozoic rocks and corresponding increase of reworked Archean along the axis of the Trans-Hudson orogen suggests complete impingement of the Archean plates during convergence. In addition, the presence of high-grade Early Proterozoic pelites (ND–5), granulites derived from Archean protoliths (ND–6, ND–7), Early Proterozoic granulites with a component of Archean material (MT–1), and probably near juvenile Early Proterozoic charnockites (ND–10) in northeastern Montana and adjacent North Dakota, suggest that the level of exposure is rather deep. Thus, the infrastructure of the Trans-Hudson orogen is present in the basement of the Dakotas. Most of the supracrustal rocks, which would include the juvenile Early Proterozoic material, have largely been removed by several tens of miles erosion mostly late in the Early Proterozoic (1.7–1.6 Ga). This concept supports the contention of Green and others (1986) that different crustal levels are exposed along strike in the Trans-Hudson orogen.

Later in the Early Proterozoic, presumed rifting of the southern margin of the composite Archean-Early Proterozoic craton culminated again in continent-arc collision along the Cheyenne belt (Central Plains orogen). Terminal collision occurred about 1,700–1,650 Ma. We interpret the Harney Peak Granite (1,710 Ma), granite of Haystack Range (1,720 Ma) of the Hartville uplift, and diorite of Twin Hills (1,740 Ma) of the Hartville uplift as being related to the Cheyenne belt suturing.

The sandstone protolith of the Sioux Quartzite probably was deposited virtually contemporaneously with development of the Central Plains orogen, although the age of the quartzite is not definitely known. If deposition of the sediment was controlled largely by faulting, as suggested by Southwick and Mossler (1984), the faults could be extensional structures related to the rifted continental margin associated with development of the Central Plains orogen.

The tectonic pattern resulting from successively younger accreted Early Proterozoic arcs in north-

Table 1.—*Major crust-forming events and associated metalliferous deposits in Precambrian basement*

[Leaders (---) indicate absent]

Age (Ga)	Terrane	Tectonic Setting	Description	Known mineral deposits	Speculative resources
3.6–2.6	Archean gneiss terrane of Superior craton.	Uncertain	Amphibolite-bearing migmatitic gneisses, younger gneisses and schists of greenstone affinity, and 2.6 Ga granite.	---	Volcanic-hosted massive sulfide deposits. Volcanic-hosted gold deposits.
3.4–2.5	Archean gneiss terrane of Wyoming craton.	Uncertain	Amphibolite-bearing migmatitic gneisses, younger greenstone, and 2.7–2.5 Ga granite.	---	Do.
2.7–2.6	Archean greenstone-granite terrane of Superior craton.	Oceanic arc	Tholeiitic basalt, komatiite, calc-alkaline basalt to dacite. Tonalite to granite intrusive rocks	Algoma-type iron-formation.	Volcanic-hosted massive sulfide deposits. Volcanic-hosted gold deposits. Gabbro-hosted nickel deposits.
1.89–1.84	Wisconsin magmatic terranes of Penokean orogen	Oceanic arc	Tholeiitic basalt, calc-alkaline andesite to rhyolite; calc-alkaline tonalite to granite; possible local anorogenic granite and ryolite (1.83 Ga).	Volcanic-hosted massive sulfide.	Volcanic-hosted gold deposits.
1.91–1.80	Early Proterozoic Trans-Hudson orogen.	Supracrustal rocks; reworked basement.	1. Superior-Churchill boundary zone—metasedimentary and metavolcanic rocks, mafic to ultramafic intrusions, and Archean basement.	---	Peridotite-hosted nickel.
		Oceanic arc	2. Central magnetic region—dominantly volcanic and intrusive rocks	---	Volcanic-hosted massive sulfide deposits. Volcanic-hosted gold deposits.
		Oceanic arc	3. Western magnetic region—dominantly volcanic and intrusive rocks	---	Do.
		Miogeoclinal rocks overlain by deeper water deposits.	4. Blacks Hills domain—quartzite, taconite, conglomerate, and marble overlain by mica schist, quartzite, basalt, and graphitic schist and by younger schist, graywacke, and quartzite; 1.715 Ga granite	Iron-formation hosted gold deposits. Algoma-type iron-formation.	---
1.80–1.63	Early Proterozoic Central Plains orogen.	Oceanic arc	Gneisses, schists, and syntectonic granitoids intruded by younger granite (1.48–1.35 Ga) and gabbro.	Zinc-copper deposits. Tungsten-copper deposits.	Gabbro-hosted iron-nickel-copper-cobalt deposits. Gabbro-ultramafic-hosted platinum-chromium-titanium deposits.

central United States terminated by about 1,600 Ma; these orogenic events were followed by the deposition of younger coeval granite-rhyolite on the southern margin of the stabilized craton (Van Schmus and Bickford, 1981; Bickford and others, 1986; Sims, 1985, 1990).

MINERAL RESOURCE POTENTIAL IN TRANS-HUDSON OROGEN

Aside from the Black Hills uplift, mineral resources in the Trans-Hudson orogen must be sought in the subsurface (table 1). The metallogeny of the greenstone-granite and the gneiss terranes of the Archean Superior craton, the Central Plains orogen, and the Sioux Quartzite was discussed earlier (Sims and others, 1987).

BLACK HILLS DOMAIN

South Dakota had a recorded gold production through 1973 of more than 35 million troy ounces, of which 91 percent came from the famous Homestake mine, at Lead in the northern tip of the Black Hills uplift. Silver production had amounted to more than 13 million oz (283,500 kg), 57 percent of which was a byproduct at the Homestake mine (Norton and Redden, 1975). The Homestake ore body is a strata-bound deposit in metamorphosed iron-formation, named appropriately the Homestake Formation. The Homestake Formation is a metamorphosed banded unit of cherty quartzite and sideroplesite (magnesium-iron carbonate). The main ore bodies are in rocks metamorphosed approximately to the garnet isograd. They are irregular pipelike structures located in a younger set of cross folds that contain pyrrhotite, pyrite, arsenopyrite, and free gold. Rye and Rye (1974) and Rye and others (1974) demonstrated that oxygen and probably sulfur in the deposits were original constituents of the Homestake Formation. Lead isotope data indicate that the lead came from a 2.5 Ga source and went through metamorphism and remobilization at 1.6 Ga, concurrent with the Central Plains orogeny. In the search for new gold deposits, Norton (1974) suggested that carbonate-facies iron-formation at the garnet isograd state of metamorphism provides the most favorable environment.

It should be noted that the Homestake Formation is confined to the vicinity of the Homestake mine, so far as known. Other iron-formations in the Black Hills have yielded some gold production, but the production is insignificant relative to that of the Homestake mine.

As can be seen from the geologic map, the Black Hills uplift is a domal structure of moderate relief at the Precambrian basement surface. Exploration for buried gold deposits within the Black Hills domain (XWbh) would be warranted under present mining conditions (1989) only in those areas a few miles outward from the Precambrian exposures.

SUPERIOR-CHURCHILL BOUNDARY ZONE

The Superior-Churchill boundary zone of the map area is the well constrained southern subsurface extension of the Thompson nickel belt, which has been a major producer of nickel and copper as well as a substantial source of platinum and cobalt directly or indirectly from ultramafic rocks (Peredery and others, 1982). According to Peredery and others, the ultramafic rocks were emplaced during the waning stages of volcanism. Similarly, abundant ultramafic rocks occur in the Fox River belt, northeast of the Thompson belt.

In the map area, mafic and ultramafic intrusions (X^2mi) have been drilled in Stanley and Jones Counties, S. Dak., and are inferred from sharp positive magnetic and gravity anomalies to be present elsewhere in the boundary zone. A particularly sharp anomaly exists east of Minot in Ward and McHenry Counties, N. Dak. Except for the southern part of the boundary zone, potential mineral deposits are too deep to be of commercial interest at present (1989). In North Dakota, the basement surface in the boundary zone is at an altitude of –5,000 to –8,000 ft.

OTHER AREAS

Economic mineral deposits occur in the Flin-Flon, LaRonge-Lynn Lake (Rottenstone-LaRonge magmatic belt), and Kisseynew domains (Lewry and others, 1985; Green, Hajnal, and Weber, 1985; fig. 1, pamphlet) in the exposed Canadian Shield, but their presumed southern extensions in the United States are too deeply buried beneath the sedimentary rocks of the Williston basin to be of current (1989) economic interest.

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APPENDIX A

The following isotopic age records are for basement samples in the map area. Location of each sample shown by section, township, range, county, and state. All ages are on the basis of isotope and decay constants recommended by the International Union of Geological Sciences Subcommission on Geochronology (Steiger and Jäger 1977). Rb-Sr whole-rock model ages are based on a calc-alkaline orogenic model of Peterman (1979b), and Sm-Nd model ages are based on a depleted mantle model of DePaolo (1981). Abbreviations used for the various types of ages are:

T(WR)	Rb-Sr or Sm-Nd whole-rock model age
T(WRI)	Rb-Sr whole-rock isochron age
TBt)	Rb-Sr or K-Ar biotite age
T(KF)	Rb-Sr K-feldspar age
T(Hb)	K–Ar hornblende age
T(Ap)	Fission-track apatite age
T(Zi)	U–Pb zircon age—concordia intercept age unless indicated otherwise.

Abbreviations used for rock types are:

Bt	Biotite
Ga	Garnet
Hy	Hypersthene.

The symbol I(Sr) means initial $^{87}Sr/^{86}Sr$ ratio.

Map No.: WY–1
Well Name: Madison #1
Location: 15–57N–65W, Crook Co., Wyoming
Rock and Sample Type: Bt gneiss, Bt-Hb gneiss, pegmatite
Isotopic Ages: (Peterman, 1981; USGS, unpub.)

Rb-Sr	T(WRI)	2.64±0.16 Ga
	I(Sr)	0.7006
K–Ar	T(Bt)	2.16 Ga
	T(Bt)	2.09 Ga
Sm-Nd	T(Hb)	2.42 Ga
	T(WR)	3.29 Ga

Comment: These gneisses probably have a Late Archean volcanic protolith as no significant prehistory is indicated by I(Sr). Middle Archean crustal development is indicated by Sm-Nd age. Complex thermal history shown by concordant Rb-Sr and K–Ar T(Bt) ages reflecting Early Proterozoic uplift and cooling at about 2.1 Ga. Cooling below 500 °C occurred at about 2.4 Ga.

Map No.: MT–1
Well Name: Amerada #1 A. Johnson
Location: 33–36N–58E, Sheridan Co., Montana
Rock and Sample Type: Mafic granulite and charnockite (core)
Isotopic Ages: (USGS, unpub.)

Rb-Sr	T(WRI)	1826±122 Ma
	I(Sr)	0.7053±0012
U–Pb	T(Zi)	1781±16 Ma
Sm-Nd	T(WR)	2.43 (charnockite)
T(WR)	2.43 Ga	(mafic gneiss)

Comment: The U–Pb zircon and Rb-Sr WRI age identify this as a deep-seated Early Proterozoic unit. The Sm-Nd model ages indicate a mixed source of Early Proterozoic and Archean material.

Map No.: MT–2
Well Name: Amerada Loucks #1
Location 35–36N–52E, Sheridan Co., Montana
Rock and Sample Type Bt quartz monzonite (cuttings)
Isotopic Ages: (USGS, unpub.)

Rb-Sr	T(WR)	1.76 Ga
Sm-Nd	T(WR)	2.28 Ga

Comment: An early Hudsonian granite derived from a mixed Early Proterozoic and Archean source (compare with MT–1).

Map No.: MT–3
Well Name: Shell Northern Pacific 32–33B
Location: 33–22N–48E, McCone Co., Montana
Rock and Sample Type: Amphibolite with granitic veins (core)
Isotopic Ages: (Burwash and others, 1962; Peterman and Hedge, 1964; USGS, unpub.)

Rb-Sr	T(KF)	1.88 Ga
K–Ar	T(Bt)	1.72 Ga
	T(Hb)	1.77 Ga
U–Pb	T(Zi)	1908±3 Ma (granite vein)

Comment: The Rb-Sr and K–Ar ages reflect uplift and cooling following the Hudsonian orogeny. The U–Pb zircon age indicates injection of granitic material during the early stages of the Hudsonian. The amphibolite is probably Archean.

Map No.: MT–4
Well Name: Madison #2
Location: 18–1N–54E, Custer Co., Montana
Rock and
Sample Type: Porphyritic Bt granite (core)
Isotopic Ages: (Peterman, 1981; Peterman and Futa, 1988)

Rb-Sr	T(WR)	2.80 Ga
	T(KF)	2.46 Ga
	T(Bt)	1.60 Ga
K–Ar	T(Bt)	2.48 Ga
U–Pb	T(Zi)	2.88 Ga
Sm-Nd	T(WR)	3.09 Ga
Fission Track	T(WR)	3.3 Ma

Comment: The Rb-Sr model age and the U–Pb zircon age establish the granite as Late Archean, and the 3.3 Ga Sm-Nd model age indicates much earlier crustal development for this part of the Wyoming age province. The Rb-Sr Bt and KF ages indicate a slow cooling history with cooling below 300 °C in the latest Early Proterozoic. The 2.48 Ga Bt age is likely the fortuitous result of excess Ar because of the deep crustal history of the pluton. The very young fission track age indicates that the rock has been near 100 °C for a very long period of time. The present bottom hole temperature is between 80 and 90 °C.

Map No.: MT–5
Well Name: Axem Resources, #1 Hackberry Creek Unit
Location: 1–5S–60E, Carter Co., Montana
Rock and
Sample Type: Bt granite (cuttings)
Isotopic Ages: (USGS, unpub.)

Rb-Sr	T(WR)	2.08 Ga

Comment: Probably partially reset from an Archean age.

Map No.: ND–1
Well Name: Coastal Oil and Gas Bjornseth #1
Location: 21–161N–77W, Bottineau Co., North Dakota
Rock and
Sample Type: Bt gneiss (cuttings)
Isotopic Ages: (USGS, unpub.)

Rb-Sr	T(WR)	2.83±0.16 Ga
Sm-Nd	T(WR)	2.76 Ga

Comment: Examination of the cuttings revealed a single crystalline rock lithotype. Impurities from uphole were removed by hand picking.

Map No.: ND–2
Well Name: Union Oil #1 Skjervheim
Location: 28–159N-63W, Cavalier Co., North Dakota
Rock and
Sample Type: Bt tonalite gneiss (core)
Isotopic Ages: (Peterman and Hedge, 1964; USGS, unpub.)

K-Ar	T(bt)	2.43 Ga
Sm-Nd	T(WR)	2.68 Ga

Comment: Sm-Nd model age reflects juvenile Late Archean crust.

Map No.: ND–3
Well Name: Herman Hanson Mueller #1
Location: 20–140N–65W, Stutzman Co., North Dakota
Rock and
Sample Type: Bt quartz monzonite (core)
Isotopic Ages: (Peterman and Hedge, 1964; USGS, unpub.)

Rb-Sr	T(WR)	2.41 Ga
	T(KF)	2.22 Ga
Sm-Nd	T(WR)	2.67 Ga

Comment: Sm-Nd model age reflects juvenile Late Archean crust.

Map No.: ND–4
Well Name: Carter Northern Ordnance #1
Location: 35–133N–75W, Emmons Co., North Dakota
Rock and
Sample Type: Bt tonalite gneiss (core)
Isotopic Ages: (Burwash and others, 1962)

K–Ar	T(Bt)	2.48 Ga

Comment: Reflects uplift and cooling following Kenoran orogeny.

Map No.: ND–5
Well Name: Shell Mott 14–34
Location: 34–164N–87W, Renville Co., North Dakota
Rock and
Sample Type: Bt-Ga gneiss (core)
Isotopic Ages: (USGS, unpub.; Peterman and Goldich, 1982)

Rb-Sr T(WRI) 1.76±0.10 Ga
T(Bt) 1.68±0.04 Ga
K–Ar T(Bt) 1.67±0.06 Ga

Comment: T(WRI) may reflect metamorphism. T(Bt) ages register uplift and cooling following Hudsonian orogeny (cratonization of the Trans-Hudson orogen).

Map No.: ND–6
Well Name: Shell Osterberg 22x–1
Location 1–161N–85W, Renville Co., North Dakota
Rock and Sample Type: Bt-Ga-Hy gneiss (mafic granulite) (core)
Isotopic Ages: (USGS, unpub.; Peterman and Goldich, 1982)
Rb-Sr Whole rocks depleted in Rb during granulite metamorphism
T(Bt) 1.66 Ga
U–Pb T(Zi) Discordia intercepts at 1.64 and 2.95 Ga

Comment: Rb-Sr WR and U–Pb zircon systematics suggest an Archean protolith metamorphosed to granulite grade during the Hudsonian orogeny. T(Bt) reflects uplift and cooling.

Map No.: ND–7
Well Name: Shell Osterberg 21–2
Location: 2–161N–85W, Renville Co., North Dakota
Rock and Sample Type: Bt-cordierite gneiss (core)
Isotopic Ages: (USGS, unpub.; Peterman and Goldich, 1982)
Rb-Sr T(WRI) 1.97 GA I(Sr) 0.715
U–Pb Discordia intercepts at 1.75 and 2.89 Ga

Comment: Rb-Sr WR and U–Pb zircon systematics suggest an Archean protolith metamorphosed to granulite grade during the Hudsonian orogeny. T(Bt) reflects uplift and cooling.

Map No.: ND–8
Well Name: Amerada ND "A" Unit 9
Location: 16–156N–95W, Williams Co., North Dakota
Rock and Sample Type: Bt-Ga gneiss (cuttings)
Isotopic Ages: (Peterman and Hedge, 1964)
Rb-Sr T(Bt) 530 Ma
K–Ar T(Bt) 665 Ma

Comment: This well is located near the center of the Williston basin. The low ages possibly reflect a Late Proterozoic or early Paleozoic thermal event that was a precursor to the development of the basin. Unfortunately, the age has not been verified because no suitable additional samples are available in the immediate vicinity (compare with ND–9).

Map No.: ND–9
Well Name: Amerada 1 Iverson-Nelson Unit
Location: 2–155N–96W, Williams Co., North Dakota
Rock and Sample Type: Altered syenite (core)—not penetratively deformed
Isotopic Ages: (Peterman and Hedge, 1964; USGS, unpub.)
Rb-Sr T(KF) 692 Ma
Sm-Nd T(WR) 980 Ma

Comment: May reflect Late Proterozoic igneous activity.

Map No.: ND–10
Well Name: Amerada Unit A Antelope
Location: 1–159N–95W, McKenzie Co., North Dakota
Rock and Sample Type: Charnockite (core)
Isotopic Ages: (USGS, unpub.)
Rb-Sr T(WR) 1.81 Ga
T(KF) 1.76 Ga
Sm-Nd T(WR) 2.17 Ga

Comment: Sm-Nd model age suggests that source of the charnockite is dominated by Early Proterozoic material with only a minor Archean component. T(WR) may be close to actual age because sample is exceptionally fresh.

Map No.: ND–11
Well Name: Amerada #8 Scoria Unit
Location: 10–139N–101W, Billings Co., North Dakota
Rock and Sample Type: Bt quartz monzonite (cuttings)
Isotopic Ages: (Goldich and others, 1966)

Rb-Sr	T(Bt)	1.69 Ga
K–Ar	T(Bt)	1.74 Ga

Comment: Biotite ages reflect uplift and cooling following the Hudsonian orogeny.

Map No.: SD–1
Well Name: Shell #1 Veal
Location: 7–17N–15E, Perkins Co., South Dakota
Rock and Sample Type: Quartz monzonite (cuttings)
Isotopic Ages: (Goldich and others, 1966)
Rb-Sr T(KF) 1.79 Ga
Comment: Minimum age.

Map No.: SD–2
Well Name: Evans #1 Querbes-Capp
Location: 19–13N–16E, Perkins Co., South Dakota
Rock and Sample Type: Quartz monzonite (cuttings)
Isotopic Ages: (Goldich and others, 1966)
Rb-Sr T(KF) 1.81 Ga
Comment: Minimum age.

Map No.: SD–3
Well Name: Mobil #1 Sipila B
Location: 14–9N–8E, Butte Co., South Dakota
Rock and Sample Type: Bt gneiss (core)
Isotopic Ages: (Goldich and others, 1966; USGS, unpub.)

Rb-Sr	T(WR)	1.71 Ga
	T(WR)	1.63 Ga
Sm-Nd	T(WR)	3.05 Ga

Comment: Sm-Nd model age indicates presence of reworked Archean within the Trans-Hudson orogen.

Map No.: SD–4
Well Name: Black Hills Ordnance Depot (Provo) No. 1
Location: 3–10S–2E, Fall River Co., South Dakota
Rock and Sample Type: Bt schist (cuttings)
Isotopic Ages: (Goldich and others, 1966)
Rb-Sr T(Bt) 1.49 Ga
Comment: Cooling age

Map No.: SD–5
Well Name: Shamrock #2 Barrick
Location: 23–7N–26E, Stanley Co., South Dakota
Rock and Sample Type: Quartz monzonite (cuttings)
Isotopic Ages: (Goldich and others, 1966)
Rb-Sr T(KF) 1.66 Ga
Comment: Minimum age.

Map No.: SD–6
Well Name: Pray No. 1 Kranzler
Location: 14–121N–77W, Walworth Co., South Dakota
Rock and Sample Type: Bt schist (cuttings)
Isotopic Ages: (Goldich and others, 1966)
Rb-Sr T(Bt) 1.75 Ga
Comment: Cooling age.

Map No.: SD–7
Well Name: Harvey Carr Farm Well
Location: 19–126N–60 W, Marshall Co., South Dakota
Rock and Sample Type: Quartz monzonite (core)
Isotopic Ages: (Goldich and others, 1966; USGS, unpub.)

Rb-Sr	T(WR)	2.49 Ga
	T(Bt)	2.35 Ga
K–Ar	T(Bt)	2.40 Ga
Sm-Nd	T(WR)	2.72 Ga

Comment: Late Archean granite reflecting juvenile Late Archean crust.

Map No.: SD–8
Well Name: Amax Exploration DDH
Location: 29–122N–57W, Day Co., South Dakota
Rock and Sample Type: Bt-staurolite schist (core)
Isotopic Ages: (Richards and others, 1986)

Rb-Sr	T(WRI)	2.56±0.06 Ga
	T(Bt)	2.44 Ga
K–Ar	T(Bt)	2.44 Ga

Comment: T(WRI) reflects metamorphism. T(Bt) ages record uplift and cooling.

Map No.: SD–9
Well Name: Hinker #1 Gerald Tonsager

Location: 15–109N–54W, Kingsbury Co., South Dakota
Rock and Sample Type: Quartz latite (core)
Isotopic Ages: (Goldich and others, 1966)
Rb-Sr T(WR) 1.70 Ga
Comment: Minimum age but may be close to true age.

Map No.: SD–10
Well Name: Joe Grassel Farm Well
Location: 21–108N–59W, Sanborn Co., South Dakota
Rock and Sample Type: Felsite porphyry (core)
Isotopic Ages: (Goldich and others, 1966)
Rb-Sr T(WR) 1.70 Ga
K–Ar T(WR) 1.68 Ga
Comment: Minimum age but may be close to true age.

Map No.: SD–11
Well Name: Smith and Davison Well
Location: Granodiorite (core)
Rock and Sample Type: 25–103N–61W, Davison Co., South Dakota
Isotopic Ages: (Goldich and others, 1966; USGS, unpub.)
Rb-Sr T(Bt) 1.67 Ga
T(WR) 2.05 Ga
Comment: Cooling age.

Map No.: SD–12
Well Name: General Crude #1 Skippy
Location: 33–95N–77W, Tripp Co., South Dakota
Rock and Sample Type: Quartz monzonite (cuttings)
Isotopic Ages: (Goldich and others, 1966)
Rb-Sr T(KF) 1.51 Ga
Comment: Minimum age.

Map No.: SD–13
Well Name: General Crude #1 Rural Credit
Location: 5–96N–75W, Tripp Co., South Dakota
Rock and Sample Type: Quartz monzonite (cuttings)
Isotopic Ages: (Goldich and others, 1966)
Rb-Sr T(KF) 1.48 Ga
Comment: Minimum age.

Map No.: SD–14
Well Name: Sioux Valley #1 La Fleur
Location: 18–90N–48W, Union Co., South Dakota
Rock and Sample Type: Quartz monzonite (cuttings)
Isotopic Ages: (Goldich and others, 1966)
Rb-Sr T(KF) 1.46 Ga
Comment: Minimum age.

Map No.: SD–15
Well Name: Exxon
Location: 16–105N–63W, Aurora Co., South Dakota
Rock and Sample Type: Bt granite (core)
Isotopic Ages;: (USGS, unpub.)
Rb-Sr WR) 1.93 Ga
U–Pb T(Zi) Pb-Pb 1.68 Ga
Comment: Sample is severely fractured and altered. Sufficient zircon for only one determination was obtained, and it is strongly discordant. Assuming it is on a chord with a 500–Ma lower intercept, the upper intercept is 1.89 Ga. Likely, the granite is Early Proterozoic.

Map No.: SD–16
Well Name: Exxon
Location: 13–108N–62W, Sanborn Co., South Dakota
Rock and Sample Type: Banded Bt gneiss (core)
Isotopic Ages: USGS, unpub.)
Rb-Sr T(WRI) 2.10±0.04 Ga (two point isochron)
T(WR) 2.71 Ga (calculated whole rock)
Sm-Nd T(WR) 2.72 Ga
Comment: T(WRI) represents subsamples of lighter and darker bands. The 2.10–Ga isochron indicates some redistribution probably related to thermal overprinting at 1.8–1.9 Ga. The Rb-Sr model age is probably close to the metamorphic age; the Sm-Nd model age indicates the Late Archean juvenile character of the protolith.

Map No.: SD–17
Well Name: Exxon W–1
Location: 35–107N–63W, Jerauld Co., South Dakota

Rock and Sample Type: Banded and contorted Bt-Ga gneiss (core)

Isotopic Ages: (USGS, unpub.)

Rb-Sr	T(WR)	2.52 Ga
	T(Bt)	1.80 Ga
Sm-Nd	T(WR)	2.83 Ga
	T(WR–Bt–Ga)	2.49 Ga

Comment: The Sm-Nd internal isochron should register the metamorphic event that produced the present mineralogy. However, it seems to be a bit young in comparison with Late Archean events to the northeast. The Sm-Nd WR age indicates a dominant Late Archean provenance for the detritus.

Map No.: SD–18

Well Name: Buckhorn Inglett #1

Location: 20–99N–71W, Gregory Co., South Dakota

Rock and Sample Type: Altered rhyolite tuff with quartzite inclusions (core)

Isotopic Ages: (USGS, unpub.)

Rb-Sr	T(WR)	1.55 Ga
U–Pb	T(Zi)	Pb-Pb 1.78–1.79 Ga

(Four fractions have nearly identical U–Pb ages and a chord is not defined. Some of the grains clearly contain older, metamict cores.)

Comment: The U–Pb data for zircon clearly establish the rhyolite as Early Proterozoic, probably 1.8–1.9 Ga. The systematics do not permit a more refined estimate of the age. The Rb-Sr WR system has been compromised by one or more younger events.

Map No.: NE–1

Well Name: Amerada #1 Federal-Geiser

Location: 10–34N–54W, Sioux Co., Nebraska

Rock and Sample Type: Quartz monzonite (core)

Isotopic Ages: (Goldich and others, 1966)

Rb-Sr	T(WR)	1.77 Ga

Comment: Minimum age.

Map No.: NE–2

Well Name: Byrd and Frost #1 Lowe

Location: 22–24N–38W, Grant Co., Nebraska

Rock and Sample Type: Quartz monzonite

Isotopic Ages: (Goldich and others, 1966)

Rb-Sr	T(KF)	1.71 Ga

Comment: Minimum age.

APPENDIX B

The number and distribution of drill holes that penetrate Precambrian basement are inadequate for delineating even first-order lithologic domains in the subsurface. However, an evaluation of basement lithologies within the framework of the lithotectonic domains defined from geophysical data is useful in comparing the gross lithologic content of these domains. In order to make this comparison without over interpreting the accuracy of the basement data (lithologic identification), we have used a classification that is both lithologic and partly genetic:

I. Metasedimentary rocks—Iron-formation, metagraywacke, phyllite, schist, biotite schist, sericite schist, muscovite schist.

II. Metavolcanic rocks—Metabasalt, metatuff, porphyritic felsite, andesite, rhyolite, talc-chlorite schist, chlorite schist, chlorite-actinolite schist, hornblende schist, biotite-epidote schist.

III. Felsic to intermediate plutonic rocks
   A. Granitoids—Trondhjemite, granodiorite, adamellite, granite, syenite, granitoid, diorite (all with various varietal names such as biotite, biotite-hornblende).
   B. Gneiss—Banded gneiss, quartz monzonite gneiss, cordierite gneiss, charnockite, tonalite gneiss, biotite-hornblende gneiss, biotite tonalite gneiss.

IV. Mafic plutonic
   A. Gabbrotoids—Gabbro, diabase.
   B. Gneiss—Serpentinite, altered chlorite gneiss.

The above classification is comparable to one that might be used in reconnaissance mapping in similar Precambrian terranes. If a rock or unit can be identified as metavolcanic or metasedimentary, it is classified (or mapped) as such regardless of metamorphic grade. The first-order division of the crystalline (plutonic) rocks is on the basis of gross composition (mafic versus felsic). The "felsic" split includes intermediate to granitic compositions in the sense of a standard rock classification. The subdivision is based on whether or not an origin can be deduced. The "granitoids" are intrusive plutonic rocks whereas the "gneisses" are generally of uncertain origin although they may also include rocks of igneous origin—again, a problem not uncommon in mapping. The "mafic plutonic" rocks are similarly divided into those of obvious igneous origin such as gabbros and diabase, and mafic gneisses. These are generally minor components of all of the terranes so the gross lithologic divisions are relatively insensitive to calls in this category.

If the wells are considered random penetrations of the basement, the accuracy of the lithologic estimates can be estimated from counting statistics. The uncertainty on any count is the square root of that count. Thus, if in one domain, 9 wells encounter metasedimentary rocks, the standard deviation is ±3 or 33 percent. The most accurate data set is for the Superior province, and the lithologic breakdown is very much what it should be for a greenstone-granite terrane like the Wabigoon or Wawa belts in Canada. In contrast, data for the Wyoming age province are at best a crude representation of its actual lithologic content (table 2).

Table 2.—*Abundance of rock types in basement domains*

	ARCHEAN		EARLY PROTEROZOIC					
TERRANE[1]	WAP	SUP	BH	WMR	CMR	SCBZ	CPO	SDB
OBSERVATIONS	14	218	23	30	35	24	63	13
Metasedimentary	0	7.3	22	7	9	0	0	0
Metavolcanic	14	16.1	0	7	9	21	13	0
Felsic plutonic								
Granitoid	50	53.7	65	53	54	63	52	100
Gneiss	36	18.8	13	33	29	4	32	0
Mafic plutonic								
Gabbro	0	3.7	0	0	0	8	3	0
Gneiss	0	0.5	0	0	0	4	0	0

[1]Abbreviations of terranes:

Archean: WAP, Wyoming age province; SUP, Superior province.

Early Proterozoic: BH, Black Hills domain; WMR, Western magnetic region; CMR, Central magnetic region; SCBZ, Superior-Churchill boundary zone; SDB, South Dakota batholith, all of the Trans-Hudson orogen; and CPO, Central Plains orogen.

APPENDIX C

This appendix contains the well records used in construction of the maps, except for Minnesota and Iowa. The format for the records follows:

Well or lease name
Section, Township, Range, County, State
Reference elevation, depth basement, elevation of basement, in feet
Basement rock type

Where information is missing in the records, it is so indicated by "not available" or "NA." Several sources were available for some records. Disagreement in depths and rock types were not uncommon. Commonly, the discrepancies in depths were only on the order of a few tens of feet. Where three sources were available, the two that agreed most closely were selected for the record. In other cases, it was simply a matter of choice between data that were very close in agreement.

Pan American State No. 1
10–25N–65W, Goshen Co., WY
4481′ 1555′ +2926′
Granite (core)

Coronado Co. #1 Govt.
4–36N–62W, Niobrara Co., WY
4538′ 2739′ +1799′
Not available

H H & W Oil
10–24N–69W, Platte Co., WY
4726′ 648′ +4078′
Granite wash

H H & W Oil
21–24N–69W, Platte Co., WY
4808′ 601′ +4207′
Granite

General Petroleum #34–15–P
15–24N–66W, Platte Co., WY
5140′ 5325′ -185′
Granite

Seaboard Oil
29–25N–65W, Platte Co., WY
4916′ 3808′ +1108′
Granite (core)

Wolf Exploration
18–25N–76W, Albany Co., WY
6843′ 3294′ +3549′
Not available

Zoller & Danneburg
19–26N–63W, Goshen Co., WY
4432′ 7809′ -3377′
Granite

A.C. Griffith Oil Enterprises
30–26N–66W, Platte Co., WY
4898′ 1560′ +3338′
Not available

J.K. Wadley
8–26N–67W, Platte Co., WY
4933′ 3480′ +1453′
Not available

A.C. Griffith Oil Enterprises
36–26N–67W, Platte Co., WY
5013′ 1830′ +3183′
Not available

Wolf Exploration
2–26N–77W, Albany Co., WY
7051′ 2892′ +4159′
Not available

Pan American Petroleum
25–27N–64W, Goshen Co., WY
4542′ 3045′ +1497′
Not available

Ohio Oil #1 Joseph Waggoner
14–28N–63W, Goshen Co., WY
4580′ 3052′ +1528′
Granite

A.C. Griffith Oil Enterprises
2–29N–69W, Platte Co., WY
5096′ 1060′ +4036′
Not available

Jewell Springs Co. #1 Berry
20–30N–67W, Platte Co., WY
4690′ 1740′ +2950′
Not available

Layton Oil
14–30N–66W, Platte Co., WY
5224′ 1240′ 3984′
Not available

General Petroleum #45–32–P
32–30N–60W, Goshen Co., WY
4754′ 7034′ -2280′
Schist, ferro-mags.

Wildcat Drilling
27–30N–69W, Platte Co., WY
4934′ 3040′ +1894′
Not available

DeGaugh Well Service
6–31N–68W, Converse Co., WY
4806′ 1445′ +3361′
Not available

Hanover Planning; K.D. Luff
16–31N–71W, Converse Co., WY
4931′ 1400′ +3531′
Not available

Keelin Syndicate #1 Alice
17–32N–65W, Niobrara Co., WY
5362′ 1285′ +4077′
Not available

Kornegay No.1
29–31N–68W, Converse Co., WY
5017′ 1118′ +3899′A
Bt granite (cores)

Raymond Oil
29–34N–60W, Niobrara Co., WY
4368′ 5052′ –684′
Granite and granite wash

Ohio Oil Hat Creek
30–35N–62W, Niobrara Co., WY
4245′ 2915′ +1330′
Granite

Coronado Petroleum
20–36N–62W, Niobrara Co., WY
4310′ 2598′ +1712′
Not available

Coronado Petroleum
10–37N–62W, Niobrara Co., WY
3969′ 3140′ +829′
Not available

Coronado Petroleum
28–37N–62W, Niobrara Co., WY
4053′ 2917′ +1136′
Not available

Coronado Petroleum
2–39N–61W, Niobrara Co., WY
3833′ 3400′ +433′
Banded gneiss (core)

Coronado Petroleum
33–37N–62W, Niobrara Co., WY
4479′ 2801′ +1678′
Granite (core)

California Co., Wilson #8
18–17N–76W, Albany Co., WY
7500′ 6135′ +1355′
Quartzite

Ackard, McKinley #1
21–31N–69W, Converse Co., WY
4630′ 1510′ +3120′
Not available

Bredthauer, Mills Ranch #1
25–33N–64W, Niobrara Co., WY
5175′ 1240′ +3935′(TD)
Not available

Western Oil Fields #1 Klink
8–13N–73W, Albany Co., WY
7466′ 710′ +6756′
Not available

Warm Springs Oil Co. #1
17–31N–71W, Converse Co., WY
4800′ 1210′ +3590′
Not available

Wyshawn #2 Lindley
35–32N–69W, Converse Co., WY
4785′ 925′ +3860′
Not available

California Co. #1 Morton-King
12–13N–68W, Laramie Co., WY
6508′ 11,205′ –4697′
Not available

Coronado Pet #1 Govt. Tuttle
10–32N-62W Niobrara Co., WY
3969′ 3140′ +829′
Not available

Wittengerger & Ankarld
26–23N–69W, Platte Co., WY
5086′ 1000′ +4086′
Not available

Madison #1
15–57N–65W, Crook Co., WY
3618′ 4299′ –681′
Bt gneiss, bt-hb gneiss,
amphibolite, granite gneiss

Not available
27–32N–56E, Sheridan Co., MT
2018′ 11,867′ –9849′
Pink and white feldspar, biotite,
muscovite, and chlorite

Not available
22–32N–56E Sheridan Co., MT
2089′ 12,296′ –10,207′
Not available

Pure No. 1 State
36–2N–51E, Custer Co., MT
3016′ 10,003′ –6987′
Granite gneiss

Not available
16–2N–61E, Carter Co., MT
3149′ 10,262′ –7113′
Not available

Carter Oil Co. #1 N.P.R.R.
19–4N–62E, Fallon Co., MT
3065′ 9654′ –6589′
Epidote-bt gneiss

Not available
13–5N–58E, Fallon Co., MT
3368′ 11,140′ –7772′
Not available

Not available
17–10N–58E Fallon Co., MT
2743′ 10,493′ –7750′
Not available

Not available
22–11N–57E Wibaux Co., MT
2640′ 10,395′ –7755′
Biotite, chlorite, green feldspar

Marathon Oil #1 State
33–22N–48E McCone Co., MT
2499′ 11,005′ –8506′
Feldspar, biotite, Fe-stained quartz

Shell N.P. 32–33B
33–22N–48E McCone Co., MT
2486′ 11,005′ –8519′
Amphibolite cut by granite stringers

Dune Oil Co., #1 State
16–23N–55E Richland Co., MT
2466′ 12,958′ –10,492′
Granite

Not available
7–6S–52E Powder River Co., MT
3340′ 9849′ –6509′
Granite

Union Oil Co. #2 Govt.-Hamilton
17–6S–58E Carter Co., MT
3674′ 7142′ –3468′
Cataclastic granite gneiss

Not available
14–7S–56E Carter Co., MT
3496′ 7079′ –3583′
Feldspar, Fe-stained quartz, biotite

Union Oil Co. #1 Gov't-Lowe
1–8S–56E Carter Co., MT
3636′ 6325′ –2689′
Biotite, quartz, feldspar

Union Oil Co. #1 Govt.-Catron
29–9S–58E Carter Co., MT
3557′ 4842′ –1285′
Granite gneiss

Union Oil Co. #1 Govt.-Newton
23–9S–59E Carter Co., MT
3430′ 4864′ –1434′
Cataclastic granite gneiss

Amerada #1A Johnson
33–36N–58E Sheridan Co., MT
2313′ 10,720′ –8407′
Mafic granulite with charnockite
veins

Amerada #1 Loucks
35–36N–52E Sheridan Co., MT
2442′ 10,729′ –8287′
Foliated leucogranite

Skelly Oil #1 Bergen
14–7S–56E Carter Co., MT
3841′ 7079′ –3238′
Adamellite

Not available
1–5S–60E Carter Co., MT
3375′ 8268′ –4893′
Granite

Not available
21–6S–57E Carter Co., MT
3708′ 7210′ –3507′
Not available

Not available
6–1S–54E Powder River Co., MT
2936′ 9596′ –6660′
Not available

Not available
36–32N–54E Sheridan Co., MT
2125′ 11,970′ –9845′
Not available

Not available
30–33N–56E Sheridan Co., MT
2140′ 12,261′ –10,121′
Granite wash

Not available
26–30N–36E Valley Co., MT
2478′ 7770′ –5292′
Not available

Not available
3–27N–36E Valley Co., MT
2375′ 7826′ –5451′
Not available

Not available
6–37N–37E Valley Co., MT
2660′ 8926′ –6266′
Not available

Madison #2
18–1N–54E Custer Co., MT
2809′ 9300′ –6491′
Bt granite

Energetics Inc. #23–7 Soelberg
7–130N–91W Adams Co., ND
2440′ 9463′ –7023′
Bt granite gneiss

Pollard & Davis #1 Guscette
20–142N–61W Barnes Co., ND
1527′ 2572′ –1045′
Quartz diorite gneiss

Jack M. Johnson #1 Vig
9–140N–59W Barnes Co., ND
1440′ 1936′ –496′
Not available

Calvert Expl. Co. #1 Stadum
31–154N–70W Benson Co., ND
1637′ 5134′ –3497′
Bt granodiorite fragments

Amerada #8 Scoria Unit
10–139N–101W Billings Co., ND
2540′ 13,508′ –10,968′
Bt tonalite gneiss

Tenneco Oil Co. #1–29BN
29–143N–100W Billings Co., ND
2642′ 14,184′ –11,542′
Not available

Gulf #1 Zabolotny
3–144N–98W Billings Co., ND
2532′ 15,366′ –12,834′
Bt tonalite gneiss

W.H. Hunt Osadchuck B–1
23–142N–100W Billings Co., ND
2726′ 14,373′ –11,647′
Bt granite

Union of California #1 Steen
20–159N–81W, Bottineau Co., ND
NA 8154′(TD) NA
Chlorite schist

Coastal 21–161–7 #1 Bjornseth
21–161N–77W Bottineau Co., ND
1474′ 6600′ –5126′
Bt granodiorite

Champlin Pet. Co. #1 Dunbar
14–162N–77W Bottineau Co., ND
1552′ 6360′ –4808′
Foliated bt-hb granodiorite

California Oil #1 Blanche Thompson
31–160N–81W Bottineau Co., ND
1526′ 8245′ –6719′
Hb schist

California Oil #4 Bert Henry
6–161N–79W Bottineau Co., ND
1694′ 7273′ –5579′
Hb schist

Amerada #1 Lillestrand
31–162N–78W Bottineau Co., ND
1486′ 6700′ -5214′
Serpentinite

Hunt #1 Cranston
8–163N–81W Bottineau Co., ND
1518′ 7555′ -6037′
Hb bt granodiorite

Hunt #1 Olson
18–163N–77W Bottineau Co., ND
1520′ 6406′ -4886′
Foliated bt trondhjemite

Lion Oil #1 Huss
23–163N–75W Bottineau Co., ND
2205′ 6434′ -4229′
Bt granite

Priebe-State #1
5–94W–161N Burke Co., ND
2394′ 10,800′(TD)
Not available

Continental Oil Co. #1 McKay
32–137N–76W Burleigh Co., ND
1869′ 6160′ -4291′
Hb-bt gneiss

Asmera #1 Welch
31–138N–78W Burleigh Co., ND
NA 6980′(TD) NA
Talc-chlorite schist

Continental #1 Duneland
3–140N–77W Burleigh Co., ND
1981′ 6860′ -4879′
Bt granite gneiss

Continental-Pure #1 Davidson
6–140N–77W Burleigh Co., ND
1909′ 6947′ -5038′
Muscovite bt granite

Hunt #1 Emma Kleven
18–140N–80W Burleigh Co., ND
1922′ 8088′ -6166′
Not available

Hunt #1 Schlabach-State
36–139N–76W Burleigh Co., ND
1895′ 5859′ -3964′
Granite?

Sun Oil #1 Thorson
17–141N–76W Burleigh Co., ND
1874′ 6794′ -4920′
Not available

Continental #1 Dronen
9–140N–75W Burleigh Co., ND
1912′ 6144′ -4232′
Bt granite gneiss

RRVDP #9 Williams
15–142N–52W Cass Co., ND
1020′ 589′ +431′
Granodiorite

Fargo City Well
(sec.?)–139N–49W Cass Co., ND
900′ 254′ +646′
Granite

RRVDP #7 Saunders
23–137N–53W Cass Co., ND
1048′ 558′ +490′
Tonalite

RRVDP 8A–1 #8A Bartholomay
33–140N–53W Cass Co., ND
997′ 519′ +478′
Chlorite schist and granite gneiss

Johnson Oil #1 Moore
10–162N–63W Cavalier Co., ND
1586′ 3365′ -1779′
Bt granodiorite

#1 A. Schmeiss
16–162N–64W Cavalier Co., ND
1617′ 3127′ -1510′
Granite

Union #1 Chris Skjervheim
28–159N–63W Cavalier Co., ND
1562′ 3404′ -1842′
Tonalite gneiss

Traugott Co. #1 Goodman
3–160N–57W Cavalier Co., ND
1555′ 2305′ -750′
Bt granite gneiss

H. Hanson #1 Billey
11–129N–63W Dickey Co., ND
1441′ 1880′ -439′
Actinolite schist

H. Hanson #1 J. Bell
14–129N–63W Dickey Co., ND
1444′ 1852′ –408′
Bt schist

Calvert Expl. #1/Kamm
22–129N–66W Dickey Co., ND
2196′ 3147′ –951′
Hb gneiss

Shell Svangstu 24–18
18–163N–95W Divide Co., ND
1918′ NA –9876′
Bt granite

Shell #43–16 Rindel
16–162N–96W Divide Co., ND
2141′ 12,348′ –10,207′
Gneiss

W.H. Hunt Rosten #1
19–160N–97W Divide Co., ND
2349′ 13,617′ –11,268′
Not available

#1 Wolberg
18–141N–95W Dunn Co., ND
2595′ NA –10,966′
Bt granite

#12–9 Anderson
9–148N–65W Eddy Co., ND
1530′ 3706′ –2176′
Not available

Calvert Exploration #1 State
8–150N–65W Eddy Co., ND
1570′ 3858′ –2288′
Leucogranite and hb schist

Zachmeier & Disney #1 Blasky
9–148N–62W Eddy Co., ND
1584′ 3084′ –1500′
Actinolite schist

Calvert Expl. #1 ND State
16–150N–67W Eddy Co., ND
1478′ 4218′ –2740′
Bt granite

Roeser-Pendelton #1 Weber
35–133N–76W Emmons Co., ND
2012′ 5543′ –3531′
Bt hb granodiorite gneiss

#1 Horner
10–132N–76W Emmons Co., ND
1887′ NA –3519′
Bt granite

Peak Drill. Co. #1 Olhauser
8–132N–78W Emmons Co., ND
1820′ 5875′ –4055′
Bt granodiorite gneiss

Northern Ord. Inc. #1 Franklin
35–133N–75W Emmons Co., ND
1909′ 5348′ –3439′
Bt granite

Pure Oil Co. #1 Carr
15–146N–66W Foster Co., ND
1547′ 3559′ –2012′
Actinolite schist

Glenfield Oil #1
18–146N–62W Foster Co., ND
1510′ 3150′ –1640′
Bt tonalite gneiss

Frazier-Conray #1 Dunbar
13–146N–63W Foster Co., ND
1518′ 3106′ –1588′
Chlorite actinolite schist

Wetch #1–A H. Spickler
25–147N–64W Foster Co., ND
1468′ 3271′ –1803′
Hb schist

Cardinal Drill. Co. #1 Smith
8–146N–65W Foster Co., ND
1533′ 3522′ –1989′
Serpentenite

Cardinal #1 Graves Fed. Land
23–146N–66W Foster Co., ND
1536′ 3792′ –2256′
Altered bt granodiorite

Evans #1 Bailey
26–145N–62W Foster Co., ND
1596′ 2955′ –1359′
Bt granodiorite gneiss

Evan #1 Erickson
24–145N–64W Foster Co., ND
1547′ 3292′ –1745′
Bt trondhjemite (mylonite)

Cardinal Drill. #1 Anderson
10–146N–67W Foster Co., ND
1588′ 4182′ –2594′
Bt granite

RRVDP 16–1 #16 Lindholm
14–153N–54W Grand Forks, ND
941′ 1079′ –138′
Granodiorite gneiss

RRVDP 16–2 #16 Lindholm
14–153N–54W Grand Forks, ND
941′ 1079′ –138′
Granodiorite gneiss

Canadian Dakota #1–A Wosick
5–153N–52W Grand Forks, ND
842′ 790′ +52′
Granodiorite

Red River Oil #1 Berg
35–152N–51W Grand Forks, ND
844′ 501′ +344′
Tonalite gneiss

North Plains #1 C.O. Haugen
22–152N–54W Grand Forks, ND
1015′ 1150′(TD)
Bt granodiorite

Canadian Dakota #1 Neresen
17–152N–51W Grand Forks, ND
837′ 558′ +279′
Hb schist, gneissic bt granodiorite

North Plains Pet. #1 Danner
24–152N–54W Grand Forks, ND
969′ 1054′ –85′
Tonalite gneiss

A.J. Scott and #1 Scott
15–151N–53W Grand Forks, ND
950′ 895′ +55′
Muscovite bt granodiorite

RRVDP 15 #15 Weekly
35–152N–51W Grand Forks Co., ND
840′ NA NA
Foliated diorite

Shell Oil #21–22 Kremers
22–137N–106W Golden Valley Co., ND
3034′ 11,503′ –8469′
Foliated bt granodiorite

#1 S. William
5–137N–88W Grant Co., ND
2342′ 11,001′ –8659′
Not available

Shell Oil BN #21–35
35–131N–88W Grant Co., ND
2498′ 8817′ –6319′
Not available

Shell Oil #44–16 Hirn.-State
16–134N–87W Grant Co., ND
2293′ 9441′ –7148′
Hb gneiss

J.M. Johnson #1 Rahlf
5–146N–61W Griggs Co., ND
1471′ 2770′ –1299′
Bt granite

Amoco Production Co. #1 Rokusek
26–133N–93W Hettinger Co., ND
2517′ 10,726′ –8209′
Granodiorite gneiss

Magnolia Pet. #1 Dakota A
36–141N–73W Kidder Co., ND
1968′ 5604′ –3636′
Leucogranite

Carter Oil Co. #1 N.D. State
16–143N–71W Kidder Co., ND
1889′ 5139′ –3250′
Granite?

Champlin Oil Co. #1 E. Heim
12–133N–65W LaMoure Co., ND
1620′ 2779′ –1159′
Foliated bt granodiorite

Fort Union Pet. Cor. #1 Ryder
22–133N–61W LaMoure Co., ND
1435′ 1843′ –408′
Bt granodiorite gneiss

Wiser Oil Co. #1 Weigel
29–135N–73W Logan Co., ND
2117′ 5310′ –3193′
Not available

Calvert Expl. #1 Craig
25–136N–71W Logan Co., ND
1917′ 4557′ –2640′
Actinolite schist

Signal Drill. #1 A.F. Boehm
11–139N–82W Morton Co., ND
NA 4920′(TD) NA
Diorite?

Amerada Pet. Corp. #1 Meyer
34–135N–83W Morton Co., ND
2120′ 8194′ –6074′
Foliated bt granite

Phillips-Carter #1 Dakota
29–136N–81W Morton Co., ND
2005′ 7778′ –5776′
Bt epidote schist

Shell Oil #22027 Vogel
17–140N–82W Morton Co., ND
1994′ 8859′ –6865′
Chlorite schist

Bass Ent. Prod. #24–1 Andes
24–151N–89W Mountrail Co., ND
2133′ 13,436′ –11,303′
Hb-bt granodiorite

Marathon Oil #1 Olsen
16–153N–88W Mountrail Co., ND
2108′ 13,174′ –11,066′
Muscovite schist

Hunit Oil #1 Shoemaker
3–157N–78W McHenry Co., ND
595′ 7198′ –5603′
Bt granite

Atlantic Richfield #1 Wunderlich
22–151N–80W McHenry Co., ND
1915′ 8748′ –6833′
Chlorite schist

Calvert Expl. #1 Karl Schock
17–131N–69W McIntosh Co., ND
2143′ 3920′ –1777′
Bt granite

General Atlas #1 A. Kettering
15–131N–73W McIntosh Co., ND
2176′ 4772′ –2596′
Bt granite

Calvert Expl. #1 Nitschke
13–130N–69W McIntosh Co., ND
2042′ 3587′ –1545′
Bt trondhjemite

Calvert Expl. #1 J. Bender
19–130N–69W McIntosh Co., ND
2056′ 3818′ –1762′
Granite gneiss

Stanolind #1 McLean County
28–150N–80W McLean Co., ND
2100′ 8873′ –6773′
Not available

Sun Oil Fahlgren #1
34–148N–81W McLean Co., ND
1815′ 8657′ –6842′
Not available

Sun Oil Flemmer #1
31–146N–80W McLean Co., ND
1900′ 8912′ –7012′
Not available

Shell Oil #34x–6 USA
6–148N–104W McKen. Co., ND
2321′ 14,350′ –12,029′
Bt gneiss

Texaco #4 F.P. Keogh
5–151N–95W McKenzie Co., ND
1180′ 10,220′ –9040′
Not available

Shell Oil #42–8 USA
18–147N–103W McKenzie Co., ND
2221′ 14,413′ –12,192′
Not available

Amerada #1 Antelope Unit A
1–152N–95W McKenzie Co., ND
2117′ 15,123′ –13,006′
Charnockitic tonalite gneiss

#1 Leutz
28–142N–89W Mercer Co., ND
NA NA 12,526′
Granite

Jack Johnson #1 Gritz
6–151N–60W Nelson Co., ND
1496′ 2753′ –1257′
Chlorite schist

Oil Expl. #1 W. Fowler
18–152N–58W Nelson Co., ND
1528′ 2407′ –879′
Granodiorite

Jack Johnson #1 Haas
32–151N–61W Nelson Co., ND
1473′ 2907′ –1434′
Not available

Reel Foot Dev. #1 L.E. Bryl
5–152N–60W Nelson Co., ND
1521′ 2735′ –1214′
Hb schist, amphibolite

Cart Oil Co. #1 E.L. Semling
18–141N–81W Oliver Co., ND
2037′ 8841′ –6807′
Diabase

Amerada #1 Samson AKRA–2
11–161N–55W Pembina Co., ND
932′ 1390′ –458′
Iron-formation, metagraywacke

Amerada #1 Sellheim HENSEL–3
8–160N–54W Pembina Co., ND
899′ 1270′ –371′
Banded iron-formation

Amerada #1 Sellheim HENSEL–2
8–160N–54W Pembina Co., ND
899′ 1270′ –371′
Oxide iron-formation

Amerada #1 Sellheim HENSEL–1
8–160N–54W Pembina Co., ND
899′ 1270′ –371′
Bt schist

Turner Oil #1 Balanus
28–164N–56W Pembina Co., ND
952′ 1542′ –590′
Granodiorite gneiss

Town of Hamilton Well
35–162N–53W Pembina Co., ND
824′ 897′ –73′
"Blue" granite

Getty Oil #1 Vetter
34–152N–73W Pierce Co., ND
1563′ 5842′ –4279′
Not available

#1 Bell
28–158N–72W Pierce Co., ND
1570′ 5833′(TD)
Not available

Midwest Expl. #1 Heckman
12–158N–69W Pierce Co., ND
1587′ 4583′ –2996′
Bt granite

Shell Oil #1 Marchus
23–157N–70W Pierce Co., ND
1652′ 4994′ –3342′
Bt granite

Calvert Expl. #1 Haley
1–153N–63W Ramsey Co., ND
1489′ 3252′ –1763′
Hb bt granodiorite gneiss

Calvert Expl. #1 C. Jack
13–153N–63W Ramsey Co., ND
1487′ 3277′ –1790′
Bt gneiss

North. Natural Gas #1 R&B Lee
36–154N–63W Ramsey Co., ND
1522′ 3220′ –1698′
Altered chlorite gneiss

McLaughlin Inc. #1 Wolff
33–158N–62W Ramsey Co., ND
1534′ 3195′ –1661′
Foliated bt granite

Johnson #1 M.P. Wolff
17–158N–62W Ramsey Co., ND
1556′ 3269′ –1713′
Foliated bt granite

Union Oil #1 Aanstad
29–158N–62W Ramsey Co., ND
1544′ 3221′ –1677′
Foliated quartz monzonite

Johnson #1 Werner
11–158N–63W Ramsey Co., ND
1554′ 3335′ –1781′
Not available

Miller & Fox #1 Lorenz
32–156N–61W Ramsey Co., ND
1514′ 2967′ –1453′
Bt granite

John Black Estate #1 Miller
14–156N–62W Ramsey Co., ND
1510′ 3079′ –1569′
Not available

Carter Oil #1 A. McDiarmid
16–154N–65W Ramsey Co., ND
1487′ NA NA
Granodiorite gneiss

Russell Drill. #1 Jedro
2–163N–57W Ransom Co., ND
1350′ 3745′(TD)
Not available

Shell Oil #41x–16 Lindblad
16–163N–87W Renville Co., ND
NA NA 9692′
Garnet bt quartz monzonite

Shell Oil #23x–9 Larson
9–163N–87W Renville Co., ND
1807′ 9675′ –7868′
Chlorite schist

Shell Oil #23–10 Wisdahl
10–163N–87W Renville Co., ND
1703′ 9514′ –7811′
Bt tonalite gneiss

Great Yellowstone #1 Ones
1–162N–87W Renville Co., ND
1716′ 9848′ –8132′
Foliated bt granodiorite

#43–5 Duerre
5–163N–87W Renville Co., ND
1822′ 9546′ –7724′
Chlorite schist and porphyritic felsite

Shell Oil #14–34 Mott
34–164N–87W Renville Co., ND
1636′ 9190′ –7554′
Tonalite gneiss

Shell Oil #22x–1 Osterburg
1–161N–85W Renville Co., ND
1715′ 9310′ –7595′
Bt garnet gneiss

Shell Oil #21–2 Osterberg
2–161N–85W Renville Co., ND
1713′ 9262′ –7549′
Cordierite gneiss

Shell Oil #32x–3 Mott
3–163N–87W Renville Co., ND
1734′ 9197′ –7463′
Garnet bt gneiss

Shell Oil #33–3 Gilbertson
3–163N–87W Renville Co., ND
1645′ 9384′ –7739′
Not available

H.W. Snowdon #1 Ruddy
11–132N–48W Richland Co., ND
955′ 280′ +675′
Chlorite schist

Downing #1 Link
16–132N–49W Richland Co., ND
970′ 425′ +545′
Bt granodiorite

Water Well
22–130N–47W Richland Co., ND
975′ 215′ +760′
Granite

F.B. Downing #1 Heitkamp
7–132N–49W Richland Co., ND
945′ 400′ +545′
Bt trondhjemite

RRVDP 2 #2 Gaulker
19–130N–51W Richland Co., ND
1150′ 650′ +500′
Metagraywacke

RRVDP #2
24–130N–52W Richland Co., ND
Not available
Metagraywacke schist

RRVDP 4 #4 Selzer
11–132N–52W Richland Co., ND
1058′ 511′ +547′
Talc chlorite schist

RRVDP 6 #6 Solhjem
29–135N–52W Richland Co., ND
1065′ 630′ +435′
Sericite chlorite schist and meta-lapilli tuff

RRVDP 3–2 #3 Wieser
25–130N–49W Richland Co., ND
990′ 294′ +696′
Granodiorite gneiss

RRVDP 5 #5 Stallman
22–132N–50W Richland Co., ND
988′ 350′ +638′
Quartz monzonite

Evans Prod. Co. #1 Johnson
23–160N–70W Rolette Co., ND
1691′ 4947′ -3256′
Muscovite bt granite

Lion Oil Co. #1 Sebelius
23–161N–73W Rolette Co., ND
1627′ 5502′ -3875′
Bt granodiorite

Sargent Mining #1 Lampart
9–129N–58W Sargent Co., ND
1388′ 1192′ +196′
Bt granodiorite

RRVDP 1–2 #1 Hanson
NW11–130N–56W Sargent Co., ND
1270′ 820′ +450′
Metandesite tuff

RRVDP 1–1 #1 Hanson
11–130N–56W Sargent Co., ND
1270′ 820′ +450′
Metabasalt

Masbacher-Pruett #29–1 Dick
29–146N–76W Sheridan Co., ND
2007′ 7233′ -5226′
Bt granite

Gulf Leviathan #1–21–1B
21–138N–92W Stark Co., ND
2372′ 12,142′ -9770′
Not available

Russell Drilling Johnson #1
21–148N–56W Steele Co., ND
1398′ 1736′ -338′
Pink granite

Calvert Expl. #1 Ganser
12–140N–67W Stutsman Co., ND
1900′ 3937′ -2037′
Chlorite schist

Herman Hanson #1 Ogilvie
21–140N–65W Stutsman Co., ND
1473′ 3290′ -1817′
Granite

Herman Hanson #2 Mueller
20–140N–65W Stutsman Co., ND
1576′ 3308′ -1732′
Bt granodiorite gneiss

Kissinger Petroleum #1–28 Stern
28–137N–67W Stutsman Co., ND
2001′ 3858′ -1857′
Not available

Calvert Exploration #1 Wanzek
12–139N–67W Stutsman Co., ND
1874′ 3890′ -2016′
Foliated leucogranite

Calvert Exploration #1 Wood
24–139N–67W Stutsman Co., ND
1874′ 3701′ -1827′
Foliated bt granite

Butterfield #1 Trautman
5–139N–68W Stutsman Co., ND
1949′ 4297′ -2348′
Actinolite gneiss (schist)

Calvert Exploration #1 Rau
35–139N–68W Stutsman Co., ND
1880′ 4097′ -2217′
Bt granodiorite gneiss

Calvert Exploration #1 Robertson
26–138N–67W Stutsman Co., ND
1919′ 3678′ -1759′
Cataclastic granodiorite gneiss

Calvert Exploration #1 Meyer
25–137N–67W Stutsman Co., ND
1907′ 3695′ -1788′
Actinolite schist

General Atlas Car. #1 Barthel
15–142N–65W Stutsman Co., ND
1552′ 3426′ -1874′
Cataclastic bt granite gneiss

Barnett Drill. Inc. #1 Gaier
11–141N–67W Stutsman Co., ND
1863′ 4132′ -2269′
Bt granodiorite gneiss

General Atlas #1 Peplinski
21–142N–63W Stutsman Co., ND
1493′ 2917′ -1424′
Actinolite schist

Water Well (Lidiak)
15–148N–51W Traill Co., ND
943′ 468′ +475′
Granite

RRVDP 12 #12 Odegard
25–148N–50W Traill Co., ND
872′ 302′ +570′
Granodiorite gneiss

RRVDP 10 #10 Dalrymple
27–145N–52W Traill Co., ND
970′ 557′ +413′
Metabasalt

RRVDP 11–1 #11 Niemeier
21–148N–52W Traill Co., ND
1183′ 680′ +503′
Foliated granodiorite

RRVDP 11–2 #11 Niemeier
SE21–148N–52W Traill Co., ND
1183′ 680′ +503′
Trondhjemite gneiss

Rhodes #1 Murphy
18–163N–65W Towner Co., ND
1597′ 3787′ -2190′
Hb bt gneiss (tonalite)

Midwest Expl. #1 Jantenen
27–163N–68W Towner Co., ND
1714′ 4433′ -2719′
Hb bt granite

Union Oil of Calif. #1 Saari
35–161N–68W Towner Co., ND
1717′ 4498′ -2781′
Tonalite gneiss

Midwest Expl. #1 Union Centr.
24–160N–67W Towner Co., ND
1544′ 4064′ -2520′
Bt granite

National Bulk Car. #1 E.L. Hild
31–158N–66W Towner Co., ND
1465′ 4033′ -2568′
Bt granite

Rhodes #1 Gibbens
17–157N–65W Towner Co., ND
1499′ 3760′ -2261′
Not available

La Hab. & Natl Acc. #1 Dunlop
7–162N–68W Towner Co., ND
1761′ 4562′ -2801′
Bt granite, hb gneiss

W.H. Hunt #1 Wald
23–155N–81W Ward Co., ND
1595′ 8624′ -7029′
Granitoid

#1 Engen
24–156N–85W Ward Co., ND
1824′ 10,130′ -8306′
Not available

Canadian Dakota D. #1 Gaarder
8–156N–56W Walsh Co., ND
1186′ 1804′ -618′
Granodiorite gneiss

RRVDP 18 #18 Schuster
8–156N–51W Walsh Co., ND
805′ 644′ +161′
Granodiorite gneiss

Town of Grafton Well
13–157N–53W Walsh Co., ND
834′ 903′ -69′
Gray granite

RRVDP 17 #17 Kilichowski
9–155N–52W Walsh Co., ND
822′ 784′ +38′
Granitoid gneiss

RRVDP 19 AB #19AB Bjorneby
30–158N–54W Walsh Co., ND
902′ 1291′ -389′
Granodiorite gneiss

Traugott Drill. #1 H. Bakke
9–156N–58W Walsh Co., ND
1562′ 2488′ -926′
Bt tonalite gneiss

Calvert Expl. #1 Zwingler
8–146N–68W Wells Co., ND
1608′ 4372′ -2764′
Granodiorite gneiss

Continental Oil #1 Leuth
27–146N–73W Wells Co., ND
1933′ 6020′ - 4087′
Trondhjemite

Caroline Leitner Hunt Trust #1
14–148N–71W Wells Co., ND
1612′ 5180′ -3568′
Chlorite schist

True Oil Co., Julier 31–35
25–148N–70W Wells Co., ND
1609′ 4800′ -3191′
Not available

Amerada #3 Beaver Lodge U
1–155N–96W Williams Co., ND
2370′ 14,564′ –12,194′
Bt syenite

Amerada #1 Nils Trogstad
17–156N–103W Williams Co., ND
2413′ 14,379′ –11,966′
Bt tonalite gneiss

Amerada #9 A Unit
16–156N–95W Williams Co., ND
2360′ 14,795′ –12,435′
Charnockitic tonalite

Amerada #9 ND C B
36–158N–95W Williams Co., ND
2457′ 14,286′ –11,829′
Bt trondhjemite

Amerada #1 Iverson-Nelson
2–155N–96W Williams Co., ND
2316′ 13,587′ –11,271′
Monzonite

Amerada #1 Lalim-Ives
26–158N–95W Williams Co., ND
2460′ 13,742′ –11,282′
Foliated bt granodiorite

Amerada #1 Ulven Unit
34–156N–96W Williams Co., ND
2286′ 14,458′ –12,172′
Not available

Amerada #1 Olsen Unit
15–155N–96W Williams Co., ND
2255′ 14,145′ –11,890′
Monzonite

Walter Scott (Stoila)
1–104N–64W Aurora Co., SD
1450′ 554′ +901′
Quartzite

White Lake City
11–103N–66W Aurora Co., SD
1644′ 855′ +789′
Quartzite

M & M #1 Hoefert
28–104N–63W Aurora Co., SD
1375′ 953′ +422′
Dark-gray granite

Exxon #W-3
16–105N–63W Aurora Co., SD
NA NA +385′
Augen gneiss

Huron City #3
1–110N–62W Beadle Co., SD
1280′KB 1090′ +190′
Granite

Wolsey #1 Kuschow
2–111N–64W Beadle Co., SD
1325′ 1163′ +162′
Red granite

Dept. of Game
17–110N–62W Beadle Co., SD
1290′ 1176′ +114′
Granite

Pullman #1 Restlawn
1–109N–62W Beadle Co., SD
NA NA +98′
Light-gray metamorphics

USGS #1 Huron
9–110N–62W Beadle Co., SD
NA NA +52′
Gneiss

SD #1 Fairgrounds
36–11N–62W Beadle Co., SD
NA NA +112′
Bt granite

Kleinsasser
4–113N–60W Beadle Co., SD
NA NA +240′
Red granite

Waters Farm
12–113N–60W Beadle Co., SD
NA NA +410′
Granite

Gulf Oil #1 Jacquot
10–39N–37W Bennett Co., SD
NA 4551′(TD) –1640′
Granite fragments, mica

KGS #1 Ferley
10–36N–35W Bennett Co., SD
NA NA -1295′
Granite

Bon Oil #1 Nick Jelsma
10–93N–60W Bon Homme Co., SD
1325′ 940′ +385′
Quartzite

Bon Oil #1 Isaac Byrne
8–93N–59W Bon Homme Co., SD
1372′ 851′ +521′
Quartzite

Scotland City
8–96N–58W Bon Homme Co., SD
1340′ 685′ +655′
Quartzite?

Kleinjam
25–11N–52W Brookings Co., SD
1690′ 1180′ +510′
Granodiorite

Aberdeen Well #3
23–123N–64W Brown Co., SD
1300′ 1300′ 0′
Granite?

#1 Harvey Carr
19–126N–60W Brown Co., SD
1305′ 900′ +405′
Granite

#7 W.A. Raetzman
33–125N–65W Brown Co., SD
1522′ 1520′ +2′
Granite

Sperry Farm
20–123N–62W Brown Co., SD
NA NA +99′
Crystalline rock

Aberdeen #1 City
18–123N–64W Brown Co., SD
NA NA +23′
Red granite

Oil Hunters #1 Raetzman
33–125N–65W Brown Co., SD
NA NA -100′
Not available

Barnes Farm
35–126N–60W Brown Co., SD
NA NA +285′
Crystalline rock

Peldo Farm
33–128N–64W Brown Co., SD
NA NA -33′
Crystalline rock

Kimball City Well
3–103N–68W Brule Co., SD
Not available
Quartzite

Hutmacker Bros.
7–105N–70W Brule Co., SD
NA NA +373′
Quartz diorite

Kucera-Winkler #1 Biskeborn
14–103N–71W Brule Co., SD
1684′ 1365′ +319′
Quartzite, granite?

Wagner #1 Glaus, W.
28–104N–71W Brule Co., SD
1716′ 1428′ +288′
Quartzite

Mobil #F–11 Sipila F–11–14P
14–9N–8E Butte Co., SD
2873′ 6314′ -3441′
Bt gneiss

Mobil Oil #1 Mickelson
7–9N–9E Butte Co., SD
2848′ 7085′ -4237′
Gneiss

Palensky #1 Wagner 1A
NESW15–95N–64W Charles Mix Co., SD
1725′ 1453′ +272′
Quartzite?

Palensky #1 1B
NESW15–95N–64W Charles Mix Co., SD
1728′ 1385′ +343′
Quartzite

#1 Wilson
15–95N–64W Charles Mix Co., SD
1696′ 4200′ -2504′
Not available

Clark Co. Well
4–113N–58W Clark Co., SD
NA NA +510′
Granite

Bohric Bros.
22–117N–59W Clark Co., SD
NA NA +292′
Granite

S.D.G.S. Core Shed
14–92N–52W Clay Co., SD
NA NA +548′
Granitoid

Match #1 Drake
10–119N–51W Codington Co., SD
1899′ 1266′ +633′
Crystalline rock fragments

Watertown Substations
2–116N–52W Codington Co., SD
NA NA +519′
Crystalline rock

#1 Chevron-Sonat-Zubrod
18–22N–21E Corson Co., SD
NA NA –5455′
Orange granite

A.M. Bartlett #1 Guyer
20–23N–23E Corson Co., SD
2350′ 7650′ –5300′
Pink granite

Shell #1 J.K. Winter
11–22N–19E Corson Co., SD
2491′ 8433′ –5942′
Bt granite

Arco #1 Weddell
33–18N–21E Corson Co., SD
NA NA –4600′
Gray and pink granite

Jewel Cave National Monument
2–4S–2E Custer Co., SD
5430′ 665′ +4765′
Schist

Smith and Davidson
28–103N–60W Davison Co., SD
Not available
Bt granite

#1 Smith & Davidson
25–103N–61W Davison Co., SD
1360′ 500′ +860′
Bt granodiorite

Oil Venturer Gas #1 Naessig
32–121N–55W Day Co., SD
1838′ 1552′ +286′
Granite

AMAX–Bristol #1 Proj. 242
29–122N–57W Day Co., SD
1800′ 1500′ +300′
Schist

Mason-Rust O.S.W. #1
35–122N–56W Day Co., SD
1817′ 1610′ +207′
Not available

Kerr-McGee Oil #1 W. Cook
32–13N–22E Dewey Co., SD
2358′ 5938′ –3580′
Gneiss

Gulf #1 Jewett
13–13N–27E Dewey Co., SD
2700′ 5343′(TD) –2643′
Mica schist

Youngblood & Y. #1 G.J. Glavin
25–16N–22E Dewey Co., SD
2288′ 6289′ –4001′
Chlorite muscovite schist

#1 Cowan
21–13N–22E Dewey Co., SD
2300′ 5703′ –3403′
Not available

Texaco #1 State C
15–17N–25E Dewey Co., SD
NA NA –3679′
Bt granite

Texaco #1 Yuker Net
16–17N–26E Dewey Co., SD
NA NA –3574′
Red and gray granite

#1 Astoria
36–113N–48W Deuel Co., SD
1835′ 1060′ +775′
Schist

SDGS #3 Coteau
36–113N–48W Deuel Co., SD
NA NA +800′
Metamorphic rock

County Well #4 Hillside
18–100N–62W Douglas Co., SD
1630′ 1025′ +605′
Hornfels

County #1 Corson
26–100N–64W Douglas Co., SD
NA NA +613′
Granite

Douglas County Well Armour
7–98N–63W Douglas Co., SD
NA NA +613′
Quartzite

Douglas #1 Clark
5–98N–64W Douglas Co., SD
1600′ 1306′ +292′
Quartzite

Amerada #1 Voorhees
25–10S–8E Fall River Co., SD
3332′ 4120′ –788′
Granite and schist

Lakota Dev. #1 Knude-Shiloh
20–10S–4E Fall River Co., SD
3615′ 3238′ +377′
Granite

Black Hills Ordinance #1 Provo
3–10S–2E Fall River Co., SD
3655′ 3910′ –255′
Bt schist

Amerada #1 Perry Moody
8–12S–6E Fall River Co., SD
3652′ 4965′ –1313′
Quartzite

Interior Oil #1 Putnam
30–10S–8E Fall River Co., SD
3389′ 4085′ –696′
Pink granite

P & M Stagecoach #13–4
4–12S–1E Fall River Co., SD
NA NA –570′
Light-red granite

Integrity #1 Hunter
4–12S–4E Fall River Co., SD
NA NA –273′
Light-red granite

Pac. Amer. Rapid City Sin. #1
21–7S–5E Fall River Co., SD
4260′ 1115′ +3145′
Not available

N.B. Hunt #1 Gutenkauf
20–118N–72W Faulk Co., SD
1940′ 2735′ –795′
Granite

Milbank #2
7–120N–48W Grant Co., SD
1150′ 315′ +835′
Granite

Milbank City well #1
12–120N–48W Grant Co., SD
NA NA +868′
Not available

Not available
25–118N–48W Grant Co., SD
NA NA +992′
Red granite

Buckhorn #14–2 State
25–97N–70W Gregory Co., SD
NA NA –71′
Gray rhyolite

Buckhorn #13–7 Englemeyer
7–97N–71W Gregory Co., SD
NA NA –108′
Red basalt

Buckhorn #1–12 Bennett
12–98N–73W Gregory Co., SD
NA NA –128′
Felsite

Buckhorn #10–12 Inglett
20–99N–71W Gregory Co., SD
NA NA –8′
Rhyolite

Buckhorn #15–10 Duling
10–99N–72W Gregory Co., SD
NA NA –50′
Basalt?

Buckhorn #13–36 State
36–100N–73W Gregory Co., SD
NA NA –107′
Basalt

Kerr-McGee Oil F.H. Chute
33–3N–19E Haakon Co., SD
2620′ NA –2802′
Quartz monzonite

Texaco 1–B State B
36–6N–21E Haakon Co., SD
2147′ 4792′ –2645′
Granite

Exeter Drill. #6–13 N. Grain
6–4N–21E Haakon Co., SD
2370′ 5006′ –2636′
Granite

F.E. Pohle #1 May
21–4N–18E Haakon Co., SD
2586′ 5550′ –2964′
Granite

Gulf Oil #1 C.E. Harry
4–3N–23E Haakon Co., SD
2228′ 4631′ –2403′
Granite

Gulf Oil #1 Fenwick
31–4N–24E Haakon Co., SD
NA NA –1678′
Felsic rock fragments

Phillip City Well
1–1N–20E Haakon Co., SD
2245′ 3730′ –1485′
Granite

#1 R. Harvey
4–109N–70W Hand Co., SD
1875′ 1935′ –60′
Granite

USGS Test Hole S.D. 17C
?–110N–67W Hand Co., SD
Not available
Gabbro

Mehling Ranch
27–11N–66W Hand Co., SD
NA NA +207′
Crystalline rock

Ralph Denner #1 Dennis Farm
18–104N–57W Hanson Co., SD
1360′ 538′ +822′
Quartzite

F.G. Butler
16–104N–57W Hanson Co., SD
1360′ 570′ +790′
Granite

SDGS Test Well
24–104N–57W Hanson Co., SD
NA NA +910′
Diabase

Not available
17–104N–57W Hanson Co., SD
NA NA +860′
Gray granite

N ot available
19–104N–57W Hanson Co., SD
NA NA +823′
Gray granite

Not available
24–104N–58W Hanson Co., SD
NA NA +838′
Granite

Not available
25–104N–58W Hanson Co., SD
NA NA +852′
Diabase

Alexandra #1 City
10–102N–58W Hanson Co., SD
NA NA +801′
Pyropholite (clay)

Emil G. Delma or unknown
7–102N–59W Hanson Co., SD
Not available
Quartzite

Ohio #1 P.D. Evenson
28–21N–1E Harding Co., SD
3175′ 8836′ –5661′
Muscovite biotite granodiorite

Texaco 1–A State of SD
35–18N–4E Harding Co., SD
3026′ 8758′ –5732′
Not available

Depco Inc. #22–24 Travers
24–22N–4E Harding Co., SD
NA 9185′(TD) NA
Basalt

Alpher #1–2 Clarkson
12–21N–4E Harding Co., SD
NA NA –6635′
Crystalline rock

Ohio Oil #1 Reinschmidt
27–112N–76W Hughes Co., SD
1709′ 2563′ –854′
Granite

#1 Pierre Airport
35–111N–79W Hughes Co., SD
1718′ 2370′ –652′
Gray granite

Menno City well or unknown
10–97N–57W Hutchinson Co., SD
1325′ 360′ +965′
Quartzite

Leo B. Pietz
29–99N–59W Hutchinson Co., SD
1310′ 356′ +954′
Quartzite

Massey Farm Well
1–97N–56W Hutchinson Co., SD
1622′ 548′ +1074′
Quartzite

Unnamed
31–98N–57W Hutchinson Co., SD
Not available
Quartzite

#1 S. Mendel Farm
9–99N–56W Hutchinson Co., SD
1458′ 324′ +1134′
Quartzite

#1 Wagner
17–99N–61W Hutchinson Co., SD
1540′ 678′ +862′
Quartzite

#1 M.A. Esoph
2–116N–71W Hyde Co., SD
1960′ 2185′ –225′
Granite

#3 School
31–116N–73W Hyde Co., SD
1904′ 2689′ –785′
Red granite

Hunt #2 School #2 State
24–116N–73W Hyde Co., SD
1889′ 2555′ –666′
Basalt

#1 Buckles-Martin
3–3S–19E Jackson Co., SD
2397′ 4139′ –1742′
Granite

Cities Service #1 Vilharer
17–2S–25E Jackson Co., SD
2332′ 4170′ –1838′
Granite

#1 Renning
35–1S–22E Jackson Co., SD
2516′ 4650′ –2134′
Granite

Sorelle & Sorelle
16–1S–22E Jackson Co., SD
2416′ 4740′ –2324′
Hb-bt schist, red and gray granite

State #1 Nesco Inc.
8–1S–22E Jackson Co., SD
2350′ 4753′ –2403′
Granite

Cities Service #1A Phipps
4–2S–23E Jackson Co., SD
2326′ 4435′ –2109′
Quartzite

#1 Schubert School
9–107N–65W Jerauld Co., SD
1910′ 1700′ +210′
Quartz monzonite

Exxon #14–2
15–106N–63W Jerauld Co., SD
NA NA +265′
Gneiss

Exxon #14–1
35–107N–63W Jerauld Co., SD
NA NA +280′
Gneiss

Shell Oil #2 A.E. Herman
3–1N–29E Jones Co., SD
2116′ 3218′ –1102′
Gabbro

Shell Oil #1 A.E. Herman
15–1N–29E Jones Co., SD
2084′ 2533′ –449′
Quartzite

Herman Estate #1
3–1N–29E Jones Co., SD
2023′ 2632′ –609′
Quartzite

Shell Oil #1 Wilbur Olsen
8–2N–26E Jones Co., SD
NA NA –1603′
Granite

Gulf Oil #1 Hulse
29–2S–31E Jones Co., SD
2123′ 2580′ –457′
Quartzite

Gulf Oil #1 State
2–4S–28E Jones Co., SD
1874′ 3180′ –1306′
Red granite

#1 Dahlke
4–3S–30E Jones Co., SD
1994′ NA –988′
Quartzite

#1 Sandy
21–2S–27E Jones Co., SD
2178′ 3723′ –1545′
Quartzite

Gulf Oil #1 Hight
15–3S–29E Jones Co., SD
2080′ 3330′ –1250′
Granite

Murdo City
36–1S–28E Jones Co., SD
NA NA –1023′
Precambrian rocks?

Tenneco #1 Herman
10–1N–29E Jones Co., SD
NA NA –565′
Quartzite

#1 Wallace Brown
24–109N–56W Kingsbury Co., SD
1720′ 1155′ +565′
Andesite/latite

Jerald Tonsager Farm Well
15–109N–54W Kingsbury Co., SD
1745′ 1040′ +705′
Andesite/latite

Atchinson Farm
16–111N–58W Kingsbury Co., SD
NA NA +375′
Crystalline rock

#1 Carmody
15–108N–54W Lake Co., SD
1750′ 752′ +998′
Not available

Madison #1 City
7–106N–52W Lake Co., SD
372′ NA NA
Hb schist

Can.-Inwood Hos. #1 Can. City
23–98N–49W Lincoln Co., SD
Not available
Granitoid

#1 P. Loeman Farm
14–100N–49W Lincoln Co., SD
1422′ 260′ +1162′
Quartzite

D. Manson #1 Peterson
18–98N–49W Lincoln Co., SD
1350′ 686′ +664′
Quartzite

#1 Ben Knock
31–98N–51W Lincoln Co., SD
1275′ 255′ +1020′
Quartzite

Buell Kittleson Farm
35–97N–50W Lincoln Co., SD
1470′ 570′ +900′
Graywacke?

Vogers Farm Well
9–98N–50W Lincoln Co., SD
NA NA +668′
Quartzite

Wolf #1 State
16–104N–78W Lyman Co., SD
1847′ 2165′ -318′
Quartzite

Gulf Oil #1 Hutchinson
4–103N–77W Lyman Co., SD
1864′ 2452′ -588′
Granite

Gulf Oil #1 J.A. Hutchinson
24–103N–77W Lyman Co., SD
1829′ 2410′ -581′
Pink granite

Red Butte #1 Burkhardt
6–104N–74W Lyman Co., SD
1779′ 1778′ +1′
Basalt

? Schlaikjer #1 Winter
24–101N–72W Lyman Co., SD
1846′ NA NA
Gray schist (Schoon) or granite (Klasner)

Carlon Well #1
15–106N–73W Lyman Co., SD
Not available
Gabbro

General Crude #1 J. Starka
22–105N–72W Lyman Co., SD
1731′ 1444′ +287′
Quartzite

AMAX #1 Langford
12–125N–59W Marshall Co., SD
1309′ 912′ +397′
Phyllite/quartzite

Dalton Doctor
20–126N–59W Marshall Co., SD
1302′ 925′ +377′
Granite

Harvey Carr Water Well
19–126N–59W Marshall Co., SD
1305′ 927′ +378′
Granodiorite

#1 Veblen City
22–128N–53W Marshall Co., SD
1270′ NA NA
Schist

Langford #1 City
29–125N–58W Marshall Co., SD
NA NA +247′
Granite

Canistota State Vermill. River
34–102N–53W McCook Co., SD
1435′ 245′ +1190′
Quartzite

Vasgaard Ellis Bros. Farm
12–103N–53W McCook Co., SD
Not available
Quartzite

Lyle DeKramer
27–102N–54W McCook Co., SD
1540′ 273′ +1267′
Granite

Harold Zelmer Water Well
4–102N–56W McCook Co., SD
Not available
Granite

Bear Butte #1 Milne
19–6N–6E Meade Co., SD
NA NA +2380′
Granite?

Camac #27–1 Nelson
27–10N–14E Meade Co., SD
NA NA -4250′
Bt granite

#1 R. Olson
14–43N–29W Mellette Co., SD
1828′ 3163′ -1335′
Bt granite

Gulf Oil #1 Rosebud Sioux
23–43N–29W Mellette Co., SD
1922′ 3270′ -1348′
Light-pink granite

Lawrence Beck Farm
16–105N–58W Miner Co., SD
1315′KB 160′ +1155′
Quartzite

Howard City
NW2–106N–56W Miner Co., SD
1550′ 685′ +865′
Quartzite?

L. Hinker
NW2–106N–56W Miner Co., SD
1570′ 585′ +985′
Quartzite?

Rocky Ridge #1 Hale
25–108N–57W Miner Co., SD
1539′ 1320′ +219′
Granite

Alexander
30–108N–57W Miner Co., SD
1420′ 557′ +863′
Diorite

SDGS #1 Conove
19–105N–55W Miner Co., SD
NA NA +905′
Diabase (+175)

Chave Farm Well
19–108N–58W Miner Co., SD
NA NA +954′
Quartzite

Phillips Exploration
15–102N–48W Minnehaha Co., SD
Not available
Diabase, claystone, quartzite

Phillips Exploration
22–105N–48W Minnehaha Co., SD
Not available
Diabase, claystone

Borehole #1
30–102N–48W Minnehaha Co., SD
NA 136′TD NA
Quartzite

SDGS #1 Minnehaha
28–101N–48W Minnehaha Co., SD
NA NA +1198′
Diabase

SDGS #1 Renner
5–102N–49W Minnehaha Co., SD
NA NA +1350′
Diabase

SDGS #1 Colton
35–104N–51W Minnehaha Co., SD
NA NA +1397′
Diabase

SDGS #1 Moody
27–105N–47W Moody Co., SD
NA NA +1250′
Quartzite

Jasper Syndicate
13–105N–48W Moody Co., SD
NA NA +618′
Precambrian

Kerr MeGee
1–106N–49W Moody Co., SD
Not available
Granite

Kerr McGee
10–107N–49W Moody Co., SD
Not available
Dark-gray basalt

Kerr McGee
30–107N–50W Moody Co., SD
Not available
Rhyolite

Wheless Drill. Fed. #10–8
10–4S–16E Pennington Co., SD
2445′ 4593′ –2148′
Granite

Wasta Well
9–1N–14E Pennington Co., SD
Not available
Graywacke

Saga #1 Clark 12–4
12–2N–17E Pennington Co., SD
NA NA –2818′
Orange granite, schist

BHP #41–1 State
1–2N–16E Pennington Co., SD
NA NA –3000′
Schist

Texas Pacific Oil #1 Elson
24–19N–16E Perkins Co., SD
2555′ 8310′ –5755′
Red bt granite

Shell Oil #1 J.H. Homme
13–20N–12E Perkins Co., SD
2768′ 9325′ –6557′
Bt (chloritized) granite

Shell Oil #1 H.D. Veal
7–17N–15E Perkins Co., SD
2672′ 8287′ –5615′
Muscovite bt granite

J.P. Evans #1 Querbes Trust
9–13N–16E Perkins Co., SD
2570′ 7307′ –4737′
Graywacke?

Dakota Tex. Oil #1 Wms.-Tmps.
27–119N–78W Potter Co., SD
1899′ 3710′ –1811′
Granite

Carter Oil #1 Whit.-Smith
34–118N–78W Potter Co., SD
1867′ 3580′ –1713′
Layered bt and bt hb gneiss

Sather Farm
18–127N–50W Roberts Co., SD
NA NA +420′
Crystalline rock

J. Grassell
21–108N–59W Sanborn Co., SD
1343′ 675′ +668′
Porphyritic rhyolite

Exxon #5–1
13–108N–62W Sanborn Co., SD
NA NA +270′
Bt gneiss

Ketcher City
15–105N–61W Sanborn Co., SD
NA NA +570′
Precambrian

S.D. Amerada #1 Red Eagle
25–36N–48W Shannon Co., SD
3346′ 3358′ –12′
Granite

Intergrity #1 Pine Ridge
35–36N–48W Shannon Co., SD
NA NA –119′
Granite

S.D. Oil Develop. #2 Dvorak
28–117N–63W Spink Co., SD
1279′ 1105′ +174′
Not available

Redfield Asylum
3–116N–64W Spink Co., SD
1300′ 1520′ –220′
Granite gneiss

S.S. Budlong
18–114N–62W Spink Co., SD
1310′ 922′ +388′
Granite

Hitchcock-Gliddon
32–114N–63W Spink Co., SD
NA NA +168′
Granite

Motley Well
7–115N–61W Spink Co., SD
NA NA +280′
Chlorite schist

Wyly-Shaffner, et al.
26–6N–27E Stanley Co., SD
2085′ 3893′ –1808′
Quartzite

Gulf Oil #1 Stanley-Federal
22–8N–26E Stanley Co., SD
1700′ 3986′ –2286′
Quartzite

Phillips #1 Dakota
16–8N–27E Stanley Co., SD
2186′ 4193′ –2007′
Granite

Tenneco #1 Rankin-Trust
10–4N–28E Stanley Co., SD
1848′ 2728′ –880′
Quartzite

Tenneco #1 Frank Hall
11–3N–27E Stanley Co., SD
1816′ 2774′ –958′
Quartzite

Shell Oil #1 McCrone
23–3N–25E Stanley Co., SD
2035′ 3989′ –1954′
Granite?

Shell Oil #1 C.C. Abbot
9–4N–27E Stanley Co., SD
2033′ 2730′ –697′
Granite?

Phillips #1 State-Stanley Fed.
36–5N–27E Stanley Co., SD
1862′ 2690′ –828′
Quartzite

Phillips #1 Lang
26–5N–28E Stanley Co., SD
1990′ 2380′ –390′
Quartzite

Shamrock #1 W.N. Barrick
23–7N–26E Stanley Co., SD
1945′ 4070′ –2125′
Granite

Cities Service #1 Barrick-Triple
18–7N–28E Stanley Co., SD
2082′ 3980′ –1898′
Granite

Shamrock #1 Barrick
29–8N–27E Stanley Co., SD
1827′ 3915′ –2088′
Granitoid, pyroxenite

Carter Oil #1 Loucks
12–9N–27E Stanley Co., SD
1788′ 3880′ –2092′
Diorite

Cities Service #1 Wagner
13–5N–29E Stanley Co., SD
1314′ 2810′ –1496′
Granite

True #23–14 Prince
14–5N–27E Stanley Co., SD
NA NA –842′
Quartzite

True #23–8 Barrick
8–5N–28E Stanley Co., SD
NA NA –1293′
Quartzite

Phillips #1 State-Dak.
19–6N–27E Stanley Co., SD
NA NA –2029′
Red granite

Tribal Land
7–38N–31W Todd Co., SD
2730′ 3394′ –664′
Granite

Gulf #1 Keyapaha-State
22–96N–79W Tripp Co., SD
2328′ 2980′ –652′
Light-pink granite

Gulf #1 Swedlund
11–102N–78W Tripp Co., SD
1951′ 2580′ –629′
Not available

General Crude #1 Assman Ranch
22–98N–78W Tripp Co., SD
2335′ 3008′ –673′
Granite gneiss

General Crude #1 H.J. Vogt
25–99N–79W Tripp Co., SD
2165′ 2875′ –710′
Granitoid

Kuchera #1 Bartels
23–100N–77W Tripp Co., SD
1874′ 2368′ –494′
Granite

#1 Kossitzky
24–102N–77W Tripp Co., SD
1699′ 2241′ –542′
Granite

General Crude #1 G. Shippy, Jr.
5–96N–75W Tripp Co., SD
2289′ 2720′ –431′
Granite

General Crude #1 Rural Credit
33–95N–77W Tripp Co., SD
2365′ 2868′ –503′
Granite

Carter Unit #1 McCullum
22–99N–79W Tripp Co., SD
NA NA –687′
Gray granite

C.J. Wheeldrier
34–100N–52W Turner Co., SD
1470′ 147′ +1323′
Graywacke

Laverne Herlyn
18–100N–54W Turner Co., SD
1460′ 200′ +1260′
Hb schist? overlain by quartzite?

Turner County Test #7
32–100N–52W Turner Co., SD
1410′ 93′ +1317′
Quartzite

Wier
8–97N–55W Turner Co., SD
1710′ 594′ +1116′
Quartzite?

Tieszen #1 Alhbrecht
13–99N–55W Turner Co., SD
1450′ 380′ +1070′
Quartzite

Herrig Farm
14–97N–55W Turner Co., SD
NA NA +885′
Quartzite

Viborg City
35–97N–53W Turner Co., SD
NA NA +605′
Quartzite

Wagner #1 Blanchard
29–92N–49W Turner Co., SD
1170′ 840′ +330′
Bt granite

Wagner #1 Larson
29–93N–50W Union Co., SD
1207′ 585′ +622′
Pink granite

Sioux Valley #1 La Fleur
18–90N–48W Union Co., SD
1112′ 1029′ +83′
Granite

SDGS #1 Huebner
25–93N–50W Union Co., SD
1260′ 791′ +469′
Gabbro

#1 O'Connor
31–94N–50W Union Co., SD
1249′ 655′ +594′
Quartzite

Peppers Ref. Co. #1 State-Fee
36–123N–76W Walworth Co., SD
2064′ 3895′ –1831′
Bt (chloritized) granite

Max Pray #1 Kranzler
14–121N–77W Walworth Co., SD
1881′ 3805′ –1924′
Bt schist and granite

Gulf #1 I. Barber
11–40N–35W Washabaugh Co., SD
2607′ 4351′ –1744′
Pink granite

Merle Johnson Farm
10–95N–54W Yankton Co., SD
1537′ 768′ +769′
Quartzite

Rittershaus #1 Jamesville
29–96N–56W Yankton Co., SD
1160′ 738′ +422′
Diabase and basalt

Westside City Well, Yankton
13–93N–56W Yankton Co., SD
NA NA +281′
Chlorite schist or granite

SDGS #1 Holzbauer
12–93N–55W Yankton Co., SD
1170′ 755′ +415′
Gabbro

Yankton City Well
14–93N–56W Yankton Co., SD
1246′ 676′ +570′
Granite

Crawford 21–7
21–25N–51W Box Butte Co., NE
4277′ 6223′ –1946′
Not available

Bird-Hain #31–15
31–26N–52W Box Butte Co., NE
4366′ 6620′ –2254′
Hb gneiss

Huckle #1
19–27N–49W Box Butte Co., NE
4135′ 5434′ –1299′
Bt hb gneiss

Manning #34–12
34–27N–52W Box Butte Co., NE
4531′ 6552′ –2021′
Gneiss?

Hughes #1
2–28N–47W Box Butte Co., NE
3807′ 3866′ –59′
Not available

Wildy #1
1–28N–48W Box Butte Co., NE
3965′ 4358′ –393′
Quartz diorite

Lanson-Wiggens #1
18–25N–29W Cherry Co., NE
3070′ 4187′ –1117′
Quartzite/granofels

Monahan #1
23–25N–35W Cherry Co., NE
3474′ 4232′ –758′
Graphic granite

Starr #1
34–26N–32W Cherry Co., NE
3294′ 4332′ –1038′
Granofels? granite

Roseberry #1
28–28N–28W Cherry Co., NE
2942′ 3851′ –909′
Not available

Hanna #1
28–28N–30W Cherry Co., NE
3013′ 4185′ –1172′
Bt granite

Chadron #1
29–28N–34W Cherry Co., NE
3374′ 4507′ –1133′
Not available

Saultz
12–29N–37W Cherry Co., NE
3487′ 4400′ –913′
Granite, diabase

Hull
11–29N–40W Cherry Co., NE
3823′ 4535′ –712′
Gneissic granite

Bachelor Ranch #1
25–30N–33W Cherry Co., NE
3131′ 4333′ –1202′
Quartz-feldspar gneiss

Vinton #1
13–30N–39W Cherry Co., NE
3537′ 4411′ –874′
Schist

Federal #28–1
28–31N–31W Cherry Co., NE
3017′ 4155′ –1138′
Granite?

Churn
1–31N–36W Cherry Co., NE
3359′ 4535′ –1176′
Granofels, granite?

Leach #1
23–31N–38W Cherry Co., NE
3506′ 4562′ –1056′
Gneiss, diorite?

Shald #1
30–32N–39W Cherry Co., NE
3429′ 4255′ –826′
Granite?

Anderson #5–16
16–33N–25W Cherry Co., NE
2552′ 3067′ –515′
Gneissic granite?

McGinley #1
32–33N–26W Cherry Co., NE
2709′ 3328′ –619′
Bt schist?

Borman #1
5–33N–27W Cherry Co., NE
2564′ 3188′ –624′
Gneiss, granite?

Cole #1
12–33N–37W Cherry Co., NE
3225′ 4639′ –1414′
Granite

Krell #1
19–33N–40W Cherry Co., NE
3649′ 4273′ –624′
Granofels

Gaskins #1
28–35N–34W Cherry Co., NE
3236′ 4590′ –1354′
Not available

Colwell #1
13–29N–47W Dawes Co., NE
3861′ 3510′ +351′
Bt hb gneiss

State #1
16–29N–49W Dawes Co., NE
4147′ 4930′ –783′
Chlorite granodiorite

Kudrna #1
22–30N–47W Dawes Co., NE
4081′ 3581′ +500′
Pegmatitic granite

Arner #1
14–30N–48W Dawes Co., NE
4153′ 4475′ –322′
Granite

Moody #2–14
14–30N–49W Dawes Co., NE
4261′ 4980′ –719′
Not available

Hulseman #1
14–30N–50W Dawes Co., NE
4386′ 5352′ –966′
Not available

Soester #1
2–30N–51W Dawes Co., NE
4519′ 5730′ –1211′
Metadiabase

Wolvington #1
7–31N–47W Dawes Co., NE
4290′ 4438′ –148′
Muscovite granite

Federal #1
22–31N–49W Dawes Co., NE
4105′ 4970′ –865′
Bt muscovite schist

Deans #1
28–31N–49W Dawes Co., NE
4416′ 5212′ –796′
Foliated granodiorite

State #34–16
16–31N–50W Dawes Co., NE
3954′ 5175′ –1221′
Not available

Richardson #1
11–31N–51W Dawes Co., NE
3785′ 5051′ –1266′
Metadiabase

Bunch #1
5–31N–51W Dawes Co., NE
3728′ 5111′ –1383′
Not available

Federal #1
17–31N–52W Dawes Co., NE
3754′ 5360′ –1606′
Actinolite chlorite schist

Murdock #1
19–32N–48W Dawes Co., NE
3856′ 4660′ –804′
Cataclastic quartz diorite

Goeffena #44–10
10–32N–49W Dawes Co., NE
3651′ 4570′ –919′
Not available

Amcrada #1
32–32N–50W Dawes Co., NE
3674′ 4962′ –1288′
Chlorite schist

Lawrence #1
6–32N–51W Dawes Co., NE
3512′ 5115′ –1603′
Bt granodiorite

Ostermeyer #1
10–32N–52W Dawes Co., NE
3649′ 5094′ –1445′
Altered muscovite granite

State #11–36
36–32N–52W Dawes Co., NE
3628′ 5112′ –1484′
Not available

Augustine #1
27–33N–47W Dawes Co., NE
3640′ 4118′ –478′
Bt hb gneiss

State #1
16–33N–49W Dawes Co., NE
3290′ 4489′ –1199′
Foliated adamellite

Morrell #1
2–33N–50W Dawes Co., NE
3423′ 4859′ –1436′
Bt gneiss?

McConaughey #1
5–33N–50W Dawes Co., NE
3459′ 4934′ –1475′
Granite

Schumacher #1
9–33N–50W Dawes Co., NE
3510′ 4820′ –1310′
Not available

Seegrist #11–1
11–33N–52W Dawes Co., NE
3528′ 5120′ –1592′
Not available

Christiansen #1
4–34N–47W Dawes Co., NE
3236′ 2727′ +509′
Foliated granite

Braddock #1
23–34N–50W Dawes Co., NE
3382′ 5040′ –1658′
Bt diorite

McDonald #1
8–34N–50W Dawes Co., NE
3572′ 5225′ –1653′
Not available

Duthie #1
33–35N–47W Dawes Co., NE
3025′ 2870′ +155′
Not available

Finegan #1
20–24N–41W Sheridan Co., NE
3923′ 5065′ –1142′
Bt granite

Mussler-Mosler 1
10–26N–42W Sheridan Co., NE
3948′ 4592′ –644′
Cataclastic bt adamellite

Caldwell #1
20–26N–44W Sheridan Co., NE
3860′ 4636′ –776′
Chlorite adamellite

Krause #1
17–26N–46W Sheridan Co., NE
3917′ 4630′ –713′
Bt hb gneiss

Herman #1
19–27N–44W Sheridan Co., NE
3853′ 4275′ –422′
Bt hb gneiss

Eckerle #1
33–28N–43W Sheridan Co., NE
4035′ 4412′ –377′
Granite

Orr #1
27–28N–44W Sheridan Co., NE
3828′ 3924′ –96′
Not available

Smith #1
28–28N–44W Sheridan Co., NE
3839′ 3950′ –111′
Not available

Nickels #1
14–28N–46W Sheridan Co., NE
3789′ 3800′ –11′
Granofels

Nickels #1
3–28N–46W Sheridan Co., NE
3775′ 3702′ +73′
Not available

Peterson #1
14–30N–46W Sheridan Co., NE
3771′ 2910′ +861′
Not available

King #1
1–30N–46W Sheridan Co., NE
3777′ 2768′ +1009′
Bt quartz diorite

King #1
12–30N–46W Sheridan Co., NE
3826′ 2818′ +1016′
Not available

State #16–1
16–31N–45W Sheridan Co., NE
3770′ 2792′ +978′
Not available

Demmer #1
22–31N–46W Sheridan Co., NE
3875′ 2752′ +1123′
Chlorite schist

State #1–36
36–31N–46W Sheridan Co., NE
3782′ 2745′ +1037′
Schist?

State #1
16–32N–45W Sheridan Co., NE
3920′ 2988′ +932′
Bt gneiss

Murray #17–24
24–32N–46W Sheridan Co., NE
3990′ 3011′ +979′
Bt hb schist

Cerny #1
27–33N–43W Sheridan Co., NE
3784′ 3665′ +119′
Bt hb schist

Bird-Laucmr #2–3
2–2N–55W Sioux Co., NE
4716′ 7766′ –3050′
Not available

Duncan #32–28
28–25N–56W Sioux Co., NE
4373′ 8120′ –3747′
Not available

Perkins #1
23–25N–57W Sioux Co., NE
4528′ 8564′ –4036′
Not available

Hilton #1–26
26–26N–56W Sioux Co., NE
4828′ 8294′ –3466′
Not available

Hatch #1
13–27N–57W Sioux Co., NE
4720′ 8233′ –3513′
Bt hb granodiorite

Newell #1
17–27N–57W Sioux Co., NE
4630′ 8022′ –3392′
Bt muscovite gneiss

Cherry #1
27–28N–56W Sioux Co., NE
4520′ 7658′ –3138′
Not available

Wear #1
10–29N–57W Sioux Co., NE
4790′ 7456′ –2666′
Gneiss?

Mann #1
27–30N–56W Sioux Co., NE
4769′ 7248′ –2479′
Bt hb gneiss

Oldaker #1
23–31N–54W Sioux Co., NE
4584′ 6532′ –1948′
Bt schist

Serres #1
4–33N–54W Sioux Co., NE
3863′ 5210′ –1347′
Bt granite

Federal-Geiser #1
10–34N–54W Sioux Co., NE
3667′ 4551′ –884′
Bt adamellite

*U.S. Government Printing Office: 1991 — 522-287/40109