OCT 16 1987

Final Report

Geothermal Resource Assessment South Dakota

Prepared by:

William D. Gosnold, Jr.
Department of Geology and Geological Engineering
Mining and Mineral Resources Research Institute
University of North Dakota
Grand Forks, North Dakota 58202

Prepared for:

The United States Department of Energy
under
DOE Contract No. DE FG07-85ID12606

N/A

Bulletin No. 87-07-MMRRI-01

July, 1987

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DOE/ID/12606--T1

DE88 000635

FINAL REPORT
GEOHERMAL RESOURCE ASSESSMENT
SOUTH DAKOTA

Prepared by:

William D. Gosnold, Jr.
Department of Geology and Geological Engineering
Mining and Mineral Resources Research Institute
University of North Dakota
Grand Forks, North Dakota 58202

Prepared for:
The United States Department of Energy
Under DOE Contract No. DE FG07-85ID12606
July, 1987

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MASTER

Jsu

TABLE OF CONTENTS

	<u>Page</u>
List of Figures.....	ii
List of Tables.....	iii
I. Abstract	1
II. Introduction.....	2
III. Geothermal Resource Definitions	3
IV. Methodology.....	5
A. Theory.....	5
B. Heat flow.....	7
C. Thermal conductivity.....	14
D. Temperatures.....	15
E. Geothermal resource calculations.....	16
V. Geothermal Aquifers.....	23
A. Deadwood Formation.....	23
B. Winnipeg Formation, Red River Formation, and.....	24
Englewood Limestone	
C. Madison Limestone.....	24
D. Minnelusa Formation.....	24
E. Minnekahta Formation.....	25
F. Inyan Kara Group.....	25
G. Newcastle Sandstone.....	25
VI. Discussion and Conclusions	26
VII. References.....	33
Appendix A Descriptions and Listing of Programs.....	A-1
Appendix B Tabulated Data on Temperature Calculations.....	B-1
Appendix C Heat Flow Data and Temperature Depth Profiles.....	C-1

LIST OF FIGURES

Page

1. Stratigraphic section of the Black Hills/Badlands area (from South Dakota School of Mines and Technology).....	4
2. Heat flow data in and around South Dakota.....	8
3. Heat flow contour map of North Central United States.....	10
4. Advective heat flow model showing the effects of both cross-formational and up-dip heat advection by flowing groundwater.....	11
5. Advective heat flow model showing the effects of up-dip groundwater flow.....	12
6. Grid of cells for South Dakota.....	17
7. Surface temperatures taken from NOAA climatic data 1931-1955.....	18
8. Surface heat flow grid.....	19
9. Heat flow grid below the Inyan Kara group and the Madison formation used for temperature calculations.....	20
10. Time-temperature path for NDGS well no. 7595 at the top of the Bakken formation in the Williston Basin.....	30

LIST OF TABLES

	<u>Page</u>
1. Geothermal Aquifers in South Dakota.....	5
2. Temperatures, Gradients, and Conductivities West of Pierre, S.D. for Advective and Conductive Heat Flow Cases.....	7
3. Geothermal Resources in South Dakota.....	21
4. Time-Temperature-index (TTI) for the Bakken Formation in Three Wells in the Williston Basin.....	31

I. ABSTRACT

Seven geothermal aquifers in South Dakota contain an accessible resource base of about $11,207 \times 10^{18}$ J. The potentially productive geothermal aquifers are: Deadwood Formation (Cambrian), Winnipeg Formation + Red River Formation + Englewood Limestone (Ordovician through Devonian), Madison Limestone (Mississippian), Minnelusa Formation (Mississippian-Permian), Inyan Kara Group (Cretaceous), and Newcastle Sandstone (Cretaceous). The resource estimate was obtained by first using heat flow, thermal conductivity, temperature gradient, and stratigraphic data to estimate aquifer temperatures. The heat content of each aquifer was determined from the product of the volumetric heat capacity, aquifer volume, and temperature difference between the aquifer and the mean annual temperature for a 14×14 grid of 240 km^2 cells. Geothermal fluid temperatures range from about 120 degrees C in the Deadwood Formation in the Williston Basin to about 30 degrees C for the Newcastle Sandstone in south-central South Dakota. The area containing the resource lies largely west of the Missouri River. About $10,000 \text{ km}^2$ of the resource area is characterized by anomalously high heat flow values greater than 100 mW m^{-2} .

II. INTRODUCTION

This evaluation of geothermal resources in South Dakota was conducted as part of the U. S. Department of Energy's State Cooperative Geothermal Resource Assessment Program. There are several direct-use applications of low-temperature geothermal waters in South Dakota and the existence of a sizeable resource is generally known. However, knowledge of the total quantity of available resource has been lacking as well as accurate temperature data on the geothermal aquifers. The goals of this project were to identify and characterize the geothermal aquifers and to assess the quantity of geothermal energy available for development in South Dakota. The products of this project are a geothermal resource map of South Dakota at a scale of 1:1,000,000, an accompanying text that explains the map, and this final report.

This evaluation of geothermal resources includes descriptions of the types of resources present and the defining parameters for resource classification in Section III. The methods for determining subsurface temperatures are described in Section IV. Section IV also includes a discussion of the basic parameters that control subsurface temperatures and details of how these parameters can be determined. These methods were first developed in the geothermal resource assessment of Nebraska (Gosnold and Eversoll, 1982) and have been modified significantly for this project. Section also IV contains a discussion of the methodology used in calculation of geothermal resources. Section V contains descriptions of seven geothermal aquifers and discussions of their development potential. Section VI contains conclusions and discussions of how the results of this study have implications for geothermal

resource exploration and development in any areas that contain low-temperature, strata-bound geothermal resources. There are also implications for other types of geological investigations including heat flow and petroleum exploration. Discussions on these implications are included near the end of the report. Section VII contains the references. Computer software for analysis of subsurface temperatures using the modified method was developed for this project. Descriptions and listings of the programs comprise Appendix A. Appendix B contains tabulated data on temperature calculations that includes: heat flow, depth, thickness, temperature, temperature gradient and thermal conductivity. Appendix C contains new heat flow data gathered in this study.

III. GEOTHERMAL RESOURCE DEFINITIONS

Geothermal resources in South Dakota fall into two categories as defined by Muffler and Guffanti (1979):

- a. Intermediate-temperature (90° - 150° C)
- b. Low-temperature ($>90^{\circ}$ C).

Geothermal resources described in this study are defined as hydrothermal fluids having temperatures high enough to provide energy in either direct or indirect use. There are seven potentially productive geothermal aquifers in South Dakota (Table 1). These aquifers were selected for analysis in this study from nineteen water-bearing formations in South Dakota (Figure 1) because they have effective porosities that would permit significant fluid production (Rahn; 1979, 1981).

GENERAL OUTCROP SECTION OF THE BLACK HILLS AREA						
		FORMATION	SECTION	THICKNESS IN FEET	DESCRIPTION	
TERTIARY	QUATERNARY	SANDS AND GRAVELS		0-50	Sand, gravel, and boulders.	
	PLIOCENE	OSALLALA GROUP		0-100	Light colored sands and silts.	
	MIOCENE	ARIKAREE GROUP		0-500	Light colored clays and silts. White ash bed at base.	
	OLIGOCENE	WHITE RIVER GROUP		0-800	Light colored clays with sandstone channel fillings and local limestone lenses.	
	PALEOCENE	FORT UNION FORMATION	TONGUE RIVER MEMBER		0-425	Light colored clays and sands, with coal-bed farther north.
			CANNONBALL MEMBER		0-225	Green marine shales and yellow sandstones, the latter often as concretions.
			LUDLOW MEMBER		0-350	Somber gray clays and sandstones with thin beds of lignite.
	?		HELL CREEK FORMATION (Lance Formation)		425	Somber-colored soft brown shale and gray sandstones, with thin lignite lenses in the upper part. Lower half more sandy. Many lignite concretions and thin lenses of iron carbonate.
	UPPER		FOX HILLS FORMATION		25-200	Grayish-white to yellow sandstone.
			PIERRE SHALE		1200-2000	Principal horizon of limestone lenses giving terrace buttes. Dark-gray shale containing scattered concretions. Widely scattered limestone masses, giving small terrace buttes. Black fissile shale with concretions.
		Shoree Springs Mem.				
		NIOBRARA FORMATION		100-225	Impure shales and calcareous shale.	
		Turner Sand Zone				
		CARLILE FORMATION		400-750	Light-gray shale with numerous large concretions and sandy layers.	
		Wall Creek Sands				
		GREENHORN FORMATION		(25-30) (200-350)	Impure starchy limestone. Weathers buff. Dark-gray calcareous shale, with thin Orman Lake limestone at base.	
LOWER		GRANEROS GROUP	BELLE FOURCHE SHALE		300-350	Gray shale with scattered limestone concretions.
			MOWRY SHALE		150-250	Light-gray siliceous shale. Fish scales and thin layers of bentonite.
	NEWCASTLE SANDSTONE			20-80	Brown to light yellow and white sandstone.	
	SKULL CREEK SHALE			170-270	Dark gray to black shale.	
	FALL RIVER (Dakota?) ss			10-200	Massive to starchy sandstone.	
	Fusion Shale Minnewasie ls			10-138		
JURASSIC	MORRISON FORMATION	UNKPAPA SS		0-225	Green to maroon shale. Thin sandstone.	
		SUNDANCE FM		250-450	Greenish-gray shale, thin limestone lenses. Glauconitic sandstone; red ss. near middle.	
		GYPSPUM SPRINGS		0-45	Red siltstone, gypsum, and limestone.	
				0-225	Massive fine-grained sandstone.	
TRIASSIC	SPEARFISH FORMATION			250-700	Red sandy shale, soft red sandstone and siltstone with gypsum and thin limestone layers.	
				250-700	Gypsum locally near the base.	
PERMIAN	MINNEKAHTA LIMESTONE			30-50	Massive gray, laminated limestone.	
		OPECHE FORMATION		50-135	Red shale and sandstone.	
PENNNSYLVANIAN	MINNELUSA FORMATION			350-850	Yellow to red cross-bedded sandstone, limestone, and anhydrite locally at top. Interbedded sandstone, limestone, dolomite, shale, and anhydrite.	
				350-850	Red shale with interbedded limestone and sandstone at base.	
MISSISSIPPIAN	PAHASAPA (MADISON) LIMESTONE			300-850	Massive light-colored limestone. Dolomite in part. Concretions in upper part.	
				300-850	Massive light-colored limestone. Dolomite in part. Concretions in upper part.	
DEVONIAN	ENGLEWOOD LIMESTONE			30-60	Pink to buff limestone. Shale locally at base.	
				30-60	Buff dolomite and limestone.	
ORDOVICIAN	WHITEWOOD (RED RIVER) FORMATION			0-100	Green shale with siltstone.	
				0-100	Massive buff sandstone. Greenish glauconitic shale, flaggy dolomite and fistulose limestone conglomerate. Sandstone, with conglomerate locally at the base.	
CAMBRIAN	DEADWOOD FORMATION			10-400	Schist, slate, quartzite, and arkose grit. Intruded by diorite, metamorphosed to amphibolite, and by granite and pegmatite.	
				10-400	Schist, slate, quartzite, and arkose grit. Intruded by diorite, metamorphosed to amphibolite, and by granite and pegmatite.	
PRE-CAMBRIAN	METAMORPHIC and IGNEOUS ROCKS					

DEPARTMENT OF GEOLOGY AND GEOLOGICAL ENGINEERING
SOUTH DAKOTA SCHOOL OF MINES AND TECHNOLOGY
RAPID CITY, SOUTH DAKOTA

1963

Figure 1. Stratigraphic section of the Black Hills/ Badlands area (from South Dakota School of Mines and Technology). The seven geothermal aquifers are numbered in the center column labelled Section.

TABLE 1
GEOHERMAL AQUIFERS IN SOUTH DAKOTA

Period	Group or Formation	Thickness Max (m)	Temperature Max. °C
Cretaceous	Newcastle	76	78
Cretaceous	Inyan Kara	70	75
Permian	Minnekahta	15	97
Perm-Penn	Minnelusa	335	98
Mississippian	Madison	396	102
Ord-Sil-Dev	(Winnipeg, Red River, Englewood)	457	110
Cambrian	Deadwood	207	120

Geothermal fluid temperatures range from about 120°C in the Deadwood Formation in the Williston Basin to about 30°C for the Newcastle Sandstone in eastern South Dakota. The minimum temperature for hydrothermal resources was defined by the U.S. Geological Survey as 10°C above the mean annual air temperature and increasing by 25 K km⁻¹ with depth (Reed, 1983). This definition has been applied to the geothermal resources in South Dakota, however fluid temperatures lower than 40°C may be inadequate for practical utilization.

IV. METHODOLOGY

A. Theory.

Quantitative analysis of the thermal structure of the subsurface requires determination of several thermal properties of the strata and the local heat flow. In the simplest case, application of Fourier's law of heat conduction would allow determination of subsurface temperature by

$$Q = dT/dZ * k \quad (\text{Eq. 1})$$

where Q is heat flow in mW m⁻², k is thermal conductivity in W m⁻¹ K⁻¹, dT is the increment of temperature change in a vertical length, dZ. The temperature

at any point, Z , can be calculated by:

$$T = T_o + \sum_{i=1}^n Z_i (Q/k_i) \quad (\text{Eq. 2})$$

where T_o is surface temperature, Q is the conductive heat flow, Z_i is the thickness of the i th layer, and k is the conductivity of the i th layer.

The gross thermal conductivity structure of the subsurface in South Dakota comprises two distinct components: a high conductivity Paleozoic carbonate section and a low conductivity Mesozoic and Cenozoic clastic section. For normal continental heat flow values of about 60 mW m^{-2} , a gradient of about 50 K km^{-1} would characterize the clastic rocks and a gradient of about 20 K km^{-1} would characterize the carbonates.

In a conductive regime, knowledge of formation thermal conductivity and stratigraphy plus local heat flow would be sufficient. However, in case of large values of heat advection in groundwater, the thermal structure of the subsurface could be more complicated. We have modified Equation 2 to treat the advective components as vertically varying conductive heat flow as

$$T = T_o + \sum_{i=1}^n Z_i (Q_i/k_i) \quad (\text{Eq. 3})$$

where Q_i is the heat flow at the i th stratum. This treatment is appropriate where the advective heat flow is due to updip or downdip groundwater flow within confined aquifers. In such cases, heat flow can be varied incrementally between adjacent aquifers and temperature gradients would be linear functions of thermal conductivity.

Where cross-formational flow occurs in fractures or other permeable zones, heat flow varies vertically in a non-incremental fashion. In this second case, temperature gradients would vary as a function of both heat flow and conductivity and would be considerably more difficult to predict accurately. Differences between conductive and advective regimes are shown for the area typical of west-central South Dakota in Table 2. In the advective case,

surface heat flow is 100 mW m^{-2} , heat flow below the Inyan Kara is 64 mW m^{-2} , and heat flow below the Madison is 50 mW m^{-2} . Heat flow in the conductive case is 86 mW m^{-2} .

The data necessary to characterize the geothermal resources in an area with these three cases are heat flow, formation conductivities, and formation thicknesses. The existing temperature data base is large and has proved highly useful in this study.

B. Heat Flow

Only 10 conventional heat flow measurements have been made within the study area (Figure 2). Four heat flow measurements are new for this study. When combined with other heat flow data (Gosnold and Eversoll, 1982) and geothermal gradient data (Schoon and McGregor, 1974; Gries, 1977; Downey, 1984), the data show a large heat flow anomaly having an amplitude that is

TABLE 2

TEMPERATURES, GRADIENTS, AND CONDUCTIVITIES WEST OF PIERRE, S.D.
FOR ADVECTIVE AND CONDUCTIVE HEAT FLOW CASES

Formation or Period	Thick. Meters	Cond. $\text{W m}^{-1}\text{k}^{-1}$	Advection		Conduction	
			Grad. K km^{-1}	Temp. $^{\circ}\text{C}$	Grad. K km^{-1}	Temp. $^{\circ}\text{C}$
Pierre	488	1.1	90.9	8.6	78.2	8.6
Newcastle	46	1.4	45.7	52.9	61.4	46.7
Inyan Kara	23	1.6	40.0	55.0	53.8	49.5
Morrison	23	1.4	45.7	55.9	61.4	50.8
Sundance	52	1.4	45.7	57.0	61.4	52.2
Spearfish	34	1.3	49.2	59.4	66.2	55.4
Minnelusa	206	2.2	22.7	61.0	39.1	57.6
Madison	93	3.5	14.3	65.7	24.6	65.6
Devonian	21	3.5	14.3	67.0	24.6	67.9
Cambrian	146	2.4	20.8	67.3	35.8	68.4
Basement				70.4		73.7

Figure 2. Heat flow data in and around South Dakota. Triangles are new data from this study. Circles are from previous studies (see Gosnold 1987a for a summary). Units are mW m⁻².

twice the expected heat flow for the mid-continent (Figure 3). The several hundred temperature gradient measurements in South Dakota (ibid.) include many values that are 2 to 3 times larger than expected for the continental platform (Schoon and McGregor, 1974; Gosnold and Eversoll 1982). For example, the least squares temperature gradients for three 150 m deep heat flow holes in the Pierre Shale near the Nebraska-South Dakota border are over 100 K km^{-1} (Gosnold and Eversoll, 1982). Also, Schoon and McGregor (1974) measured several temperature gradients of about 130 K km^{-1} west of the Missouri River in Gregory County, South Dakota. These temperature gradients are anomalously high partly because they were measured in the Pierre Shale (Cretaceous) which has a very low thermal conductivity of about $1.1 \text{ W m}^{-1} \text{ K}^{-1}$. The thermal conductivity of the Pierre shale was previously reported to be about $1.7 \text{ W m}^{-1} \text{ K}^{-1}$ (Sass et al., 1976; Combs and Simmons, 1973). However recent measurements on shales indicate that the thermal conductivity is on the order of 1.1 to $1.2 \text{ W m}^{-1} \text{ K}^{-1}$ (Blackwell and Steele, 1981; Sass and Galanis, 1983). Thus a normal continental heat flow of about 60 mW m^{-2} would cause geothermal gradients of 50 to 55 K km^{-1} in the Pierre Shale.

Recently, this heat flow anomaly has been attributed to a large advective heat flow disturbance within the Kennedy Basin (Gosnold, 1985; 1987a). In concept, the heat flow anomaly results from the thermal effects of groundwater flow in regional aquifers such as the Dakota Sandstone and the Madison Limestone. These aquifers recharge at high elevations at outcrops in the Black Hills and discharge in eastern South Dakota.

Two modes of heat advection are suggested to occur. One is due to cross-formational flow from deep aquifers toward the surface (Figure 4) and the other is due to updip flow within the Dakota and Madison aquifers (Figure 5). Both modes of advection can be modeled to provide estimates of heat

Figure 3. Interpreted heat flow contours in central United States. Data in South Dakota from this study, Data in Nebraska from Gosnold and Eversoll (1982), Data elsewhere modified after Sass et al (1981). Units are mW m^{-2} .

Figure 4. Advective heat flow model showing the effects of both cross-formational and up-dip heat advection by flowing groundwater. The arrows in the grid diagram indicate direction of flow. The model is based on a regularly spaced grid of cells having a vertical dimension of 0.5 km and a horizontal dimension of 5 km.

Figure 5. Advective heat flow model showing the effects of up-dip groundwater flow. Model parameters are the same as in Fig. 4.

advection and groundwater flow. For example, a relationship between heat flow, water velocity, and distance of flow for a vertical one-dimensional system (Lachenbruch and Sass, 1977) can be applied to the cross-formational flow model as follows:

$$\ln \frac{Q_2}{Q_1} = \frac{VD \rho C_p}{k} \quad (\text{Eq. 4})$$

where Q_1 is heat flow at the base of the zone of flow, Q_2 is heat flow at the top of the zone of flow, V is Darcy velocity in m s^{-1} , D is the length of the zone of flow in meters, ρ is density of the fluid in Kg m^{-3} , C_p is heat capacity of the fluid in W s Kg^{-1} , and k is thermal conductivity in $\text{W m}^{-1} \text{K}^{-1}$.

Pertinent parameters for this model include depths to the Dakota aquifer, which range from 1000 m in the west to about 500 m in the east, and surface heat flow which ranges from 80 mW m^{-2} in the west to 130 mW m^{-2} in the east, and estimates of heat flow below the aquifer. For an assumed heat flow of 60 mW m^{-2} below the advection zone, i.e. below the Dakota, Equation 4 predicts that a vertical water flow velocity on the order of 5 mm y^{-1} could account for the entire thermal anomaly.

Advection by updip flow of groundwater within the Dakota and Madison aquifers was modeled numerically using finite differences. In this model, Darcy velocities on the order of 2 m y^{-1} could account for anomalous heat flows on the order of 80 to 100 mW m^{-2} . However the extremely high heat flow values of 130 mW m^{-2} are difficult to account for with this model alone, it is likely that both proposed modes of advection generate the anomalous heat flow.

A measurement of advective heat flow in the anomalous area has been made in a well that penetrates to basement near Burton, Nebraska about 5 miles from the South Dakota state line (Gosnold, 1987a). At this site heat flow is about 106 mW m^{-2} above the Dakota aquifer and is estimated to be about 84 mW m^{-2}

below the aquifer. The estimate is based on assumed thermal conductivity values for the Paleozoic carbonates in the lower portion of the well. It is expected that heat flow below the advective zone should be lower than the background heat flow, i.e., less than about 60 mW m^{-2} . However, the estimated heat flow of 84 mW m^{-2} below the Dakota suggests the existence of additional sources, such as advection in the Ordovician-Devonian carbonates or gravels on the Precambrian surface, or anomalously high radioactivity in the basement rocks. The temperature at a depth of 700 meters at Burton is 60°C which is at least 30°C higher than it would be if the heat flow were normal i.e., about 60 mW m^{-2} . Another heat flow measurement in the anomalous area at a site near Hayes, South Dakota has a value 84 mW m^{-2} (Sass and Galanis, 1983).

C. Thermal Conductivity

The question of thermal conductivity is critical because of the essentially two-component conductivity structure of the subsurface in South Dakota. From Equation 1 it is apparent that the thermal gradients from the surface to the shallowest major geothermal aquifer, the Newcastle, or Dakota, Sandstone, are largely a function of the thermal conductivity and the heat flow in the shales.

Shale conductivities are particularly difficult to measure in the laboratory because shales are too soft for measurement of cores in a divided bar apparatus and their anisotropic nature causes a bias toward high values when using the chip method (Sass et al., 1971; Blackwell and Steele, 1981). Consequently we developed a procedure for estimating the thermal conductivities of these rocks. The procedure combines stratigraphic, lithologic, thermal conductivity, and temperature gradient data to deduce formation conductivities.

The general problem of thermal conductivities of shales was critically examined by Blackwell and Steele (1981) after they observed discrepancies in

interval heat flows for alternating limestone and shale layers in Paleozoic rocks in Kansas. In essence it is analogous to using a borehole as a divided bar thermal conductivity apparatus.

The thickest shale unit is the Pierre Shale which underlies virtually all of South Dakota except for the extreme eastern part and the Black Hills. Total shale thicknesses include the Pierre through the Mowry Shale and range from about 1000 m in the Williston basin in the northwestern part of the state to about 300 m at the limit of the geothermal resource area in eastern South Dakota. Sass and Galanis (1983) made thermal conductivity measurements on core samples of the Pierre Shale from a well near Pierre, South Dakota using a needle probe oriented both radially and axially. Their reported value of $1.2 \text{ W m}^{-1} \text{ K}^{-1}$ agrees with the shale estimates of Blackwell and Steele (1981). Consequently a range of shale conductivities of 1.1 to $1.2 \text{ W m}^{-1} \text{ K}^{-1}$ was adopted for this study.

Thermal conductivities of carbonates and sandstones in the subsurface are better known because samples can be measured relatively easily. The basic thermal conductivity scheme for the stratigraphic section in South Dakota is included in Table 2.

D. Temperatures

The majority of subsurface temperature and temperature gradient data from South Dakota comes from measurements in deep water wells and is summarized in reports by Schoon and McGregor (1974), Gries (1977), and Downey (1984). This study has included all of the existing data and new data compiled by the State Energy Office in Pierre. In the report by Schoon and McGregor (1974), temperature gradients were not measured by making interval or continuous temperature logs but were calculated from the bottom hole temperatures. This method is acceptable for temperature gradient calculations only if the temperature data

are accurate and the thermal conductivity of the rocks from the surface to the bottom of the well is constant. The temperature data were recorded in flowing wells or were measured in waters produced from the wells. Thus they are largely accurate temperature data, and provide the primary data base for this resource evaluation.

Few wells were available for logging due to minimal exploration efforts in the region. However there was good cooperation from the South Dakota Geological Survey and two oil operators in finding deep wells to log in the western part of South Dakota.

E. Geothermal Resource Calculations

The accessible resource base for each aquifer is calculated by

$$q_r = \rho_c * v * (T - T_o) \quad (\text{Eq. 5})$$

where q_r is the accessible resource base, ρ_c is the volumetric specific heat of the aquifer, v is the volume of fluid that can be produced, T is the average temperature of the aquifer, and T_o is the mean annual air temperature. Calculations were done using a 14 X 14 grid with cell sizes of 240 km² (Figure 6).

The mean annual surface temperatures were obtained from NOAA climatic data and are given in Figure 7 and in Appendix B. Heat flow data for each cell were deduced from the conventional heat flow measurements and from the geothermal gradient data. In particular the temperatures on the Madison Formation given by Gries (1977) and Downey (1984) were used as constraining data in estimating heat flow values. The deduced heat flow data for the grid are given in Figures 8 and 9 as well as in Appendix B. Stratigraphic data for the analysis were derived primarily from Rahn (1979,1981) and are included in tables of columnated data in Appendix B. Other tabulated data in Appendix B includes deduced thermal conductivities, calculated temperatures, calculated

Figure 6. Grid of cells for South Dakota

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A	6.4	6.4	6.2	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1
B	6.6	6.6	6.6	6.6	6.6	6.7	6.7	6.7	6.7	6.9	7.0	7.0	6.9	6.7
C	6.8	6.8	6.8	6.8	6.9	6.9	7.0	7.2	7.2	7.4	7.4	7.4	7.3	7.2
D	7.5	7.5	7.3	7.2	7.3	7.4	7.4	7.4	7.6	7.6	7.6	7.6	7.6	7.4
E	8.2	8.1	7.8	7.7	7.6	7.6	7.7	7.8	7.9	7.9	7.9	7.9	7.8	7.8
F	8.2	8.2	7.9	7.8	7.8	7.8	7.9	8.0	8.2	8.2	8.3	8.3	8.2	8.1
G	7.8	7.9	7.9	7.8	7.8	7.9	8.0	8.2	8.4	8.4	8.5	8.4	8.3	8.3
H	7.4	7.4	7.4	7.6	7.8	7.9	8.2	8.5	8.6	8.6	8.6	8.7	8.7	8.6
I	7.5	7.6	7.8	7.8	7.8	8.1	8.4	8.7	8.7	8.8	8.8	8.9	8.9	8.8
J	7.6			7.8	7.9	8.2	8.4	8.7	8.7	8.8	8.9	9.0	9.1	9.1
K	7.7	7.7	7.8	7.9	8.0	8.3	8.6	8.8	9.0	9.0	9.1	9.2	9.2	9.2
L	7.8	7.8	7.9	8.0	8.4	8.5	8.8	9.0	9.1	9.2	9.3	9.4	9.5	9.5
M	7.8	7.9	8.0	8.2	8.6	8.8	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.7
N	7.9	7.9	8.0	8.2	8.7	8.9	9.2	9.3	9.4	9.5	9.5	9.7	9.8	9.8

Figure 7. Surface temperatures taken from NOAA Climatic Data 1931-1955.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A	60	60	60	60	60	60	60	60	60	60	60	60	60	60
B	60	60	60	60	60	60	60	60	60	60	60	60	60	60
C	60	60	60	60	60	60	60	60	60	60	60	60	60	60
D	55	55	55	55	55	60	60	60	60	60	60	60	60	60
E	50	50	50	50	55	55	60	60	60	60	60	60	60	60
F	50	50	50	55	55	60	60	60	64	65	65	60	60	60
G	50	50	44	45	47	50	60	70	79	85	75	75	80	80
H				45	45	50	60	70	80	90	100	75	100	100
I				45	45	50	62	72	72	110	100	100	110	130
J				57	45	45	46	50	54	70	74	80	95	100
K				52	45	45	50	60	60	60	60	88	95	100
L				52	45	45	50	60	60	70	80	95	100	100
M	90	96	80	50	45	50	60	70	80	90	100	110	110	110
N	90	96	80	50	45	50	60	70	80	90	100	110	110	110

Figure 8. Surface heat flow grid. Heat flow values were determined from equation 3 with constraining data from 14 heat flow measurements (Figure 2), surface temperature data (Fig. 7), geothermal gradient data (Schoon and McGregor, 1974; Gosnold and Eversoll, 1982), and temperature data on the Madison Formation from Gries (1977) and Downey (1984).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
A	60	60	60	60	60	60	60	60	60	60	60	60	60	60
B	60	60	60	60	60	60	60	60	60	60	60	60	60	60
C	60	60	60	60	60	60	60	60	60	60	60	60	60	60
D	55	55	55	55	55	60	60	60	60	60	60	60	60	60
E	50	50	50	50	55	55	60	60	60	60	60	60	60	60
F	50	50	50	55	55	60	60	60	64	65	65	60	60	60
G	50	50	44	45	47	50	60	70	79	85	75	75	80	80
H				45	45	50	60	70	60	60	60	75	100	100
I				45	45	50	62	72	72	60	60	100	110	130
J				57	45	45	46	50	54	70	74	80	95	100
K				52	45	45	50	60	60	60	60	88	95	100
L				52	45	45	50	60	60	70	80	95	100	100
M	90	96	80	50	45	50	60	70	80	90	100	110	110	110
N	90	96	80	50	45	50	60	70	80	90	100	110	85	85

Figure 9. Heat flow grid below the Inyan Kara Group and the Madison Formation used for temperature calculations. Heat flow values were determined from equation 3 with constraining data from 14 heat flow measurements (Figure 2), surface temperature data (Fig. 7), geothermal gradient data (Schoon and McGregor, 1974; Gosnold and Eversoll, 1982), and temperature data on the Madison Formation from Gries (1977) and Downey (1984).

gradients, depths to formation tops, and calculated values for stored energy in the seven geothermal aquifers where they are present. The stored-energy calculated as the mean accessible resource base for each aquifer is discussed in the next section and the data are summarized in Table 3 at the end of the section.

TABLE 3
GEOTHERMAL RESOURCES IN SOUTH DAKOTA

Formation	Mean Accessible Resource (10^{18} J)
Newcastle	347.112 $\pm$ 3.10
Inyan Kara	458.358 $\pm$ 3.54
Minnekahta	91.206 $\pm$ 1.98
Minnelusa	2,529.780 $\pm$ 5.73
Madison	2,825.945 $\pm$ 4.99
Winnepeg etc.	2,787.431 $\pm$ 9.74
Deadwood	<u>2,168.099</u> $\pm$ 2.68
TOTAL	11,207.931 $\pm$ 31.76

(See text for discussion of error estimates)

Accuracies of calculations were estimated from the uncertainties in the various critical data as follows. Thermal conductivities, formation thicknesses, and heat flow are combined in equation 3 to calculate the aquifer temperatures. In a similar study in Nebraska, Gosnold and Eversoll (1982) projected bottom hole temperatures in wells up to 2 km depth to within 2 °C of measured equilibrium temperatures for nine different wells. The control on heat flow data was about the same in the Nebraska study as in this study. However, thermal conductivities and stratigraphic thicknesses are much better known for South Dakota than for Nebraska due to the work of Gosnold (1985, 1987a) and Rahn (1979). Nevertheless, we prefer to err on the conservative

side and have adopted a temperature accuracy of $\pm 5^{\circ}\text{C}$ for formation temperatures. The accuracy of energy calculations based on the adopted temperature error is $\pm 0.008 \times 10^{18} \text{ J}$.

A particularly critical factor in calculation of the energy resource base for a formation is the formation thickness. Subsurface data can be resolved to within about ± 5 feet (1.6 m), but the production of isopach maps from a data base tends to smooth the formation surfaces. The data used in this study were isopach data prepared by Rahn (1979) and have contour intervals ranging from 50 to 100 feet (15.2 to 30.4 m) for the selected geothermal aquifers. We have adopted an uncertainty of half the contour interval for an aquifer in estimating possible errors. The accuracy of resource base calculations for the adopted uncertainty is $0.012 \times 10^{18} \text{ J}$ for ± 25 feet (7.6 m) and $0.024 \times 10^{18} \text{ J}$ for ± 50 feet (15.2 m). The possible range of volumetric specific heats for the different aquifers causes errors several orders of magnitude less than the errors discussed above and they are not included in the total error calculation. The estimated error for resource base calculations is $\pm 0.20 \times 10^{18} \text{ J}$ per 240 km^2 cell formations having 50 foot (15.2 m) contours, i.e., Newcastle, Inyan Kara, and Minekahta, and $\pm 0.032 \times 10^{18}$ per 240 km^2 cell for formations having 100 foot (30.3 m) contours, i.e., Minnelusa, Madison, and Deadwood. The Ordovician-Devonian section has 200 foot (60.6 m) contours and the error for that geothermal aquifer system is estimated to be $\pm 0.056 \times 10^{18}$ per 240 km^2 cell. The total error for each aquifer was determined by multiplying the error-per-cell times the number of cells containing the aquifers.

V. GEOTHERMAL AQUIFERS

Nineteen different water bearing formations have been described in South Dakota (Rahn, 1979), eleven of which contain water having temperatures that exceed the minimum limits for low temperature geothermal resources. Seven of these formations or groups of formations are aquifers with an effective porosity greater than five percent and have potential for significant production of geothermal fluids. Isopach maps of these aquifers (Rahn, 1979, 1981) provide the basic stratigraphic data for temperature calculations in this study. Temperatures on each of these aquifers were calculated using Equation 3 with constraining data from Gries (1977), Schoon and McGregor (1974), Sass and Galanis (1983), Gosnold and Eversoll (1982), Gosnold (1984) and the data collected as part of this study.

A. Deadwood Formation

In exposures in the Black Hills, the Deadwood Formation consists of four lithologic units that are described as a massive, buff sandstone; greenish, glauconitic shale; flaggy dolomite and flatpebble conglomerate; and a sandstone with conglomerate locally at the base (S. Dakota School of Mines and Technology, 1963). Rahn (1979) estimated the total porosity of the Deadwood as about 10 percent and its effective porosity as greater than 5 percent. Water near the recharge area is relatively fresh but water elsewhere is considered to be relatively saline (Rahn, 1981). There are approximately 347 km^3 of recoverable water in the Deadwood Formation. Temperature in the resource area range from about 47°C where the aquifer is close to the surface to about 120°C in the Williston Basin in northwestern South Dakota. The mean accessible resource base is $2,168.099 \times 10^{18} \pm 2.68 \times 10^{18} \text{ J}$.

B. Winnipeg Formation, Red River Formation, and Englewood Limestone

The Ordovician, Silurian and Devonian rocks between the Deadwood and the Madison Limestone were grouped as a single aquifer system by Rahn (1981). In the Williston Basin in North Dakota, Gosnold (1984) used the local terminology for the upper two units, i.e., Red River and Duperow Formations, and calculated the thermal content of their waters separately. Because these units are essentially carbonates with similar porosities, it was convenient to use the isopach data of Rahn (1981) and treat them as a single unit in this study. Rahn's (1981) value for porosity is 20 percent which suggests a relatively productive system. This aquifer system contains about $1,537 \text{ km}^3$ of recoverable water. Temperatures at the top of the system range from about 47°C to about 110°C and the mean accessible resource base is $2,787.431 \times 10^{18} \pm 9.744 \times 10^{18} \text{ J}$.

C. Madison Limestone

The Madison Limestone is well known as an aquifer and oil producing formation throughout the northern Great Plains and the Rocky Mountains. Its geothermal potential has been estimated by Gries (1977) and Sorey et al, (1983b). However the estimate by Gries (1977) is qualitative and the estimate by Sorey et al (1983b) did not include the temperature data from Gries (1977). The average porosity of the Madison Formation is about 11 percent and the formation contains about 746 km^3 of recoverable water (Rahn, 1981). Temperatures range from about 30°C to about 102°C and the mean accessible resource base is $2,825.945 \times 10^{18} \pm 4.99 \times 10^{18} \text{ J}$. The Madison is one of two geothermal aquifers that are presently used in direct-heat applications.

D. Minnelusa Formation

At outcrops in the Black Hills, the Minnelusa Formation includes a yellow-to-red cross-bedded sandstone and a limestone with anhydrite locally at

the top. At certain localities the porosity of sandstone units approaches 25 percent, although the average porosity of the sandstones is generally less than 10 percent (Rahn, 1981). Carbonates predominate the lithology of the Minnelusa Formation and have a porosity of about 10 percent (Rahn, 1981). Rahn (1981) estimates the effective porosity as 5 percent and the total volume of recoverable water as about 946 km^3 . The temperature range in the resource area is from about 40°C to about 98°C and the mean accessible resource base is $2,530 \times 10^{18} \pm 5/728 \times 10^{18} \text{ J}$.

E. Minnekahta Limestone

This relatively thin unit occurs as a massive gray, laminated limestone that attains thicknesses on the order of only 15 m in western South Dakota. It has an effective porosity of about 5 percent and contains about 26 km^3 of recoverable water (Rahn, 1982). Temperature ranges in the resource area are from about 38°C to about 97°C and the mean accessible resource base is $91.206 \times 10^{18} \pm 1.980 \times 10^{18} \text{ J}$.

F. Inyan Kara Group

The basal Cretaceous Dakota Formation lies unconformably on the Morrison Formation. The lower most unit in South Dakota is the Inyan Kara Group. It consists of sandstone, some shale and limestone. Its maximum thickness in South Dakota is about 70 meters but it has a high effective porosity or the order of 17 percent and the amount of recoverable water is about 662 km^3 (Rahn, 1981). Temperatures in the resource area range from about 36°C to about 78°C and the mean accessible resource base is $458.358 \times 10^{18} \pm 3.540 \times 10^{18} \text{ J}$.

G. Newcastle - Dakota Sandstone

This Cretaceous sandstone has been called the Dakota Sandstone where it is over about 15 m thick (Baker, 1972). It reaches a maximum thickness of about 76 m in southwestern South Dakota. Most of the water wells in South

Dakota produce from the lower Cretaceous (Dakota Group) which may be either the Newcastle Sandstone or the Fall River Sandstone. The Dakota has a high effective porosity and contains about 501 km^3 of recoverable water. The Dakota is one of two aquifers that currently produce geothermal waters in South Dakota. Temperatures in the resource area range from about 31°C to about 75°C and the mean accessible resource base is $347.112 \times 10^{18} \pm 3.100 \times 10^{18} \text{ J}$.

VI. DISCUSSION AND CONCLUSIONS

The total mean accessible resource base in the study area is $11,207.931 \times 10^{18} \pm 31.76 \times 10^{18} \text{ J}$. The previous estimate of geothermal resources in South Dakota gave $1,490 \pm 154 \times 10^{18} \text{ J}$ in the Madison limestone, $310 \pm 57 \times 10^{18} \text{ J}$ in the Dakota sandstone and 0.83 ± 0.21 in isolated systems for a total of about $1,800 \pm 211 \times 10^{18} \text{ J}$ (Sorey et al, 1983). The mean accessible resource base given in this study is approximately a 622 percent increase in estimated resources over the previous estimate. There are several reasons for the differences, and in order of importance they are: (1) this study addressed the resources in seven aquifers whereas the previous study included only two aquifers; (2) temperatures used in this study were based on accurate measurements or were deduced from careful calculations whereas those in the previous study were based on bottom-hole temperatures that were largely inaccurate; (3) calculations of the accessible resource base in this study were based on actual mean annual temperatures in South Dakota rather than 15°C ; (4) estimates of aquifer volumes based on small cells provide better accuracy.

The actual resource is that part of the accessible resource base that can be produced at the wellhead assuming suitable economics and technological capabilities. (Sorey et al, 1983a). Calculation of the resource requires

additional information on well spacing, specific reference temperatures, volumetric discharge for each well, and the production period. In the general case of sedimentary basins the resource is on the order of one-thousandth of the accessible resource base (Sorey et al, 1983).

Development of South Dakota's geothermal resources already exists on a small scale with direct use in institutions such as schools and a hospital, and in heating greenhouses and farm buildings. Large scale utilization may occur at some future time if economic conditions change to make the resource competitive on the energy market.

A spin-off of this research is the analysis of temperatures in petroleum provinces. The thermal evolution of sedimentary basins has received increased attention from the petroleum industry since Waples' (1980) discussion of Lopatin's (1971) method for predicting thermal maturity. In concept, the thermal maturity of petroleum source rocks should be calculable if one can accurately determine the temperature profile for the source rock through time. A number of workers have approached this problem by using present day geothermal gradients to determine paleotemperatures (Lopatin, 1971, Waples, 1980; Schmoker and Hester, 1983; Price et al., 1984). Other workers have proposed thermo-mechanical models for basin formation and have projected basin temperatures as a function of the subsidence rate and the decrease in heat flow that drives the model (McKenzie, 1978; Turcotte and Ahern, 1977; Haxby et al., 1976; Ahern and Mrkvicka, 1984; Nunn et al., 1984; Garner and Turcotte, 1984).

Each of these approaches has provided insight into important aspects of the thermal evolution of sedimentary basins. However in some cases these models produce conflicting results. For example, several workers have based estimates of the thermal maturity of the Bakken formation in the Williston Basin on temperature gradients derived from bottom hole temperatures (Webster, 1984;

Schmoker and Hester, 1983). Their estimates conflict with interpretations of geochemical data by Price et al. (1984) who suggest that the Bakken has reached thermal maturity levels that exceed those predicted using estimates of present-day basin temperatures.

A fundamental problem in this type of analysis is that of obtaining a valid estimate of present day temperatures. The common technique for analyzing basin temperatures, i.e., projecting linear temperature gradients based on bottom hole temperatures of oil wells has been applied to the Williston Basin by Nixon (1973) and Meissner (1978) and has been used for paleotemperature estimates by Webster (1984) and Price et al. (1984). The temperature gradients used in these estimates are on the order of $34^{\circ}\text{C km}^{-1}$. However, equilibrium temperature gradients measured with thermistor probes reveal a complex temperature gradient profile that is non-linear and, in a single profile, may range from 20 to $60^{\circ}\text{C km}^{-1}$ (Gosnold, 1985).

Another fundamental problem arises from using present day temperatures as paleotemperatures. This problem has been recognized for the Williston Basin by Price et al (1984) whose geochemical data indicate significantly higher paleotemperatures than would obtain from the present day temperature gradients given by Meissner (1978). Another example of differences between present and past basin temperatures was given by Naeser (1984) using fission-track dating. Naeser (1984) compared fission track closing temperatures to present-day geothermal gradient data and suggested that several Tertiary basins in the western United States had significantly higher temperature gradients in the past.

Gosnold and Huang (1987) addressed these problems in modeling a basins' thermal history by analyzing the factors that control present and past temperature profiles. Their work was partially based on the methodology used

in this geothermal resource evaluation. In particular, Gosnold and Huang (1987) showed that the assumption that linear temperature gradients can be used to estimate basin temperatures may be invalid in the general case and is particularly inappropriate for the Williston Basin. They also examined the assumption that present day gradients may be used to determine paleotemperatures and suggested explanations for inferences of high paleotemperatures in some basins. The essential elements of their work are included in this study of geothermal resources and in a decompaction model developed by Sclater and Christie (1980).

Results of Gosnold and Huang's (1987) calculations of Time Temperature Index (TTI) (Waples, 1980) for four wells in the Williston Basin are given in Figure 10 and Table 4. Webster (1984) applied similar calculations to the Bakken Formation for two wells in the Williston Basin and obtained values of 130 and 265 based on a temperature gradient of about 34 K km^{-1} . Gosnold and Huang (1987) computed TTI for three wells in the Williston Basin using four different temperature profiles: Model A - Present temperature profile as determined by Eq. 2. Model B - Historical temperature profile as determined by the decompaction model of Sclater and Christie (1980) with thermal conductivity varying with porosity and temperature but with constant heat flow. Model C - A profile similar to Model B but with heat flow decreasing exponentially with time. Model D - The profile resulting from a linear geothermal gradient of 34 K km^{-1} .

NDGS #7595

Figure 10. Time-temperature path for NDGS Well No. 7595 at the top of the Bakken Formation in the Williston Basin. Model descriptions are given in the text and in Table 4.

TABLE 4

TIME-TEMPERATURE-INDEX (TTI) FOR THE BAKKEN FORMATIONS
IN THREE WELL IN THE WILLISTON BASIN

<u>NDGS Well No.</u>	<u>Model A</u> ¹	<u>Model B</u> ²	<u>Model C</u> ³	<u>Model D</u> ⁴
9264	220	290	312	73
7565	110	281	300	74
7595	115	307	336	76

¹Model A - uses an accurate present-day temperature profile.

²Model B - uses a decompaction calculation to determine paleotemperatures based on time-variations in thickness and thermal conductivity but with constant heat flow.

³Model C - is similar to model B except it introduces a thermal event during the Ordovician after the suggestion of Ahern and Mrkvica (1984) .

⁴Model D - uses a linear geothermal gradient based on present-day bottom-hole-temperatures to predict paleotemperatures.

The effects of decompaction and the temperature dependent variation in thermal conductivity (Models B and C) increase the TTI values significantly for each of the wells over the TTI values calculated for constant thermal conductivity and no decompaction (Model A). The effects of an exponential decrease in heat flow from high values to the present value (Model C) to approximate a basin formation model such as that of Ahern and Mrkvicka (1984) increase the TTI values somewhat. However, because the higher heat flow would have occurred early in the Basin's history the increase is not large over the TTI values for Model B.

The differences between the TTI values calculated using a linear-temperature gradient model (Model D) and the more sophisticated models are significant. Waples (1980) analysis of Lopatin's (1971) TTI indicates that oil generation occurs between TTI values of 15 and 160. All of the Model D values suggest that the Bakken is still well within the oil generation window. The same conclusion applies to Model A which uses accurate, present-day

temperatures in the TTI calculation. Models B and C more accurately approximate the thermal history of the Basin, and both indicate that the Bakken is past the oil generation window.

The time-temperature paths for models A, B and D for NDGS 9264 (Figure 10) are relatively similar for the early history of the Basin. However the effects of the thick blanket of low-conductivity shales move paths A and B several tens of degrees above that of D during the Tertiary. The consequence of this thick blanket is that the temperatures within the Basin rose dramatically during the Tertiary. Curve D lies between curves A and B for the early history of the Basin because the gradient of 34.6 K km^{-1} exceeds the present day gradient used for curve A.

These results suggest solutions to some problems in interpretation of thermal maturity data in previous studies. In particular, the suggestion that higher heat flow values characterized the Williston Basin in the Cretaceous (Price et al., 1984) can be dismissed. The suggestion by Naeser (1984) that several Tertiary basins had experienced a thermal event can be discounted similarly. In general, these results suggest that thermal maturity calculations based on any linear-temperature gradient model or even present-day temperatures may be in error not only for the Williston Basin but for any non-homogeneous basin.

ACKNOWLEDGEMENTS

This study was funded by U.S. Dept. of Energy Contract No. DE-FG07-85ID12606. M.J. Tipton and R. Schoon of the South Dakota Geological Survey, F. Steece of the Department of Water and Natural Resources, and Steve Wegman of the State Energy Office all provided data or supporting information. Koch Exploration and Citation Oil Company provided access to shut-in wells for temperature logging. A critical review of this report by H. Ross, U.U.R.I., significantly improved the manuscript.

REFERENCES

- Ahern, J.L., and S.R. Mrkvicka, 1984, A mechanical and thermal model for the evolution of the Williston Basin, *Tectonics*, 3, 79-102.
- Baker, R.K., 1972, The ground water capacity of the Newcastle-Dakota Sandstones in central and western South Dakota: Unpub. M.S. Thesis, S. Dak. School of Mines and Tech., 130 pp.
- Blackwell, D.D., and J.L. Steele, 1981, Heat flow and geothermal potential of Kansas, Final report for Kansas State Agency Contract 949, 69 pp.
- Combs, J., and Simmons, G, 1973, Terrestrial heat flow determinations in the north Central United States, *J. Geophys. Res.*, 78, 441-461.
- Downey, J.S., 1984, Geohydrology of the Madison and associated aquifers in parts of Montana, Nebraska, North Dakota, South Dakota, and Wyoming, U.S. Geol. Surv. Prof. Paper 1273-G, 47pp.
- Garner, D.L., and D.L. Turcotte, 1984, The thermal and mechanical evolution of the Anadarko Basin, *Tectonophysics*, 107, 1-24.
- Gosnold, W.D., Jr., and Eversoll, D.A., 1982, Geothermal resources of Nebraska, 1:500,000 map, N.O.A.A., Boulder, Co.
- Gosnold, W.D., Jr., 1984, Geothermal Resources of North Dakota - Final Report to U.S. Dept. Energy, Univ. North Dakota, E.E.S. Bull. No. 83-10-MMRRI-01.

Gosnold, W.D., Jr., 1985, Heat flow and groundwater flow in the Great Plains of the United States, *J. Geodynamics*, 4, 247-264.

Gosnold, W.D., Jr., 1987a, Heat flow in the Great Plains of the United States, *J. Geophysical Res.*, (in press).

Gosnold, W.D., Jr. and Huang, Y.C., 1987, Factors in determining the thermal history of a continental basin, in, Fifth International Williston Basin Symposium, Saskatchewan Geological Society Special Pub. no. 9, p 17-22.

Gries, J.P., 1977, Geothermal applications of the Madison (Pahasapa) aquifer system in South Dakota: Final Report, South Dakota School of Mines and Technology, 96 pp.

Haxby, W.F., D.L. Turcotte, and J.M. Bird, 1976, Thermal and mechanical evolution of the Michigan Basin, *Tectonophysics*, 36, 57-75.

Lachenbruch, A.H., and Sass, J.A., 1977, Heat flow in the United States and the thermal regime of the crust, in *The Earth's Crust*, J.G. Heacock, Amer. Geophys. Union, Mono. 20, 209-250.

Lopatin, N.V., 1971, Temperature and time as geologic factors in coalification: *Akademiia Nauk SSSR, Izvestiia Serii Geologicheskuyu*, 3, 95-106.

- McKenzie, D., 1978, Some remarks on the development of sedimentary basins, Earth Planet. Sci. Lett., 40, 25-32. Meissner, F.F., 1978, Petroleum geology of the Bakken Formation, Williston Basin, North Dakota and Montana, in Williston Basin Symposium: Billings, Montana Geol. Soc., p. 207-227.
- Muffler, L.P.J., and Guffanti, M., 1979, Introduction, in Muffler, L.P.J., ed., Assessment of geothermal resources of the United States 1978: U.S. Geol. Surv. Circ. 790, 1-7.
- Nixon, R.P., 1973, Oil source beds in Cretaceous Mowry Shale of northwestern interior United States: AAPG Bull., 57, 136-161.
- Naeser, N.D., 1984, Thermal history determined by fission-track dating for three sedimentary basins in California and Wyoming, GSA Abstracts with Programs, 1984, p.607.
- Nunn, J.A., Sleep, N.H., and Moore, E.W., 1984, Thermal Subsidence and generation of hydrocarbons in the Michigan Basin, Amer. Assoc. Petrol. Geol. Bull., 68, 296-315.
- Price, L.C., T. Ging, T. Daws, A. Love, M. Pawlewicz, and D. Anders, 1984, Organic metamorphism in the Mississippian Devonian Bakken Shale, North Dakota portion of the Williston Basin, in Hydrocarbon Source Rocks of the Rocky Mountain Region, Woodward, J. F.F. Meissner, and J.L. Clayton eds., R.M.A.G., p. 83-134.

Rahn, P.H., 1979, Ground water resources of western South Dakota: Report to U.S. Army Corps of Engineers, Omaha District.

Rahn, P.H., 1981, Ground water stored in the rocks of western South Dakota, in Rich F. J., ed., Geology of the Black Hills, South Dakota and Wyoming, second edition, Amer. Geol. Inst., 154-174.

Reed, M.J., 1983, Introduction, in Reed, M.J., ed., Assessment of low-temperature geothermal resources of the United States - 1982, U.S. Geol. Surv. Circ. 892, 1-8.

Sass, J.H., Lachenbruch, A.H., and Monroe, R.J., 1971, Thermal conductivity of rocks from measurements on fragments and its application to heat flow determinations, J. Geophys. Res., 76, 3391-3401.

Sass, J.H., Diment, W.H., Lachenbruch, A.H., Marshall, B.V., Monroe, R.J., Moses, T.H., Jr., and Urban, T.C., 1976, A new heat-flow contour map of the United States, U.S. Geol. Surv. Open-File Rpt. No. 76-756.

Sass, J.A., and Galanis, S.P., 1983, Temperatures, thermal conductivity, and heat flow from a well in Pierre Shale near Hayes, South Dakota, U.S. Geol. Surv. Open-File Rpt. No. 83-25.

Schmoker, J.W., and T.C. Hester, 1983, Organic carbon in the Bakken Formation, United States portion of the Williston Basin, AAPG Bull, 67, 2165-2174.

Schoon, R.A., and McGregor, D.J., 1974, Geothermal potentials in South Dakota, South Dakota Geol. Surv. Rpt. of Investigations No. 110, 76 pp.

Sclater, J.G., and P.A.F. Christie, 1980, Continental stretching: An explanation of the post-Mid-Cretaceous subsidence of the central North Sea Basin, J. Geophys. Res., 85, 3711-3739.

Sorey, M.L., Nathenson, M., and Smith, C., 1983a, Methods for assessing low-temperature geothermal resources, in Assessment of low temperature geothermal resources of the United States - 1982, M.J. Reed, editor, U.S. Geol. Surv. Cir, 892, 17-30.

Sorey, M.L., M.J. Reed, D. Foley, and J. Renner, 1983b, Low temperature geothermal resources in the central and eastern United States, in Assessment of low temperature geothermal resources of the United States - 1982, M.J. Reed, editor, U.S. Geol. Surv. Cir, 892, p. 51-66.

Turcotte, D.L., and J.L. Ahern, 1977, On the thermal subsidence History of sedimentary basins, J. Geophys. Res., 82, 3762- 3766.

Waples, D.W., 1980, Time and temperature in petroleum formation: application of Lopatin's method to petroleum exploration: AAPG Bull., 64, 916-926.

Webster, R.L., 1984, Petroleum source rocks and stratigraphy of the Bakken Formation in North Dakota, in Hydrocarbon Source Rocks of the Rocky Mountain Region, Woodward, J., F.F. Meissner, and J.L. Clayton eds., R.M.A.G., p. 57-82.

APPENDIX A

COMPUTER SOFTWARE

Four computer programs were written to assist in computations used in this study. These programs were written in Microsoft BASIC on an IBM PC. Listings and discussion of operation of the programs follows.

1. Program STRAT:

Program STRAT writes data to disk files for processing by program TEMSTRAT. Program STRAT also allows editing of any data point if the edit option is chosen. The data necessary to create data files with STRAT are formation thicknesses. The program is presently set up to accept 18 different formation thicknesses. The data used in this study were taken from Rahn (1979, 1981) and were originally in feet. The conversion to meters is done in the program beginning at line 590. If you wish to enter thicknesses in meters simply change statement 590 to: 590 SI = 1. The program will waste some time (microseconds) dividing each formation thickness by 1, but it will not be noticeable to the operator.

To change the number of formations in the program, statement numbers 240, 250, 310, 320, 370-450, 490, 500, 630-980, and 1010-1190 may need changing. Each formation thickness is assigned 5 bytes in the data file and there are 18 thicknesses giving a total of 95 bytes per record. To change the number of formations you must make the appropriate changes in the "OPEN" statements 240, 310, and 490. That is the "...LEN = 95" part must be changed to = 5 times the # of formations. For example to use 20 formations the statements would read "...LEN = 100".

To increase the number of formations, the "FIELD" statements 250, 320, and 500 must be changed. Simply add new string variable definitions to the end of each statement, i.e. "...5 as T\$, 5 as U\$" etc. To decrease the number of formations, simply remove the appropriate number of defined string variables starting at the end of each statement.

The same argument applies to statements 370-390 and 1010-1190.

To use different formation names as well as to change the number of formations, change the names in statements 400-470 and 630-980. It is imperative that the line numbers in the "IF...THEN...ELSE..." statements 550 and 560 match the line numbers changed between 630-980.

To run the program using the BASIC interpreter:

- 1: Boot the system using DOS
- 2: Type BASICA <RETURN> to load the basic interpreter
- 3: Type "LOAD" (OR USE THE FUNCTION KEY F3) STRAT <RETURN>
- 4: Press function key F2 to run

```

10 REM*****
20 CLS:KEY OFF
30 SI = 3.2808
40 REM ***PROGRAM "STRAT"***
50 LOCATE 10,33:PRINT" PROGRAM  STRAT"
60 REM THIS PROGRAM WRITES DATA TO DISKETTE FOR PROCESSING BY PROGRAM TEMSTRAT
70 LOCATE 12,5:PRINT"THIS PROGRAM WRITES DATA TO DISKETTE FOR PROCESSING BY
PROGRAM TEMSTRAT
80 REM*****
90 LOCATE 15,20:PRINT"PUT DATA DISKETTE IN DEFAULT DRIVE"
100 LOCATE 16,23:PRINT"THEN PRESS ANY KEY TO BEGIN"
110 DR$ = INKEY$:IF DR$ ="" THEN 110
120 PRT = 0
130 CLS
140 REM*****
145 GOTO 155
150 LOCATE 2,30:PRINT "LAST FILE NAME WAS "; NM$
155 LOCATE 12,30:INPUT "ENTER FILE NAME"; NM$
160 REM*****
170 REM***SELECT OPTION TO PRINT FILE ON SCREEN IF EDITING AN EXISTING FILE***
180 REM*****
190 REM ***SELECT OPTION TO EDIT OR ENTER NEW DATA***
200 LOCATE 18,10:INPUT "Type 1 to edit; press RETURN to enter new data"; ED
210 IF ED = 1 GOTO 310
220 REM*****
230 REM ***OPEN FILE FOR DATA ENTRY***
240 OPEN NM$ AS # 1 LEN=95
250 FIELD #1, 5 AS A$, 5 AS B$, 5 AS C$, 5 AS D$, 5 AS E$, 5 AS F$, 5 AS G$, 5
AS H$, 5 AS I$, 5 AS J$, 5 AS K$, 5 AS L$, 5 AS M$, 5 AS N$, 5 AS O$, 5 AS P$, 5
AS Q$, 5 AS R$, 5 AS S$
260 IF EK <>0 GOTO 990
270 REM INPUT "TYPE NUMBER OF first RECORD - TYPE 9999 TO END"; CODE%
280 GOTO 530
290 REM*****
300 REM ***DATA EDIT SECTION***
310 CLS:OPEN NM$ AS # 1 LEN=95
320 FIELD #1, 5 AS A$, 5 AS B$, 5 AS C$, 5 AS D$, 5 AS E$, 5 AS F$, 5 AS G$, 5
AS H$, 5 AS I$, 5 AS J$, 5 AS K$, 5 AS L$, 5 AS M$, 5 AS N$, 5 AS O$, 5 AS P$, 5
AS Q$, 5 AS R$, 5 AS S$
330 REM INPUT "TYPE NUMBER OF RECORD TO EDIT - TYPE 9999 TO END"; CODE%
340 REM IF CODE% = 9999 THEN CLOSE: END
350 GOTO 360
360 GET #1
370 A=CVS(A$):B=CVS(B$):C=CVS(C$):D=CVS(D$):E=CVS(E$):F=CVS(F$):G=CVS(G$)
380 H=CVS(H$):I=CVS(I$):J=CVS(J$):K=CVS(K$):L=CVS(L$):M=CVS(M$):N=CVS(N$)
390 O=CVS(O$):P=CVS(P$):Q=CVS(Q$):R=CVS(R$)
400 PRINT"19 QUATERNARY = ";A:PRINT "18 PLIOCENE = ";B:PRINT "17 MIOCENE = ";C:
410 PRINT"16 OLIGOCENE = ";D:PRINT "15 PALEOCENE = ";E:PRINT"14 FOXHILLS = ";F:
420 PRINT "13 PIERRE = ";G:PRINT"12 NEWCASTLE = ";H:PRINT"11 INYAN KARA = ";I:PRINT"10
MORRISON = ";J
430 PRINT"9 SUNDANCE = ";K:PRINT "8 SPEARFISH = ";L:PRINT "7 MINNEKAHTA = ";M:
440 PRINT"6 OPECHE = ";N:PRINT "5 MINNELUSA = ";O:PRINT"4 MADISON = ";P:

```



```

450 PRINT"3 DEVONIAN = ";Q:PRINT"2 CAMBRIAN = ";R
460 INPUT "TO EDIT FILE TYPE 1 - TO CONTINUE HIT RETURN"; EK
470 IF EK = 1 THEN CLOSE: GOTO 490
480 CLS:CLOSE:GOTO 1230
490 OPEN NM$ AS # 1 LEN=95
500 FIELD #1, 5 AS A$, 5 AS B$, 5 AS C$, 5 AS D$, 5 AS E$, 5 AS F$, 5 AS G$, 5
AS H$, 5 AS I$, 5 AS J$, 5 AS K$, 5 AS L$, 5 AS M$, 5 AS N$, 5 AS O$, 5 AS P$, 5
AS Q$, 5 AS R$, 5 AS S$
510 REM*****
520 REM ***DATA ENTRY***
530 IF EK = 1 THEN GOTO 540 ELSE GOTO 580
540 INPUT" type number of data point to edit else press return to end edit";EN
550 IF EN=19 THEN 630 ELSE IF EN=18 THEN 650 ELSE IF EN=17 THEN 670 ELSE IF EN
= 16 THEN 690 ELSE IF EN=15 THEN 710 ELSE IF EN=14 THEN 730 ELSE IF EN=13 THEN
750 ELSE IF EN=12 THEN 770 ELSE IF EN=11 THEN 790 ELSE GOTO 560
560 IF EN=10 THEN 810 ELSE IF EN=9 THEN 830 ELSE IF EN=8 THEN 850 ELSE IF EN=7
THEN 870 ELSE IF EN=6 THEN 890 ELSE IF EN=5 THEN 910 ELSE IF EN=4 THEN 930 ELSE
IF EN=3 THEN 950 ELSE IF EN=2 THEN 970 ELSE 570
570 CLOSE:GOTO 230
580 PRINT "*** SOUTH DAKOTA GEOTHERMAL MAP "NM$,CODE%
590 SI = 3.2808
600 REM INPUT "ELEVATION "; ELEV
610 IF ELEV = 9999 THEN CLOSE: GOTO 1260
620 ELEV = ELEV/3.2808
630 INPUT "THICKNESS OF (19) QUATERNARY"; A
640 A = A/SI:IF EK<>0 THEN GOTO 540
650 INPUT "THICKNESS OF (18) PLIOCENE"; B
660 B=B/SI:IF EK<>0 THEN GOTO 540
670 INPUT "THICKNESS OF (17) MIOCENE"; C
680 C=C/SI:IF EK<>0 THEN GOTO 540
690 INPUT "THICKNESS OF (16) OLIGOCENE"; D
700 D=D/SI:IF EK<>0 THEN GOTO 540
710 INPUT "THICKNESS OF (15) PALEOCENE"; E
720 E=E/SI:IF EK<>0 THEN GOTO 540
730 INPUT "THICKNESS OF (14) FOXHILLS "; F
740 F=F/SI:IF EK<>0 THEN GOTO 540
750 INPUT "THICKNESS OF (13) PIERRE"; G
760 G=G/SI:IF EK<>0 THEN GOTO 540
770 INPUT "THICKNESS OF (12) NEWCASTLE "; H
780 H=H/SI:IF EK<>0 THEN GOTO 540
790 INPUT "THICKNESS OF (11) INYAN KARA "; I
800 I=I/SI:IF EK<>0 THEN GOTO 540
810 INPUT "THICKNESS OF (10) JURASSIC MORRISON";J
820 J=J/SI:IF EK<>0 THEN GOTO 540
830 INPUT "THICKNESS OF ( 9) JURASSIC SUNDANCE"; K
840 K=K/SI:IF EK<>0 THEN GOTO 540
850 INPUT "THICKNESS OF ( 8) SPEARFISH "; L
860 L=L/SI:IF EK<>0 THEN GOTO 540
870 INPUT "THICKNESS OF ( 7) MINNEKAHATA "; M
880 M=M/SI:IF EK<>0 THEN GOTO 540
890 INPUT "THICKNESS OF ( 6) OPECHE "; N
900 N=N/SI:IF EK<>0 THEN GOTO 540

```

```

910 INPUT "THICKNESS OF ( 5) MINNELUSA "; O
920 O=O/SI:IF EK<>0 THEN GOTO 540
930 INPUT "THICKNESS OF ( 4) MADISON "; P
940 P=P/SI:IF EK<>0 THEN GOTO 540
950 INPUT "THICKNESS OF ( 3) ORDOVICIAN-DEVONIAN "; Q
960 Q=Q/SI:IF EK<>0 THEN GOTO 540
970 INPUT "THICKNESS OF ( 2) CAMBRIAN "; R
980 R=R/SI:IF EK<>0 THEN GOTO 540
990 REM*****
1000 REM***CONVERT TO STRING CHARCTERS AND WRITE TO DISK***
1010 LSET A$ = MKS$(A)
1020 LSET B$ = MKS$(B)
1030 LSET C$ = MKS$(C)
1040 LSET D$ = MKS$(D)
1050 LSET E$ = MKS$(E)
1060 LSET F$ = MKS$(F)
1070 LSET G$ = MKS$(G)
1080 LSET H$ = MKS$(H)
1090 LSET I$ = MKS$(I)
1100 LSET J$ = MKS$(J)
1110 LSET K$ = MKS$(K)
1120 LSET L$ = MKS$(L)
1130 LSET M$ = MKS$(M)
1140 LSET N$ = MKS$(N)
1150 LSET O$ = MKS$(O)
1160 LSET P$ = MKS$(P)
1170 LSET Q$ = MKS$(Q)
1180 LSET R$ = MKS$(R)
1190 LSET S$ = MKS$(S)
1200 PUT #1
1210 BEEP
1220 INPUT "TO ENTER ANOTHER RECORD TYPE 1,ELSE PRESS ENTER";AGN
1230 IF AGN<>0 THEN GOTO 1240 ELSE GOTO 1250
1240 ED=0:EK=0:CLS:CLOSE:GOTO 150
1250 CLOSE:
1260 PRINT "END OF DATA ENTRY LAST FILE WAS " NM$

```

2. PROGRAM TEMSTRAT:

Program TEMSTRAT reads the data from STRAT and computes temperatures, depths to formation tops, temperature gradients, and stored energy in Joules. It also creates data files for summation of the stored resource by program SUMMER. The data necessary for running TEMSTRAT are: surface temperature, heat flow, and the disk containing data files created by STRAT. One other set of data necessary for running TEMSTRAT is the effective thermal conductivity of each formation. However, the conductivity data are part of the program source code and may be altered by editing statement numbers 260-280. As in program STRAT, changes in the number of formations may be made by editing several statements, i.e., 350, 370, 440-540, 560-750, 950-1590, 1680-2330, and 2350-2390.

Variables are named so that they are easily identifiable. Most variables beginning with "T", as in TQUAT, refer to temperature. In this example, TQUAT is the temperature on top of the Quaternary. Most variables beginning with "D" refer to depth. The variables ending with CON AND GRAD that begin with sequential letters of the alphabet are for thermal conductivity and temperature gradient respectively. The QR(I) variables, where $i = 1-7$, are for the stored energy in 10^{18} Joules in the geothermal aquifers.

To run the program using the BASIC interpreter:

- 1: Boot the system using DOS
- 2: Type BASICA (return) to load the basic interpreter
- 3: Type "LOAD" (or use the function key F3) TEMSTRAT <return>
- 4: Press function key F2 to run

```

10 REM ***** PROGRAM TEMSTRAT *****
20 CLS:KEY OFF:ARC = 0
30 DIM QR(7)
40 LOCATE 8,33:PRINT" PROGRAM TEMSTRAT"
50 LOCATE 11,10:PRINT" PROGRAM FOR CALCULATING SUBSURFACE TEMPERATURES AND
STORED ENERGY IN JOULES"
60 LOCATE 15,5: INPUT:"ENTER NAME OF STUDY AREA OR STATE NAME";PLACES
70 LOCATE 20,22: PRINT "DATA DISK SHOULD BE IN THE DEFAULT DRIVE"
80 LOCATE 22,25: PRINT "TO SEE FILES ON DISK, TYPE `FILES'"
90 REM ***** DATA FILE SHOULD BE IN DEFAULT DRIVE *****
100 LOCATE 24,38: INPUT:"FILE NAME";NM$
110 WIDTH "LPT1:",120
120 CLS
130 IF NM$="FILES" THEN GOTO 140 ELSE IF NM$="files" THEN GOTO 140 ELSE
GOTO 150
140 FILES:GOTO 100
150 CLS:ARC = ARC +1
160 QR$ = NM$ + "QR"
170 LOCATE 10,20:INPUT "ENTER SURFACE TEMPERATURE";SURT
180 LOCATE 11,20:INPUT "ENTER SURFACE HEAT FLOW IN MILLIWATTS/METER^2";AQ
190 LOCATE 12,20:INPUT "ENTER HEAT FLOW BELOW DAKOTA";DQ
200 IF DQ = 0 THEN DQ = AQ
210 LOCATE 13,20:INPUT "ENTER HEAT FLOW BELOW MADISON";MQ
220 IF MQ = 0 THEN MQ = DQ
230 REM ***** "THERMAL CONDUCTIVITIES IN Mw/m/k "*****
240 REM ***** "ADDITIONAL CONDUCTIVITIES MAY BE ADDED BY CONTINUING LINE 220
250 REM ***** "ANY CONDUCTIVITY MAY BE CHANGED BY EDITING AND SAVING THE LINE
260 ACON=1400:BCON=1200:CCON=1200:DCON=1200:ECON=1200:FCON=1200:GCON=1100
270 HCON=1400:ICON=1600:JCON=1400:KCON=1400:LCON=1300:MCON=3000:NCON=1400
280 OCON=2200:PCON=3500:QCON=3500:RCON=2400
290 CLS
300 REM ***** READ DATA FROM DISK - NOTE THAT THE NUMBER OF STRATA IS 18
310 REM ***** THE NUMBER MAY BE CHANGED BY EDITING THIS PROGRAM BUT IT
320 REM ***** MUST AGREE WITH THE NUMBER OF DATA WRITTEN BY PROGRAM "STRAT"
330 OPEN NM$ AS #1 LEN=95
340 CHT = 1
350 FIELD #1, 5 AS A$,5 AS B$,5 AS C$,5 AS D$,5 AS E$,5 AS F$,5 AS G$,5 AS H$,
5 AS I$,5 AS J$,5 AS K$,5 AS L$,5 AS M$,5 AS N$,5 AS O$,5 AS P$,5 AS Q$,5 AS R$
360 GET #1
370 A=CVS(A$):B=CVS(B$):C=CVS(C$):D=CVS(D$):E=CVS(E$):F=CVS(F$):G=CVS(G$):
H=CVS(H$):I=CVS(I$):J=CVS(J$):K=CVS(K$):L=CVS(L$):M=CVS(M$):N=CVS(N$):O=CVS(O$):
P=CVS(P$):Q=CVS(Q$):R=CVS(R$)
380 PRINT:PRINT
390 INPUT "TYPE 1 TO PRINT THE DATA, ELSE PRESS RETURN "; PIT
400 CLOSE
410 TSUM = 0
420 REM ***** CHANGES IN THE NUMBER OF DATA REQUIRE CHANGES IN THE
430 REM ***** FOLLOWING ALGORITHMS. THE NUMBER OF STRATA MUST BE CONSISTENT
440 DQUAT = 0:DPLI=A:DMIO=DPLI+B:DOLI=DMIO+C:DPAL=DOLI+D
450 DFHL=DPAL+E:DPIR=DFHL+F:DNCW=DPIR+G:DINK=DNCW+H:DUJR=DINK+I
460 DLJR=DUJR+J:DSPF=DLJR+K:DMKH=DSPF+L:DOPC=DMKH+M:DMIN=DOPC+N
470 DMAD=DMIN+O:DODV=DMAD+P:DCAM=DODV+Q:DPRC=DCAM+R

```

```

480 TQUAT =SURT:TPLI=TQUAT+TSUM+AQ*((A)/ACON):AGRAD=1000*AQ/ACON:TSUM = TPLI
490 TMIO = AQ*((B)/BCON) + TSUM: TSUM = TMIO:BGRAD=AQ/BCON*1000
500 TOLI = AQ*((C)/CCON) + TSUM: TSUM = TOLI:CGRAD=AQ/CCON*1000
510 TPAL = AQ*((D)/DCON) + TSUM: TSUM = TPAL:DGRAD=AQ/DCON*1000
520 TFHL = AQ*((E)/ECON) + TSUM: TSUM = TFHL:EGRAD=AQ/ECON*1000
530 TPIR = AQ*((F)/FCON) + TSUM: TSUM = TPIR:FGRAD=AQ/FCON*1000
540 TNCW = AQ*((G)/GCON) + TSUM: TSUM = TNCW:GGRAD=AQ/GCON*1000
550 PC = 2600000!:AREA = 6.1749E+08
560 IF TNCW<15 THEN GOTO 590
570 QR(1) = (PC*H*AREA*(TNCW-SURT))/1E+18
580 TINK = DQ*((H)/HCON) + TSUM: TSUM = TINK:HGRAD=DQ/HCON*1000
590 IF TINK<15 THEN GOTO 610
600 QR(2) = (PC*I*AREA*(TINK-SURT))/1E+18
610 TUJR = DQ*((I)/ICON) + TSUM: TSUM = TUJR:IGRAD=DQ/ICON*1000
620 TLJR = DQ*((J)/JCON) + TSUM: TSUM = TLJR:JGRAD=DQ/JCON*1000
630 TSPF = DQ*((K)/KCON) + TSUM: TSUM = TSPF:KGRAD=DQ/KCON*1000
640 TMKH = DQ*((L)/LCON) + TSUM: TSUM = TMKH:LGRAD=DQ/LCON*1000
650 QR(3) = (PC*M*AREA*(TMKH-SURT))/1E+18
660 TOPC = DQ*((M)/MCON) + TSUM: TSUM = TOPC:MGRAD=DQ/MCON*1000
670 TMIN = DQ*((N)/NCON) + TSUM: TSUM = TMIN:NGRAD=DQ/NCON*1000
680 QR(4) = (PC*O*AREA*(TMIN-SURT))/1E+18
690 TMAD = MQ*((O)/OCON) + TSUM: TSUM = TMAD:OGRAD=MQ/OCON*1000
700 QR(5) = (PC*P*AREA*(TMAD-SURT))/1E+18
710 TODV = MQ*((P)/PCON) + TSUM: TSUM = TODV:PGRAD=MQ/PCON*1000
720 QR(6) = (PC*Q*AREA*(TODV-SURT))/1E+18
730 TCAM = MQ*((Q)/QCON) + TSUM: TSUM = TCAM:QGRAD=MQ/QCON*1000
740 QR(7) = (PC*R*AREA*(TCAM-SURT))/1E+18
750 TPRC = MQ*((R)/RCON) + TSUM:RGRAD=MQ/RCON*1000
760 CLS
770 IF PIT = 1 THEN 780 ELSE 790
780 LPRINT PLACE$; "Geothermal: calculation point ";NM$:LPRINT:LPRINT
790 LOCATE 2,15:PRINT PLACE$;" Geothermal: calculation point ";NM$
800 LOCATE 3,1
810 IF PIT = 1 THEN 820 ELSE 850
820 LPRINT"SURFACE TEMP =";SURT;" HEAT FLOW: SURFACE =";AQ;" DAKOTA =";DQ;
" MADISON =";MQ:LPRINT:LPRINT
830 LPRINT USING"###.##";SURT;
840 LPRINT" HEAT FLOW: SURFACE =";AQ;" DAKOTA =";DQ;" MADISON =";MQ;
LPRINT:LPRINT
850 PRINT"SURFACE TEMP ="SURT;" HEAT FLOW: SURFACE =";AQ;" DAKOTA =";DQ;"
MADISON =";MQ
860 IF PIT = 1 THEN 870 ELSE 900
870 LPRINT " TEMPERATURE THICKNESS DEPTH COND. GRADIENT ENERGY"
880 LPRINT " DEGREES C METERS METERS S.I. DEG/KM J X10^18"
890 LPRINT " :LPRINT
900 PRINT " TEMPERATURE THICKNESS DEPTH COND. GRADIENT ENERGY"
910 PRINT " DEGREES C METERS METERS S.I. DEG/KM J X10^18"
920 PRINT "
:PRINT
930 LOCATE 7,1
940 IF A = 0 THEN GOTO 970
950 PRINT "QUATERNARY ";

```

```

960 PRINT USING"#####.##";TQUAT,A,ZZZ,ACON/1000,AGRAD
970 IF B = 0 THEN GOTO 1000
980 PRINT "PLIOCENE ";
990 PRINT USING"#####.##";TPLI,B,DPLI,BCON/1000,BGRAD
1000 IF C = 0 THEN GOTO 1030
1010 PRINT "MIOCENE ";
1020 PRINT USING"#####.##";TMIO,C,DMIO,CCON/1000,CGRAD
1030 IF D = 0 THEN GOTO 1060
1040 PRINT "OLIGOCENE ";
1050 PRINT USING"#####.##";TOLI,D,DOLI,DCON/1000,DGRAD
1060 IF E = 0 THEN GOTO 1090
1070 PRINT "PALEOCENE ";
1080 PRINT USING"#####.##";TPAL,E,DPAL,ECON/1000,EGRAD
1090 IF F = 0 THEN GOTO 1120
1100 PRINT "FOX HILLS ";
1110 PRINT USING"#####.##";TFHL,F,DFHL,FCON/1000,FGRAD
1120 IF G = 0 THEN GOTO 1150
1130 PRINT "PIERRE ";
1140 PRINT USING"#####.##";TPIR,G,DPIR,GCON/1000,GGRAD
1150 IF H = 0 THEN GOTO 1190
1160 PRINT "NEWCASTLE ";
1170 PRINT USING"#####.##";TNCW,H,DNCW,HCON/1000,HGRAD;
1180 PRINT USING"#####.###";QR(1)
1190 IF I = 0 THEN GOTO 1230
1200 PRINT "INYAN KARA ";
1210 PRINT USING"#####.##";TINK,I,DINK,ICON/1000,IGRAD;
1220 PRINT USING"#####.###";QR(2)
1230 IF J = 0 THEN GOTO 1260
1240 PRINT "MORRISON ";
1250 PRINT USING"#####.##";TUJR,J,DUJR,JCON/1000,JGRAD
1260 IF K = 0 THEN GOTO 1290
1270 PRINT "SUNDANCE ";
1280 PRINT USING"#####.##";TLJR,K,DLJR,KCON/1000,KGRAD
1290 IF L = 0 THEN GOTO 1320
1300 PRINT "SPEARFISH ";
1310 PRINT USING"#####.##";TSPF,L,DSPF,LCON/1000,LGRAD
1320 IF M = 0 THEN GOTO 1360
1330 PRINT "MINNEKAHATA";
1340 PRINT USING"#####.##";TMKH,M,DMKH,MCON/1000,MGRAD;
1350 PRINT USING"#####.###";QR(3)
1360 IF N = 0 THEN GOTO 1390
1370 PRINT "OPECHE ";
1380 PRINT USING"#####.##";TOPC,N,DOPC,NCON/1000,NGRAD
1390 IF O = 0 THEN GOTO 1430
1400 PRINT "MINNELUSA ";
1410 PRINT USING"#####.##";TMIN,O,DMIN,OCON/1000,OGRAD;
1420 PRINT USING"#####.###";QR(4)
1430 IF P = 0 THEN GOTO 1480
1440 PRINT "MADISON ";
1450 TMSS = (TMAD*1.8) +32
1460 PRINT USING"#####.##";TMAD,P,DMAD,PCON/1000,PGRAD;
1470 PRINT USING"#####.###";QR(5)

```

```

1480 IF Q = 0 THEN GOTO 1520
1490 PRINT "DEVONIAN ";
1500 PRINT USING"#####.##";TODV,Q,DODV,QCON/1000,QGRAD;
1510 PRINT USING"#####.###";QR(6)
1520 IF R = 0 THEN GOTO 1560
1530 PRINT "CAMBRIAN ";
1540 PRINT USING"#####.##";TCAM,R,DCAM,RCON/1000,RGRAD;
1550 PRINT USING"#####.###";QR(7)
1560 PRINT "BASEMENT ";
1570 PRINT USING"#####.##";TPRC;
1580 PRINT " ";
1590 PRINT USING"#####.##";DPRC;
1600 IF PIT = 1 THEN GOSUB 1680 ELSE GOSUB 2350
1610 LOCATE 24,30:PRINT"{press any key to continue}"
1620 AV$=INKEY$:IF AV$="" GOTO 1620
1630 CLS
1640 LOCATE 15,1:INPUT"ENTER 1 TO RUN ANOTHER FILE, ENTER 2 TO CHANGE HEAT FLOW,
ELSE RETURN TO END";NMS
1650 IF NMS =1 THEN GOTO 80 ELSE IF NMS = 2 THEN GOTO 180 ELSE GOTO 1660
1660 CLOSE
1670 END
1680 IF A = 0 THEN GOTO 1710
1690 LPRINT "QUATERNARY ";
1700 LPRINT USING"#####.##";TQUAT,A,ZZZ,ACON/1000,AGRAD
1710 IF B = 0 THEN GOTO 1740
1720 LPRINT "PLIOCENE ";
1730 LPRINT USING"#####.##";TPLI,B,DPLI,BCON/1000,BGRAD
1740 IF C = 0 THEN GOTO 1770
1750 LPRINT "MIOCENE ";
1760 LPRINT USING"#####.##";TMIO,C,DMIO,CCON/1000,CGRAD
1770 IF D = 0 THEN GOTO 1800
1780 LPRINT "OLIGOCENE ";
1790 LPRINT USING"#####.##";TOLI,D,DOLI,DCON/1000,DGRAD
1800 IF E = 0 THEN GOTO 1830
1810 LPRINT "PALEOCENE ";
1820 LPRINT USING"#####.##";TPAL,E,DPAL,ECON/1000,EGRAD
1830 IF F = 0 THEN GOTO 1860
1840 LPRINT "FOX HILLS ";
1850 LPRINT USING"#####.##";TFHL,F,DFHL,FCON/1000,FGRAD
1860 IF G = 0 THEN GOTO 1890
1870 LPRINT "PIERRE ";
1880 LPRINT USING"#####.##";TPIR,G,DPIR,GCON/1000,GGRAD
1890 IF H = 0 THEN GOTO 1930
1900 LPRINT "NEWCASTLE ";
1910 LPRINT USING"#####.##";TNCW,H,DNCW,HCON/1000,HGRAD;
1920 LPRINT USING"#####.###";QR(1)
1930 IF I = 0 THEN GOTO 1970
1940 LPRINT "INYAN KARA ";
1950 LPRINT USING"#####.##";TINK,I,DINK,ICON/1000,IGRAD;
1960 LPRINT USING"#####.###";QR(2)
1970 IF J = 0 THEN GOTO 2000
1980 LPRINT "MORRISON ";

```

```

1990 LPRINT USING"#####.##";TUJR,J,DUJR,JCON/1000,JGRAD
2000 IF K = 0 THEN GOTO 2030
2010 LPRINT "SUNDANCE ";
2020 LPRINT USING"#####.##";TLJR,K,DLJR,KCON/1000,KGRAD
2030 IF L = 0 THEN GOTO 2060
2040 LPRINT "SPEARFISH ";
2050 LPRINT USING"#####.##";TSPF,L,DSPF,LCON/1000,JGRAD
2060 IF M = 0 THEN GOTO 2100
2070 LPRINT "MINNEKAHATA";
2080 LPRINT USING"#####.##";TMKH,M,DMKH,MCON/1000,MGRAD;
2090 LPRINT USING"#####.###";QR(3)
2100 IF N = 0 THEN GOTO 2130
2110 LPRINT "OPECHE ";
2120 LPRINT USING"#####.##";TOPC,N,DOPC,NCON/1000,NGRAD
2130 IF O = 0 THEN GOTO 2170
2140 LPRINT "MINNELUSA ";
2150 LPRINT USING"#####.##";TMIN,O,DMIN,OCON/1000,OGRAD;
2160 LPRINT USING"#####.###";QR(4)
2170 IF P = 0 THEN GOTO 2210
2180 LPRINT "MADISON ";
2190 LPRINT USING"#####.##";TMAD,P,DMAD,PCON/1000,PGRAD;
2200 LPRINT USING"#####.###";QR(5)
2210 IF Q = 0 THEN GOTO 2250
2220 LPRINT "DEVONIAN ";
2230 LPRINT USING"#####.##";TODV,Q,DODV,QCON/1000,QGRAD;
2240 LPRINT USING"#####.###";QR(6)
2250 IF R = 0 THEN GOTO 2290
2260 LPRINT "CAMBRIAN ";
2270 LPRINT USING"#####.##";TCAM,R,DCAM,RCON/1000,RGRAD;
2280 LPRINT USING"#####.###";QR(7)
2290 LPRINT "BASEMENT ";
2300 LPRINT USING"#####.##";TPRC;
2310 LPRINT " ";
2320 LPRINT USING"#####.##";DPRC;
2330 LPRINT:LPRINT:LPRINT
2340 GOTO 2450
2350 OPEN QR$ AS #1 LEN = 40
2360 FIELD #1,5 AS DA$,5 AS DB$,5 AS DC$,5 AS DD$,5 AS DE$,5 AS DF$,5 AS DG$,
5 AS DH$
2370 LSET DA$=NM$:LSET DB$=MK$$(QR(1)):LSET DC$=MK$$(QR(2)):LSET DD$=
MK$$(QR(3)):LSET DE$=MK$$(QR(4)):LSET DF$=MK$$(QR(5)):LSET DG$=
MK$$(QR(6)):LSET DH$=MK$$(QR(7))
2380 PUT #1
2390 WRITE #1,NM$,DA$,DB$,DC$,DD$,DE$,DF$,DG$,DH$
2400 CLOSE
2410 CKO = ARC/2
2420 IF CKO = 1 THEN GOTO 2430 ELSE GOTO 2450
2430 ARC = 0
2440 IF PIT = 1 THEN LPRINT CHR$(12)
2450 RETURN

```


3. PROGRAM SUMMER

Program SUMMER reads the data files created by temstrat, sums the stored energy, and prints the totals on the screen and on the line printer. The program is non-essential, but it greatly reduces work by rapidly summing the data. It is set up now so that the particular cells to be summed must be entered as a prompt appears on the screen. The South Dakota grid has 14 horizontal cells, and the program is set up to execute 14 prompts. To change this to another number or even to allow for variable prompts, change statement 40.

The program prompts the user to enter the name of the file name for the cell. The file name written by statement 2350 in program TEMSTRAT "QR\$" which is the original file name, e.g. A1 + QR. The resulting name in this example is A1QR. The sums are given by formation for each horizontal cell. The totals must be calculated by hand or by using program TOTALS.

4. PROGRAM TOTALS

Program TOTAL is a non-essential program that may be used to sum the totals given by program SUMMER. Data are entered from the keyboard and the output is on the screen only.

Both program SUMMER and program TOTALS will be modified to form a single program that will print the total stored energy using a printer. These modifications will occur after the project ends.

```

1 REM***** PROGRAM SUMMER *****
10 CLS:FILES
20 DIM INK(15),NEC(15),MKH(15),MIN(15),MAD(15),ORD(15), CAM(15),N$(1)
30 INPUT;"ENTER NUMBER OF FIRST FILE COLUMN";N
40 FOR I = N TO 14
50 INPUT;"ENTER FILE DESIGNATION";NM$
60 REM INPUT;"ENTER NUMBER OF FIRST FILE COLUMN";N
70 CLS
80 OPEN NM$ AS #1 LEN = 40
90 FIELD #1,5 AS DA$,5 AS DB$,5 AS DC$,5 AS DD$,5 AS DE$,5 AS DF$,5 AS DG$,5 AS
DH$
100 GET #1
110 PRINT DA$;CVS(DB$);CVS(DC$);CVS(DD$);CVS(DE$);CVS(DF$); CVS(DG$);CVS(DH$)
120 INK(I)=CVS(DB$):NEC(I)=CVS(DC$):MKH(I)=CVS(DD$): MIN(I)=CVS(DE$):MAD(I)=
CVS(DF$):ORD(I)=CVS(DG$):CAM(I)=CVS(DH$)
130 SINK = SINK + INK(I):SNEC = SNEC + NEC(I):SMKH=SMKH+MKH(I): SMIN=SMIN+
MIN(I)
140 SMAD = SMAD + MAD(I):SORD = SORD + ORD(I):SCAM=SCAM+CAM(I)
150 STOTAL = SINK+SNEC+SMKH+SMIN+SMAD+SORD+SCAM
160 PRINT NM$;
170 PRINT USING"#####.###";SINK;SNEC;SMKH;SMIN;SMAD;SORD; SCAM; STOTAL
180 LPRINT NM$;
190 LPRINT USING"#####.###";SINK;SNEC;SMKH;SMIN;SMAD;SORD;SCAM; STOTAL
200 CLOSE #1
210 NEXT I
220 LPRINT:LPRINT:LPRINT

```

```

1  REM***** PROGRAM TOTALS *****
10 CLS
20 DIM INK(15),NEC(15),MKH(15),MIN(15),MAD(15),ORD(15),CAM(15), N$(1)
   FOR I = N TO 14
40 INPUT;"ENTER data INYAN KARA      ";INK(I):PRINT
50 INPUT;"ENTER data NEWCASTLE      ";NEC(I):PRINT
60 INPUT;"ENTER data MINNEHAHTA     ";MKH(I):PRINT
70 INPUT;"ENTER data MINNELUSA      ";MIN(I):PRINT
80 INPUT;"ENTER data MADISON        ";MAD(I):PRINT
90 INPUT;"ENTER data ORDOVICIAN     ";ORD(I):PRINT
100 INPUT;"ENTER data CAMBRIAN      ";CAM(I):PRINT
110 INKTOTAL = INKTOTAL+INK(I)
120 NECTOTAL = NECTOTAL+NEC(I)
130 MKHTOTAL = MKHTOTAL+MKH(I)
140 MINTOTAL = MINTOTAL+MIN(I)
150 MADTOTAL = MADTOTAL+MAD(I)
160 ORDTOTAL = ORDTOTAL+ORD(I)
170 CAMTOTAL = CAMTOTAL+CAM(I)
180 PRINT NM$;
190 REM PRINT USING"#####.###";INKTOTAL;NECTOTAL;MKHTOTAL;MINTOTAL;MADTOTAL;
   ORDTOTAL;CAMTOTAL
200 NEXT
210 PRINT USING"#####.###";INKTOTAL;NECTOTAL;MKHTOTAL;MINTOTAL; MADTOTAL;
   ORDTOTAL;CAMTOTAL
220 TOT = INKTOTAL+NECTOTAL+MKHTOTAL+MINTOTAL+MADTOTAL+ORDTOTAL + CAMTOTAL
230 PRINT TOT

```

APPENDIX B

TABULATED DATA ON TEMPERATURE CALCULATIONS

SOUTH DAKOTAGEothermal: calculation point a1

SURFACE TEMP = 6.4 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.4 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.4	152.4	0.0	1.2	50.0	
FOX HILLS	14.0	36.6	152.4	1.2	50.0	
PIERRE	15.8	1127.8	189.0	1.1	54.5	
INYAN KARA	77.4	42.7	1316.8	1.6	37.5	4.862
MORRISON	79.0	61.0	1359.4	1.4	42.9	
SUNDANCE	81.6	167.6	1420.4	1.4	42.9	
SPEARFISH	88.8	167.6	1588.0	1.3	42.9	
MINNEKAHATA	96.5	12.2	1755.7	3.0	20.0	1.764
OPECHE	96.7	44.2	1767.9	1.4	42.9	
MINNELUSA	98.6	137.2	1812.1	2.2	27.3	20.311
MADISON	102.4	390.1	1949.2	3.5	17.1	60.118
DEVONIAN	109.1	368.8	2339.4	3.5	17.1	60.790
CAMBRIAN	115.4	207.3	2708.2	2.4	25.0	36.267
BASEMENT	120.6		2915.4			

SOUTH DAKOTAGEothermal: calculation point a2

SURFACE TEMP = 6.4 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.4 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.4	152.4	0.0	1.2	50.0	
FOX HILLS	14.0	24.4	152.4	1.2	50.0	
PIERRE	15.2	1097.3	176.8	1.1	54.5	
NEWCASTLE	75.1	6.1	1274.1	1.4	42.9	0.672
INYAN KARA	75.4	48.8	1280.2	1.6	37.5	5.399
MORRISON	77.2	54.9	1328.9	1.4	42.9	
SUNDANCE	79.5	185.9	1383.8	1.4	42.9	
SPEARFISH	87.5	152.4	1569.7	1.3	42.9	
MINNEKAHATA	94.5	10.7	1722.1	3.0	20.0	1.510
OPECHE	94.7	44.2	1732.8	1.4	42.9	
MINNELUSA	96.6	129.5	1777.0	2.2	27.3	18.768
MADISON	100.2	399.3	1906.5	3.5	17.1	60.115
DEVONIAN	107.0	420.6	2305.8	3.5	17.1	67.950
CAMBRIAN	114.2	201.2	2726.5	2.4	25.0	34.827
BASEMENT	119.3		2927.6			

SOUTH DAKOTAGEothermal: calculation point a3

SURFACE TEMP = 6.2 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.2 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.2	198.1	0.0	1.2	50.0	
FOX HILLS	16.1	64.0	198.1	1.2	50.0	
PIERRE	19.3	1082.1	262.1	1.1	54.5	
INYAN KARA	78.3	42.7	1344.2	1.6	37.5	4.941
MORRISON	79.9	38.1	1386.9	1.4	42.9	
SUNDANCE	81.6	182.9	1425.0	1.4	42.9	
SPEARFISH	89.4	121.9	1607.8	1.3	42.9	
MINNEKAHATA	95.0	9.1	1729.8	3.0	20.0	1.304
OPECHE	95.2	44.2	1738.9	1.4	42.9	
MINNELUSA	97.1	161.5	1783.1	2.2	27.3	23.576
MADISON	101.5	405.4	1944.6	3.5	17.1	62.031
DEVONIAN	108.5	442.0	2350.0	3.5	17.1	72.559
CAMBRIAN	116.0	195.1	2792.0	2.4	25.0	34.399
BASEMENT	120.9		2987.1			

SOUTH DAKOTAGEothermal: calculation point a4

SURFACE TEMP = 6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.1	213.4	0.0	1.2	50.0	
FOX HILLS	16.8	70.1	213.4	1.2	50.0	
PIERRE	20.3	1036.3	283.5	1.1	54.5	
INYAN KARA	76.8	51.8	1319.8	1.6	37.5	5.882
MORRISON	78.7	24.4	1371.6	1.4	42.9	
SUNDANCE	79.8	137.2	1396.0	1.4	42.9	
SPEARFISH	85.7	91.4	1533.2	1.3	42.9	
MINNEKAHATA	89.9	7.6	1624.6	3.0	20.0	1.025
OPECHE	90.0	45.1	1632.2	1.4	42.9	
MINNELUSA	92.0	185.9	1677.3	2.2	27.3	25.634
MADISON	97.0	396.2	1863.3	3.5	17.1	57.855
DEVONIAN	103.8	457.2	2259.5	3.5	17.1	71.742
CAMBRIAN	111.7	192.0	2716.7	2.4	25.0	32.548
BASEMENT	116.5		2908.7			

SOUTH DAKOTAGEOTHERMAL: calculation point a5

SURFACE TEMP = 6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.1	236.2	0.0	1.2	50.0	
FOX HILLS	17.9	79.2	236.2	1.2	50.0	
PIERRE	21.9	990.6	315.5	1.1	54.5	
NEWCASTLE	75.9	3.0	1306.1	1.4	42.9	0.342
INYAN KARA	76.0	48.8	1309.1	1.6	37.5	5.476
MORRISON	77.9	22.9	1357.9	1.4	42.9	
SUNDANCE	78.8	140.2	1380.8	1.4	42.9	
SPEARFISH	84.9	82.3	1521.0	1.3	42.9	
MINNEKAHATA	88.7	6.1	1603.3	3.0	20.0	0.808
OPECHE	88.8	45.1	1609.4	1.4	42.9	
MINNELUSA	90.7	195.1	1654.5	2.2	27.3	26.498
MADISON	96.0	399.3	1849.5	3.5	17.1	57.649
DEVONIAN	102.9	484.6	2248.8	3.5	17.1	75.297
CAMBRIAN	111.2	189.0	2733.5	2.4	25.0	31.882
BASEMENT	115.9		2922.5			

SOUTH DAKOTAGEOTHERMAL: calculation point a6

SURFACE TEMP = 6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.1	251.5	0.0	1.2	50.0	
FOX HILLS	18.7	79.2	251.5	1.2	50.0	
PIERRE	22.6	960.1	330.7	1.1	54.5	
NEWCASTLE	75.0	3.0	1290.8	1.4	42.9	0.337
INYAN KARA	75.1	42.7	1293.9	1.6	37.5	4.730
MORRISON	76.7	36.6	1336.6	1.4	42.9	
SUNDANCE	78.3	137.2	1373.1	1.4	42.9	
SPEARFISH	84.2	68.6	1510.3	1.3	42.9	
MINNEKAHATA	87.3	4.6	1578.9	3.0	20.0	0.596
OPECHE	87.4	39.6	1583.5	1.4	42.9	
MINNELUSA	89.1	185.9	1623.1	2.2	27.3	24.787
MADISON	94.2	390.1	1809.0	3.5	17.1	55.189
DEVONIAN	100.9	457.2	2199.2	3.5	17.1	69.584
CAMBRIAN	108.7	185.9	2656.4	2.4	25.0	30.637
BASEMENT	113.4		2842.3			

SOUTH DAKOTAGEOTHERMAL: calculation point a7

SURFACE TEMP = 6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.1	173.7	0.0	1.2	50.0	
FOX HILLS	14.8	80.8	173.7	1.2	50.0	
PIERRE	18.8	914.4	254.5	1.1	54.5	
NEWCASTLE	68.7	3.0	1168.9	1.4	42.9	0.306
INYAN KARA	68.8	36.6	1172.0	1.6	37.5	3.684
MORRISON	70.2	38.1	1208.5	1.4	42.9	
SUNDANCE	71.8	131.1	1246.6	1.4	42.9	
SPEARFISH	77.5	48.8	1377.7	1.3	42.9	
MINNEKAHATA	79.7	3.0	1426.5	3.0	20.0	0.360
OPECHE	79.8	33.5	1429.5	1.4	42.9	
MINNELUSA	81.2	176.8	1463.1	2.2	27.3	21.316
MADISON	86.0	378.0	1639.8	3.5	17.1	48.498
DEVONIAN	92.5	442.0	2017.8	3.5	17.1	61.309
CAMBRIAN	100.1	176.8	2459.8	2.4	25.0	26.674
BASEMENT	104.5		2636.6			

SOUTH DAKOTAGEOTHERMAL: calculation point a8

SURFACE TEMP = 6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.1	128.0	0.0	1.2	50.0	
FOX HILLS	12.5	79.2	128.0	1.2	50.0	
PIERRE	16.5	838.2	207.3	1.1	54.5	
NEWCASTLE	62.2	1.5	1045.5	1.4	42.9	0.137
INYAN KARA	62.2	27.4	1047.0	1.6	37.5	2.473
MORRISON	63.3	33.5	1074.4	1.4	42.9	
SUNDANCE	64.7	126.5	1108.0	1.4	42.9	
SPEARFISH	70.1	24.4	1234.5	1.3	42.9	
OPECHE	71.3	24.4	1258.8	1.4	42.9	
MINNELUSA	72.3	176.8	1283.2	2.2	27.3	18.791
MADISON	77.1	359.7	1460.0	3.5	17.1	41.014
DEVONIAN	83.3	429.8	1819.7	3.5	17.1	53.263
CAMBRIAN	90.7	161.5	2249.5	2.4	25.0	21.932
BASEMENT	94.7		2411.0			

SOUTH DAKOTA Geothermal: calculation point a9

SURFACE TEMP = 6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.1	76.2	0.0	1.2	50.0	
FOX HILLS	9.9	77.7	76.2	1.2	50.0	
PIERRE	13.8	768.1	153.9	1.1	54.5	
NEWCASTLE	55.7	3.0	922.0	1.4	42.9	0.243
INYAN KARA	55.8	29.0	925.1	1.6	37.5	2.312
MORRISON	56.9	15.2	954.0	1.4	42.9	
SUNDANCE	57.6	121.9	969.3	1.4	42.9	
SPEARFISH	62.8	12.2	1091.2	1.3	42.9	
OPECHE	63.4	15.8	1103.4	1.4	42.9	
MINNELUSA	64.0	210.3	1119.2	2.2	27.3	19.560
MADISON	69.8	313.9	1329.6	3.5	17.1	32.090
DEVONIAN	75.1	426.7	1643.5	3.5	17.1	47.304
CAMBRIAN	82.5	146.3	2070.2	2.4	25.0	17.937
BASEMENT	86.1		2216.5			

SOUTH DAKOTA Geothermal: calculation point a10

SURFACE TEMP = 6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.1	64.0	0.0	1.2	50.0	
FOX HILLS	9.3	76.2	64.0	1.2	50.0	
PIERRE	13.1	701.0	140.2	1.1	54.5	
NEWCASTLE	51.3	6.1	841.3	1.4	42.9	0.443
INYAN KARA	51.6	33.5	847.4	1.6	37.5	2.450
MORRISON	52.9	12.2	880.9	1.4	42.9	
SUNDANCE	53.4	94.5	893.1	1.4	42.9	
MINNELUSA	57.4	198.1	987.6	2.2	27.3	16.330
MADISON	62.8	289.6	1185.7	3.5	17.1	26.379
DEVONIAN	67.8	396.2	1475.2	3.5	17.1	39.256
CAMBRIAN	74.6	125.0	1871.5	2.4	25.0	13.744
BASEMENT	77.7		1996.5			

SOUTH DAKOTAGEothermal: calculation point a11

SURFACE TEMP = 6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.1	30.5	0.0	1.2	50.0	
FOX HILLS	7.6	68.6	30.5	1.2	50.0	
PIERRE	11.1	609.6	99.1	1.1	54.5	
NEWCASTLE	44.3	7.6	708.7	1.4	42.9	0.467
INYAN KARA	44.6	33.5	716.3	1.6	37.5	2.074
MORRISON	45.9	9.1	749.8	1.4	42.9	
SUNDANCE	46.3	61.0	759.0	1.4	42.9	
MINNELUSA	48.9	137.2	819.9	2.2	27.3	9.423
MADISON	52.6	268.2	957.1	3.5	17.1	20.039
DEVONIAN	57.2	393.2	1225.3	3.5	17.1	32.278
CAMBRIAN	64.0	111.3	1618.5	2.4	25.0	10.337
BASEMENT	66.8		1729.8			

SOUTH DAKOTAGEothermal: calculation point a12

SURFACE TEMP = 6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
FOX HILLS	6.1	30.5	0.0	1.2	50.0	
PIERRE	7.6	548.6	30.5	1.1	54.5	
NEWCASTLE	37.6	7.6	579.1	1.4	42.9	0.385
INYAN KARA	37.9	36.6	586.7	1.6	37.5	1.866
MORRISON	39.2	6.1	623.3	1.4	42.9	
SUNDANCE	39.5	54.9	629.4	1.4	42.9	
MINNELUSA	41.9	76.2	684.3	2.2	27.3	4.375
MADISON	43.9	246.9	760.5	3.5	17.1	14.999
DEVONIAN	48.2	362.7	1007.4	3.5	17.1	24.500
CAMBRIAN	54.4	97.5	1370.1	2.4	25.0	7.562
BASEMENT	56.8		1467.6			

SOUTH DAKOTAGEothermal: calculation point a13

SURFACE TEMP = 6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	6.1	487.7	0.0	1.1	54.5	
INYAN KARA	32.7	39.6	487.7	1.6	37.5	1.692
MORRISON	34.2	6.1	527.3	1.4	42.9	
SUNDANCE	34.4	51.8	533.4	1.4	42.9	
MINNELUSA	36.7	45.7	585.2	2.2	27.3	2.244
MADISON	37.9	234.7	630.9	3.5	17.1	11.988
DEVONIAN	41.9	335.3	865.6	3.5	17.1	19.292
CAMBRIAN	47.7	85.3	1200.9	2.4	25.0	5.698
BASEMENT	49.8		1286.3			

SOUTH DAKOTAGEothermal: calculation point a14

SURFACE TEMP = 6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	6.1	457.2	0.0	1.1	54.5	
INYAN KARA	31.0	42.7	457.2	1.6	37.5	1.709
MORRISON	32.6	6.1	499.9	1.4	42.9	
SUNDANCE	32.9	48.8	506.0	1.4	42.9	
MINNELUSA	35.0	45.7	554.7	2.2	27.3	2.121
MADISON	36.2	219.5	600.5	3.5	17.1	10.618
DEVONIAN	40.0	335.3	819.9	3.5	17.1	18.248
CAMBRIAN	45.7	70.1	1155.2	2.4	25.0	4.462
BASEMENT	47.5		1225.3			

SOUTH DAKOTAGEothermal: calculation point b1

SURFACE TEMP = 6.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.6	152.4	0.0	1.2	50.0	
FOX HILLS	14.2	51.8	152.4	1.2	50.0	
PIERRE	16.8	1097.3	204.2	1.1	54.5	
INYAN KARA	76.7	47.2	1301.5	1.6	37.5	5.314
MORRISON	78.4	48.8	1348.8	1.4	42.9	
SUNDANCE	80.5	176.8	1397.5	1.4	42.9	
SPEARFISH	88.1	164.6	1574.3	1.3	42.9	
MINNEKAHATA	95.7	13.7	1738.9	3.0	20.0	1.962
OPECHE	96.0	38.1	1752.6	1.4	42.9	
MINNELUSA	97.6	143.3	1790.7	2.2	27.3	20.931
MADISON	101.5	381.0	1934.0	3.5	17.1	58.057
DEVONIAN	108.0	350.5	2315.0	3.5	17.1	57.088
CAMBRIAN	114.1	201.2	2665.5	2.4	25.0	34.705
BASEMENT	119.1		2866.7			

SOUTH DAKOTAGEothermal: calculation point b2

SURFACE TEMP = 6.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.6	121.9	0.0	1.2	50.0	
FOX HILLS	12.7	64.0	121.9	1.2	50.0	
PIERRE	15.9	1112.5	185.9	1.1	54.5	
NEWCASTLE	76.6	1.5	1298.5	1.4	42.9	0.171
INYAN KARA	76.6	62.5	1300.0	1.6	37.5	7.027
MORRISON	79.0	57.9	1362.5	1.4	42.9	
SUNDANCE	81.5	192.0	1420.4	1.4	42.9	
SPEARFISH	89.7	125.0	1612.4	1.3	42.9	
MINNEKAHATA	95.5	12.2	1737.4	3.0	20.0	1.740
OPECHE	95.7	36.6	1749.6	1.4	42.9	
MINNELUSA	97.3	152.4	1786.1	2.2	27.3	22.187
MADISON	101.4	381.0	1938.6	3.5	17.1	58.010
DEVONIAN	108.0	61.0	2319.6	3.5	17.1	9.921
CAMBRIAN	109.0	195.1	2380.5	2.4	25.0	32.074
BASEMENT	113.9		2575.6			

SOUTH DAKOTAGEothermal: calculation point b3

SURFACE TEMP = 6.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.6	176.8	0.0	1.2	50.0	
FOX HILLS	15.4	61.0	176.8	1.2	50.0	
PIERRE	18.5	1066.8	237.7	1.1	54.5	
NEWCASTLE	76.7	3.0	1304.6	1.4	42.9	0.343
INYAN KARA	76.8	51.8	1307.6	1.6	37.5	5.841
MORRISON	78.8	45.7	1359.4	1.4	42.9	
SUNDANCE	80.7	123.4	1405.1	1.4	42.9	
SPEARFISH	86.0	112.8	1528.6	1.3	42.9	
MINNEKAHATA	91.2	10.7	1641.4	3.0	20.0	1.449
OPECHE	91.4	38.1	1652.0	1.4	42.9	
MINNELUSA	93.1	175.3	1690.1	2.2	27.3	24.326
MADISON	97.8	384.1	1865.4	3.5	17.1	56.252
DEVONIAN	104.4	420.6	2249.5	3.5	17.1	66.056
CAMBRIAN	111.6	192.0	2670.1	2.4	25.0	32.379
BASEMENT	116.4		2862.1			

SOUTH DAKOTAGEothermal: calculation point b4

SURFACE TEMP = 6.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.6	198.1	0.0	1.2	50.0	
FOX HILLS	16.5	68.6	198.1	1.2	50.0	
PIERRE	19.9	1030.2	266.7	1.1	54.5	
NEWCASTLE	76.1	1.5	1296.9	1.4	42.9	0.170
INYAN KARA	76.2	51.8	1298.5	1.6	37.5	5.790
MORRISON	78.1	32.0	1350.3	1.4	42.9	
SUNDANCE	79.5	88.4	1382.3	1.4	42.9	
SPEARFISH	83.3	97.5	1470.7	1.3	42.9	
MINNEKAHATA	87.8	9.1	1568.2	3.0	20.0	1.192
OPECHE	88.0	41.1	1577.4	1.4	42.9	
MINNELUSA	89.7	185.9	1618.5	2.2	27.3	24.820
MADISON	94.8	387.1	1804.4	3.5	17.1	54.825
DEVONIAN	101.5	432.8	2191.5	3.5	17.1	65.912
CAMBRIAN	108.9	189.0	2624.4	2.4	25.0	31.030
BASEMENT	113.6		2813.3			

SOUTH DAKOTAGeothermal: calculation point b5

SURFACE TEMP = 6.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 6

6.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.6	216.4	0.0	1.2	50.0	
FOX HILLS	17.4	76.2	216.4	1.2	50.0	
PIERRE	21.2	987.6	292.6	1.1	54.5	
INYAN KARA	75.1	48.8	1280.2	1.6	37.5	5.363
MORRISON	76.9	22.9	1328.9	1.4	42.9	
SUNDANCE	77.9	128.0	1351.8	1.4	42.9	
SPEARFISH	83.4	80.8	1479.8	1.3	42.9	
MINNEKAHATA	87.1	7.6	1560.6	3.0	20.0	0.985
OPECHE	87.3	41.1	1568.2	1.4	42.9	
MINNELUSA	89.0	160.0	1609.4	2.2	27.3	21.179
MADISON	93.4	381.0	1769.4	3.5	17.1	53.095
DEVONIAN	99.9	435.9	2150.4	3.5	17.1	65.312
CAMBRIAN	107.4	185.9	2586.3	2.4	25.0	30.091
BASEMENT	112.1		2772.2			

SOUTH DAKOTAGeothermal: calculation point b6

SURFACE TEMP = 6.7 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 6

6.7 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.7	189.0	0.0	1.2	50.0	
FOX HILLS	16.1	83.8	189.0	1.2	50.0	
PIERRE	20.3	954.0	272.8	1.1	54.5	
INYAN KARA	72.4	42.7	1226.8	1.6	37.5	4.500
MORRISON	74.0	30.5	1269.5	1.4	42.9	
SUNDANCE	75.3	137.2	1300.0	1.4	42.9	
SPEARFISH	81.2	71.6	1437.1	1.3	42.9	
MINNEKAHATA	84.5	6.1	1508.8	3.0	20.0	0.761
OPECHE	84.6	36.6	1514.9	1.4	42.9	
MINNELUSA	86.2	146.3	1551.5	2.2	27.3	18.664
MADISON	90.1	367.3	1697.8	3.5	17.1	49.207
DEVONIAN	96.4	432.8	2065.0	3.5	17.1	62.362
CAMBRIAN	103.9	176.8	2497.9	2.4	25.0	27.578
BASEMENT	108.3		2674.7			

SOUTH DAKOTAGEothermal: calculation point b7

SURFACE TEMP = 6.7 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.7 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.7	106.7	0.0	1.2	50.0	
FOX HILLS	12.0	85.3	106.7	1.2	50.0	
PIERRE	16.3	920.5	192.0	1.1	54.5	
INYAN KARA	66.5	33.5	1112.5	1.6	37.5	3.220
MORRISON	67.8	45.7	1146.1	1.4	42.9	
SUNDANCE	69.7	121.9	1191.8	1.4	42.9	
SPEARFISH	75.0	59.4	1313.7	1.3	42.9	
MINNEKAHATA	77.7	3.0	1373.1	3.0	20.0	0.347
OPECHE	77.8	27.4	1376.2	1.4	42.9	
MINNELUSA	78.9	146.3	1403.6	2.2	27.3	16.967
MADISON	82.9	350.5	1549.9	3.5	17.1	42.895
DEVONIAN	88.9	426.7	1900.5	3.5	17.1	56.337
CAMBRIAN	96.2	164.6	2327.2	2.4	25.0	23.663
BASEMENT	100.4		2491.8			

SOUTH DAKOTAGEothermal: calculation point b8

SURFACE TEMP = 6.7 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.7 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.7	53.3	0.0	1.2	50.0	
FOX HILLS	9.4	85.3	53.3	1.2	50.0	
PIERRE	13.6	835.2	138.7	1.1	54.5	
INYAN KARA	59.2	18.3	973.8	1.6	37.5	1.541
MORRISON	59.9	51.8	992.1	1.4	42.9	
SUNDANCE	62.1	106.7	1044.0	1.4	42.9	
SPEARFISH	66.7	35.1	1150.6	1.3	42.9	
MINNEKAHATA	68.3	1.5	1185.7	3.0	20.0	0.151
OPECHE	68.3	21.3	1187.2	1.4	42.9	
MINNELUSA	69.2	149.4	1208.5	2.2	27.3	14.994
MADISON	73.3	304.8	1357.9	3.5	17.1	32.593
DEVONIAN	78.5	417.6	1662.7	3.5	17.1	48.155
CAMBRIAN	85.7	149.4	2080.3	2.4	25.0	18.940
BASEMENT	89.4		2229.6			

SOUTH DAKOTAGeothermal: calculation point b9

SURFACE TEMP = 6.7 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.7 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.7	6.1	0.0	1.2	50.0	
FOX HILLS	7.0	80.8	6.1	1.2	50.0	
PIERRE	11.0	746.8	86.9	1.1	54.5	
NEWCASTLE	51.8	3.0	833.6	1.4	42.9	0.221
INYAN KARA	51.9	12.2	836.7	1.6	37.5	0.885
MORRISON	52.4	27.4	848.9	1.4	42.9	
SUNDANCE	53.5	94.5	876.3	1.4	42.9	
SPEARFISH	57.6	10.7	970.8	1.3	42.9	
OPECHE	58.1	7.6	981.5	1.4	42.9	
MINNELUSA	58.4	155.4	989.1	2.2	27.3	12.905
MADISON	62.6	289.6	1144.5	3.5	17.1	26.009
DEVONIAN	67.6	393.2	1434.1	3.5	17.1	38.452
CAMBRIAN	74.4	131.1	1827.3	2.4	25.0	14.236
BASEMENT	77.6		1958.4			

SOUTH DAKOTAGeothermal: calculation point b10

SURFACE TEMP = 6.9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	6.9	685.8	0.0	1.1	54.5	
NEWCASTLE	44.3	6.1	685.8	1.4	42.9	0.366
INYAN KARA	44.6	13.7	691.9	1.6	37.5	0.830
MORRISON	45.1	13.7	705.6	1.4	42.9	
SUNDANCE	45.7	79.2	719.3	1.4	42.9	
MINNELUSA	49.1	143.3	798.6	2.2	27.3	9.698
MADISON	53.0	271.3	941.8	3.5	17.1	20.067
DEVONIAN	57.6	371.9	1213.1	3.5	17.1	30.283
CAMBRIAN	64.0	115.8	1585.0	2.4	25.0	10.618
BASEMENT	66.9		1700.8			

SOUTH DAKOTAGEOTHERMAL: calculation point b11

SURFACE TEMP = 7 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.0 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.0	557.8	0.0	1.1	54.5	
NEWCASTLE	37.4	7.6	557.8	1.4	42.9	0.372
INYAN KARA	37.8	27.4	565.4	1.6	37.5	1.354
MORRISON	38.8	10.7	592.8	1.4	42.9	
SUNDANCE	39.2	57.9	603.5	1.4	42.9	
MINNELUSA	41.7	134.1	661.4	2.2	27.3	7.476
MADISON	45.4	243.8	795.5	3.5	17.1	15.024
DEVONIAN	49.6	359.7	1039.4	3.5	17.1	24.574
CAMBRIAN	55.7	103.6	1399.0	2.4	25.0	8.107
BASEMENT	58.3		1502.7			

SOUTH DAKOTAGEOTHERMAL: calculation point b12

SURFACE TEMP = 7 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.0 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.0	518.2	0.0	1.1	54.5	
NEWCASTLE	35.3	7.6	518.2	1.4	42.9	0.346
INYAN KARA	35.6	36.6	525.8	1.6	37.5	1.679
MORRISON	37.0	7.6	562.4	1.4	42.9	
SUNDANCE	37.3	54.9	570.0	1.4	42.9	
MINNELUSA	39.6	100.6	624.8	2.2	27.3	5.271
MADISON	42.4	219.5	725.4	3.5	17.1	12.467
DEVONIAN	46.1	304.8	944.9	3.5	17.1	19.156
CAMBRIAN	51.4	85.3	1249.7	2.4	25.0	6.080
BASEMENT	53.5		1335.0			

SOUTH DAKOTAGEothermal: calculation point b13

SURFACE TEMP = 6.9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	6.9	487.7	0.0	1.1	54.5	
INYAN KARA	33.5	39.6	487.7	1.6	37.5	1.692
MORRISON	35.0	6.1	527.3	1.4	42.9	
SUNDANCE	35.2	51.8	533.4	1.4	42.9	
MINNELUSA	37.5	61.0	585.2	2.2	27.3	2.992
MADISON	39.1	189.0	646.2	3.5	17.1	9.779
DEVONIAN	42.4	304.8	835.2	3.5	17.1	17.358
CAMBRIAN	47.6	54.9	1140.0	2.4	25.0	3.585
BASEMENT	49.0		1194.8			

SOUTH DAKOTAGEothermal: calculation point b14

SURFACE TEMP = 6.9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	6.9	472.4	0.0	1.1	54.5	
INYAN KARA	32.7	42.7	472.4	1.6	37.5	1.765
MORRISON	34.3	6.1	515.1	1.4	42.9	
SUNDANCE	34.5	48.8	521.2	1.4	42.9	
MINNELUSA	36.6	61.0	570.0	2.2	27.3	2.909
MADISON	38.3	189.0	630.9	3.5	17.1	9.522
DEVONIAN	41.5	304.8	819.9	3.5	17.1	16.943
CAMBRIAN	46.7	54.9	1124.7	2.4	25.0	3.510
BASEMENT	48.1		1179.6			

SOUTH DAKOTAGEothermal: calculation point c1

SURFACE TEMP = 6.8 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.8 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.8	45.7	0.0	1.2	50.0	
FOX HILLS	9.1	67.1	45.7	1.2	50.0	
PIERRE	12.4	1005.9	112.8	1.1	54.5	
INYAN KARA	67.3	42.7	1118.6	1.6	37.5	4.145
MORRISON	68.9	33.5	1161.3	1.4	42.9	
SUNDANCE	70.3	181.4	1194.8	1.4	42.9	
SPEARFISH	78.1	129.5	1376.2	1.3	42.9	
MINNEKAHATA	84.1	14.6	1505.7	3.0	20.0	1.816
OPECHE	84.4	57.9	1520.4	1.4	42.9	
MINNELUSA	86.9	144.8	1578.3	2.2	27.3	18.611
MADISON	90.8	359.7	1723.1	3.5	17.1	48.514
DEVONIAN	97.0	301.8	2082.7	3.5	17.1	43.689
CAMBRIAN	102.2	195.1	2384.5	2.4	25.0	29.864
BASEMENT	107.0		2579.6			

SOUTH DAKOTAGEothermal: calculation point c2

SURFACE TEMP = 6.8 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.8 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.8	118.9	0.0	1.2	50.0	
FOX HILLS	12.7	67.1	118.9	1.2	50.0	
PIERRE	16.1	1066.8	185.9	1.1	54.5	
INYAN KARA	74.3	48.8	1252.7	1.6	37.5	5.284
MORRISON	76.1	42.7	1301.5	1.4	42.9	
SUNDANCE	77.9	176.8	1344.2	1.4	42.9	
SPEARFISH	85.5	132.6	1521.0	1.3	42.9	
MINNEKAHATA	91.6	13.7	1653.6	3.0	20.0	1.868
OPECHE	91.9	27.4	1667.3	1.4	42.9	
MINNELUSA	93.1	155.4	1694.7	2.2	27.3	21.535
MADISON	97.3	347.5	1850.2	3.5	17.1	50.503
DEVONIAN	103.3	329.2	2197.6	3.5	17.1	50.993
CAMBRIAN	108.9	192.0	2526.8	2.4	25.0	31.486
BASEMENT	113.7		2718.8			

SOUTH DAKOTAGEothermal: calculation point c3

SURFACE TEMP = 6.8 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.8 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.8	118.9	0.0	1.2	50.0	
FOX HILLS	12.7	57.9	118.9	1.2	50.0	
PIERRE	15.6	1051.6	176.8	1.1	54.5	
INYAN KARA	73.0	42.7	1228.4	1.6	37.5	4.535
MORRISON	74.6	39.6	1271.0	1.4	42.9	
SUNDANCE	76.3	88.4	1310.7	1.4	42.9	
SPEARFISH	80.1	126.5	1399.0	1.3	42.9	
MINNEKAHATA	85.9	12.2	1525.5	3.0	20.0	1.549
OPECHE	86.2	29.0	1537.7	1.4	42.9	
MINNELUSA	87.4	160.0	1566.7	2.2	27.3	20.709
MADISON	91.8	350.5	1726.7	3.5	17.1	47.818
DEVONIAN	97.8	359.7	2077.2	3.5	17.1	52.536
CAMBRIAN	103.9	189.0	2436.9	2.4	25.0	29.474
BASEMENT	108.7		2625.9			

SOUTH DAKOTAGEothermal: calculation point c4

SURFACE TEMP = 6.8 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.8 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.8	160.0	0.0	1.2	50.0	
FOX HILLS	14.8	68.6	160.0	1.2	50.0	
PIERRE	18.2	1036.3	228.6	1.1	54.5	
NEWCASTLE	74.8	1.5	1264.9	1.4	42.9	0.166
INYAN KARA	74.8	48.8	1266.5	1.6	37.5	5.326
MORRISON	76.7	27.4	1315.2	1.4	42.9	
SUNDANCE	77.8	54.9	1342.7	1.4	42.9	
SPEARFISH	80.2	97.5	1397.5	1.3	42.9	
MINNEKAHATA	84.7	10.7	1495.1	3.0	20.0	1.334
OPECHE	84.9	33.5	1505.7	1.4	42.9	
MINNELUSA	86.3	149.4	1539.3	2.2	27.3	19.070
MADISON	90.4	362.7	1688.6	3.5	17.1	48.685
DEVONIAN	96.6	378.0	2051.3	3.5	17.1	54.504
CAMBRIAN	103.1	185.9	2429.3	2.4	25.0	28.746
BASEMENT	107.7		2615.2			

SOUTH DAKOTAGEothermal: calculation point c5

SURFACE TEMP = 6.9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.9	185.9	0.0	1.2	50.0	
FOX HILLS	16.2	80.8	185.9	1.2	50.0	
PIERRE	20.2	990.6	266.7	1.1	54.5	
NEWCASTLE	74.3	3.0	1257.3	1.4	42.9	0.330
INYAN KARA	74.4	50.3	1260.4	1.6	37.5	5.450
MORRISON	76.3	24.4	1310.7	1.4	42.9	
SUNDANCE	77.3	120.4	1335.0	1.4	42.9	
SPEARFISH	82.5	80.8	1455.4	1.3	42.9	
MINNEKAHATA	86.2	9.1	1536.2	3.0	20.0	1.164
OPECHE	86.4	36.6	1545.4	1.4	42.9	
MINNELUSA	88.0	167.6	1581.9	2.2	27.3	21.819
MADISON	92.5	359.7	1749.6	3.5	17.1	49.452
DEVONIAN	98.7	402.3	2109.2	3.5	17.1	59.302
CAMBRIAN	105.6	182.9	2511.6	2.4	25.0	28.981
BASEMENT	110.2		2694.5			

SOUTH DAKOTAGEothermal: calculation point c6

SURFACE TEMP = 6.9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

6.9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	6.9	175.3	0.0	1.2	50.0	
FOX HILLS	15.7	96.0	175.3	1.2	50.0	
PIERRE	20.5	960.1	271.3	1.1	54.5	
NEWCASTLE	72.8	3.0	1231.4	1.4	42.9	0.323
INYAN KARA	73.0	27.4	1234.5	1.6	37.5	2.910
MORRISON	74.0	39.6	1261.9	1.4	42.9	
SUNDANCE	75.7	137.2	1301.5	1.4	42.9	
SPEARFISH	81.6	68.6	1438.7	1.3	42.9	
MINNEKAHATA	84.7	7.6	1507.3	3.0	20.0	0.952
OPECHE	84.9	33.5	1514.9	1.4	42.9	
MINNELUSA	86.3	189.0	1548.4	2.2	27.3	24.098
MADISON	91.5	344.4	1737.4	3.5	17.1	46.770
DEVONIAN	97.4	399.3	2081.8	3.5	17.1	58.005
CAMBRIAN	104.2	167.6	2481.1	2.4	25.0	26.195
BASEMENT	108.4		2648.7			

SOUTH DAKOTAGEOTHERMAL: calculation point c7

SURFACE TEMP = 7 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.0 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	7.0	149.4	0.0	1.2	50.0	
FOX HILLS	14.5	106.7	149.4	1.2	50.0	
PIERRE	19.8	920.5	256.0	1.1	54.5	
NEWCASTLE	70.0	1.5	1176.5	1.4	42.9	0.154
INYAN KARA	70.1	32.0	1178.1	1.6	37.5	3.241
MORRISON	71.3	54.9	1210.1	1.4	42.9	
SUNDANCE	73.6	115.8	1264.9	1.4	42.9	
SPEARFISH	78.6	54.9	1380.8	1.3	42.9	
MINNEKAHATA	81.1	6.1	1435.6	3.0	20.0	0.725
OPECHE	81.2	21.3	1441.7	1.4	42.9	
MINNELUSA	82.2	216.4	1463.1	2.2	27.3	26.114
MADISON	88.1	320.0	1679.5	3.5	17.1	41.652
DEVONIAN	93.5	396.2	1999.5	3.5	17.1	55.059
CAMBRIAN	100.3	150.9	2395.8	2.4	25.0	22.610
BASEMENT	104.1		2546.6			

SOUTH DAKOTAGEOTHERMAL: calculation point c8

SURFACE TEMP = 7.2 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.2 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	7.2	114.3	0.0	1.2	50.0	
FOX HILLS	12.9	103.6	114.3	1.2	50.0	
PIERRE	18.1	829.1	217.9	1.1	54.5	
NEWCASTLE	63.3	1.5	1047.0	1.4	42.9	0.137
INYAN KARA	63.4	16.8	1048.5	1.6	37.5	1.512
MORRISON	64.0	91.4	1065.3	1.4	42.9	
SUNDANCE	67.9	97.5	1156.7	1.4	42.9	
SPEARFISH	72.1	36.6	1254.3	1.3	42.9	
MINNEKAHATA	73.8	4.6	1290.8	3.0	20.0	0.489
OPECHE	73.9	19.8	1295.4	1.4	42.9	
MINNELUSA	74.7	201.2	1315.2	2.2	27.3	21.814
MADISON	80.2	288.0	1516.4	3.5	17.1	33.770
DEVONIAN	85.2	378.0	1804.4	3.5	17.1	47.309
CAMBRIAN	91.6	125.0	2182.4	2.4	25.0	16.942
BASEMENT	94.8		2307.4			

SOUTH DAKOTAGEothermal: calculation point c9

SURFACE TEMP = 7.2 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.2 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	7.2	61.0	0.0	1.2	50.0	
FOX HILLS	10.2	97.5	61.0	1.2	50.0	
PIERRE	15.1	746.8	158.5	1.1	54.5	
NEWCASTLE	55.9	3.0	905.3	1.4	42.9	0.238
INYAN KARA	56.0	12.2	908.3	1.6	37.5	0.955
MORRISON	56.4	44.2	920.5	1.4	42.9	
SUNDANCE	58.3	82.3	964.7	1.4	42.9	
SPEARFISH	61.9	7.6	1047.0	1.3	42.9	
MINNEKAHATA	62.2	3.0	1054.6	3.0	20.0	0.269
OPECHE	62.3	3.0	1057.7	1.4	42.9	
MINNELUSA	62.4	137.2	1060.7	2.2	27.3	12.158
MADISON	66.2	262.1	1197.9	3.5	17.1	24.809
DEVONIAN	70.6	365.8	1460.0	3.5	17.1	37.256
CAMBRIAN	76.9	115.8	1825.8	2.4	25.0	12.964
BASEMENT	79.8		1941.6			

SOUTH DAKOTAGEothermal: calculation point c10

SURFACE TEMP = 7.4 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.4 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
FOX HILLS	7.4	91.4	0.0	1.2	50.0	
PIERRE	12.0	685.8	91.4	1.1	54.5	
NEWCASTLE	49.4	6.1	777.2	1.4	42.9	0.411
INYAN KARA	49.6	12.2	783.3	1.6	37.5	0.827
MORRISON	50.1	24.4	795.5	1.4	42.9	
SUNDANCE	51.1	70.1	819.9	1.4	42.9	
MINNEKAHATA	54.1	0.6	890.0	3.0	20.0	0.046
MINNELUSA	54.2	91.4	890.6	2.2	27.3	6.865
MADISON	56.7	240.8	982.1	3.5	17.1	19.041
DEVONIAN	60.8	341.4	1222.9	3.5	17.1	29.257
CAMBRIAN	66.6	103.6	1564.3	2.4	25.0	9.855
BASEMENT	69.2		1667.9			

SOUTH DAKOTAGEOTHERMAL: calculation point c11

SURFACE TEMP = 7.4 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.4 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
FOX HILLS	7.4	64.0	0.0	1.2	50.0	
PIERRE	10.6	554.7	64.0	1.1	54.5	
NEWCASTLE	40.9	7.6	618.8	1.4	42.9	0.409
INYAN KARA	41.2	15.2	626.4	1.6	37.5	0.827
MORRISON	41.8	15.2	641.6	1.4	42.9	
SUNDANCE	42.4	54.9	656.9	1.4	42.9	
MINNELUSA	44.8	115.8	711.7	2.2	27.3	6.948
MADISON	47.9	216.4	827.5	3.5	17.1	14.079
DEVONIAN	51.6	307.9	1044.0	3.5	17.1	21.861
CAMBRIAN	56.9	88.4	1351.8	2.4	25.0	7.026
BASEMENT	59.1		1440.2			

SOUTH DAKOTAGEOTHERMAL: calculation point c12

SURFACE TEMP = 7.4 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.4 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.4	518.2	0.0	1.1	54.5	
NEWCASTLE	35.7	10.7	518.2	1.4	42.9	0.484
INYAN KARA	36.1	22.9	528.8	1.6	37.5	1.054
MORRISON	37.0	12.2	551.7	1.4	42.9	
SUNDANCE	37.5	51.8	563.9	1.4	42.9	
MINNELUSA	39.7	97.5	615.7	2.2	27.3	5.061
MADISON	42.4	201.2	713.2	3.5	17.1	11.298
DEVONIAN	45.8	277.4	914.4	3.5	17.1	17.113
CAMBRIAN	50.6	61.0	1191.8	2.4	25.0	4.227
BASEMENT	52.1		1252.7			

SOUTH DAKOTAGEOTHERMAL: calculation point c13

SURFACE TEMP = 7.3 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.3 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.3	487.7	0.0	1.1	54.5	
NEWCASTLE	33.9	30.5	487.7	1.4	42.9	1.302
INYAN KARA	35.2	27.4	518.2	1.6	37.5	1.229
MORRISON	36.2	9.1	545.6	1.4	42.9	
SUNDANCE	36.6	48.8	554.7	1.4	42.9	
MINNELUSA	38.7	61.0	603.5	2.2	27.3	3.075
MADISON	40.4	182.9	664.5	3.5	17.1	9.713
DEVONIAN	43.5	259.1	847.4	3.5	17.1	15.064
CAMBRIAN	48.0	45.7	1106.4	2.4	25.0	2.984
BASEMENT	49.1		1152.2			

SOUTH DAKOTAGEOTHERMAL: calculation point c14

SURFACE TEMP = 7.2 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.2 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.2	472.4	0.0	1.1	54.5	
NEWCASTLE	33.0	30.5	472.4	1.4	42.9	1.261
INYAN KARA	34.3	30.5	502.9	1.6	37.5	1.325
MORRISON	35.4	6.1	533.4	1.4	42.9	
SUNDANCE	35.7	45.7	539.5	1.4	42.9	
MINNELUSA	37.6	61.0	585.2	2.2	27.3	2.979
MADISON	39.3	167.6	646.2	3.5	17.1	8.640
DEVONIAN	42.2	243.8	813.8	3.5	17.1	13.693
CAMBRIAN	46.4	30.5	1057.7	2.4	25.0	1.916
BASEMENT	47.1		1088.1			

SOUTH DAKOTAGEothermal: calculation point d1

SURFACE TEMP = 7.5 HEAT FLOW: SURFACE = 55 DAKOTA = 55 MADISON = 55

7.5 HEAT FLOW: SURFACE = 55 DAKOTA = 55 MADISON = 55

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	7.5	30.5	0.0	1.2	45.8	
FOX HILLS	8.9	61.0	30.5	1.2	45.8	
PIERRE	11.7	823.0	91.4	1.1	50.0	
INYAN KARA	52.8	39.6	914.4	1.6	34.4	2.884
MORRISON	54.2	18.3	954.0	1.4	39.3	
SUNDANCE	54.9	173.7	972.3	1.4	39.3	
SPEARFISH	61.7	216.4	1146.1	1.3	39.3	
MINNEKAHATA	70.9	18.3	1362.5	3.0	18.3	1.862
OPECHE	71.2	27.4	1380.8	1.4	39.3	
MINNELUSA	72.3	140.2	1408.2	2.2	25.0	14.590
MADISON	75.8	317.0	1548.4	3.5	15.7	34.770
DEVONIAN	80.8	243.8	1865.4	3.5	15.7	28.696
CAMBRIAN	84.6	189.0	2109.2	2.4	22.9	23.402
BASEMENT	89.0		2298.2			

SOUTH DAKOTAGEothermal: calculation point d2

SURFACE TEMP = 7.5 HEAT FLOW: SURFACE = 55 DAKOTA = 55 MADISON = 55

7.5 HEAT FLOW: SURFACE = 55 DAKOTA = 55 MADISON = 55

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	7.5	57.9	0.0	1.2	45.8	
FOX HILLS	10.2	61.0	57.9	1.2	45.8	
PIERRE	12.9	883.9	118.9	1.1	50.0	
NEWCASTLE	57.1	3.0	1002.8	1.4	39.3	0.243
INYAN KARA	57.3	44.2	1005.9	1.6	34.4	3.531
MORRISON	58.8	18.3	1050.0	1.4	39.3	
SUNDANCE	59.5	155.4	1068.3	1.4	39.3	
SPEARFISH	65.6	213.4	1223.8	1.3	39.3	
MINNEKAHATA	74.6	15.2	1437.1	3.0	18.3	1.643
OPECHE	74.9	25.9	1452.4	1.4	39.3	
MINNELUSA	75.9	144.8	1478.3	2.2	25.0	15.907
MADISON	79.6	307.9	1623.1	3.5	15.7	35.612
DEVONIAN	84.4	274.3	1930.9	3.5	15.7	33.864
CAMBRIAN	88.7	192.0	2205.3	2.4	22.9	25.034
BASEMENT	93.1		2397.3			

SOUTH DAKOTAGEOTHERMAL: calculation point d3

SURFACE TEMP = 7.3 HEAT FLOW: SURFACE = 55 DAKOTA = 55 MADISON = 55

7.3 HEAT FLOW: SURFACE = 55 DAKOTA = 55 MADISON = 55

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	7.3	54.9	0.0	1.2	45.8	
FOX HILLS	9.8	61.0	54.9	1.2	45.8	
PIERRE	12.6	960.1	115.8	1.1	50.0	
NEWCASTLE	60.6	3.0	1076.0	1.4	39.3	0.261
INYAN KARA	60.7	45.7	1079.0	1.6	34.4	3.922
MORRISON	62.3	51.8	1124.7	1.4	39.3	
SUNDANCE	64.3	88.4	1176.5	1.4	39.3	
SPEARFISH	67.8	152.4	1264.9	1.3	39.3	
MINNEKAHATA	74.3	14.6	1417.3	3.0	18.3	1.573
OPECHE	74.5	24.4	1432.0	1.4	39.3	
MINNELUSA	75.5	147.8	1456.4	2.2	25.0	16.184
MADISON	79.2	304.8	1604.2	3.5	15.7	35.177
DEVONIAN	84.0	304.8	1909.0	3.5	15.7	37.521
CAMBRIAN	88.8	189.0	2213.8	2.4	22.9	24.716
BASEMENT	93.1		2402.8			

SOUTH DAKOTAGEOTHERMAL: calculation point d4

SURFACE TEMP = 7.2 HEAT FLOW: SURFACE = 55 DAKOTA = 55 MADISON = 55

7.2 HEAT FLOW: SURFACE = 55 DAKOTA = 55 MADISON = 55

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	7.2	64.0	0.0	1.2	45.8	
FOX HILLS	10.1	67.1	64.0	1.2	45.8	
PIERRE	13.2	975.4	131.1	1.1	50.0	
NEWCASTLE	62.0	3.0	1106.4	1.4	39.3	0.268
INYAN KARA	62.1	38.1	1109.5	1.6	34.4	3.358
MORRISON	63.4	42.7	1147.6	1.4	39.3	
SUNDANCE	65.1	64.0	1190.3	1.4	39.3	
SPEARFISH	67.6	97.5	1254.3	1.3	39.3	
MINNEKAHATA	71.7	13.7	1351.8	3.0	18.3	1.421
OPECHE	72.0	27.4	1365.5	1.4	39.3	
MINNELUSA	73.1	170.7	1393.0	2.2	25.0	18.046
MADISON	77.3	303.3	1563.6	3.5	15.7	34.142
DEVONIAN	82.1	457.2	1866.9	3.5	15.7	54.968
CAMBRIAN	89.3	182.9	2324.1	2.4	22.9	24.097
BASEMENT	93.5		2507.0			

SOUTH DAKOTAGEOTHERMAL: calculation point d5

SURFACE TEMP = 7.3 HEAT FLOW: SURFACE = 55 DAKOTA = 55 MADISON = 55

7.3 HEAT FLOW: SURFACE = 55 DAKOTA = 55 MADISON = 55

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	7.3	118.9	0.0	1.2	45.8	
FOX HILLS	12.7	76.2	118.9	1.2	45.8	
PIERRE	16.2	975.4	195.1	1.1	50.0	
NEWCASTLE	65.0	6.1	1170.4	1.4	39.3	0.565
INYAN KARA	65.2	36.6	1176.5	1.6	34.4	3.403
MORRISON	66.5	33.5	1213.1	1.4	39.3	
SUNDANCE	67.8	125.0	1246.6	1.4	39.3	
SPEARFISH	72.7	79.2	1371.6	1.3	39.3	
MINNEKAHATA	76.1	12.2	1450.9	3.0	18.3	1.346
OPECHE	76.3	33.5	1463.1	1.4	39.3	
MINNELUSA	77.6	201.2	1496.6	2.2	25.0	22.714
MADISON	82.7	201.2	1697.8	3.5	15.7	24.338
DEVONIAN	85.8	359.7	1898.9	3.5	15.7	45.339
CAMBRIAN	91.5	170.7	2258.6	2.4	22.9	23.066
BASEMENT	95.4		2429.3			

SOUTH DAKOTAGEOTHERMAL: calculation point d6

SURFACE TEMP = 7.4 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.4 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	7.4	128.0	0.0	1.2	50.0	
FOX HILLS	13.8	79.2	128.0	1.2	50.0	
PIERRE	17.8	944.9	207.3	1.1	54.5	
NEWCASTLE	69.3	9.1	1152.2	1.4	42.9	0.909
INYAN KARA	69.7	39.6	1161.3	1.6	37.5	3.963
MORRISON	71.2	24.4	1200.9	1.4	42.9	
SUNDANCE	72.2	137.2	1225.3	1.4	42.9	
SPEARFISH	78.1	64.0	1362.5	1.3	42.9	
MINNEKAHATA	81.1	10.7	1426.5	3.0	20.0	1.262
OPECHE	81.3	24.4	1437.1	1.4	42.9	
MINNELUSA	82.3	217.9	1461.5	2.2	27.3	26.212
MADISON	88.3	317.0	1679.5	3.5	17.1	41.152
DEVONIAN	93.7	364.2	1996.5	3.5	17.1	50.463
CAMBRIAN	99.9	152.4	2360.7	2.4	25.0	22.642
BASEMENT	103.7		2513.1			

SOUTH DAKOTAGEOTHERMAL: calculation point d7

SURFACE TEMP = 7.4 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.4 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	7.4	61.0	0.0	1.2	50.0	
FOX HILLS	10.4	82.3	61.0	1.2	50.0	
PIERRE	14.6	914.4	143.3	1.1	54.5	
NEWCASTLE	64.4	6.1	1057.7	1.4	42.9	0.558
INYAN KARA	64.7	24.4	1063.8	1.6	37.5	2.243
MORRISON	65.6	30.5	1088.1	1.4	42.9	
SUNDANCE	66.9	121.9	1118.6	1.4	42.9	
SPEARFISH	72.1	48.8	1240.6	1.3	42.9	
MINNEKAHATA	74.4	7.6	1289.3	3.0	20.0	0.820
OPECHE	74.6	22.9	1296.9	1.4	42.9	
MINNELUSA	75.5	219.5	1319.8	2.2	27.3	24.005
MADISON	81.5	286.5	1539.3	3.5	17.1	34.093
DEVONIAN	86.4	362.7	1825.8	3.5	17.1	46.020
CAMBRIAN	92.6	131.1	2188.5	2.4	25.0	17.937
BASEMENT	95.9		2319.6			

SOUTH DAKOTAGEOTHERMAL: calculation point d8

SURFACE TEMP = 7.4 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.4 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	7.4	6.1	0.0	1.2	50.0	
FOX HILLS	7.7	83.8	6.1	1.2	50.0	
PIERRE	11.9	829.1	89.9	1.1	54.5	
NEWCASTLE	57.1	3.0	919.0	1.4	42.9	0.243
INYAN KARA	57.2	15.2	922.0	1.6	37.5	1.220
MORRISON	57.8	76.2	937.3	1.4	42.9	
SUNDANCE	61.1	89.9	1013.5	1.4	42.9	
SPEARFISH	64.9	32.0	1103.4	1.3	42.9	
MINNEKAHATA	66.4	4.6	1135.4	3.0	20.0	0.433
OPECHE	66.5	18.3	1140.0	1.4	42.9	
MINNELUSA	67.3	210.3	1158.3	2.2	27.3	20.223
MADISON	73.0	253.0	1368.6	3.5	17.1	26.655
DEVONIAN	77.4	356.6	1621.6	3.5	17.1	40.058
CAMBRIAN	83.5	115.8	1978.2	2.4	25.0	14.147
BASEMENT	86.4		2094.0			

SOUTH DAKOTAGEothermal: calculation point d9

SURFACE TEMP = 7.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = (

7.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
FOX HILLS	7.6	85.3	0.0	1.2	50.0	
PIERRE	11.9	731.5	85.3	1.1	54.5	
NEWCASTLE	51.8	6.1	816.9	1.4	42.9	0.432
INYAN KARA	52.0	12.2	823.0	1.6	37.5	0.870
MORRISON	52.5	74.7	835.2	1.4	42.9	
SUNDANCE	55.7	79.2	909.8	1.4	42.9	
SPEARFISH	59.1	9.1	989.1	1.3	42.9	
MINNEKAHATA	59.5	3.0	998.2	3.0	20.0	0.254
OPECHE	59.6	1.5	1001.3	1.4	42.9	
MINNELUSA	59.6	137.2	1002.8	2.2	27.3	11.458
MADISON	63.4	234.7	1140.0	3.5	17.1	21.016
DEVONIAN	67.4	323.1	1374.7	3.5	17.1	31.017
CAMBRIAN	72.9	97.5	1697.8	2.4	25.0	10.231
BASEMENT	75.4		1795.3			

SOUTH DAKOTAGEothermal: calculation point d10

SURFACE TEMP = 7.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = (

7.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
FOX HILLS	7.6	67.1	0.0	1.2	50.0	
PIERRE	11.0	670.6	67.1	1.1	54.5	
NEWCASTLE	47.5	9.1	737.6	1.4	42.9	0.586
INYAN KARA	47.9	9.1	746.8	1.6	37.5	0.592
MORRISON	48.3	32.0	755.9	1.4	42.9	
SUNDANCE	49.6	64.0	787.9	1.4	42.9	
MINNELUSA	52.4	125.0	851.9	2.2	27.3	8.984
MADISON	55.8	213.4	976.9	3.5	17.1	16.506
DEVONIAN	59.4	304.8	1190.3	3.5	17.1	25.371
CAMBRIAN	64.7	88.4	1495.1	2.4	25.0	8.099
BASEMENT	66.9		1583.5			

SOUTH DAKOTAGEothermal: calculation point d11

SURFACE TEMP = 7.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.6	551.7	0.0	1.1	54.5	
NEWCASTLE	37.7	12.2	551.7	1.4	42.9	0.589
INYAN KARA	38.2	12.2	563.9	1.6	37.5	0.599
MORRISON	38.7	22.9	576.1	1.4	42.9	
SUNDANCE	39.7	53.3	598.9	1.4	42.9	
MINNELUSA	41.9	167.6	652.3	2.2	27.3	9.242
MADISON	46.5	198.1	819.9	3.5	17.1	12.377
DEVONIAN	49.9	274.3	1018.0	3.5	17.1	18.633
CAMBRIAN	54.6	67.1	1292.4	2.4	25.0	5.061
BASEMENT	56.3		1359.4			

SOUTH DAKOTAGEothermal: calculation point d12

SURFACE TEMP = 7.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.6	518.2	0.0	1.1	54.5	
NEWCASTLE	35.9	42.7	518.2	1.4	42.9	1.936
INYAN KARA	37.7	15.5	560.8	1.6	37.5	0.751
MORRISON	38.3	13.7	576.4	1.4	42.9	
SUNDANCE	38.9	50.3	590.1	1.4	42.9	
MINNELUSA	41.0	158.5	640.4	2.2	27.3	8.504
MADISON	45.3	152.4	798.9	3.5	17.1	9.234
DEVONIAN	48.0	243.8	951.3	3.5	17.1	15.798
CAMBRIAN	52.1	42.7	1195.1	2.4	25.0	3.051
BASEMENT	53.2		1237.8			

SOUTH DAKOTAGEOTHERMAL: calculation point d13

SURFACE TEMP = 7.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.6	487.7	0.0	1.1	54.5	
NEWCASTLE	34.2	51.8	487.7	1.4	42.9	2.213
INYAN KARA	36.4	22.9	539.5	1.6	37.5	1.058
MORRISON	37.3	10.7	562.4	1.4	42.9	
SUNDANCE	37.7	47.2	573.0	1.4	42.9	
MINNELUSA	39.8	85.3	620.3	2.2	27.3	4.407
MADISON	42.1	152.4	705.6	3.5	17.1	8.439
DEVONIAN	44.7	228.6	858.0	3.5	17.1	13.617
CAMBRIAN	48.6	30.5	1086.6	2.4	25.0	2.007
BASEMENT	49.4		1117.1			

SOUTH DAKOTAGEOTHERMAL: calculation point d14

SURFACE TEMP = 7.4 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.4 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.4	457.2	0.0	1.1	54.5	
NEWCASTLE	32.3	51.8	457.2	1.4	42.9	2.075
INYAN KARA	34.6	30.5	509.0	1.6	37.5	1.329
MORRISON	35.7	7.6	539.5	1.4	42.9	
SUNDANCE	36.0	44.2	547.1	1.4	42.9	
MINNELUSA	37.9	61.0	591.3	2.2	27.3	2.987
MADISON	39.6	152.4	652.3	3.5	17.1	7.875
DEVONIAN	42.2	213.4	804.7	3.5	17.1	11.920
CAMBRIAN	45.9	15.2	1018.0	2.4	25.0	0.941
BASEMENT	46.2		1033.3			

SOUTH DAKOTAGEOTHERMAL: calculation point e1

SURFACE TEMP = 8.2 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

8.2 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	8.2	3.0	0.0	1.2	41.7	
FOX HILLS	8.3	61.0	3.0	1.2	41.7	
PIERRE	10.9	670.6	64.0	1.1	45.5	
INYAN KARA	41.3	38.1	734.6	1.6	31.3	2.028
MORRISON	42.5	21.3	772.7	1.4	35.7	
SUNDANCE	43.3	167.6	794.0	1.4	35.7	
SPEARFISH	49.3	246.9	961.7	1.3	35.7	
MINNEKAHATA	58.8	17.7	1208.5	3.0	16.7	1.436
OPECHE	59.1	38.1	1226.2	1.4	35.7	
MINNELUSA	60.4	134.1	1264.3	2.2	22.7	11.248
MADISON	63.5	268.2	1398.4	3.5	14.3	23.808
DEVONIAN	67.3	179.8	1666.7	3.5	14.3	17.069
CAMBRIAN	69.9	182.9	1846.5	2.4	20.8	18.112
BASEMENT	73.7		2029.4			

SOUTH DAKOTAGEOTHERMAL: calculation point e2

SURFACE TEMP = 8.1 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

8.1 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.1	731.5	0.0	1.1	45.5	
NEWCASTLE	41.4	3.0	731.5	1.4	35.7	0.163
INYAN KARA	41.5	39.6	734.6	1.6	31.3	2.122
MORRISON	42.7	24.4	774.2	1.4	35.7	
SUNDANCE	43.6	146.3	798.6	1.4	35.7	
SPEARFISH	48.8	231.7	944.9	1.3	35.7	
MINNEKAHATA	57.7	15.2	1176.5	3.0	16.7	1.214
OPECHE	58.0	36.6	1191.8	1.4	35.7	
MINNELUSA	59.3	128.0	1228.4	2.2	22.7	10.516
MADISON	62.2	265.2	1356.4	3.5	14.3	23.021
DEVONIAN	66.0	185.9	1621.6	3.5	14.3	17.272
CAMBRIAN	68.6	228.6	1807.5	2.4	20.8	22.211
BASEMENT	73.4		2036.1			

SOUTH DAKOTAGEOTHERMAL: calculation point e3

SURFACE TEMP = 7.8 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 5

7.8 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.8	838.2	0.0	1.1	45.5	
NEWCASTLE	45.9	6.1	838.2	1.4	35.7	0.373
INYAN KARA	46.1	27.4	844.3	1.6	31.3	1.688
MORRISON	47.0	45.7	871.7	1.4	35.7	
SUNDANCE	48.6	121.9	917.5	1.4	35.7	
SPEARFISH	53.0	205.7	1039.4	1.3	35.7	
MINNEKAHATA	60.9	15.2	1245.1	3.0	16.7	1.299
OPECHE	61.1	33.5	1260.4	1.4	35.7	
MINNELUSA	62.3	161.5	1293.9	2.2	22.7	14.142
MADISON	66.0	259.1	1455.4	3.5	14.3	24.208
DEVONIAN	69.7	182.9	1714.5	3.5	14.3	18.175
CAMBRIAN	72.3	249.9	1897.4	2.4	20.8	25.887
BASEMENT	77.5		2147.3			

SOUTH DAKOTAGEOTHERMAL: calculation point e4

SURFACE TEMP = 7.7 HEAT FLOW: SURFACE = 55 DAKOTA = 55 MADISON = 5

7.7 HEAT FLOW: SURFACE = 55 DAKOTA = 55 MADISON = 55

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.7	929.7	0.0	1.1	50.0	
NEWCASTLE	54.2	3.0	929.7	1.4	39.3	0.227
INYAN KARA	54.3	24.4	932.7	1.6	34.4	1.824
MORRISON	55.1	39.6	957.1	1.4	39.3	
SUNDANCE	56.7	121.9	996.7	1.4	39.3	
SPEARFISH	61.5	103.6	1118.6	1.3	39.3	
MINNEKAHATA	65.9	15.2	1222.3	3.0	18.3	1.423
OPECHE	66.2	27.4	1237.5	1.4	39.3	
MINNELUSA	67.2	195.1	1264.9	2.2	25.0	18.644
MADISON	72.1	300.2	1460.0	3.5	15.7	31.044
DEVONIAN	76.8	170.7	1760.2	3.5	15.7	18.942
CAMBRIAN	79.5	277.4	1930.9	2.4	22.9	31.976
BASEMENT	85.9		2208.3			

SOUTH DAKOTAGEOTHERMAL: calculation point e5

SURFACE TEMP = 7.6 HEAT FLOW: SURFACE = 55 DAKOTA = 55 MADISON = 55

7.6 HEAT FLOW: SURFACE = 55 DAKOTA = 55 MADISON = 55

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	7.6	30.5	0.0	1.2	45.8	
FOX HILLS	9.0	70.1	30.5	1.2	45.8	
PIERRE	12.2	944.9	100.6	1.1	50.0	
NEWCASTLE	59.5	3.0	1045.5	1.4	39.3	0.254
INYAN KARA	59.6	25.9	1048.5	1.6	34.4	2.162
MORRISON	60.5	36.6	1074.4	1.4	39.3	
SUNDANCE	61.9	131.1	1111.0	1.4	39.3	
SPEARFISH	67.1	71.6	1242.1	1.3	39.3	
MINNEKAHATA	70.1	14.3	1313.7	3.0	18.3	1.437
OPECHE	70.3	25.9	1328.0	1.4	39.3	
MINNELUSA	71.4	216.4	1353.9	2.2	25.0	22.154
MADISON	76.8	289.6	1570.3	3.5	15.7	32.157
DEVONIAN	81.3	152.4	1859.9	3.5	15.7	18.038
CAMBRIAN	83.7	304.8	2012.3	2.4	22.9	37.248
BASEMENT	90.7		2317.1			

SOUTH DAKOTAGEOTHERMAL: calculation point e6

SURFACE TEMP = 7.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.6 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	7.6	36.6	0.0	1.2	50.0	
FOX HILLS	9.4	71.6	36.6	1.2	50.0	
PIERRE	13.0	853.5	108.2	1.1	54.5	
NEWCASTLE	59.6	7.6	961.7	1.4	42.9	0.636
INYAN KARA	59.9	30.5	969.3	1.6	37.5	2.559
MORRISON	61.0	32.0	999.8	1.4	42.9	
SUNDANCE	62.4	131.1	1031.8	1.4	42.9	
SPEARFISH	68.0	54.9	1162.8	1.3	42.9	
MINNEKAHATA	70.6	12.2	1217.7	3.0	20.0	1.232
OPECHE	70.8	22.9	1229.9	1.4	42.9	
MINNELUSA	71.8	221.0	1252.7	2.2	27.3	22.769
MADISON	77.8	283.5	1473.7	3.5	17.1	31.949
DEVONIAN	82.7	134.1	1757.2	3.5	17.1	16.162
CAMBRIAN	85.0	307.9	1891.3	2.4	25.0	38.236
BASEMENT	92.7		2199.2			

SOUTH DAKOTAGEothermal: calculation point e7

SURFACE TEMP = 7.7 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.7 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	7.7	30.5	0.0	1.2	50.0	
FOX HILLS	9.2	70.1	30.5	1.2	50.0	
PIERRE	12.7	838.2	100.6	1.1	54.5	
NEWCASTLE	58.4	12.2	938.8	1.4	42.9	0.993
INYAN KARA	59.0	14.6	951.0	1.6	37.5	1.204
MORRISON	59.5	24.4	965.6	1.4	42.9	
SUNDANCE	60.6	121.9	990.0	1.4	42.9	
SPEARFISH	65.8	45.7	1111.9	1.3	42.9	
MINNEKAHATA	67.9	9.1	1157.6	3.0	20.0	0.884
OPECHE	68.1	21.3	1166.8	1.4	42.9	
MINNELUSA	69.0	222.5	1188.1	2.2	27.3	21.898
MADISON	75.1	262.1	1410.6	3.5	17.1	28.351
DEVONIAN	79.6	115.8	1672.8	3.5	17.1	13.363
CAMBRIAN	81.5	307.9	1788.6	2.4	25.0	36.498
BASEMENT	89.2		2096.4			

SOUTH DAKOTAGEothermal: calculation point e8

SURFACE TEMP = 7.8 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.8 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PALEOCENE	7.8	3.0	0.0	1.2	50.0	
FOX HILLS	8.0	67.1	3.0	1.2	50.0	
PIERRE	11.3	792.5	70.1	1.1	54.5	
NEWCASTLE	54.5	15.8	862.6	1.4	42.9	1.189
INYAN KARA	55.2	14.6	878.4	1.6	37.5	1.114
MORRISON	55.8	32.0	893.1	1.4	42.9	
SUNDANCE	57.1	88.4	925.1	1.4	42.9	
SPEARFISH	60.9	41.1	1013.5	1.3	42.9	
MINNEKAHATA	62.8	6.1	1054.6	3.0	20.0	0.538
OPECHE	62.9	18.3	1060.7	1.4	42.9	
MINNELUSA	63.7	216.4	1079.0	2.2	27.3	19.431
MADISON	69.6	234.7	1295.4	3.5	17.1	23.296
DEVONIAN	73.7	93.0	1530.1	3.5	17.1	9.828
CAMBRIAN	75.2	303.3	1623.1	2.4	25.0	32.839
BASEMENT	82.8		1926.4			

SOUTH DAKOTAGEOTHERMAL: calculation point e9

SURFACE TEMP = 7.9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 6

7.9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
FOX HILLS	7.9	64.0	0.0	1.2	50.0	
PIERRE	11.1	701.0	64.0	1.1	54.5	
NEWCASTLE	49.3	12.2	765.1	1.4	42.9	0.811
INYAN KARA	49.9	12.2	777.2	1.6	37.5	0.821
MORRISON	50.3	38.1	789.4	1.4	42.9	
SUNDANCE	52.0	73.2	827.5	1.4	42.9	
SPEARFISH	55.1	27.4	900.7	1.3	42.9	
MINNEKAHATA	56.4	3.0	928.1	3.0	20.0	0.237
OPECHE	56.4	3.0	931.2	1.4	42.9	
MINNELUSA	56.5	202.7	934.2	2.2	27.3	15.830
MADISON	62.1	214.9	1136.9	3.5	17.1	18.689
DEVONIAN	65.8	109.7	1351.8	3.5	17.1	10.192
CAMBRIAN	67.6	286.5	1461.5	2.4	25.0	27.479
BASEMENT	74.8		1748.0			

SOUTH DAKOTAGEOTHERMAL: calculation point e10

SURFACE TEMP = 7.9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 6

7.9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
FOX HILLS	7.9	1.5	0.0	1.2	50.0	
PIERRE	8.0	640.1	1.5	1.1	54.5	
NEWCASTLE	42.9	12.2	641.6	1.4	42.9	0.685
INYAN KARA	43.4	12.2	653.8	1.6	37.5	0.695
MORRISON	43.9	54.9	666.0	1.4	42.9	
SUNDANCE	46.2	62.5	720.9	1.4	42.9	
MINNEKAHATA	48.9	1.5	783.3	3.0	20.0	0.100
MINNELUSA	48.9	213.4	784.9	2.2	27.3	14.055
MADISON	54.7	192.0	998.2	3.5	17.1	14.443
DEVONIAN	58.0	64.0	1190.3	3.5	17.1	5.153
CAMBRIAN	59.1	262.1	1254.3	2.4	25.0	21.563
BASEMENT	65.7		1516.4			

SOUTH DAKOTAGEOTHERMAL: calculation point e11

SURFACE TEMP = 7.9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 6

7.9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.9	548.6	0.0	1.1	54.5	
NEWCASTLE	37.8	42.7	548.6	1.4	42.9	2.050
INYAN KARA	39.7	14.6	591.3	1.6	37.5	0.746
MORRISON	40.2	30.5	605.9	1.4	42.9	
SUNDANCE	41.5	51.8	636.4	1.4	42.9	
MINNELUSA	43.7	196.6	688.2	2.2	27.3	11.309
MADISON	49.1	179.8	884.8	3.5	17.1	11.893
DEVONIAN	52.2	33.5	1064.7	3.5	17.1	2.383
CAMBRIAN	52.8	240.8	1098.2	2.4	25.0	17.339
BASEMENT	58.8		1339.0			

SOUTH DAKOTAGEOTHERMAL: calculation point e12

SURFACE TEMP = 7.9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 6

7.9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.9	518.2	0.0	1.1	54.5	
NEWCASTLE	36.2	51.8	518.2	1.4	42.9	2.351
INYAN KARA	38.4	18.3	570.0	1.6	37.5	0.895
MORRISON	39.1	16.8	588.3	1.4	42.9	
SUNDANCE	39.8	48.8	605.0	1.4	42.9	
MINNELUSA	41.9	149.4	653.8	2.2	27.3	8.148
MADISON	46.0	164.6	803.2	3.5	17.1	10.055
DEVONIAN	48.8	18.3	967.8	3.5	17.1	1.200
CAMBRIAN	49.1	213.4	986.0	2.4	25.0	14.109
BASEMENT	54.4		1199.4			

SOUTH DAKOTAGEOTHERMAL: calculation point e13

SURFACE TEMP = 7.8 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON =

7.8 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.8	487.7	0.0	1.1	54.5	
NEWCASTLE	34.4	51.8	487.7	1.4	42.9	2.213
INYAN KARA	36.6	25.9	539.5	1.6	37.5	1.199
MORRISON	37.6	12.2	565.4	1.4	42.9	
SUNDANCE	38.1	45.7	577.6	1.4	42.9	
MINNELUSA	40.1	76.2	623.3	2.2	27.3	3.949
MADISON	42.2	152.4	699.5	3.5	17.1	8.406
CAMBRIAN	44.8	182.9	851.9	2.4	25.0	10.854
BASEMENT	49.3		1034.8			

SOUTH DAKOTAGEOTHERMAL: calculation point e14

SURFACE TEMP = 7.8 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON =

7.8 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.8	454.2	0.0	1.1	54.5	
NEWCASTLE	32.6	51.8	454.2	1.4	42.9	2.061
INYAN KARA	34.8	33.5	506.0	1.6	37.5	1.453
MORRISON	36.1	9.1	539.5	1.4	42.9	
SUNDANCE	36.4	42.7	548.6	1.4	42.9	
MINNELUSA	38.3	61.0	591.3	2.2	27.3	2.982
MADISON	39.9	121.9	652.3	3.5	17.1	6.290
CAMBRIAN	42.0	152.4	774.2	2.4	25.0	8.374
BASEMENT	45.8		926.6			

SOUTH DAKOTAGEothermal: calculation point f1

SURFACE TEMP = 8.2 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON =

8.2 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.2	454.2	0.0	1.1	45.5	
INYAN KARA	28.8	27.4	454.2	1.6	31.3	0.909
MORRISON	29.7	36.6	481.6	1.4	35.7	
SUNDANCE	31.0	149.4	518.2	1.4	35.7	
SPEARFISH	36.3	251.5	667.5	1.3	35.7	
MINNEKAHATA	46.0	16.8	919.0	3.0	16.7	1.018
OPECHE	46.3	48.8	935.7	1.4	35.7	
MINNELUSA	48.0	128.0	984.5	2.2	22.7	8.187
MADISON	50.9	237.7	1112.5	3.5	14.3	16.315
DEVONIAN	54.3	170.7	1350.3	3.5	14.3	12.644
CAMBRIAN	56.8	152.4	1521.0	2.4	20.8	11.886
BASEMENT	60.0		1673.4			

SOUTH DAKOTAGEothermal: calculation point f2

SURFACE TEMP = 8.2 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON =

8.2 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.2	609.6	0.0	1.1	45.5	
NEWCASTLE	35.9	4.6	609.6	1.4	35.7	0.203
INYAN KARA	36.1	27.4	614.2	1.6	31.3	1.228
MORRISON	36.9	51.8	641.6	1.4	35.7	
SUNDANCE	38.8	135.6	693.4	1.4	35.7	
SPEARFISH	43.6	228.6	829.1	1.3	35.7	
MINNEKAHATA	52.4	14.6	1057.7	3.0	16.7	1.039
OPECHE	52.7	45.7	1072.3	1.4	35.7	
MINNELUSA	54.3	121.9	1118.0	2.2	22.7	9.023
MADISON	57.1	231.7	1239.9	3.5	14.3	18.173
DEVONIAN	60.4	176.8	1471.6	3.5	14.3	14.808
CAMBRIAN	62.9	176.8	1648.4	2.4	20.8	15.525
BASEMENT	66.6		1825.2			

SOUTH DAKOTAGEothermal: calculation point f3

SURFACE TEMP = 7.9 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

7.9 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.9	701.0	0.0	1.1	45.5	
NEWCASTLE	39.8	3.0	701.0	1.4	35.7	0.156
INYAN KARA	39.9	24.4	704.1	1.6	31.3	1.252
MORRISON	40.6	45.7	728.5	1.4	35.7	
SUNDANCE	42.3	132.6	774.2	1.4	35.7	
SPEARFISH	47.0	192.0	906.8	1.3	35.7	
MINNEKAHATA	54.4	13.7	1098.8	3.0	16.7	1.024
OPECHE	54.6	41.1	1112.5	1.4	35.7	
MINNELUSA	56.1	178.3	1153.7	2.2	22.7	13.795
MADISON	60.1	234.7	1332.0	3.5	14.3	19.685
DEVONIAN	63.5	170.7	1566.7	3.5	14.3	15.235
CAMBRIAN	65.9	185.9	1737.4	2.4	20.8	17.323
BASEMENT	69.8		1923.3			

SOUTH DAKOTAGEothermal: calculation point f4

SURFACE TEMP = 7.8 HEAT FLOW: SURFACE = 55 DAKOTA = 55 MADISON = 55

7.8 HEAT FLOW: SURFACE = 55 DAKOTA = 55 MADISON = 55

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.8	792.5	0.0	1.1	50.0	
NEWCASTLE	47.4	4.6	792.5	1.4	39.3	0.291
INYAN KARA	47.6	33.5	797.1	1.6	34.4	2.143
MORRISON	48.8	41.1	830.6	1.4	39.3	
SUNDANCE	50.4	129.5	871.7	1.4	39.3	
SPEARFISH	55.5	91.4	1001.3	1.3	39.3	
MINNEKAHATA	59.3	15.2	1092.7	3.0	18.3	1.261
OPECHE	59.6	36.6	1108.0	1.4	39.3	
MINNELUSA	61.0	210.3	1144.5	2.2	25.0	17.979
MADISON	66.3	251.5	1354.9	3.5	15.7	23.620
DEVONIAN	70.3	153.9	1606.3	3.5	15.7	15.435
CAMBRIAN	72.7	216.4	1760.2	2.4	22.9	22.540
BASEMENT	77.6		1976.7			

SOUTH DAKOTAGeothermal: calculation point f5

SURFACE TEMP = 7.8 HEAT FLOW: SURFACE = 55 DAKOTA = 55 MADISON = 55

7.8 HEAT FLOW: SURFACE = 55 DAKOTA = 55 MADISON = 55

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.8	823.0	0.0	1.1	50.0	
NEWCASTLE	48.9	7.6	823.0	1.4	39.3	0.503
INYAN KARA	49.2	24.4	830.6	1.6	34.4	1.623
MORRISON	50.1	38.1	855.0	1.4	39.3	
SUNDANCE	51.6	123.4	893.1	1.4	39.3	
SPEARFISH	56.4	65.5	1016.5	1.3	39.3	
MINNEKAHATA	59.2	14.6	1082.1	3.0	18.3	1.207
OPECHE	59.5	32.0	1096.7	1.4	39.3	
MINNELUSA	60.7	219.5	1128.7	2.2	25.0	18.649
MADISON	66.2	259.1	1348.1	3.5	15.7	24.299
DEVONIAN	70.3	140.2	1607.2	3.5	15.7	14.066
CAMBRIAN	72.5	243.8	1747.4	2.4	22.9	25.326
BASEMENT	78.1		1991.3			

SOUTH DAKOTAGeothermal: calculation point f6

SURFACE TEMP = 7.8 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.8 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
FOX HILLS	7.8	30.5	0.0	1.2	50.0	
PIERRE	9.3	731.5	30.5	1.1	54.5	
NEWCASTLE	49.2	12.2	762.0	1.4	42.9	0.811
INYAN KARA	49.7	21.3	774.2	1.6	37.5	1.437
MORRISON	50.5	33.5	795.5	1.4	42.9	
SUNDANCE	52.0	112.8	829.1	1.4	42.9	
SPEARFISH	56.8	54.9	941.8	1.3	42.9	
MINNEKAHATA	59.4	12.2	996.7	3.0	20.0	1.009
OPECHE	59.6	21.3	1008.9	1.4	42.9	
MINNELUSA	60.5	76.2	1030.2	2.2	27.3	6.448
MADISON	62.6	246.9	1106.4	3.5	17.1	21.716
DEVONIAN	66.8	121.9	1353.3	3.5	17.1	11.553
CAMBRIAN	68.9	249.9	1475.2	2.4	25.0	24.522
BASEMENT	75.2		1725.2			

SOUTH DAKOTA Geothermal: calculation point f7

SURFACE TEMP = 7.9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

7.9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
FOX HILLS	7.9	15.2	0.0	1.2	50.0	
PIERRE	8.7	695.0	15.2	1.1	54.5	
NEWCASTLE	46.6	12.2	710.2	1.4	42.9	0.757
INYAN KARA	47.1	18.3	722.4	1.6	37.5	1.151
MORRISON	47.8	27.4	740.7	1.4	42.9	
SUNDANCE	49.0	93.0	768.1	1.4	42.9	
SPEARFISH	52.9	48.8	861.1	1.3	42.9	
MINNEKAHATA	55.2	9.1	909.8	3.0	20.0	0.694
OPECHE	55.4	19.8	919.0	1.4	42.9	
MINNELUSA	56.2	231.7	938.8	2.2	27.3	17.970
MADISON	62.5	228.6	1170.4	3.5	17.1	20.053
DEVONIAN	66.5	93.0	1399.0	3.5	17.1	8.740
CAMBRIAN	68.0	253.0	1492.0	2.4	25.0	24.431
BASEMENT	74.4		1745.0			

SOUTH DAKOTA Geothermal: calculation point f8

SURFACE TEMP = 8 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

8.0 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.0	664.5	0.0	1.1	54.5	
NEWCASTLE	44.2	12.2	664.5	1.4	42.9	0.709
INYAN KARA	44.8	12.2	676.7	1.6	37.5	0.720
MORRISON	45.2	19.8	688.9	1.4	42.9	
SUNDANCE	46.1	82.3	708.7	1.4	42.9	
SPEARFISH	49.6	42.7	791.0	1.3	42.9	
MINNEKAHATA	51.6	6.1	833.6	3.0	20.0	0.426
OPECHE	51.7	18.3	839.7	1.4	42.9	
MINNELUSA	52.5	231.7	858.0	2.2	27.3	16.541
MADISON	58.8	210.3	1089.7	3.5	17.1	17.150
DEVONIAN	62.4	76.2	1300.0	3.5	17.1	6.655
CAMBRIAN	63.7	249.9	1376.2	2.4	25.0	22.353
BASEMENT	70.0		1626.1			

SOUTH DAKOTAGEOTHERMAL: calculation point f9

SURFACE TEMP = 8.2 HEAT FLOW: SURFACE = 64 DAKOTA = 64 MADISON = 64

8.2 HEAT FLOW: SURFACE = 64 DAKOTA = 64 MADISON = 64

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.2	640.1	0.0	1.1	58.2	
NEWCASTLE	45.4	15.2	640.1	1.4	45.7	0.911
INYAN KARA	46.1	13.7	655.3	1.6	40.0	0.835
MORRISON	46.7	29.0	669.0	1.4	45.7	
SUNDANCE	48.0	70.1	698.0	1.4	45.7	
SPEARFISH	51.2	38.1	768.1	1.3	45.7	
MINNEKAHATA	53.1	3.0	806.2	3.0	21.3	0.220
OPECHE	53.2	4.6	809.3	1.4	45.7	
MINNELUSA	53.4	225.6	813.8	2.2	29.1	16.355
MADISON	59.9	190.5	1039.4	3.5	18.3	15.820
DEVONIAN	63.4	57.9	1229.9	3.5	18.3	5.133
CAMBRIAN	64.5	243.8	1287.8	2.4	26.7	22.028
BASEMENT	71.0		1531.6			

SOUTH DAKOTAGEOTHERMAL: calculation point f10

SURFACE TEMP = 8.2 HEAT FLOW: SURFACE = 65 DAKOTA = 65 MADISON = 65

8.2 HEAT FLOW: SURFACE = 65 DAKOTA = 65 MADISON = 65

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.2	579.1	0.0	1.1	59.1	
NEWCASTLE	42.4	38.1	579.1	1.4	46.4	2.093
INYAN KARA	44.2	22.9	617.2	1.6	40.6	1.321
MORRISON	45.1	35.1	640.1	1.4	46.4	
SUNDANCE	46.7	57.9	675.1	1.4	46.4	
SPEARFISH	49.4	32.0	733.1	1.3	46.4	
MINNEKAHATA	51.0	2.4	765.1	3.0	21.7	0.168
MINNELUSA	51.1	213.4	767.5	2.2	29.5	14.691
MADISON	57.4	173.7	980.9	3.5	18.6	13.721
DEVONIAN	60.6	18.3	1154.6	3.5	18.6	1.539
CAMBRIAN	61.0	228.6	1172.9	2.4	27.1	19.363
BASEMENT	67.1		1401.5			

SOUTH DAKOTAGEOTHERMAL: calculation point f11

SURFACE TEMP = 8.3 HEAT FLOW: SURFACE = 65 DAKOTA = 65 MADISON = 65

8.3 HEAT FLOW: SURFACE = 65 DAKOTA = 65 MADISON = 65

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.3	542.6	0.0	1.1	59.1	
NEWCASTLE	40.4	51.8	542.6	1.4	46.4	2.667
INYAN KARA	42.8	30.5	594.4	1.6	40.6	1.687
MORRISON	44.0	29.0	624.8	1.4	46.4	
SUNDANCE	45.3	48.8	653.8	1.4	46.4	
MINNELUSA	47.6	192.0	702.6	2.2	29.5	12.120
MADISON	53.3	160.0	894.6	3.5	18.6	11.557
DEVONIAN	56.3	12.2	1054.6	3.5	18.6	0.939
CAMBRIAN	56.5	189.0	1066.8	2.4	27.1	14.619
BASEMENT	61.6		1255.8			

SOUTH DAKOTAGEOTHERMAL: calculation point f12

SURFACE TEMP = 8.3 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

8.3 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.3	506.0	0.0	1.1	54.5	
NEWCASTLE	35.9	51.8	506.0	1.4	42.9	2.296
INYAN KARA	38.1	36.6	557.8	1.6	37.5	1.751
MORRISON	39.5	16.8	594.4	1.4	42.9	
SUNDANCE	40.2	45.7	611.1	1.4	42.9	
MINNELUSA	42.2	118.9	656.9	2.2	27.3	6.464
MADISON	45.4	150.9	775.7	3.5	17.1	8.989
DEVONIAN	48.0	6.1	926.6	3.5	17.1	0.389
CAMBRIAN	48.1	179.8	932.7	2.4	25.0	11.492
BASEMENT	52.6		1112.5			

SOUTH DAKOTAGEOTHERMAL: calculation point f13

SURFACE TEMP = 8.2 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

8.2 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.2	469.4	0.0	1.1	54.5	
NEWCASTLE	33.8	61.0	469.4	1.4	42.9	2.506
INYAN KARA	36.4	39.6	530.4	1.6	37.5	1.795
MORRISON	37.9	12.2	570.0	1.4	42.9	
SUNDANCE	38.4	42.7	582.2	1.4	42.9	
MINNELUSA	40.3	76.2	624.8	2.2	27.3	3.921
BASEMENT	42.3		701.0			

SOUTH DAKOTAGEOTHERMAL: calculation point f14

SURFACE TEMP = 8.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

8.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.1	432.8	0.0	1.1	54.5	
NEWCASTLE	31.7	70.1	432.8	1.4	42.9	2.657
INYAN KARA	34.7	42.7	502.9	1.6	37.5	1.823
MORRISON	36.3	9.1	545.6	1.4	42.9	
SUNDANCE	36.7	39.6	554.7	1.4	42.9	
MINNELUSA	38.4	61.0	594.4	2.2	27.3	2.966
BASEMENT	40.1		655.3			

SOUTH DAKOTAGEothermal: calculation point g1

SURFACE TEMP = 7.8 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

7.8 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
MORRISON	7.8	45.7	0.0	1.4	35.7	
SUNDANCE	9.4	128.0	45.7	1.4	35.7	
SPEARFISH	14.0	253.0	173.7	1.3	35.7	
MINNEKAHATA	23.7	16.8	426.7	3.0	16.7	0.429
OPECHE	24.0	51.8	443.5	1.4	35.7	
MINNELUSA	25.9	125.0	495.3	2.2	22.7	3.625
MADISON	28.7	195.1	620.3	3.5	14.3	6.547
DEVONIAN	31.5	153.9	815.3	3.5	14.3	5.855
CAMBRIAN	33.7	115.8	969.3	2.4	20.8	4.815
BASEMENT	36.1		1085.1			

SOUTH DAKOTAGEothermal: calculation point g2

SURFACE TEMP = 7.9 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

7.9 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.9	182.9	0.0	1.1	45.5	
MORRISON	16.2	67.1	182.9	1.4	35.7	
SUNDANCE	18.6	115.8	249.9	1.4	35.7	
SPEARFISH	22.7	189.0	365.8	1.3	35.7	
MINNEKAHATA	30.0	14.6	554.7	3.0	16.7	0.519
OPECHE	30.3	48.8	569.4	1.4	35.7	
MINNELUSA	32.0	123.4	618.1	2.2	22.7	4.776
MADISON	34.8	198.1	741.6	3.5	14.3	8.558
DEVONIAN	37.6	164.6	939.7	3.5	14.3	7.857
CAMBRIAN	40.0	115.8	1104.3	2.4	20.8	5.966
BASEMENT	42.4		1220.1			

SOUTH DAKOTAGEothermal: calculation point g3

SURFACE TEMP = 7.9 HEAT FLOW: SURFACE = 44 DAKOTA = 44 MADISON = 44

7.9 HEAT FLOW: SURFACE = 44 DAKOTA = 44 MADISON = 44

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.9	487.7	0.0	1.1	40.0	
NEWCASTLE	27.4	1.5	487.7	1.4	31.4	0.048
INYAN KARA	27.5	48.8	489.2	1.6	27.5	1.531
MORRISON	28.8	79.2	538.0	1.4	31.4	
SUNDANCE	31.3	117.3	617.2	1.4	31.4	
SPEARFISH	35.0	106.7	734.6	1.3	31.4	
MINNEKAHATA	38.6	13.7	841.3	3.0	14.7	0.676
OPECHE	38.8	47.2	855.0	1.4	31.4	
MINNELUSA	40.3	176.8	902.2	2.2	20.0	9.188
MADISON	43.8	198.1	1079.0	3.5	12.6	11.422
DEVONIAN	46.3	155.4	1277.1	3.5	12.6	9.583
CAMBRIAN	48.3	115.8	1432.6	2.4	18.3	7.504
BASEMENT	50.4		1548.4			

SOUTH DAKOTAGEothermal: calculation point g4

SURFACE TEMP = 7.8 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

7.8 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.8	701.0	0.0	1.1	40.9	
NEWCASTLE	36.5	4.6	701.0	1.4	32.1	0.211
INYAN KARA	36.6	45.7	705.6	1.6	28.1	2.116
MORRISON	37.9	45.7	751.3	1.4	32.1	
SUNDANCE	39.4	109.7	797.1	1.4	32.1	
SPEARFISH	42.9	89.9	906.8	1.3	32.1	
MINNEKAHATA	46.0	14.6	996.7	3.0	15.0	0.898
OPECHE	46.2	42.7	1011.3	1.4	32.1	
MINNELUSA	47.6	207.3	1054.0	2.2	20.5	13.248
MADISON	51.9	210.3	1261.3	3.5	12.9	14.874
DEVONIAN	54.6	146.3	1471.6	3.5	12.9	10.982
CAMBRIAN	56.4	176.8	1617.9	2.4	18.8	13.804
BASEMENT	59.8		1794.7			

SOUTH DAKOTAGEOTHERMAL: calculation point g5

SURFACE TEMP = 7.8 HEAT FLOW: SURFACE = 47 DAKOTA = 47 MADISON = 47

7.8 HEAT FLOW: SURFACE = 47 DAKOTA = 47 MADISON = 47

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.8	792.5	0.0	1.1	42.7	
NEWCASTLE	41.7	9.1	792.5	1.4	33.6	0.497
INYAN KARA	42.0	48.8	801.6	1.6	29.4	2.675
MORRISON	43.4	42.7	850.4	1.4	33.6	
SUNDANCE	44.8	97.5	893.1	1.4	33.6	
SPEARFISH	48.1	67.1	990.6	1.3	33.6	
MINNEKAHATA	50.5	13.7	1057.7	3.0	15.7	0.941
OPECHE	50.7	38.1	1071.4	1.4	33.6	
MINNELUSA	52.0	221.0	1109.5	2.2	21.4	15.691
MADISON	56.7	227.1	1330.5	3.5	13.4	17.845
DEVONIAN	59.8	125.0	1557.5	3.5	13.4	10.432
CAMBRIAN	61.5	207.3	1682.5	2.4	19.6	17.861
BASEMENT	65.5		1889.8			

SOUTH DAKOTAGEOTHERMAL: calculation point g6

SURFACE TEMP = 7.9 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

7.9 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
FOX HILLS	7.9	76.2	0.0	1.2	41.7	
PIERRE	11.1	762.0	76.2	1.1	45.5	
NEWCASTLE	45.7	13.7	838.2	1.4	35.7	0.833
INYAN KARA	46.2	44.2	851.9	1.6	31.3	2.718
MORRISON	47.6	39.6	896.1	1.4	35.7	
SUNDANCE	49.0	85.3	935.7	1.4	35.7	
SPEARFISH	52.0	56.4	1021.1	1.3	35.7	
MINNEKAHATA	54.2	12.2	1077.5	3.0	16.7	0.907
OPECHE	54.4	33.5	1089.7	1.4	35.7	
MINNELUSA	55.6	228.6	1123.2	2.2	22.7	17.512
MADISON	60.8	225.6	1351.8	3.5	14.3	19.160
DEVONIAN	64.0	103.6	1577.4	3.5	14.3	9.339
CAMBRIAN	65.5	219.5	1681.0	2.4	20.8	20.299
BASEMENT	70.1		1900.5			

SOUTH DAKOTA Geothermal: calculation point g7

SURFACE TEMP = 8 HEAT FLOW: SURFACE = 65 DAKOTA = 65 MADISON = 65

8.0 HEAT FLOW: SURFACE = 65 DAKOTA = 65 MADISON = 65

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
FOX HILLS	8.0	30.5	0.0	1.2	54.2	
PIERRE	9.7	701.0	30.5	1.1	59.1	
NEWCASTLE	51.1	18.3	731.5	1.4	46.4	1.265
INYAN KARA	51.9	21.3	749.8	1.6	40.6	1.505
MORRISON	52.8	33.5	771.2	1.4	46.4	
SUNDANCE	54.3	79.2	804.7	1.4	46.4	
SPEARFISH	58.0	50.3	883.9	1.3	46.4	
MINNEKAHATA	60.5	9.1	934.2	3.0	21.7	0.771
OPECHE	60.7	24.4	943.4	1.4	46.4	
MINNELUSA	61.9	231.7	967.8	2.2	29.5	20.036
MADISON	68.7	204.2	1199.4	3.5	18.6	19.907
DEVONIAN	72.5	82.3	1403.6	3.5	18.6	8.523
CAMBRIAN	74.0	228.6	1485.9	2.4	27.1	24.237
BASEMENT	80.2		1714.5			

SOUTH DAKOTA Geothermal: calculation point g8

SURFACE TEMP = 8.2 HEAT FLOW: SURFACE = 70 DAKOTA = 70 MADISON = 70

8.2 HEAT FLOW: SURFACE = 70 DAKOTA = 70 MADISON = 70

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.2	670.6	0.0	1.1	63.6	
NEWCASTLE	50.9	13.7	670.6	1.4	50.0	0.940
INYAN KARA	51.6	12.2	684.3	1.6	43.8	0.849
MORRISON	52.1	27.4	696.5	1.4	50.0	
SUNDANCE	53.5	74.7	723.9	1.4	50.0	
SPEARFISH	57.2	44.2	798.6	1.3	50.0	
MINNEKAHATA	59.6	6.1	842.8	3.0	23.3	0.503
OPECHE	59.7	18.3	848.9	1.4	50.0	
MINNELUSA	60.6	237.7	867.2	2.2	31.8	20.014
MADISON	68.2	182.9	1104.9	3.5	20.0	17.616
DEVONIAN	71.9	42.7	1287.8	3.5	20.0	4.361
CAMBRIAN	72.7	216.4	1330.5	2.4	29.2	22.413
BASEMENT	79.0		1546.9			

SOUTH DAKOTAGEOTHERMAL: calculation point g9

SURFACE TEMP = 8.399999 HEAT FLOW: SURFACE = 79 DAKOTA = 79 MADISON = 79

8.4 HEAT FLOW: SURFACE = 79 DAKOTA = 79 MADISON = 79

TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.4	579.1	0.0	1.1	71.8
NEWCASTLE	50.0	22.9	579.1	1.4	56.4
INYAN KARA	51.3	12.2	602.0	1.6	49.4
MORRISON	51.9	24.4	614.2	1.4	56.4
SUNDANCE	53.3	65.5	638.6	1.4	56.4
SPEARFISH	57.0	41.1	704.1	1.3	56.4
MINNEKAHATA	59.5	3.0	745.2	3.0	26.3
OPECHE	59.5	4.6	748.3	1.4	56.4
MINNELUSA	59.8	240.8	752.9	2.2	35.9
MADISON	68.4	160.0	993.7	3.5	22.6
DEVONIAN	72.1	12.2	1153.7	3.5	22.6
CAMBRIAN	72.3	216.4	1165.9	2.4	32.9
BASEMENT	79.5		1382.3		

SOUTH DAKOTAGEOTHERMAL: calculation point g10

SURFACE TEMP = 8.399999 HEAT FLOW: SURFACE = 85 DAKOTA = 85 MADISON = 85

8.4 HEAT FLOW: SURFACE = 85 DAKOTA = 85 MADISON = 85

TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.4	548.6	0.0	1.1	77.3
NEWCASTLE	50.8	51.8	548.6	1.4	60.7
INYAN KARA	53.9	22.9	600.5	1.6	53.1
MORRISON	55.2	25.9	623.3	1.4	60.7
SUNDANCE	56.7	54.9	649.2	1.4	60.7
SPEARFISH	60.1	36.6	704.1	1.3	60.7
MINNEKAHATA	62.5	1.5	740.7	3.0	28.3
MINNELUSA	62.5	231.7	742.2	2.2	38.6
MADISON	71.4	150.9	973.8	3.5	24.3
DEVONIAN	75.1	7.6	1124.7	3.5	24.3
CAMBRIAN	75.3	185.9	1132.3	2.4	35.4
BASEMENT	81.9		1318.3		

SOUTH DAKOTAGEOTHERMAL: calculation point g11

SURFACE TEMP = 8.5 HEAT FLOW: SURFACE = 75 DAKOTA = 75 MADISON = 75

8.5 HEAT FLOW: SURFACE = 75 DAKOTA = 75 MADISON = 75

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.5	515.1	0.0	1.1	68.2	
NEWCASTLE	43.6	48.8	515.1	1.4	53.6	2.750
INYAN KARA	46.2	30.5	563.9	1.6	46.9	1.847
MORRISON	47.7	21.3	594.4	1.4	53.6	
SUNDANCE	48.8	51.8	615.7	1.4	53.6	
SPEARFISH	51.6	32.0	667.5	1.3	53.6	
MINNELUSA	53.4	207.3	699.5	2.2	34.1	14.950
MADISON	60.5	131.1	906.8	3.5	21.4	10.941
CAMBRIAN	63.3	155.4	1037.9	2.4	31.3	13.677
BASEMENT	68.2		1193.3			

SOUTH DAKOTAGEOTHERMAL: calculation point g12

SURFACE TEMP = 8.399999 HEAT FLOW: SURFACE = 75 DAKOTA = 75 MADISON = 75

8.4 HEAT FLOW: SURFACE = 75 DAKOTA = 75 MADISON = 75

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.4	481.6	0.0	1.1	68.2	
NEWCASTLE	41.2	64.0	481.6	1.4	53.6	3.374
INYAN KARA	44.7	33.5	545.6	1.6	46.9	1.952
MORRISON	46.2	13.7	579.1	1.4	53.6	
SUNDANCE	47.0	45.7	592.8	1.4	53.6	
MINNELUSA	49.4	185.9	638.6	2.2	34.1	12.245
MADISON	55.8	64.0	824.5	3.5	21.4	4.867
CAMBRIAN	57.1	143.3	888.5	2.4	31.3	11.208
BASEMENT	61.6		1031.8			

SOUTH DAKOTAGeothermal: calculation point g13

SURFACE TEMP = 8.3 HEAT FLOW: SURFACE = 80 DAKOTA = 80 MADISON = 80

8.3 HEAT FLOW: SURFACE = 80 DAKOTA = 80 MADISON = 80

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.3	454.2	0.0	1.1	72.7	
NEWCASTLE	41.3	76.2	454.2	1.4	57.1	4.041
INYAN KARA	45.7	36.6	530.4	1.6	50.0	2.195
MORRISON	47.5	9.1	566.9	1.4	57.1	
SUNDANCE	48.0	39.6	576.1	1.4	57.1	
MINNELUSA	50.3	120.4	615.7	2.2	36.4	8.118
BASEMENT	54.7		736.1			

SOUTH DAKOTAGeothermal: calculation point g14

SURFACE TEMP = 8.3 HEAT FLOW: SURFACE = 80 DAKOTA = 80 MADISON = 80

8.3 HEAT FLOW: SURFACE = 80 DAKOTA = 80 MADISON = 80

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.3	423.7	0.0	1.1	72.7	
NEWCASTLE	39.1	76.2	423.7	1.4	57.1	3.770
INYAN KARA	43.5	39.6	499.9	1.6	50.0	2.237
MORRISON	45.4	6.1	539.5	1.4	57.1	
SUNDANCE	45.8	33.5	545.6	1.4	57.1	
MINNELUSA	47.7	61.0	579.1	2.2	36.4	3.857
BASEMENT	49.9		640.1			

SOUTH DAKOTAGEothermal: calculation point h4

SURFACE TEMP = 7.6 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

7.6 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.6	73.2	0.0	1.1	40.9	
NEWCASTLE	10.6	4.6	73.2	1.4	0.0	0.000
INYAN KARA	0.0	12.2	77.7	1.6	28.1	0.000
MORRISON	10.9	54.9	89.9	1.4	32.1	
SUNDANCE	12.7	94.5	144.8	1.4	32.1	
SPEARFISH	15.7	94.5	239.3	1.3	32.1	
MINNEKAHATA	19.0	12.2	333.8	3.0	15.0	0.223
OPECHE	19.2	42.7	346.0	1.4	32.1	
MINNELUSA	20.6	195.1	388.6	2.2	20.5	4.059
MADISON	24.6	164.6	583.7	3.5	12.9	4.479
DEVONIAN	26.7	123.4	748.3	3.5	12.9	3.779
CAMBRIAN	28.3	121.9	871.7	2.4	18.8	4.043
BASEMENT	30.5		993.7			

SOUTH DAKOTAGEothermal: calculation point h5

SURFACE TEMP = 7.8 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

7.8 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.8	746.8	0.0	1.1	40.9	
NEWCASTLE	38.3	9.1	746.8	1.4	32.1	0.448
INYAN KARA	38.6	12.2	755.9	1.6	28.1	0.604
MORRISON	39.0	48.8	768.1	1.4	32.1	
SUNDANCE	40.6	83.8	816.9	1.4	32.1	
SPEARFISH	43.2	76.2	900.7	1.3	32.1	
MINNEKAHATA	45.9	13.7	976.9	3.0	15.0	0.839
OPECHE	46.1	39.6	990.6	1.4	32.1	
MINNELUSA	47.4	222.5	1030.2	2.2	20.5	14.134
MADISON	51.9	189.0	1252.7	3.5	12.9	13.385
DEVONIAN	54.3	109.7	1441.7	3.5	12.9	8.200
CAMBRIAN	55.8	176.8	1551.5	2.4	18.8	13.611
BASEMENT	59.1		1728.2			

SOUTH DAKOTAGEOTHERMAL: calculation point h6

SURFACE TEMP = 7.9 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

7.9 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.9	838.2	0.0	1.1	45.5	
NEWCASTLE	46.0	14.3	838.2	1.4	35.7	0.876
INYAN KARA	46.5	33.5	852.5	1.6	31.3	2.078
MORRISON	47.6	46.3	886.1	1.4	35.7	
SUNDANCE	49.2	76.2	932.4	1.4	35.7	
SPEARFISH	51.9	62.5	1008.6	1.3	35.7	
MINNEKAHATA	54.3	14.6	1071.1	3.0	16.7	1.091
OPECHE	54.6	36.6	1085.7	1.4	35.7	
MINNELUSA	55.9	228.6	1122.3	2.2	22.7	17.613
MADISON	61.1	179.8	1350.9	3.5	14.3	15.355
DEVONIAN	63.7	91.4	1530.7	3.5	14.3	8.185
CAMBRIAN	65.0	189.0	1622.2	2.4	20.8	17.312
BASEMENT	68.9		1811.1			

SOUTH DAKOTAGEOTHERMAL: calculation point h7

SURFACE TEMP = 8.2 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

8.2 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.2	792.5	0.0	1.1	54.5	
NEWCASTLE	51.4	33.5	792.5	1.4	42.9	2.327
INYAN KARA	52.9	30.5	826.0	1.6	37.5	2.186
MORRISON	54.0	42.7	856.5	1.4	42.9	
SUNDANCE	55.8	67.1	899.2	1.4	42.9	
SPEARFISH	58.7	53.3	966.2	1.3	42.9	
MINNEKAHATA	61.2	14.6	1019.6	3.0	20.0	1.244
OPECHE	61.5	32.0	1034.2	1.4	42.9	
MINNELUSA	62.8	236.2	1066.2	2.2	27.3	20.720
MADISON	69.3	189.0	1302.4	3.5	17.1	18.531
DEVONIAN	72.5	61.0	1491.4	3.5	17.1	6.295
CAMBRIAN	73.6	207.3	1552.4	2.4	25.0	21.750
BASEMENT	78.7		1759.6			

SOUTH DAKOTAGEOTHERMAL: calculation point h8

SURFACE TEMP = 8.5 HEAT FLOW: SURFACE = 70 DAKOTA = 70 MADISON = 70

8.5 HEAT FLOW: SURFACE = 70 DAKOTA = 70 MADISON = 70

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.5	701.0	0.0	1.1	63.6	
NEWCASTLE	53.1	21.3	701.0	1.4	50.0	1.528
INYAN KARA	54.2	12.2	722.4	1.6	43.8	0.894
MORRISON	54.7	36.6	734.6	1.4	50.0	
SUNDANCE	56.5	67.1	771.2	1.4	50.0	
SPEARFISH	59.9	45.7	838.2	1.3	50.0	
MINNEKAHATA	62.4	7.6	883.9	3.0	23.3	0.659
OPECHE	62.5	22.9	891.6	1.4	50.0	
MINNELUSA	63.7	249.9	914.4	2.2	31.8	22.141
MADISON	71.6	164.6	1164.4	3.5	20.0	16.682
DEVONIAN	74.9	24.4	1328.9	3.5	20.0	2.600
CAMBRIAN	75.4	192.0	1353.3	2.4	29.2	20.628
BASEMENT	81.0		1545.4			

SOUTH DAKOTAGEOTHERMAL: calculation point h9

SURFACE TEMP = 8.6 HEAT FLOW: SURFACE = 80 DAKOTA = 60 MADISON = 60

8.6 HEAT FLOW: SURFACE = 80 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.6	640.1	0.0	1.1	72.7	
NEWCASTLE	55.2	33.5	640.1	1.4	42.9	2.506
INYAN KARA	56.6	18.3	673.6	1.6	37.5	1.409
MORRISON	57.3	27.4	691.9	1.4	42.9	
SUNDANCE	58.5	59.4	719.3	1.4	42.9	
SPEARFISH	61.0	39.6	778.8	1.3	42.9	
MINNEKAHATA	62.8	4.6	818.4	3.0	20.0	0.398
OPECHE	62.9	3.0	823.0	1.4	42.9	
MINNELUSA	63.0	242.3	826.0	2.2	27.3	21.182
MADISON	69.7	125.0	1068.3	3.5	17.1	12.250
DEVONIAN	71.8	15.2	1193.3	3.5	17.1	1.546
CAMBRIAN	72.1	179.8	1208.5	2.4	25.0	18.322
BASEMENT	76.6		1388.4			

SOUTH DAKOTAGEOTHERMAL: calculation point h10

SURFACE TEMP = 8.6 HEAT FLOW: SURFACE = 90 DAKOTA = 60 MADISON = 60

8.6 HEAT FLOW: SURFACE = 90 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.6	487.7	0.0	1.1	81.8	
NEWCASTLE	48.5	45.7	487.7	1.4	42.9	2.929
INYAN KARA	50.5	22.9	533.4	1.6	37.5	1.536
MORRISON	51.3	22.9	556.3	1.4	42.9	
SUNDANCE	52.3	51.8	579.1	1.4	42.9	
SPEARFISH	54.5	33.5	630.9	1.3	42.9	
MINNELUSA	56.1	205.7	664.5	2.2	27.3	15.679
MADISON	61.7	93.0	870.2	3.5	17.1	7.922
DEVONIAN	63.3	21.3	963.2	3.5	17.1	1.873
CAMBRIAN	63.6	146.3	984.5	2.4	25.0	12.928
BASEMENT	67.3		1130.8			

SOUTH DAKOTAGEOTHERMAL: calculation point h11

SURFACE TEMP = 8.6 HEAT FLOW: SURFACE = 100 DAKOTA = 60 MADISON = 60

8.6 HEAT FLOW: SURFACE = 100 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.6	457.2	0.0	1.1	90.9	
NEWCASTLE	50.2	67.1	457.2	1.4	42.9	4.475
INYAN KARA	53.0	27.4	524.3	1.6	37.5	1.957
MORRISON	54.1	18.3	551.7	1.4	42.9	
SUNDANCE	54.9	42.7	570.0	1.4	42.9	
SPEARFISH	56.7	1.5	612.7	1.3	42.9	
MINNELUSA	56.7	185.9	614.2	2.2	27.3	14.373
MADISON	61.8	62.5	800.1	3.5	17.1	5.339
CAMBRIAN	62.9	118.9	862.6	2.4	25.0	10.361
BASEMENT	65.9		981.5			

SOUTH DAKOTAGeothermal: calculation point h12

SURFACE TEMP = 8.7 HEAT FLOW: SURFACE = 75 DAKOTA = 75 MADISON = 75

8.7 HEAT FLOW: SURFACE = 75 DAKOTA = 75 MADISON = 75

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.7	487.7	0.0	1.1	68.2	
NEWCASTLE	42.0	76.2	487.7	1.4	53.6	4.068
INYAN KARA	46.0	30.5	563.9	1.6	46.9	1.827
MORRISON	47.5	13.7	594.4	1.4	53.6	
SUNDANCE	48.2	33.5	608.1	1.4	53.6	
MINNELUSA	50.0	61.0	641.6	2.2	34.1	4.041
MADISON	52.1	36.6	702.6	3.5	21.4	2.547
CAMBRIAN	52.9	118.9	739.1	2.4	31.3	8.427
BASEMENT	56.6		858.0			

SOUTH DAKOTAGeothermal: calculation point h13

SURFACE TEMP = 8.7 HEAT FLOW: SURFACE = 100 DAKOTA = 100 MADISON = 100

8.7 HEAT FLOW: SURFACE = 100 DAKOTA = 100 MADISON = 100

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.7	454.2	0.0	1.1	90.9	
NEWCASTLE	50.0	76.2	454.2	1.4	71.4	5.051
INYAN KARA	55.4	30.5	530.4	1.6	62.5	2.287
MORRISON	57.3	7.6	560.8	1.4	71.4	
SUNDANCE	57.9	15.2	568.5	1.4	71.4	
MINNELUSA	59.0	61.0	583.7	2.2	45.5	4.920
BASEMENT	61.7		644.7			

SOUTH DAKOTA Geothermal: calculation point h14

SURFACE TEMP = 8.6 HEAT FLOW: SURFACE = 100 DAKOTA = 100 MADISON = 100

8.6 HEAT FLOW: SURFACE = 100 DAKOTA = 100 MADISON = 100

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.6	396.2	0.0	1.1	90.9	
NEWCASTLE	44.6	54.9	396.2	1.4	71.4	3.173
INYAN KARA	48.5	38.1	451.1	1.6	62.5	2.443
MINNELUSA	50.9	61.0	489.2	2.2	45.5	4.142
BASEMENT	53.7		550.2			

SOUTH DAKOTAGEOTHERMAL: calculation point i4

SURFACE TEMP = 7.8 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

7.8 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.8	518.2	0.0	1.1	40.9	
NEWCASTLE	29.0	1.5	518.2	1.4	32.1	0.052
INYAN KARA	29.0	53.3	519.7	1.6	28.1	1.820
MORRISON	30.5	79.2	573.0	1.4	32.1	
SUNDANCE	33.1	96.0	652.3	1.4	32.1	
SPEARFISH	36.2	106.7	748.3	1.3	32.1	
MINNEKAHATA	39.9	13.7	855.0	3.0	15.0	0.706
OPECHE	40.1	47.2	868.7	1.4	32.1	
MINNELUSA	41.6	205.7	915.9	2.2	20.5	11.164
MADISON	45.8	91.4	1121.7	3.5	12.9	5.579
DEVONIAN	47.0	134.1	1213.1	3.5	12.9	8.436
CAMBRIAN	48.7	67.1	1347.2	2.4	18.8	4.404
BASEMENT	50.0		1414.3			

SOUTH DAKOTAGEOTHERMAL: calculation point i5

SURFACE TEMP = 7.8 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

7.8 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.8	716.3	0.0	1.1	40.9	
NEWCASTLE	37.1	10.7	716.3	1.4	32.1	0.502
INYAN KARA	37.4	39.6	727.0	1.6	28.1	1.886
MORRISON	38.6	76.2	766.6	1.4	32.1	
SUNDANCE	41.0	85.3	842.8	1.4	32.1	
SPEARFISH	43.8	76.2	928.1	1.3	32.1	
MINNEKAHATA	46.4	14.3	1004.3	3.0	15.0	0.888
OPECHE	46.6	42.7	1018.7	1.4	32.1	
MINNELUSA	48.0	224.0	1061.3	2.2	20.5	14.451
MADISON	52.6	88.4	1285.4	3.5	12.9	6.352
DEVONIAN	53.7	146.3	1373.8	3.5	12.9	10.780
CAMBRIAN	55.6	121.9	1520.1	2.4	18.8	9.352
BASEMENT	57.9		1642.0			

SOUTH DAKOTAGEothermal: calculation point i6

SURFACE TEMP = 8.100001 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 5

8.1 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.1	823.0	0.0	1.1	45.5
NEWCASTLE	45.5	18.3	823.0	1.4	35.7
INYAN KARA	46.2	45.7	841.3	1.6	31.3
MORRISON	47.6	79.2	887.0	1.4	35.7
SUNDANCE	50.4	70.1	966.2	1.4	35.7
SPEARFISH	52.9	59.4	1036.3	1.3	35.7
MINNEKAHATA	55.2	14.6	1095.8	3.0	16.7
OPECHE	55.5	36.6	1110.4	1.4	35.7
MINNELUSA	56.8	231.7	1147.0	2.2	22.7
MADISON	62.0	153.9	1378.6	3.5	14.3
DEVONIAN	64.2	88.4	1532.6	3.5	14.3
CAMBRIAN	65.5	152.4	1620.9	2.4	20.8
BASEMENT	68.7		1773.3		

SOUTH DAKOTAGEothermal: calculation point i7

SURFACE TEMP = 8.399999 HEAT FLOW: SURFACE = 62 DAKOTA = 62 MADISON =

8.4 HEAT FLOW: SURFACE = 62 DAKOTA = 62 MADISON = 62

TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
FOX HILLS	8.4	30.5	0.0	1.2	51.7
PIERRE	10.0	807.7	30.5	1.1	56.4
NEWCASTLE	55.5	24.4	838.2	1.4	44.3
INYAN KARA	56.6	36.6	862.6	1.6	38.8
MORRISON	58.0	79.2	899.2	1.4	44.3
SUNDANCE	61.5	57.9	978.4	1.4	44.3
SPEARFISH	64.1	53.3	1036.3	1.3	44.3
MINNEKAHATA	66.6	14.6	1089.7	3.0	20.7
OPECHE	66.9	33.5	1104.3	1.4	44.3
MINNELUSA	68.4	242.3	1137.8	2.2	28.2
MADISON	75.2	152.4	1380.2	3.5	17.7
DEVONIAN	77.9	64.0	1532.6	3.5	17.7
CAMBRIAN	79.1	176.8	1596.6	2.4	25.8
BASEMENT	83.6		1773.3		

SOUTH DAKOTAGEothermal: calculation point i8

SURFACE TEMP = 8.7 HEAT FLOW: SURFACE = 72 DAKOTA = 72 MADISON = 72

8.7 HEAT FLOW: SURFACE = 72 DAKOTA = 72 MADISON = 72

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.7	701.0	0.0	1.1	65.5	
NEWCASTLE	54.6	24.4	701.0	1.4	51.4	1.796
INYAN KARA	55.8	32.0	725.4	1.6	45.0	2.422
MORRISON	57.3	68.6	757.4	1.4	51.4	
SUNDANCE	60.8	51.8	826.0	1.4	51.4	
SPEARFISH	63.5	45.7	877.8	1.3	51.4	
MINNEKAHATA	66.0	7.6	923.6	3.0	24.0	0.701
OPECHE	66.2	21.3	931.2	1.4	51.4	
MINNELUSA	67.3	240.8	952.5	2.2	32.7	22.648
MADISON	75.2	143.3	1193.3	3.5	20.6	15.287
DEVONIAN	78.1	54.9	1336.6	3.5	20.6	6.114
CAMBRIAN	79.2	161.5	1391.4	2.4	30.0	18.296
BASEMENT	84.1		1553.0			

SOUTH DAKOTAGEothermal: calculation point i9

SURFACE TEMP = 8.7 HEAT FLOW: SURFACE = 72 DAKOTA = 72 MADISON = 72

8.7 HEAT FLOW: SURFACE = 72 DAKOTA = 72 MADISON = 72

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.7	594.4	0.0	1.1	65.5	
NEWCASTLE	47.6	61.0	594.4	1.4	51.4	3.808
INYAN KARA	50.7	24.4	655.3	1.6	45.0	1.646
MORRISON	51.8	45.7	679.7	1.4	51.4	
SUNDANCE	54.2	45.7	725.4	1.4	51.4	
SPEARFISH	56.5	36.6	771.2	1.3	51.4	
MINNEKAHATA	58.6	3.0	807.7	3.0	24.0	0.244
OPECHE	58.6	0.6	810.8	1.4	51.4	
MINNELUSA	58.7	239.3	811.4	2.2	32.7	19.195
MADISON	66.5	125.0	1050.7	3.5	20.6	11.597
DEVONIAN	69.1	42.7	1175.6	3.5	20.6	4.136
CAMBRIAN	69.9	125.0	1218.3	2.4	30.0	12.289
BASEMENT	73.7		1343.3			

SOUTH DAKOTAGEOTHERMAL: calculation point i10

SURFACE TEMP = 8.8 HEAT FLOW: SURFACE = 110 DAKOTA = 60 MADISON = 60

8.8 HEAT FLOW: SURFACE = 110 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.8	243.8	0.0	1.1	100.0	
NEWCASTLE	33.2	54.9	243.8	1.4	42.9	2.148
INYAN KARA	35.5	21.3	298.7	1.6	37.5	0.916
MORRISON	36.3	24.4	320.0	1.4	42.9	
SUNDANCE	37.4	39.6	344.4	1.4	42.9	
SPEARFISH	39.1	15.2	384.1	1.3	42.9	
MINNELUSA	39.8	207.3	399.3	2.2	27.3	10.310
MADISON	45.4	105.2	606.6	3.5	17.1	6.185
DEVONIAN	47.2	18.3	711.7	3.5	17.1	1.129
CAMBRIAN	47.6	115.8	730.0	2.4	25.0	7.206
BASEMENT	50.4		845.8			

SOUTH DAKOTAGEOTHERMAL: calculation point i11

SURFACE TEMP = 8.8 HEAT FLOW: SURFACE = 100 DAKOTA = 60 MADISON = 60

8.8 HEAT FLOW: SURFACE = 100 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.8	426.7	0.0	1.1	90.9	
NEWCASTLE	47.6	68.6	426.7	1.4	42.9	4.271
INYAN KARA	50.5	21.3	495.3	1.6	37.5	1.430
MORRISON	51.3	13.7	516.6	1.4	42.9	
SUNDANCE	51.9	30.5	530.4	1.4	42.9	
MINNELUSA	53.2	143.3	560.8	2.2	27.3	10.218
MADISON	57.1	53.3	704.1	3.5	17.1	4.139
DEVONIAN	58.0	12.2	757.4	3.5	17.1	0.964
CAMBRIAN	58.3	100.6	769.6	2.4	25.0	7.987
BASEMENT	60.8		870.2			

SOUTH DAKOTAGEOTHERMAL: calculation point i12

SURFACE TEMP = 8.899999 HEAT FLOW: SURFACE = 100 DAKOTA = 100 MADISON = 1

8.9 HEAT FLOW: SURFACE = 100 DAKOTA = 100 MADISON = 100

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.9	548.6	0.0	1.1	90.9	
NEWCASTLE	58.8	79.2	548.6	1.4	71.4	6.346
INYAN KARA	64.4	24.4	627.9	1.6	62.5	2.174
MORRISON	66.0	12.2	652.3	1.4	71.4	
SUNDANCE	66.8	3.0	664.5	1.4	71.4	
MINNELUSA	67.1	85.3	667.5	2.2	45.5	7.968
MADISON	70.9	1.5	752.9	3.5	28.6	0.152
DEVONIAN	71.0	18.3	754.4	3.5	28.6	1.823
CAMBRIAN	71.5	97.5	772.7	2.4	41.7	9.802
BASEMENT	75.6		870.2			

SOUTH DAKOTAGEOTHERMAL: calculation point i13

SURFACE TEMP = 8.999991 HEAT FLOW: SURFACE = 110 DAKOTA = 110 MADISON = 1

9.0 HEAT FLOW: SURFACE = 110 DAKOTA = 110 MADISON = 110

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	9.0	457.2	0.0	1.1	100.0	
NEWCASTLE	54.7	73.2	457.2	1.4	78.6	5.370
INYAN KARA	60.5	27.4	530.4	1.6	68.8	2.267
MORRISON	62.4	3.0	557.8	1.4	78.6	
MINNELUSA	62.6	30.5	560.8	2.2	50.0	2.623
BASEMENT	64.1		591.3			

SOUTH DAKOTA Geothermal: calculation point i14

SURFACE TEMP = 8.8 HEAT FLOW: SURFACE = 130 DAKOTA = 130 MADISON = 130

8.8 HEAT FLOW: SURFACE = 130 DAKOTA = 130 MADISON = 130

TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸	
PIERRE	8.8	426.7	0.0	1.1	118.2	
NEWCASTLE	59.2	54.9	426.7	1.4	92.9	4.442
INYAN KARA	64.3	45.7	481.6	1.6	81.3	4.076
BASEMENT	68.0		527.3			

SOUTH DAKOTAGEOTHERMAL: calculation point j4

SURFACE TEMP = 7.8 HEAT FLOW: SURFACE = 57 DAKOTA = 57 MADISON = 57

7.8 HEAT FLOW: SURFACE = 57 DAKOTA = 57 MADISON = 57

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.8	457.2	0.0	1.1	51.8	
NEWCASTLE	31.5	1.5	457.2	1.4	40.7	0.058
INYAN KARA	31.6	27.4	458.7	1.6	35.6	1.046
MORRISON	32.5	21.3	486.2	1.4	40.7	
SUNDANCE	33.4	99.1	507.5	1.4	40.7	
SPEARFISH	37.4	112.8	606.6	1.3	40.7	
MINNEKAHATA	42.4	13.7	719.3	3.0	19.0	0.761
OPECHE	42.6	51.8	733.1	1.4	40.7	
MINNELUSA	44.7	213.4	784.9	2.2	25.9	12.656
MADISON	50.3	105.2	998.2	3.5	16.3	7.171
DEVONIAN	52.0	54.9	1103.4	3.5	16.3	3.892
CAMBRIAN	52.9	51.8	1158.3	2.4	23.8	3.750
BASEMENT	54.1		1210.1			

SOUTH DAKOTAGEOTHERMAL: calculation point j5

SURFACE TEMP = 7.9 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

7.9 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.9	701.0	0.0	1.1	40.9	
NEWCASTLE	36.6	12.2	701.0	1.4	32.1	0.561
INYAN KARA	37.0	39.6	713.2	1.6	28.1	1.849
MORRISON	38.1	82.3	752.9	1.4	32.1	
SUNDANCE	40.7	76.2	835.2	1.4	32.1	
SPEARFISH	43.2	68.6	911.4	1.3	32.1	
MINNEKAHATA	45.6	13.7	979.9	3.0	15.0	0.829
OPECHE	45.8	42.7	993.7	1.4	32.1	
MINNELUSA	47.1	225.6	1036.3	2.2	20.5	14.207
MADISON	51.7	118.9	1261.9	3.5	12.9	8.368
DEVONIAN	53.3	57.9	1380.8	3.5	12.9	4.219
CAMBRIAN	54.0	61.0	1438.7	2.4	18.8	4.514
BASEMENT	55.2		1499.6			

SOUTH DAKOTAGEothermal: calculation point j6

SURFACE TEMP = 8.2 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

8.2 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.2	746.8	0.0	1.1	40.9	
NEWCASTLE	38.7	35.1	746.8	1.4	32.1	1.719
INYAN KARA	39.9	35.1	781.8	1.6	28.1	1.783
MORRISON	40.9	83.8	816.9	1.4	32.1	
SUNDANCE	43.6	68.6	900.7	1.4	32.1	
SPEARFISH	45.8	54.9	969.3	1.3	32.1	
MINNEKAHATA	47.7	15.2	1024.1	3.0	15.0	0.965
OPECHE	47.9	38.1	1039.4	1.4	32.1	
MINNELUSA	49.1	228.6	1077.5	2.2	20.5	15.016
MADISON	53.8	121.9	1306.1	3.5	12.9	8.924
DEVONIAN	55.4	67.1	1428.0	3.5	12.9	5.077
CAMBRIAN	56.2	115.8	1495.1	2.4	18.8	8.929
BASEMENT	58.4		1610.9			

SOUTH DAKOTAGEothermal: calculation point j7

SURFACE TEMP = 8.399999 HEAT FLOW: SURFACE = 46 DAKOTA = 46 MADISON = 46

8.4 HEAT FLOW: SURFACE = 46 DAKOTA = 46 MADISON = 46

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
FOX HILLS	8.4	30.5	0.0	1.2	38.3	
PIERRE	9.6	731.5	30.5	1.1	41.8	
NEWCASTLE	40.2	44.2	762.0	1.4	32.9	2.254
INYAN KARA	41.6	27.4	806.2	1.6	28.8	1.463
MORRISON	42.4	83.8	833.6	1.4	32.9	
SUNDANCE	45.2	57.9	917.5	1.4	32.9	
SPEARFISH	47.1	45.7	975.4	1.3	32.9	
MINNEKAHATA	48.7	13.7	1021.1	3.0	15.3	0.887
OPECHE	48.9	33.5	1034.8	1.4	32.9	
MINNELUSA	50.0	236.2	1068.3	2.2	20.9	15.772
MADISON	54.9	118.9	1304.6	3.5	13.1	8.879
DEVONIAN	56.5	73.2	1423.4	3.5	13.1	5.648
CAMBRIAN	57.5	121.9	1496.6	2.4	19.2	9.601
BASEMENT	59.8		1618.5			

SOUTH DAKOTAGEothermal: calculation point j8

SURFACE TEMP = 8.7 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

8.7 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.7	685.8	0.0	1.1	45.5	
NEWCASTLE	39.9	54.9	685.8	1.4	35.7	2.746
INYAN KARA	41.8	25.9	740.7	1.6	31.3	1.378
MORRISON	42.6	80.8	766.6	1.4	35.7	
SUNDANCE	45.5	48.8	847.4	1.4	35.7	
SPEARFISH	47.3	38.1	896.1	1.3	35.7	
MINNEKAHATA	48.7	7.6	934.2	3.0	16.7	0.490
OPECHE	48.9	22.9	941.8	1.4	35.7	
MINNELUSA	49.7	239.3	964.7	2.2	22.7	15.741
MADISON	55.1	89.9	1204.0	3.5	14.3	6.701
DEVONIAN	56.4	45.7	1293.9	3.5	14.3	3.501
CAMBRIAN	57.1	125.0	1339.6	2.4	20.8	9.701
BASEMENT	59.7		1464.6			

SOUTH DAKOTAGEothermal: calculation point j9

SURFACE TEMP = 8.7 HEAT FLOW: SURFACE = 54 DAKOTA = 54 MADISON = 54

8.7 HEAT FLOW: SURFACE = 54 DAKOTA = 54 MADISON = 54

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.7	612.7	0.0	1.1	49.1	
NEWCASTLE	38.8	76.2	612.7	1.4	38.6	3.679
INYAN KARA	41.7	32.0	688.9	1.6	33.8	1.696
MORRISON	42.8	64.0	720.9	1.4	38.6	
SUNDANCE	45.3	38.1	784.9	1.4	38.6	
SPEARFISH	46.7	27.4	823.0	1.3	38.6	
MINNELUSA	47.9	249.9	850.4	2.2	24.5	15.719
MADISON	54.0	89.9	1100.3	3.5	15.4	6.541
DEVONIAN	55.4	16.8	1190.3	3.5	15.4	1.257
CAMBRIAN	55.7	103.6	1207.0	2.4	22.5	7.812
BASEMENT	58.0		1310.7			

SOUTH DAKOTA Geothermal: calculation point j10

SURFACE TEMP = 8.8 HEAT FLOW: SURFACE = 70 DAKOTA = 70 MADISON = 70

8.8 HEAT FLOW: SURFACE = 70 DAKOTA = 70 MADISON = 70

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.8	518.2	0.0	1.1	63.6	
NEWCASTLE	41.8	44.2	518.2	1.4	50.0	2.340
INYAN KARA	44.0	27.4	562.4	1.6	43.8	1.550
MORRISON	45.2	30.5	589.8	1.4	50.0	
SUNDANCE	46.7	15.2	620.3	1.4	50.0	
MINNELUSA	47.5	243.8	635.5	2.2	31.8	15.139
MADISON	55.2	100.6	879.4	3.5	20.0	7.498
DEVONIAN	57.2	9.1	979.9	3.5	20.0	0.711
CAMBRIAN	57.4	91.4	989.1	2.4	29.2	7.138
BASEMENT	60.1		1080.5			

SOUTH DAKOTA Geothermal: calculation point j11

SURFACE TEMP = 8.899999 HEAT FLOW: SURFACE = 74 DAKOTA = 74 MADISON = 74

8.9 HEAT FLOW: SURFACE = 74 DAKOTA = 74 MADISON = 74

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.9	512.1	0.0	1.1	67.3	
NEWCASTLE	43.3	68.6	512.1	1.4	52.9	3.793
INYAN KARA	47.0	24.4	580.7	1.6	46.3	1.491
MORRISON	48.1	18.3	605.0	1.4	52.9	
MINNELUSA	49.1	190.5	623.3	2.2	33.6	12.285
MADISON	55.5	91.4	813.8	3.5	21.1	6.838
DEVONIAN	57.4	7.6	905.3	3.5	21.1	0.593
CAMBRIAN	57.6	88.4	912.9	2.4	30.8	6.907
BASEMENT	60.3		1001.3			

SOUTH DAKOTAGEothermal: calculation point j12

SURFACE TEMP = 9 HEAT FLOW: SURFACE = 80 DAKOTA = 80 MADISON = 80

9.0 HEAT FLOW: SURFACE = 80 DAKOTA = 80 MADISON = 80

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	9.0	502.9	0.0	1.1	72.7	
NEWCASTLE	45.6	54.9	502.9	1.4	57.1	3.222
INYAN KARA	48.7	27.4	557.8	1.6	50.0	1.749
MORRISON	50.1	10.7	585.2	1.4	57.1	
MINNELUSA	50.7	114.3	595.9	2.2	36.4	7.651
MADISON	54.8	30.5	710.2	3.5	22.9	2.244
CAMBRIAN	55.5	82.3	740.7	2.4	33.3	6.150
BASEMENT	58.3		823.0			

SOUTH DAKOTAGEothermal: calculation point j13

SURFACE TEMP = 9.100001 HEAT FLOW: SURFACE = 100 DAKOTA = 100 MADISON = 100

9.1 HEAT FLOW: SURFACE = 100 DAKOTA = 100 MADISON = 100

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	9.1	475.5	0.0	1.1	90.9	
NEWCASTLE	52.3	67.1	475.5	1.4	71.4	4.654
INYAN KARA	57.1	30.5	542.6	1.6	62.5	2.350
MORRISON	59.0	4.6	573.0	1.4	71.4	
MINNELUSA	59.3	61.0	577.6	2.2	45.5	4.918
BASEMENT	62.1		638.6			

SOUTH DAKOTA Geothermal: calculation point j14

SURFACE TEMP = 9.100001 HEAT FLOW: SURFACE = 130 DAKOTA = 130 MADISON = 13

9.1 HEAT FLOW: SURFACE = 130 DAKOTA = 130 MADISON = 130

TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
--------------------------	---------------------	-----------------	---------------	--------------------	-------------------------------

PIERRE	9.1	442.0	0.0	1.1	118.2	
NEWCASTLE	61.3	53.3	442.0	1.4	92.9	4.473
INYAN KARA	66.3	64.0	495.3	1.6	81.3	5.877
BASEMENT	71.5		559.3			

SOUTH DAKOTAGEothermal: calculation point k4

SURFACE TEMP = 7.9 HEAT FLOW: SURFACE = 52 DAKOTA = 52 MADISON = 52

7.9 HEAT FLOW: SURFACE = 52 DAKOTA = 52 MADISON = 52

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
OLIGOCENE	7.9	61.0	0.0	1.2	43.3	
PIERRE	10.5	457.2	61.0	1.1	47.3	
NEWCASTLE	32.2	18.3	518.2	1.4	37.1	0.712
INYAN KARA	32.8	53.3	536.5	1.6	32.5	2.135
MORRISON	34.6	83.8	589.8	1.4	37.1	
SUNDANCE	37.7	91.4	673.6	1.4	37.1	
SPEARFISH	41.1	106.7	765.1	1.3	37.1	
MINNEKAHATA	45.3	13.7	871.7	3.0	17.3	0.825
OPECHE	45.6	61.0	885.5	1.4	37.1	
MINNELUSA	47.8	225.6	946.4	2.2	23.6	14.466
MADISON	53.2	82.3	1172.0	3.5	14.9	5.982
DEVONIAN	54.4	30.5	1254.3	3.5	14.9	2.276
CAMBRIAN	54.9	36.6	1284.7	2.4	21.7	2.757
BASEMENT	55.6		1321.3			

SOUTH DAKOTAGEothermal: calculation point k5

SURFACE TEMP = 8 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

8.0 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.0	640.1	0.0	1.1	40.9	
NEWCASTLE	34.2	30.5	640.1	1.4	32.1	1.281
INYAN KARA	35.2	42.7	670.6	1.6	28.1	1.861
MORRISON	36.4	83.8	713.2	1.4	32.1	
SUNDANCE	39.1	61.0	797.1	1.4	32.1	
SPEARFISH	41.0	93.0	858.0	1.3	32.1	
MINNEKAHATA	44.2	12.2	951.0	3.0	15.0	0.709
OPECHE	44.4	51.8	963.2	1.4	32.1	
MINNELUSA	46.1	228.6	1015.0	2.2	20.5	13.978
MADISON	50.8	68.6	1243.6	3.5	12.9	4.708
DEVONIAN	51.6	33.5	1312.2	3.5	12.9	2.349
CAMBRIAN	52.1	36.6	1345.7	2.4	18.8	2.588
BASEMENT	52.8		1382.3			

SOUTH DAKOTAGEothermal: calculation point k6

SURFACE TEMP = 8.3 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

8.3 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
OLIGOCENE	8.3	76.2	0.0	1.2	37.5	
PIERRE	11.2	670.6	76.2	1.1	40.9	
NEWCASTLE	38.6	44.2	746.8	1.4	32.1	2.149
INYAN KARA	40.0	33.5	791.0	1.6	28.1	1.707
MORRISON	41.0	85.3	824.5	1.4	32.1	
SUNDANCE	43.7	68.6	909.8	1.4	32.1	
SPEARFISH	45.9	53.3	978.4	1.3	32.1	
MINNEKAHATA	47.7	13.7	1031.8	3.0	15.0	0.869
OPECHE	48.0	12.2	1045.5	1.4	32.1	
MINNELUSA	48.3	231.7	1057.7	2.2	20.5	14.893
MADISON	53.1	57.9	1289.3	3.5	12.9	4.164
DEVONIAN	53.8	48.8	1347.2	3.5	12.9	3.565
CAMBRIAN	54.5	54.9	1396.0	2.4	18.8	4.066
BASEMENT	55.5		1450.9			

SOUTH DAKOTAGEothermal: calculation point k7

SURFACE TEMP = 8.600001 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

8.6 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
OLIGOCENE	8.6	64.0	0.0	1.2	41.7	
PIERRE	11.3	701.0	64.0	1.1	45.5	
NEWCASTLE	43.1	65.5	765.1	1.4	35.7	3.633
INYAN KARA	45.5	27.4	830.6	1.6	31.3	1.624
MORRISON	46.3	82.3	858.0	1.4	35.7	
SUNDANCE	49.3	57.9	940.3	1.4	35.7	
SPEARFISH	51.3	45.7	998.2	1.3	35.7	
MINNEKAHATA	53.1	7.6	1044.0	3.0	16.7	0.544
OPECHE	53.2	6.1	1051.6	1.4	35.7	
MINNELUSA	53.4	234.7	1057.7	2.2	22.7	16.896
MADISON	58.8	27.4	1292.4	3.5	14.3	2.210
DEVONIAN	59.2	61.0	1319.8	3.5	14.3	4.949
CAMBRIAN	60.0	59.4	1380.8	2.4	20.8	4.908
BASEMENT	61.3		1440.2			

SOUTH DAKOTAGEothermal: calculation point k8

SURFACE TEMP = 8 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

8.0 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
OLIGOCENE	8.0	64.0	0.0	1.2	50.0	
PIERRE	11.2	701.0	64.0	1.1	54.5	
NEWCASTLE	49.4	76.2	765.1	1.4	42.9	5.070
INYAN KARA	52.7	29.9	841.3	1.6	37.5	2.144
MORRISON	53.8	77.7	871.1	1.4	42.9	
SUNDANCE	57.2	38.1	948.9	1.4	42.9	
SPEARFISH	58.8	33.5	987.0	1.3	42.9	
MINNEKAHATA	60.3	3.0	1020.5	3.0	20.0	0.256
OPECHE	60.4	21.3	1023.5	1.4	42.9	
MINNELUSA	61.3	237.7	1044.9	2.2	27.3	20.349
MADISON	67.8	3.0	1282.6	3.5	17.1	0.293
CAMBRIAN	67.8	61.0	1285.7	2.4	25.0	5.857
BASEMENT	69.4		1346.6			

SOUTH DAKOTAGEothermal: calculation point k9

SURFACE TEMP = 9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

9.0 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	9.0	670.6	0.0	1.1	54.5	
NEWCASTLE	45.6	82.3	670.6	1.4	42.9	4.833
INYAN KARA	49.1	38.1	752.9	1.6	37.5	2.453
MORRISON	50.5	51.8	791.0	1.4	42.9	
SUNDANCE	52.8	12.2	842.8	1.4	42.9	
SPEARFISH	53.3	10.7	855.0	1.3	42.9	
MINNELUSA	53.8	242.3	865.6	2.2	27.3	17.416
CAMBRIAN	60.4	67.1	1108.0	2.4	25.0	5.531
BASEMENT	62.1		1175.0			

SOUTH DAKOTAGEOTHERMAL: calculation point k10

SURFACE TEMP = 9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

9.0 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	9.0	655.3	0.0	1.1	54.5	
NEWCASTLE	44.7	70.1	655.3	1.4	42.9	4.023
INYAN KARA	47.7	30.5	725.4	1.6	37.5	1.896
MORRISON	48.9	27.4	755.9	1.4	42.9	
MINNELUSA	50.1	242.3	783.3	2.2	27.3	15.977
MADISON	56.7	39.6	1025.7	3.5	17.1	3.033
CAMBRIAN	57.4	67.1	1065.3	2.4	25.0	5.206
BASEMENT	59.0		1132.3			

SOUTH DAKOTAGEOTHERMAL: calculation point k11

SURFACE TEMP = 9.100001 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

9.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	9.1	640.1	0.0	1.1	54.5	
NEWCASTLE	44.0	65.5	640.1	1.4	42.9	3.673
INYAN KARA	46.8	30.5	705.6	1.6	37.5	1.846
MORRISON	48.0	16.8	736.1	1.4	42.9	
MINNELUSA	48.7	189.0	752.9	2.2	27.3	12.010
MADISON	53.8	64.0	941.8	3.5	17.1	4.597
CAMBRIAN	54.9	64.0	1005.9	2.4	25.0	4.710
BASEMENT	56.5		1069.9			

SOUTH DAKOTAGEOTHERMAL: calculation point k12

SURFACE TEMP = 9.2 HEAT FLOW: SURFACE = 88 DAKOTA = 88 MADISON = 88

9.2 HEAT FLOW: SURFACE = 88 DAKOTA = 88 MADISON = 88

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	9.2	579.1	0.0	1.1	80.0	
NEWCASTLE	55.5	48.8	579.1	1.4	62.9	3.627
INYAN KARA	58.6	30.5	627.9	1.6	55.0	2.417
MORRISON	60.3	10.7	658.4	1.4	62.9	
MINNELUSA	60.9	164.6	669.0	2.2	40.0	13.673
MADISON	67.5	61.0	833.6	3.5	25.1	5.708
CAMBRIAN	69.1	61.0	894.6	2.4	36.7	5.858
BASEMENT	71.3		955.6			

SOUTH DAKOTAGEOTHERMAL: calculation point k13

SURFACE TEMP = 9.2 HEAT FLOW: SURFACE = 95 DAKOTA = 95 MADISON = '95

9.2 HEAT FLOW: SURFACE = 95 DAKOTA = 95 MADISON = 95

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	9.2	487.7	0.0	1.1	86.4	
NEWCASTLE	51.3	45.1	487.7	1.4	67.9	3.050
INYAN KARA	54.4	38.1	532.8	1.6	59.4	2.764
MORRISON	56.6	4.6	570.9	1.4	67.9	
MINNELUSA	57.0	99.1	575.5	2.2	43.2	7.594
BASEMENT	61.2		674.5			

SOUTH DAKOTA Geothermal: calculation point k14

SURFACE TEMP = 9.2 HEAT FLOW: SURFACE = 100 DAKOTA = 100 MADISON = 100

9.2 HEAT FLOW: SURFACE = 100 DAKOTA = 100 MADISON = 100

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	9.2	448.1	0.0	1.1	90.9	
NEWCASTLE	49.9	46.3	448.1	1.4	71.4	3.030
INYAN KARA	53.2	57.9	494.4	1.6	62.5	4.095
MINNELUSA	56.9	33.5	552.3	2.2	45.5	2.566
BASEMENT	58.4		585.8			

SOUTH DAKOTAGEOTHERMAL: calculation point 14

SURFACE TEMP = 8 HEAT FLOW: SURFACE = 52 DAKOTA = 52 MADISON = 52

8.0 HEAT FLOW: SURFACE = 52 DAKOTA = 52 MADISON = 52

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.0	655.3	0.0	1.1	47.3	
INYAN KARA	39.0	99.1	655.3	1.6	32.5	4.927
MORRISON	42.2	54.9	754.4	1.4	37.1	
SUNDANCE	44.2	88.4	809.3	1.4	37.1	
SPEARFISH	47.5	85.3	897.6	1.3	37.1	
MINNEKAHATA	50.9	12.2	983.0	3.0	17.3	0.840
OPECHE	51.1	67.1	995.2	1.4	37.1	
MINNELUSA	53.6	240.8	1062.2	2.2	23.6	17.642
MADISON	59.3	54.9	1303.0	3.5	14.9	4.521
DEVONIAN	60.1	7.6	1357.9	3.5	14.9	0.638
CAMBRIAN	60.3	12.2	1365.5	2.4	21.7	1.023
BASEMENT	60.5		1377.7			

SOUTH DAKOTAGEOTHERMAL: calculation point 15

SURFACE TEMP = 8.399999 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

8.4 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
OLIGOCENE	8.4	30.5	0.0	1.2	37.5	
PIERRE	9.5	655.3	30.5	1.1	40.9	
NEWCASTLE	36.4	24.4	685.8	1.4	32.1	1.094
INYAN KARA	37.1	86.9	710.2	1.6	28.1	4.008
MORRISON	39.6	39.6	797.1	1.4	32.1	
SUNDANCE	40.9	80.8	836.7	1.4	32.1	
SPEARFISH	43.4	68.6	917.5	1.3	32.1	
MINNEKAHATA	45.8	10.7	986.0	3.0	15.0	0.641
OPECHE	46.0	64.0	996.7	1.4	32.1	
MINNELUSA	48.0	231.7	1060.7	2.2	20.5	14.743
MADISON	52.8	21.3	1292.4	3.5	12.9	1.520
DEVONIAN	53.1	15.2	1313.7	3.5	12.9	1.093
CAMBRIAN	53.2	9.1	1328.9	2.4	18.8	0.658
BASEMENT	53.4		1338.1			

SOUTH DAKOTAGEOTHERMAL: calculation point 16

SURFACE TEMP = 8.5 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 4

8.5 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
OLIGOCENE	8.5	54.9	0.0	1.2	37.5	
PIERRE	10.6	670.6	54.9	1.1	40.9	
NEWCASTLE	38.0	48.8	725.4	1.4	32.1	2.309
INYAN KARA	39.6	85.3	774.2	1.6	28.1	4.255
MORRISON	42.0	36.6	859.5	1.4	32.1	
SUNDANCE	43.1	67.1	896.1	1.4	32.1	
SPEARFISH	45.3	50.3	963.2	1.3	32.1	
MINNEKAHATA	47.0	9.1	1013.5	3.0	15.0	0.566
OPECHE	47.2	62.5	1022.6	1.4	32.1	
MINNELUSA	49.2	225.6	1085.1	2.2	20.5	14.729
DEVONIAN	53.8	13.7	1310.7	3.5	12.9	0.997
CAMBRIAN	54.0	9.1	1324.4	2.4	18.8	0.667
BASEMENT	54.1		1333.5			

SOUTH DAKOTAGEOTHERMAL: calculation point 17

SURFACE TEMP = 8.8 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

8.8 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
OLIGOCENE	8.8	57.9	0.0	1.2	41.7	
PIERRE	11.2	701.0	57.9	1.1	45.5	
NEWCASTLE	43.1	71.6	759.0	1.4	35.7	3.942
INYAN KARA	45.6	79.2	830.6	1.6	31.3	4.687
MORRISON	48.1	33.5	909.8	1.4	35.7	
SUNDANCE	49.3	56.4	943.4	1.4	35.7	
SPEARFISH	51.3	41.1	999.8	1.3	35.7	
MINNEKAHATA	52.9	6.1	1040.9	3.0	16.7	0.432
OPECHE	53.0	45.7	1047.0	1.4	35.7	
MINNELUSA	54.6	222.5	1092.7	2.2	22.7	16.376
CAMBRIAN	59.7	21.3	1315.2	2.4	20.8	1.744
BASEMENT	60.1		1336.6			

SOUTH DAKOTAGEOTHERMAL: calculation point 18

SURFACE TEMP = 9 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

9.0 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
OLIGOCENE	9.0	54.9	0.0	1.2	50.0	
PIERRE	11.7	701.0	54.9	1.1	54.5	
NEWCASTLE	50.0	82.3	755.9	1.4	42.9	5.415
INYAN KARA	53.5	68.6	838.2	1.6	37.5	4.901
MORRISON	56.1	38.1	906.8	1.4	42.9	
SUNDANCE	57.7	29.0	944.9	1.4	42.9	
SPEARFISH	59.0	29.0	973.8	1.3	42.9	
MINNEKAHATA	60.3	1.5	1002.8	3.0	20.0	0.125
OPECHE	60.3	24.4	1004.3	1.4	42.9	
MINNELUSA	61.4	231.7	1028.7	2.2	27.3	19.476
CAMBRIAN	67.7	30.5	1260.4	2.4	25.0	2.872
BASEMENT	68.4		1290.8			

SOUTH DAKOTAGEOTHERMAL: calculation point 19

SURFACE TEMP = 9.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

9.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
OLIGOCENE	9.1	64.0	0.0	1.2	50.0	
PIERRE	12.3	685.8	64.0	1.1	54.5	
NEWCASTLE	49.7	82.3	749.8	1.4	42.9	5.365
INYAN KARA	53.2	45.7	832.1	1.6	37.5	3.240
MORRISON	54.9	39.6	877.8	1.4	42.9	
MINNELUSA	56.6	249.9	917.5	2.2	27.3	19.080
CAMBRIAN	63.5	42.7	1167.4	2.4	25.0	3.724
BASEMENT	64.5		1210.1			

SOUTH DAKOTAGEothermal: calculation point 110

SURFACE TEMP = 9.2 HEAT FLOW: SURFACE = 70 DAKOTA = 70 MADISON = 70

9.2 HEAT FLOW: SURFACE = 70 DAKOTA = 70 MADISON = 70

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
OLIGOCENE	9.2	45.7	0.0	1.2	58.3	
PIERRE	11.9	670.6	45.7	1.1	63.6	
NEWCASTLE	54.5	76.2	716.3	1.4	50.0	5.547
INYAN KARA	58.3	27.4	792.5	1.6	43.8	2.165
MORRISON	59.5	35.1	819.9	1.4	50.0	
MINNELUSA	61.3	185.9	855.0	2.2	31.8	15.553
CAMBRIAN	67.2	48.8	1040.9	2.4	29.2	4.543
BASEMENT	68.6		1089.7			

SOUTH DAKOTAGEothermal: calculation point 111

SURFACE TEMP = 9.3 HEAT FLOW: SURFACE = 80 DAKOTA = 80 MADISON = 80

9.3 HEAT FLOW: SURFACE = 80 DAKOTA = 80 MADISON = 80

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
OLIGOCENE	9.3	54.9	0.0	1.2	66.7	
PIERRE	13.0	640.1	54.9	1.1	72.7	
NEWCASTLE	59.5	70.1	695.0	1.4	57.1	5.651
INYAN KARA	63.5	15.2	765.1	1.6	50.0	1.327
MORRISON	64.3	29.0	780.3	1.4	57.1	
MINNELUSA	65.9	134.1	809.3	2.2	36.4	12.194
CAMBRIAN	70.8	47.2	943.4	2.4	33.3	4.665
BASEMENT	72.4		990.6			

SOUTH DAKOTAGEOTHERMAL: calculation point 112

SURFACE TEMP = 9.4 HEAT FLOW: SURFACE = 95 DAKOTA = 95 MADISON = 95

9.4 HEAT FLOW: SURFACE = 95 DAKOTA = 95 MADISON = 95

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
OLIGOCENE	9.4	70.1	0.0	1.2	79.2	
PIERRE	14.9	612.7	70.1	1.1	86.4	
NEWCASTLE	67.9	65.5	682.8	1.4	67.9	6.151
INYAN KARA	72.3	10.7	748.3	1.6	59.4	1.077
MORRISON	72.9	30.5	759.0	1.4	67.9	
MINNELUSA	75.0	114.3	789.4	2.2	43.2	12.040
MADISON	79.9	18.3	903.7	3.5	27.1	2.071
CAMBRIAN	80.4	45.7	922.0	2.4	39.6	5.215
BASEMENT	82.3		967.8			

SOUTH DAKOTAGEOTHERMAL: calculation point 113

SURFACE TEMP = 9.5 HEAT FLOW: SURFACE = 100 DAKOTA = 100 MADISON = 100

9.5 HEAT FLOW: SURFACE = 100 DAKOTA = 100 MADISON = 100

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
OLIGOCENE	9.5	70.1	0.0	1.2	83.3	
PIERRE	15.3	502.9	70.1	1.1	90.9	
NEWCASTLE	61.1	57.9	573.0	1.4	71.4	4.794
INYAN KARA	65.2	3.0	630.9	1.6	62.5	0.273
MORRISON	65.4	44.2	634.0	1.4	71.4	
MINNELUSA	68.5	115.8	678.2	2.2	45.5	10.980
MADISON	73.8	1.5	794.0	3.5	28.6	0.157
BASEMENT	73.9		795.5			

SOUTH DAKOTA Geothermal: calculation point 114

SURFACE TEMP = 9.5 HEAT FLOW: SURFACE = 100 DAKOTA = 100 MADISON = 10

9.5 HEAT FLOW: SURFACE = 100 DAKOTA = 100 MADISON = 100

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
OLIGOCENE	9.5	61.0	0.0	1.2	83.3	
PIERRE	14.6	445.0	61.0	1.1	90.9	
NEWCASTLE	55.0	24.4	506.0	1.4	71.4	1.783
MORRISON	56.8	77.7	530.4	1.4	71.4	
MINNELUSA	62.3	76.2	608.1	2.2	45.5	6.463
BASEMENT	65.8		684.3			

SOUTH DAKOTAGeothermal: calculation point m1

SURFACE TEMP = 7.8 HEAT FLOW: SURFACE = 90 DAKOTA = 60 MADISON = 60

7.8 HEAT FLOW: SURFACE = 90 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.8	1.5	0.0	1.1	81.8	
INYAN KARA	0.0	70.1	1.5	1.6	37.5	0.000
MORRISON	10.6	76.2	71.6	1.4	42.9	
SUNDANCE	13.8	112.8	147.8	1.4	42.9	
SPEARFISH	18.7	143.3	260.6	1.3	42.9	
MINNEKAHATA	25.3	13.7	403.9	3.0	20.0	0.385
OPECHE	25.5	67.1	417.6	1.4	42.9	
MINNELUSA	28.4	350.5	484.6	2.2	27.3	11.600
MADISON	38.0	94.5	835.2	3.5	17.1	4.577
DEVONIAN	39.6	12.2	929.7	3.5	17.1	0.622
CAMBRIAN	39.8	9.1	941.8	2.4	25.0	0.470
BASEMENT	40.0		951.0			

SOUTH DAKOTAGeothermal: calculation point m2

SURFACE TEMP = 7.9 HEAT FLOW: SURFACE = 96 DAKOTA = 60 MADISON = 60

7.9 HEAT FLOW: SURFACE = 96 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
INYAN KARA	0.0	57.9	0.0	1.6	37.5	0.000
MORRISON	10.1	76.2	57.9	1.4	42.9	
SUNDANCE	13.3	118.9	134.1	1.4	42.9	
SPEARFISH	18.4	106.7	253.0	1.3	42.9	
MINNEKAHATA	23.4	12.2	359.7	3.0	20.0	0.303
OPECHE	23.6	67.1	371.9	1.4	42.9	
MINNELUSA	26.5	307.9	438.9	2.2	27.3	9.180
MADISON	34.9	89.9	746.8	3.5	17.1	3.893
DEVONIAN	36.4	18.3	836.7	3.5	17.1	0.837
CAMBRIAN	36.7	4.6	855.0	2.4	25.0	0.212
BASEMENT	36.8		859.5			

SOUTH DAKOTAGEOTHERMAL: calculation point m3

SURFACE TEMP = 8 HEAT FLOW: SURFACE = 80 DAKOTA = 80 MADISON = 80

8.0 HEAT FLOW: SURFACE = 80 DAKOTA = 80 MADISON = 80

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
INYAN KARA	0.0	54.9	0.0	1.6	50.0	0.000
MORRISON	10.7	93.0	54.9	1.4	57.1	
SUNDANCE	16.1	118.9	147.8	1.4	57.1	
SPEARFISH	22.8	106.7	266.7	1.3	57.1	
MINNEKAHATA	29.4	12.2	373.4	3.0	26.7	0.419
OPECHE	29.7	67.1	385.6	1.4	57.1	
MINNELUSA	33.6	262.1	452.6	2.2	36.4	10.761
MADISON	43.1	64.0	714.8	3.5	22.9	3.607
DEVONIAN	44.6	24.4	778.8	3.5	22.9	1.431
BASEMENT	45.1		803.2			

SOUTH DAKOTAGEOTHERMAL: calculation point m4

SURFACE TEMP = 8.2 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

8.2 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.2	457.2	0.0	1.1	45.5	
NEWCASTLE	29.0	10.7	457.2	1.4	35.7	0.356
INYAN KARA	29.4	64.0	467.9	1.6	31.3	2.175
MORRISON	31.4	89.9	531.9	1.4	35.7	
SUNDANCE	34.6	83.8	621.8	1.4	35.7	
SPEARFISH	37.6	89.9	705.6	1.3	35.7	
MINNEKAHATA	41.0	12.2	795.5	3.0	16.7	0.643
OPECHE	41.2	67.1	807.7	1.4	35.7	
MINNELUSA	43.6	253.0	874.8	2.2	22.7	14.388
MADISON	49.4	30.5	1127.8	3.5	14.3	2.015
DEVONIAN	49.8	12.2	1158.3	3.5	14.3	0.814
BASEMENT	50.0		1170.4			

SOUTH DAKOTAGEOTHERMAL: calculation point m5

SURFACE TEMP = 8.6 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

8.6 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.6	670.6	0.0	1.1	40.9	
NEWCASTLE	36.0	22.9	670.6	1.4	32.1	1.007
INYAN KARA	36.8	48.8	693.4	1.6	28.1	2.205
MORRISON	38.1	85.3	742.2	1.4	32.1	
SUNDANCE	40.9	106.7	827.5	1.4	32.1	
SPEARFISH	44.3	64.0	934.2	1.3	32.1	
MINNEKAHATA	46.5	9.1	998.2	3.0	15.0	0.557
OPECHE	46.7	67.1	1007.4	1.4	32.1	
MINNELUSA	48.8	240.8	1074.4	2.2	20.5	15.548
DEVONIAN	53.7	9.1	1315.2	3.5	12.9	0.663
BASEMENT	53.9		1324.4			

SOUTH DAKOTAGEOTHERMAL: calculation point m6

SURFACE TEMP = 8.8 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

8.8 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.8	701.0	0.0	1.1	45.5	
NEWCASTLE	40.7	39.6	701.0	1.4	35.7	2.027
INYAN KARA	42.1	42.7	740.7	1.6	31.3	2.280
MORRISON	43.4	85.3	783.3	1.4	35.7	
SUNDANCE	46.5	65.5	868.7	1.4	35.7	
SPEARFISH	48.8	48.8	934.2	1.3	35.7	
MINNEKAHATA	50.7	6.1	983.0	3.0	16.7	0.410
OPECHE	50.8	64.0	989.1	1.4	35.7	
MINNELUSA	53.1	211.8	1053.1	2.2	22.7	15.055
DEVONIAN	57.9	9.1	1264.9	3.5	14.3	0.721
BASEMENT	58.0		1274.1			

SOUTH DAKOTAGEothermal: calculation point m7

SURFACE TEMP = 9.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 6

9.1 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	9.1	701.0	0.0	1.1	54.5	
NEWCASTLE	47.3	61.0	701.0	1.4	42.9	3.742
INYAN KARA	50.0	44.2	762.0	1.6	37.5	2.899
MORRISON	51.6	79.2	806.2	1.4	42.9	
SUNDANCE	55.0	48.8	885.5	1.4	42.9	
SPEARFISH	57.1	38.1	934.2	1.3	42.9	
MINNEKAHATA	58.9	51.8	972.3	3.0	20.0	4.139
OPECHE	59.9	48.8	1024.1	1.4	42.9	
MINNELUSA	62.0	210.3	1072.9	2.2	27.3	17.855
DEVONIAN	67.7	9.1	1283.2	3.5	17.1	0.861
BASEMENT	67.9		1292.4			

SOUTH DAKOTAGEothermal: calculation point m8

SURFACE TEMP = 9.2 HEAT FLOW: SURFACE = 70 DAKOTA = 70 MADISON = 7

9.2 HEAT FLOW: SURFACE = 70 DAKOTA = 70 MADISON = 70

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	9.2	701.0	0.0	1.1	63.6	
NEWCASTLE	53.8	73.2	701.0	1.4	50.0	5.239
INYAN KARA	57.5	48.8	774.2	1.6	43.8	3.779
MORRISON	59.6	65.5	823.0	1.4	50.0	
SUNDANCE	62.9	24.4	888.5	1.4	50.0	
SPEARFISH	64.1	18.3	912.9	1.3	50.0	
MINNEKAHATA	65.1	0.6	931.2	3.0	23.3	0.055
OPECHE	65.1	33.5	931.8	1.4	50.0	
MINNELUSA	66.8	219.5	965.3	2.2	31.8	20.286
DEVONIAN	73.8	21.3	1184.8	3.5	20.0	2.211
CAMBRIAN	74.2	3.0	1206.1	2.4	29.2	0.318
BASEMENT	74.3		1209.2			

SOUTH DAKOTA Geothermal: calculation point m9

SURFACE TEMP = 9.3 HEAT FLOW: SURFACE = 80 DAKOTA = 80 MADISON = 80

9.3 HEAT FLOW: SURFACE = 80 DAKOTA = 80 MADISON = 80

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	9.3	701.0	0.0	1.1	72.7	
NEWCASTLE	60.3	82.3	701.0	1.4	57.1	6.736
INYAN KARA	65.0	44.2	783.3	1.6	50.0	3.951
MORRISON	67.2	45.7	827.5	1.4	57.1	
MINNELUSA	69.8	222.5	873.3	2.2	36.4	21.616
DEVONIAN	77.9	30.5	1095.8	3.5	22.9	3.357
CAMBRIAN	78.6	7.6	1126.2	2.4	33.3	0.848
BASEMENT	78.9		1133.9			

SOUTH DAKOTA Geothermal: calculation point m10

SURFACE TEMP = 9.4 HEAT FLOW: SURFACE = 90 DAKOTA = 90 MADISON = 90

9.4 HEAT FLOW: SURFACE = 90 DAKOTA = 90 MADISON = 90

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	9.4	685.8	0.0	1.1	81.8	
NEWCASTLE	65.5	79.2	685.8	1.4	64.3	7.139
INYAN KARA	70.6	42.7	765.1	1.6	56.3	4.193
MORRISON	73.0	28.0	807.7	1.4	64.3	
MINNELUSA	74.8	134.1	835.8	2.2	40.9	14.084
DEVONIAN	80.3	42.7	969.9	3.5	25.7	4.857
CAMBRIAN	81.4	15.2	1012.6	2.4	37.5	1.762
BASEMENT	82.0		1027.8			

SOUTH DAKOTAGeothermal: calculation point m11

SURFACE TEMP = 9.5 HEAT FLOW: SURFACE = 100 DAKOTA = 100 MADISON = 100

9.5 HEAT FLOW: SURFACE = 100 DAKOTA = 100 MADISON = 100

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	9.5	640.1	0.0	1.1	90.9	
NEWCASTLE	67.7	73.2	640.1	1.4	71.4	6.834
INYAN KARA	72.9	44.2	713.2	1.6	62.5	4.500
MORRISON	75.7	16.8	757.4	1.4	71.4	
MINNELUSA	76.9	99.1	774.2	2.2	45.5	10.715
DEVONIAN	81.4	48.8	873.3	3.5	28.6	5.628
CAMBRIAN	82.8	22.9	922.0	2.4	41.7	2.689
BASEMENT	83.7		944.9			

SOUTH DAKOTAGeothermal: calculation point m12

SURFACE TEMP = 9.6 HEAT FLOW: SURFACE = 110 DAKOTA = 60 MADISON = 60

9.6 HEAT FLOW: SURFACE = 110 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	9.6	594.4	0.0	1.1	100.0	
NEWCASTLE	69.0	62.5	594.4	1.4	42.9	5.963
INYAN KARA	71.7	47.2	656.9	1.6	37.5	4.711
MORRISON	73.5	6.1	704.1	1.4	42.9	
MINNELUSA	73.7	85.3	710.2	2.2	27.3	8.789
DEVONIAN	76.1	47.2	795.5	3.5	17.1	5.042
CAMBRIAN	76.9	24.4	842.8	2.4	25.0	2.634
BASEMENT	77.5		867.2			

SOUTH DAKOTAGEOTHERMAL: calculation point m13

SURFACE TEMP = 9.7 HEAT FLOW: SURFACE = 110 DAKOTA = 60 MADISON = 60

9.7 HEAT FLOW: SURFACE = 110 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	9.7	518.2	0.0	1.1	100.0	
NEWCASTLE	61.5	44.2	518.2	1.4	42.9	3.677
INYAN KARA	63.4	73.2	562.4	1.6	37.5	6.308
MINNELUSA	66.2	96.0	635.5	2.2	27.3	8.702
DEVONIAN	68.8	45.7	731.5	3.5	17.1	4.336
BASEMENT	69.6		777.2			

SOUTH DAKOTAGEOTHERMAL: calculation point m14

SURFACE TEMP = 9.7 HEAT FLOW: SURFACE = 110 DAKOTA = 60 MADISON = 60

9.7 HEAT FLOW: SURFACE = 110 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	9.7	442.0	0.0	1.1	100.0	
NEWCASTLE	53.9	42.7	442.0	1.4	42.9	3.028
INYAN KARA	55.7	93.0	484.6	1.6	37.5	6.869
MINNELUSA	59.2	97.5	577.6	2.2	27.3	7.753
DEVONIAN	61.9	45.7	675.1	3.5	17.1	3.830
BASEMENT	62.7		720.9			

SOUTH DAKOTAGEothermal: calculation point n1

SURFACE TEMP = 7.9 HEAT FLOW: SURFACE = 90 DAKOTA = 90 MADISON = 90

7.9 HEAT FLOW: SURFACE = 90 DAKOTA = 90 MADISON = 90

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.9	792.5	0.0	1.1	81.8	
NEWCASTLE	72.7	3.0	792.5	1.4	64.3	0.317
INYAN KARA	72.9	71.6	795.5	1.6	56.3	7.479
MORRISON	77.0	83.8	867.2	1.4	64.3	
SUNDANCE	82.4	115.8	951.0	1.4	64.3	
SPEARFISH	89.8	106.7	1066.8	1.3	64.3	
MINNEKAHATA	97.2	13.7	1173.5	3.0	30.0	1.966
OPECHE	97.6	70.1	1187.2	1.4	64.3	
MINNELUSA	102.1	317.0	1257.3	2.2	40.9	47.943
MADISON	115.1	82.3	1574.3	3.5	25.7	14.160
DEVONIAN	117.2	9.1	1656.6	3.5	25.7	1.604
BASEMENT	117.4		1665.8			

SOUTH DAKOTAGEothermal: calculation point n2

SURFACE TEMP = 7.9 HEAT FLOW: SURFACE = 96 DAKOTA = 96 MADISON = 96

7.9 HEAT FLOW: SURFACE = 96 DAKOTA = 96 MADISON = 96

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	7.9	243.8	0.0	1.1	87.3	
NEWCASTLE	29.2	3.0	243.8	1.4	68.6	0.104
INYAN KARA	29.4	61.0	246.9	1.6	60.0	2.103
MORRISON	33.0	83.8	307.9	1.4	68.6	
SUNDANCE	38.8	128.0	391.7	1.4	68.6	
SPEARFISH	47.6	85.3	519.7	1.3	68.6	
MINNEKAHATA	53.9	12.2	605.0	3.0	32.0	0.900
OPECHE	54.3	70.1	617.2	1.4	68.6	
MINNELUSA	59.1	271.3	687.3	2.2	43.6	22.287
MADISON	70.9	68.6	958.6	3.5	27.4	6.938
BASEMENT	72.8		1027.2			

SOUTH DAKOTAGEothermal: calculation point n3

SURFACE TEMP = 8 HEAT FLOW: SURFACE = 80 DAKOTA = 80 MADISON = 80

8.0 HEAT FLOW: SURFACE = 80 DAKOTA = 80 MADISON = 80

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.0	304.8	0.0	1.1	72.7	
NEWCASTLE	30.2	15.2	304.8	1.4	57.1	0.542
INYAN KARA	31.0	64.0	320.0	1.6	50.0	2.368
MORRISON	34.2	85.3	384.1	1.4	57.1	
SUNDANCE	39.1	91.4	469.4	1.4	57.1	
SPEARFISH	44.3	67.1	560.8	1.3	57.1	
MINNEKAHATA	48.5	12.2	627.9	3.0	26.7	0.792
OPECHE	48.8	70.1	640.1	1.4	57.1	
MINNELUSA	52.8	240.8	710.2	2.2	36.4	17.319
MADISON	61.6	42.7	951.0	3.5	22.9	3.669
BASEMENT	62.5		993.7			

SOUTH DAKOTAGEothermal: calculation point n4

SURFACE TEMP = 8.2 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

8.2 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.2	304.8	0.0	1.1	45.5	
NEWCASTLE	22.1	19.8	304.8	1.4	35.7	0.441
INYAN KARA	22.8	67.1	324.6	1.6	31.3	1.568
MORRISON	24.9	85.3	391.7	1.4	35.7	
SUNDANCE	27.9	88.4	477.0	1.4	35.7	
SPEARFISH	31.1	64.0	565.4	1.3	35.7	
MINNEKAHATA	33.5	12.2	629.4	3.0	16.7	0.496
OPECHE	33.7	70.1	641.6	1.4	35.7	
MINNELUSA	36.2	243.8	711.7	2.2	22.7	10.974
BASEMENT	41.8		955.6			

SOUTH DAKOTAGEothermal: calculation point n5

SURFACE TEMP = 8.7 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

8.7 HEAT FLOW: SURFACE = 45 DAKOTA = 45 MADISON = 45

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.7	457.2	0.0	1.1	40.9	
NEWCASTLE	27.4	38.1	457.2	1.4	32.1	1.144
INYAN KARA	28.6	61.0	495.3	1.6	28.1	1.950
MORRISON	30.3	85.3	556.3	1.4	32.1	
SUNDANCE	33.1	73.2	641.6	1.4	32.1	
SPEARFISH	35.4	61.0	714.8	1.3	32.1	
MINNEKAHATA	37.5	9.1	775.7	3.0	15.0	0.424
OPECHE	37.7	67.1	784.9	1.4	32.1	
MINNELUSA	39.8	242.3	851.9	2.2	20.5	12.115
BASEMENT	44.8		1094.2			

SOUTH DAKOTAGEothermal: calculation point n6

SURFACE TEMP = 8.899999 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

8.9 HEAT FLOW: SURFACE = 50 DAKOTA = 50 MADISON = 50

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PIERRE	8.9	640.1	0.0	1.1	45.5	
NEWCASTLE	38.0	48.8	640.1	1.4	35.7	2.278
INYAN KARA	39.7	61.0	688.9	1.6	31.3	3.018
MORRISON	41.6	85.3	749.8	1.4	35.7	
SUNDANCE	44.7	59.4	835.2	1.4	35.7	
SPEARFISH	46.8	47.2	894.6	1.3	35.7	
MINNEKAHATA	48.6	6.1	941.8	3.0	16.7	0.389
OPECHE	48.7	67.1	947.9	1.4	35.7	
MINNELUSA	51.1	210.3	1015.0	2.2	22.7	14.258
BASEMENT	55.9		1225.3			

SOUTH DAKOTA Geothermal: calculation point n7

SURFACE TEMP = 9.2 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

9.2 HEAT FLOW: SURFACE = 60 DAKOTA = 60 MADISON = 60

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
MIOCENE	9.2	91.4	0.0	1.2	50.0	
PIERRE	13.8	701.0	91.4	1.1	54.5	
NEWCASTLE	52.0	59.4	792.5	1.4	42.9	4.085
INYAN KARA	54.6	54.9	851.9	1.6	37.5	3.995
MORRISON	56.6	79.2	906.8	1.4	42.9	
SUNDANCE	60.0	12.2	986.0	1.4	42.9	
SPEARFISH	60.5	39.6	998.2	1.3	42.9	
MINNEKAHATA	62.4	3.0	1037.9	3.0	20.0	0.260
OPECHE	62.4	64.0	1040.9	1.4	42.9	
MINNELUSA	65.2	207.3	1104.9	2.2	27.3	18.624
BASEMENT	70.8		1312.2			

SOUTH DAKOTA Geothermal: calculation point n8

SURFACE TEMP = 9.3 HEAT FLOW: SURFACE = 70 DAKOTA = 70 MADISON = 70

9.3 HEAT FLOW: SURFACE = 70 DAKOTA = 70 MADISON = 70

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PLIOCENE	9.3	15.2	0.0	1.2	58.3	
MIOCENE	10.2	121.9	15.2	1.2	58.3	
PIERRE	17.3	701.0	137.2	1.1	63.6	
NEWCASTLE	61.9	70.1	838.2	1.4	50.0	5.922
INYAN KARA	65.4	51.8	908.3	1.6	43.8	4.669
MORRISON	67.7	67.1	960.1	1.4	50.0	
SUNDANCE	71.0	18.3	1027.2	1.4	50.0	
SPEARFISH	72.0	22.9	1045.5	1.3	50.0	
MINNEKAHATA	73.2	0.6	1068.3	3.0	23.3	0.063
OPECHE	73.2	33.5	1068.9	1.4	50.0	
MINNELUSA	74.9	208.8	1102.5	2.2	31.8	21.981
DEVONIAN	81.5	3.0	1311.3	3.5	20.0	0.353
BASEMENT	81.6		1314.3			

SOUTH DAKOTAGeothermal: calculation point n9

SURFACE TEMP = 9.399999 HEAT FLOW: SURFACE = 80 DAKOTA = 80 MADISON = 80

9.4 HEAT FLOW: SURFACE = 80 DAKOTA = 80 MADISON = 80

TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PLIOCENE	9.4	30.5	0.0	1.2	66.7
MIOCENE	11.4	121.9	30.5	1.2	66.7
PIERRE	19.6	701.0	152.4	1.1	72.7
NEWCASTLE	70.5	82.3	853.5	1.4	57.1
INYAN KARA	75.2	47.2	935.7	1.6	50.0
MORRISON	77.6	48.8	983.0	1.4	57.1
OPECHE	80.4	0.6	1031.8	1.4	57.1
MINNELUSA	80.4	161.5	1032.4	2.2	36.4
DEVONIAN	86.3	7.6	1193.9	3.5	22.9
BASEMENT	86.5		1201.5		

SOUTH DAKOTAGeothermal: calculation point n10

SURFACE TEMP = 9.5 HEAT FLOW: SURFACE = 90 DAKOTA = 90 MADISON = 90

9.5 HEAT FLOW: SURFACE = 90 DAKOTA = 90 MADISON = 90

TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PLIOCENE	9.5	91.4	0.0	1.2	75.0
MIOCENE	16.4	91.4	91.4	1.2	75.0
PIERRE	23.2	670.6	182.9	1.1	81.8
NEWCASTLE	78.1	79.2	853.5	1.4	64.3
INYAN KARA	83.2	47.2	932.7	1.6	56.3
MORRISON	85.8	32.0	979.9	1.4	64.3
MINNELUSA	87.9	118.9	1011.9	2.2	40.9
DEVONIAN	92.8	15.2	1130.8	3.5	25.7
BASEMENT	93.1		1146.1		

SOUTH DAKOTAGEothermal: calculation point n11

SURFACE TEMP = 9.5 HEAT FLOW: SURFACE = 100 DAKOTA = 100 MADISON = 100

9.5 HEAT FLOW: SURFACE = 100 DAKOTA = 100 MADISON = 100

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PLIOCENE	9.5	137.2	0.0	1.2	83.3	
MIOCENE	20.9	61.0	137.2	1.2	83.3	
PIERRE	26.0	64.0	198.1	1.1	90.9	
NEWCASTLE	31.8	640.1	262.1	1.4	71.4	22.946
INYAN KARA	77.5	70.1	902.2	1.6	62.5	7.659
MORRISON	81.9	57.9	972.3	1.4	71.4	
SUNDANCE	86.1	18.3	1030.2	1.4	71.4	
MINNELUSA	87.4	88.4	1048.5	2.2	45.5	11.051
BASEMENT	91.4		1136.9			

SOUTH DAKOTAGEothermal: calculation point n12

SURFACE TEMP = 9.7 HEAT FLOW: SURFACE = 110 DAKOTA = 110 MADISON = 110

9.7 HEAT FLOW: SURFACE = 110 DAKOTA = 110 MADISON = 110

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PLIOCENE	9.7	121.9	0.0	1.2	91.7	
MIOCENE	20.9	45.7	121.9	1.2	91.7	
PIERRE	25.1	609.6	167.6	1.1	100.0	
NEWCASTLE	86.0	64.0	777.2	1.4	78.6	7.844
INYAN KARA	91.1	70.1	841.3	1.6	68.8	9.157
MORRISON	95.9	3.0	911.4	1.4	78.6	
MINNELUSA	96.1	79.2	914.4	2.2	50.0	10.995
BASEMENT	100.1		993.7			

SOUTH DAKOTAGEothermal: calculation point n13

SURFACE TEMP = 9.8 HEAT FLOW: SURFACE = 110 DAKOTA = 85 MADISON = 85

9.8 HEAT FLOW: SURFACE = 110 DAKOTA = 85 MADISON = 85

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PLIOCENE	9.8	61.0	0.0	1.2	91.7	
MIOCENE	15.4	36.6	61.0	1.2	91.7	
PIERRE	18.7	472.4	97.5	1.1	100.0	
NEWCASTLE	66.0	45.7	570.0	1.4	60.7	4.124
INYAN KARA	68.8	79.2	615.7	1.6	53.1	7.502
MINNELUSA	73.0	82.3	695.0	2.2	38.6	8.347
BASEMENT	76.2		777.2			

SOUTH DAKOTAGEothermal: calculation point n14

SURFACE TEMP = 9.8 HEAT FLOW: SURFACE = 110 DAKOTA = 85 MADISON = 85

9.8 HEAT FLOW: SURFACE = 110 DAKOTA = 85 MADISON = 85

	TEMPERATURE DEGREES C	THICKNESS METERS	DEPTH METERS	COND. S.I.	GRADIENT DEG/KM	ENERGY J X10 ¹⁸
PLIOCENE	9.8	15.2	0.0	1.2	91.7	
MIOCENE	11.2	30.5	15.2	1.2	91.7	
PIERRE	14.0	442.0	45.7	1.1	100.0	
NEWCASTLE	58.2	44.2	487.7	1.4	60.7	3.433
INYAN KARA	60.9	93.0	531.9	1.6	53.1	7.622
MINNELUSA	65.8	100.6	624.8	2.2	38.6	9.045
BASEMENT	69.7		725.4			

APPENDIX C

HEAT FLOW DATA AND TEMPERATURE DEPTH PROFILES

This appendix contains heat flow data and temperature depth profiles for five wells logged as part of this study. Four of the wells are deep and penetrate several formations. One of the wells, Valley Springs, is a shallow, stratigraphic test-hole drilled by the South Dakota Geological Survey.

Heat flow calculations are done using Equation 1, where the gradient is the linear, least-square gradient in the selected interval and k is the effective conductivity in that interval.

<u>Well Name</u>	<u>Location</u>	<u>Twp</u>	<u>Rng</u>	<u>Sec</u>
Valley Springs	SE South Dakota	102N	47W	34DAA
Koch No. 34-17	NW South Dakota	21N	103W	Koch Oil Field
Koch No. 14-15	NW South Dakota	21N	103W	Koch Oil Field
Citation S.D. No. 1	SW South Dakota	10S	57W	3AAD
Burton	NC Nebraska	34N	19W	8AB

<u>Well Name</u>	<u>Interval</u> <u>m</u>	<u>Gradient</u> <u>K km⁻¹</u>	<u>Cond.</u> <u>W m⁻¹ K⁻¹</u>	<u>Heat Flow</u> <u>m W m⁻²</u>
Valley Springs	60-95	30.2	2.3(?)	69.5(?)
Koch No. 34-17	200-650	46.8	1.1	51.5
Koch No. 14-15	200-500	52.9	1.1	58.2
Citation S.D. No.1	350-560	54.1	1.1	59.5
Burton	100-400	93.0	1.1	102.3

Heat flow at the Valley Springs site is uncertain because the thermal conductivity is unknown. The published range for the Sioux quartzite is $2.3 \text{ W m}^{-1} \text{ K}^{-1}$ to $7.45 \text{ W m}^{-1} \text{ K}^{-1}$ with a mean value near $5.5 \text{ W m}^{-1} \text{ K}^{-1}$ (Sass et al. 1981). The temperature gradient data are valid so the higher conductivity values would produce surprisingly high heat flow values. We prefer to let this heat flow value remain unresolved until additional data are available.

KOCH EXPLORATION WELL NO. 34-17

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km
1	10.00	9.83	0.00
2	20.00	10.51	67.69
3	30.00	10.81	30.31
4	40.00	11.22	40.54
5	50.00	11.39	17.11
6	60.00	11.67	27.52
7	70.00	11.91	24.94
8	80.00	12.20	28.35
9	90.00	12.43	22.93
10	100.00	12.88	44.84
11	110.00	13.26	38.89
12	120.00	13.50	23.33
13	130.00	13.89	39.06
14	140.00	14.19	30.61
15	150.00	14.44	24.68
16	160.00	14.74	29.58
17	170.00	15.08	34.36
18	180.00	15.41	33.17
19	190.00	15.70	28.61
20	200.00	16.28	58.20
21	210.00	16.58	29.86
22	220.00	17.04	46.10
23	230.00	17.37	33.24
24	240.00	17.74	36.84
25	250.00	18.39	64.91
26	260.00	18.69	29.58
27	270.00	19.21	52.57
28	280.00	19.49	27.76
29	290.00	19.99	50.42
30	310.00	20.88	44.13
31	320.00	21.32	44.79
32	330.00	21.79	46.69
33	340.00	22.11	31.42
34	350.00	22.64	53.65
35	360.00	23.15	50.73
36	370.00	23.65	49.97
37	380.00	24.12	47.14
38	390.00	24.56	43.50
39	400.00	25.01	45.19
40	410.00	25.45	44.16
41	420.00	25.91	46.27
42	430.00	26.33	41.61
43	440.00	26.86	53.62
44	450.00	27.46	59.92
45	460.00	28.10	63.93
46	470.00	28.69	58.75
47	480.00	29.01	32.43
48	490.00	29.47	45.32
49	500.00	29.92	44.86
50	510.00	30.32	40.59

KOCH EXPLORATION WELL NO. 34-17

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km
51	520.00	30.67	34.86
52	530.00	30.86	19.09
53	540.00	31.10	23.52
54	550.00	31.42	31.97
55	560.00	32.05	63.77
56	570.00	32.92	86.86
57	580.00	33.87	95.03
58	590.00	34.29	41.31
59	600.00	34.86	57.27
60	610.00	35.45	59.05
61	620.00	35.79	34.14
62	630.00	36.28	48.66
63	640.00	36.74	46.40
64	650.00	37.26	52.12
65	660.00	39.59	232.76
66	670.00	40.13	54.05
67	680.00	39.25	-87.70
68	690.00	38.75	-49.95
69	700.00	38.41	-34.85
70	710.00	38.48	7.39
71	720.00	38.64	16.56

KOCH EXPLORATION WELL NO. 14-15

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km
1	50.00	11.20	0.00
2	100.00	12.53	26.60
3	110.00	13.06	53.06
4	120.00	13.24	17.93
5	130.00	13.54	30.08
6	140.00	13.91	36.42
7	150.00	14.20	29.39
8	160.00	14.62	42.06
9	170.00	14.97	35.00
10	180.00	15.45	48.06
11	190.00	15.84	38.41
12	200.00	16.09	25.59
13	210.00	16.67	57.81
14	220.00	17.16	48.62
15	230.00	17.85	69.50
16	240.00	18.26	41.25
17	250.00	18.91	64.56
18	260.00	19.40	48.92
19	270.00	19.88	48.23
20	280.00	20.35	46.91
21	290.00	20.92	56.64
22	300.00	21.40	48.51
23	310.00	21.86	46.19
24	320.00	22.43	56.37
25	330.00	22.97	54.22
26	340.00	23.39	42.14
27	350.00	24.02	63.36
28	360.00	24.56	53.19
29	370.00	25.08	52.79
30	380.00	25.58	49.55
31	390.00	26.13	54.72
32	400.00	26.72	59.46
33	410.00	27.29	57.00
34	420.00	27.88	58.56
35	430.00	28.41	53.20
36	440.00	28.93	52.25
37	450.00	29.47	53.67
38	460.00	29.94	47.33
39	470.00	30.47	53.20
40	480.00	30.96	49.12
41	490.00	31.32	35.28
42	500.00	31.97	64.86
43	510.00	32.45	48.34
44	520.00	32.93	48.32
45	530.00	33.43	49.68
46	540.00	33.92	48.72
47	550.00	34.41	49.64
48	560.00	34.95	54.07
49	570.00	35.40	44.58
50	580.00	36.13	72.74

KOCH EXPLORATION WELL NO. 14-15

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km
51	590.00	36.68	55.13
52	600.00	37.06	37.95
53	610.00	37.43	37.43
54	620.00	37.79	35.76
55	630.00	38.16	36.83
56	640.00	38.55	39.07
57	650.00	38.95	40.26
58	660.00	39.32	37.36
59	670.00	39.69	36.73
60	680.00	40.09	39.68
61	690.00	40.48	39.70
62	700.00	40.91	42.20

VALLEY SPRINGS SOUTH DAKOTA

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km
1	60.00	9.98	0.00
2	65.00	10.13	30.00
3	70.00	10.26	26.00
4	75.00	10.38	24.00
5	80.00	10.53	30.00
6	85.00	10.72	38.00
7	90.00	10.89	34.00
8	95.00	11.03	28.00
9	100.00	11.11	16.00
10	102.70	11.15	14.81

CITATION OIL COMPANY

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km
51	670.00	40.96	39.82
52	680.00	41.43	47.47
53	690.00	41.83	39.92
54	700.00	42.16	32.66
55	710.00	42.51	35.09

BURTON NEBRASKA HEAT FLOW SITE

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km
1	100.00	20.03	0.00
2	105.00	20.52	98.07
3	110.00	21.00	96.10
4	115.00	21.48	94.58
5	120.00	21.96	96.03
6	125.00	22.43	95.70
7	130.00	22.93	99.07
8	135.00	23.33	81.08
9	140.00	23.80	93.72
10	145.00	24.27	93.90
11	150.00	24.74	93.41
12	155.00	25.19	89.53
13	160.00	25.65	92.27
14	165.00	26.05	80.57
15	170.00	26.64	118.38
16	175.00	27.26	122.33
17	180.00	28.28	204.63
18	185.00	28.60	64.08
19	190.00	28.94	67.88
20	195.00	29.31	73.38
21	200.00	29.88	114.70
22	205.00	30.51	126.05
23	210.00	30.98	94.20
24	215.00	31.48	100.05
25	220.00	32.03	110.51
26	225.00	32.58	109.30
27	230.00	33.08	99.94
28	235.00	33.59	102.75
29	240.00	34.09	100.12
30	245.00	34.85	151.42
31	250.00	35.50	130.38
32	255.00	35.89	77.83
33	260.00	36.39	99.18
34	265.00	36.84	90.79
35	270.00	37.26	84.02
36	275.00	37.66	79.03
37	280.00	38.08	85.63
38	285.00	38.49	80.49
39	290.00	38.84	70.63
40	295.00	39.18	67.12
41	300.00	39.45	54.32
42	305.00	39.71	52.60
43	310.00	40.36	129.19
44	315.00	40.81	90.37
45	320.00	41.18	73.70
46	325.00	41.52	68.60
47	330.00	41.81	58.29
48	335.00	42.26	89.36
49	340.00	42.64	75.46
50	345.00	43.04	81.84

BURTON NEBRASKA HEAT FLOW SITE

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km
51	350.00	43.43	77.84
52	355.00	43.75	64.22
53	360.00	44.26	100.63
54	365.00	44.64	76.12
55	370.00	45.19	109.94
56	375.00	45.60	83.33
57	380.00	45.90	58.28
58	385.00	46.24	69.34
59	390.00	46.75	102.06
60	395.00	47.08	65.62
61	400.00	47.52	88.32
62	405.00	47.79	53.43
63	410.00	48.01	44.43
64	415.00	48.18	33.58
65	420.00	48.39	41.90
66	425.00	48.56	34.09
67	430.00	48.74	35.97
68	435.00	48.90	32.92
69	440.00	49.13	44.79
70	445.00	49.28	30.08
71	450.00	49.43	30.26
72	455.00	49.57	28.75
73	460.00	49.72	28.91
74	465.00	49.86	29.08
75	470.00	50.03	32.71
76	475.00	50.20	34.66
77	480.00	50.36	31.40
78	485.00	50.52	31.60
79	490.00	50.67	30.03
80	495.00	50.82	30.20
81	500.00	50.97	30.40
82	505.00	51.18	41.41
83	510.00	51.35	34.47
84	515.00	51.50	31.04
85	520.00	51.66	31.24
86	525.00	51.83	33.29
87	530.00	51.98	31.64
88	535.00	52.23	48.79
89	540.00	52.41	35.96
90	545.00	52.56	30.47
91	550.00	52.74	36.43
92	555.00	52.91	32.83
93	560.00	53.06	31.09
94	565.00	53.22	31.29
95	570.00	53.39	33.45
96	575.00	53.56	35.68
97	580.00	53.77	41.94
98	585.00	53.97	38.24
99	590.00	54.16	38.55
100	595.00	54.38	45.01
101	600.00	54.53	28.85

BURTON NEBRASKA HEAT FLOW SITE

	DEPTH meters	TEMPERATURE deg Celsius	GRADIENT K/km
102	605.00	54.75	43.60
103	610.00	55.00	50.28
104	615.00	55.23	46.55
105	620.00	55.43	40.54
106	625.00	55.66	45.20
107	630.00	55.95	58.72
108	635.00	56.20	50.57
109	640.00	56.37	33.26
110	645.00	56.54	33.48
111	650.00	56.70	31.45
112	655.00	56.86	33.92
113	660.00	57.17	61.63
114	665.00	57.40	46.15
115	670.00	57.66	51.26
116	675.00	57.85	37.60
117	680.00	58.03	35.52
118	685.00	58.20	35.77
119	690.00	58.37	33.62
120	695.00	58.51	26.57
121	700.00	58.66	31.59
122	705.00	58.83	34.25
123	710.00	59.03	39.42
124	715.00	59.17	27.28
125	720.00	59.31	27.44
126	725.00	59.46	30.10
127	730.00	59.61	30.27
128	735.00	59.75	27.92
129	740.00	59.86	22.96
130	741.00	59.89	25.54
131	742.00	59.90	12.82
132	743.00	59.93	25.63
133	744.00	59.94	12.79
134	745.00	59.96	25.67
135	746.00	59.99	25.70
136	747.00	60.00	12.85
137	748.00	60.02	12.85
138	749.00	60.03	12.88
139	750.00	60.04	12.88
140	751.00	60.05	12.88
141	752.00	60.08	25.76
142	753.00	60.09	12.88
143	754.00	60.12	25.82
144	755.00	60.16	38.79
145	756.00	60.17	12.94
146	757.00	60.20	25.88
147	758.00	60.24	38.91
148	759.00	60.25	12.94
149	760.00	60.26	13.00
150	761.00	60.27	12.97
151	762.00	60.27	0.00