

Energy and Groundwater in Montana

Summary of Montana's Geothermal Areas

John Metesh

Montana Bureau of Mines and Geology
July 31, 2012



Geologic Map of Montana

Sedimentary (origins)

Rocky Mountain thrust belt

uplift followed by extension
(thrust faults become normal)

intrusives

Coal, oil, gas (minor)

Base metals, Au, Ag

geothermal?

Sedimentary

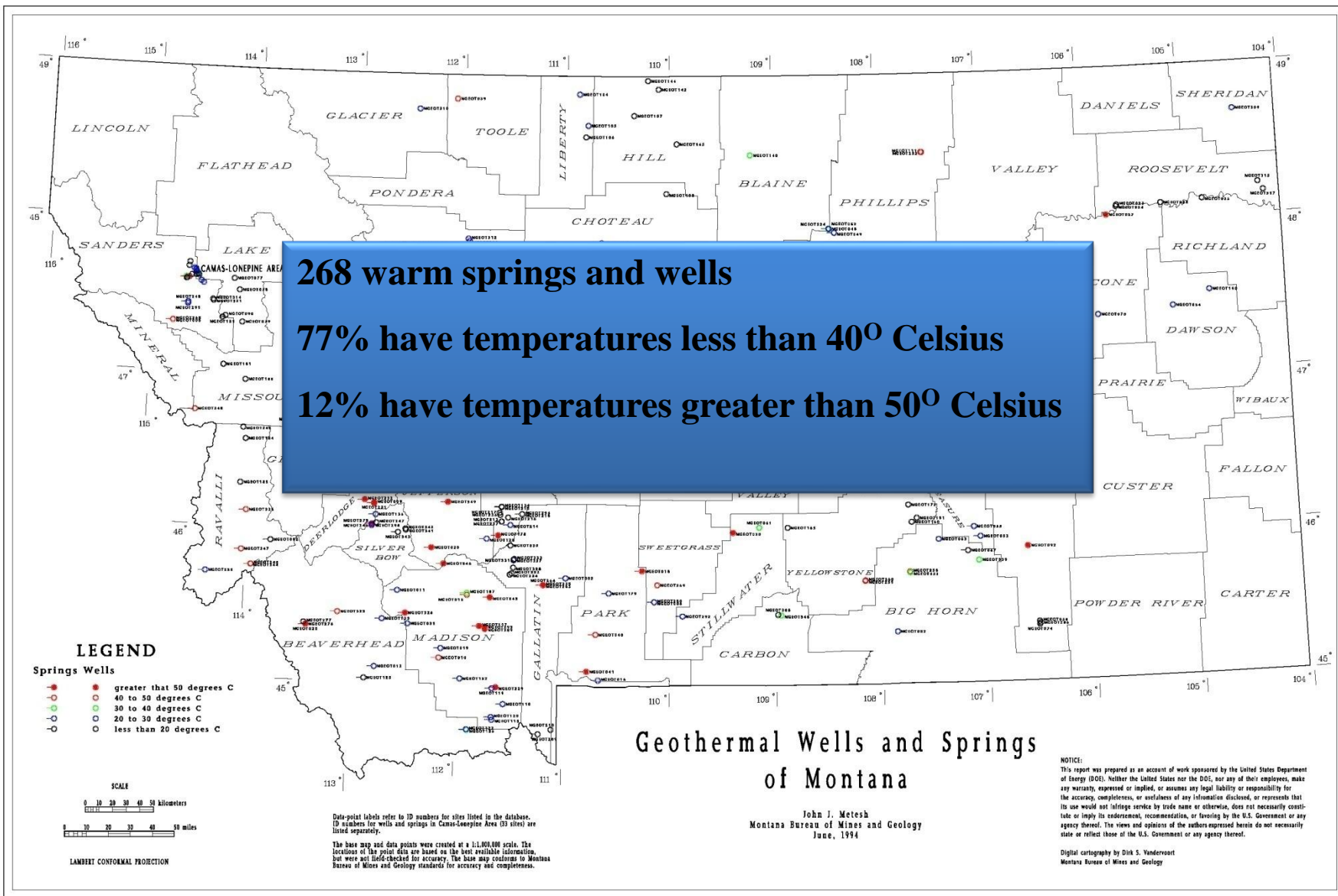
Flat lying (somewhat)

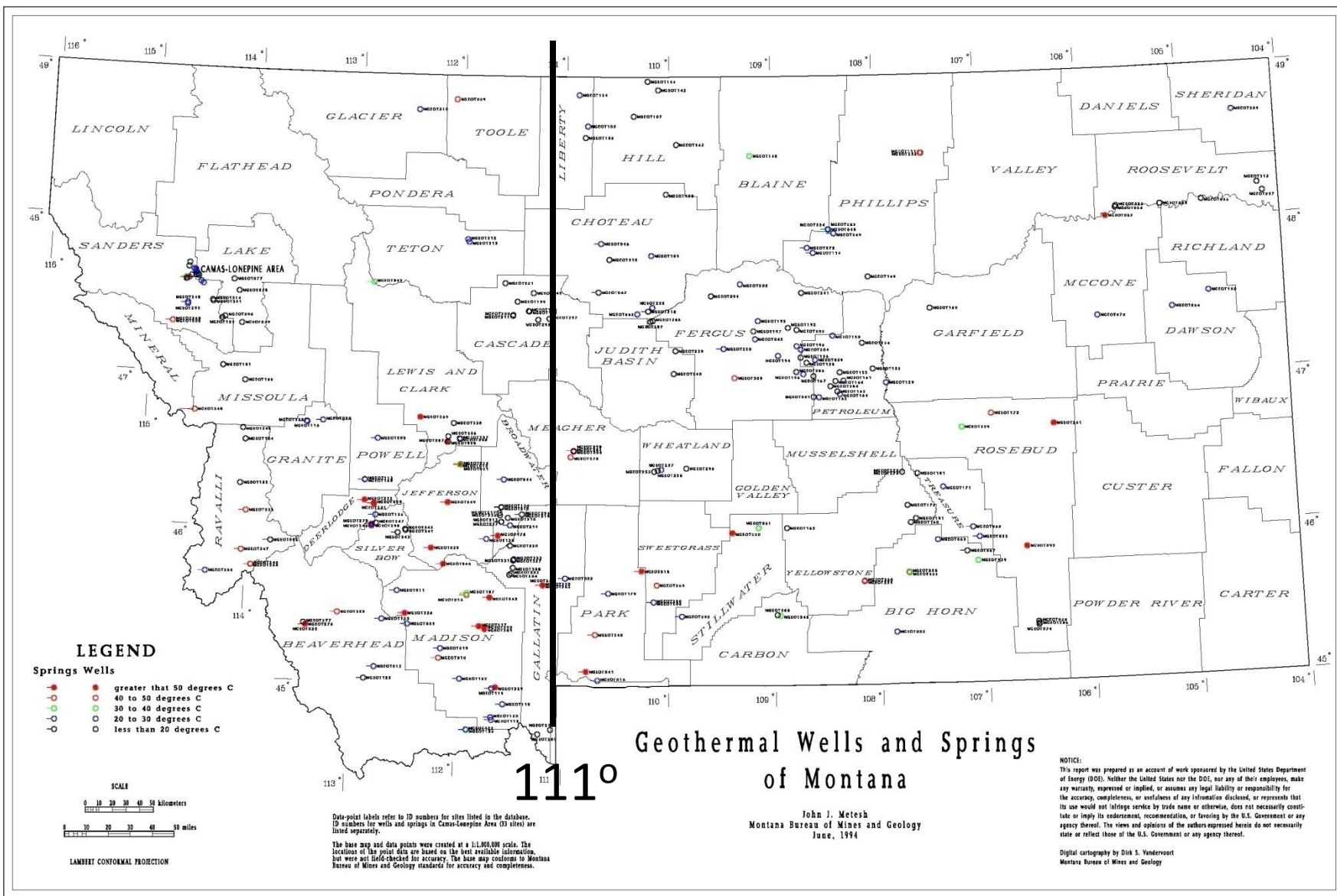
Tertiary through Mesozoic
and Paleozoic

Coal, oil, gas,
geothermal?

limestone KGRA



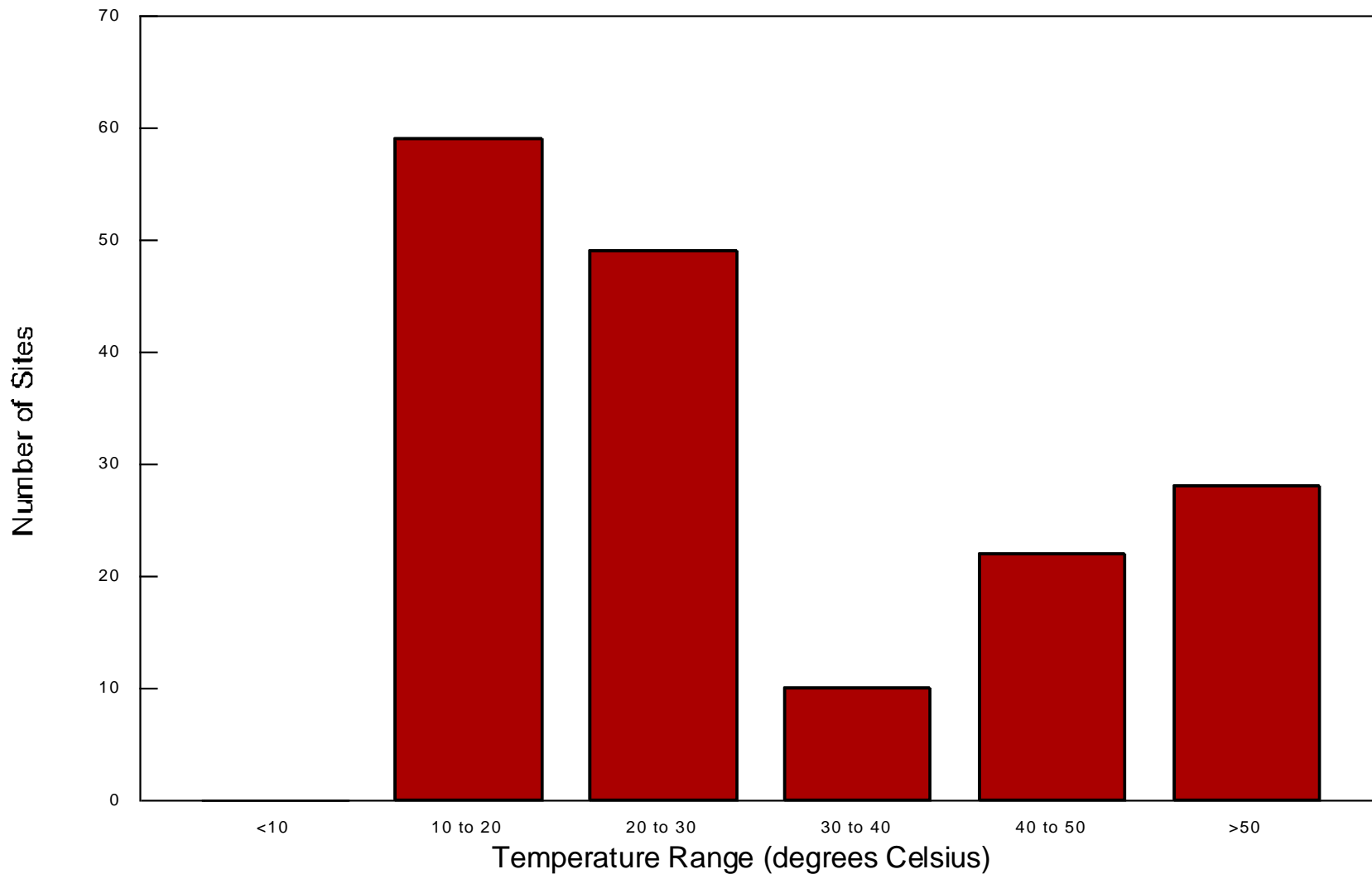




Data-point labels refer to ID numbers for sites listed in the database. ID numbers for wells and springs in Camas-Lonepine Area (33 sites) are listed separately.

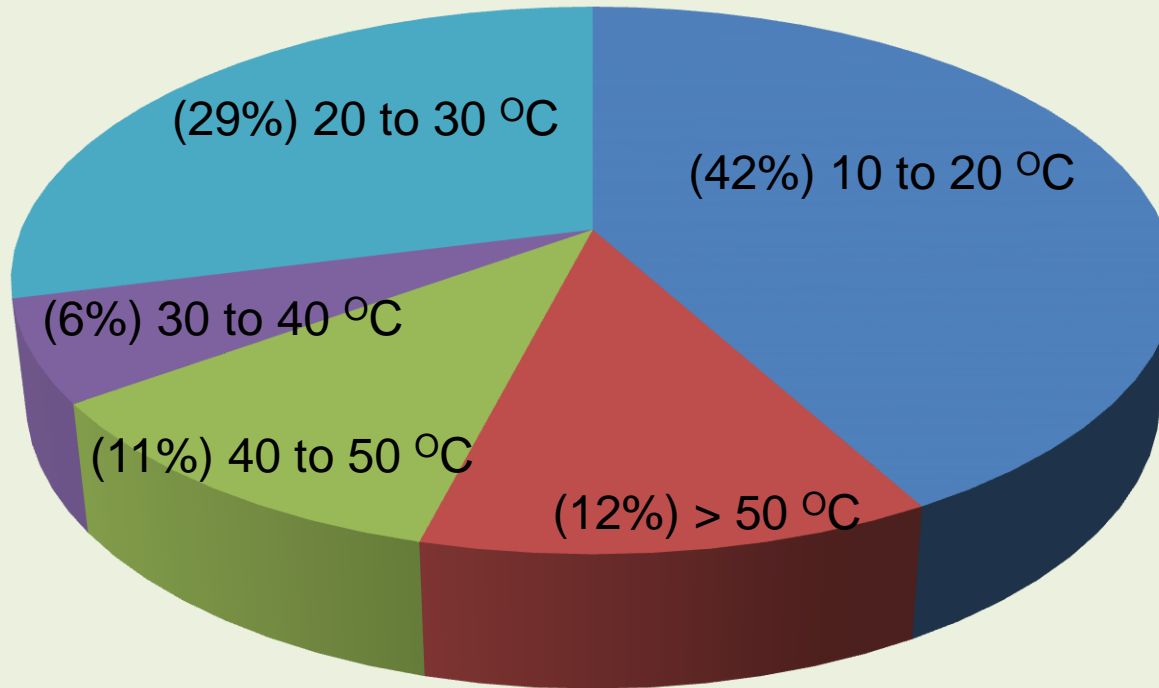
The base map and data points were created at a 1:1,000,000 scale. The locations of the point data are based on the best available information, but were not field-checked for accuracy. The base map conforms to Montana Bureau of Mines and Geology standards for accuracy and completeness.

DISTRIBUTION OF SITES WEST OF 111 DEGREES LONGITUDE



Number of Sites = 153

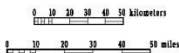
Distribution by temperature - statewide



LEGEND

- Springs Wells**
- greater than 50 degrees
 - 40 to 50 degrees
 - 30 to 40 degrees
 - 20 to 30 degrees
 - less than 20 degrees

SCALE



LAMBERT CONFORMAL PROJECTION

Data-point labels refer to ID numbers for sites listed in the database. ID numbers for wells and springs in Census-Designated Area (CDA) sites are listed separately.

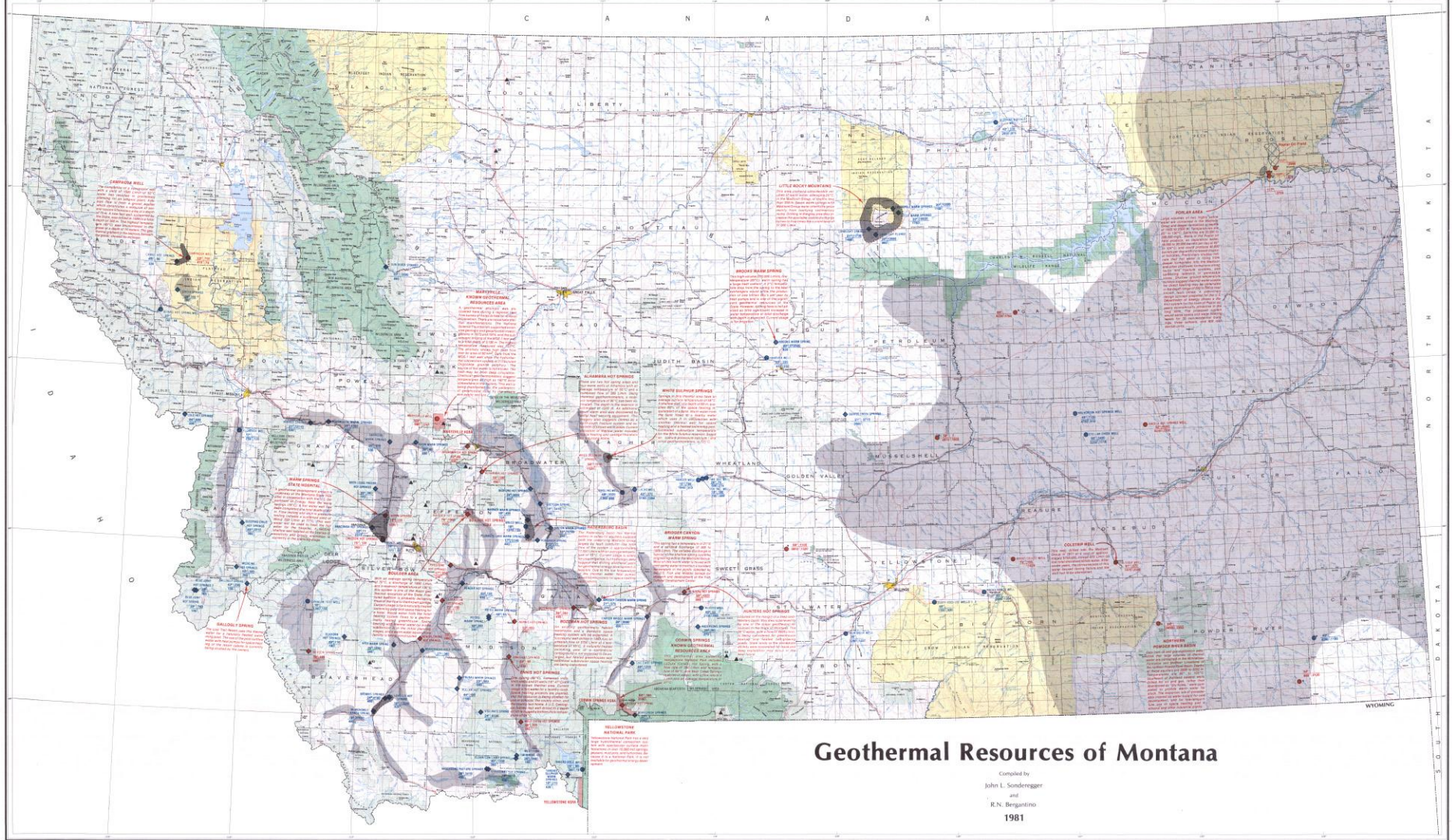
The base map and data points were created at a 1:1,000,000 scale. The locations of the point data are based on the best available information, but were not field-checked for accuracy. The base map conforms to Montana Bureau of Mines and Geology standards for accuracy and completeness.

of Montana

John J. Metesh
Montana Bureau of Mines and Geology
June, 1994

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Digital cartography by Dirk S. Vandervoort
Montana Bureau of Mines and Geology



Geothermal Resources of Montana

Compiled by
John L. Sonderegger
and
R.N. Bergantino
1981

Low-Temperature Geothermal Waters
Existing knowledge does not permit the accurate delineation of low-temperature waters. The gray areas, not the boundaries, represent the areas of low-temperature geothermal waters. These waters are typically found in areas where the geothermal gradient is high and the permeability is low. The gray areas are not the boundaries of the geothermal waters, but they are the areas where the geothermal gradient is high and the permeability is low.

Unconventional Geysers
This is the 1981 revision. These are geysers that are not typical of the geysers of the Yellowstone National Park area. They are found in areas where the geothermal gradient is high and the permeability is low. The gray areas are not the boundaries of the geothermal waters, but they are the areas where the geothermal gradient is high and the permeability is low.

Heat Flow
Heat flow is the amount of heat that is transferred from the Earth's interior to the surface. It is measured in units of kilowatts per square meter. The map shows heat flow contours and areas of high heat flow.

Thermal Springs
Natural temperature $K \le 100^{\circ}$
Natural temperature $K > 100^{\circ}$

Thermal Wells
Natural temperature $K \le 100^{\circ}$
Natural temperature $K > 100^{\circ}$

Thermal Wells
Natural temperature $K \le 100^{\circ}$
Natural temperature $K > 100^{\circ}$

Metric Conversion Factors
1 inch = 2.54 centimeters
1 foot = 0.3048 meters
1 mile = 1.60934 kilometers
1 gallon = 3.78541 liters
1 pound = 0.453592 kilograms
1 square foot = 0.092903 square meters
1 acre = 0.404686 hectares
1 cubic foot = 0.0283168 cubic meters
1 barrel = 0.163659 cubic meters

Scale
1:50,000
1 centimeter = 0.3937 inches
1 inch = 2.54 centimeters

Legend
Steam Springs
Geysers
Hot Springs
Geysers
Unconventional Geysers
Heat Flow
Thermal Wells
Thermal Wells
Thermal Wells

This map was prepared by John L. Sonderegger and R.N. Bergantino for the Montana Bureau of Mines and Geology, a Department of Montana College of Mineral Science and Technology. The map is based on data from the Montana Bureau of Mines and Geology, the U.S. Geological Survey, and other sources. The map is a revision of the 1978 map of Montana geothermal resources by John L. Sonderegger and R.N. Bergantino. The map is available for sale from the Montana Bureau of Mines and Geology, 1500 University Avenue, Butte, Montana 59717.

Geothermal data compiled by the
Montana Bureau of Mines and Geology

Map available for charge from Montana Bureau of Mines and Geology, Montana College of Mineral Science and Technology, Butte, Montana 59717.

Map available for charge from Montana Bureau of Mines and Geology, Montana College of Mineral Science and Technology, Butte, Montana 59717.

Map available for charge from Montana Bureau of Mines and Geology, Montana College of Mineral Science and Technology, Butte, Montana 59717.

Northeast and eastern Montana (carbonate rocks)

Depth: 2500+m

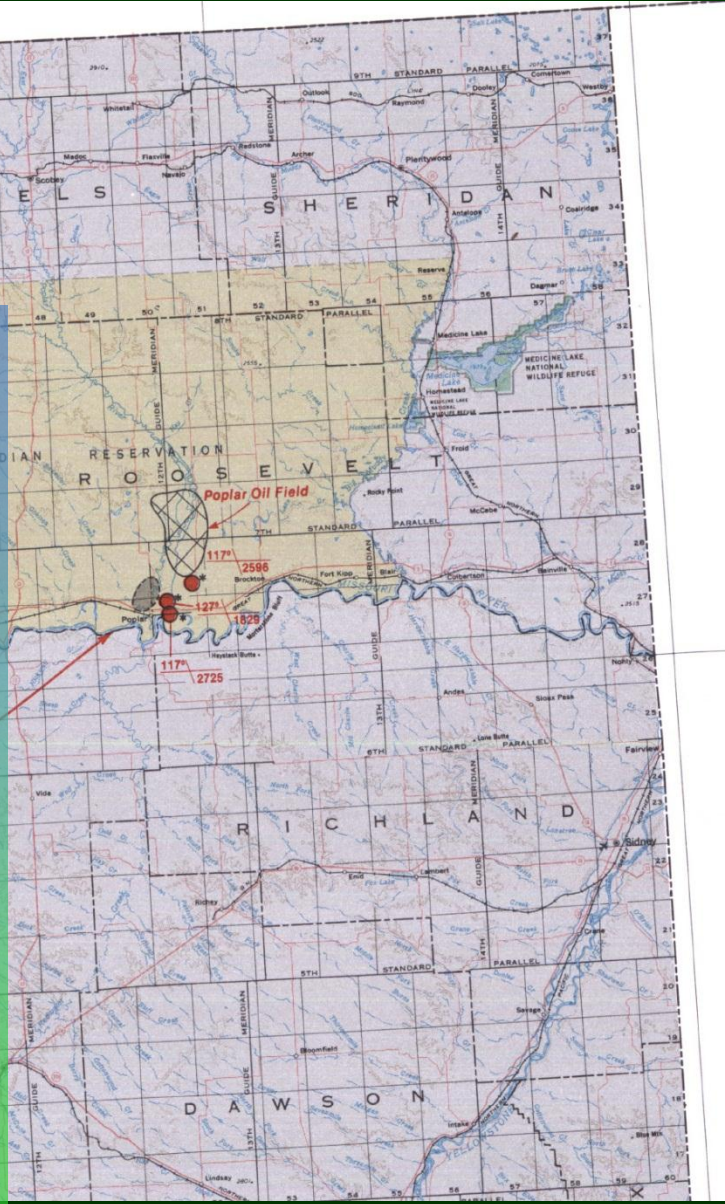
Madison Limestone – oil/gas wells

90 to 104°C,

flow: 10,000's Lpm

Saline (TDS = 35,000 to 260,000 mg/L)

POPULAR AREA
Hot, highly saline water is contained in the Madison Group and deeper formations at depths of 1650 to 2300 m. Temperatures are 65° to 130°C. Salinities are 35,000 to 268,000 mg/L. Wells in the Poplar oil field produce, as separation water, 18,000 to 20,000 barrels per day at 93° to 104°C, and could produce 40,000 barrels per day with increased disposal facilities. Preliminary studies indicate that hot water is rising from deeper formations into the Madison and other shallower formations along faults and fracture systems, and spreading laterally in permeable zones. Shallow ground-temperature surveys suggest thermal water usable for direct heating may be obtainable in the depth range of 200 to 500 m near known fault-zones. A preliminary design concept prepared for the U.S. Department of Energy shows a district heating system for the town of Poplar, Montana, which would serve space heating needs for 30 non-residential buildings, three schools, and 800 residential units.



West Central Montana (crystalline rocks)

Depth: 2,000m

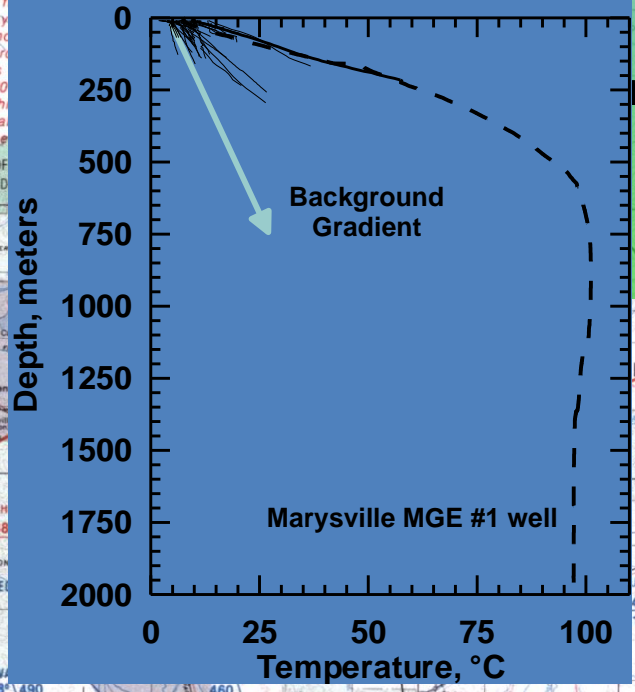
103°C Marysville

MARYSVILLE KNOWN GEOTHERMAL RESOURCES AREA

A geothermal anomaly was discovered here during a regional heat flow survey of holes drilled for mineral exploration. There are no surface thermal manifestations. The National Science Foundation supported extensive geologic and geophysical investigations in 1973 and 1974, and the subsequent drilling of the MGE-1 test well to a total depth of 2,100 m. The highest temperature measured was 103°C. The anomaly shows high heat flow over an area of 50 km². Data from the MGE-1 test well show the hydrothermal convection system is in Tertiary Oligocene granite porphyry source of hot water is not known. Chemical geothermometers temperatures as high as 180°C somewhere in the system. The being maintained for the cause of geophysical tools by the and public sectors.

BROOKS WARM SPRING

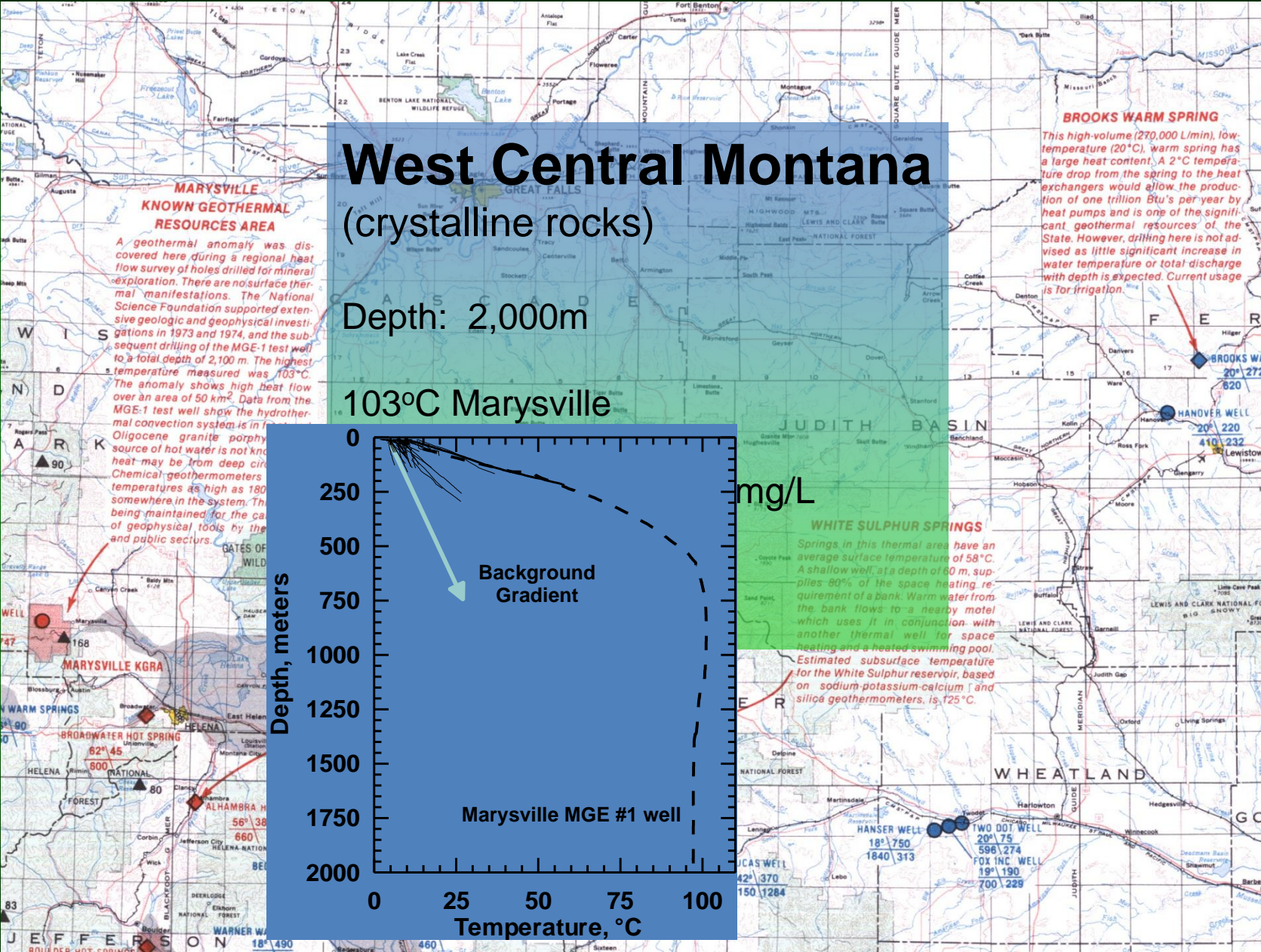
This high-volume (270,000 L/min), low-temperature (20°C), warm spring has a large heat content. A 2°C temperature drop from the spring to the heat exchangers would allow the production of one trillion Btu's per year by heat pumps and is one of the significant geothermal resources of the State. However, drilling here is not advised as little significant increase in water temperature or total discharge with depth is expected. Current usage is for irrigation.

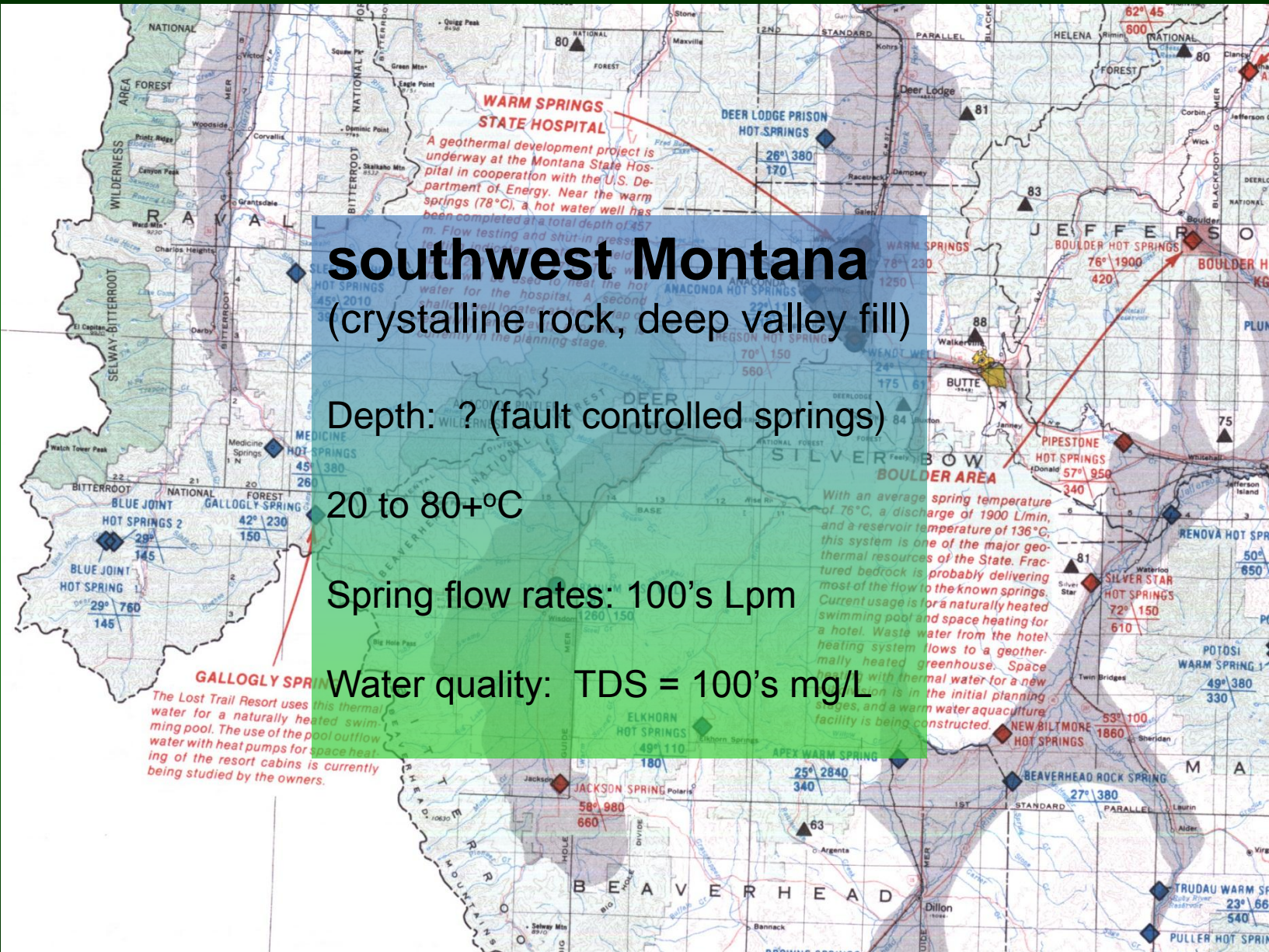


mg/L

WHITE SULPHUR SPRINGS

Springs in this thermal area have an average surface temperature of 58°C. A shallow well at a depth of 80 m, supplies 80% of the space heating requirement of a bank. Warm water from the bank flows to a nearby motel which uses it in conjunction with another thermal well for space heating and a heated swimming pool. Estimated subsurface temperature for the White Sulphur reservoir, based on sodium-potassium-calcium and silica geothermometers, is 125°C.





WARM SPRINGS STATE HOSPITAL

A geothermal development project is underway at the Montana State Hospital in cooperation with the U.S. Department of Energy. Near the warm springs (78°C), a hot water well has been completed at a total depth of 457 m. Flow testing and shut-in pressure testing are being conducted. The water is used to heat the hot water for the hospital. A second well is in the planning stage.

southwest Montana
(crystalline rock, deep valley fill)

Depth: ? (fault controlled springs)

20 to 80+°C

Spring flow rates: 100's Lpm

Water quality: TDS = 100's mg/L

GALLOGLY SPRING
The Lost Trail Resort uses this thermal water for a naturally heated swimming pool. The use of the pool outflow water with heat pumps for space heating of the resort cabins is currently being studied by the owners.

With an average spring temperature of 76°C, a discharge of 1900 L/min, and a reservoir temperature of 136°C, this system is one of the major geothermal resources of the State. Fractured bedrock is probably delivering most of the flow to the known springs. Current usage is for a naturally heated swimming pool and space heating for a hotel. Waste water from the hotel heating system flows to a geothermally heated greenhouse. Space heating with thermal water for a new hotel is in the initial planning stages, and a warm water aquaculture facility is being constructed.

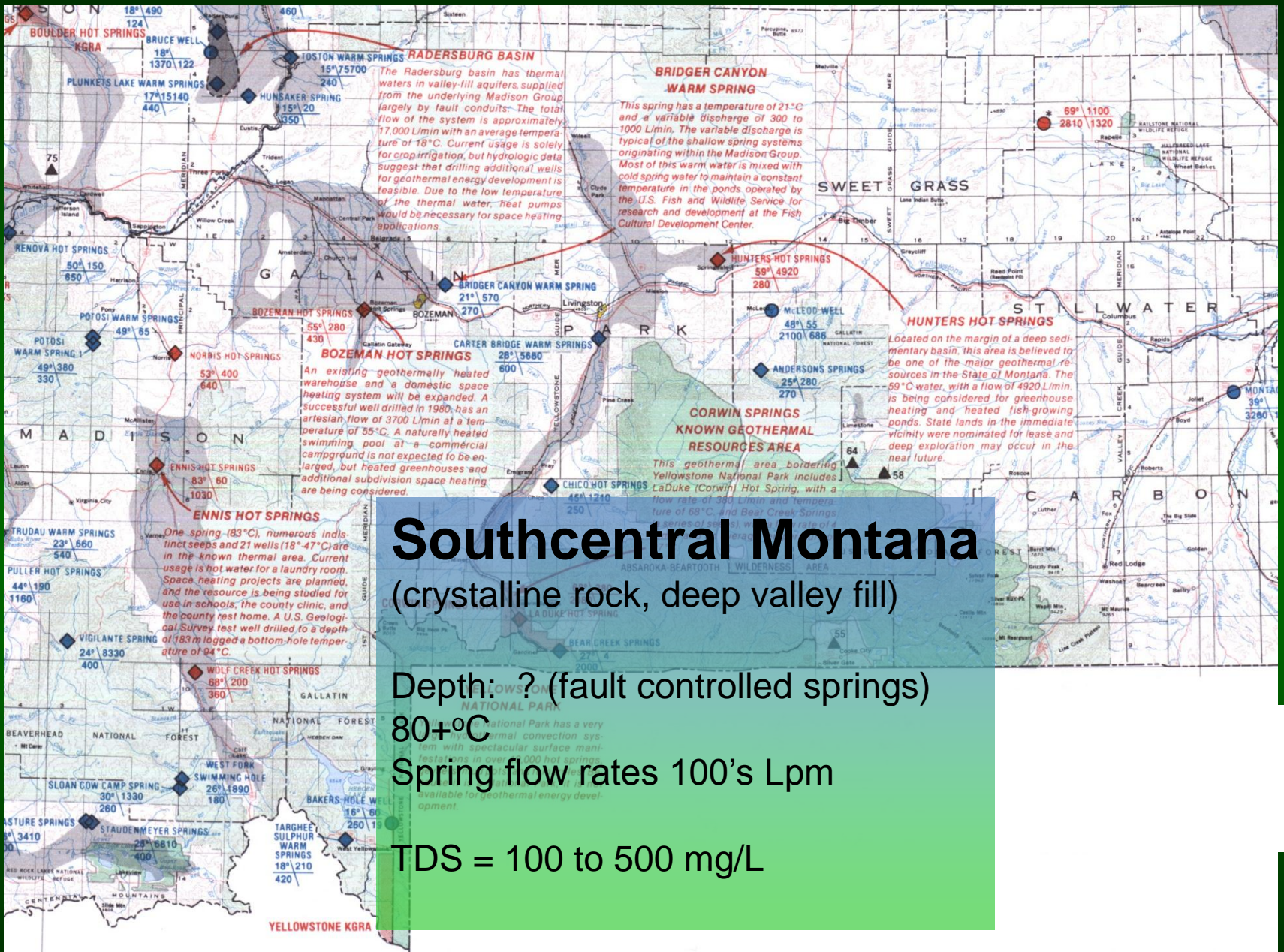
southwest Montana
(crystalline rock, deep valley fill)

Depth: ? (fault controlled springs)

20 to 80+°C

Spring flow rates: 100's Lpm

Water quality: TDS = 100's mg/L



RADERSBURG BASIN
 The Radersburg basin has thermal waters in valley-fill aquifers, supplied from the underlying Madison Group largely by fault conduits. The total flow of the system is approximately 17,000 L/min with an average temperature of 18°C. Current usage is solely for crop irrigation, but hydrologic data suggest that drilling additional wells for geothermal energy development is feasible. Due to the low temperature of the thermal water, heat pumps would be necessary for space heating applications.

BRIDGER CANYON WARM SPRING
 This spring has a temperature of 21°C and a variable discharge of 300 to 1000 L/min. The variable discharge is typical of the shallow spring systems originating within the Madison Group. Most of this warm water is mixed with cold spring water to maintain a constant temperature in the ponds operated by the U.S. Fish and Wildlife Service for research and development at the Fish Cultural Development Center.

BOZEMAN HOT SPRINGS
 An existing geothermally heated warehouse and a domestic space heating system will be expanded. A successful well drilled in 1980, has an artesian flow of 3700 L/min at a temperature of 55°C. A naturally heated swimming pool at a commercial campground is not expected to be enlarged, but heated greenhouses and additional subdivision space heating are being considered.

CORWIN SPRINGS KNOWN GEOTHERMAL RESOURCES AREA
 This geothermal area bordering Yellowstone National Park includes LaDuke (Corwin) Hot Spring, with a flow rate of 390 L/min and temperature of 68°C, and Bear Creek Springs

HUNTERS HOT SPRINGS
 Located on the margin of a deep sedimentary basin, this area is believed to be one of the major geothermal resources in the State of Montana. The 59°C water, with a flow of 4920 L/min, is being considered for greenhouse heating and heated fish-growing ponds. State lands in the immediate vicinity were nominated for lease and deep exploration may occur in the near future.

Southcentral Montana

(crystalline rock, deep valley fill)

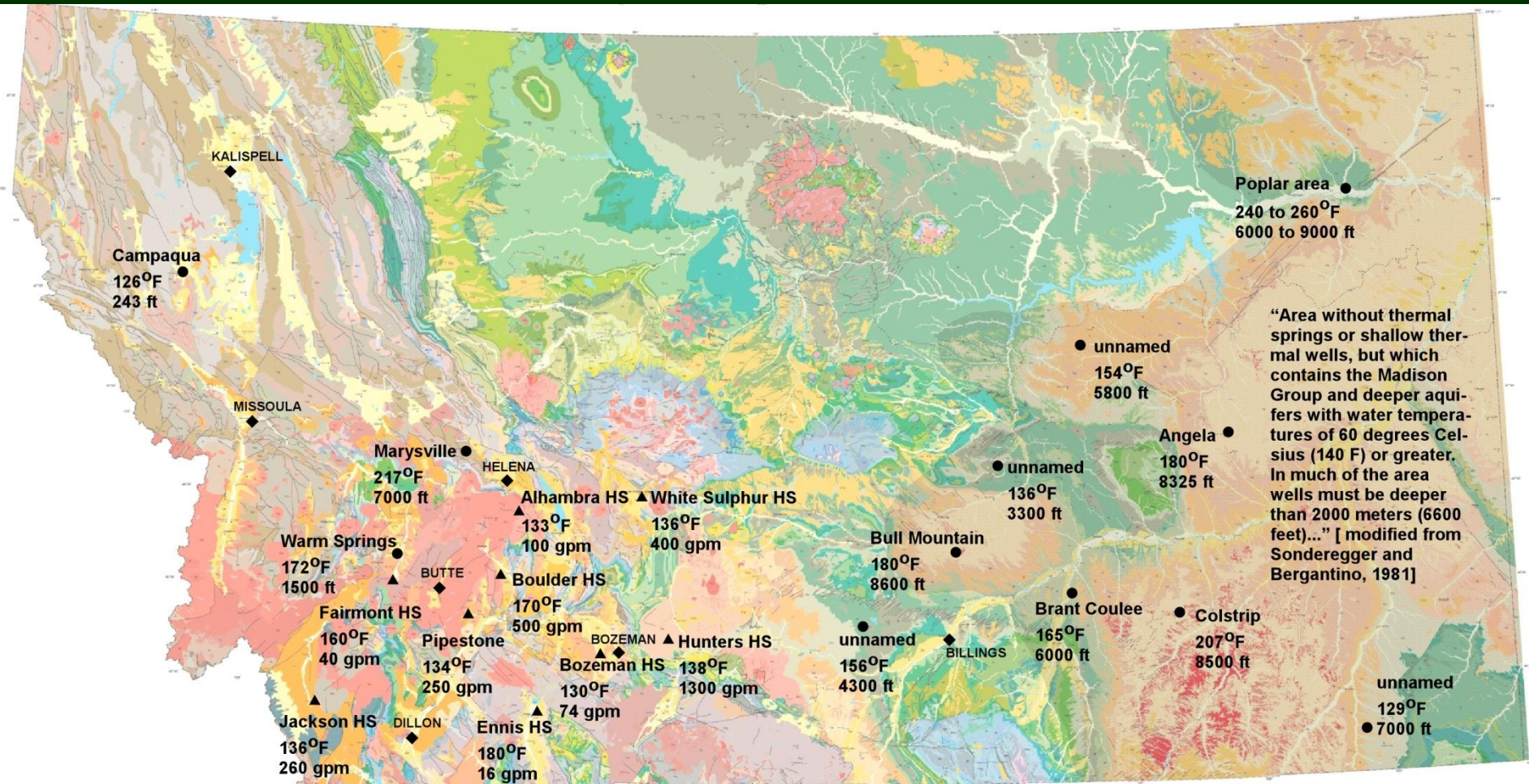
Depth: ? (fault controlled springs)

80+°C

Spring flow rates 100's Lpm

TDS = 100 to 500 mg/L

YELLOWSTONE KGRA



Poplar area
240 to 260°F
6000 to 9000 ft

“Area without thermal springs or shallow thermal wells, but which contains the Madison Group and deeper aquifers with water temperatures of 60 degrees Celsius (140 F) or greater. In much of the area wells must be deeper than 2000 meters (6600 feet)...” [modified from Sonderegger and Bergantino, 1981]

▲ Spring
Surface temperature (°F)
surface flow gallons per minute (gpm)
● Well
downhole temperature (°F)
depth of well (feet below ground surface)

Campaqua
126°F
243 ft

KALISPELL

MISSOULA

Marysville
217°F
7000 ft

HELENA

Alhambra HS ▲ White Sulphur HS
133°F 100 gpm 136°F 400 gpm

Warm Springs
172°F
1500 ft

BUTTE

Boulder HS
170°F
500 gpm

Bull Mountain
180°F
8600 ft

Fairmont HS
160°F
40 gpm

Pipestone
134°F
250 gpm

Bozeman HS
130°F
74 gpm

Hunters HS
138°F
1300 gpm

unnamed
156°F
4300 ft

Brant Coulee
165°F
6000 ft

Colstrip
207°F
8500 ft

Jackson HS
136°F
260 gpm

DILLON

Ennis HS
180°F
16 gpm

unnamed
136°F
3300 ft

unnamed
154°F
5800 ft

Angela
180°F
8325 ft

unnamed
129°F
7000 ft

BILLINGS

unnamed
156°F
4300 ft

Heat Flow (mW/m²)

187	White Earth (east of Helena)
800	Ennis
500	Marysville
	Butte
40,000	YNP

Geothermal Gradient (°C/Km and °F/100ft)

72-231	5-13.6	White Earth
400	23	Ennis
240	14	Marysville
32+	3.0+	Butte
400+	23.0+	YNP
22.1	0.7	“background”

YELLOWSTONE NATIONAL PARK
CONTROLLED GROUND WATER AREA

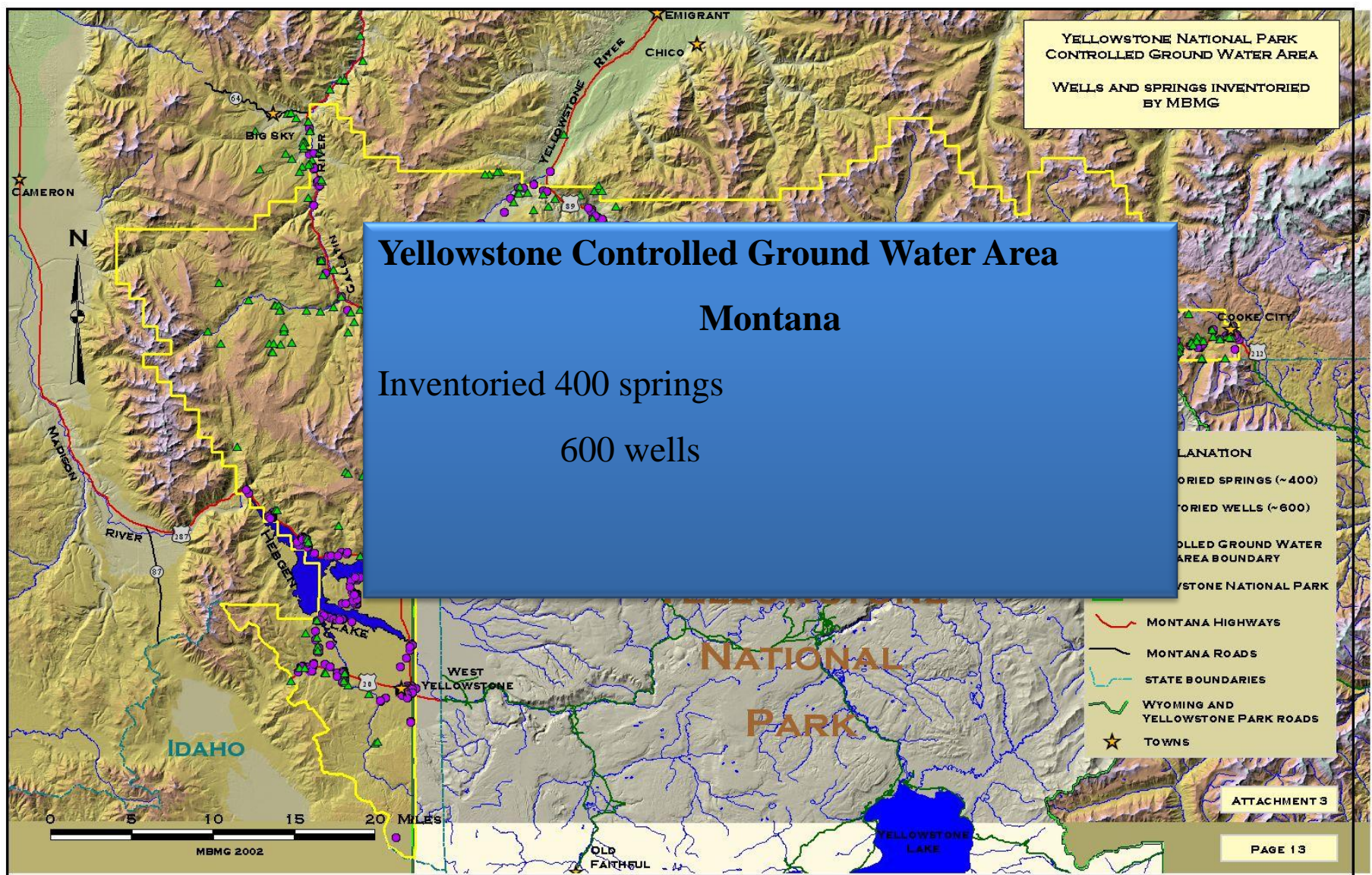
WELLS AND SPRINGS INVENTORIED
BY MBMG

Yellowstone Controlled Ground Water Area
Montana
Inventoried 400 springs
600 wells

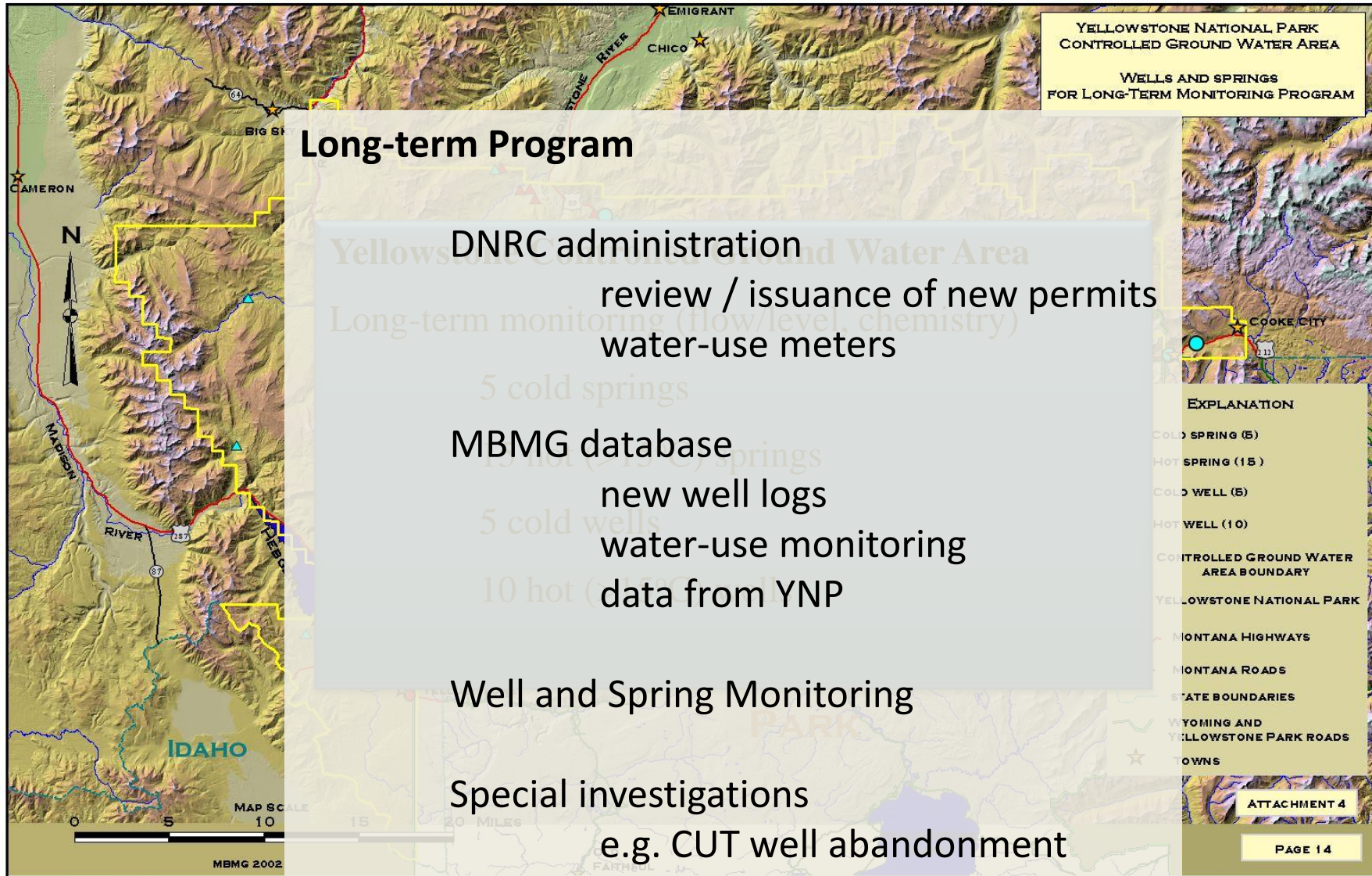
- EXPLANATION
- INVENTORIED SPRINGS (~400)
 - INVENTORIED WELLS (~600)
 - CONTROLLED GROUND WATER AREA BOUNDARY
 - YELLOWSTONE NATIONAL PARK
 - MONTANA HIGHWAYS
 - MONTANA ROADS
 - STATE BOUNDARIES
 - WYOMING AND YELLOWSTONE PARK ROADS
 - TOWNS

ATTACHMENT 3

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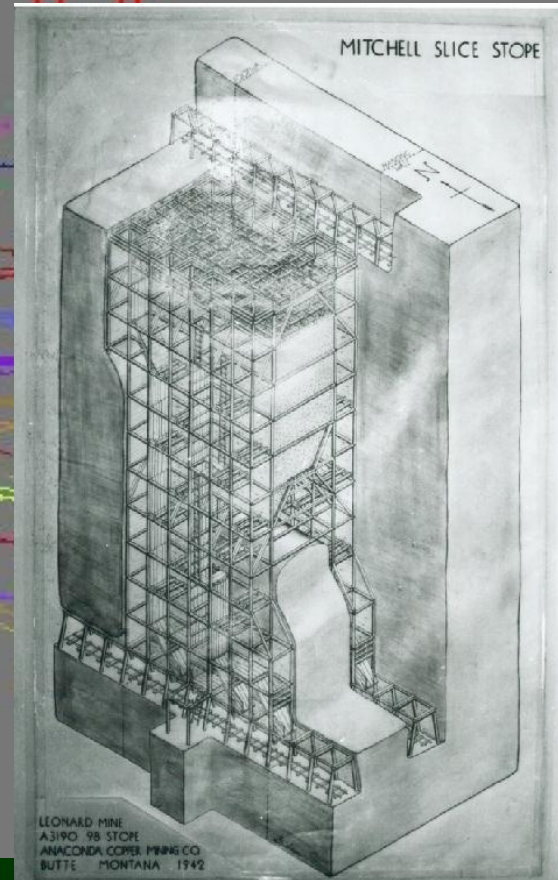
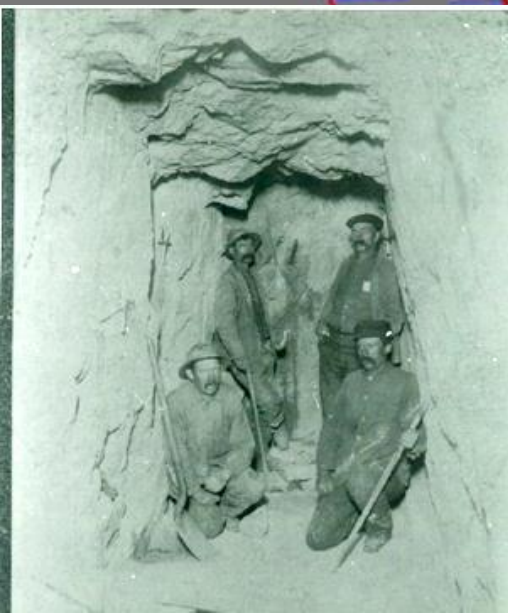
MBMG 2002



7 square miles

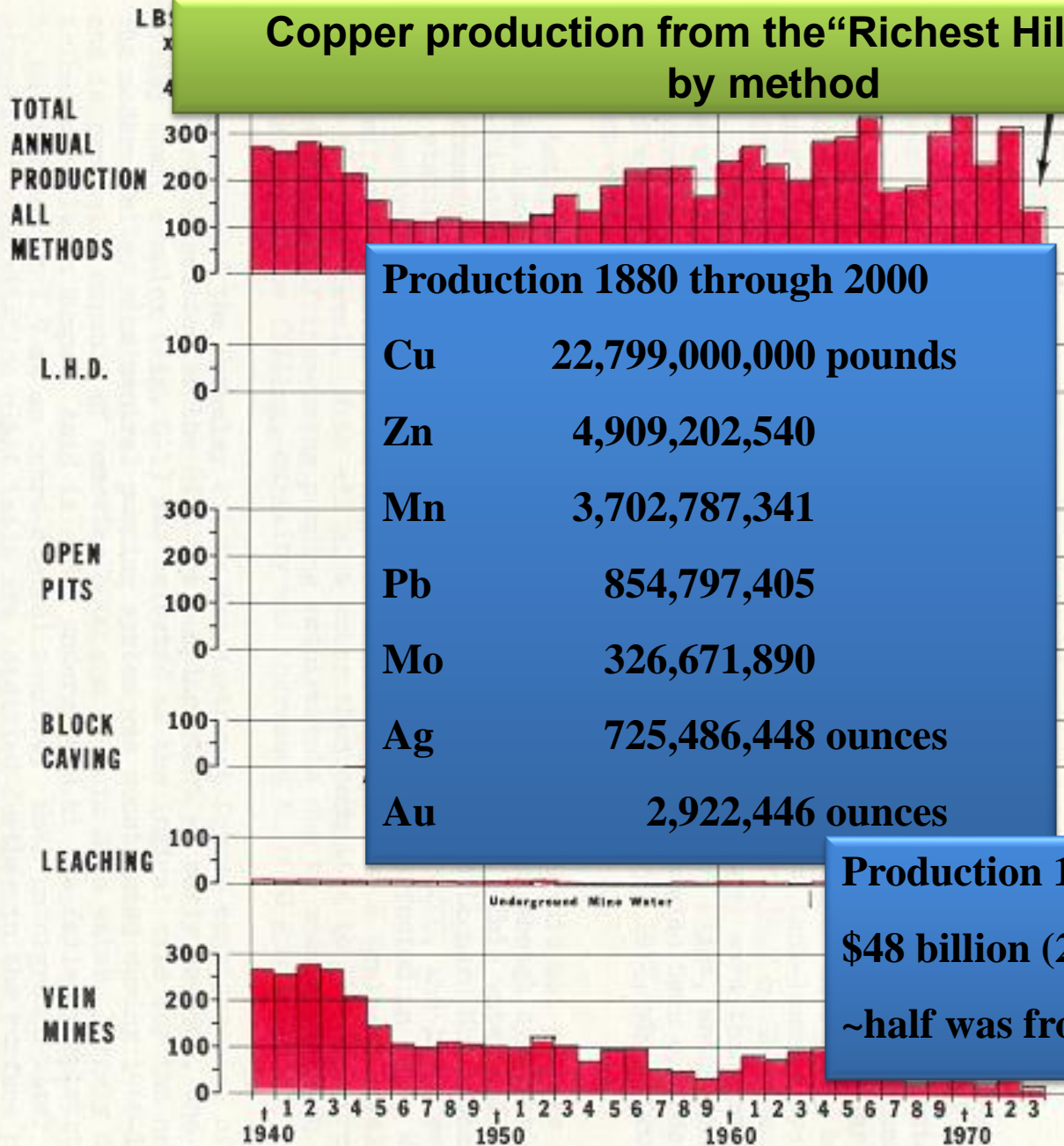
5,600 miles of workings

49 miles of shafts



Butte Historic Mining District

Copper production from the "Richest Hill on Earth" by method



Production 1880 through 2000

Cu	22,799,000,000 pounds
Zn	4,909,202,540
Mn	3,702,787,341
Pb	854,797,405
Mo	326,671,890
Ag	725,486,448 ounces
Au	2,922,446 ounces

Production 1880 through 2000
\$48 billion (2003 dollars)
~half was from copper production



~3100 feet in 30 years
(5285 amsl, April 2012)

Kelley shaft

December 2003 (5252' amsl)

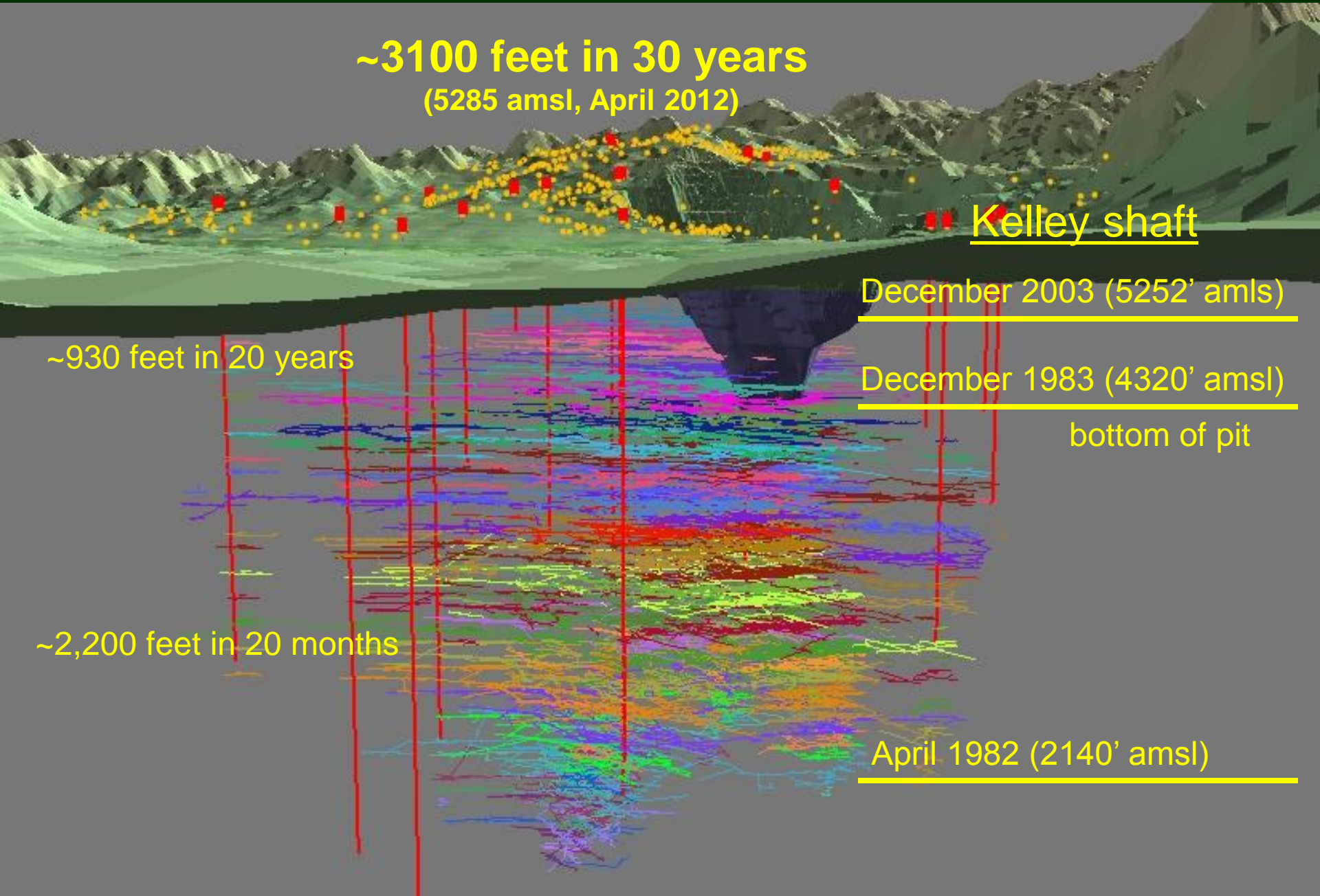
~930 feet in 20 years

December 1983 (4320' amsl)

bottom of pit

~2,200 feet in 20 months

April 1982 (2140' amsl)



Marget Ann



PERIPHERAL ZONE

Temperature C
date

Pilot Butte

Badger
17.4
3.23.00

Granite Mountain

Horseshoe Bend

Lexington
15.0
4.05.90

INTERMEDIATE ZONE

Miss

Mountain Con

Syndicate Pit

Kelley

High Ore

"BARREN" ZONE

Anselmo
17.65
5.02.07

Steward
22.14
5.02.07

Original
32.75
6.22.07

CENTRAL ZONE

Berkeley Pit

Pittsmont #2

Pittsmont #3

Orphan Boy
26.74
6.22.07

Montana Tech

Travona
12.82
3.29.07

Ophir

Belmont
11.9
3.23.95

Pittsmont air shaft

Pittsmont #1

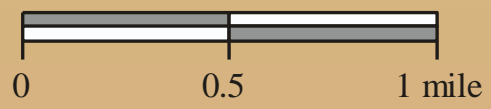
Pittsmont #4

LEGEND

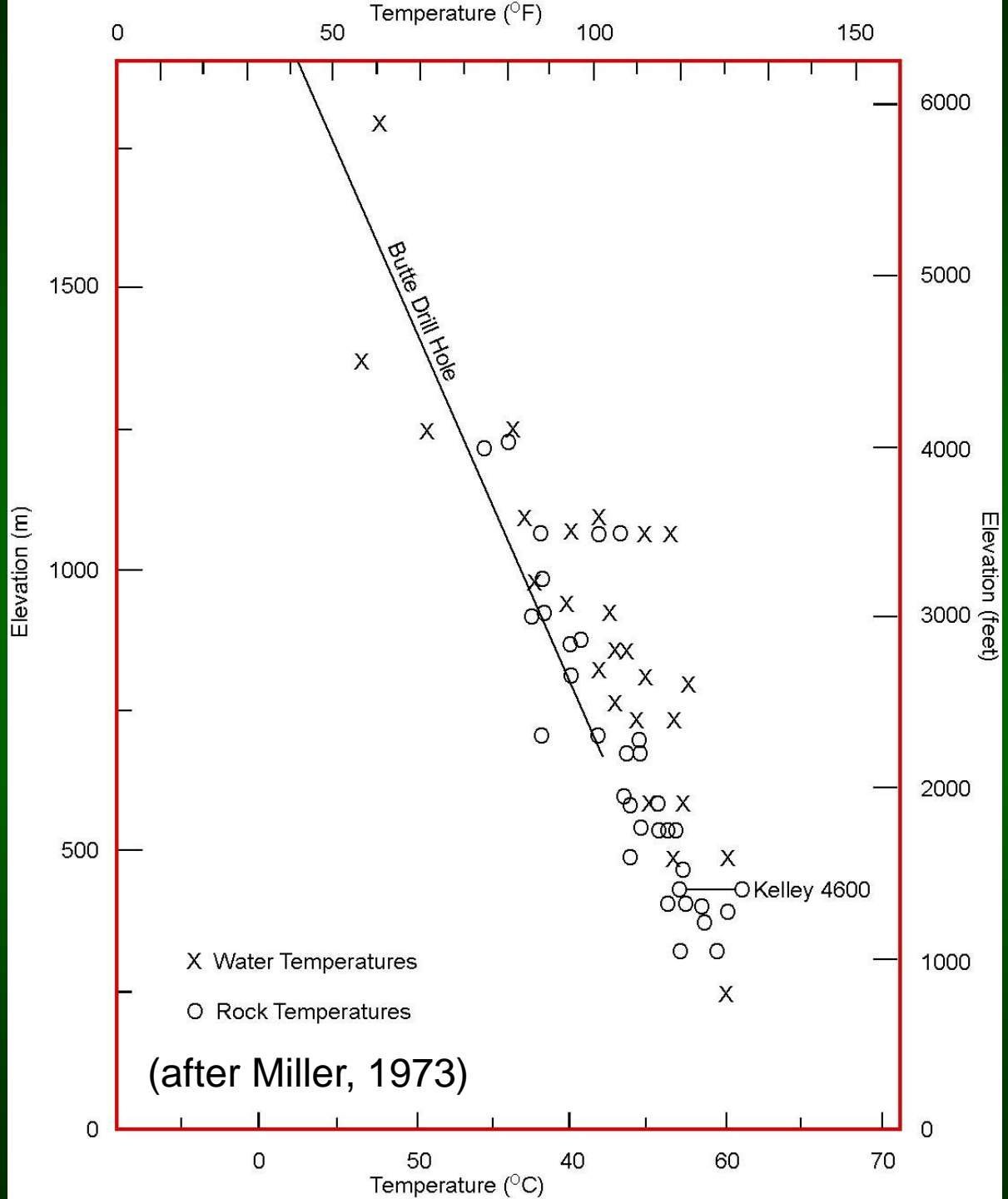
Mine Shaft (bold where sampled)

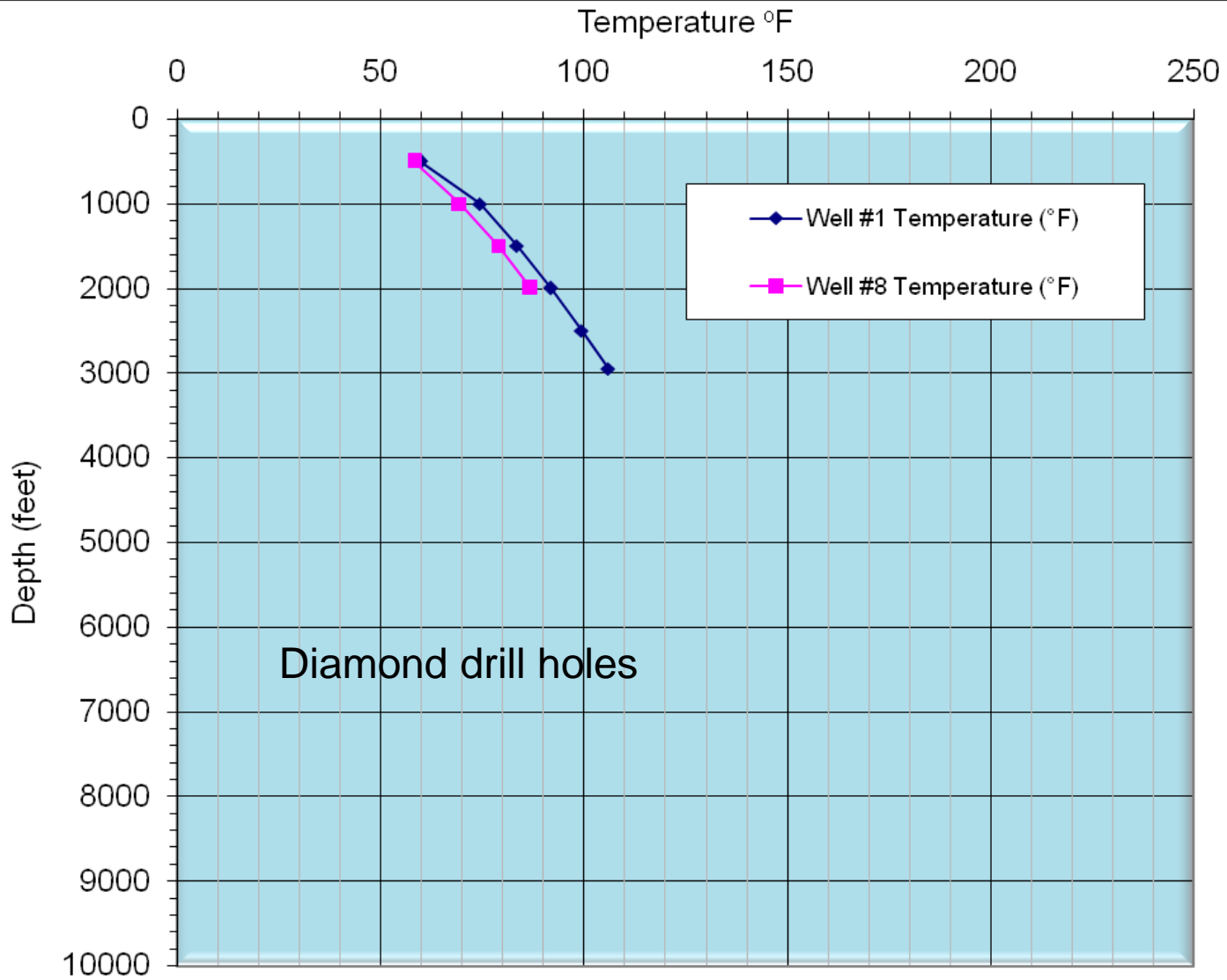
Connection between mines (dashed where bulkheaded)


SCALE



After Sales, 1914





Ring This Bell 
If You Want Cage

NO SMOKING
Within 25ft. Of Shaft

DANGER
KEEP AWAY

There's plenty more where that came from...

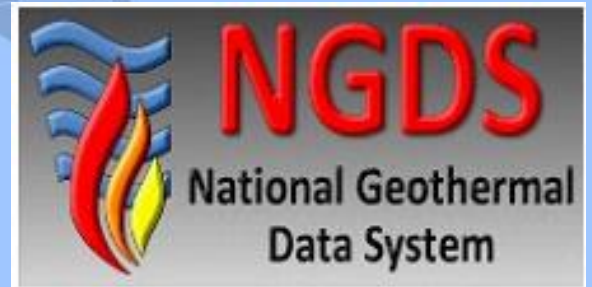
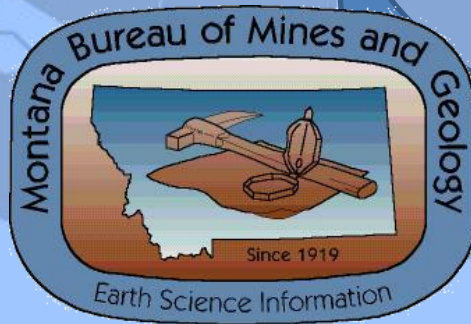
State Geological Survey Contributions to the NGDS

U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy



\$401,000 over 3 years



National Geothermal Data System (NGDS)

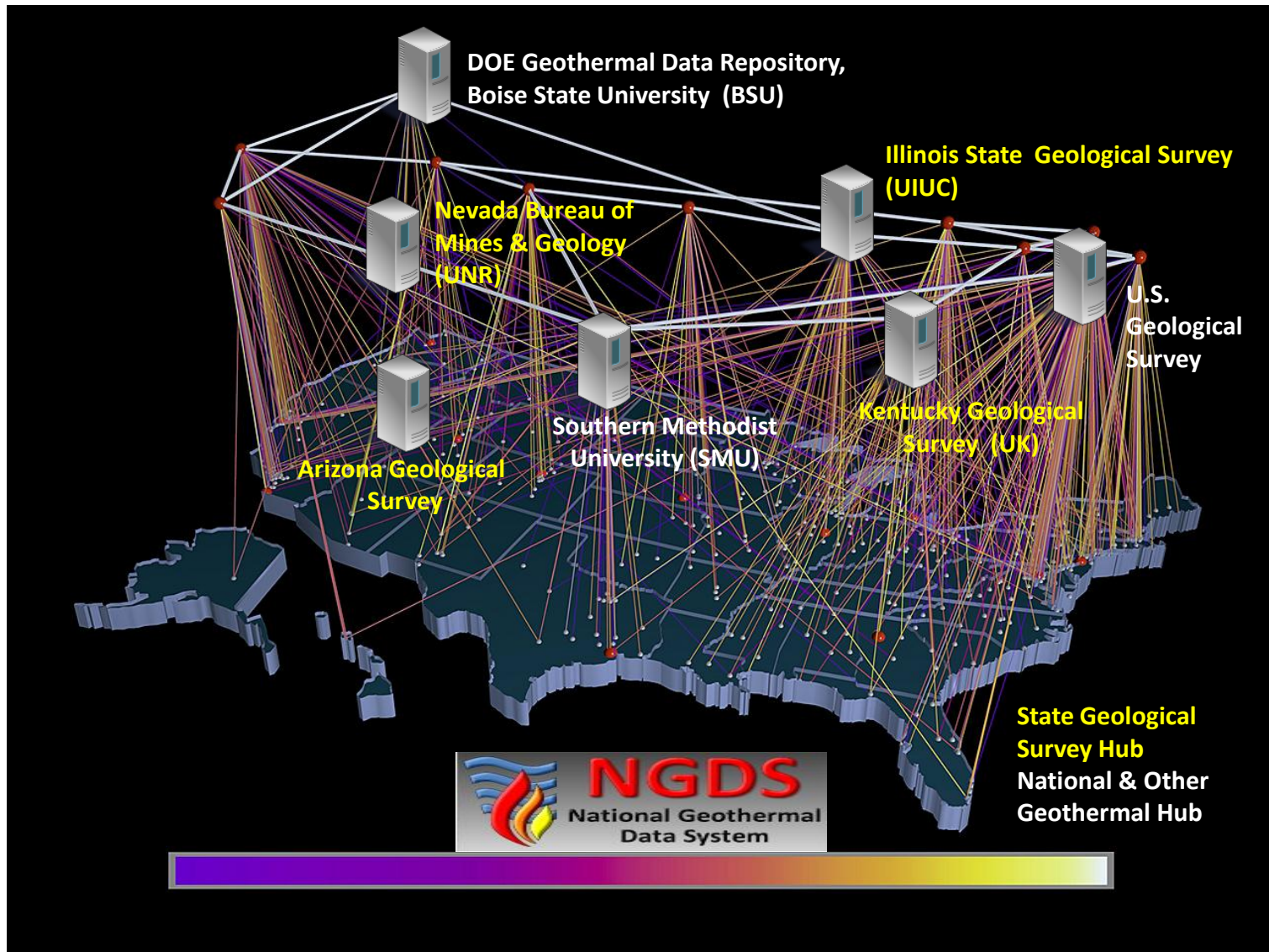
The NGDS is a distributed network of repositories and data sites mitigating the upfront risk of geothermal energy development by employing state-of-the-art information science to provide access to quality and comprehensive data.

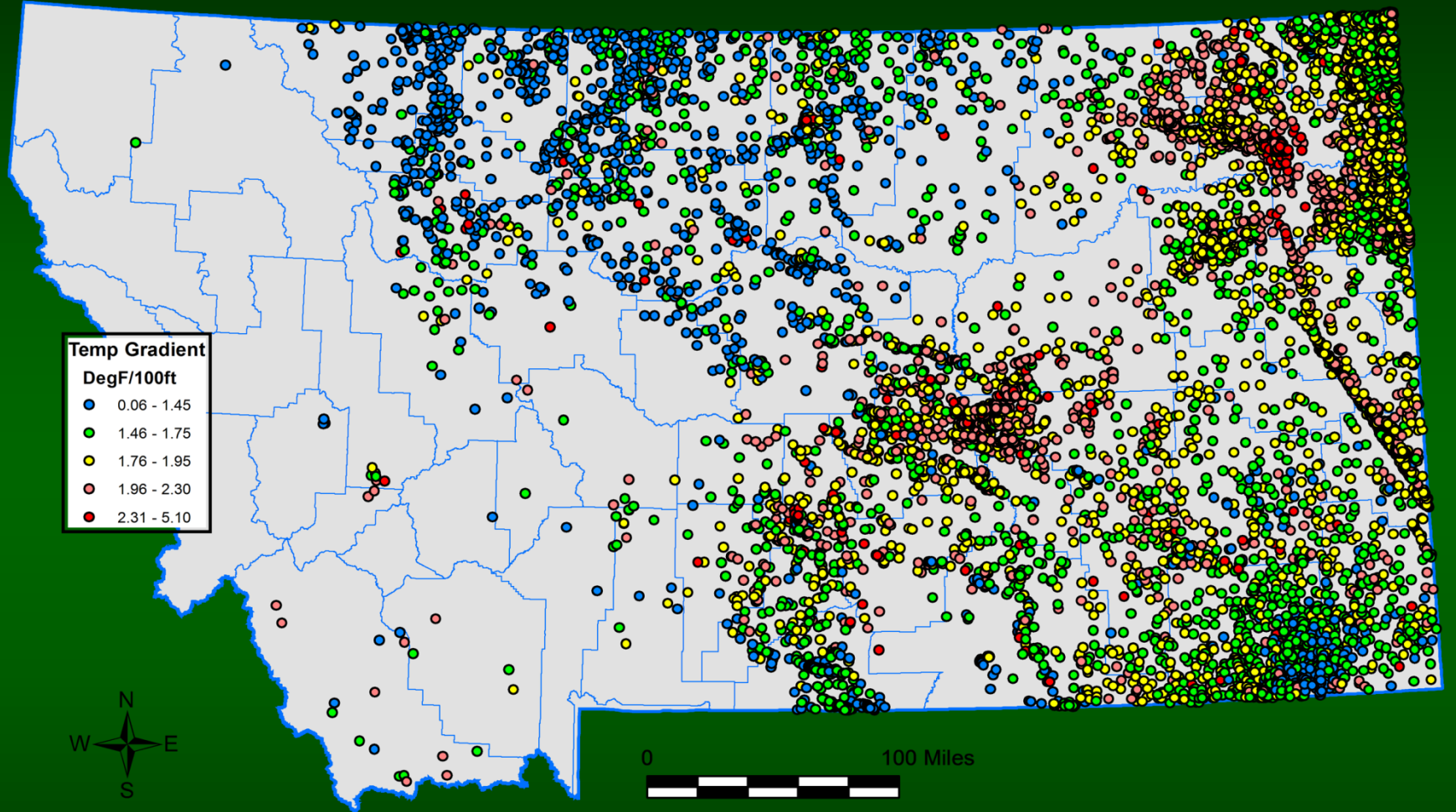
Top 15 Funded States

State	Funding Amount
Washington	\$1,249,146
Nevada	\$1,070,639
Utah	\$966,834
Oregon	\$958,847
Idaho	\$873,562
Texas	\$743,481
Colorado	\$617,021
New Mexico	\$605,483
Kentucky	\$585,977
Massachusetts	\$515,901
Illinois	\$507,809
Hawaii	\$499,951
Montana	\$401,009
Indiana	\$378,499
Wisconsin	\$329,135

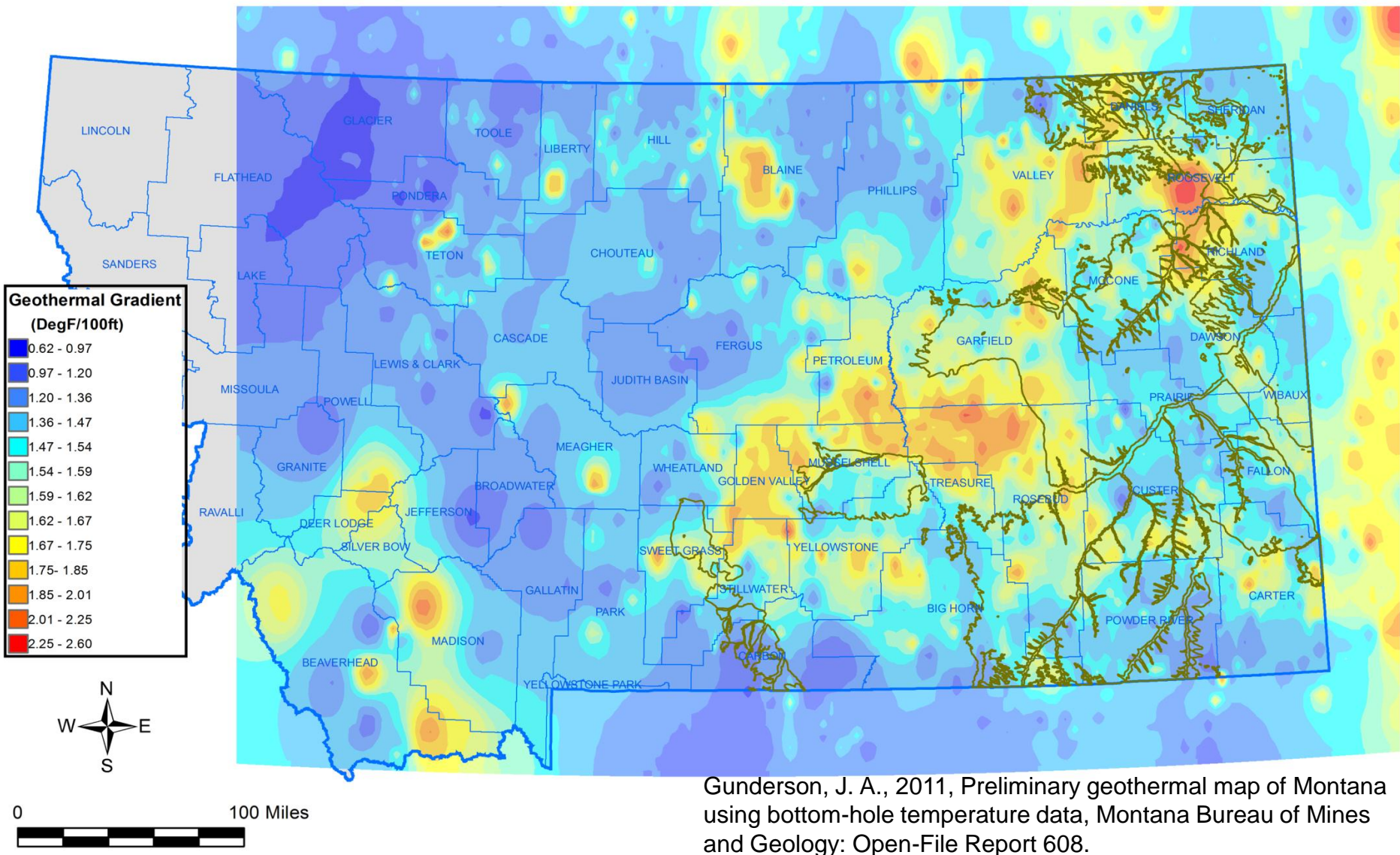
***AZ & CA data collection is part of the AZGS award and is not included in this summary**

NGDS Architecture: An Integrated, Distributed Data Network





Gunderson, J. A., 2011, Preliminary geothermal map of Montana using bottom-hole temperature data, Montana Bureau of Mines and Geology: Open-File Report 608.



Gunderson, J. A., 2011, Preliminary geothermal map of Montana using bottom-hole temperature data, Montana Bureau of Mines and Geology: Open-File Report 608.

Analytical Integration



Contents

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 - Active Geothermal Sites (Moderate to High-Temperature)
 - Public Lands Not Withdrawn
 - Land Managed for Biodiversity
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 - Known Geothermal Resource Areas
 - Ave. Potential (Linear Regression)
 - Google, Temperature with Depth
 - 3.5 km
 - 4.5 km
 - 5.5 km
 - 6.5 km
 - 7.5 km
 - 10 km
 - 2004 Heatflow Maps
 - Continental US,

