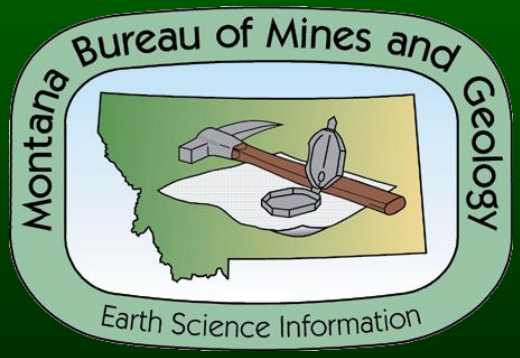
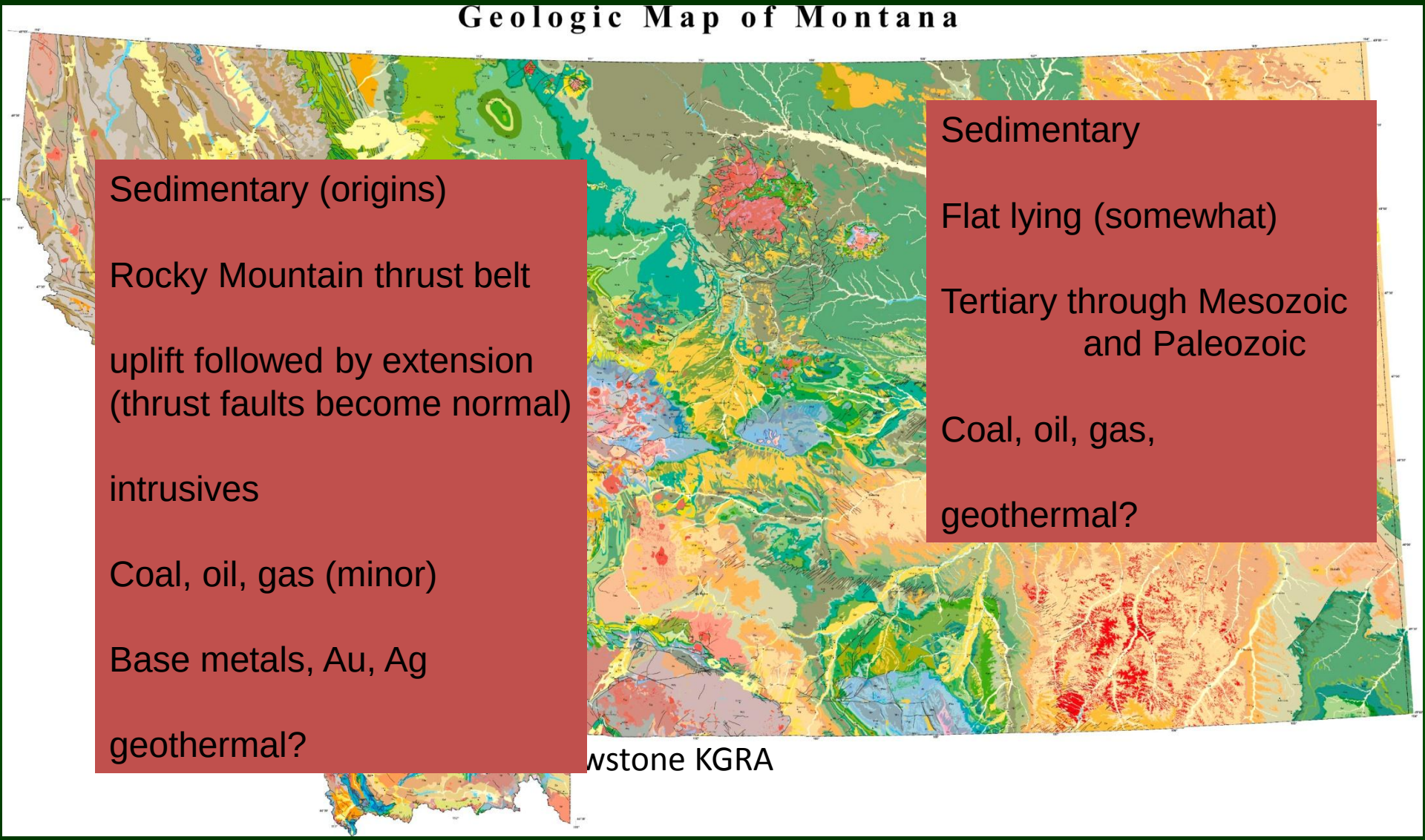
Energy and Groundwater in Montana

Summary of Montana's Geothermal Areas

John Metesh

Montana Bureau of Mines and Geology
July 31, 2012





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

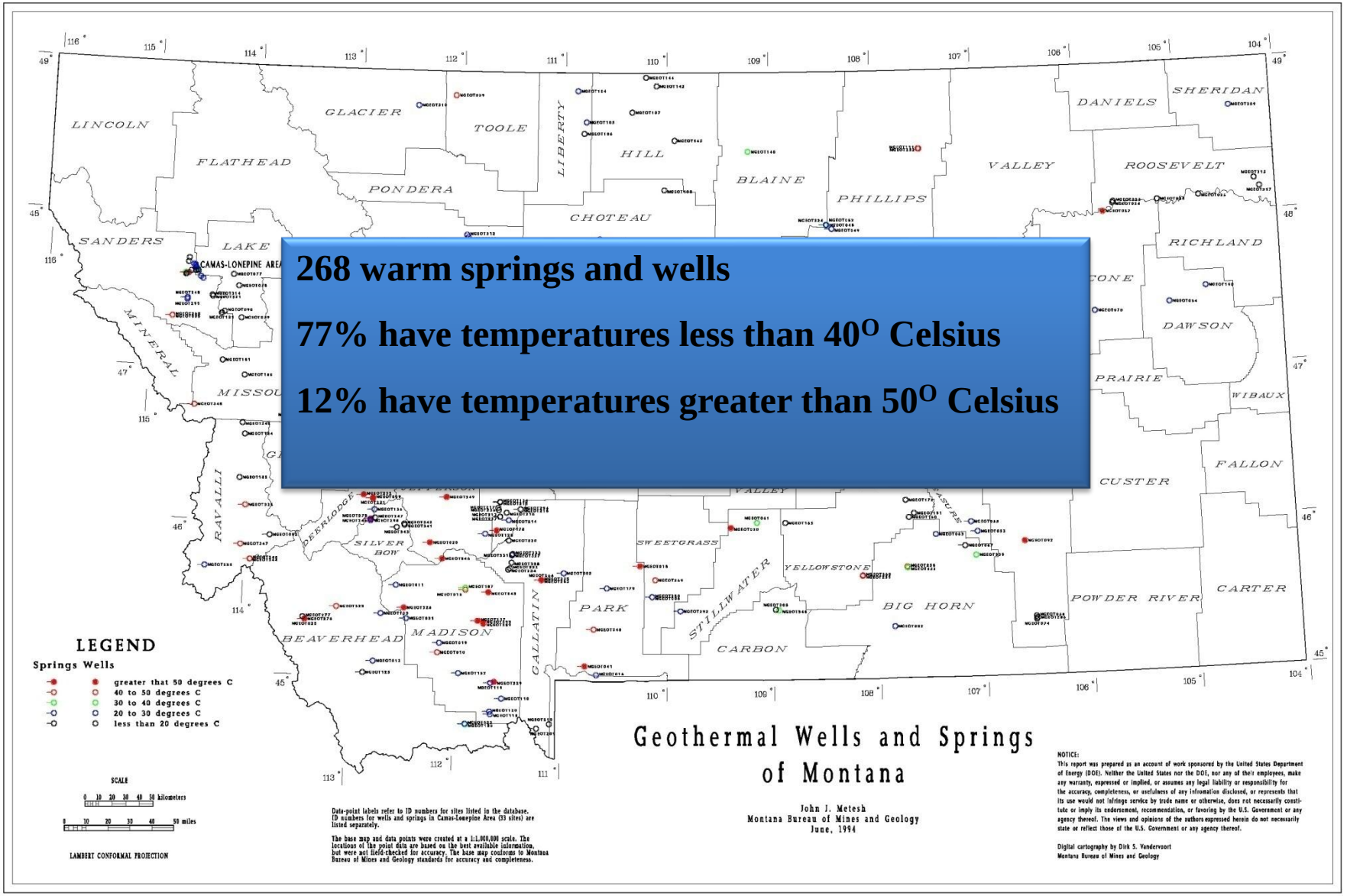
Flat lying (somewhat)

Tertiary through Mesozoic and Paleozoic

Coal, oil, gas,

geothermal?

wstone KGRA


268 warm springs and wells
77% have temperatures less than 40O Celsius
12% have temperatures greater than 50O Celsius
LEGEND
Springs Wells
greater that 50 degrees C
40 to 50 degrees C
30 to 40 degrees C
20 to 30 degrees C
less than 20 degrees C
SCALE
0 10 20 30 40 50 kilometers
0 10 20 30 40 50 miles
LAMBERT CONFORMAL PROJECTION
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.
Geothermal Wells and Springs of Montana
John J. Metesh
Montana Bureau of Mines and Geology
June, 1994
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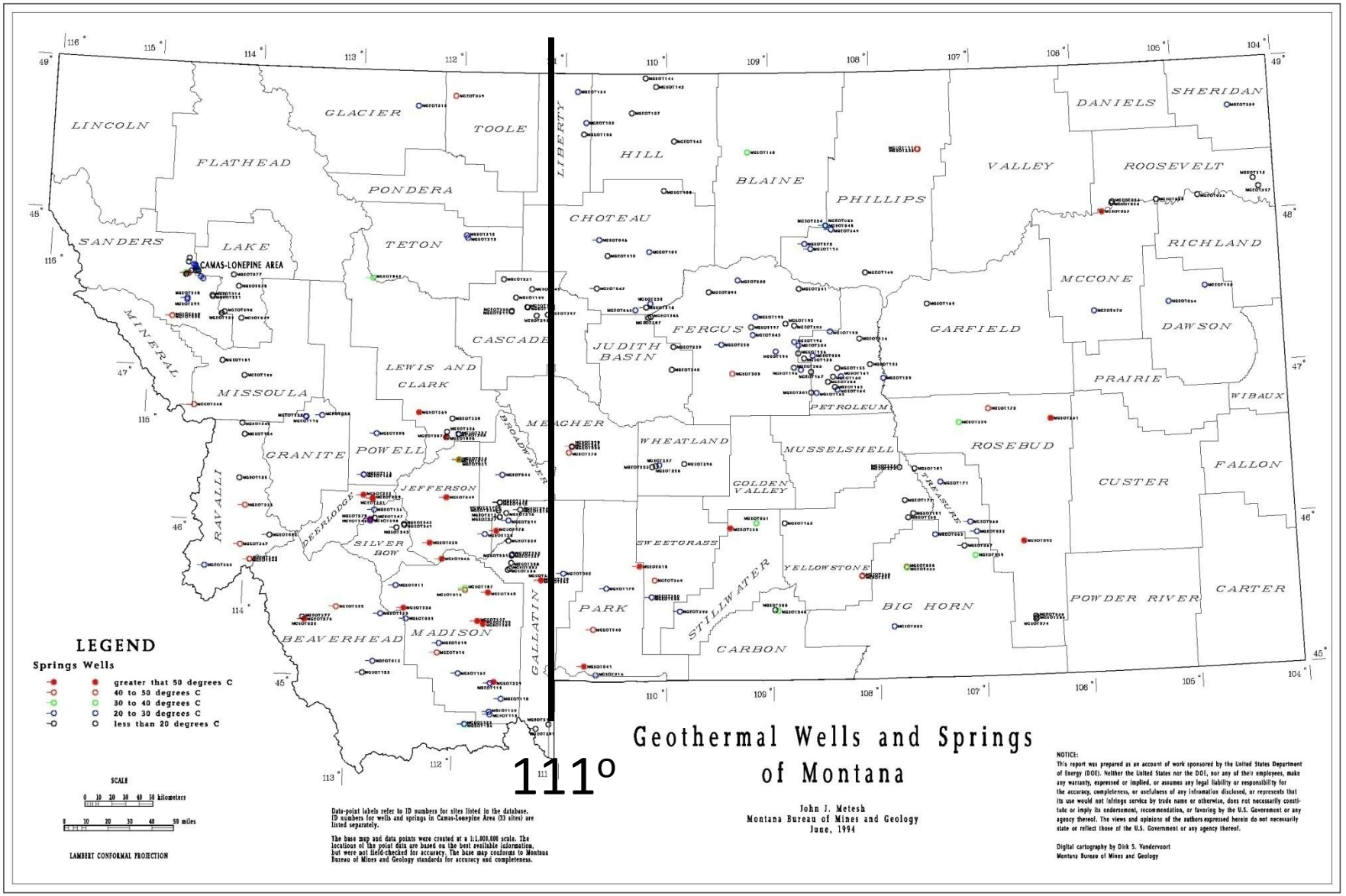
Digital cartography by Dirk S. Vandervoort
Montana Bureau of Mines and Geology
LINCOLN
FLATHEAD
GLACIER
TOOLE
PONDERA
LIBERTY
HILL
BLAINE
CHOTEAU
PHILLIPS
VALLEY
DANIELS
SHERIDAN
ROOSEVELT
RICHLAND
DAWSON
PRAIRIE
WIBAUX
FALLON
CUSTER
SANDERS
LAKE
CAMAS-LONEPINE AREA
MINERAL
MISSOULA
RAVALLI
BEAVERHEAD
DEERLODGE
SILVER BOW
MADISON
GALLATIN
PARK
SWEETGRASS
STILLWATER
YELLOWSTONE
CARBON
BIG HORN
POWDER RIVER
CARTER



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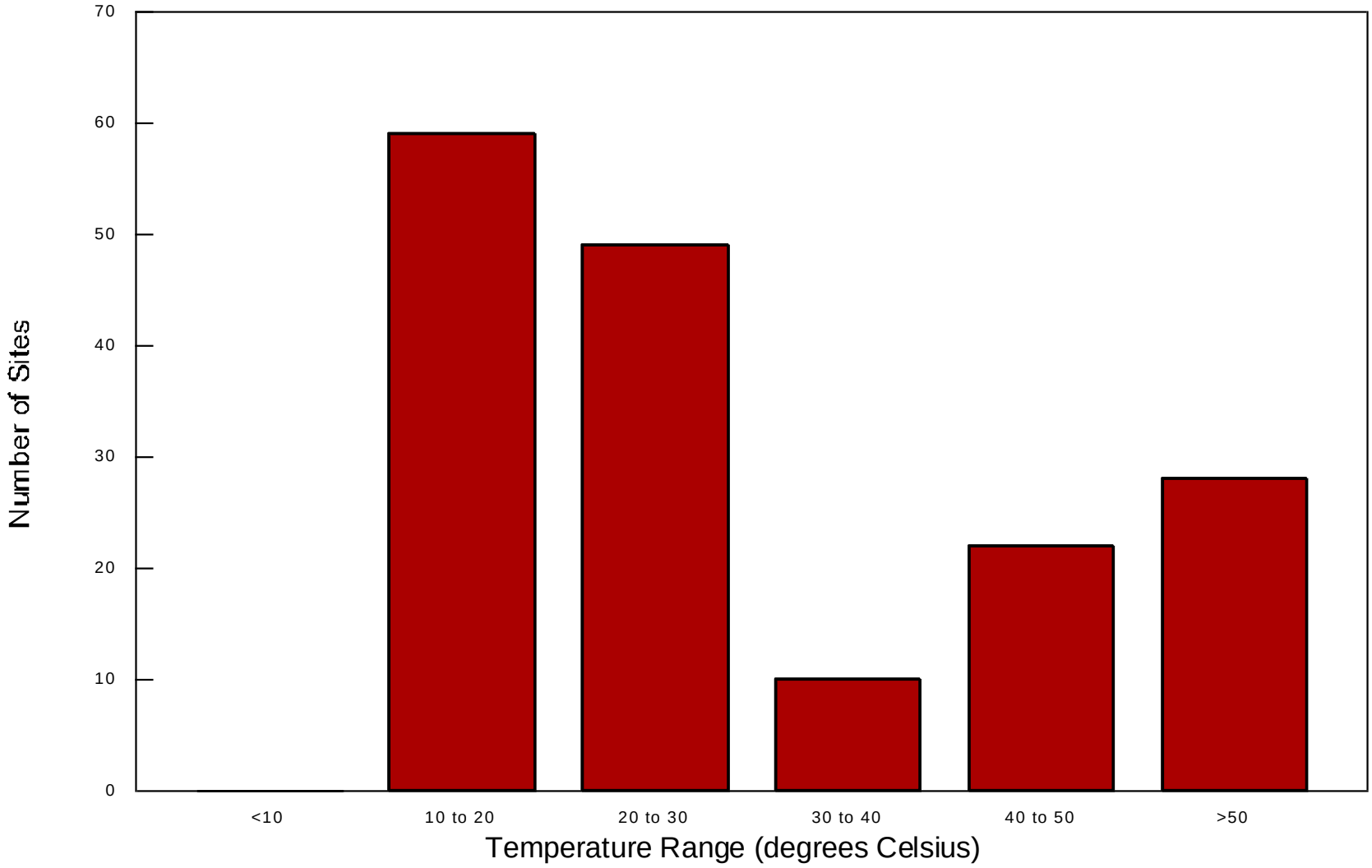
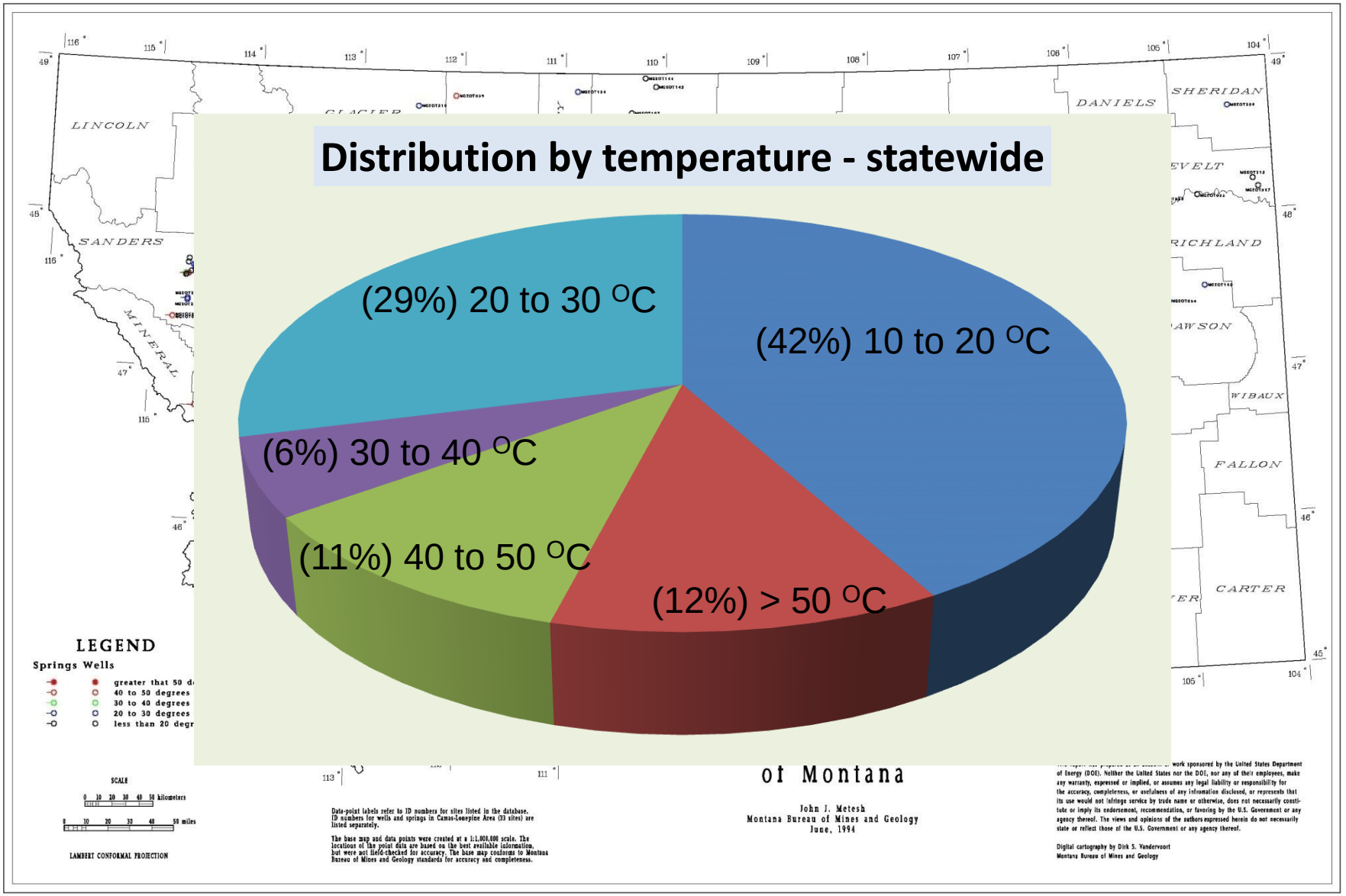
DISTRIBUTION OF SITES

WEST OF 111 DEGREES LONGITUDE



Number of Sites = 153


Distribution by temperature - statewide
(29%) 20 to 30 °C
(42%) 10 to 20 °C
(6%) 30 to 40 °C
(11%) 40 to 50 °C
(12%) > 50 °C
LEGEND
Springs Wells
greater that 50 d
40 to 50 degrees
30 to 40 degrees
20 to 30 degrees
less than 20 degr
SCALE
0 10 20 30 40 50 kilometers
0 10 20 30 40 50 miles
LAMBERT CONFORMAL PROJECTION
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of Montana
John J. Metesh
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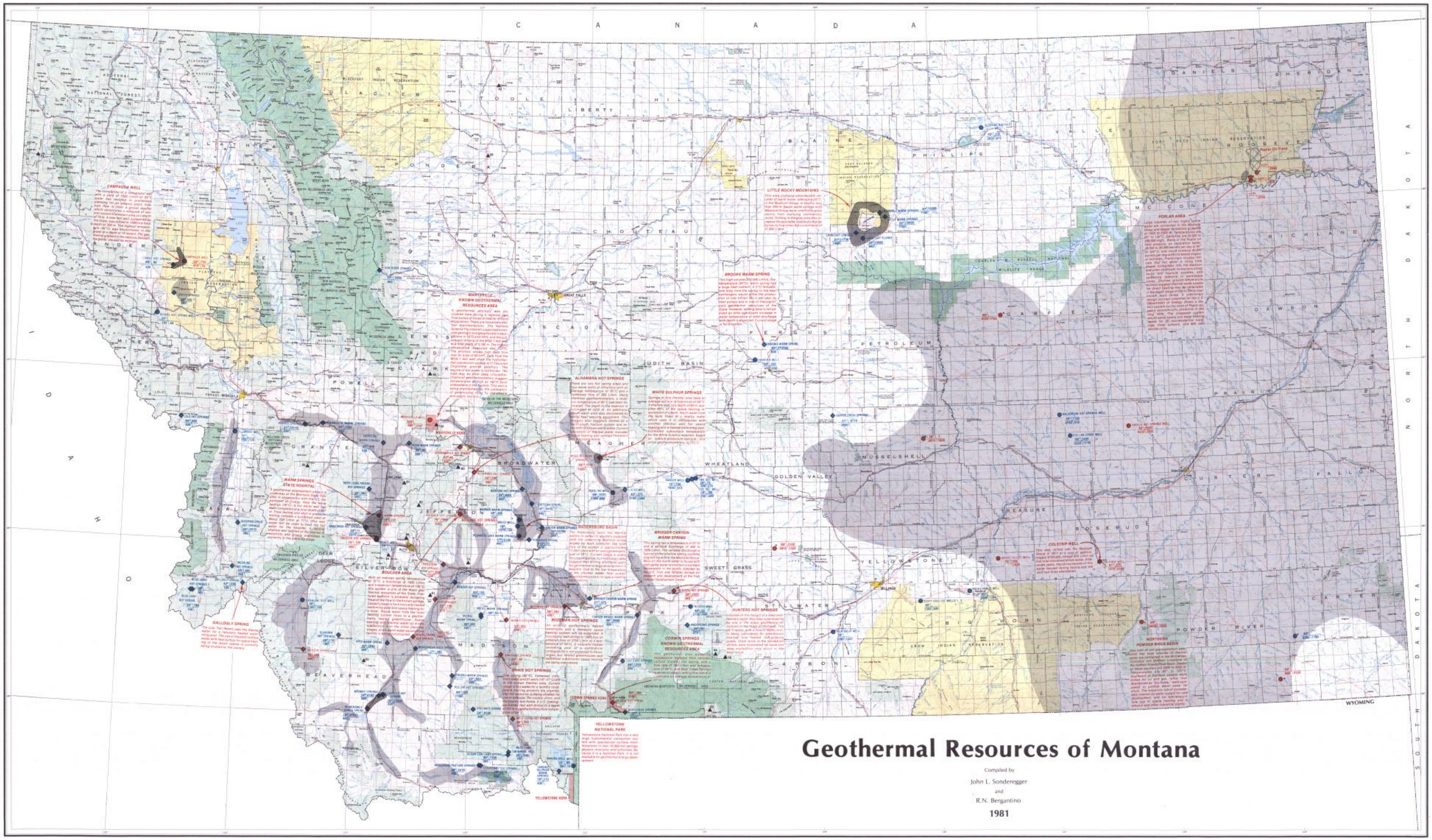
Digital cartography by Dirk S. Vandervoort
Montana Bureau of Mines and Geology
LINCOLN
SANDERS
MINERAL
DANIELS
SHERIDAN
RICHLAND
WIBAUX
FALLON
CARTER

MONTANA BUREAU OF MINES AND GEOLOGY
A Department of Montana College of Mineral Science and Technology

Hydrogeologic Map HM 4
Geothermal Resources of Montana
Sonderegger and Bergantino, 1981



Low-Temperature Geothermal Waters

Thermal Springs

Thermal Wells

Heat Flow

Metric Conversion Factors

SCALE 1:1,000,000
1 centimeter equals 10 kilometers
1 inch equals approximately 16 miles

Contour interval 500 feet

Datum is mean sea level

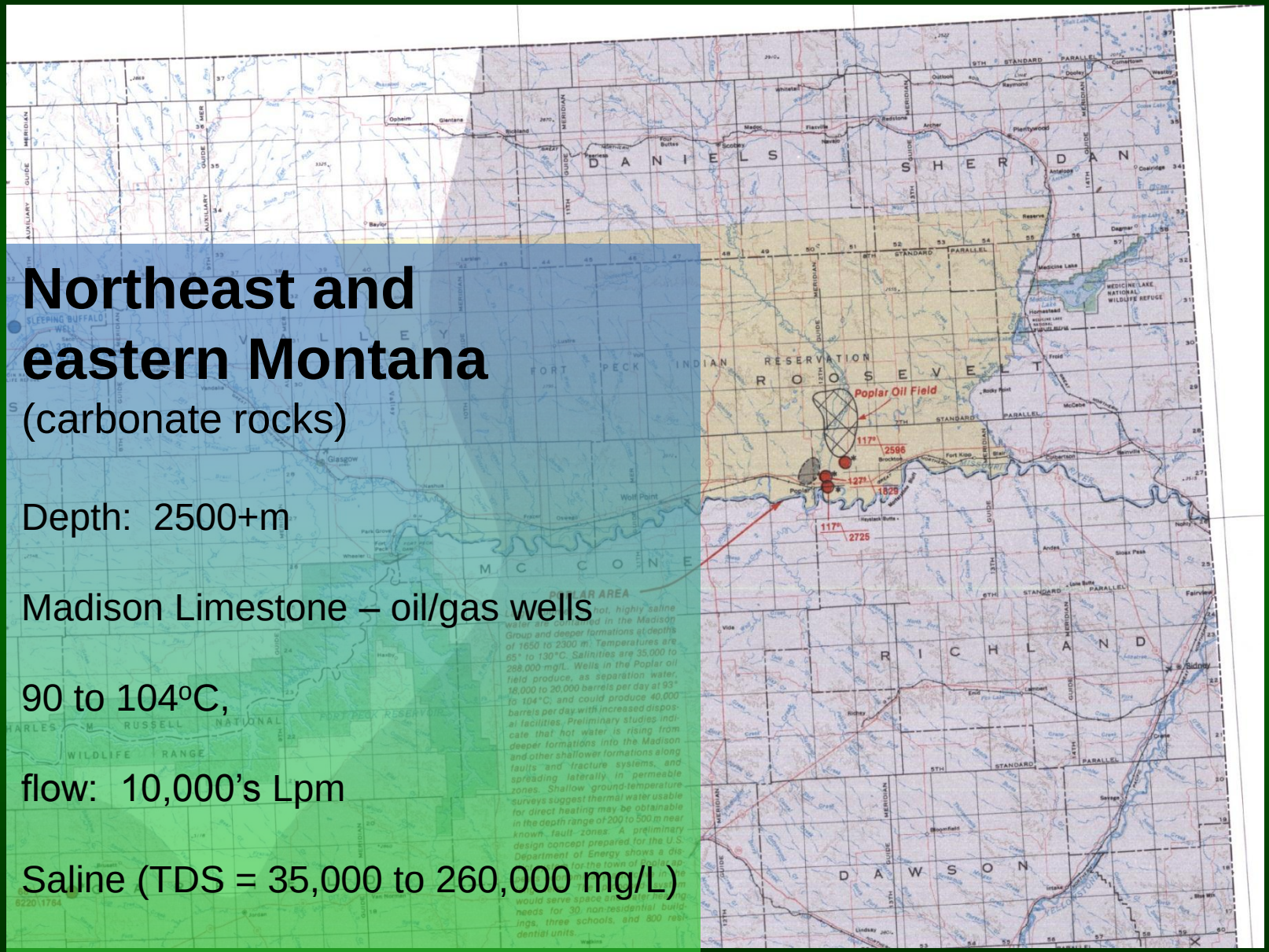
1927 North American Datum

Lambert conformal conic projection based on standard parallels 33° and 45°

Data for thermal springs and most thermal wells in Montana are in the accompanying tables. For additional information about the geothermal resources of Montana contact the Montana Bureau of Mines and Geology. Published literature is listed in
Rautio, S.A., and Sonderegger, J.L., 1980, Annotated bibliography of the geothermal resources of Montana: Montana Bureau of Mines and Geology Bulletin 110, 25 p.

Map available free of charge from: Montana Bureau of Mines and Geology, Montana College of Mineral Science and Technology, Butte, Montana 59701

Geothermal data compiled by the
Montana Bureau of Mines and Geology
Map produced by the
National Geophysical and Solar-Terrestrial Data Center
National Oceanic and Atmospheric Administration
for the
Division of Geothermal Energy
United States Department of Energy



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)

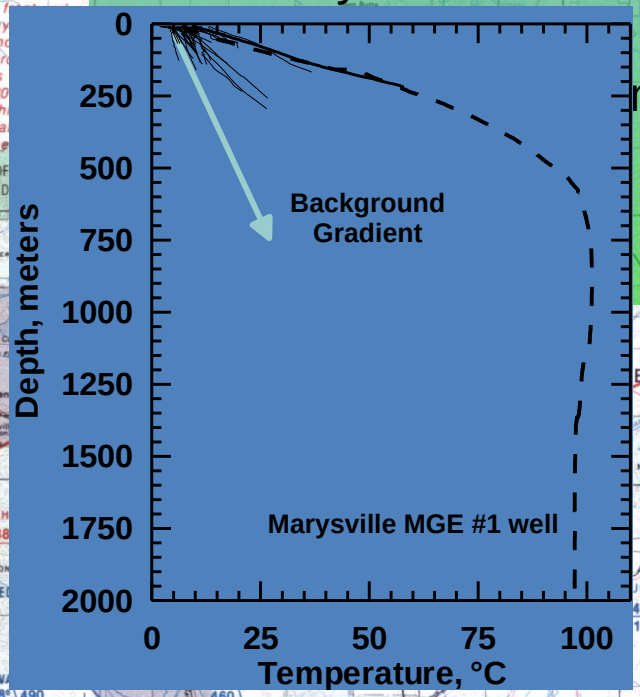
West Central Montana

(crystalline rocks)

Depth: 2,000m

103ºC Marysville

mg/L



MARYSVILLE KNOWN GEOTHERMAL RESOURCES AREA

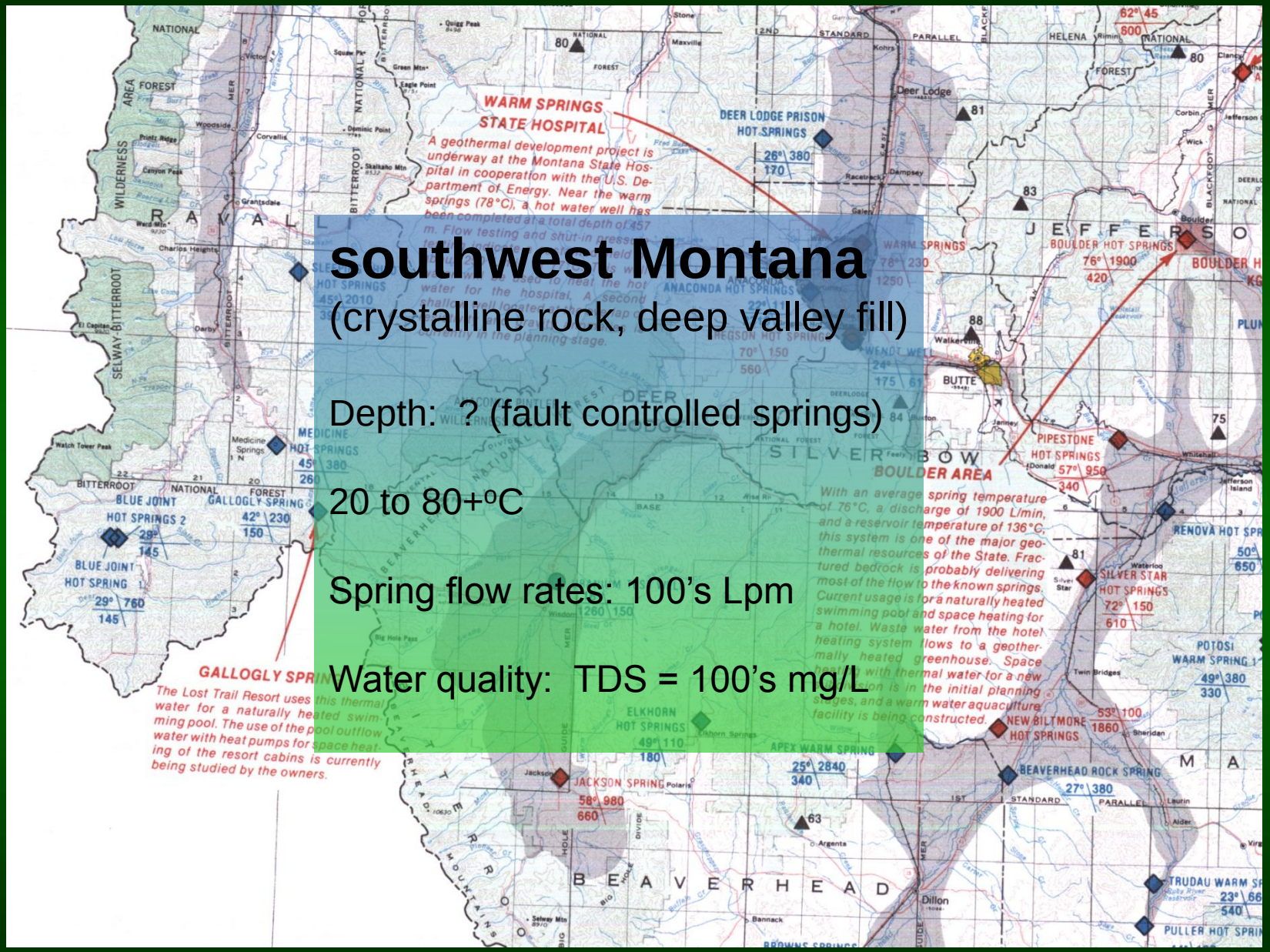
A geothermal anomaly was discovered here during a regional heat flow survey of holes drilled for mineral exploration. There are no surface thermal manifestations. The National Science Foundation supported extensive geologic and geophysical investigations in 1973 and 1974, and the subsequent drilling 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 Oligocene granite porphy source of hot water is not kn heat may be from deep cir Chemical geothermometers temperatures as high as 180 somewhere in the system. Th being maintained for the ca 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.

WHITE SULPHUR SPRINGS

Springs in this thermal area have an average surface temperature of 58°C. A shallow well, at a depth of 60 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.



southwest Montana

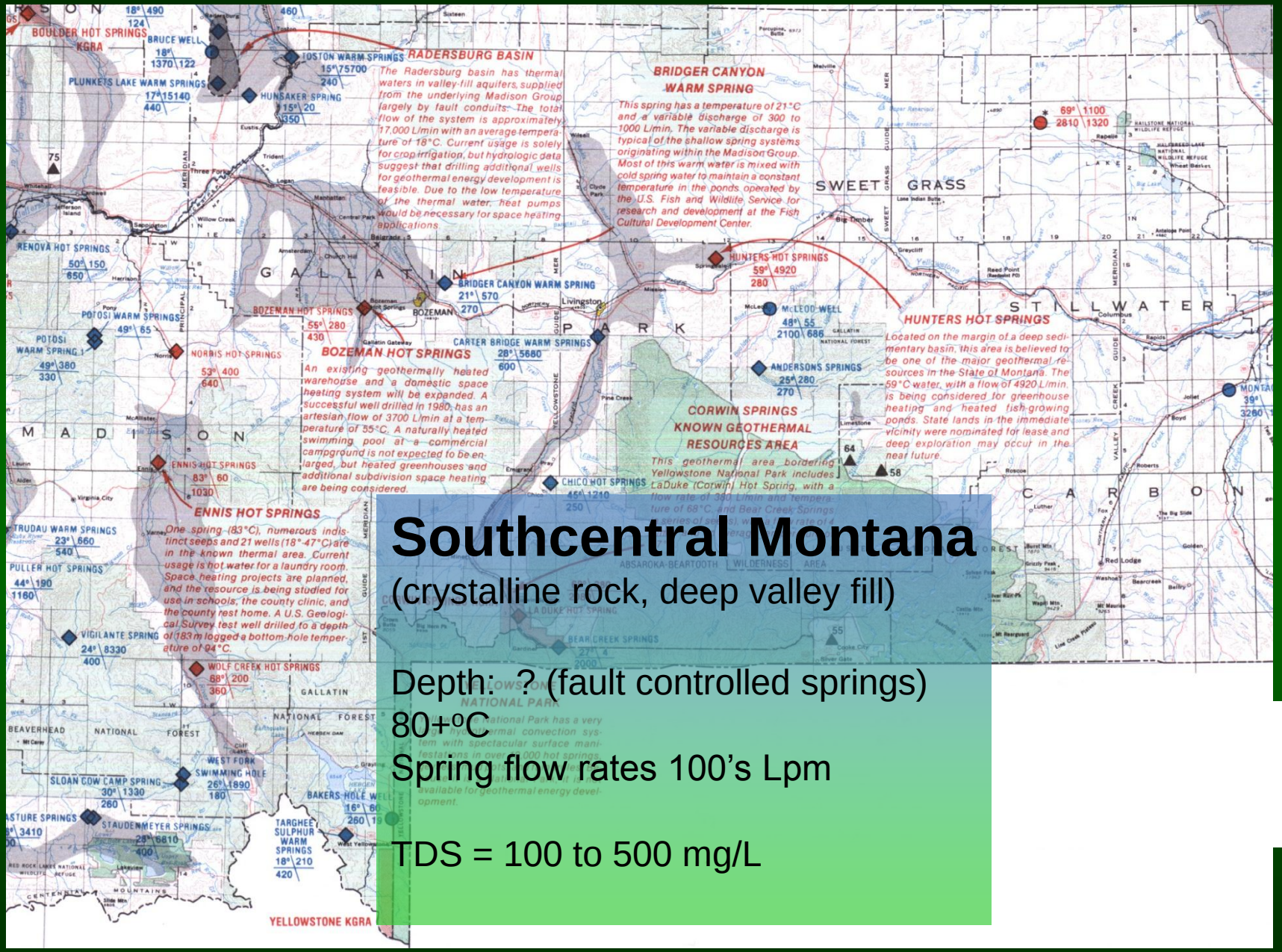
(crystalline rock, deep valley fill)

Depth: ? (fault controlled springs)

20 to 80+°C

Spring flow rates: 100's Lpm

Water quality: TDS = 100's mg/L



Southcentral Montana

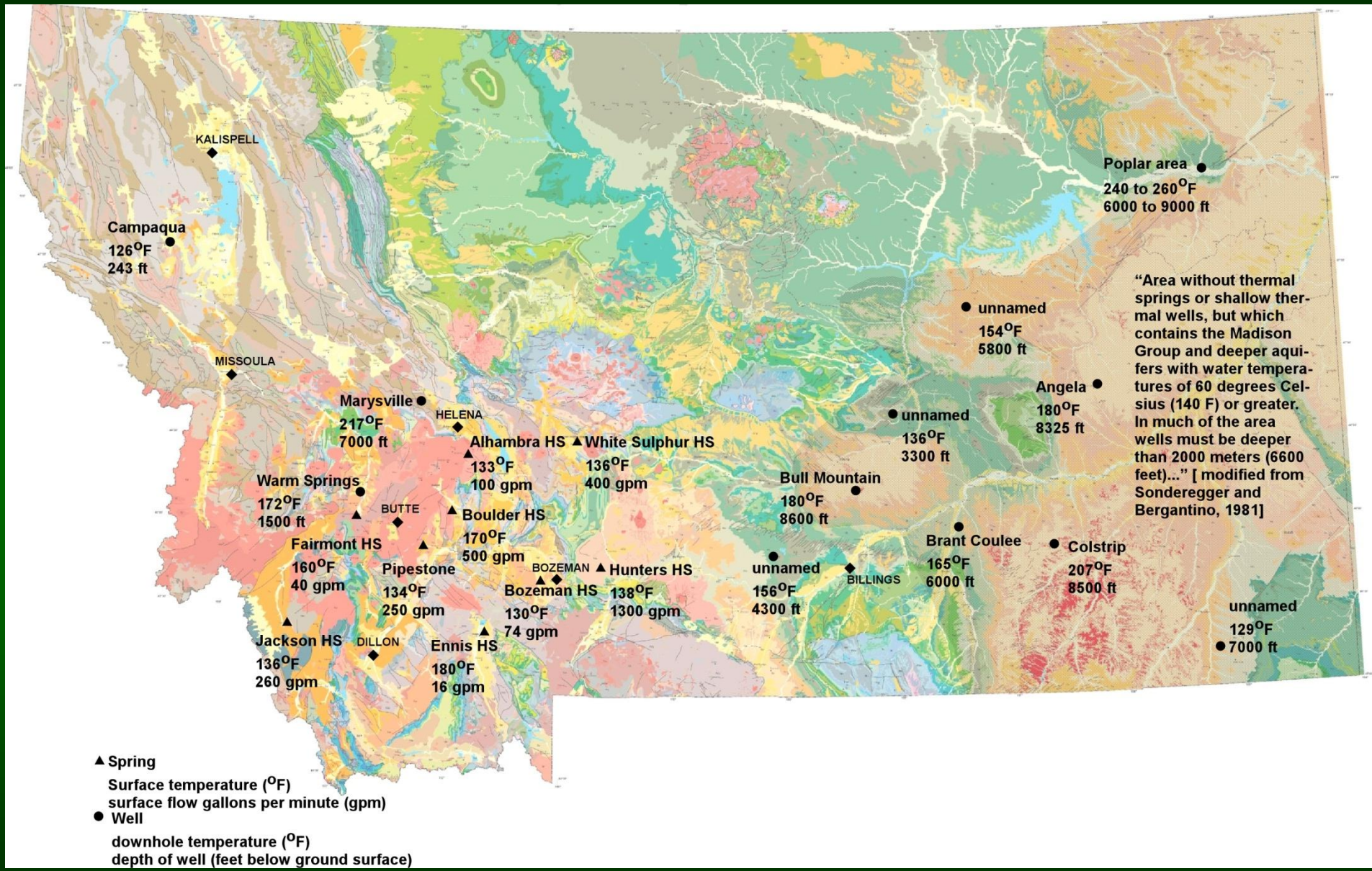
(crystalline rock, deep valley fill)

Depth: ? (fault controlled springs)

80+°C

Spring flow rates 100's Lpm

TDS = 100 to 500 mg/L

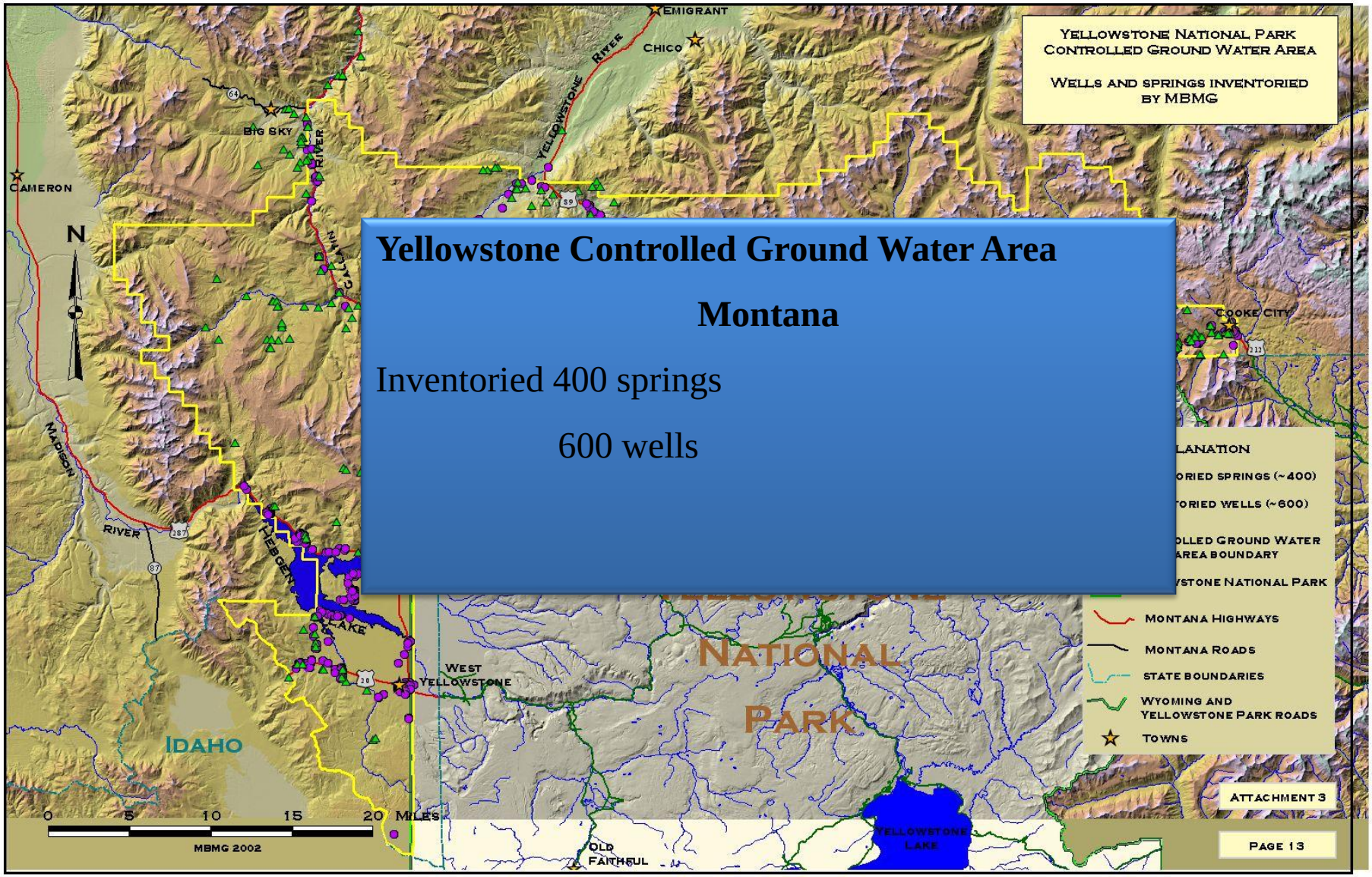

KALISPELL
Campaqua
126°F
243 ft
MISSOULA
Marysville
217°F
7000 ft
HELENA
Alhambra HS
133°F
100 gpm
White Sulphur HS
136°F
400 gpm
Warm Springs
172°F
1500 ft
BUTTE
Boulder HS
170°F
500 gpm
Fairmont HS
160°F
40 gpm
Pipestone
134°F
250 gpm
BOZEMAN
Hunters HS
138°F
1300 gpm
Bozeman HS
130°F
74 gpm
Jackson HS
136°F
260 gpm
DILLON
Ennis HS
180°F
16 gpm
Poplar area
240 to 260°F
6000 to 9000 ft
unnamed
154°F
5800 ft
Angela
180°F
8325 ft
unnamed
136°F
3300 ft
Bull Mountain
180°F
8600 ft
Brant Coulee
165°F
6000 ft
Colstrip
207°F
8500 ft
unnamed
156°F
4300 ft
BILLINGS
unnamed
129°F
7000 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)

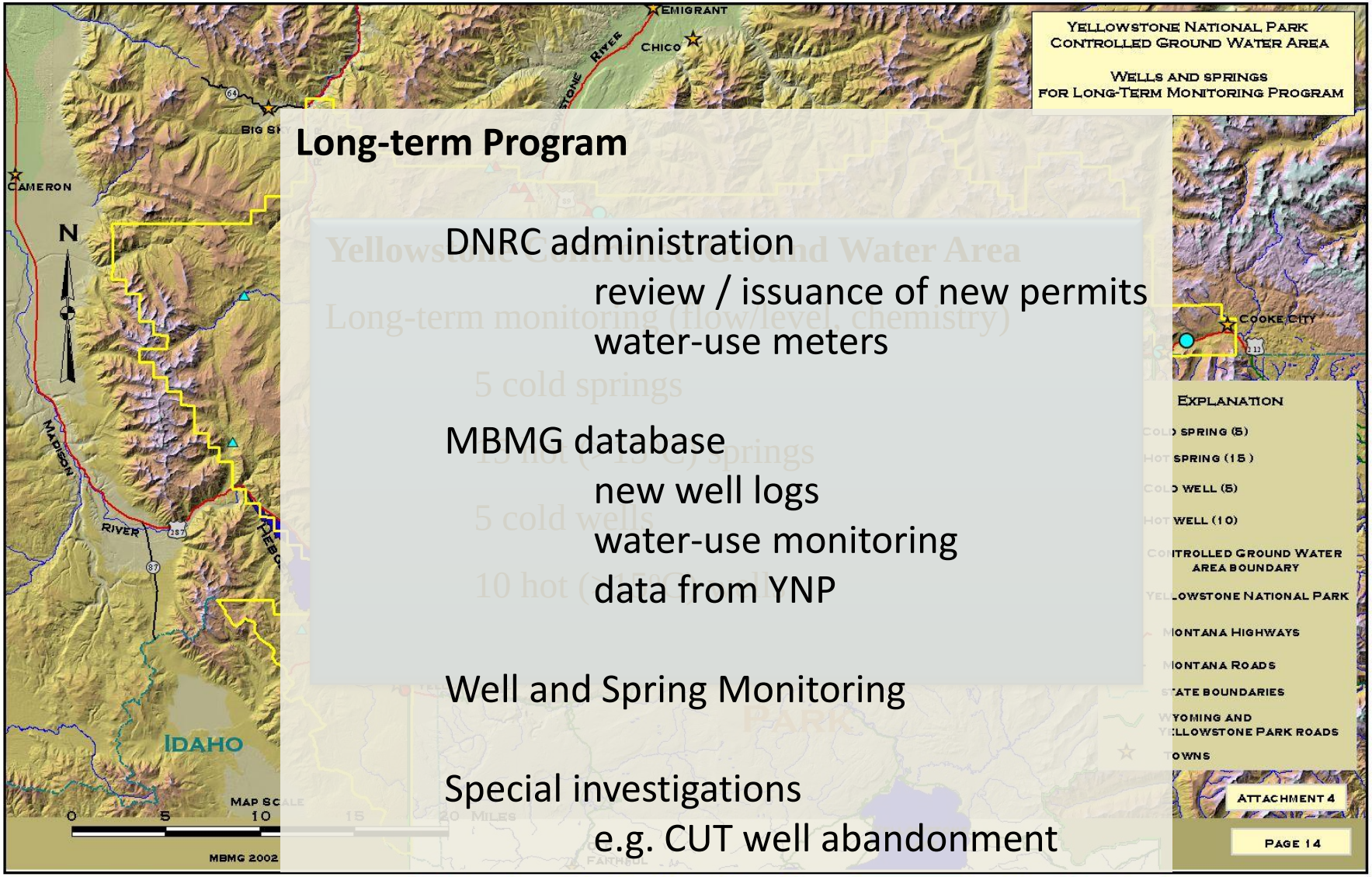
Heat Flow (mW/m^2)

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

Geothermal Gradient ($^oC/Km$ and $^oF/100ft$)

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
EMIGRANT
CHICO
BIG SKY
CAMERON
COOKE CITY
WEST YELLOWSTONE
OLD FAITHFUL
YELLOWSTONE LAKE
IDAHO
NATIONAL PARK
MADISON RIVER
YELLOWSTONE RIVER
GALLATIN RIVER
HEBGEN LAKE
N
0 5 10 15 20 MILES
MBMG 2002
LANATION
ORIED SPRINGS (~400)
TORIED WELLS (~600)
OLLED GROUND WATER
AREA BOUNDARY
YSTONE NATIONAL PARK
MONTANA HIGHWAYS
MONTANA ROADS
STATE BOUNDARIES
WYOMING AND
YELLOWSTONE PARK ROADS
TOWNS
ATTACHMENT 3
PAGE 13



Long-term Program

DNRC administration
- review / issuance of new permits
- water-use meters

MBMG database
- new well logs
- water-use monitoring
- data from YNP

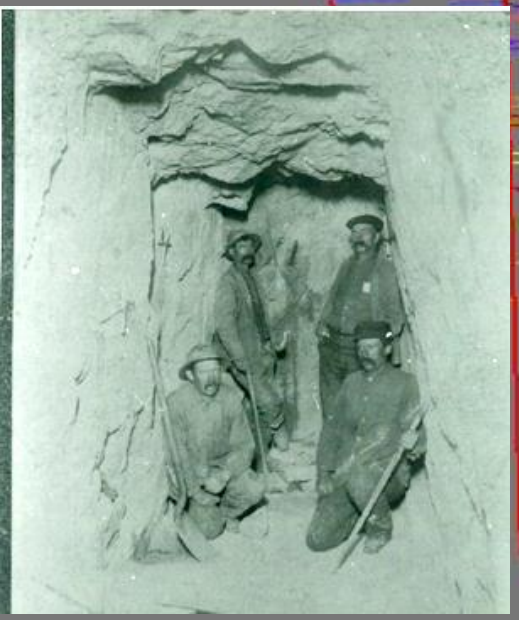
Well and Spring Monitoring

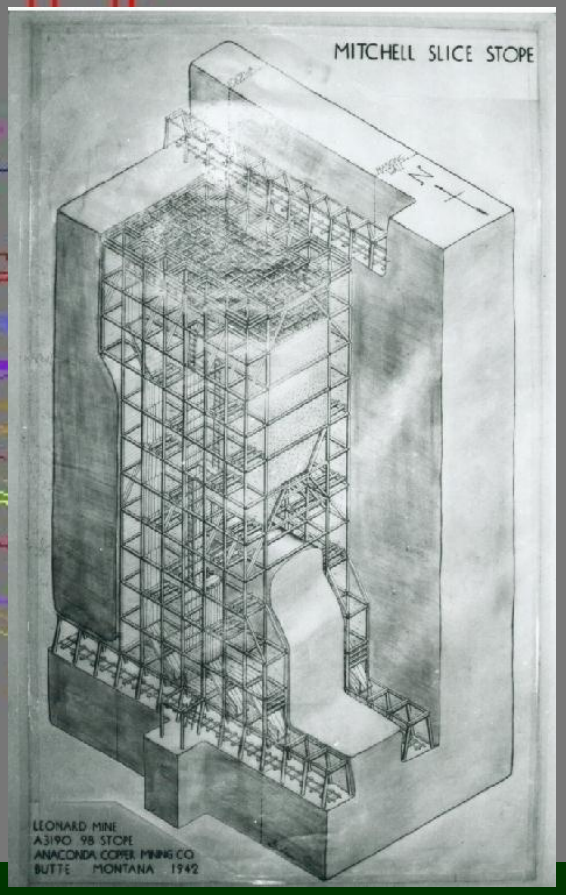
Special investigations
- e.g. CUT well abandonment

7 square miles

5,600 miles of workings

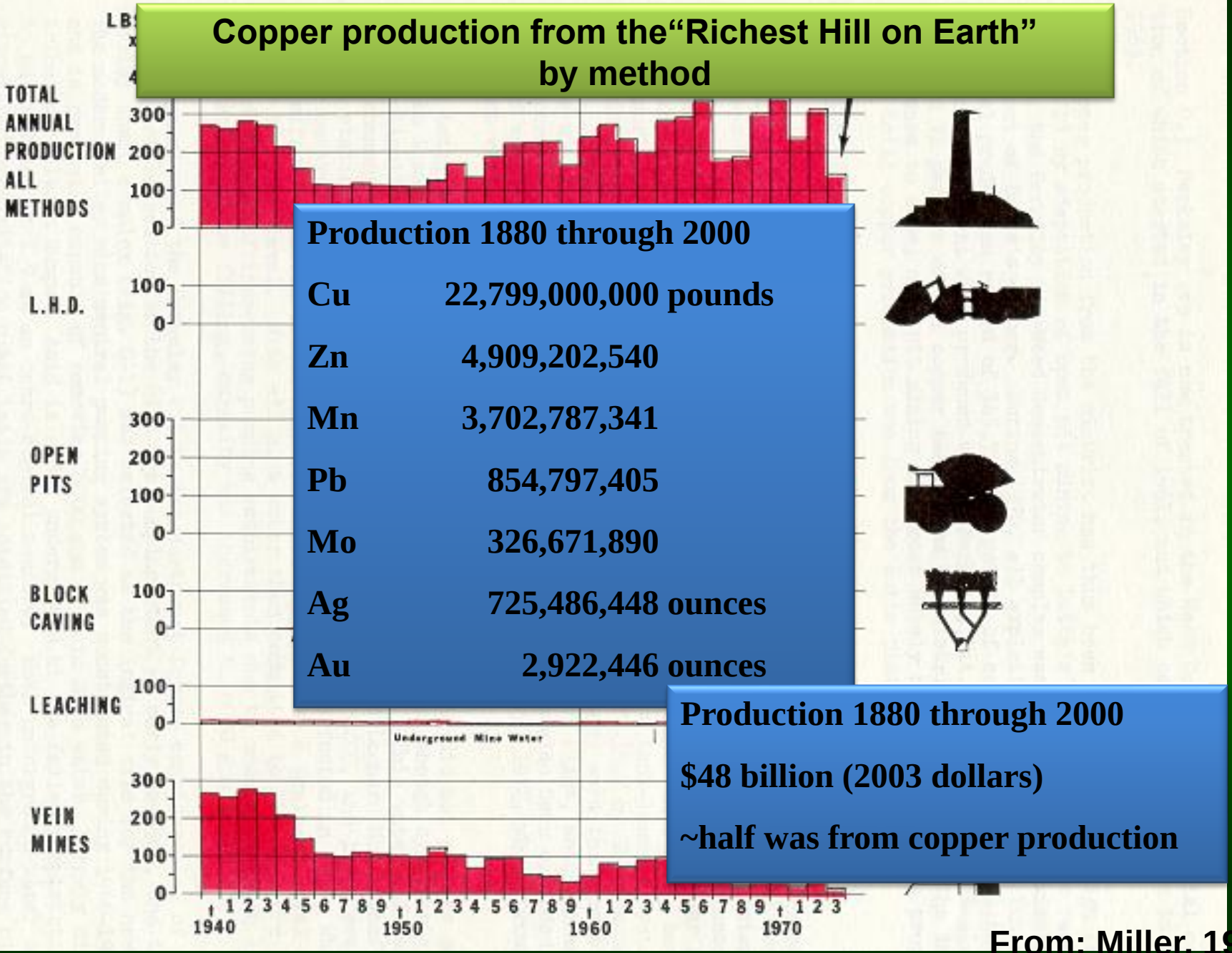
49 miles of shafts





Butte Historic Mining District

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



Production 1880 through 2000

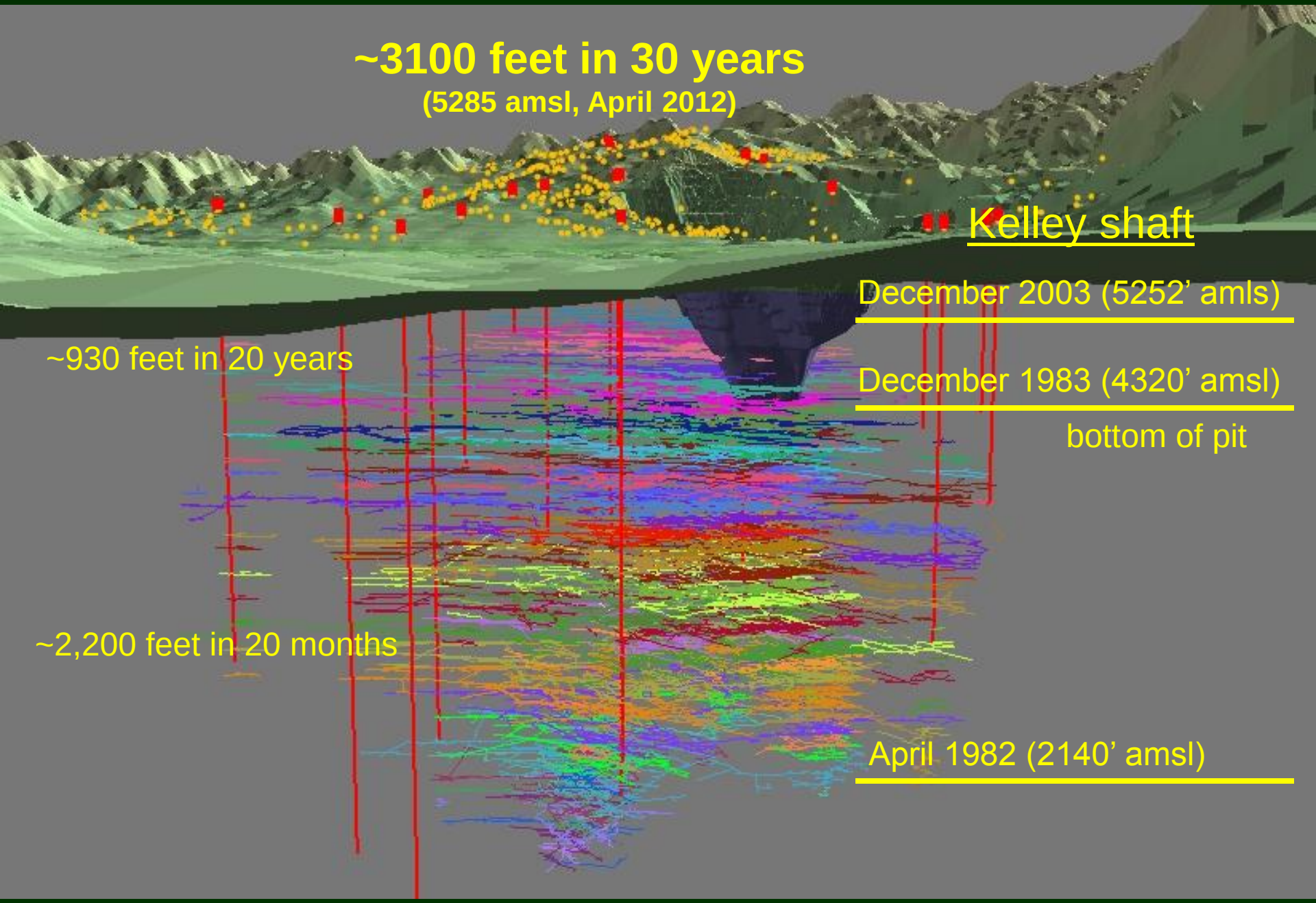
Cu	22,799,000,000 pounds
Zn	4,909,202,540
Mn	3,702,787,341
Pb	854,797,405
Mo	326,671,890
Ag	725,486,448 ounces
Au	2,922,446 ounces

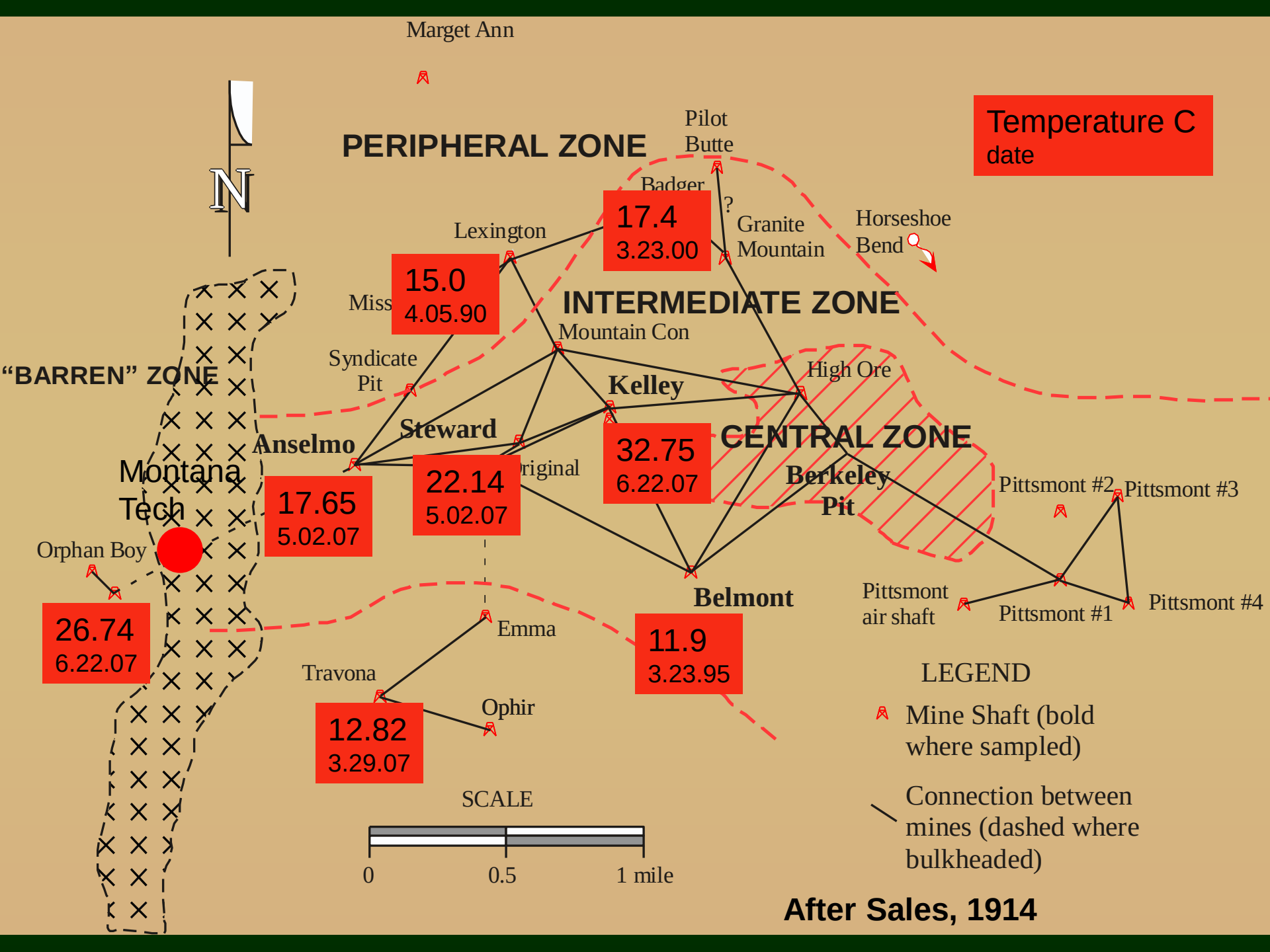
Production 1880 through 2000

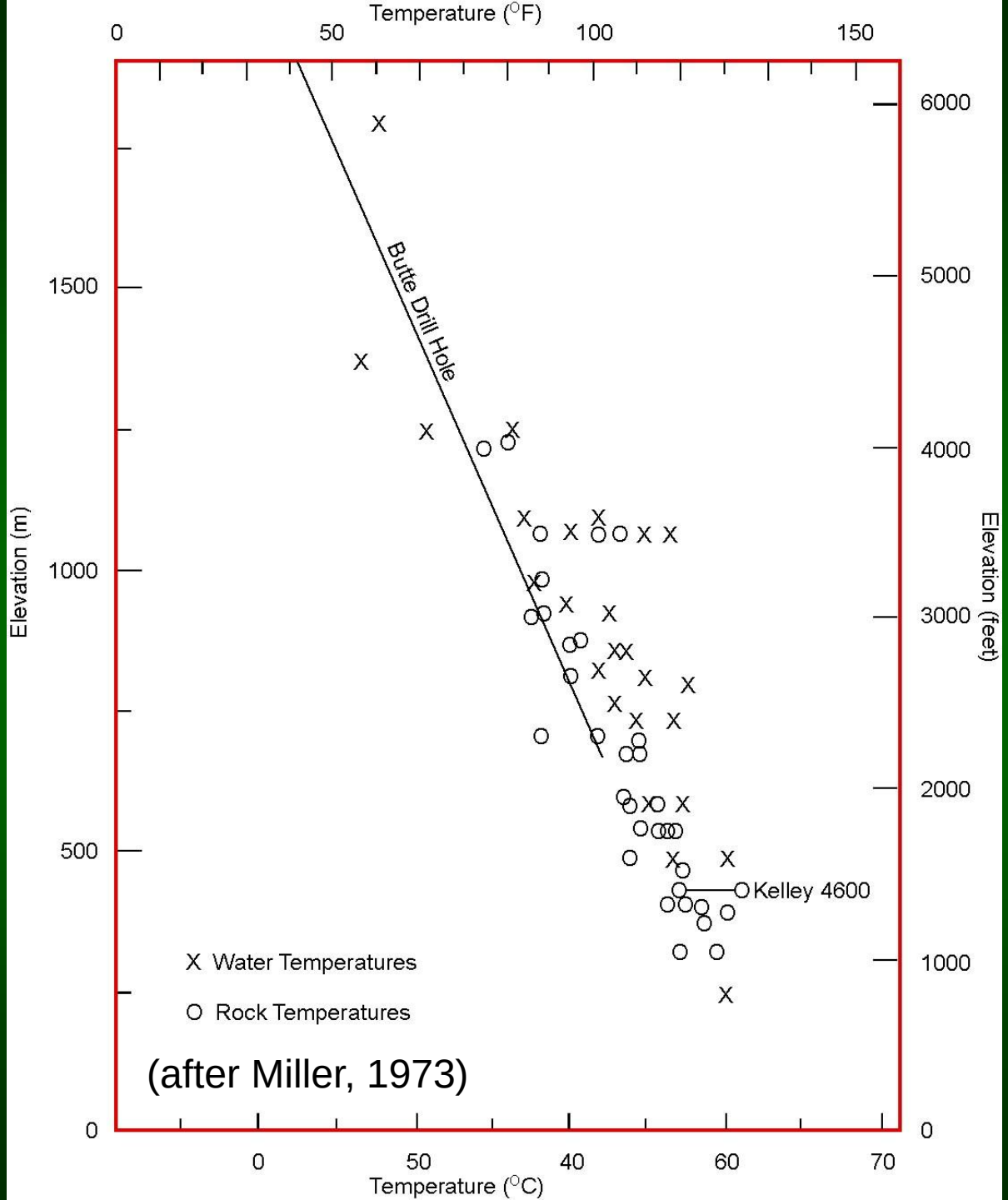
$48 billion (2003 dollars)

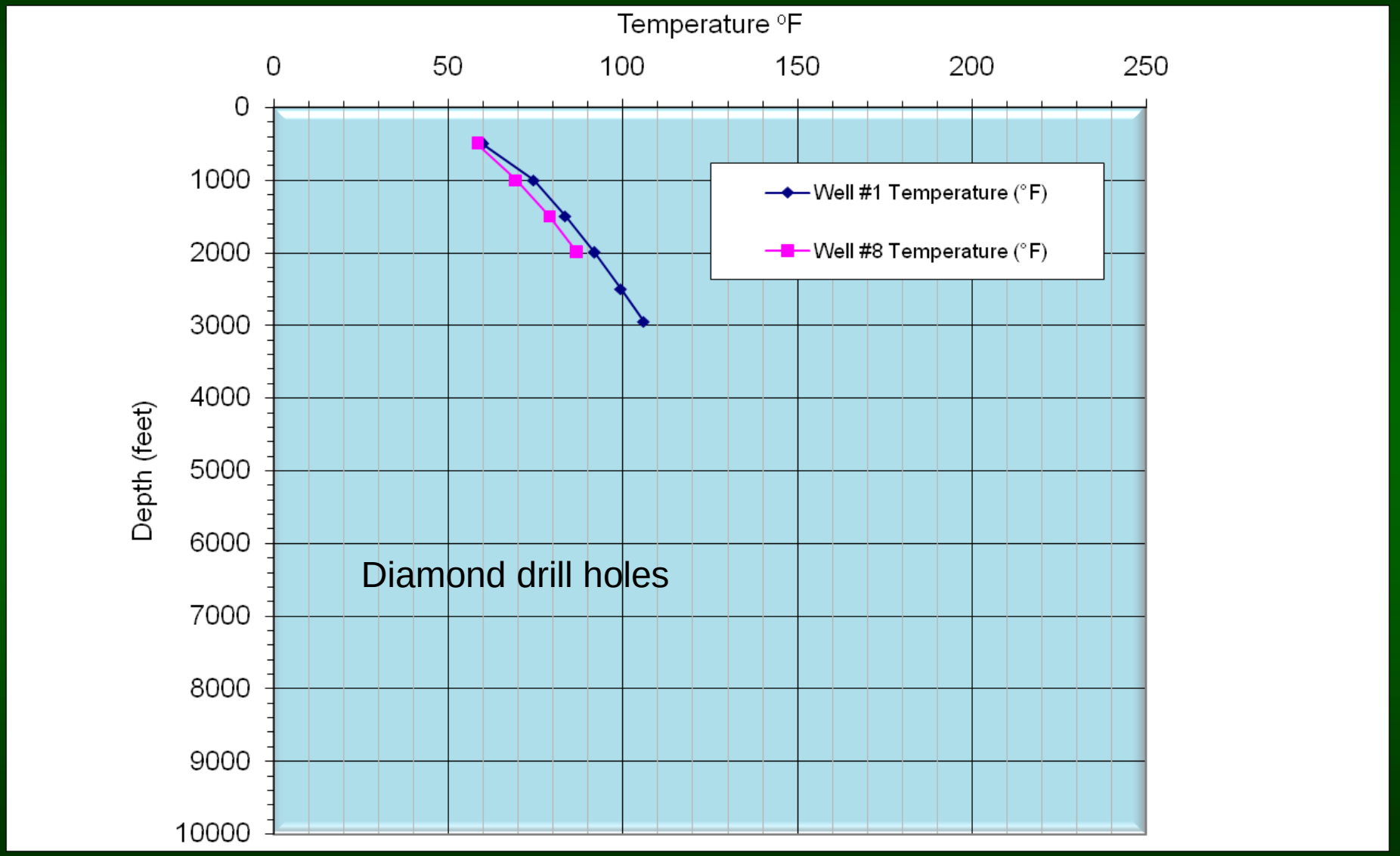
~half was from copper production

From: Miller, 1973


~3100 feet in 30 years
(5285 amsl, April 2012)
Kelley shaft
December 2003 (5252’ amls)
~930 feet in 20 years
December 1983 (4320’ amsl)
bottom of pit
~2,200 feet in 20 months
April 1982 (2140’ amsl)

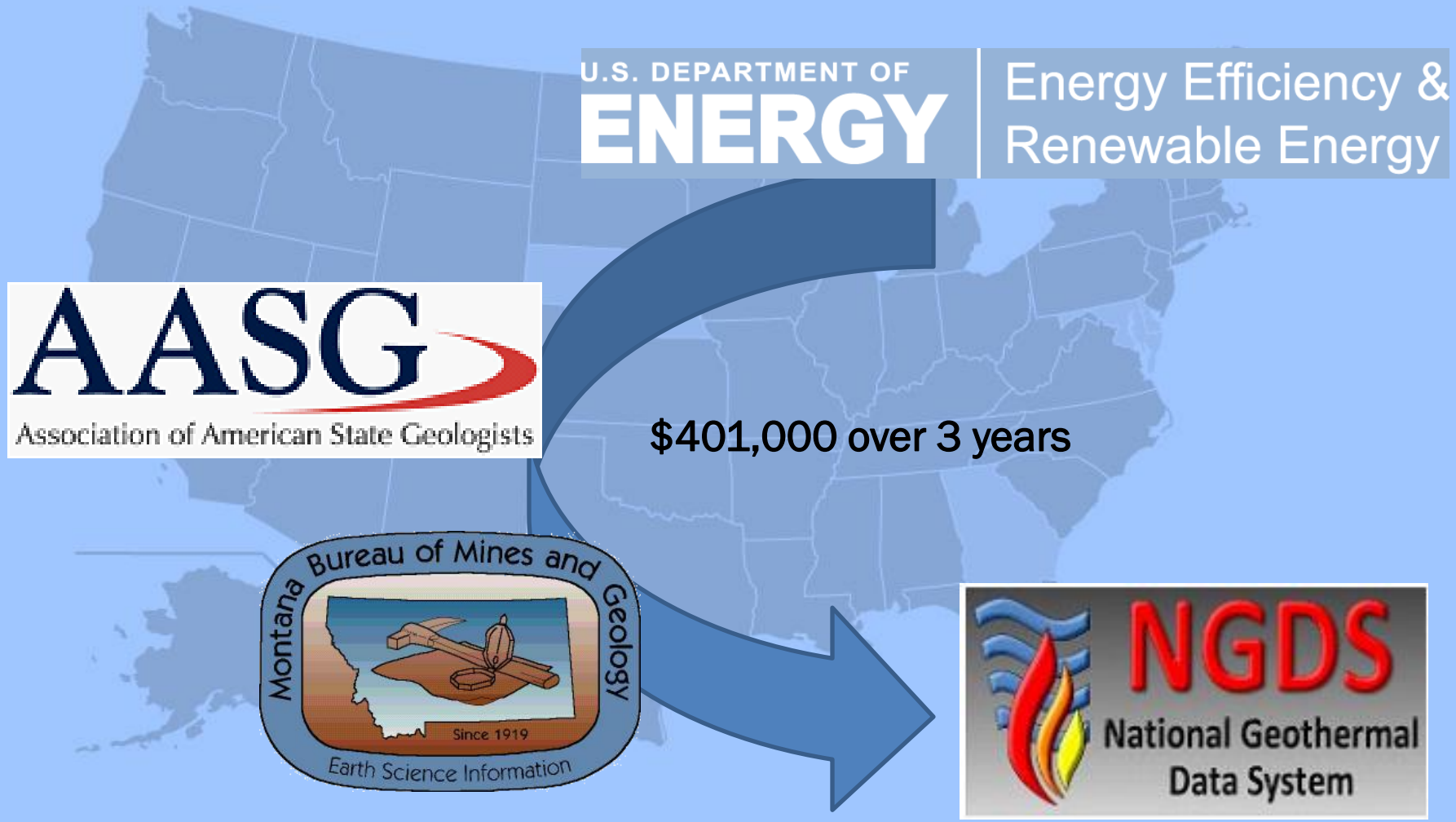

Marget Ann
PERIPHERAL ZONE
Pilot Butte
Badger
?
Granite Mountain
Horseshoe Bend
Lexington
17.4
3.23.00
15.0
4.05.90
Miss
INTERMEDIATE ZONE
Mountain Con
Syndicate Pit
"BARREN" ZONE
Kelley
High Ore
Steward
Anselmo
32.75
6.22.07
CENTRAL ZONE
Montana Tech
17.65
5.02.07
22.14
5.02.07
riginal
Berkeley Pit
Pittsmont #2
Pittsmont #3
Orphan Boy
26.74
6.22.07
Belmont
Pittsmont air shaft
Pittsmont #1
Pittsmont #4
Emma
11.9
3.23.95
Travona
Ophir
12.82
3.29.07
SCALE
0
0.5
1 mile
Temperature C
date
LEGEND
Mine Shaft (bold where sampled)
Connection between mines (dashed where bulkheaded)
After Sales, 1914


Temperature (°F)
0
50
100
150
Butte Drill Hole
Kelley 4600
X Water Temperatures
O Rock Temperatures
(after Miller, 1973)
Elevation (m)
1500
1000
500
0
Elevation (feet)
6000
5000
4000
3000
2000
1000
0
0
50
40
60
70
Temperature (°C)


Temperature °F
0
50
100
150
200
250
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Depth (feet)
Well #1 Temperature (°F)
Well #8 Temperature (°F)
Diamond drill holes

There's plenty more where that came from…

State Geological Survey Contributions to the NGDS



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.

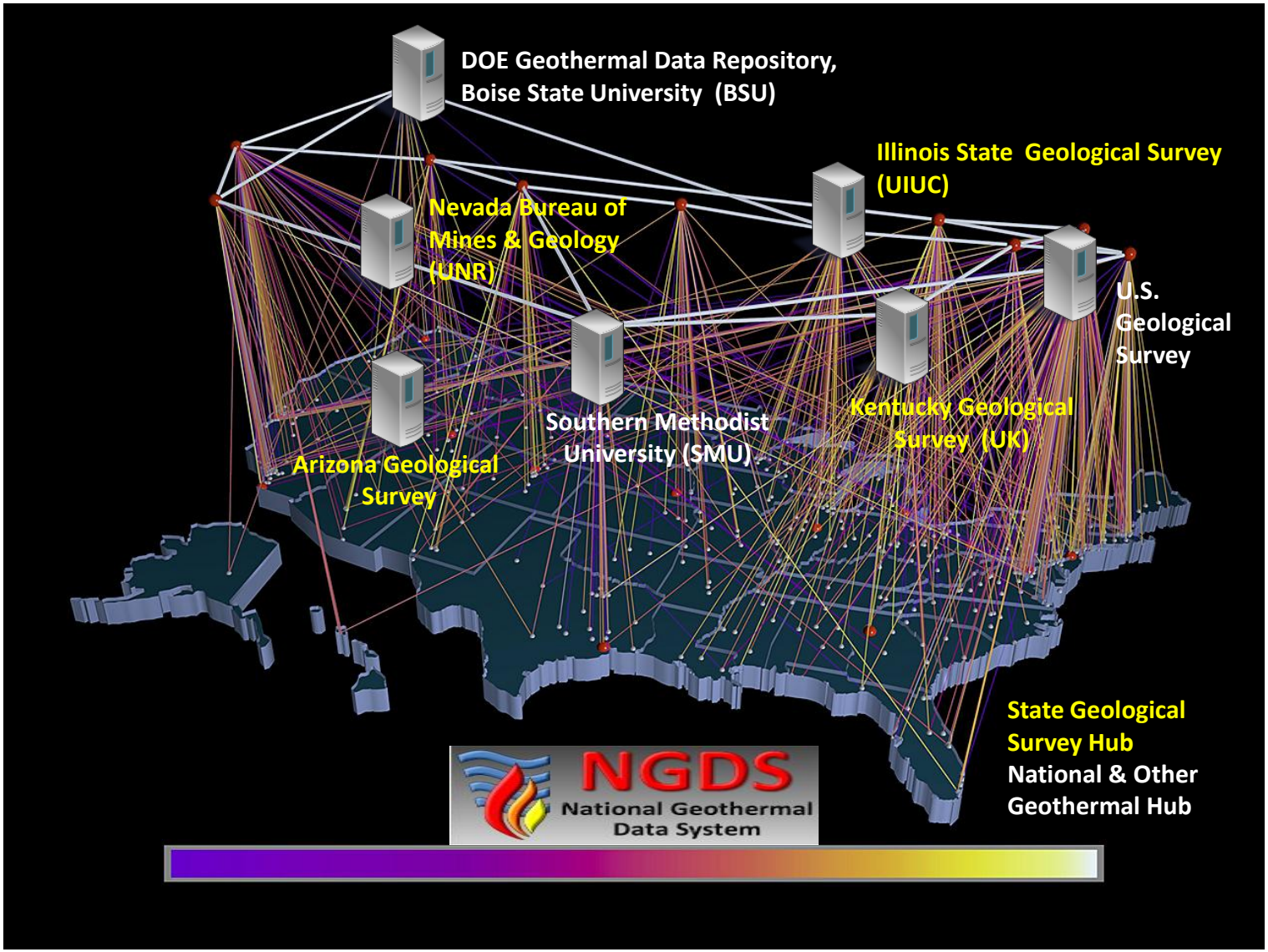
Top 15 Funded States

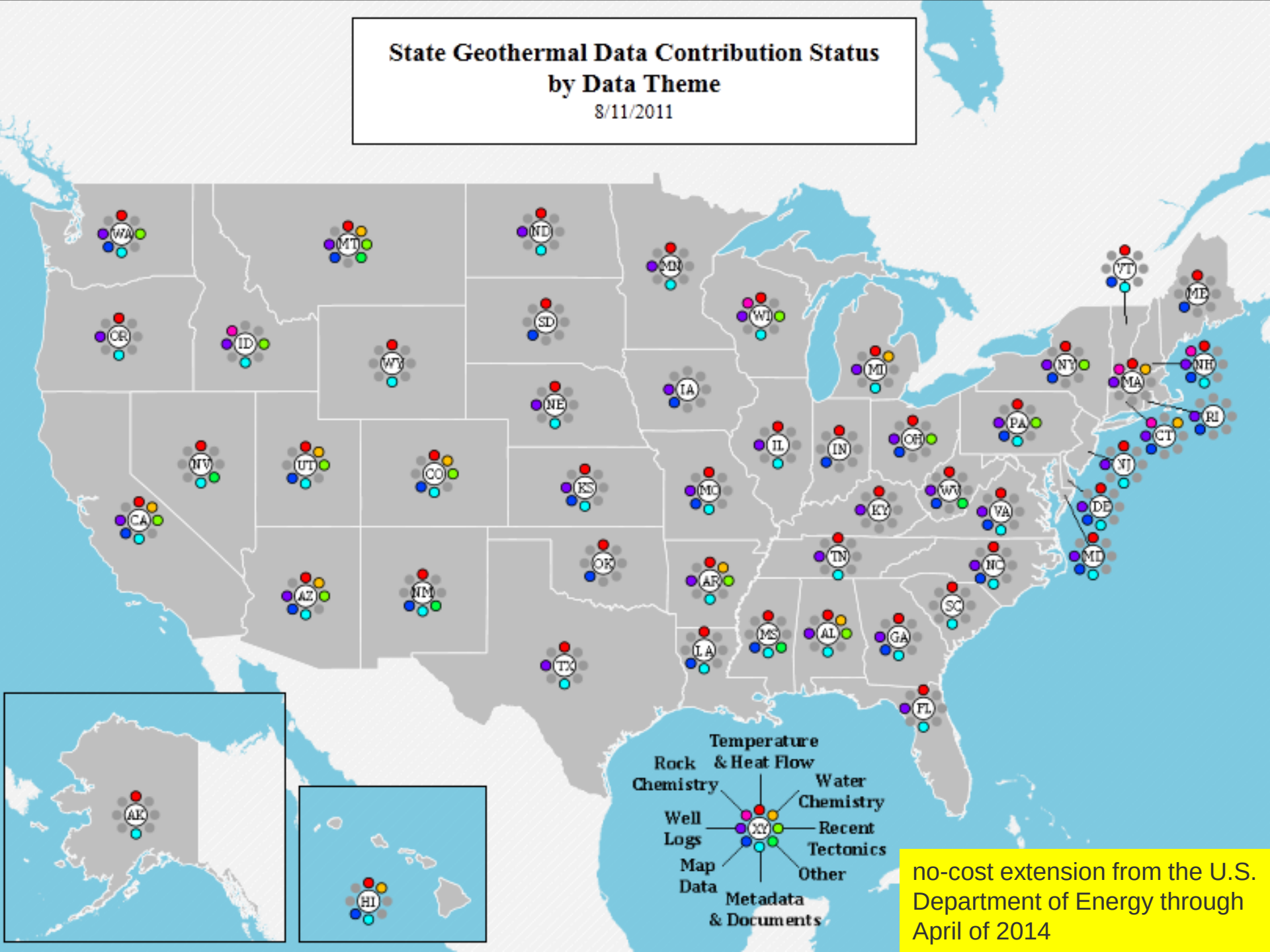
State	Funding Amount
Washington	$1,249,146
Nevada	$1,070,639
Utah	$966,834
Oregon	$958,847
Idaho	$873,562
Texas	$743,481
Colorado	$617,021
New Mexico	$605,483
Kentucky	$585,977
Massachusetts	$515,901
Illinois	$507,809
Hawaii	$499,951
Montana	$401,009
Indiana	$378,499
Wisconsin	$329,135

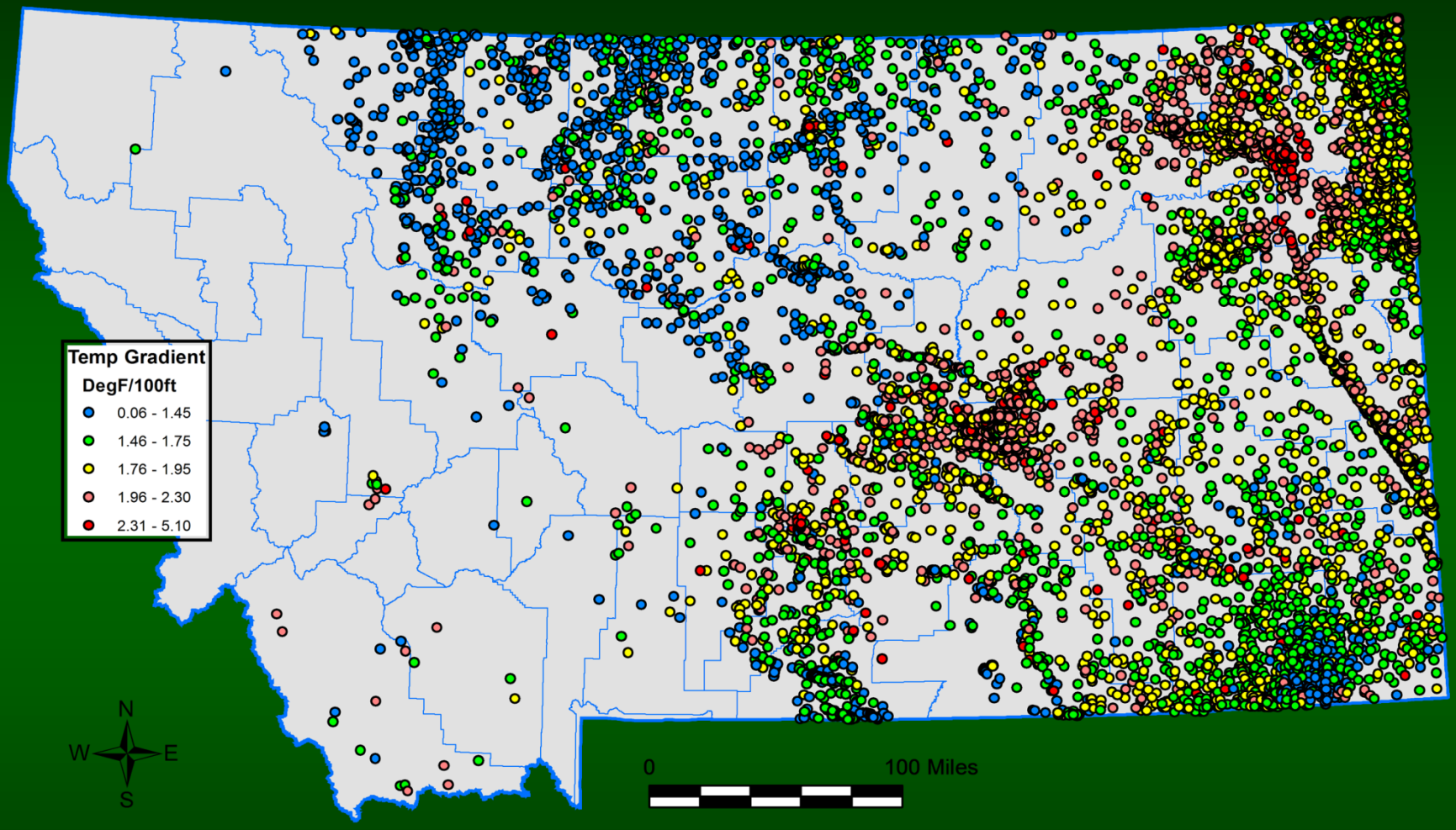
***AZ & CA data collection is part of the AZGS award and is not included in this summary**

NGDS Architecture: An Integrated, Distributed Data Network

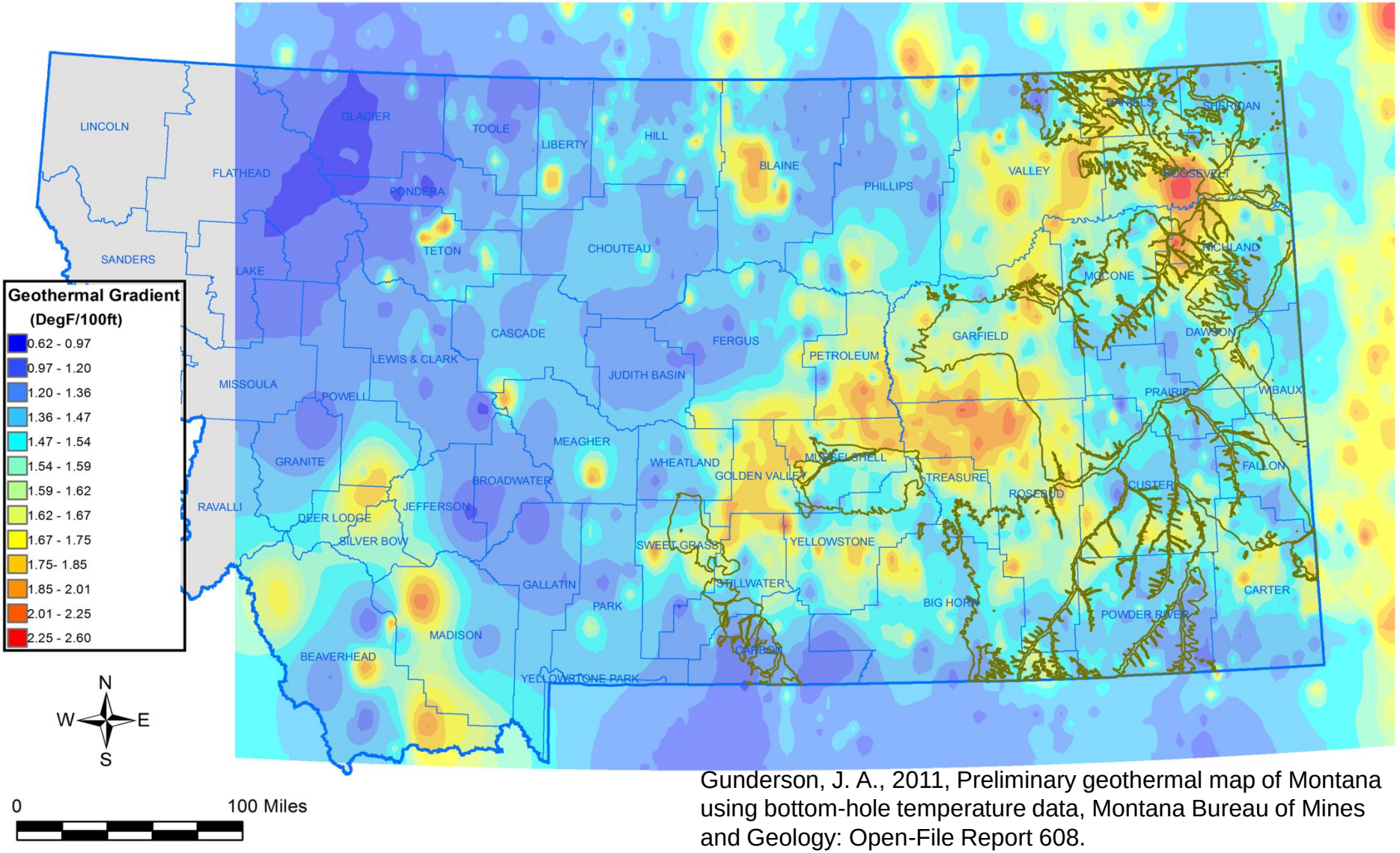
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy




State Geothermal Data Contribution Status
by Data Theme
8/11/2011
Temperature
& Heat Flow
Rock
Chemistry
Water
Chemistry
Well
Logs
Recent
Tectonics
Map
Data
Other
Metadata
& Documents
XY
no-cost extension from the U.S. Department of Energy through April of 2014



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

NGDS
National Geothermal Data System

Contents

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