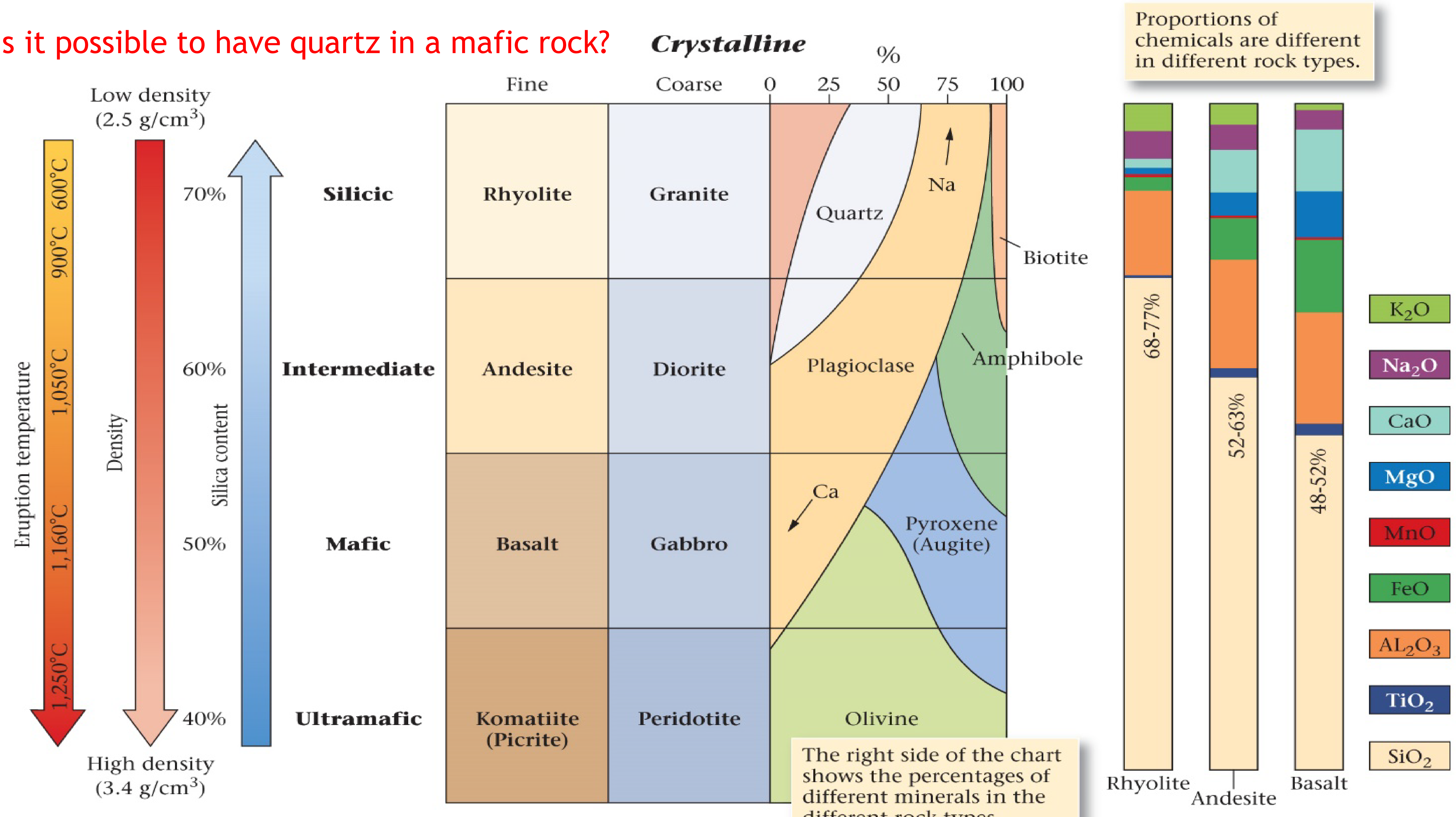
Economic Geology Minnesota & Iowa

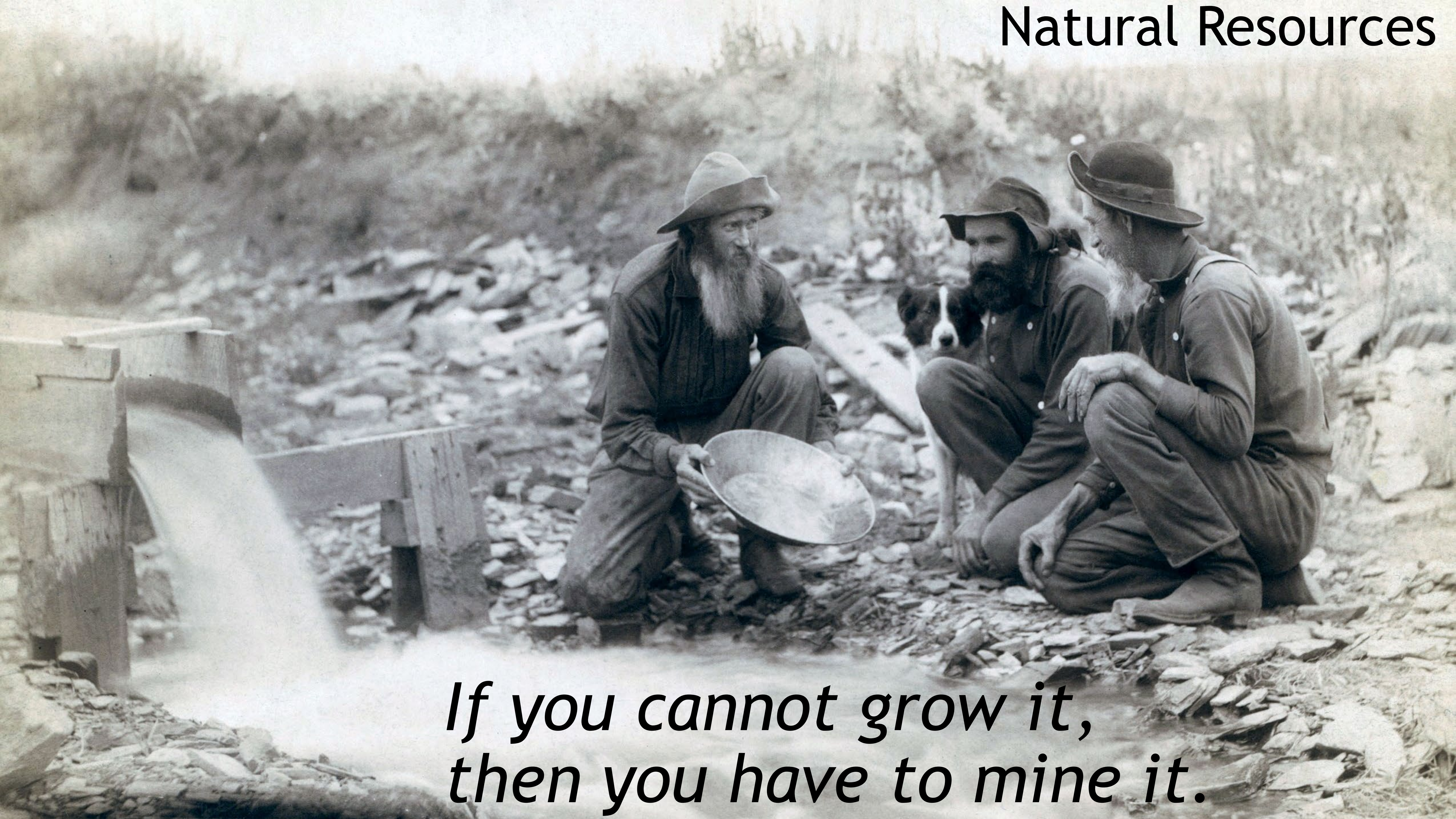
Mafic

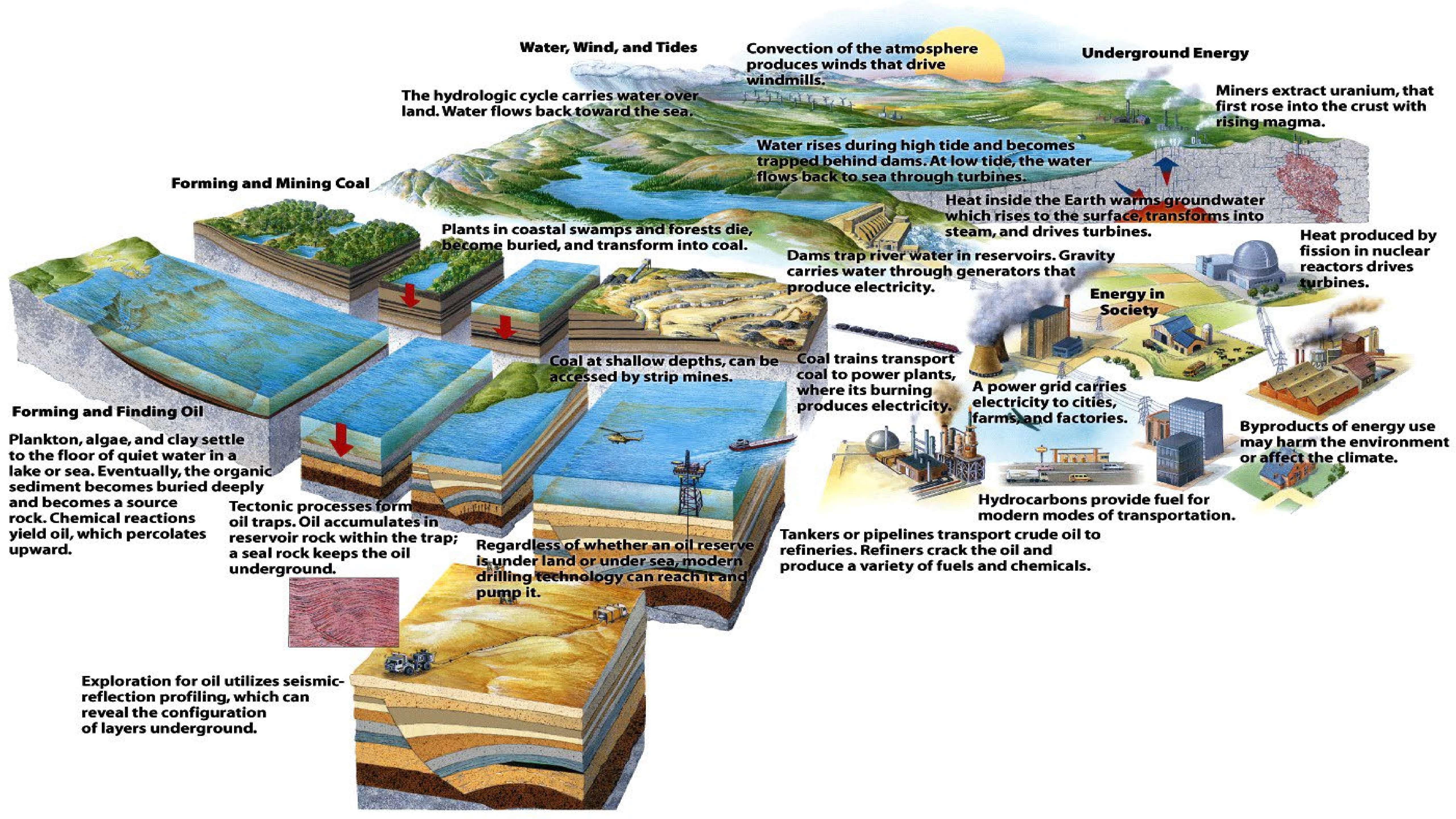
University of Northern Iowa
Dr. Chad Heinzel
With borrowed images from Marshak's Earth Portrait of a Planet
Ray Anderson and others

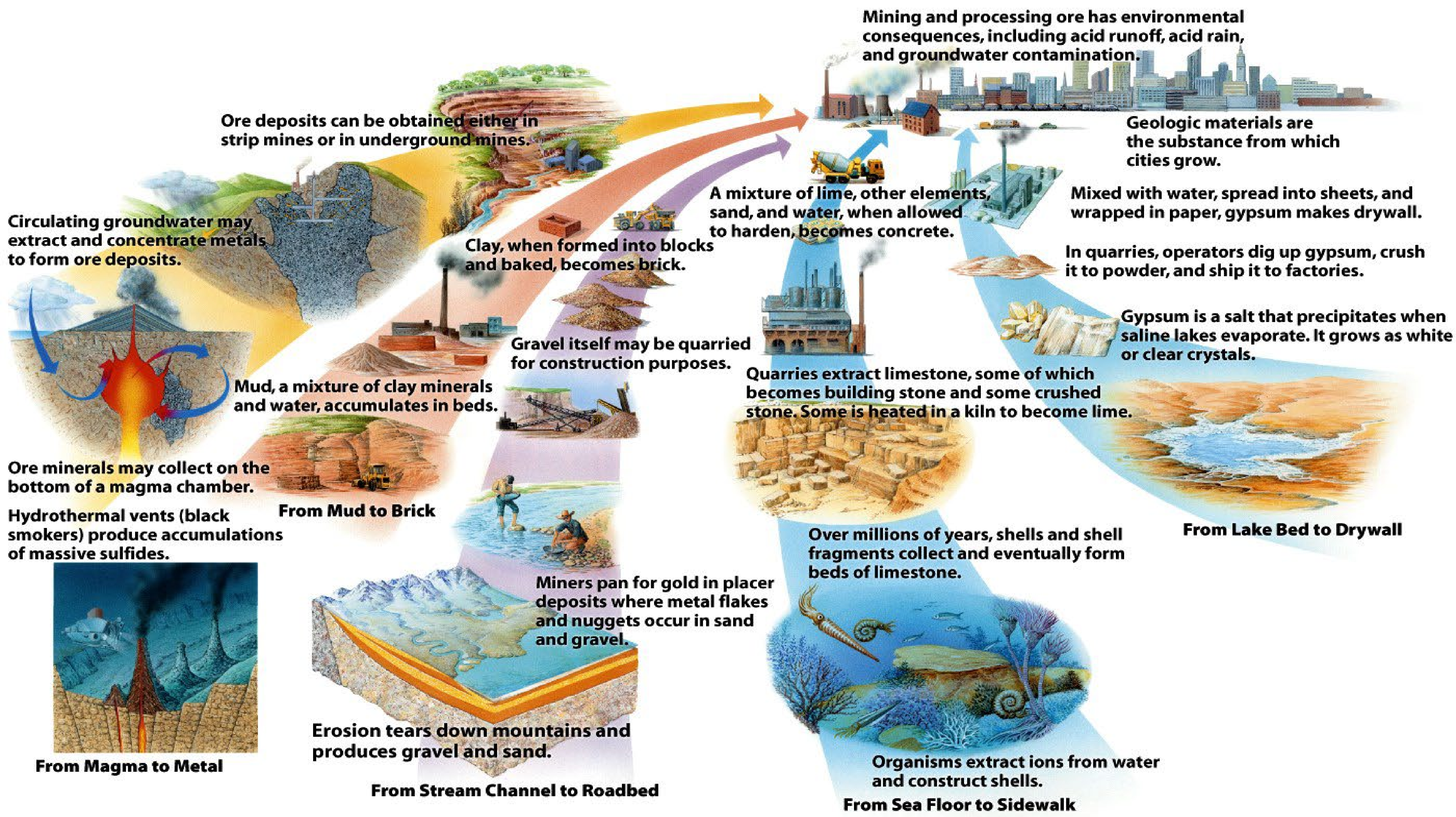
Is it possible to have quartz in a mafic rock?

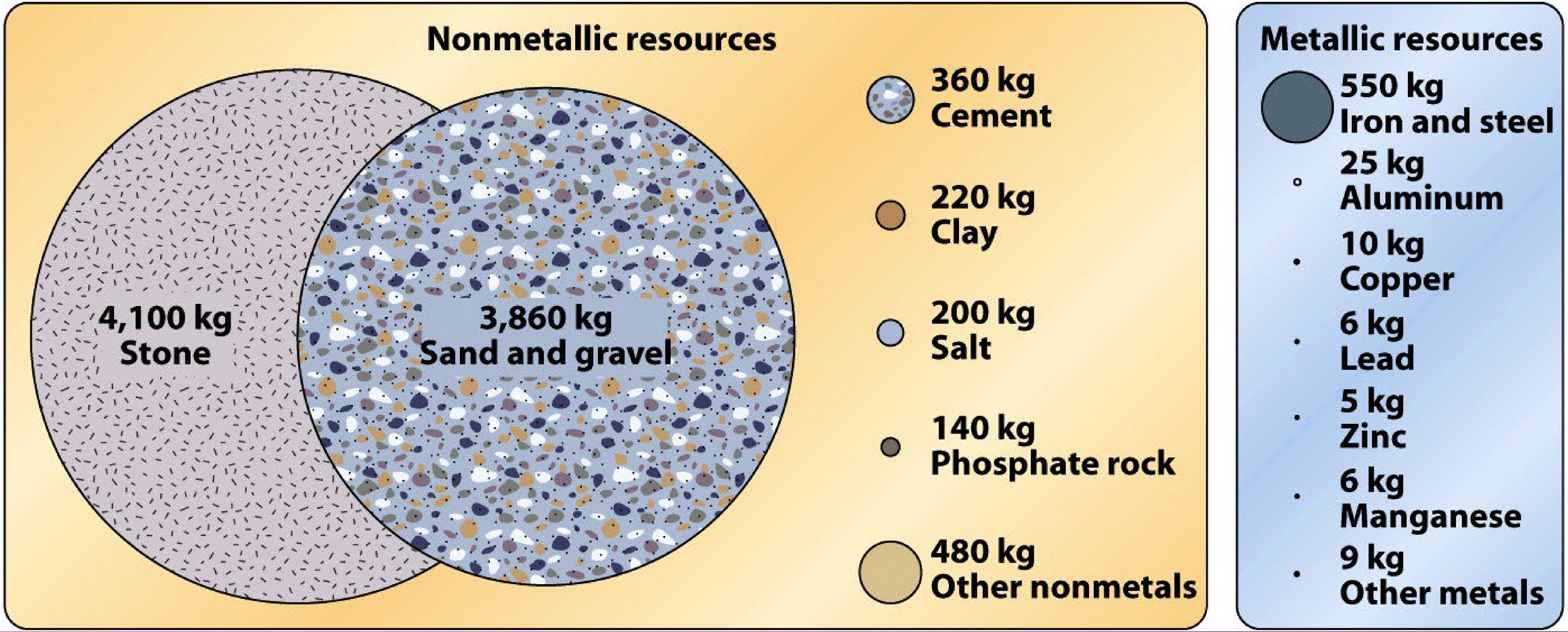


(a)


Natural Resources
If you cannot grow it,
then you have to mine it.


Water, Wind, and Tides
Convection of the atmosphere produces winds that drive windmills.
Underground Energy
The hydrologic cycle carries water over land. Water flows back toward the sea.
Miners extract uranium, that first rose into the crust with rising magma.
Water rises during high tide and becomes trapped behind dams. At low tide, the water flows back to sea through turbines.
Forming and Mining Coal
Heat inside the Earth warms groundwater which rises to the surface, transforms into steam, and drives turbines.
Plants in coastal swamps and forests die, become buried, and transform into coal.
Heat produced by fission in nuclear reactors drives turbines.
Dams trap river water in reservoirs. Gravity carries water through generators that produce electricity.
Energy in Society
Coal at shallow depths, can be accessed by strip mines.
Coal trains transport coal to power plants, where its burning produces electricity.
A power grid carries electricity to cities, farms, and factories.
Forming and Finding Oil
Plankton, algae, and clay settle to the floor of quiet water in a lake or sea. Eventually, the organic sediment becomes buried deeply and becomes a source rock. Chemical reactions yield oil, which percolates upward.
Byproducts of energy use may harm the environment or affect the climate.
Tectonic processes form oil traps. Oil accumulates in reservoir rock within the trap; a seal rock keeps the oil underground.
Hydrocarbons provide fuel for modern modes of transportation.
Tankers or pipelines transport crude oil to refineries. Refiners crack the oil and produce a variety of fuels and chemicals.
Regardless of whether an oil reserve is under land or under sea, modern drilling technology can reach it and pump it.
Exploration for oil utilizes seismic-reflection profiling, which can reveal the configuration of layers underground.


Mining and processing ore has environmental consequences, including acid runoff, acid rain, and groundwater contamination.
Geologic materials are the substance from which cities grow.
Ore deposits can be obtained either in strip mines or in underground mines.
Circulating groundwater may extract and concentrate metals to form ore deposits.
Clay, when formed into blocks and baked, becomes brick.
A mixture of lime, other elements, sand, and water, when allowed to harden, becomes concrete.
Mixed with water, spread into sheets, and wrapped in paper, gypsum makes drywall.
In quarries, operators dig up gypsum, crush it to powder, and ship it to factories.
Gypsum is a salt that precipitates when saline lakes evaporate. It grows as white or clear crystals.
Gravel itself may be quarried for construction purposes.
Quarries extract limestone, some of which becomes building stone and some crushed stone. Some is heated in a kiln to become lime.
Mud, a mixture of clay minerals and water, accumulates in beds.
Ore minerals may collect on the bottom of a magma chamber.
From Mud to Brick
Hydrothermal vents (black smokers) produce accumulations of massive sulfides.
Over millions of years, shells and shell fragments collect and eventually form beds of limestone.
From Lake Bed to Drywall
Miners pan for gold in placer deposits where metal flakes and nuggets occur in sand and gravel.
Erosion tears down mountains and produces gravel and sand.
From Magma to Metal
Organisms extract ions from water and construct shells.
From Stream Channel to Roadbed
From Sea Floor to Sidewalk


Nonmetallic resources
4,100 kg
Stone
3,860 kg
Sand and gravel
360 kg
Cement
220 kg
Clay
200 kg
Salt
140 kg
Phosphate rock
480 kg
Other nonmetals
Metallic resources
550 kg
Iron and steel
25 kg
Aluminum
10 kg
Copper
6 kg
Lead
5 kg
Zinc
6 kg
Manganese
9 kg
Other metals

Metal	Mineral Name	Chemical Formula
Copper	Chalcocite	Cu_2S
	Chalcopyrite	$CuFeS_2$
	Bornite	Cu_5FeS_4
	Azurite	$Cu_3(CO_3)_2(OH)_2$
	Malachite	$Cu_2(CO_3)(OH)_2$
Iron	Hematite	Fe_2O_3
	Magnetite	Fe_3O_4
Tin	Cassiterite	SnO_2
Lead	Galena	PbS
Mercury	Cinnabar	HgS
Zinc	Sphalerite	ZnS
Aluminum	Kaolinite	$Al_2Si_2O_5(OH)_4$
	Corundum	Al_2O_3
Chrome	Chromite	$(Fe,Mg)(Cr,Al,Fe)2O_4$
Nickel	Pentlandite	$(Ni,Fe)_9S_8$
Titanium	Rutile	TiO_2
	Ilmenite	$FeTiO_3$
Tungsten	Sheelite	$CaWO_4$
Molybdenum	Molybdenite	MoS_2
Magnesium	Magnesite	$MgCO_3$
	Dolomite	$CaMg(CO_3)_2$
Manganese	Pyrolusite	MnO_2
	Rhodochrosite	$MnCO_3$

Metal	World Resources	U.S. Resources
Iron	120	40
Aluminum	330	2
Copper	65	40
Lead	20	40
Zinc	30	25
Gold	30	20
Platinum	45	1
Nickel	75	less than 1
Cobalt	50	less than 1
Manganese	70	0
Chromium	75	0

National Security

> "RELIABLE ACCESS TO CRITICAL MINERALS IS A MATTER OF BOTH ECONOMIC AND GEOSTRATEGIC IMPORTANCE TO THE UNITED STATES. ALTHOUGH CONCERN ABOUT ACCESS TO MINERALS WAXES AND WANES, IT IS RISING NOW DUE TO INCREASING DEMAND, NEW COMPETITORS CAPTURING LARGE MARKET SHARES AND OTHER TRENDS THAT DEFY EASY PREDICTION. THESE SAME TRENDS CAN INTERFERE WITH FOREIGN AND DEFENSE POLICY GOALS AND GIVE MINERAL SUPPLIERS EASY LEVERAGE OVER THE UNITED STATES AND OTHER COUNTRIES RELIANT ON GLOBAL SUPPLY CHAINS."
>
> CHRISTINE PARTHEMORE
> FORMER FELLOW
> CENTER FOR A NEW AMERICAN SECURITY

Top 10 Standard Materials

Used by Department of Defense

		Regular DoD Demand in STONS/YR
1	ALUMINUM METAL	275,219.8
2	COPPER	105,625.8
3	LEAD	88,464.8
4	FLUORSPAR ACID GRADE	56,544.5
5	ZINC	51,085.5
6	RUBBER (NATURAL)	29,490.3
7	MANGANESE ORE CHEM/METAL GRADE	25,041.8
8	NICKEL	17,311.8
9	CHROMIUM FERRO (FERROCHROMIUM)	9,667.8
10	CHROMITE ORE (ALL GRADES)	9,630.5

Source: "Reconfiguration of the National Defense Stockpile Report to Congress," U.S. Department of Defense, April 2009.

Rhenium
Nickel

+

Lanthanum
Gadolinium
Yttrium

+

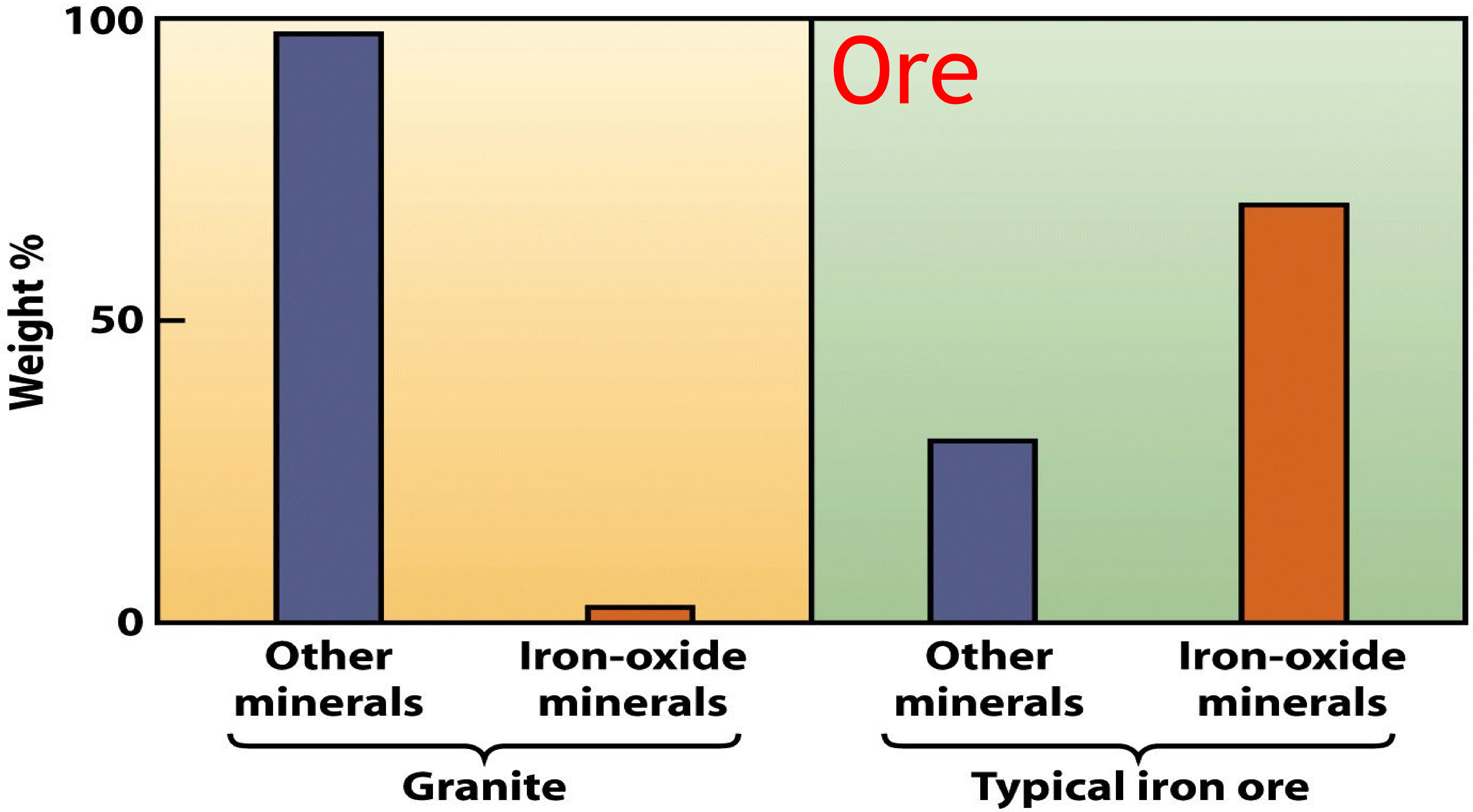
Aluminum
Copper

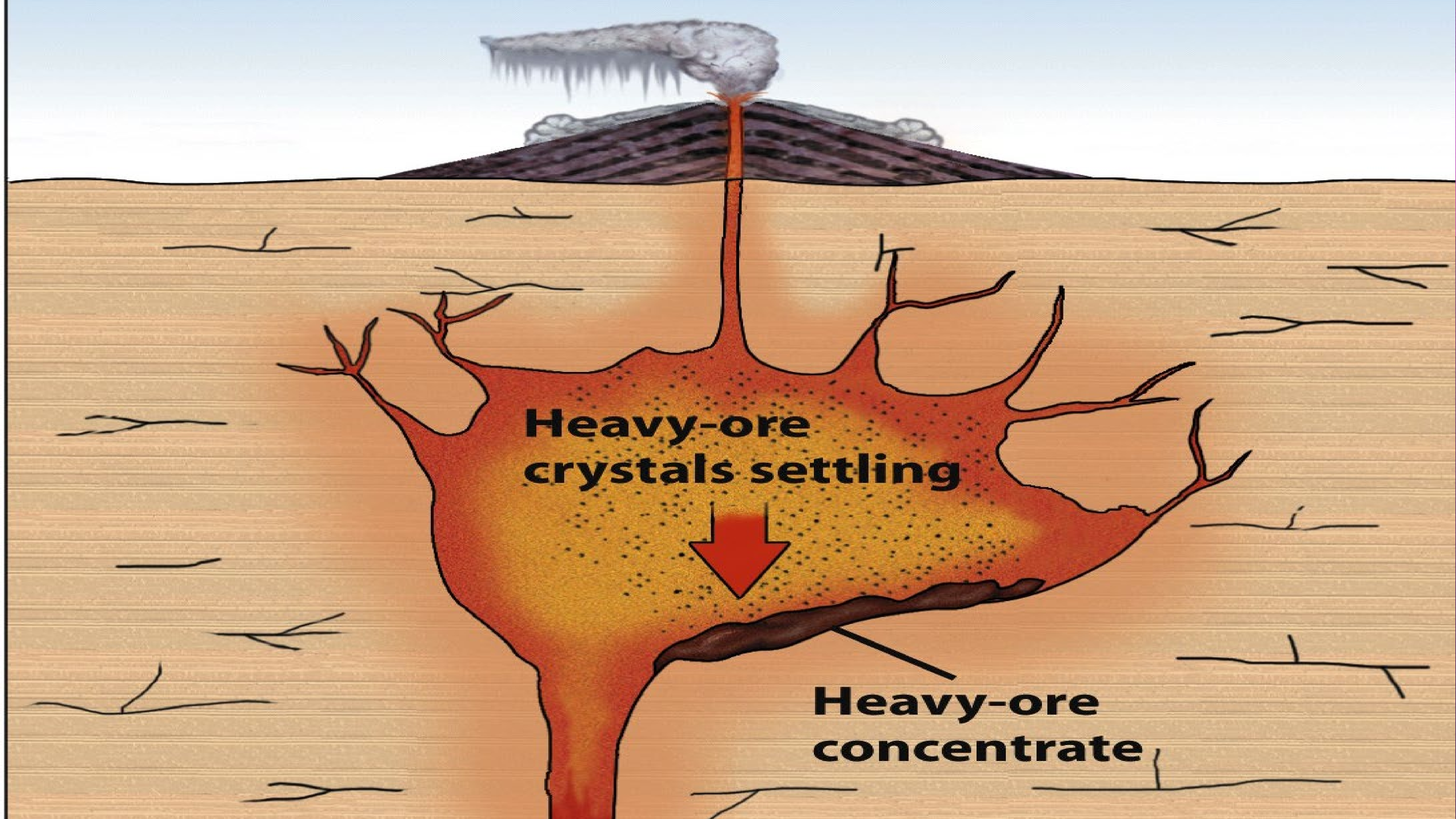
+

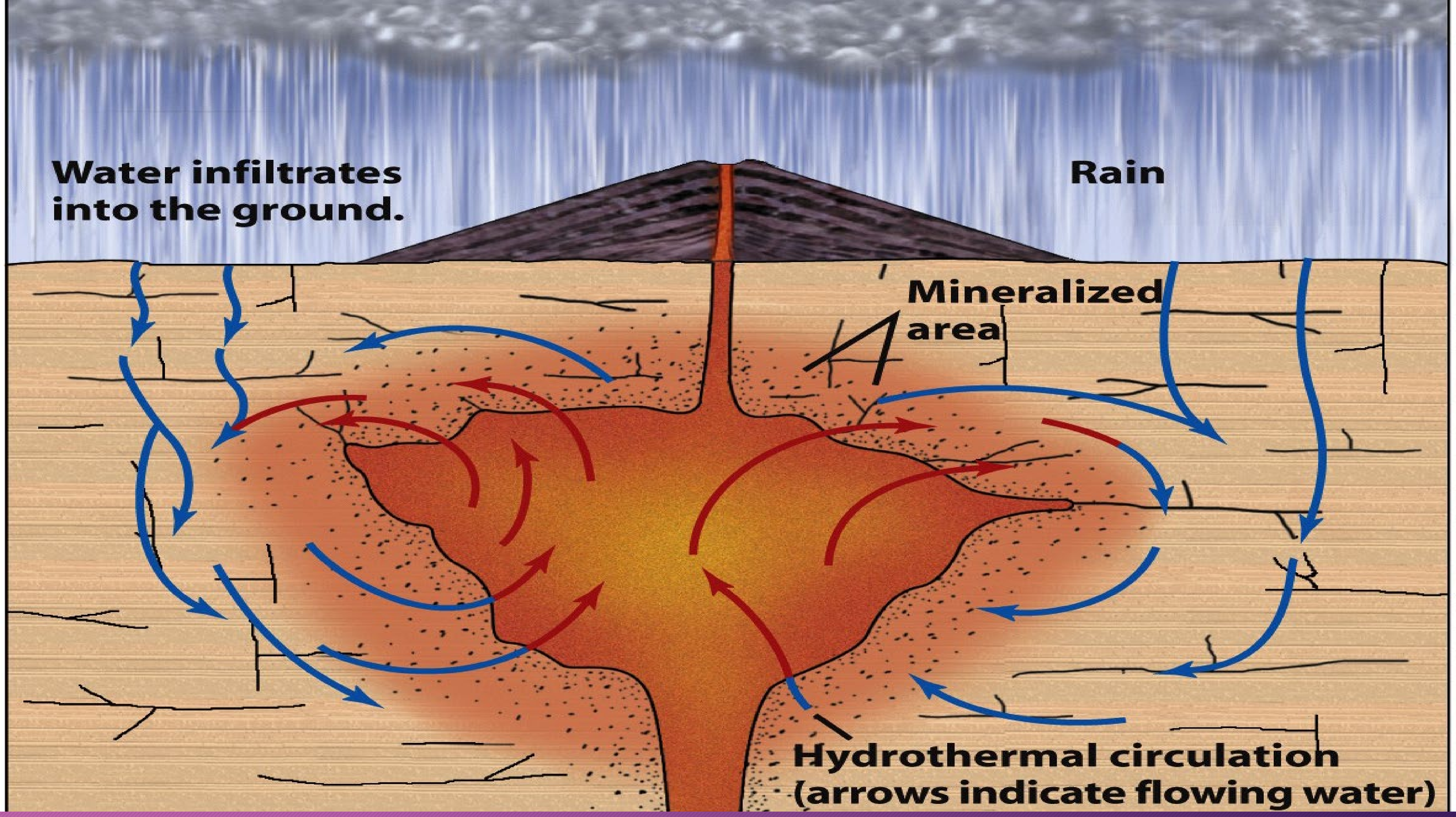
Manganese
Molybdenum

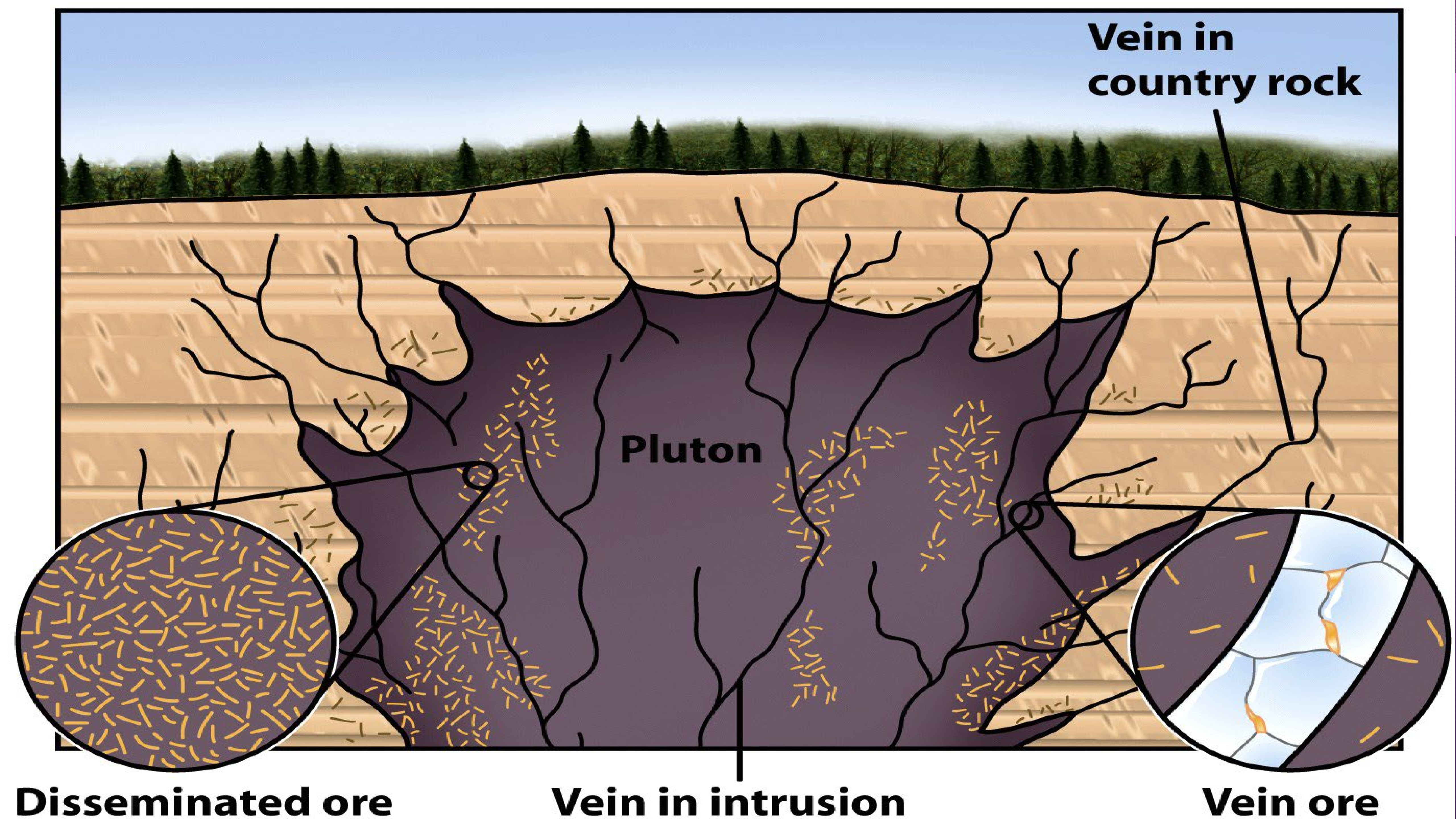
=

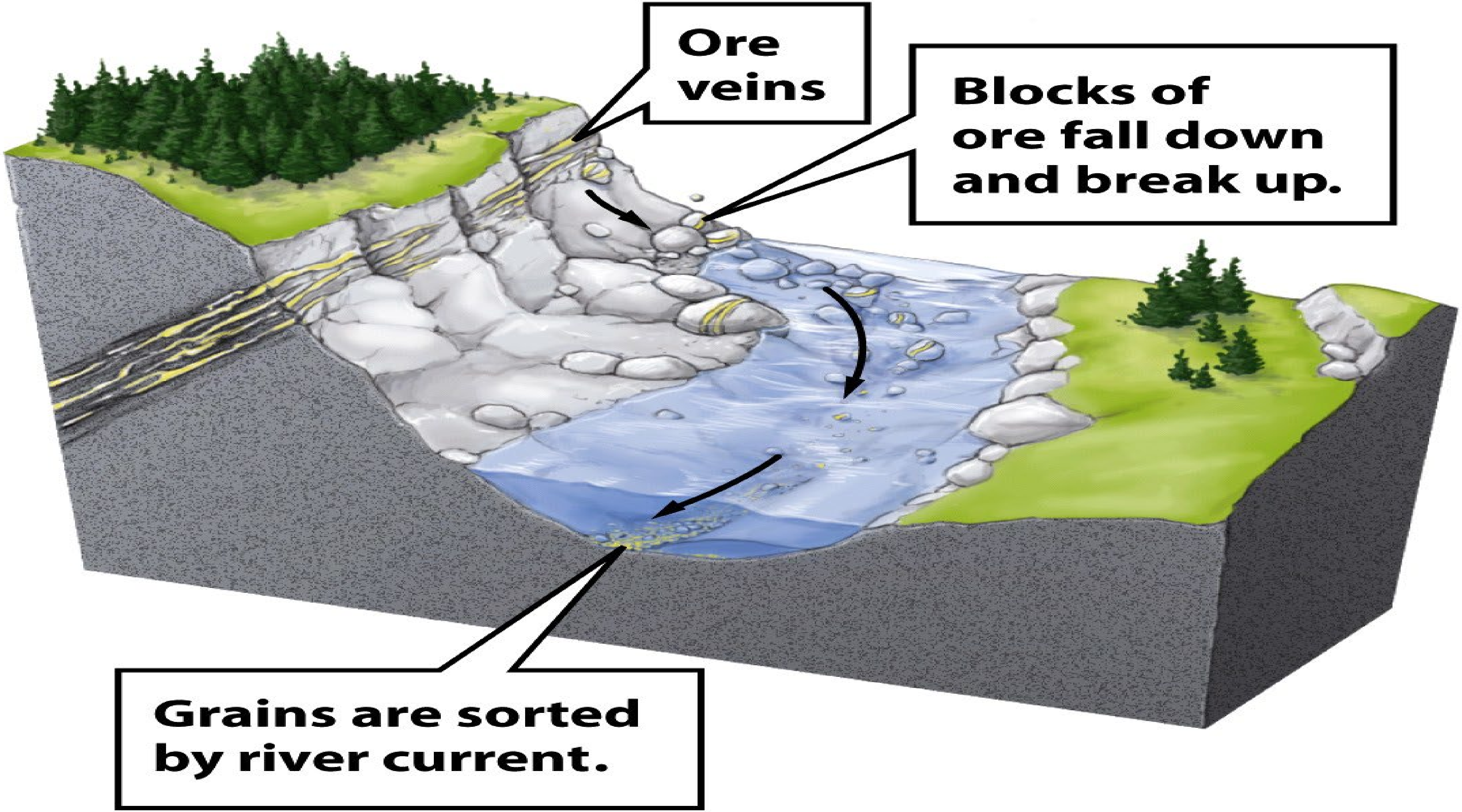
Nearly 750,000
Tons
of Minerals Annually


Ore
100
50
0
Weight %
Other minerals
Iron-oxide minerals
Granite
Other minerals
Iron-oxide minerals
Typical iron ore


Heavy-ore
crystals settling
Heavy-ore
concentrate


Water infiltrates into the ground.
Rain
Mineralized area
Hydrothermal circulation (arrows indicate flowing water)

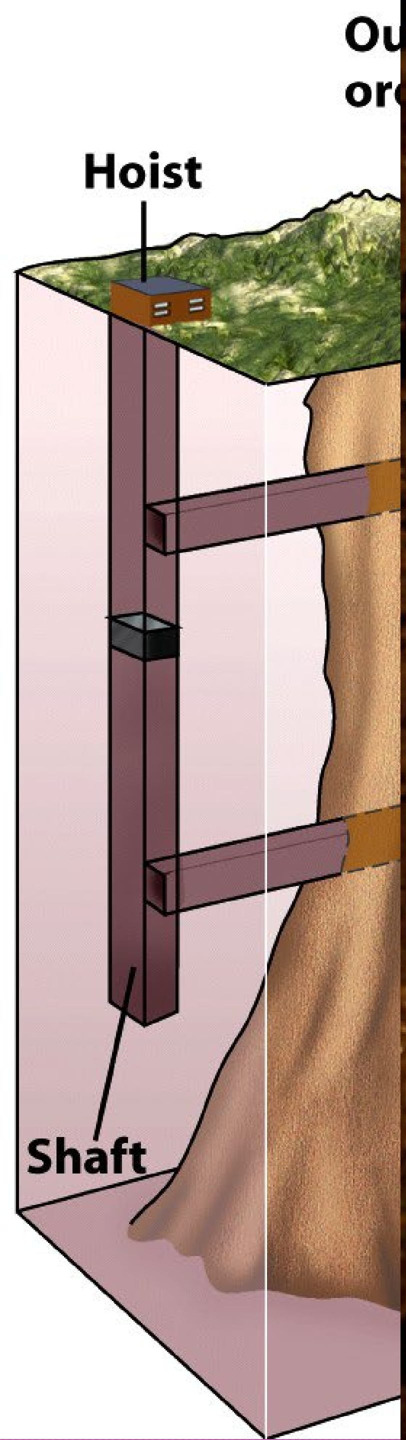

Vein in
country rock
Pluton
Disseminated ore
Vein in intrusion
Vein ore



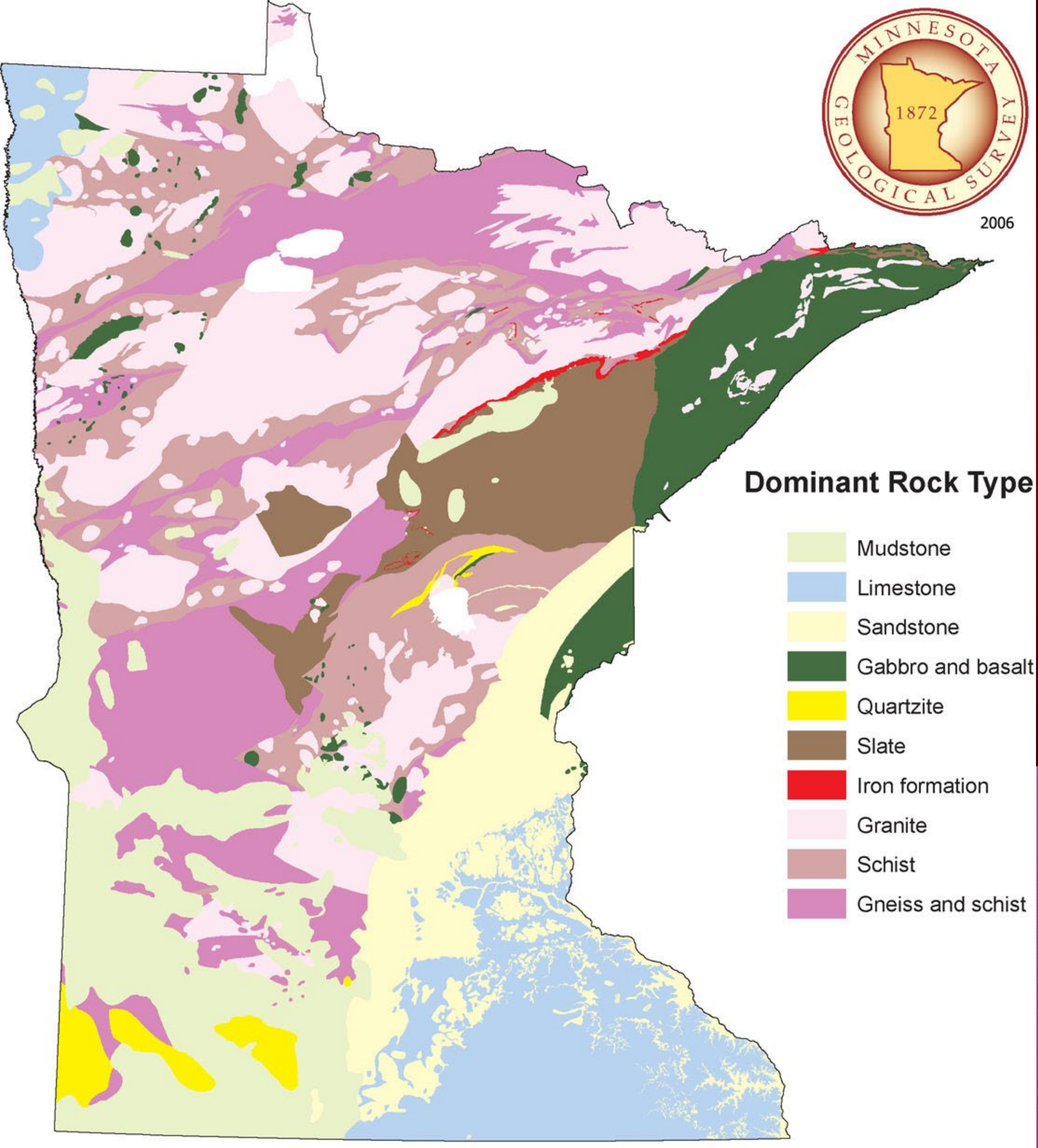
Ore veins
Blocks of ore fall down and break up.
Grains are sorted by river current.

Homestake
Gold Mine
Lead
S. Dakota

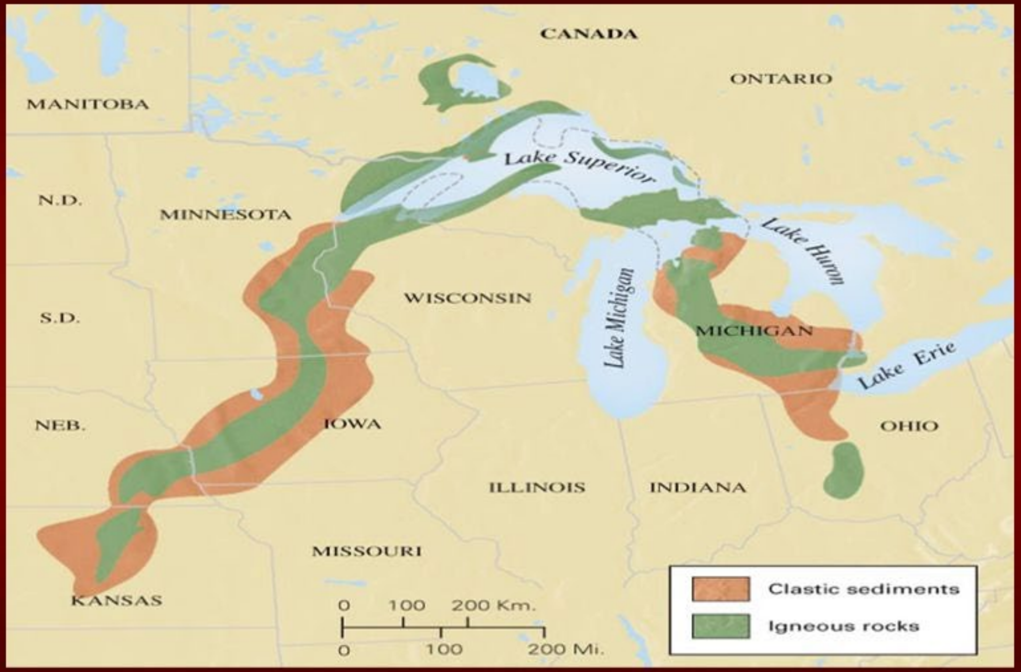

© V.C. Wald 2007


Hoist
Shaft

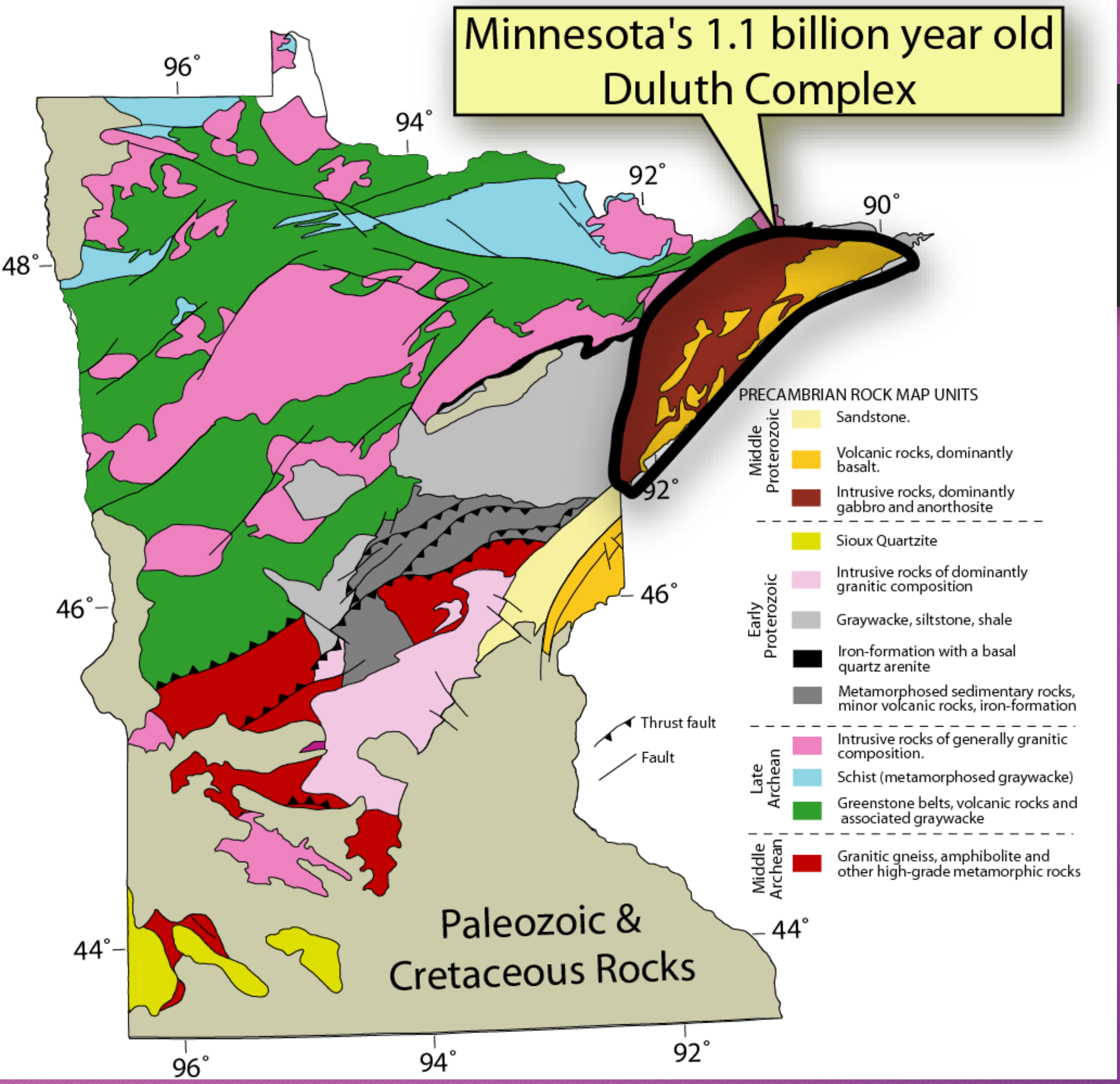

Minerals & Rocks of Northern Minnesota



Map of Mid-continent Rift



- ~2500 km long and 150-200 km wide



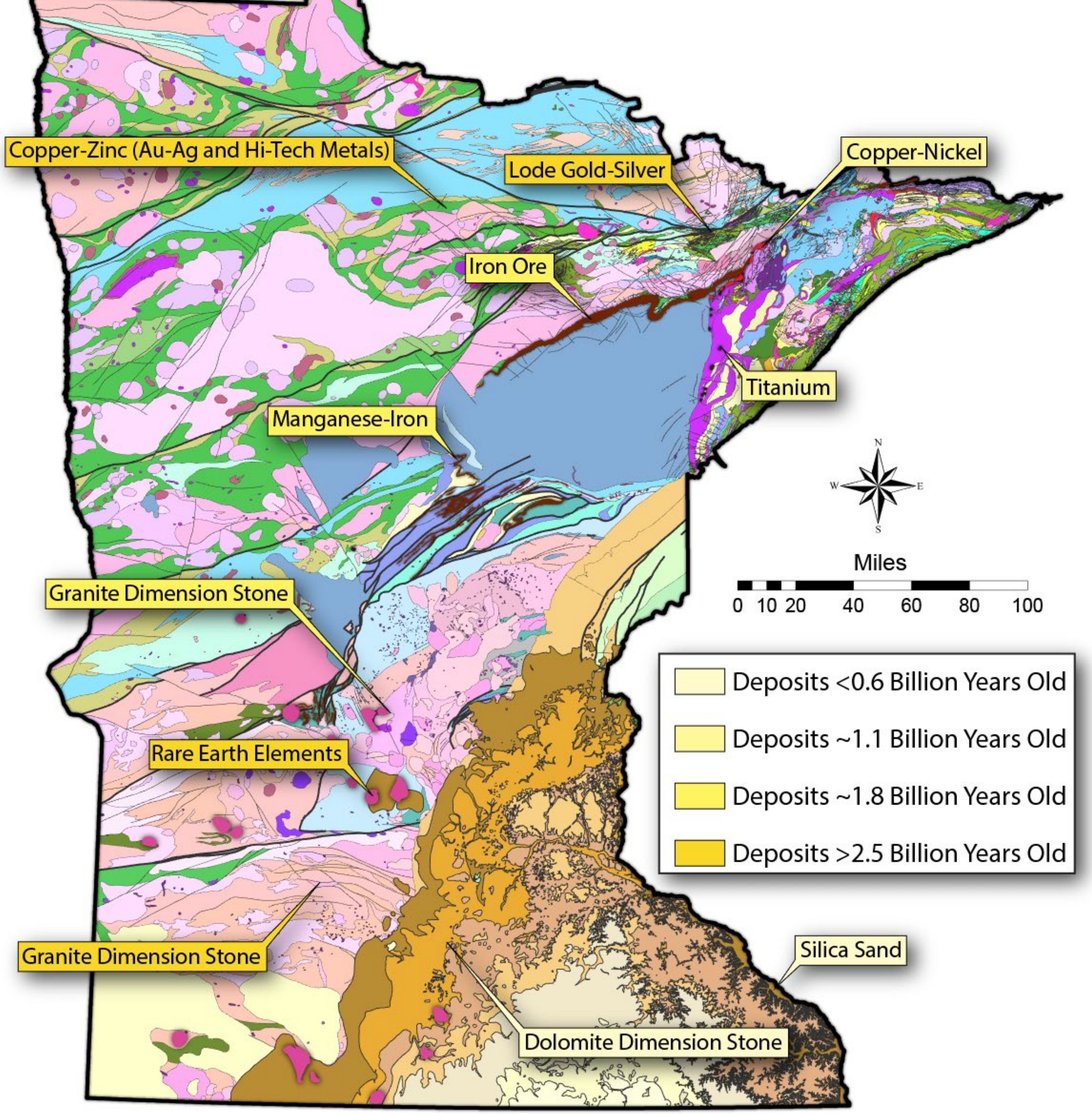
1.1 Billion year old Duluth Complex

Deposition of great quantities of metal in igneous intrusions derived from melting the Earth's Mantle.

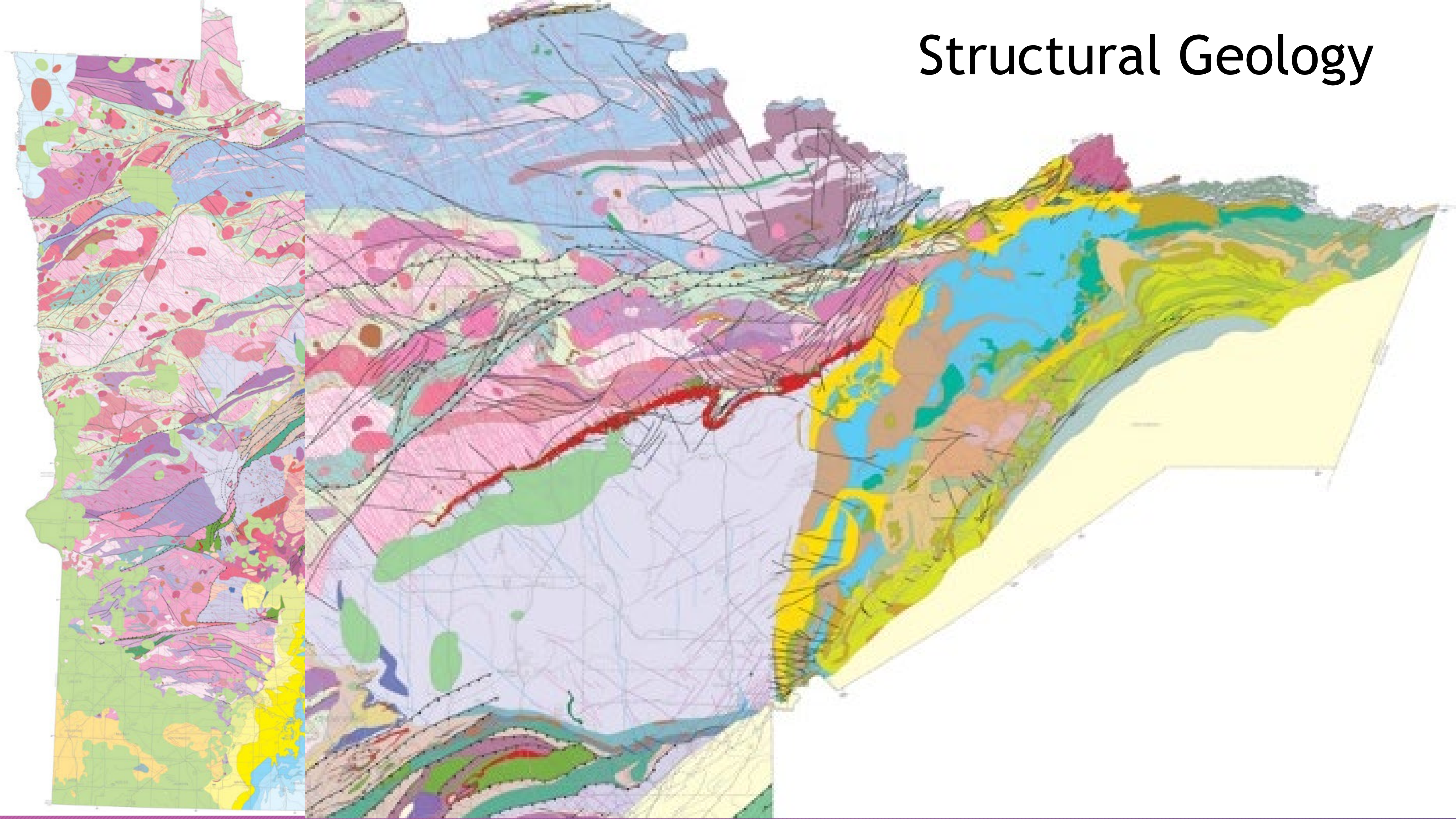
Cu-Ni-PGE

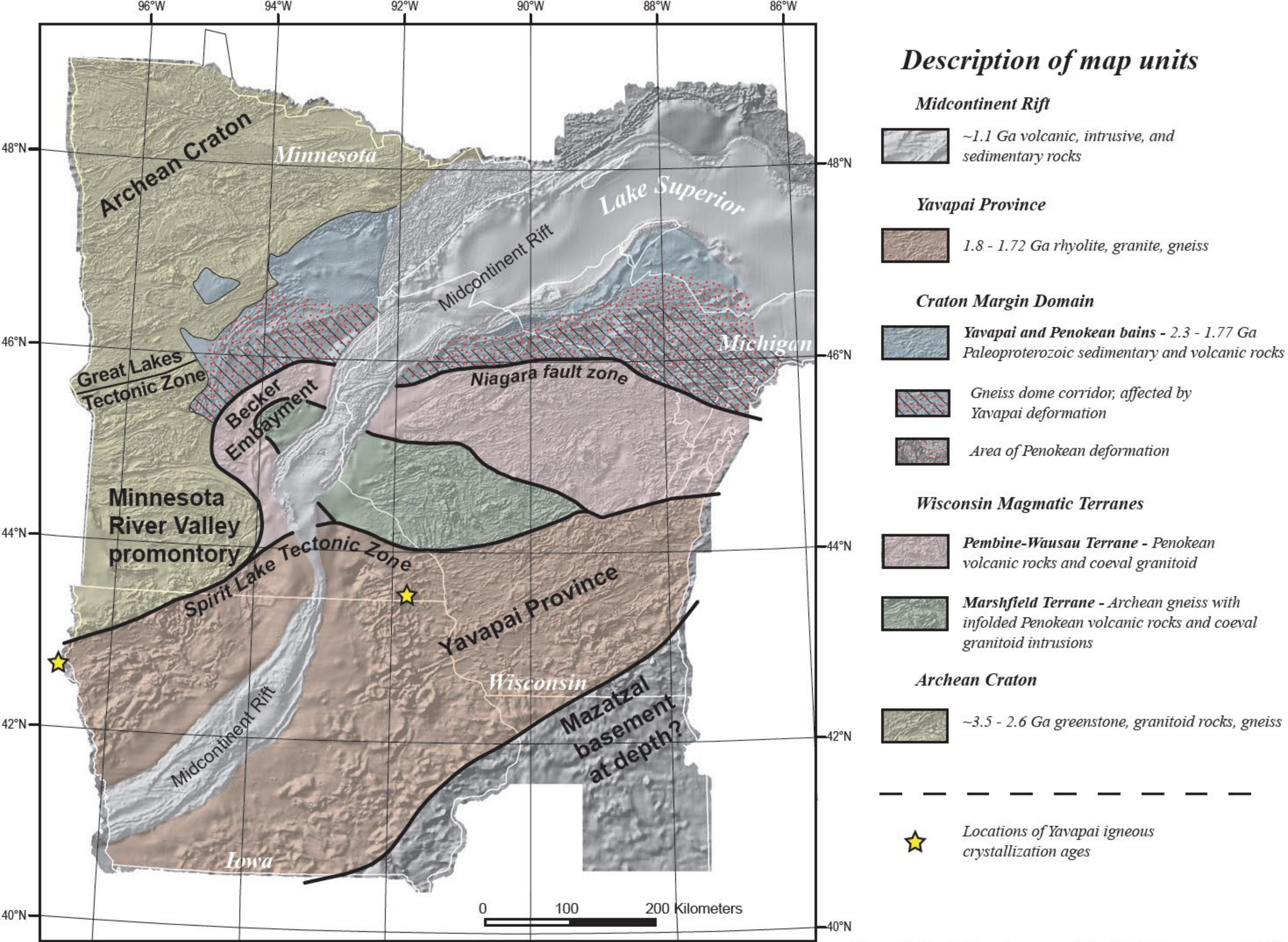
TiO_2

Minnesota Minerals



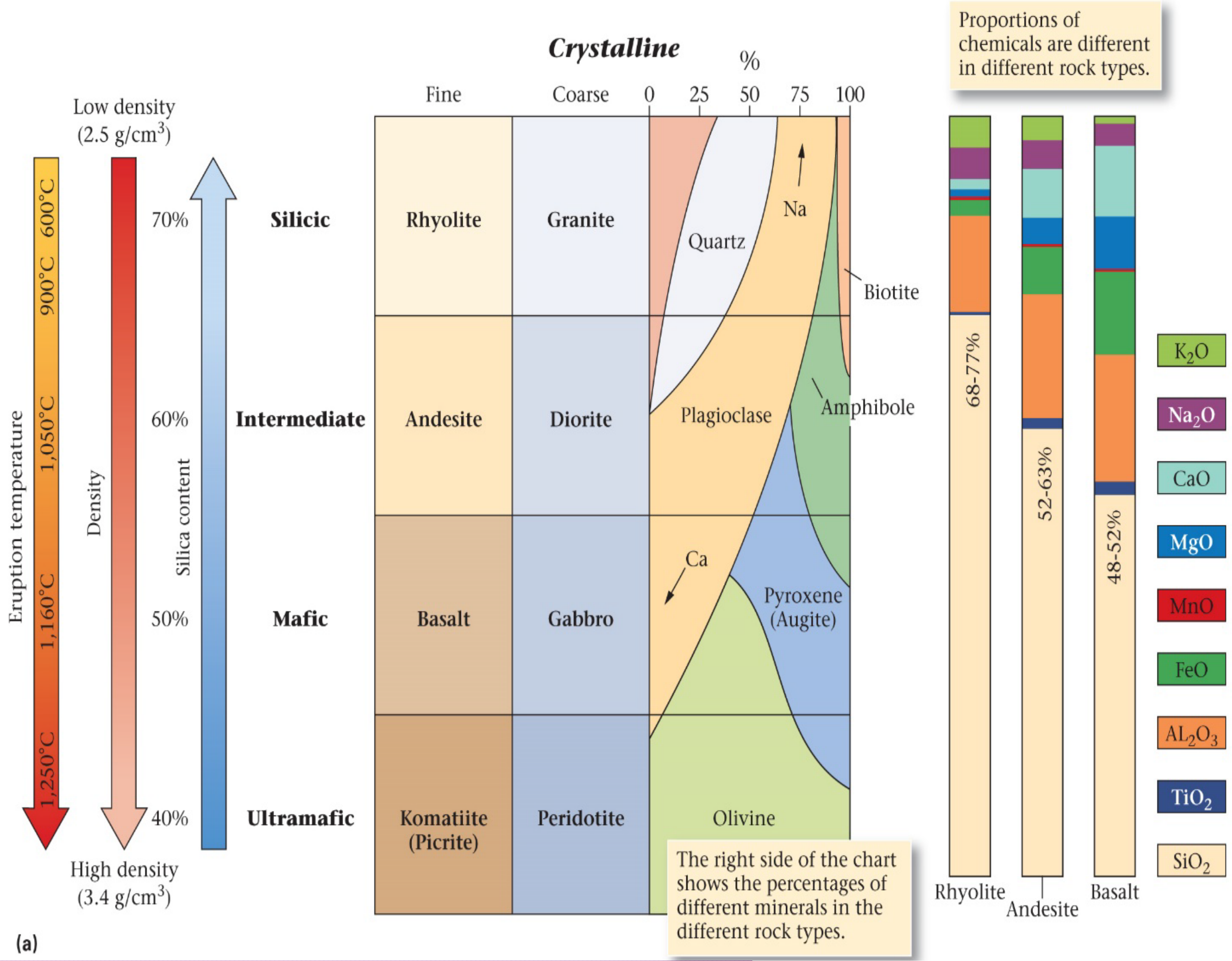
Structural Geology





(Compiled by T. Boerboom and the NICE Geo-group, 2006)

One of Chad’s Favorite MN Rocks
Q1 – Name it, then discuss how does it formed?



Crystalline
Fine
Coarse
%
0 25 50 75 100
Low density
(2.5 g/cm³)
High density
(3.4 g/cm³)
Eruption temperature
600°C 900°C 1,050°C 1,160°C 1,250°C
Density
Silica content
70%
60%
50%
40%
Silicic
Intermediate
Mafic
Ultramafic
Rhyolite
Andesite
Basalt
Komatiite (Picrite)
Granite
Diorite
Gabbro
Peridotite
Quartz
Na
Plagioclase
Ca
Biotite
Amphibole
Pyroxene (Augite)
Olivine
The right side of the chart shows the percentages of different minerals in the different rock types.
Proportions of chemicals are different in different rock types.
68-77%
52-63%
48-52%
Rhyolite
Andesite
Basalt
K2O
Na2O
CaO
MgO
MnO
FeO
AL2O3
TiO2
SiO2

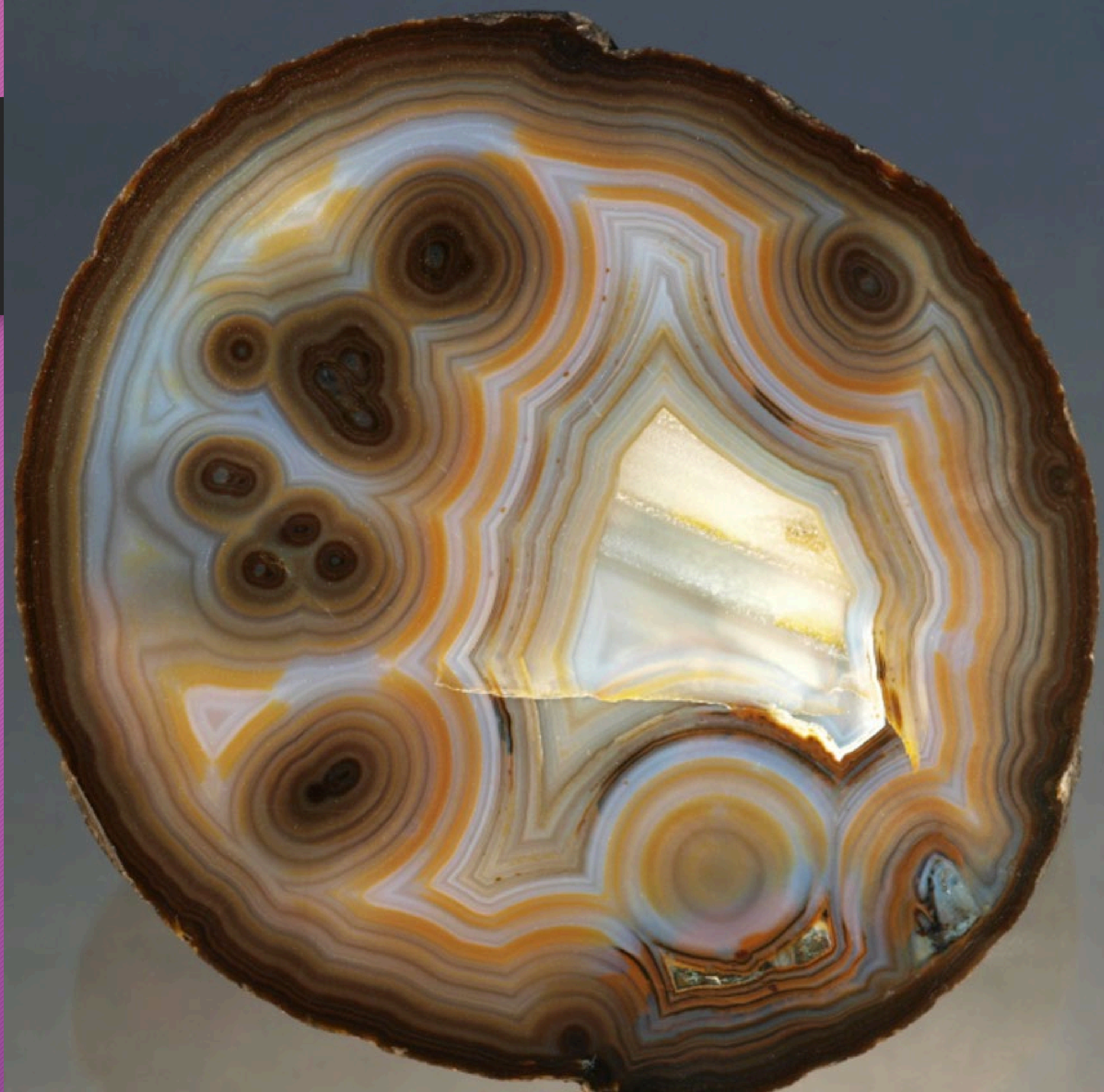
(a)

Agates

- Formation
- Types
- Differential weathering

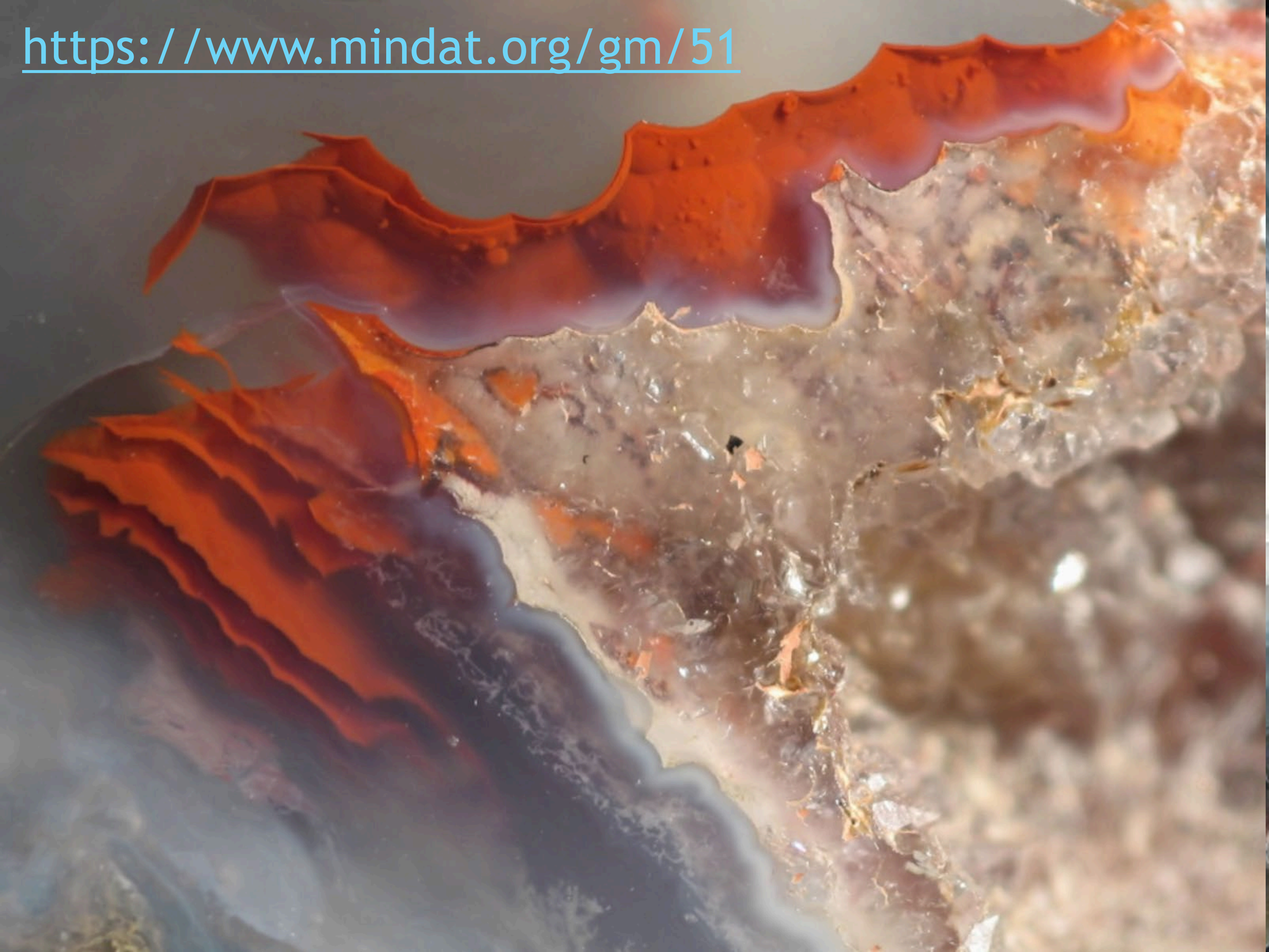
Can you find
Lake Superior Agates
in Iowa?

SiO_2 silicon dioxide



Lake Superior Agates

https://www.mindat.org/gm/51

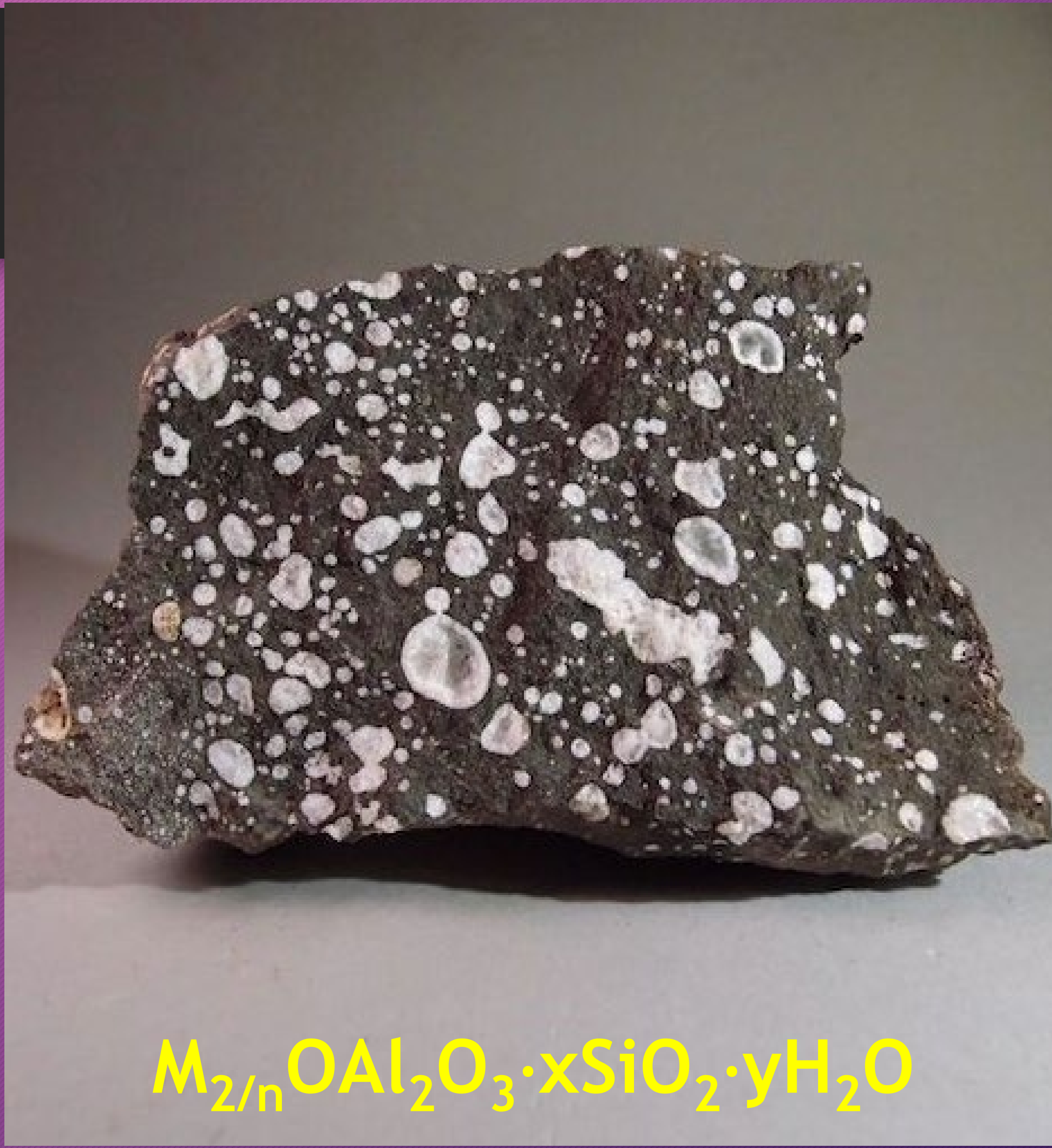


Zeolite – Alumniosilicate minerals

- Volcanic environments – ash
- Alkaline groundwater
- Trace – Ti, Zn,
- Zeolite agates not as easy to find

Why not?

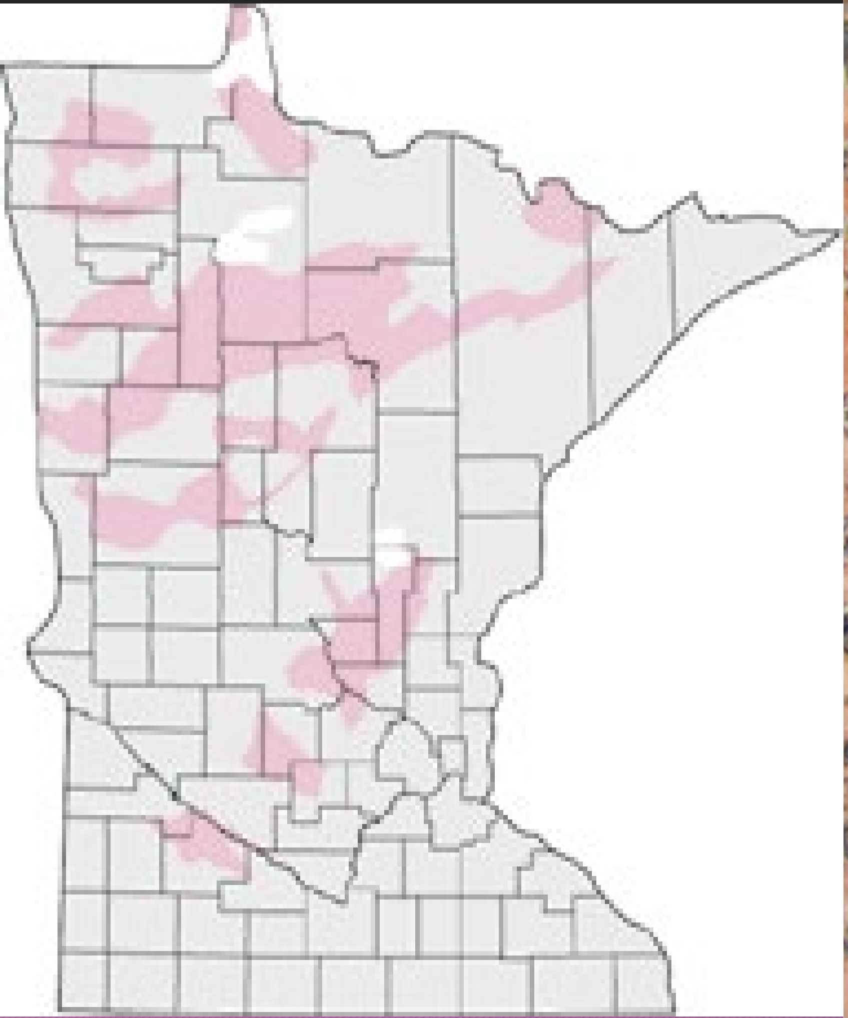
Why is it a bad idea to put them near a campfire?



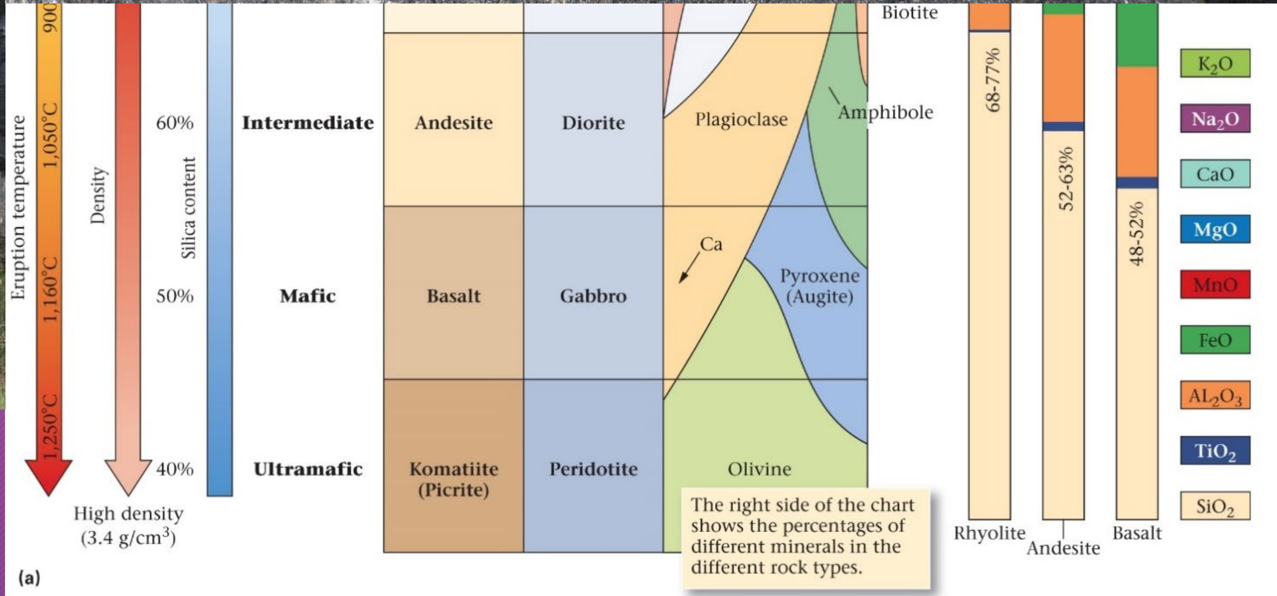
$$M_{2/n}OAl_2O_3 \cdot xSiO_2 \cdot yH_2O$$

Rhyolite

Granite



Anorthosite

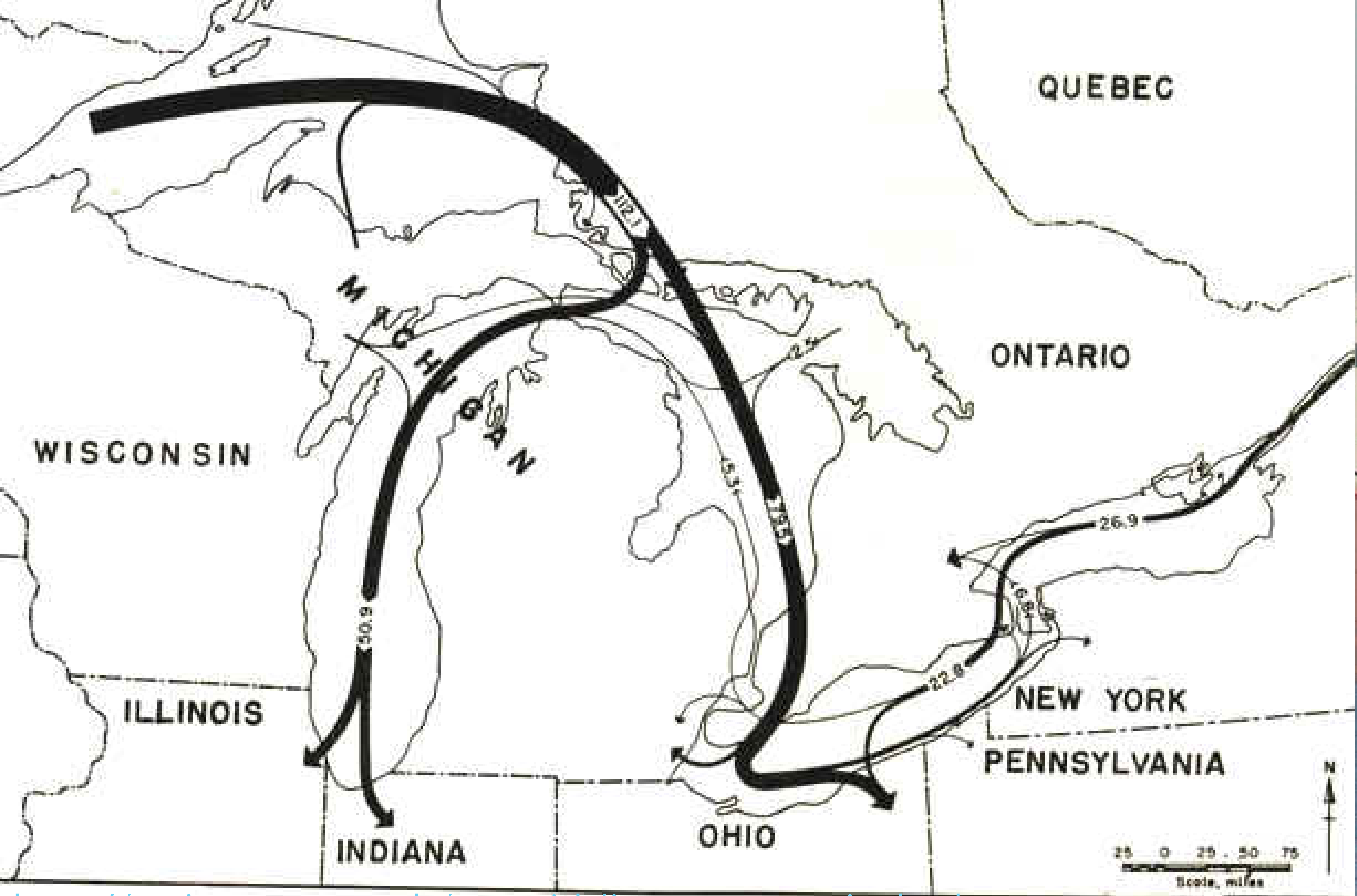


plagioclase feldspar (90–100%)


Banded Iron
Formation
(BIF)


LEVEL NO. 27
2341 FEET BELOW THE SURFACE
689 FEET BELOW SEA LEVEL

Taconite



https://project.geo.msu.edu/geogmich/iron_ore__taconite.html

FIGURE 2. - Projected Iron Ore Traffic Flow, 1995. Million net tons.

Platinum Group Element Mineralization

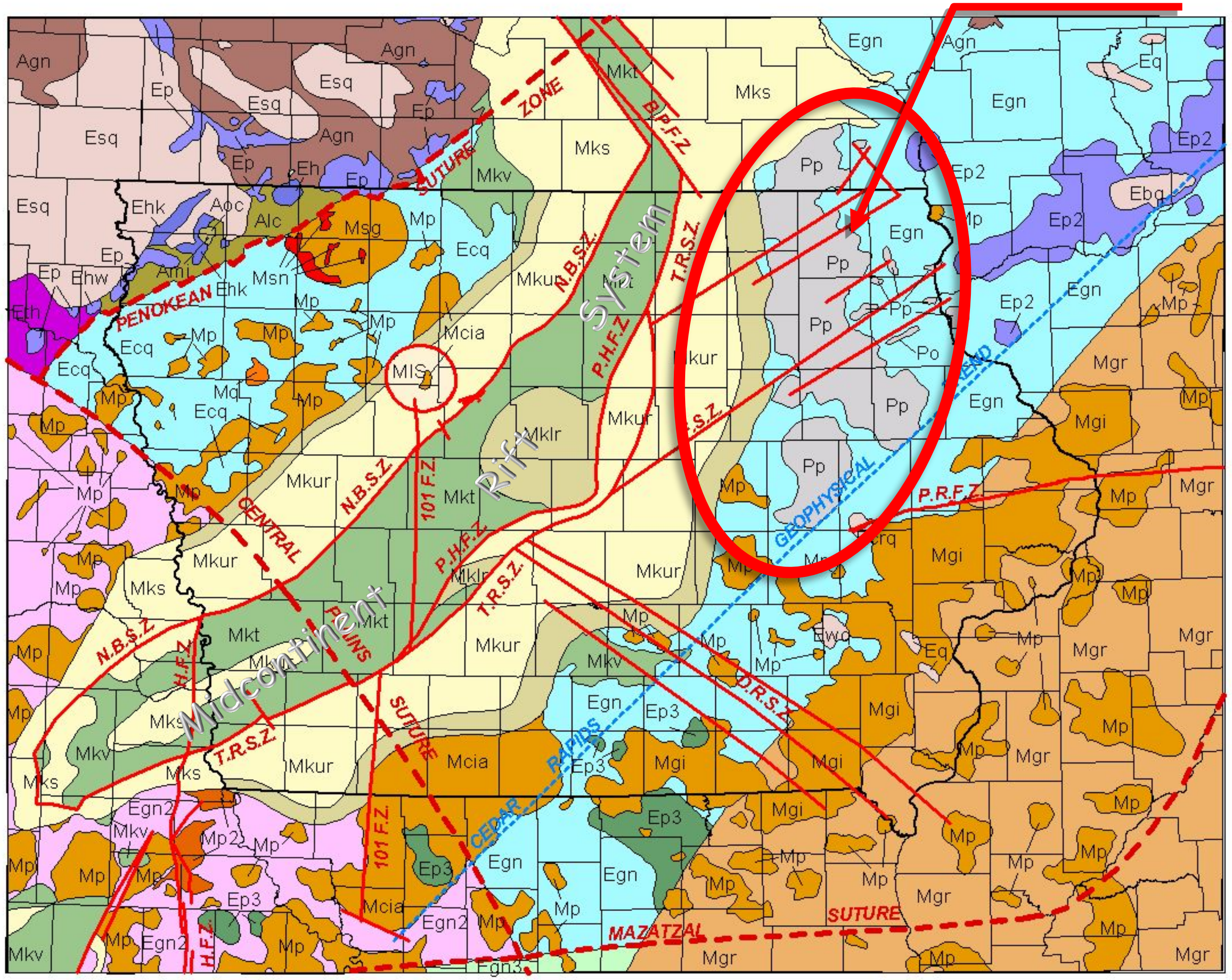
in Northeast Iowa

Ray Anderson & Ryan Clark
Iowa Geological Survey

Geology of the Precambrian Surface of Iowa and surrounding area

Raymond R. Anderson - 1999

Northeast Iowa Plutonic Complex



LEGEND

(ages given in millions of years - Ma)

PROTEROZOIC (2500 - 530 Ma)

GRENVILLE INTERVAL (1350-1000 Ma)
- (Mks) Keweenawan Clastic Sedimentary Rocks
  - (Mkur) Keweenawan Upper Red Clastic Group
  - (Mklr) Keweenawan Lower Red Clastic Group
- (Mkv) Keweenawan Volcanic / Plutonic Rocks
  - (Mkt) Keweenawan Thor Volcanic Group

SOUTHERN GRANITE / RHYO. INTERVAL (1380 - 1310 Ma)
- (Mp2) Granitic plutons

EASTERN GRANITE / RHYOL. INTERVAL (1500 -1430 Ma)
- (Mgr) Rhyolite and granitic plutons
- (Mp) Granitic plutons
  - (Mq) Quimby granite (1433 ± 6 Ma)
  - (Mgi) Green Island Plutonic Group (1485 ± 10 Ma)
  - (Msn) Spencer Norite
  - (Msg) Spencer Granite (1373 ± 7 Ma)

BARABOO INTERVAL (1620 - 1500 Ma)
- (Eq) quartzite dominated
  - (Ebq) Baraboo Quartzite
  - (Esq) Sioux Quartzite
  - (Ecrq) Cedar Rapids Quartzite
  - (Ewq) Washington County Quartzite

MAZATZAL INTERVAL (1650-1620 Ma)
- (Ep3) Granitic plutons dominant
- (Egn3) Gneiss dominant

CENTRAL PLAINS INTERVAL (1800-1700 Ma)
- (Egn2) Gneiss and granite dominant

PENOKEAN INTERVAL (2100-1800 Ma)
Penokean Orogenic Belt
- (Ep) Post-orogenic granitic plutons
  - (Ehk) Hull Keratophyre (1782 ± 4 Ma)
  - (Eh) Harris Granite (1804 ± 17 Ma)
  - (Ehw) Hawarden Granite
- (Ep2) Late-stage granitic plutons
- (Egn) Orogenic gneiss and granite
  - (Ecq) Camp Quest Gneiss (2065 ± 10 Ma)

Trans-Hudson Orogenic Belt
- (Eth) Ganite and gneiss dominant

ARCHEAN (>2500 Ma)

- (Alc) Lyon County Gneiss (2523 ± 5 Ma)
- (Ami) Matlock Banded Iron Formation
- (Aoc) Otter Creek Mafic Complex (2890 ± 90 Ma)
- (Agn) Early to Middle Archean gneiss and migmatite terrane

ROCKS OF UNCERTAIN AFFINITIES
- (Mcia) Central Iowa Arch Granites
- (Po) Osborne Mafic Complex
- (Pp) Northeast Iowa Plutonic Complex

- (MIS) Late Cretaceous (73.8 ± 3 Ma) Manson Impact Strucuture

- known or inferred faults
- Proterozoic sutures
- geophysical trend

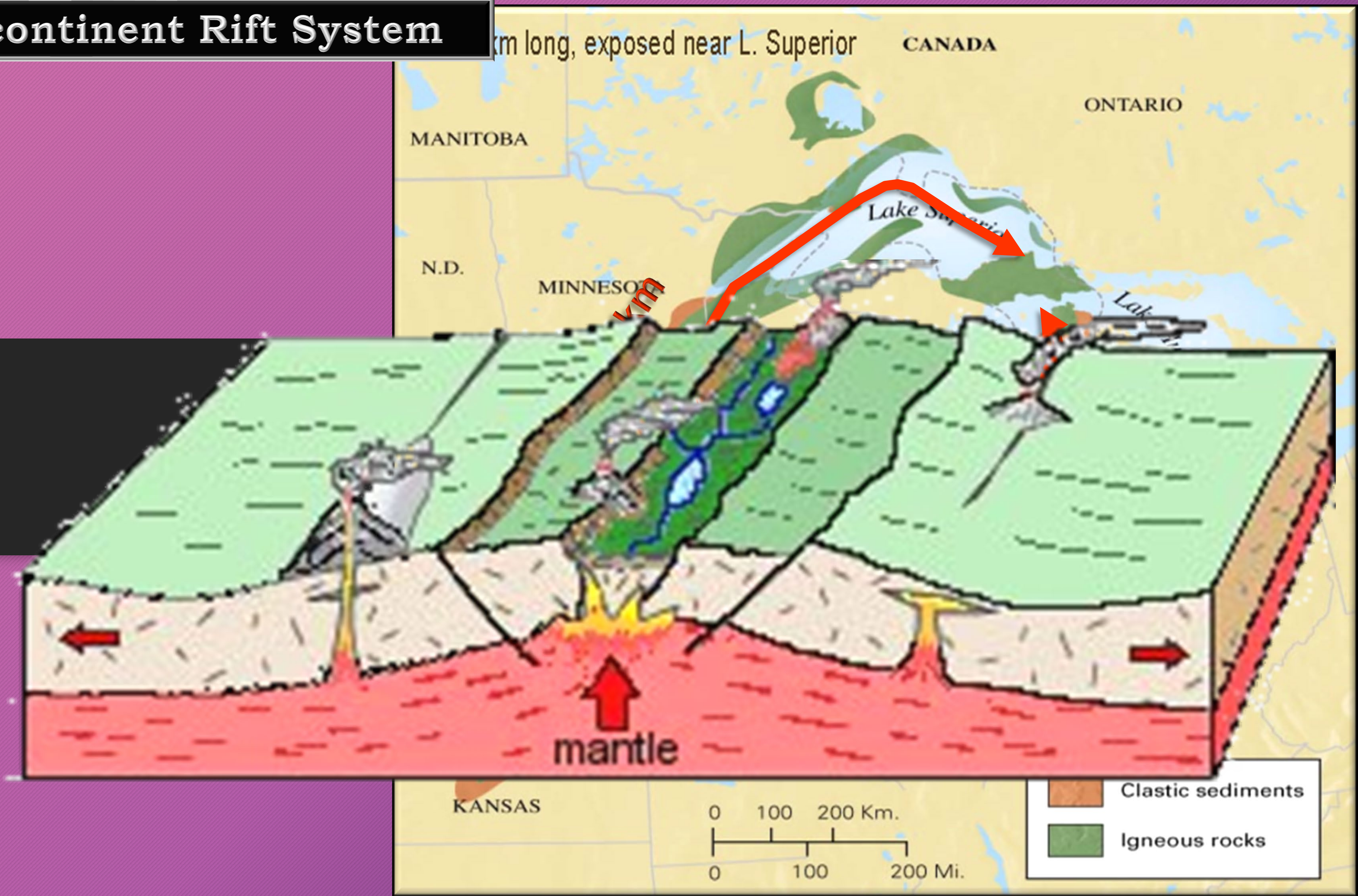
0 100 Miles

N W E S

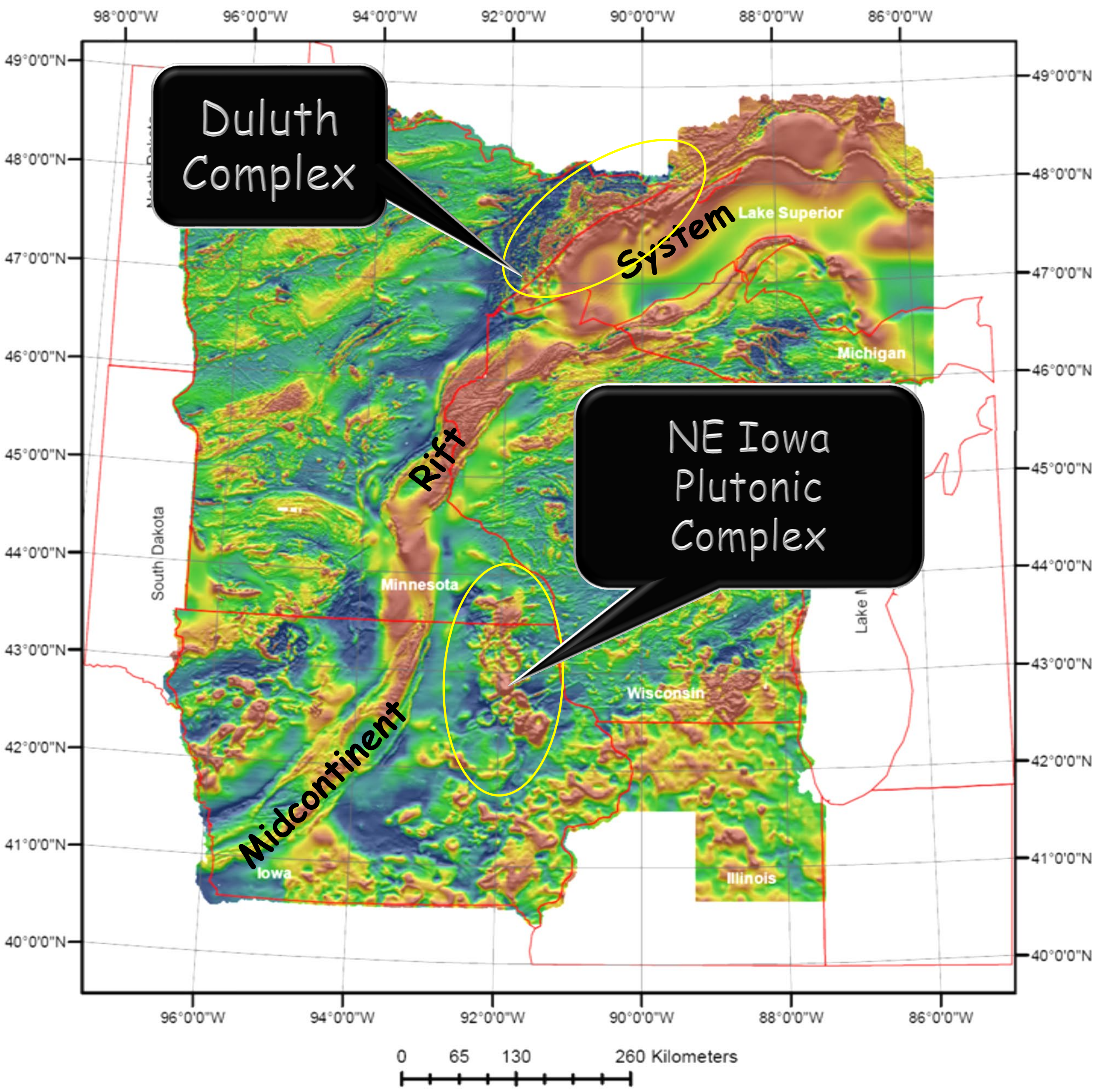
key to mapped faults

N.B.F.Z.	N.B.F.Z. Northern Boundary Falut Zone	P.R.F.Z.	Plum River Fault Zone
T.R.S.Z.	Thurman-Redfield Fault Zone	D.R.F.Z.	Des Moines River Fault Zone
P.H.F.Z.	Perry-Hampton Fault Zone	101 F.Z.	101 Fault Zone
B.P.F.Z.	Belle Plaine Fault Zone	F.S.Z.	Fayette Structural Zone
H.F.Z.	Humboldt Fault Zone		

The Midcontinent Rift System



Shaded-Relief Total Magnetic Intensity Anomaly



NanoTesla

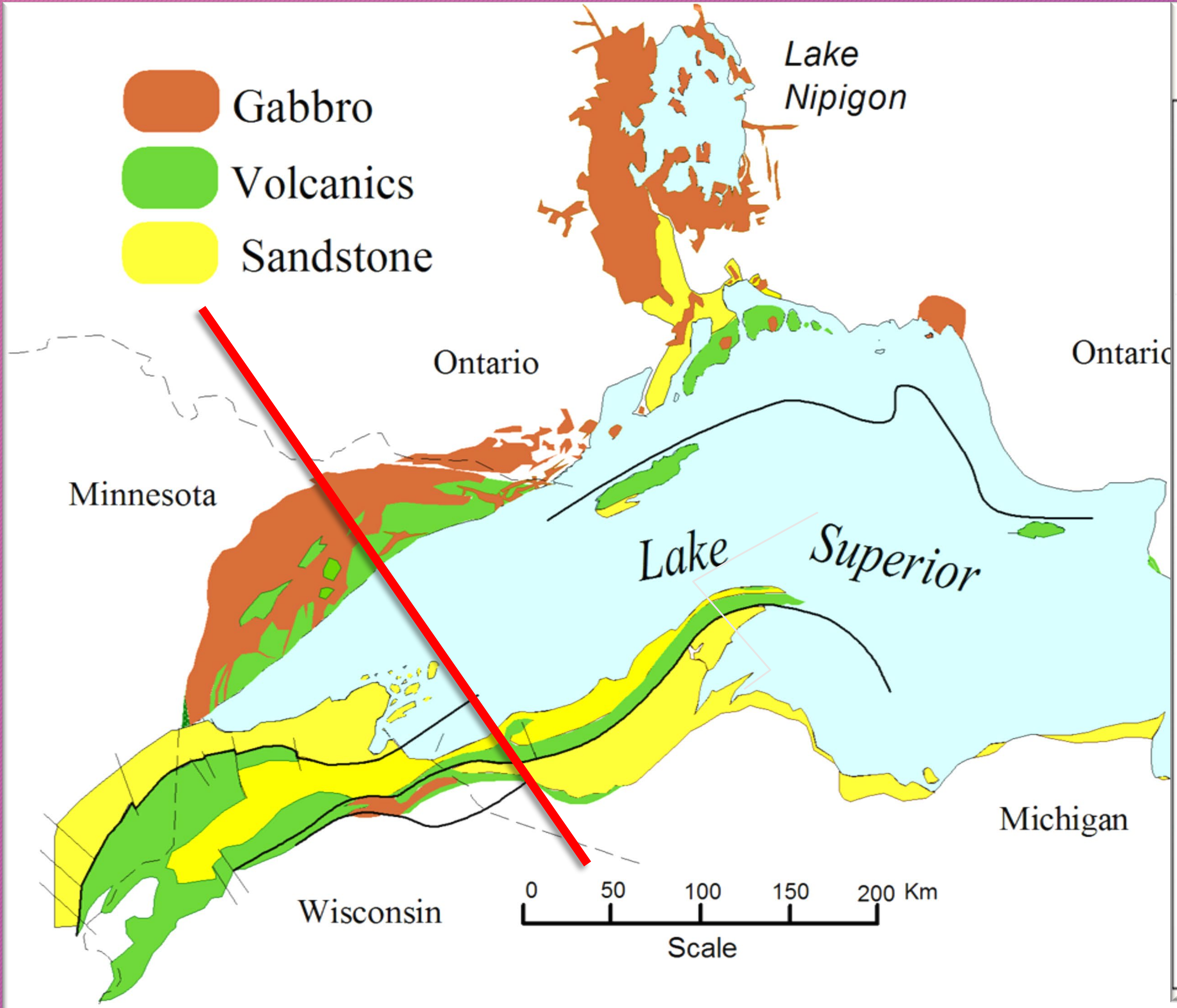
High : 30661.777344

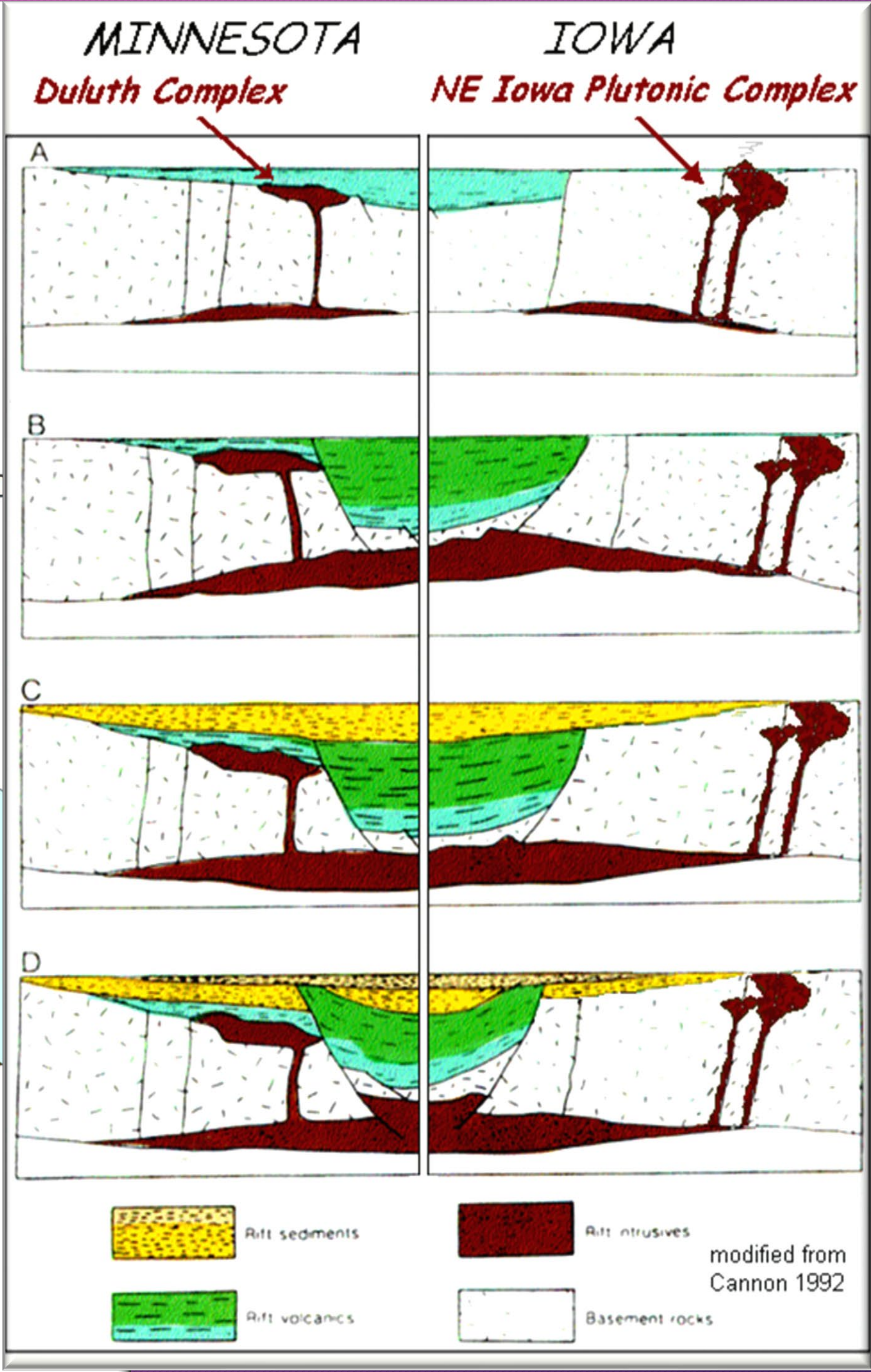
Low : -9982.036133

Shaded-relief map of the total magnetic intensity anomaly for the north-central United States. Data compiled by David L. Daniels and Stephen L. Snyder of the U.S. Geological Survey from various sources. Most of Minnesota was flown with a line spacing of 400 meters and an elevation (above land surface) of 150 meters, whereas much of Wisconsin was flown at line spacings of 400-800 meters and elevations between 150 to 305 meters. The remaining areas were generally flown at flight line spacings of 1600 meters or wider and at elevations of 305 meters or greater. Following gridding, all data were continued to a common elevation of 305 meters and merged. For more detailed descriptions of the original data sets the reader is referred to:

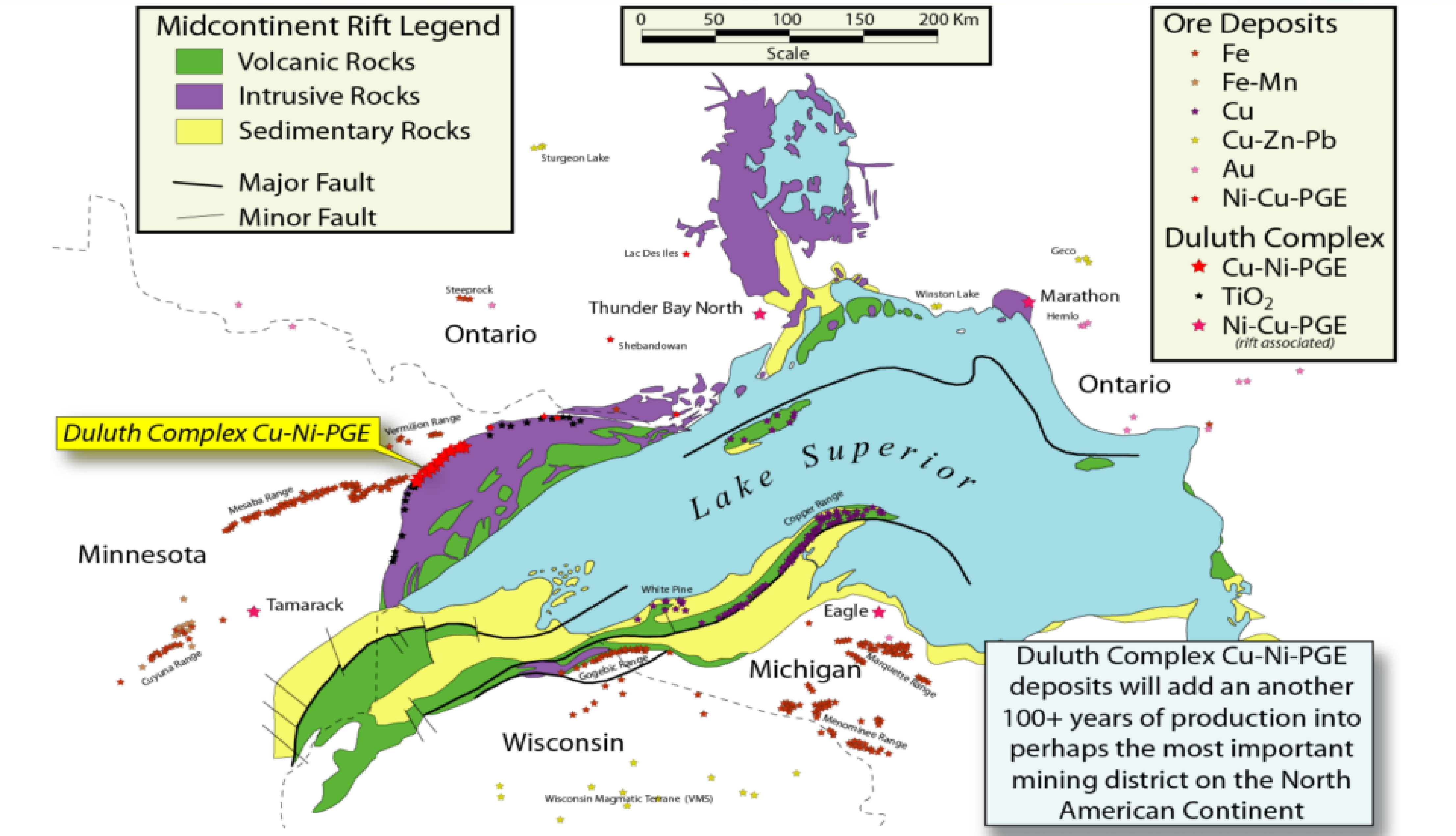
U.S. Geological Survey Crustal Imaging and Characterization Team Web Site.

Aeromagnetic data in Minnesota were acquired by the Minnesota Geological Survey (MGS), with support from the Legislative Commission on Minnesota Resources. Aeromagnetic data in Wisconsin were acquired with support from the Wisconsin Geological and Natural History Survey and the U. S. Geological Survey. Hillshade illumination is from the North with an inclination of 30 degrees.


Gabbro
Volcanics
Sandstone
Lake Nipigon
Ontario
Ontari
Minnesota
Lake Superior
Michigan
Wisconsin
0 50 100 150 200 Km
Scale

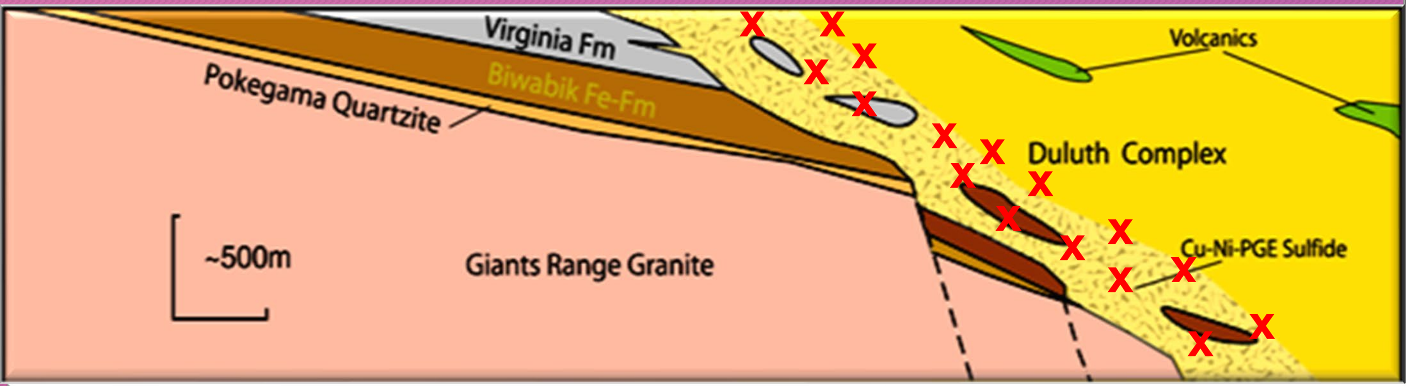

MINNESOTA
IOWA
Duluth Complex
NE Iowa Plutonic Complex
A
B
C
D
Rift sediments
Rift intrusives
Rift volcanics
Basement rocks
modified from Cannon 1992

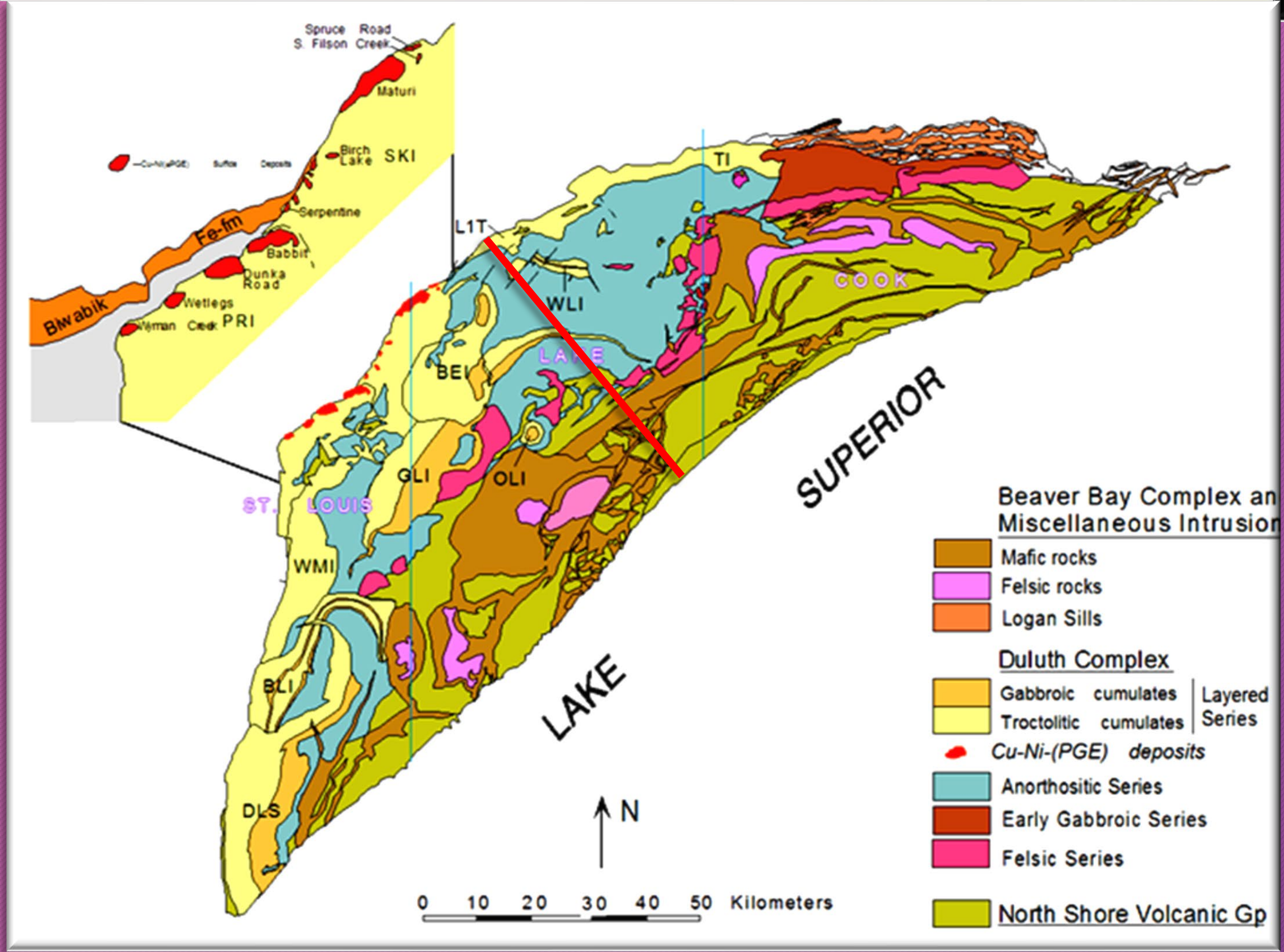
The Lake Superior Mining District



Duluth Complex Cu-Ni-PGE deposits will add an another 100+ years of production into perhaps the most important mining district on the North American Continent

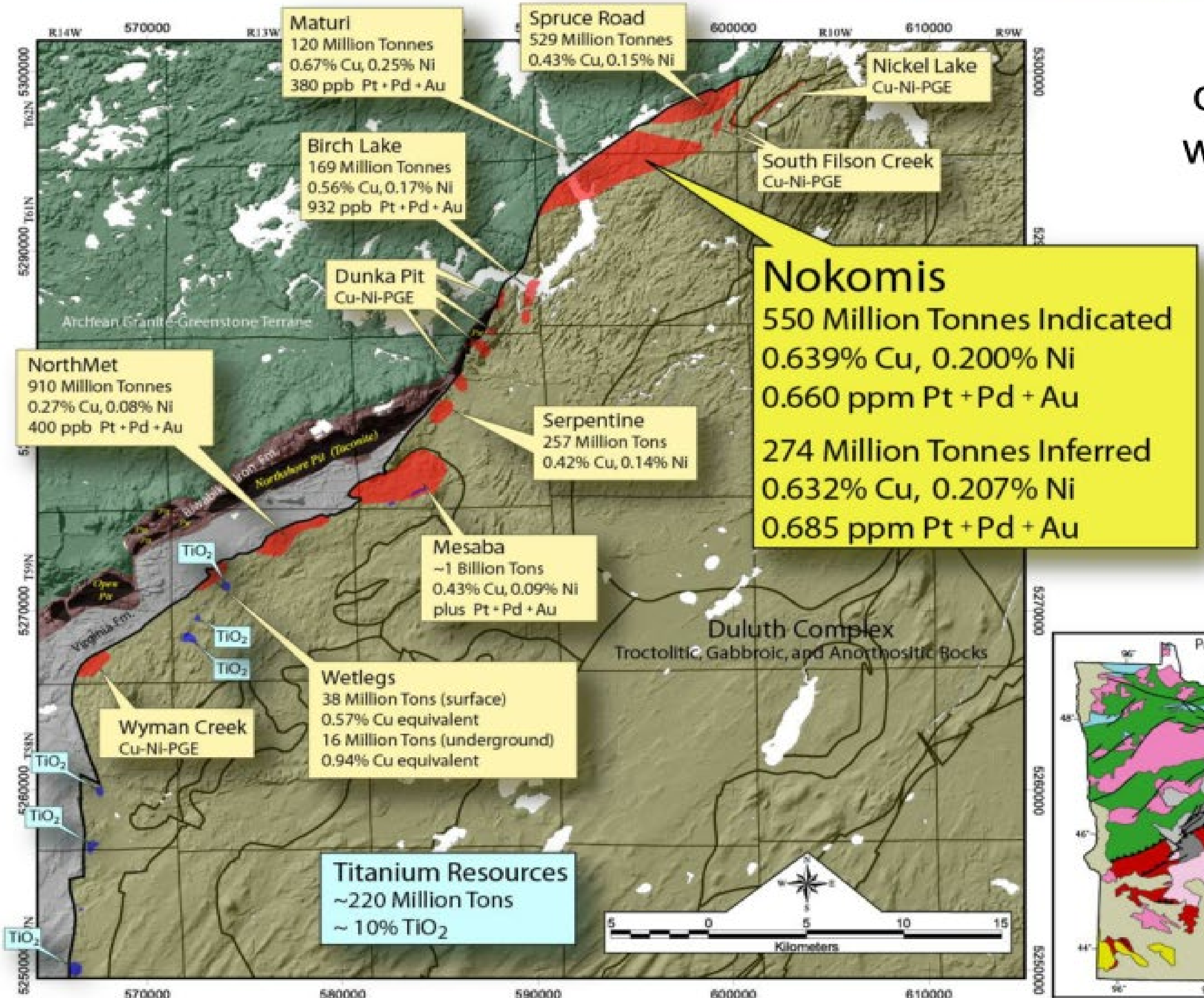
The Cu-Ni-PGE Deposits of the Duluth Complex

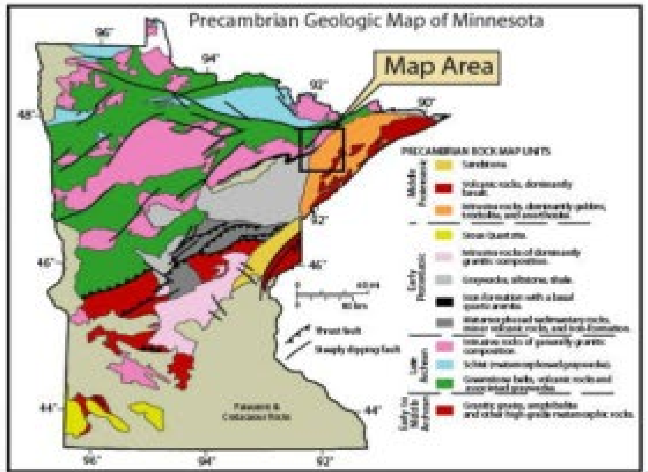




Duluth Complex Mineral Resources

On the cusp of developing one of the world's most important new mining districts.





Updated TMM December 2012 Resource Estimate

Contained Metals in TMM NI 43-101Resource*

	Metal	Indicated	Inferred	
Base	Copper	13.7 Billion lbs.	11.8 Billion lbs.	$41 billion
	Nickel	4.4 Billion lbs.	4.0 Billion lbs.	$33 billion
Precious	Platinum	5.6 Million ozs.	3.5 Million ozs.	$8.6 billion
	Palladium	12.6 Million ozs.	7.6 Million ozs.	$8.8 billion
	Gold	3.0 Million ozs.	1.7 Million ozs.	$5.0 billion
	TPM (Pt+Pd+Au)	21.2 Million ozs.	12.8 Million ozs.	$96.4 billion

*Reference: December 4, 2012 Company press release entitled "Duluth Metals Announces an Updated Mineral Resource Estimate Confirming Large Increases to Twin Metals Contained Metal, Grade and Indicated Tonnage"

** Note – These resource estimates include 100% of the identified material in each deposit, and include mineral resources acquired as a part of TMM's acquisition of Franconia Minerals Corporation in 2011. Franconia's principal assets are a 70% interest in the Birch Lake, 'old' Maturi and Spruce Road deposits in northeastern Minnesota through the Birch Lake Joint Venture. Franconia announced in November, 2010 its intention to increase its ownership at the Birch Lake Joint Venture to 82%; see Franconia's company profile at www.SEDAR.com for Technical Reports. TMM's ownership of the resource will be factored by these percentages where applicable.*

Duluth Complex Exploration

- Duluth Metals Ltd.
- PolyMet Mining
- Teck Cominco Ltd.
- Franconia Minerals Corp.
- Encampment Minerals Inc.

Target Types

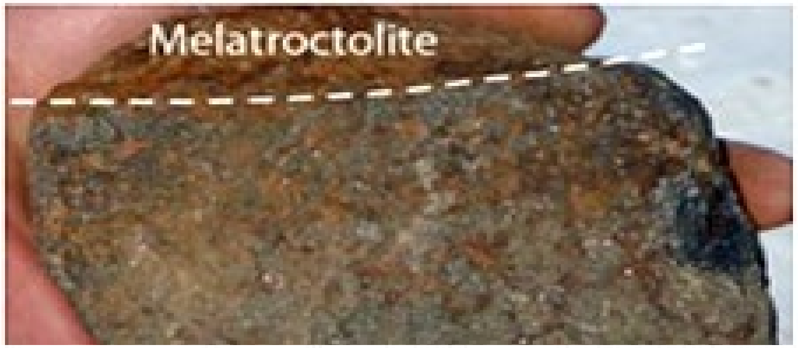
"The Duluth Complex is perhaps the world's largest untapped resource of (copper, nickel and platinum group metals) with multibillion tons of geologic resources estimated to be worth more than $1 trillion," stated a 2007 report by geologists at the Natural Resources Research Institute of the University of Minnesota Duluth.

Findings reported in recent months by Duluth Metals · · · indicate even the $1 trillion number may be too small.

--Duluth News Tribune, June 20, 2010

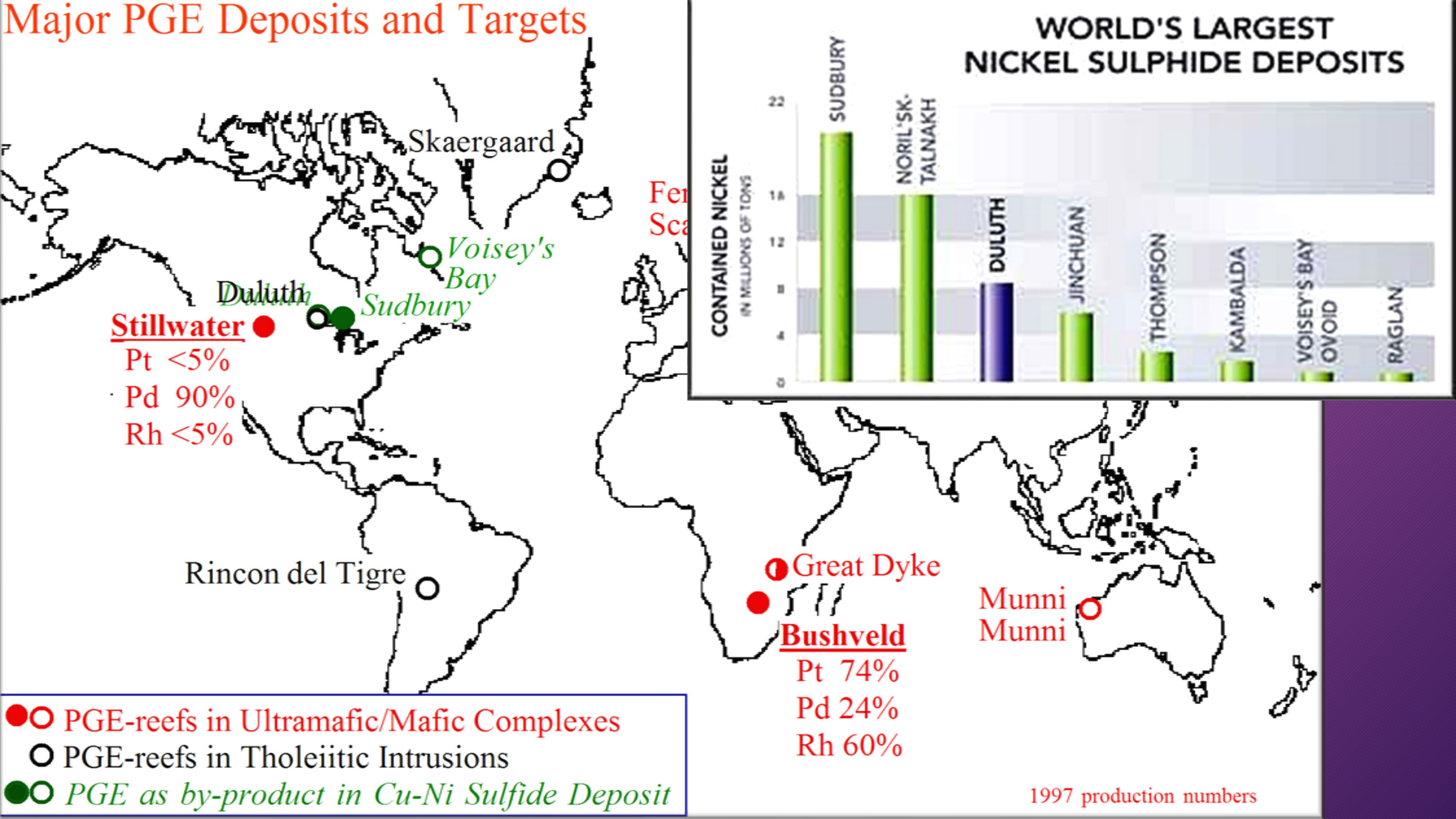
Ni-rich Massive Sulfide

Pt-Pd Reefs w/ Cr

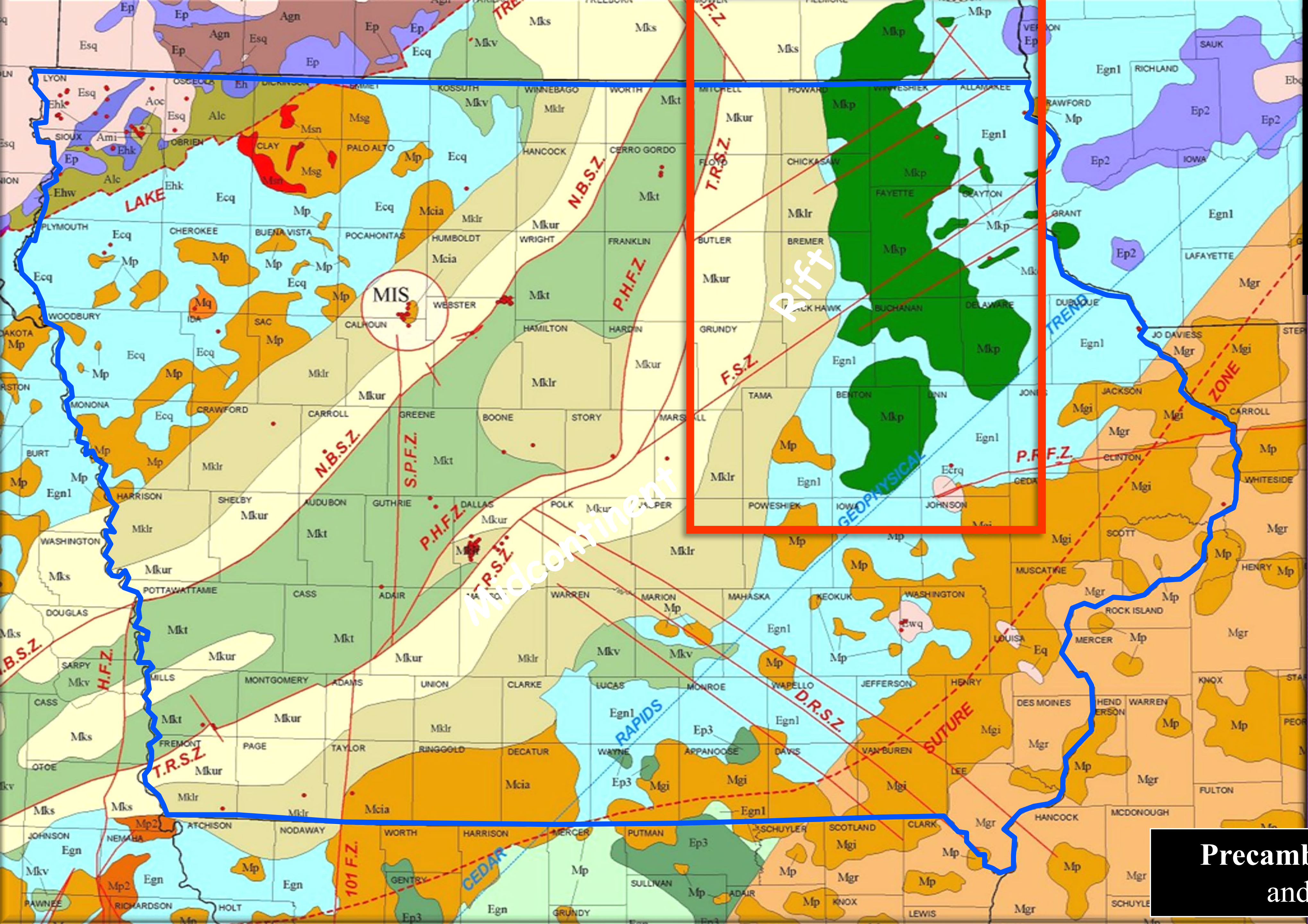


Disseminated Cu-Ni-PGE

Major PGE Deposits and Targets

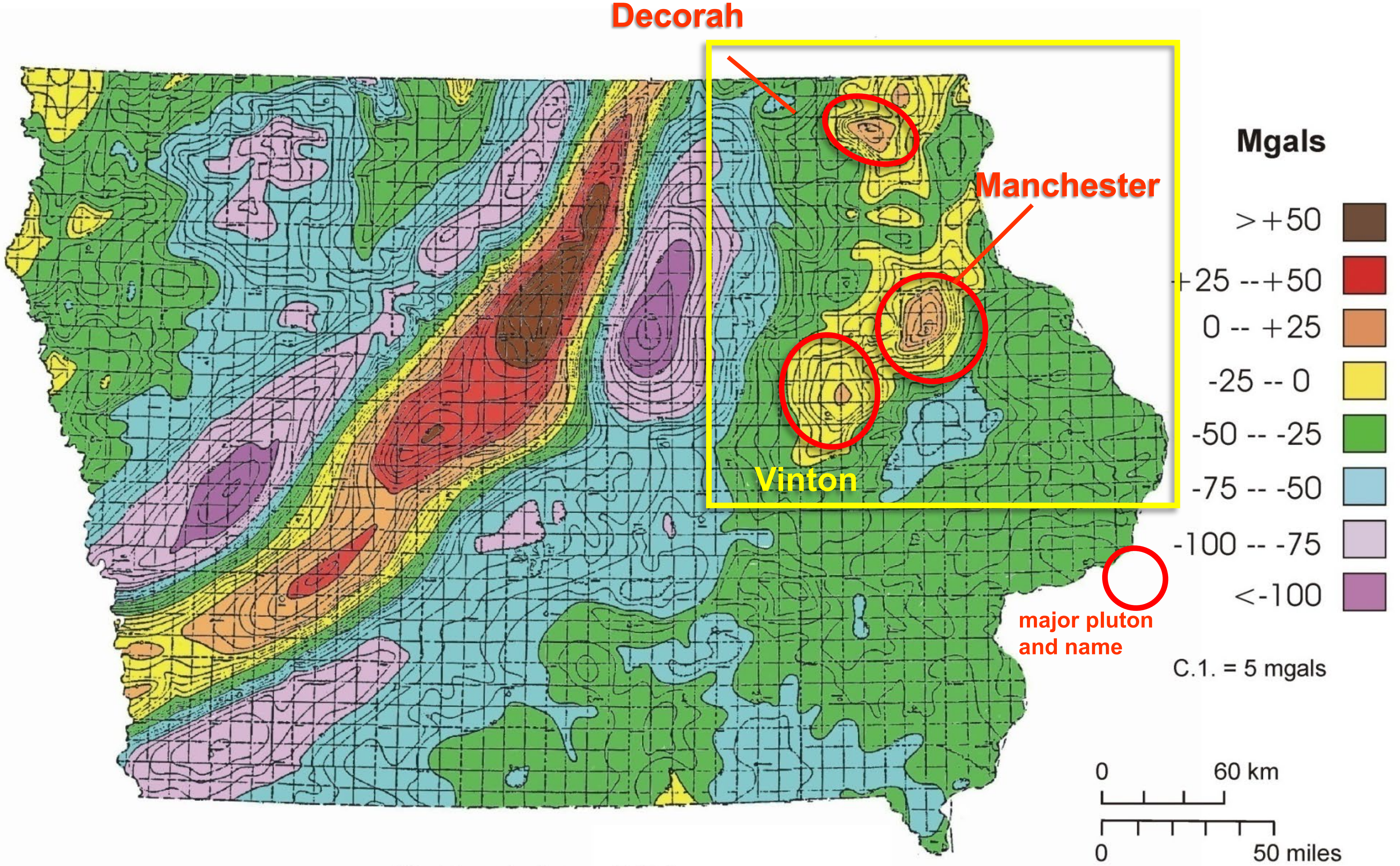


Northeast Iowa Plutonic Complex

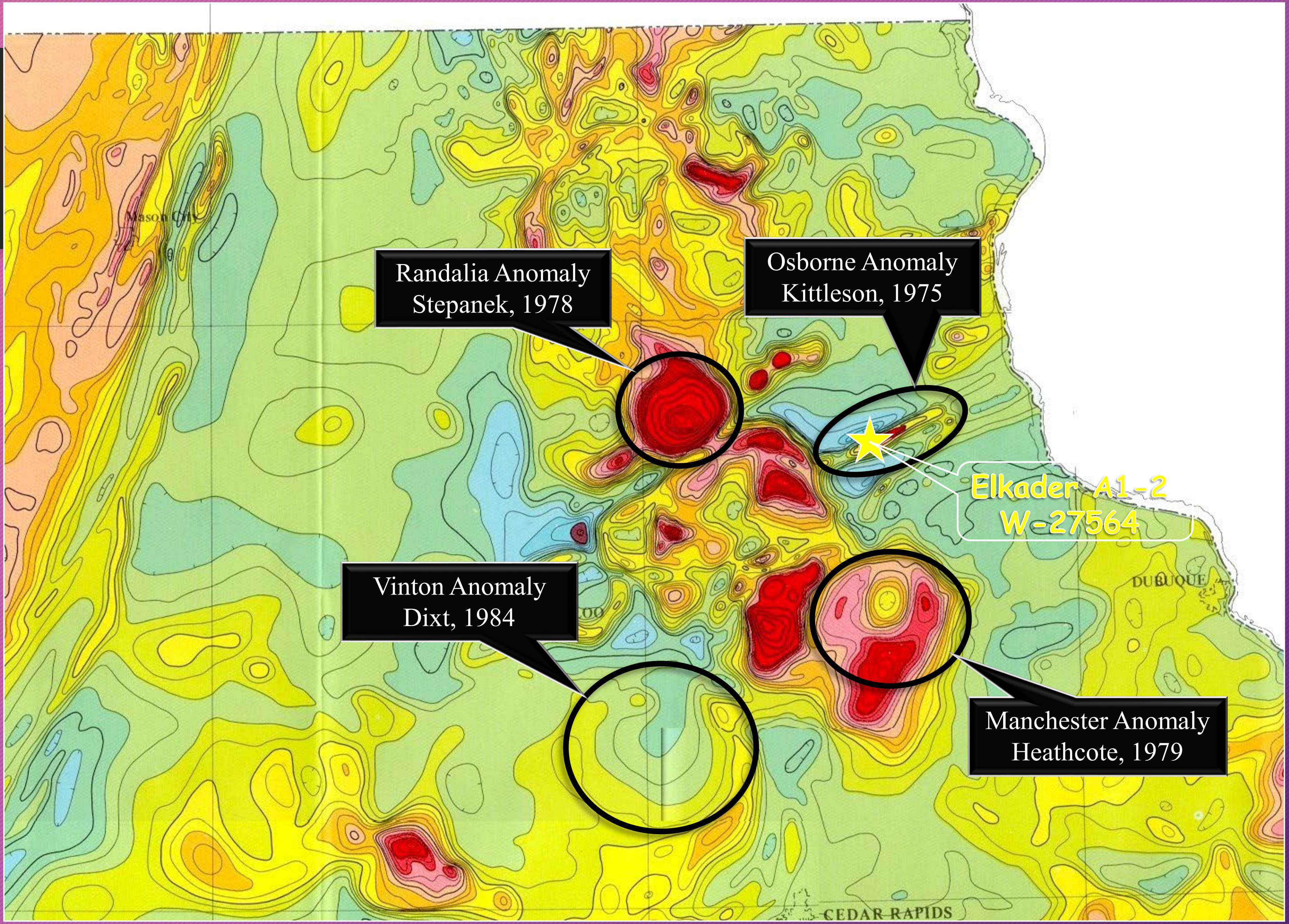


Precambrian Geology of Iowa
and surrounding area

BOUGUER GRAVITY ANOMALY MAP OF IOWA



modified from Anderson (1981)



Randalia Anomaly
Stepanek, 1978
Osborne Anomaly
Kittleson, 1975
Elkader A1-2
W-27564
Vinton Anomaly
Dixt, 1984
Manchester Anomaly
Heathcote, 1979
Mason City
DUBUQUE
CEDAR RAPIDS

A GRAVITY STUDY OF THE OSBORNE MAGNETIC ANOMALY,

CLAYTON COUNTY, IOWA

by

Kendall Lloyd Kittleson

A thesis submitted in partial fulfillment of the
requirements for the Degree of Master of Science
in the Department of Geology
in the Graduate College of
The University of Iowa

May, 1975

Thesis supervisor: Professor Kenneth F. Clark

Osborne Norite

Elkader Al-2 W-27564-

oxide cumulate

Al-2	Al-2	Al-2
2170'	2172'	2515'

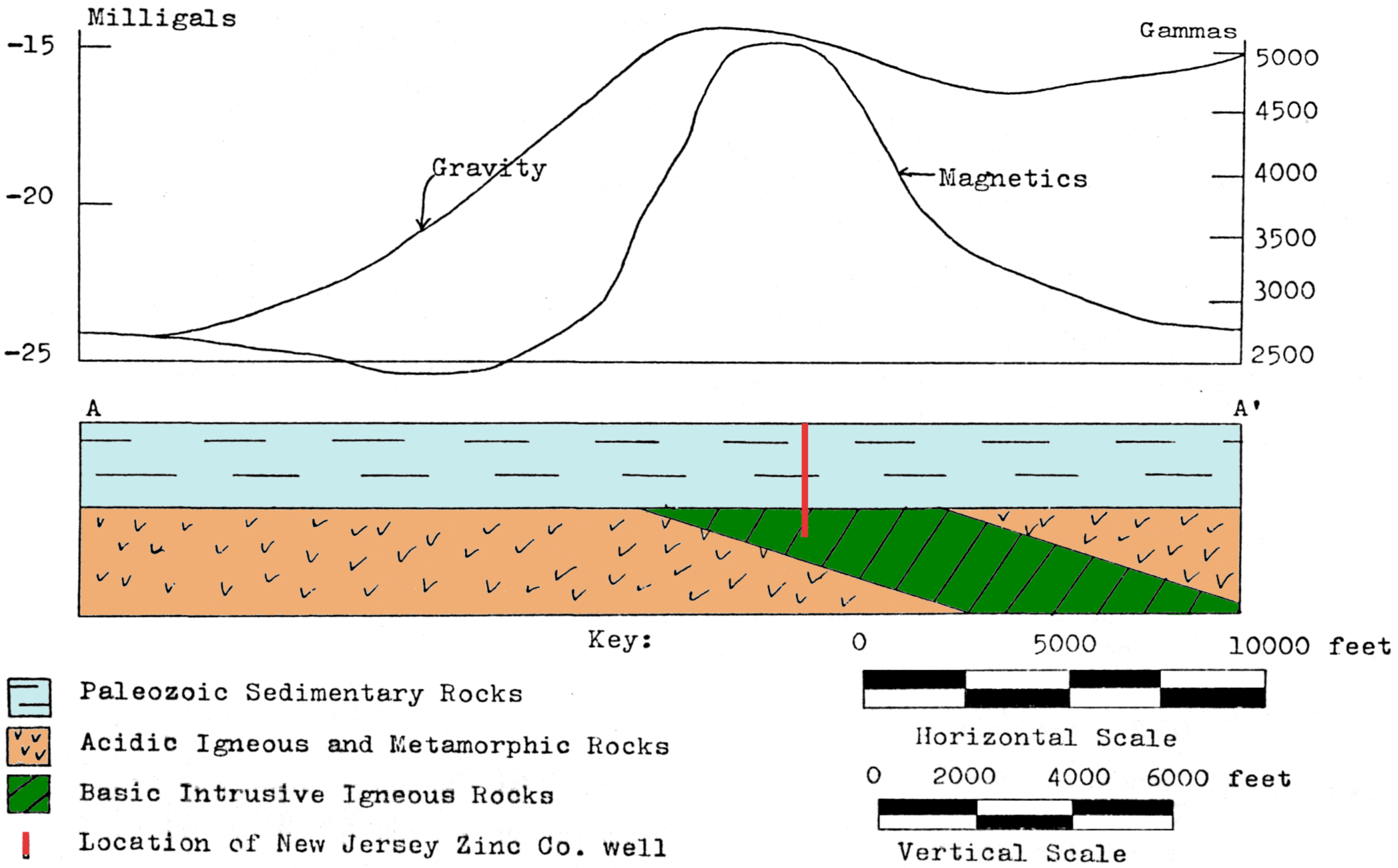
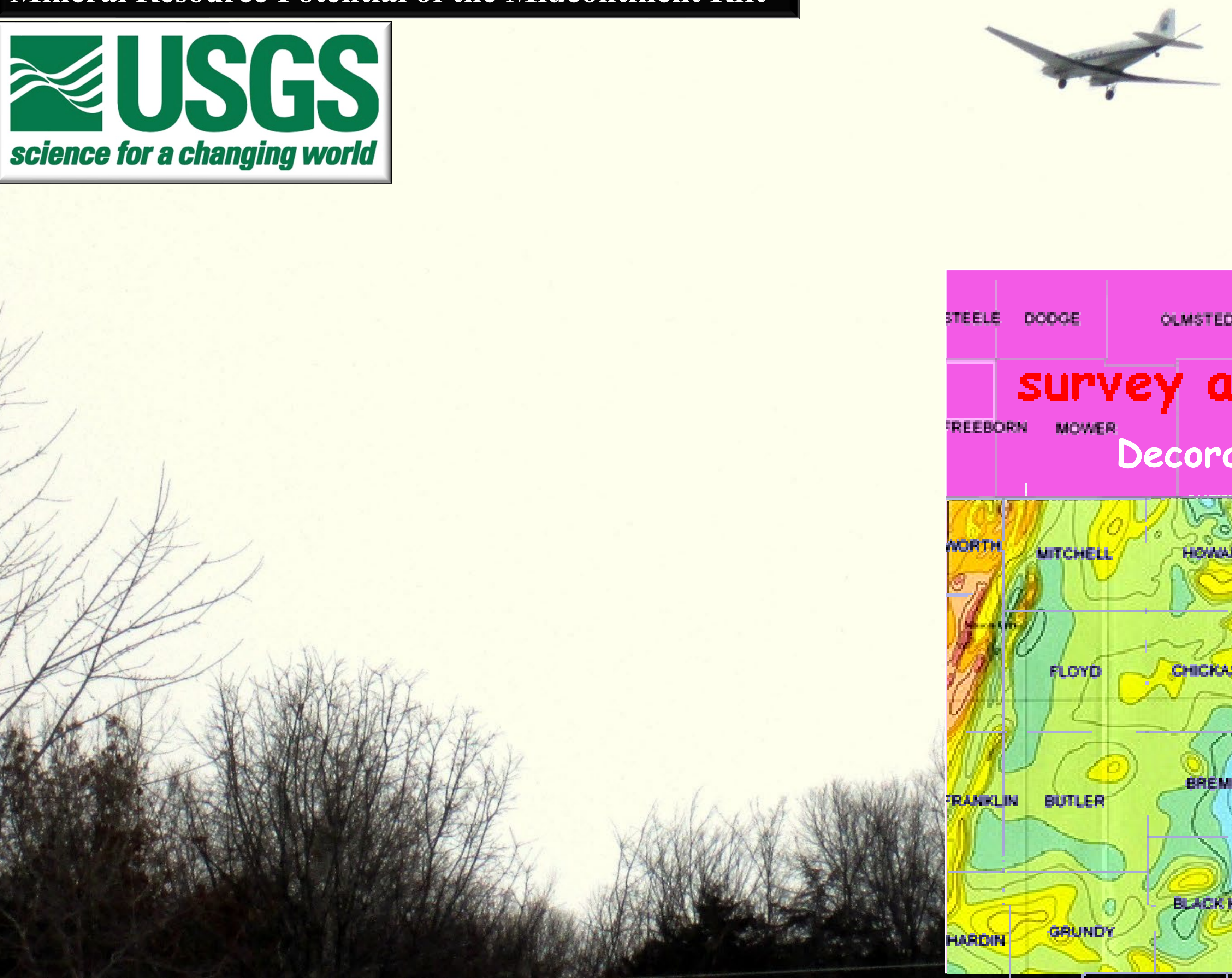


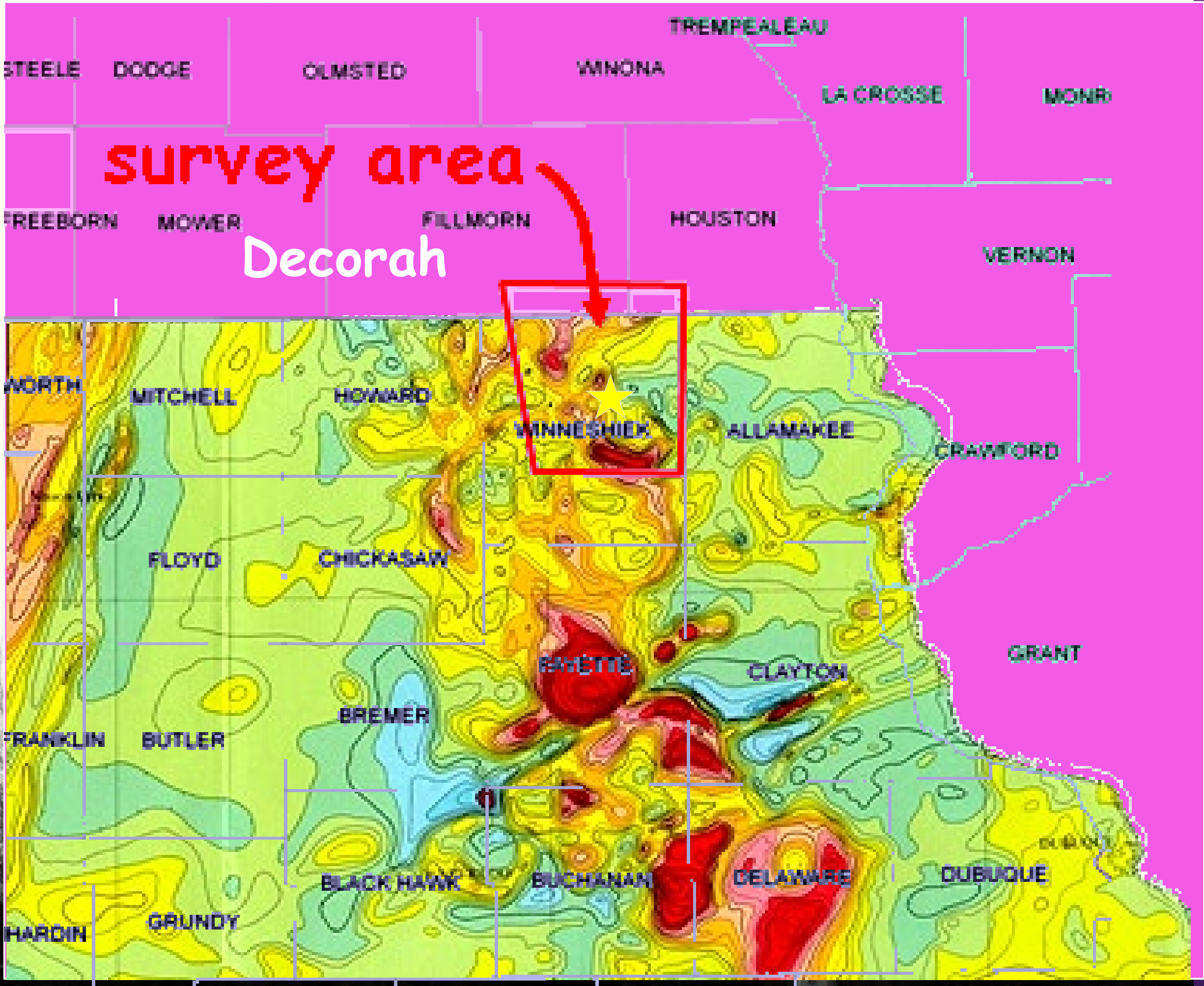
Figure 18. Profile A-A' (Osborne Magnetic Anomaly) Kittleson, 1975

Mineral Resource Potential of the Midcontinent Rift

USGS
science for a changing world

photo by John Hjelle Dec 2012





BT-67 fixed wing turboprop aircraft that carried the gravity survey instrument

3,333 km = 2,071 mi of flight lines

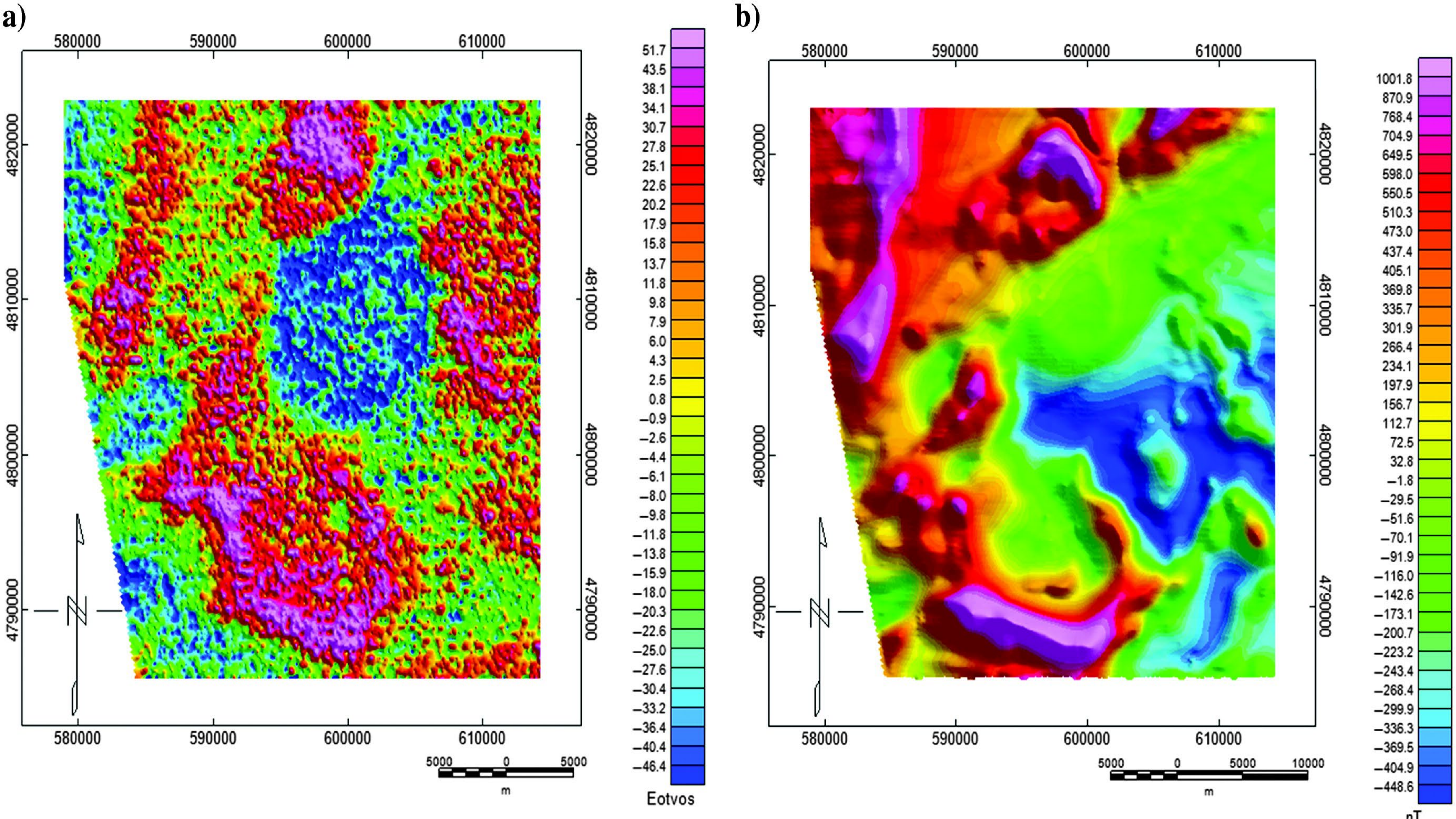
400 m = $\frac{1}{4}$ mile flight line EW spacing
3.5 km = 2 $\frac{1}{4}$ mile flight line NS spacing

100 – 500 feet above the landscape

USGS
science for a changing world

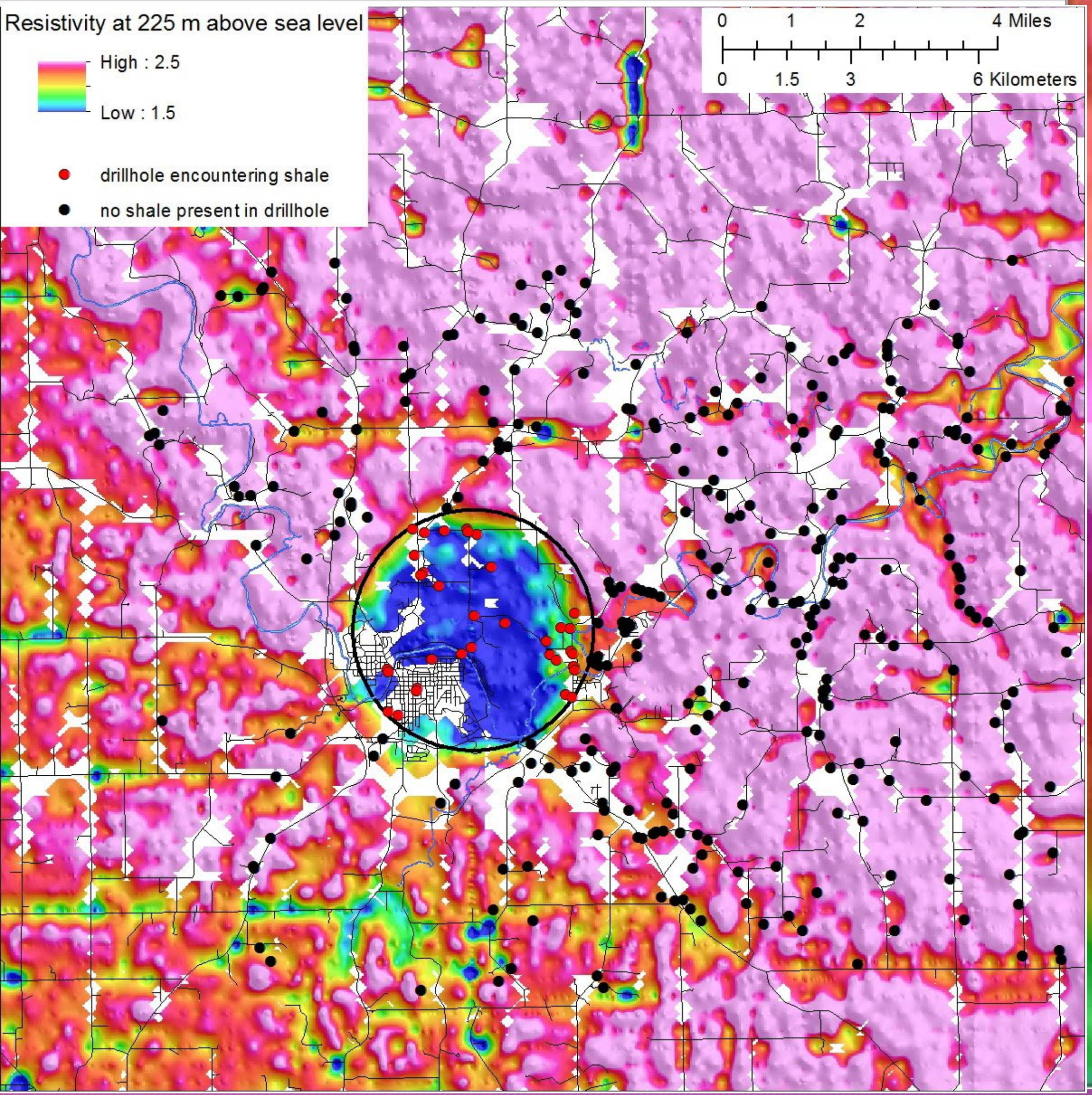
Agusta Westland AW119 Koala helicopter that carried the magnetometer and electromagnetic surveys
(see **VTEM** detector suspended below helicopter)

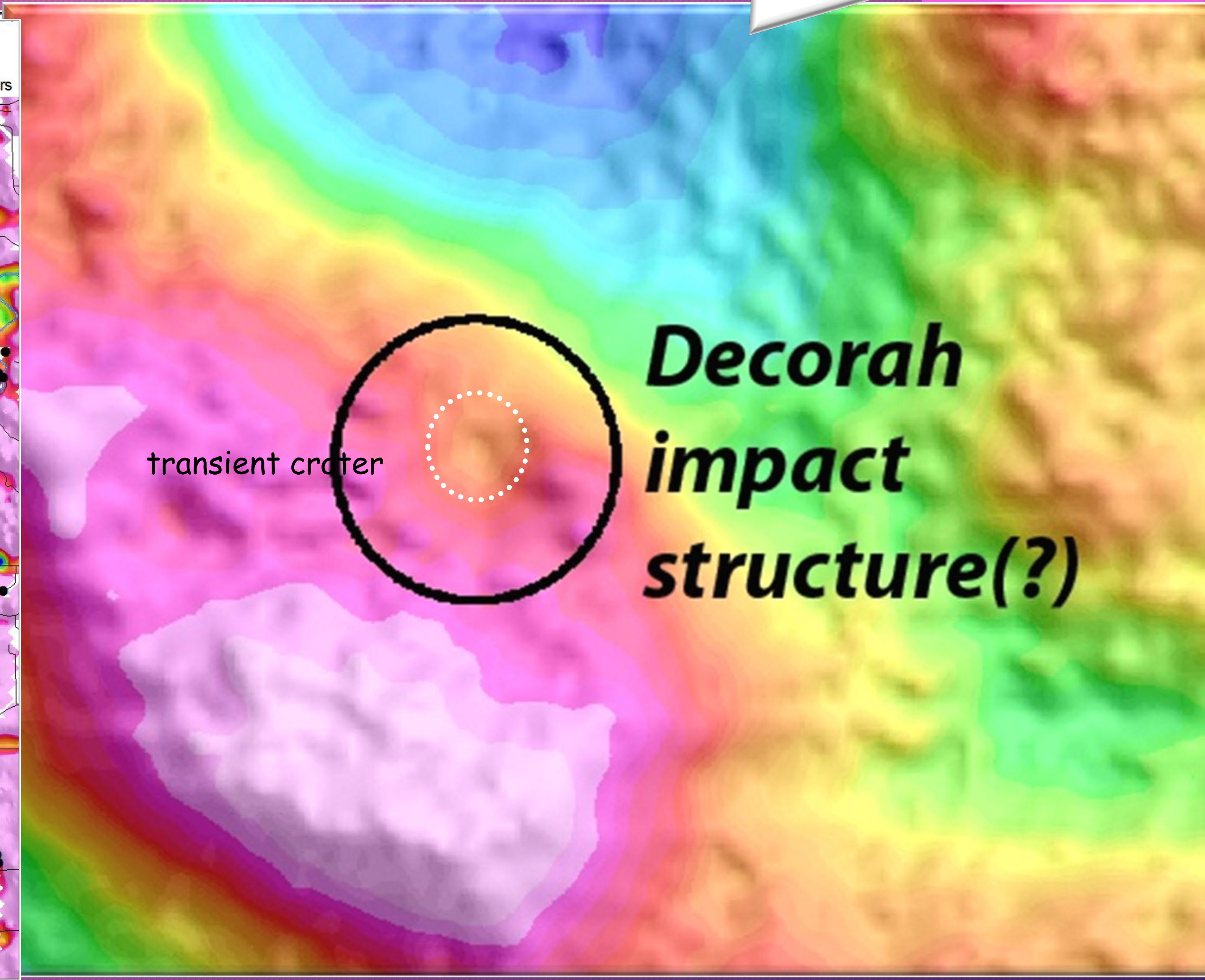
Versatile **T**ime Domain **E**lectro**m**agnetic Surveying



a)
580000
590000
600000
610000
4820000
4810000
4800000
4790000
51.7
43.5
38.1
34.1
30.7
27.8
25.1
22.6
20.2
17.9
15.8
13.7
11.8
9.8
7.9
6.0
4.3
2.5
0.8
−0.9
−2.6
−4.4
−6.1
−8.0
−9.8
−11.8
−13.8
−15.9
−18.0
−20.3
−22.6
−25.0
−27.6
−30.4
−33.2
−36.4
−40.4
−46.4
Eotvos
5000 0 5000
m
b)
580000
590000
600000
610000
4820000
4810000
4800000
4790000
1001.8
870.9
768.4
704.9
649.5
598.0
550.5
510.3
473.0
437.4
405.1
369.8
335.7
301.9
266.4
234.1
197.9
156.7
112.7
72.5
32.8
−1.8
−29.5
−51.6
−70.1
−91.9
−116.0
−142.6
−173.1
−200.7
−223.2
−243.4
−268.4
−299.9
−336.3
−369.5
−404.9
−448.6
nT
5000 0 5000 10000
m

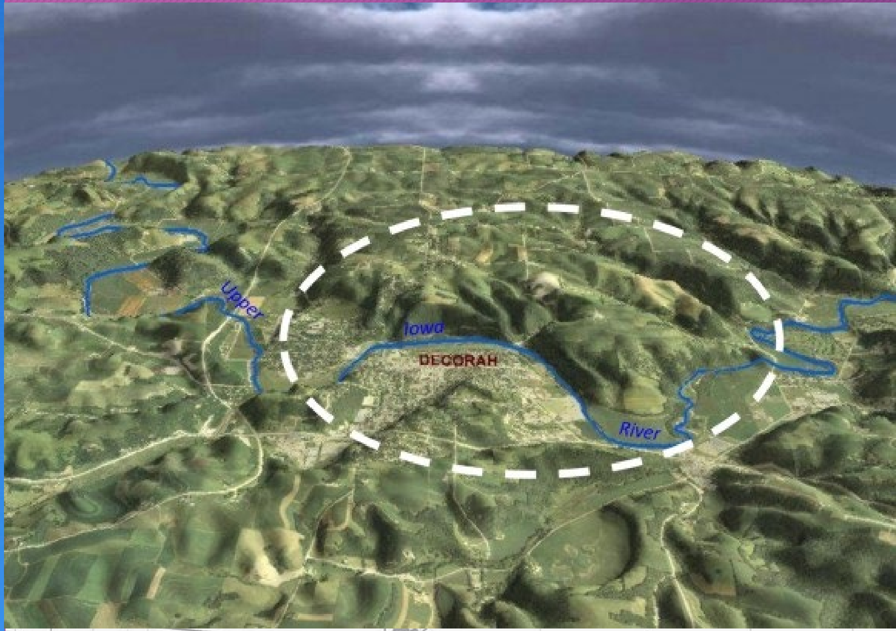
Preliminary Data from USGS Airborne Gravity Survey

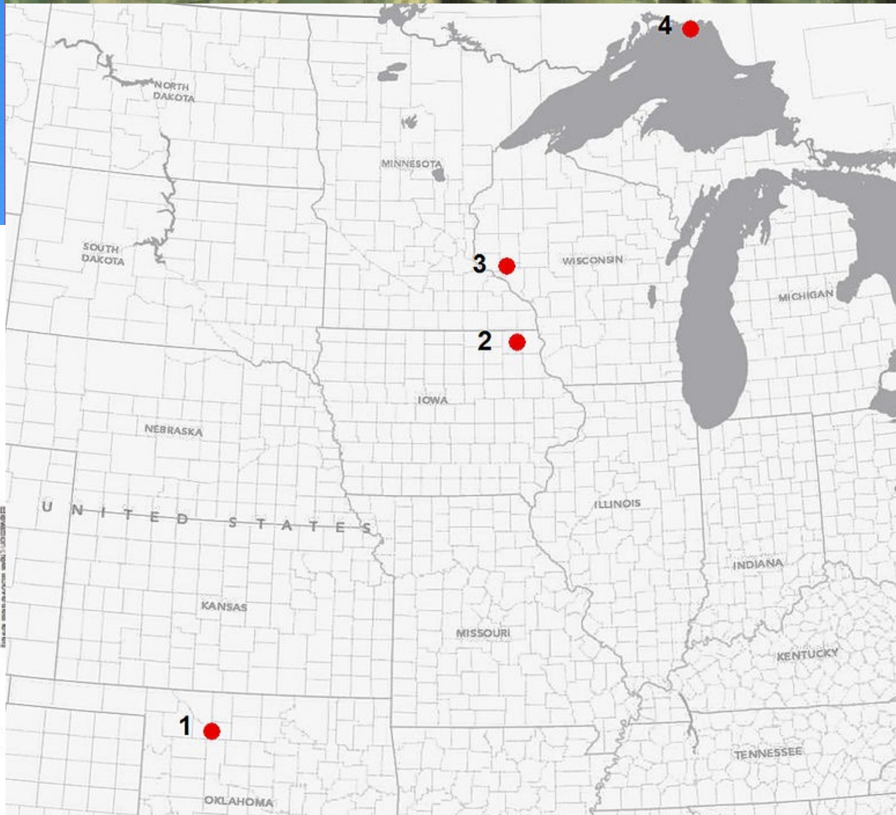


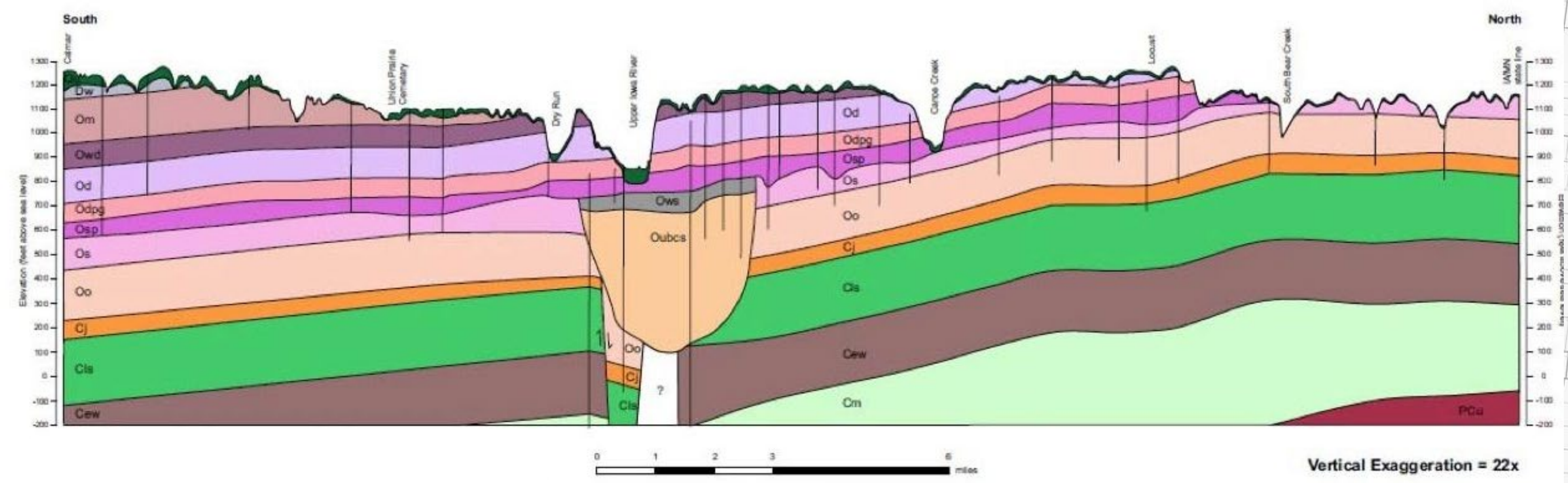


Airborne Electromagnetic Survey 2013

Decorah Structure

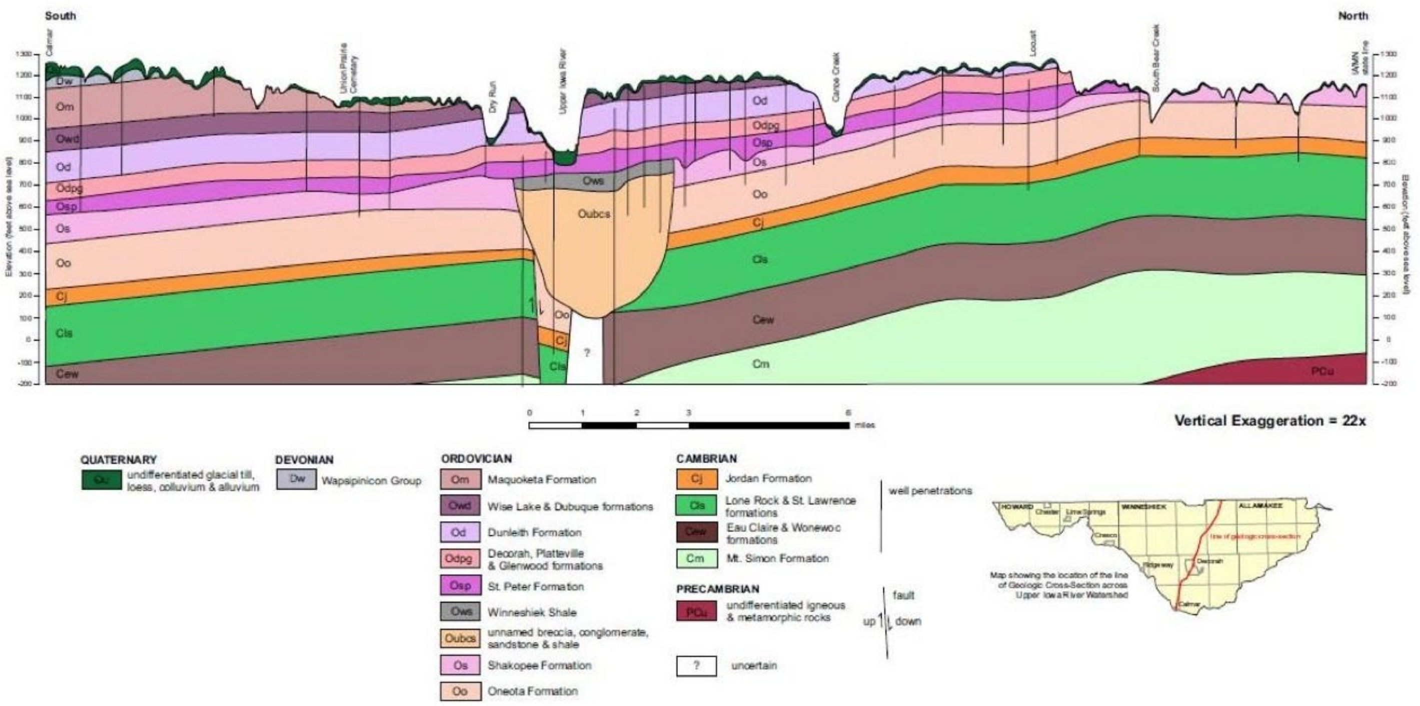


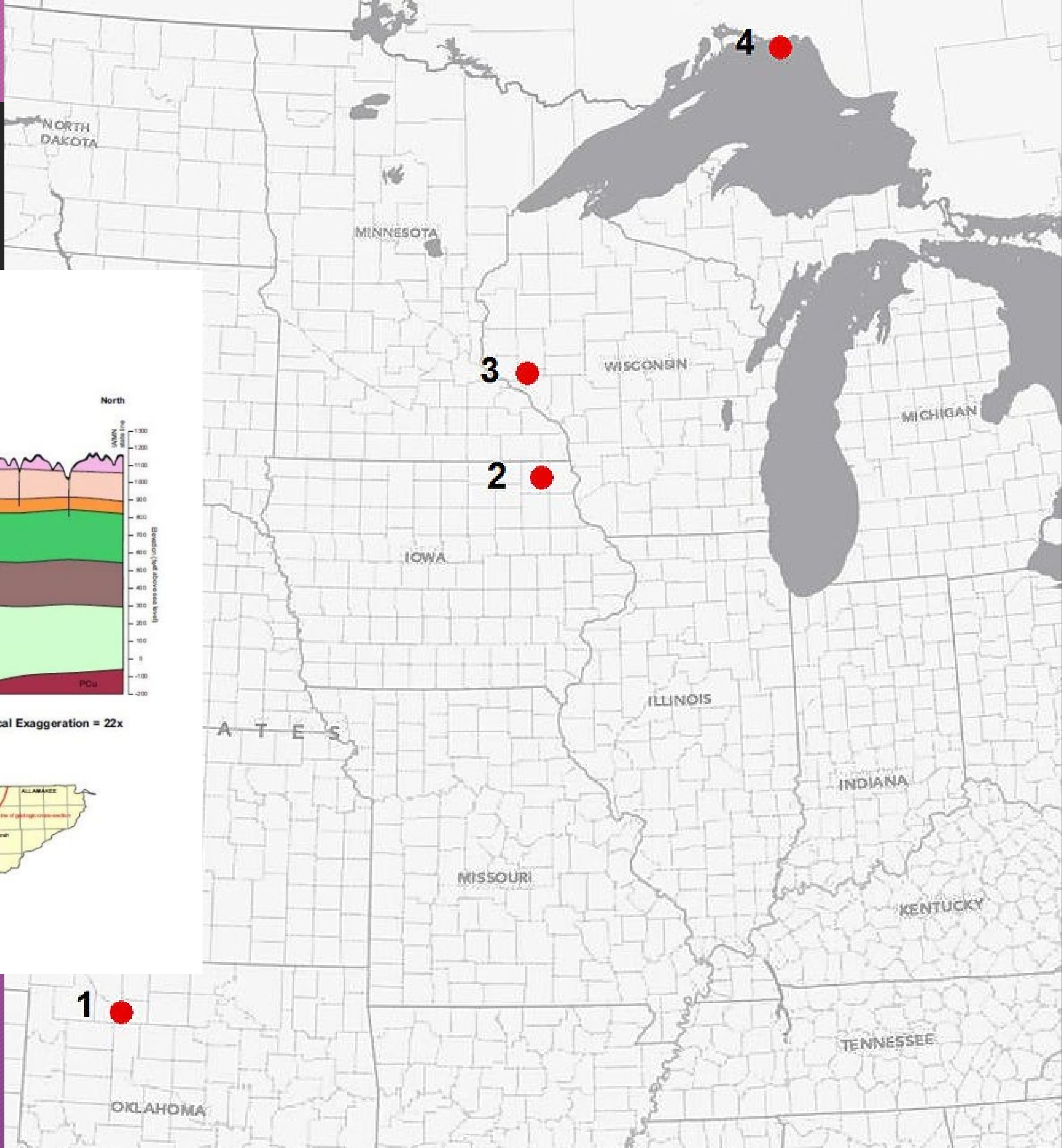


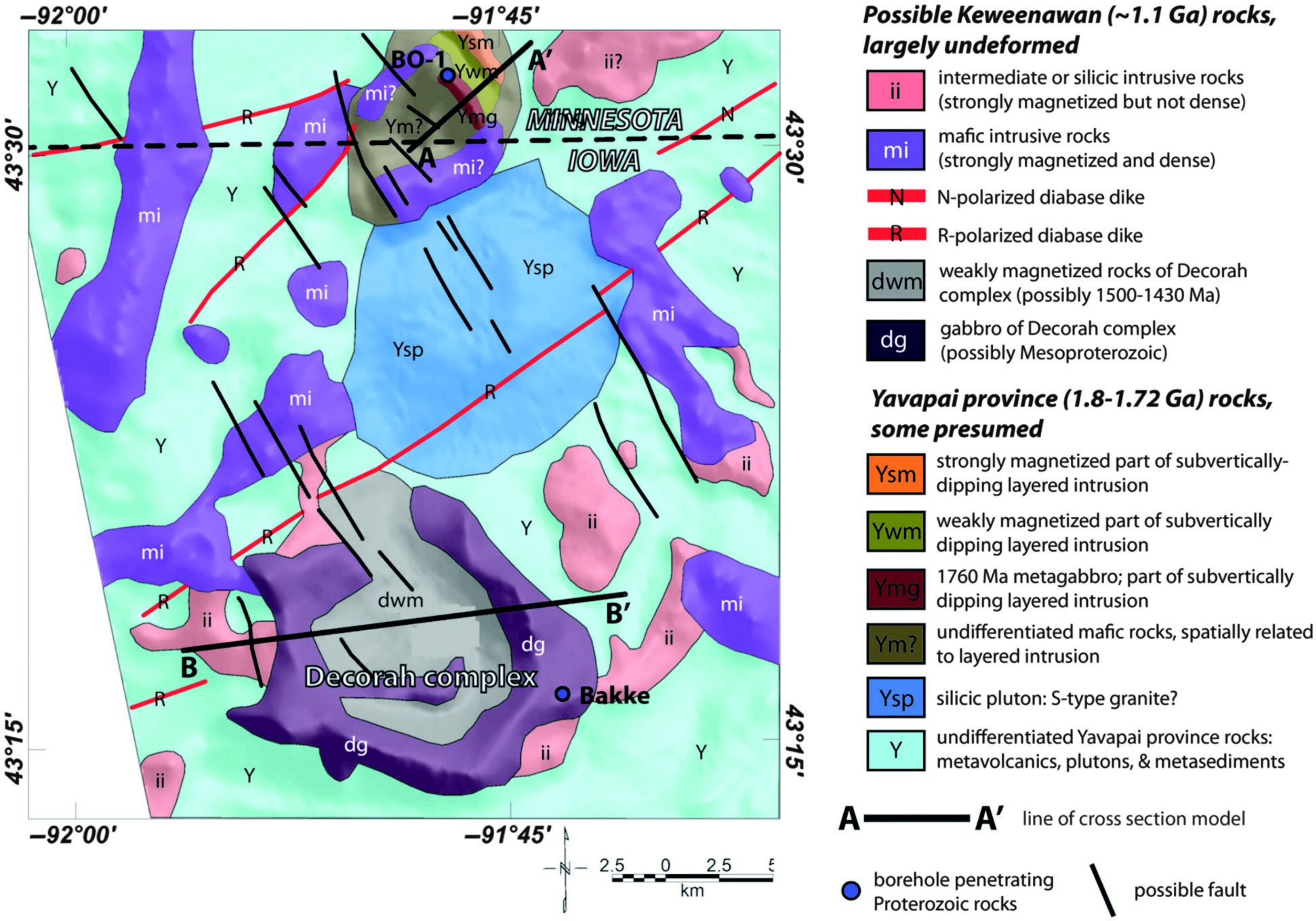



a
b
c
d
5cm
e

Decorah Impact Structure

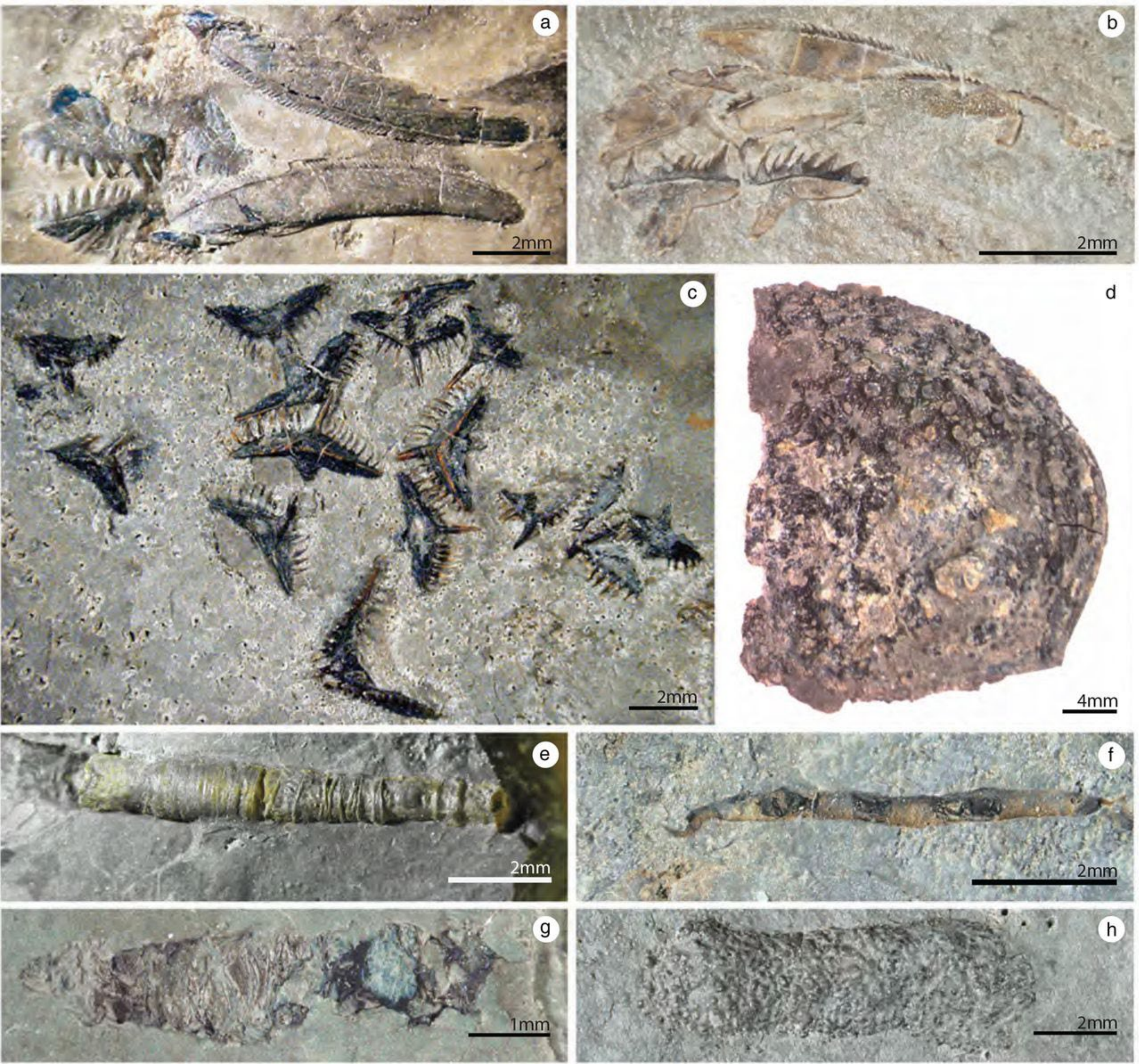


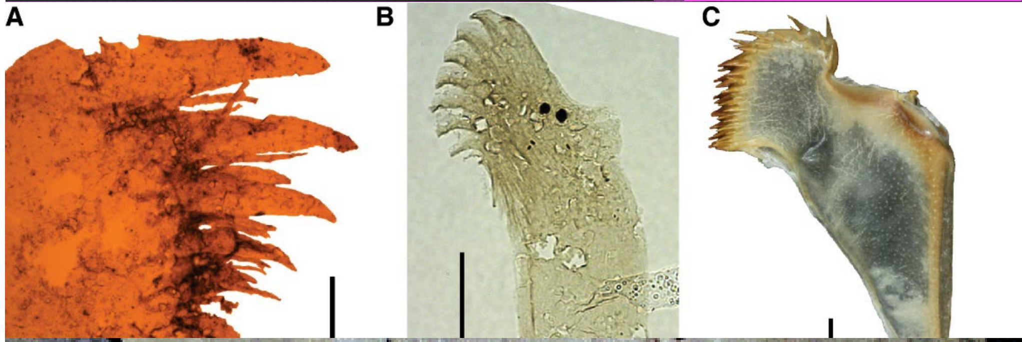




−92°00'
−91°45'
43°30'
43°15'
BO-1
A
A'
B
B'
Ysm
Ywm
Ymg
Ym?
mi?
mi
ii?
ii
Y
R
N
MINNESOTA
IOWA
Ysp
dwm
dg
Decorah complex
Bakke
N
2.5 0 2.5 5
km
Possible Keweenawan (~1.1 Ga) rocks, largely undeformed
ii intermediate or silicic intrusive rocks (strongly magnetized but not dense)
mi mafic intrusive rocks (strongly magnetized and dense)
N N-polarized diabase dike
R R-polarized diabase dike
dwm weakly magnetized rocks of Decorah complex (possibly 1500-1430 Ma)
dg gabbro of Decorah complex (possibly Mesoproterozoic)
Yavapai province (1.8-1.72 Ga) rocks, some presumed
Ysm strongly magnetized part of subvertically-dipping layered intrusion
Ywm weakly magnetized part of subvertically dipping layered intrusion
Ymg 1760 Ma metagabbro; part of subvertically dipping layered intrusion
Ym? undifferentiated mafic rocks, spatially related to layered intrusion
Ysp silicic pluton: S-type granite?
Y undifferentiated Yavapai province rocks: metavolcanics, plutons, & metasediments
A — A' line of cross section model
borehole penetrating Proterozoic rocks
possible fault

Decorah Lagerstätten



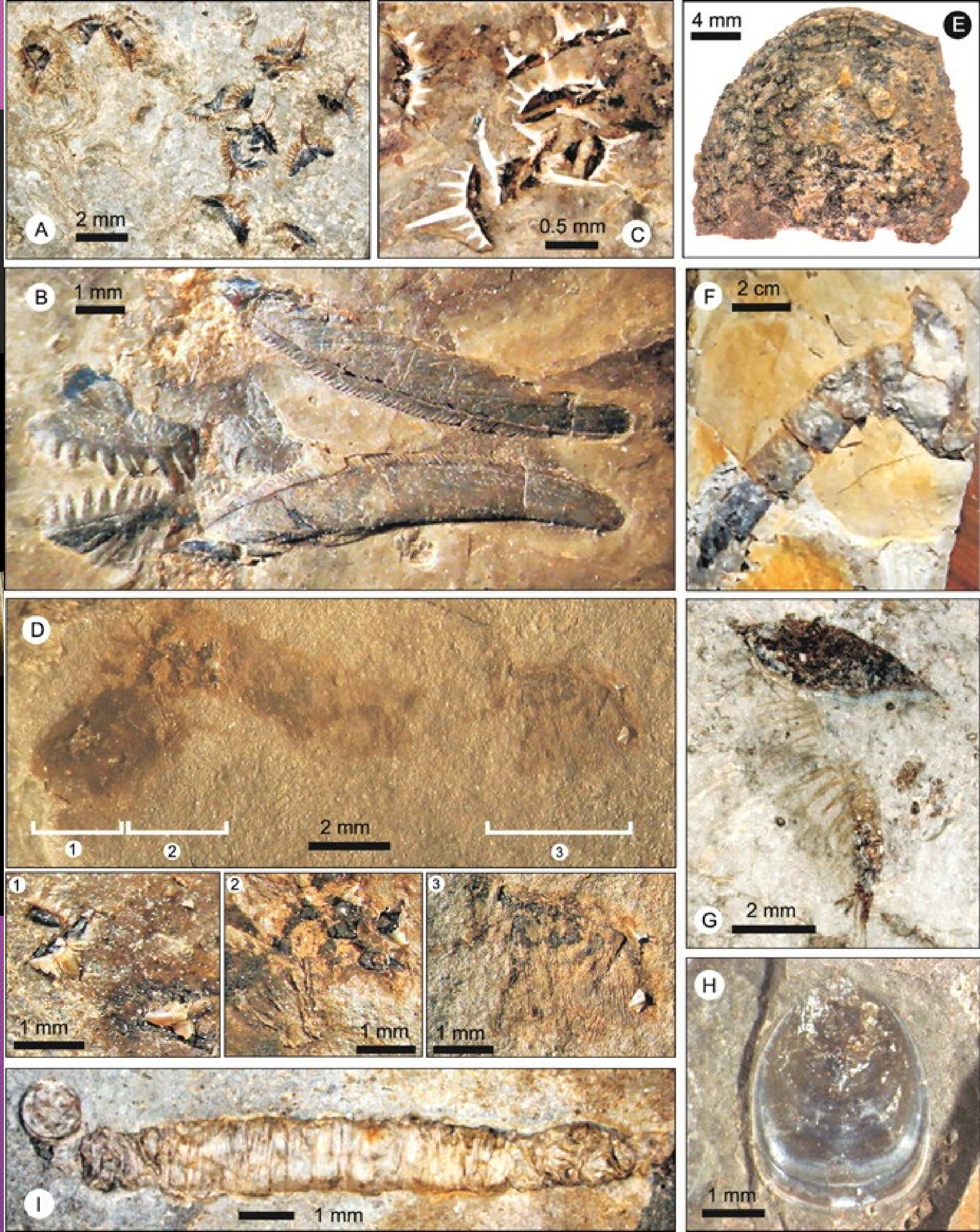


Eurypterids – Sea Scorpions

Extinct arthropods

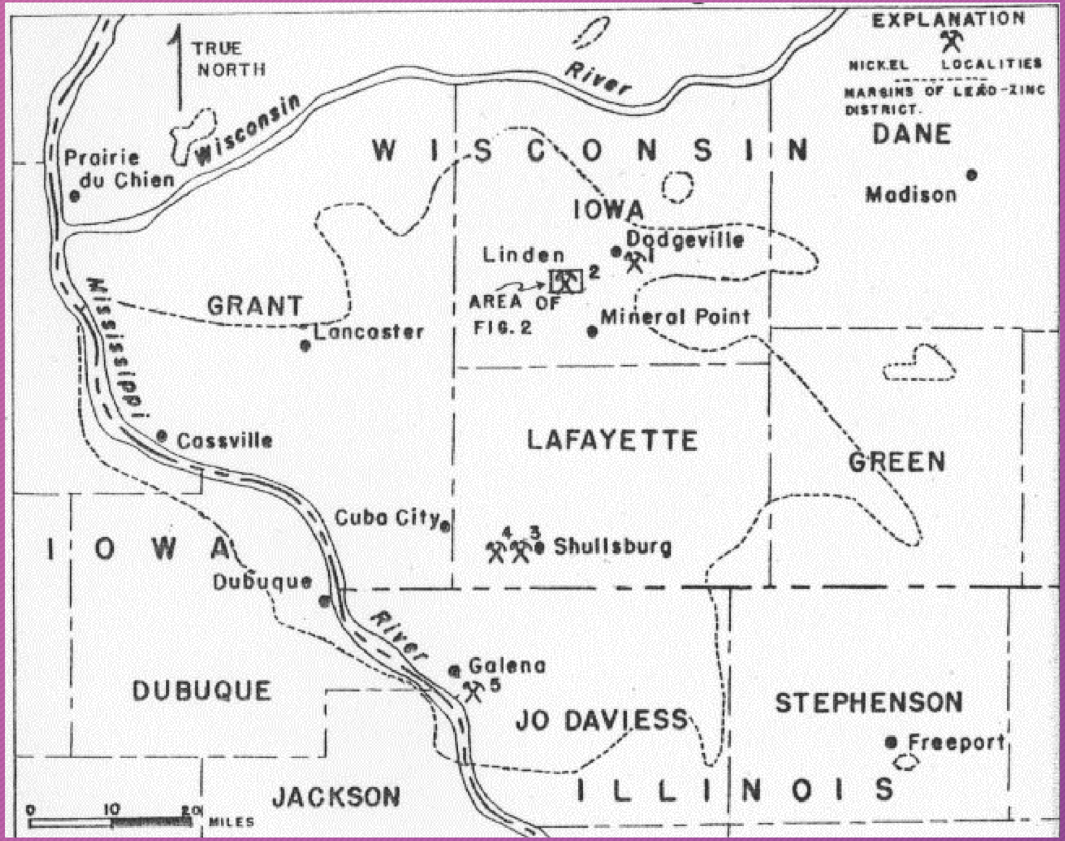
Ordovician Life:
Warm shallow seas = ☺ Life

- Brachiopods
- Bryozoans
- Corals
- Receptaculitides
- Mollusks
- Worms
- Arthropods
- Echinoderms
- Graptolities
- Conodonts

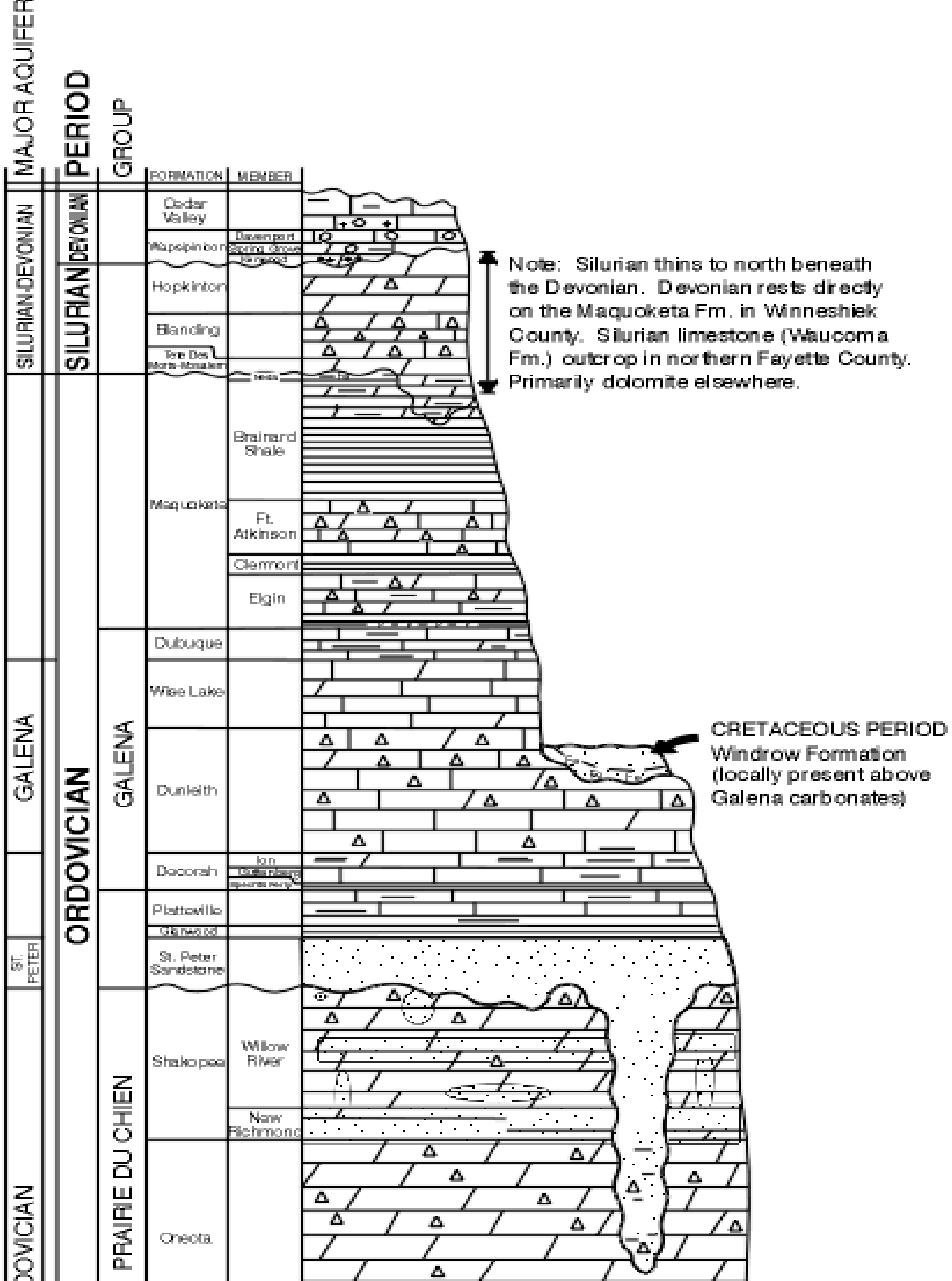


Galena Group

- Dunleith, Wise Lake, and Dubuque Formations

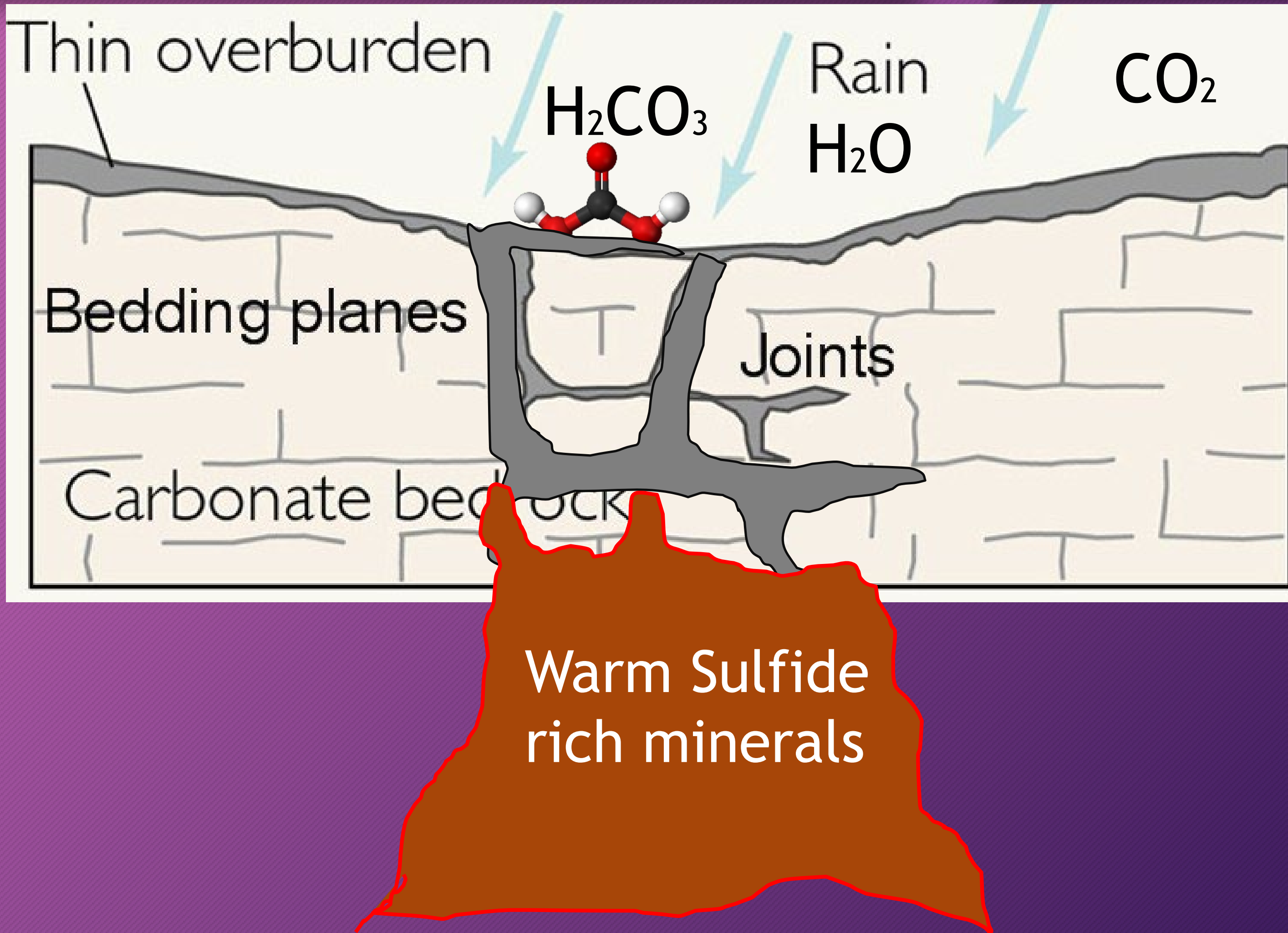


Upper Mississippi Valley Zinc and Lead District



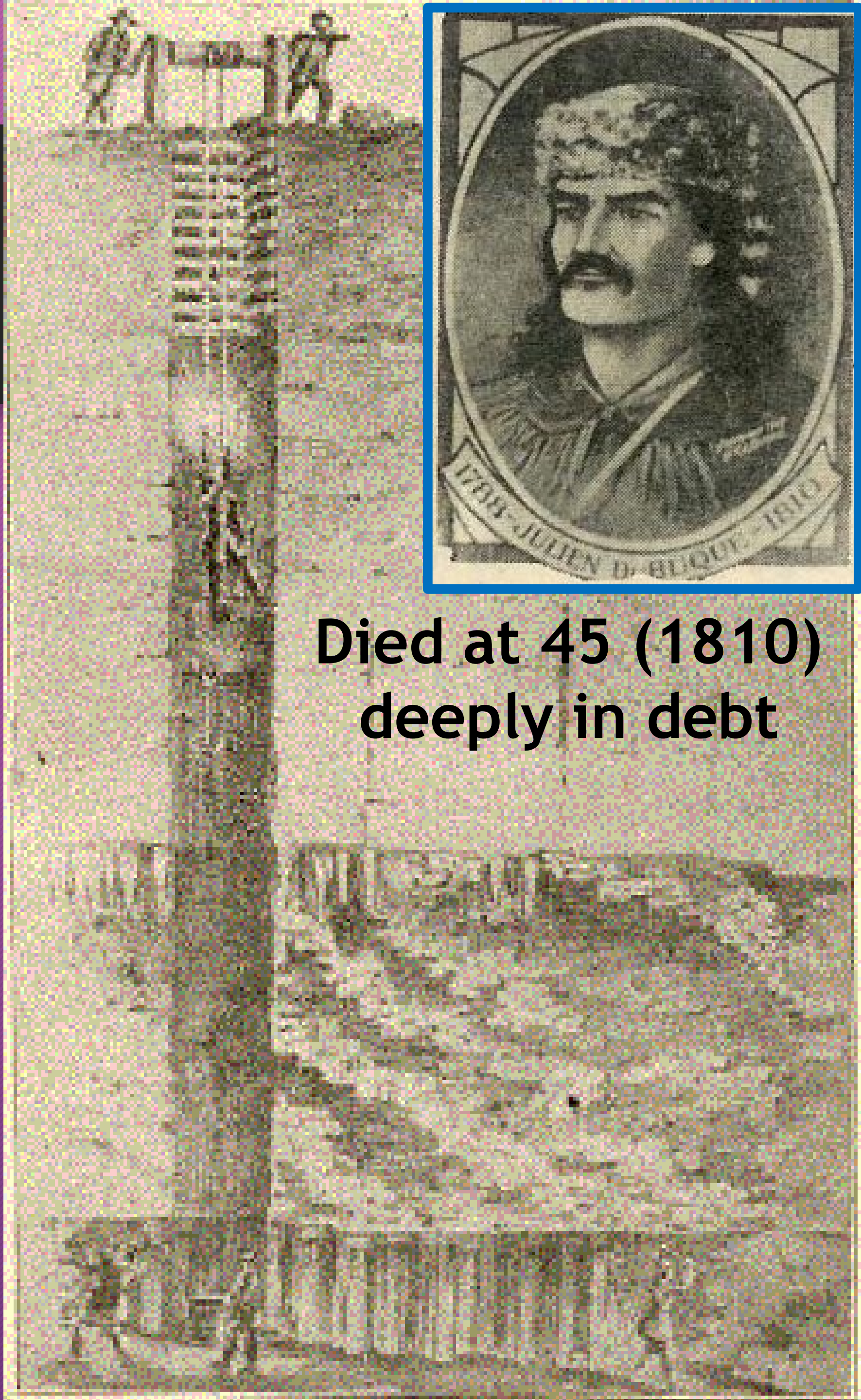
How does Galena & Zinc form in Limestone?

- Space is created, through karst processes
- Warm sulfide-rich solutions migrate upwards and infiltrate the new space
- Sulfide minerals precipitate out of solution and along the edges of these new spaces
- The Mississippi cuts its channel into the landscape and lowers the water table
- Exposing the sulfide minerals, creating Iron sulfide, Lead sulfide, and Zinc sulfides



Lead and Zinc Mining 1788-1810

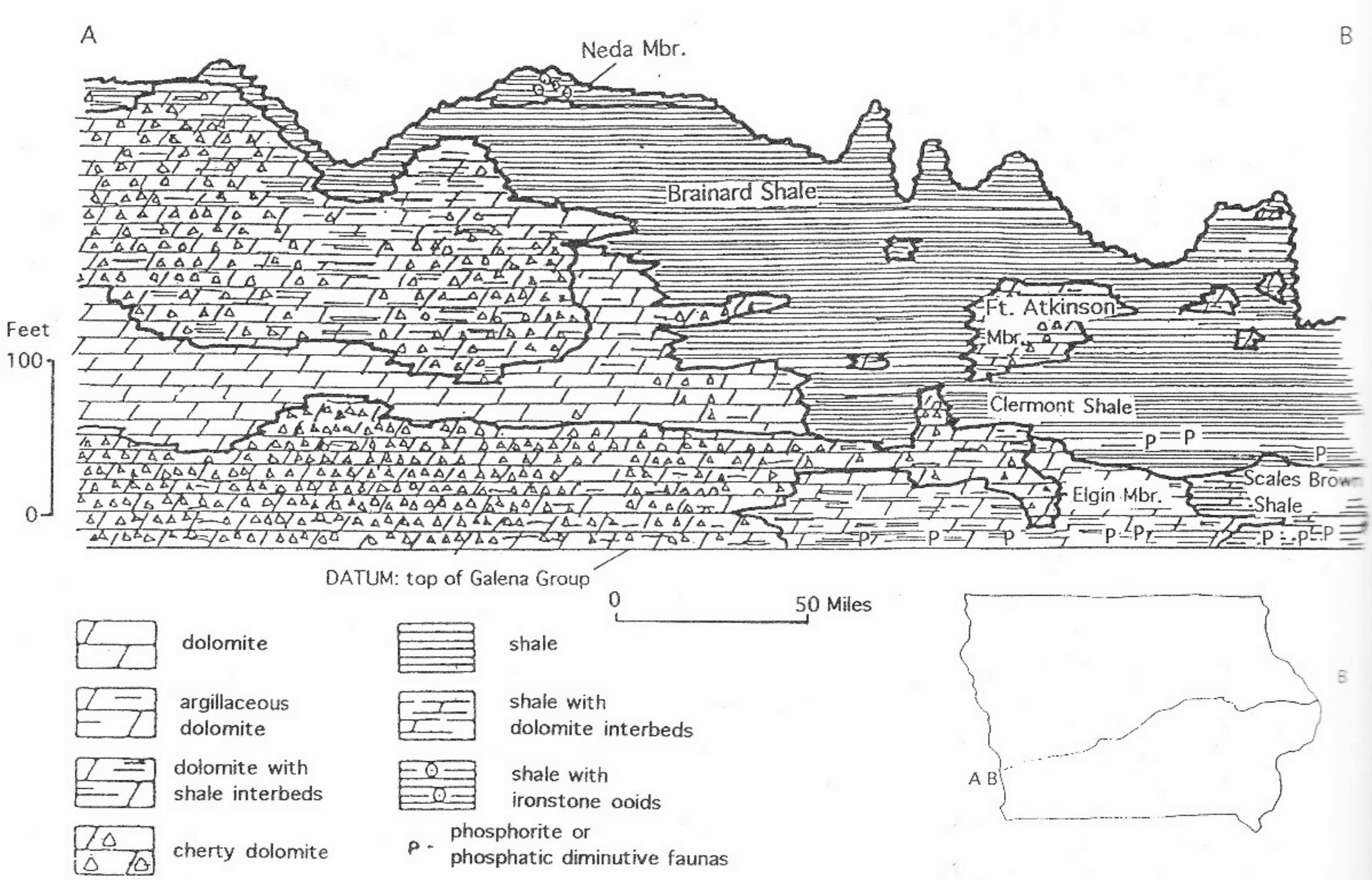
- Spain ruled Iowa via the Treaty of Paris (1763) as a product of the French and Indian War (1756-1763)
- Julien Dubuque became friends with the local Meskwaki, eventually marrying Potosa and entering their culture as *Little Night*.
- Julien, identified the mineral recourses and with the Meskwaki's permission began mining
- Julien, requested ownership/confirmation of his land from the Spain, and it was granted in 1796. 'The Mines of Spain'



Died at 45 (1810) deeply in debt

Maquoketa Formation

- Thick impermeable shale
- Large caverns were excavated under Johnson and Polk counties to seasonally store liquefied petroleum gas
- Enables the pipeline industry to store their product so that they can meet demand during the winter



Manufacturing Depends on Minerals

- Manufactures use minerals to create the high-tech devices that connect us to the world. TVs require 35 different minerals and computer chips can require up to 60 minerals and elements.
- From the mirrors and paint to the body frame and engine, minerals are integral to every vehicle on the road. Gold, platinum and aluminum are just a few of the minerals used by auto manufacturers.
- Advanced energy technologies such as wind turbines, electric vehicles and solar panels depend on minerals including rare earths, copper and zinc.

Minerals Make Economic Growth Possible

Jobs and Wages

- A job in U.S. metals mining carries an average salary of approximately $85,500 a year—74 percent higher than the combined average of all private sector jobsi.

- More than 1.3 million U.S. jobs are supported through minerals mining — 433,000 Americans are directly employed and more than 872,000 are indirectly employed.

- For every job in metals mining, an estimated 2.9 additional jobs are generated, and for every nonmetals mining job, an additional 1.8 jobs are created.