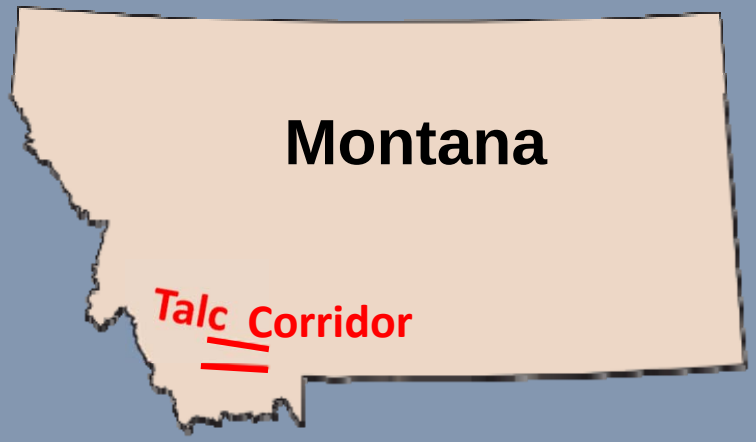
World Class Talc Deposits of Southwestern Montana



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May 9, 2017
Mine Design Operations and Closure Conference

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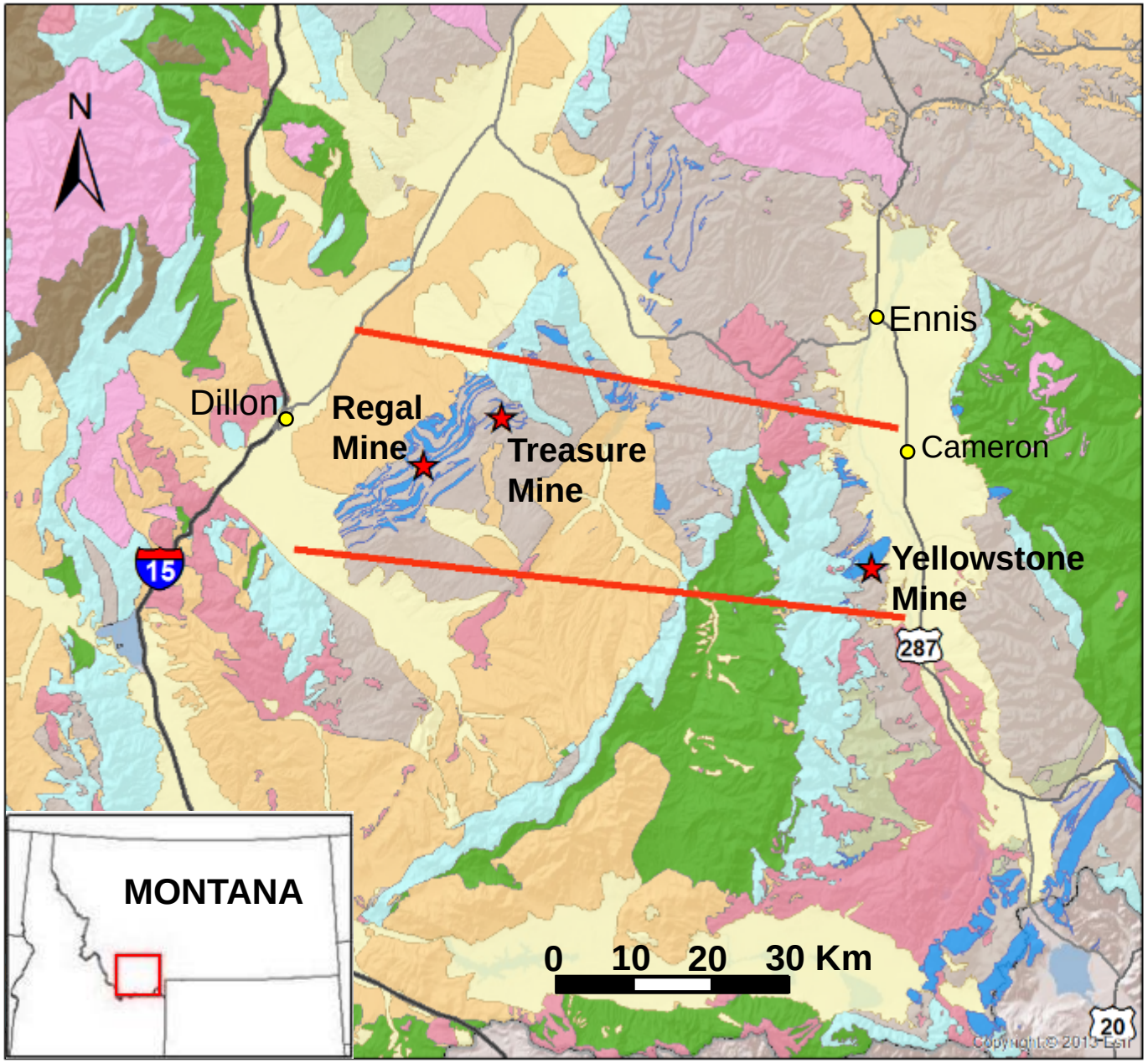
- Childs Geoscience Inc. Staff: Sandy Underwood, Chad Walby, Rex McLachlin, and Troy Himes
- Todd Johnson (Consulting geologist)

Regional Geology of Southwest Montana



- Active Talc Mines
- Talc Corridor
- Quaternary Deposits
- Tertiary Sedimentary
- Tertiary Igneous
- Cretaceous Igneous
- Mesozoic Sedimentary
- Paleozoic Sedimentary
- Mesoproterozoic Sedimentary (Belt Supergroup)
- Archean Metamorphic
- Archean marble

Geology after Vuke et al., 2007

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Characteristics of the Talc Corridor

- An east-west trending deep-seated structural zone 65 km long by 25 km wide (between Dillon and Cameron, MT)
- Contains abundant Archean marble layers (talc host)
- Contains 3 currently operating talc mines with ~18 million tonnes of talc reserves (Dec. 31, 2014), 1 talc resource, 3 past talc producers, and numerous talc prospects
- Contains abundant N/NW-striking diabase dikes that occupy faults inferred to have been conduits for talc-forming fluids
- Age, structural setting, and chemistry suggest talc formed during development of a southern extension of the Proterozoic Belt Basin

The corridor acted as a locus for development of major talc deposits

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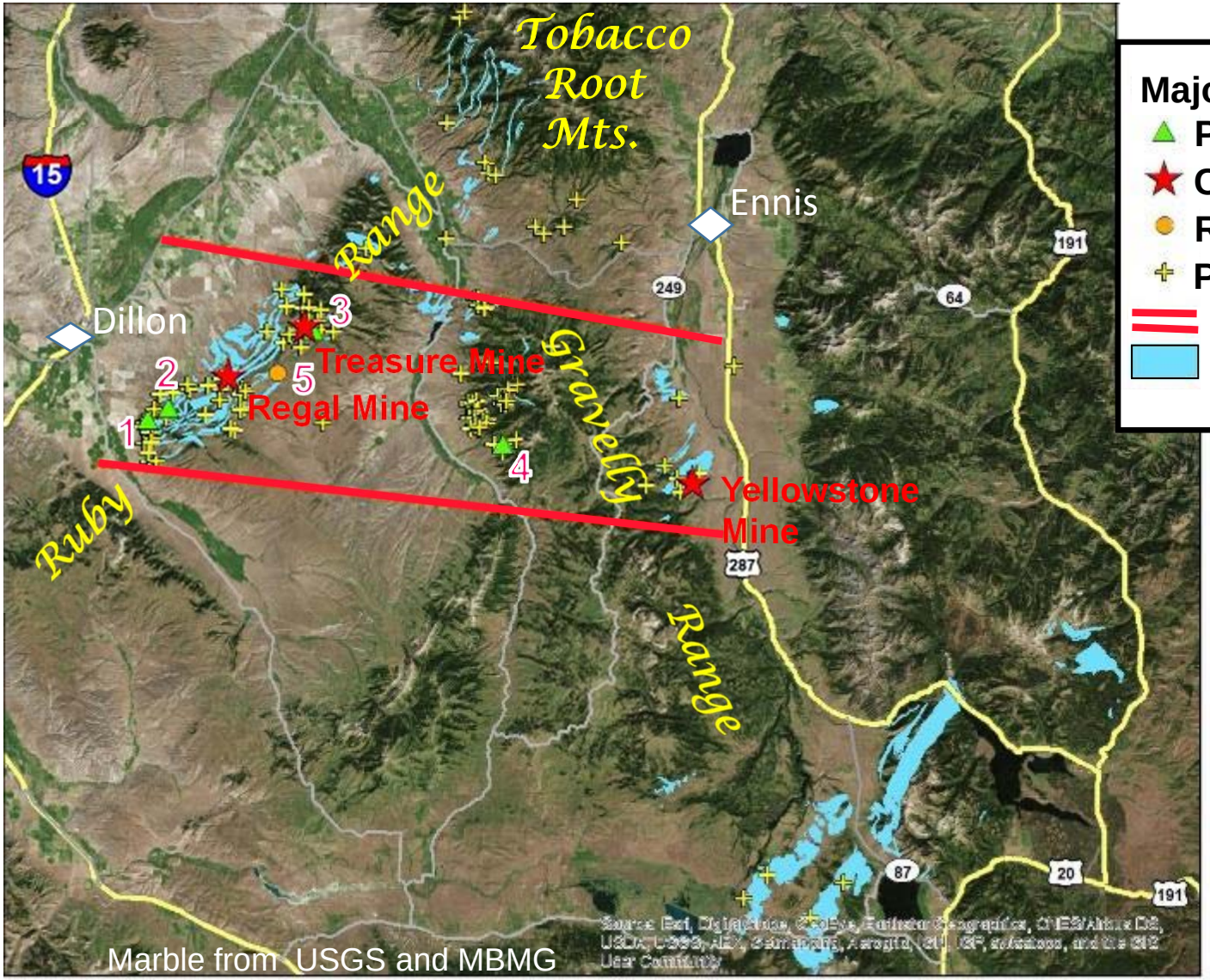
Talc and Marble Occurrences in SW Montana

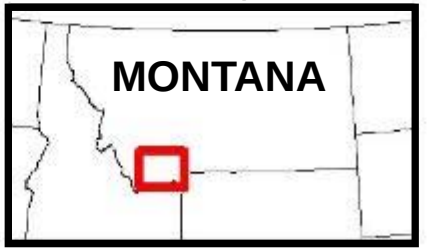


Major Talc Occurrences

- Past Producer
- Current Producer
- Resource
- Prospect
- Talc Corridor
- Archean to Early Proterozoic marble

Past Producer or Resource

1. Smith-Dillon Mine
2. Mineral King Mine
3. Beaverhead Mine
4. Willow Creek Mine
5. MP Prospect



0 10 20 30 40 Km

N

Yellow = Major highways
Gray = Other roads

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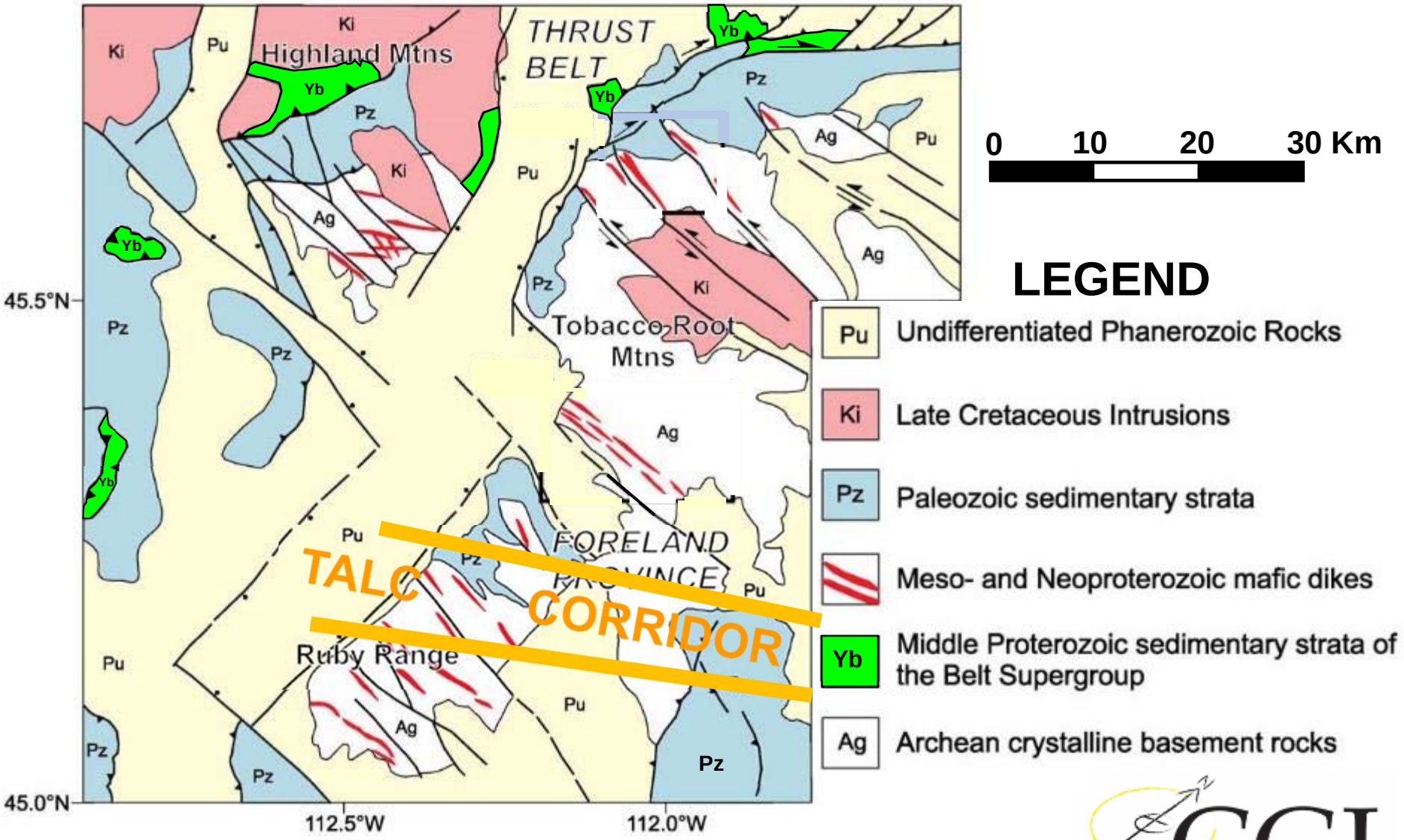
Mafic Dike Distribution in SW Montana



Geology from Harlan et al. (2007)

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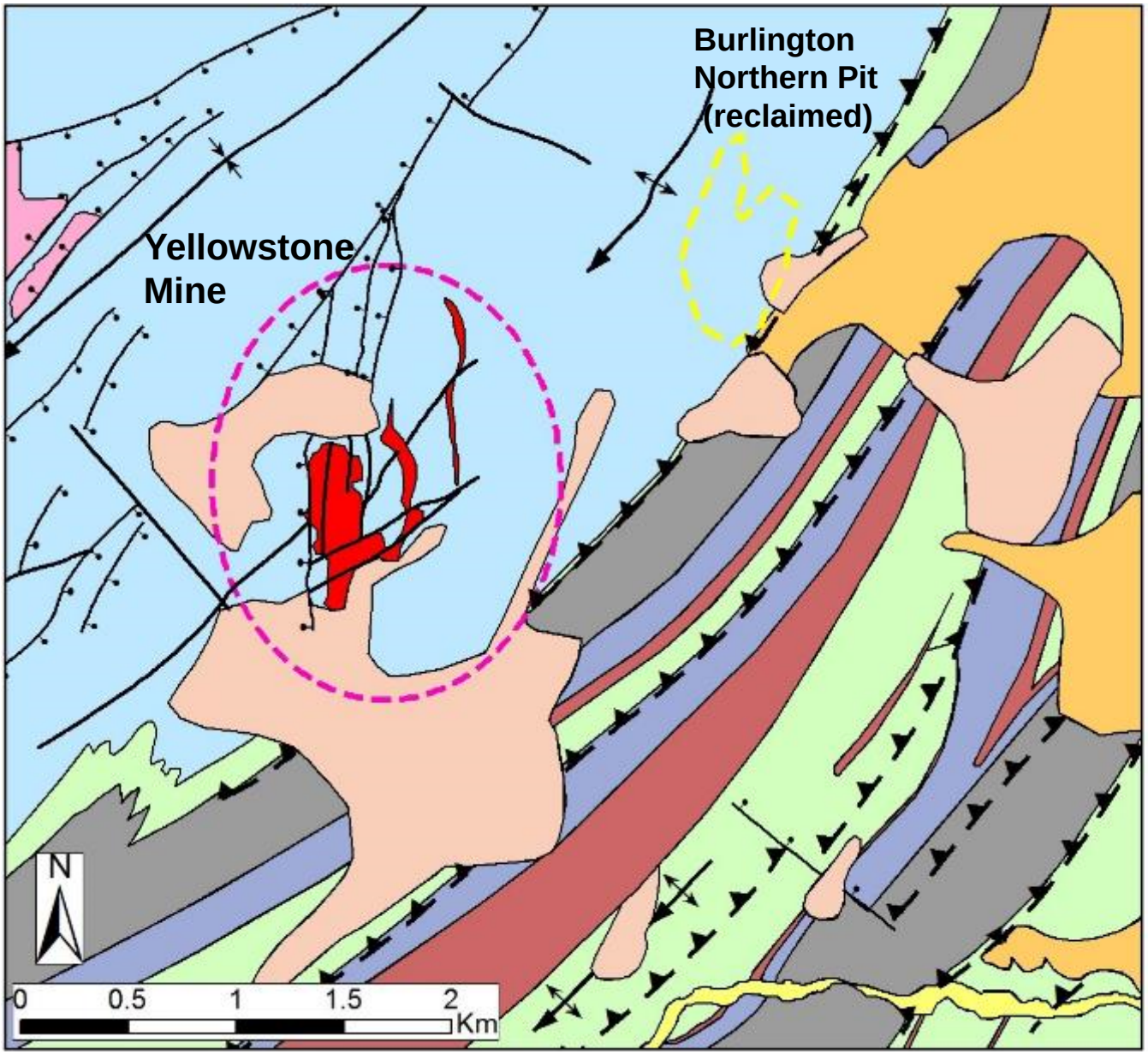
Yellowstone Mine Geologic Map (Talc in red)



Quaternary
- Alluvium
- Gravel

Pleistocene
- Huckleberry Ridge Volcanics

Cambrian
- Flathead Quartzite

Proterozoic
- Talc ore

Archean
- Phyllite
- Amphibolite
- Banded Iron Formation
- Biotite Plagioclase Schist
- Marble

- Normal Faults
- Thrust Faults
- Other Faults
- Plunging Anticline
- Plunging Syncline

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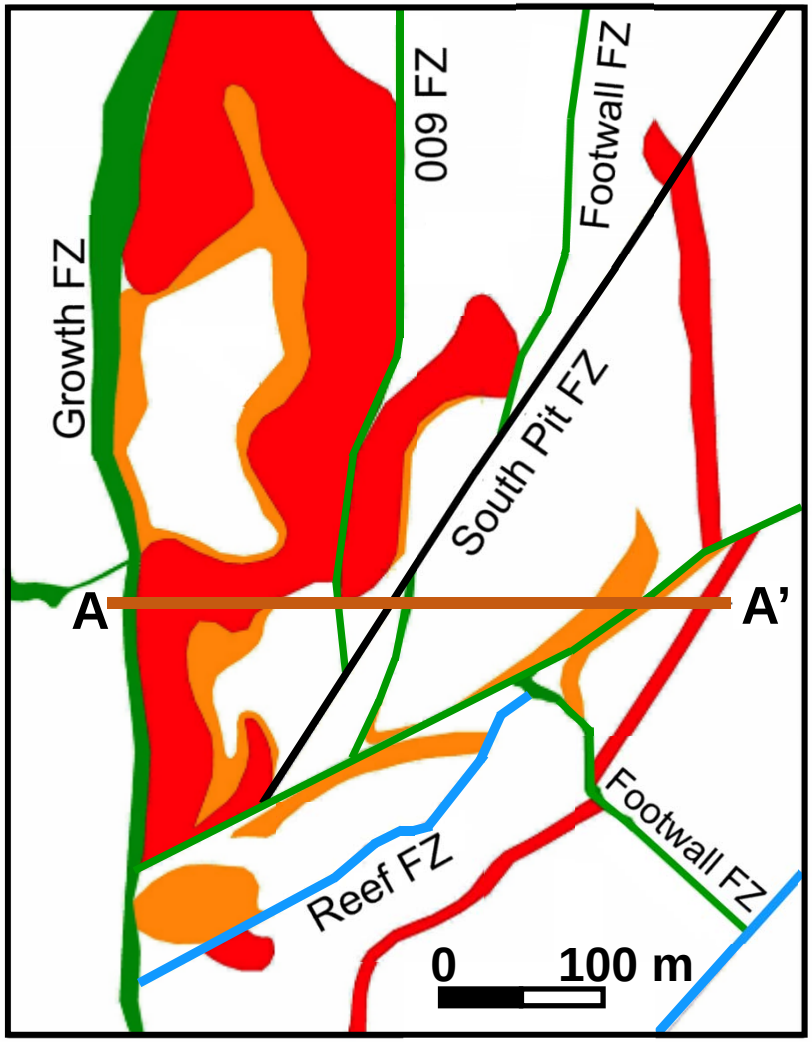
Geology from Cerino (2002)

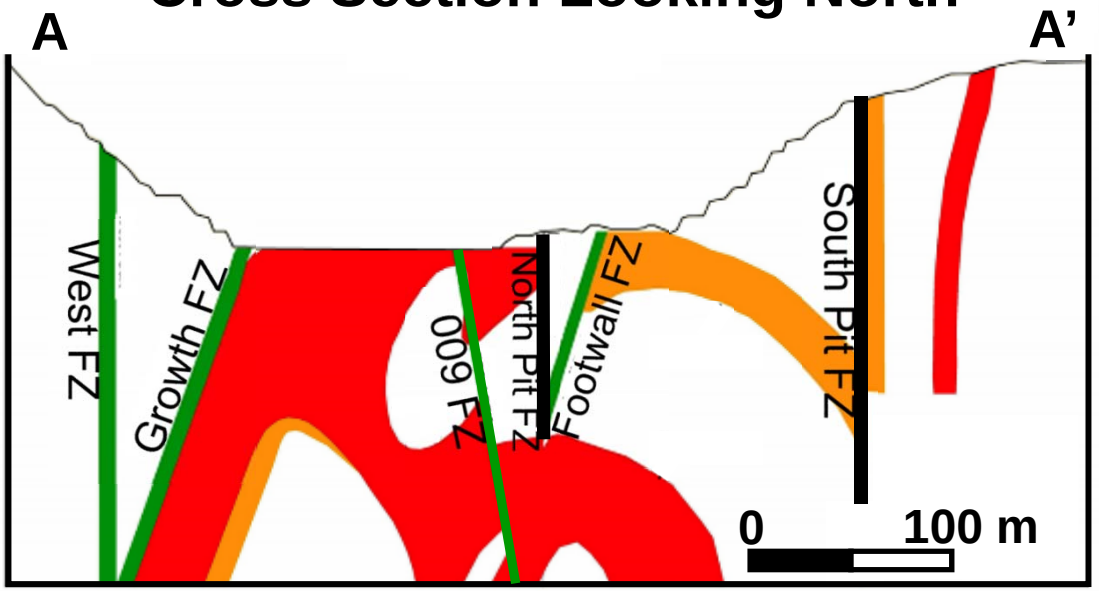
Yellowstone Mine Talc Distribution

1,753m (5,750 ft) Level Plan Map



from Cerino (2007)

Cross Section Looking North



MAP AND SECTION LEGEND

- >90 percent talc
- 50-90 percent talc
- Dolomitic marble
- Fault (FZ) with name

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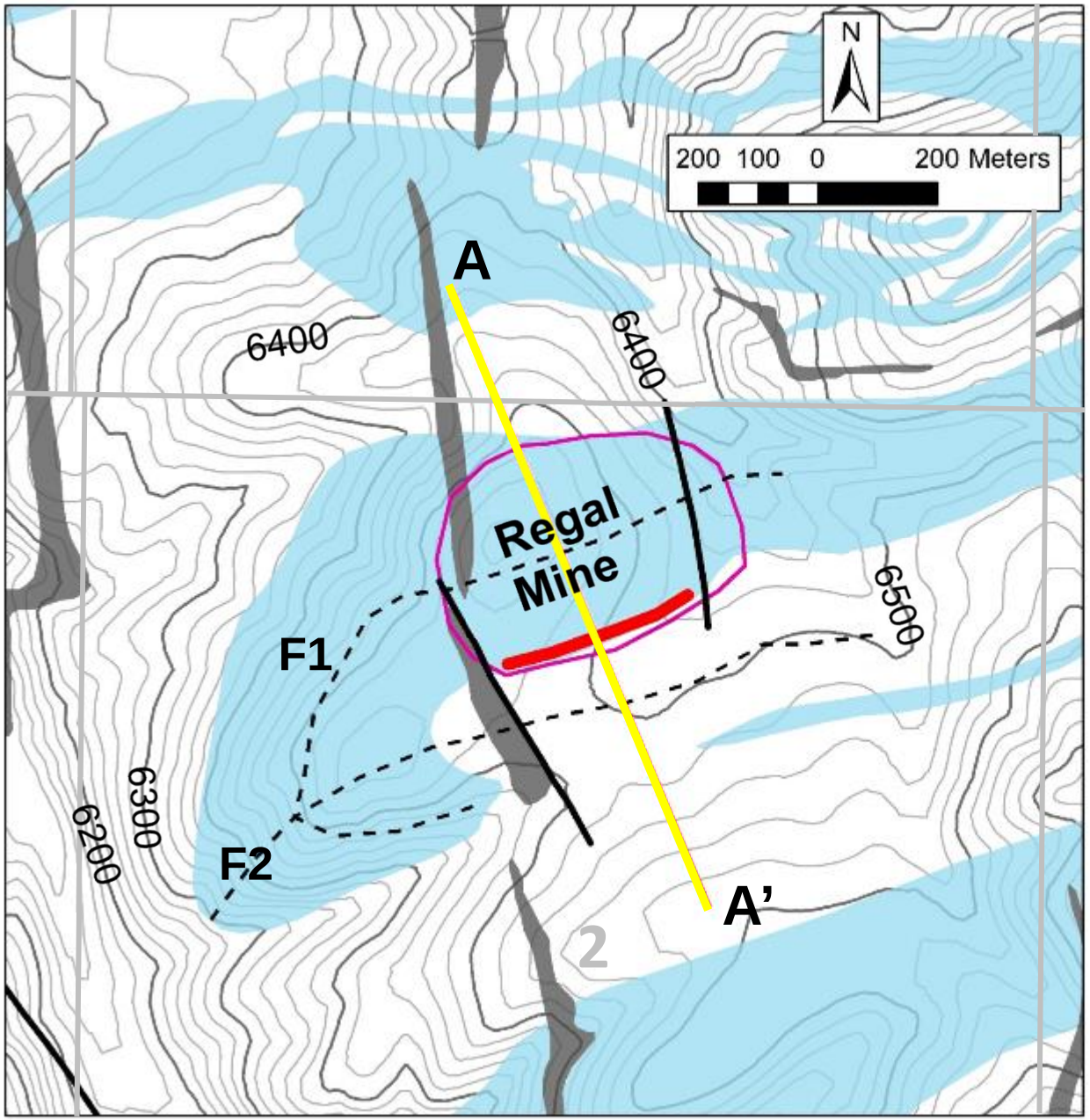
Regal Mine Geologic Map



LEGEND

- Pit Outline as of 2011
- Section A-A'
- Fold Hinges
- Faults
- Talc
- Diabase (dikes)
- Marble
- Undifferentiated Metasediments

Contour Interval = 20 ft

Modified from Okuma (1973)

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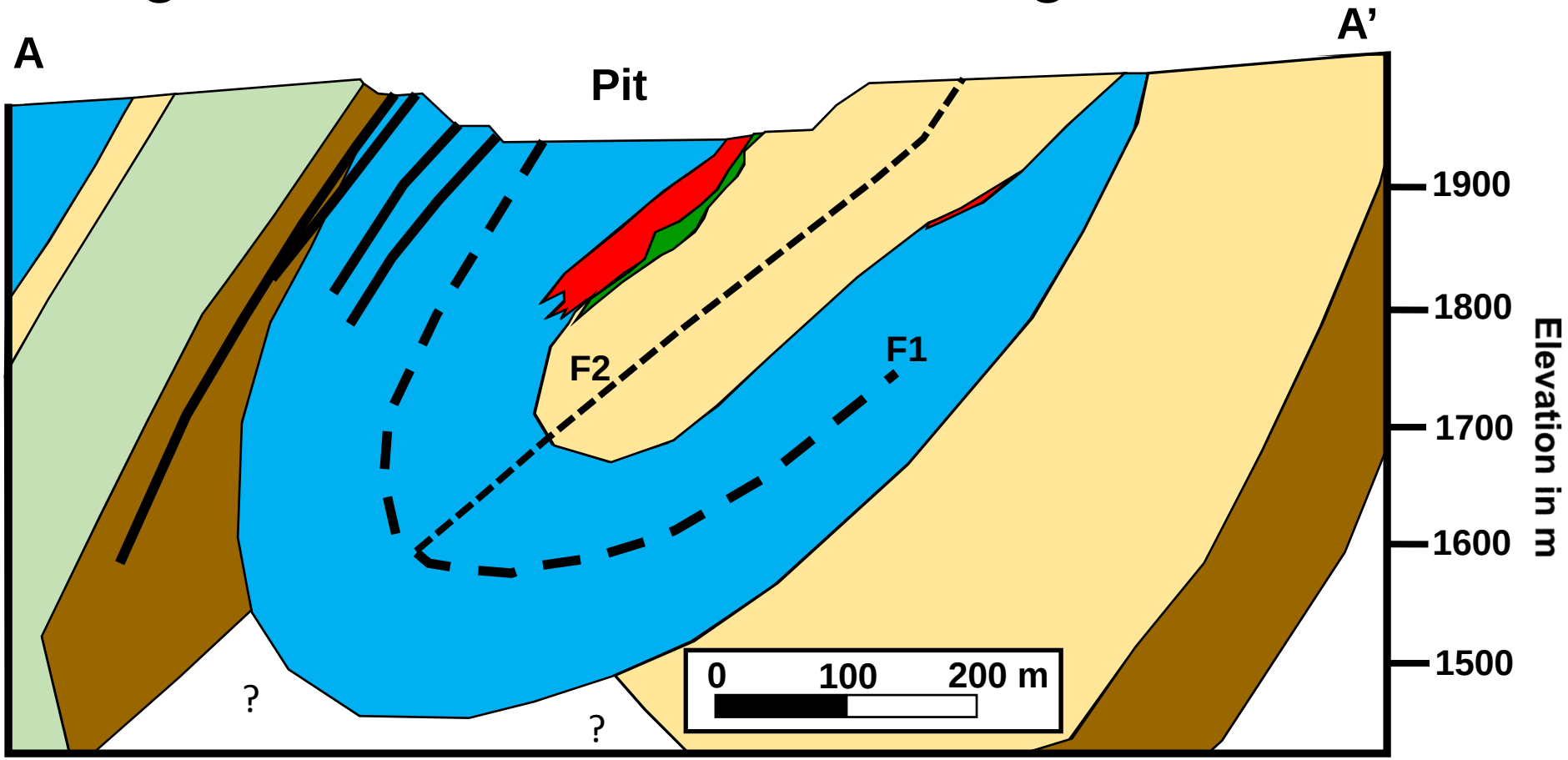
Regal Cross-Section A-A’ Looking East-Northeast



Talc
Chlorite
Amphibolite
Marble (refolded)
Undifferentiated metasediments
Biotite Gneiss
Fault

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Regal Mine Looking South as of 2007

Photo by Julia Gwinn (2011)

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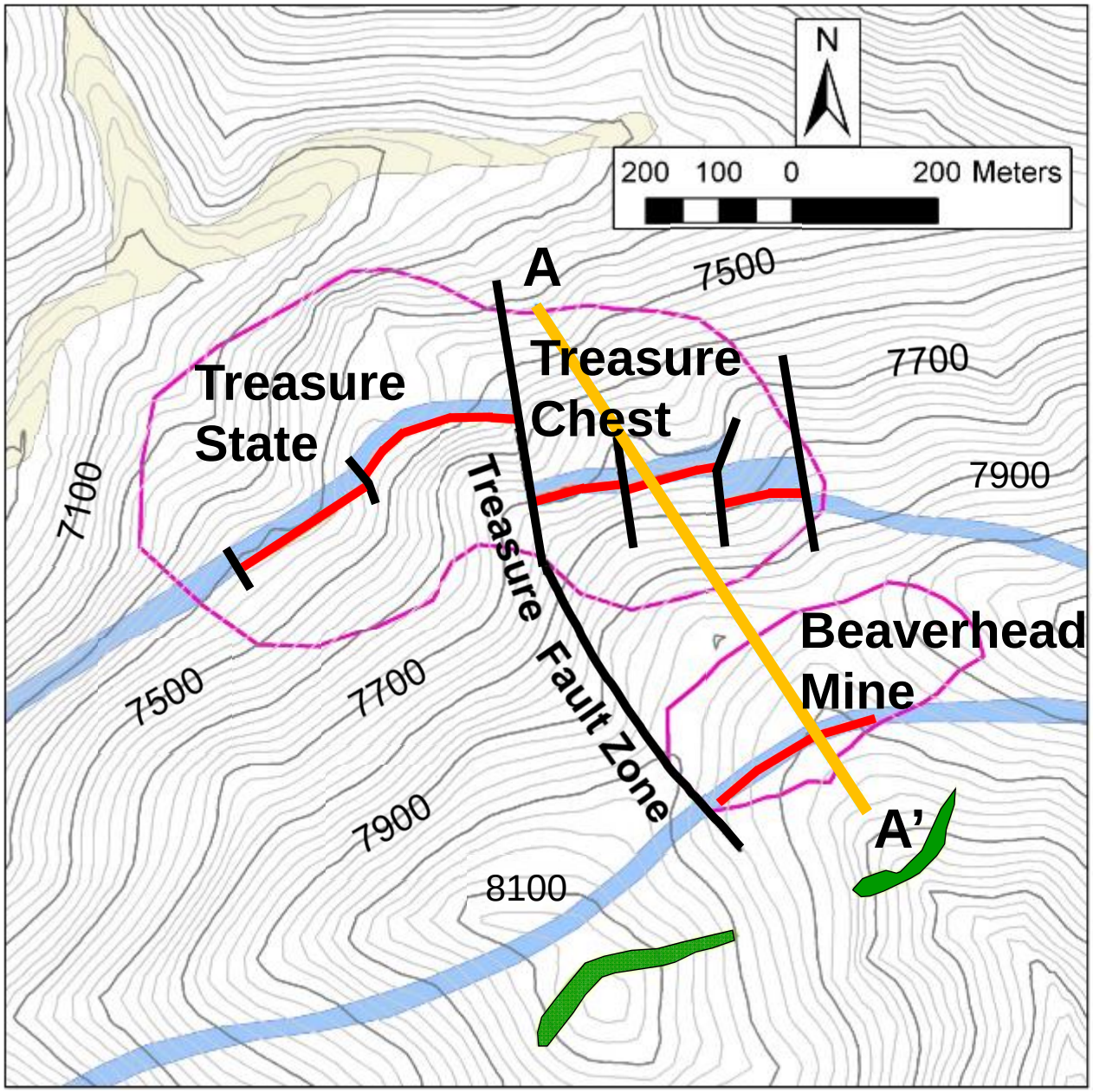
Treasure and Beaverhead Geologic Map



LEGEND

- Pit outlines as of 2011
- Cross Section Line
- Fault
- Quaternary Alluvium
- Talc
- Pegmatite (dikes)
- Marble
- Undifferentiated metasedimentary rocks

Contour Interval = 20 ft

Geology modified from Garihan (1973)

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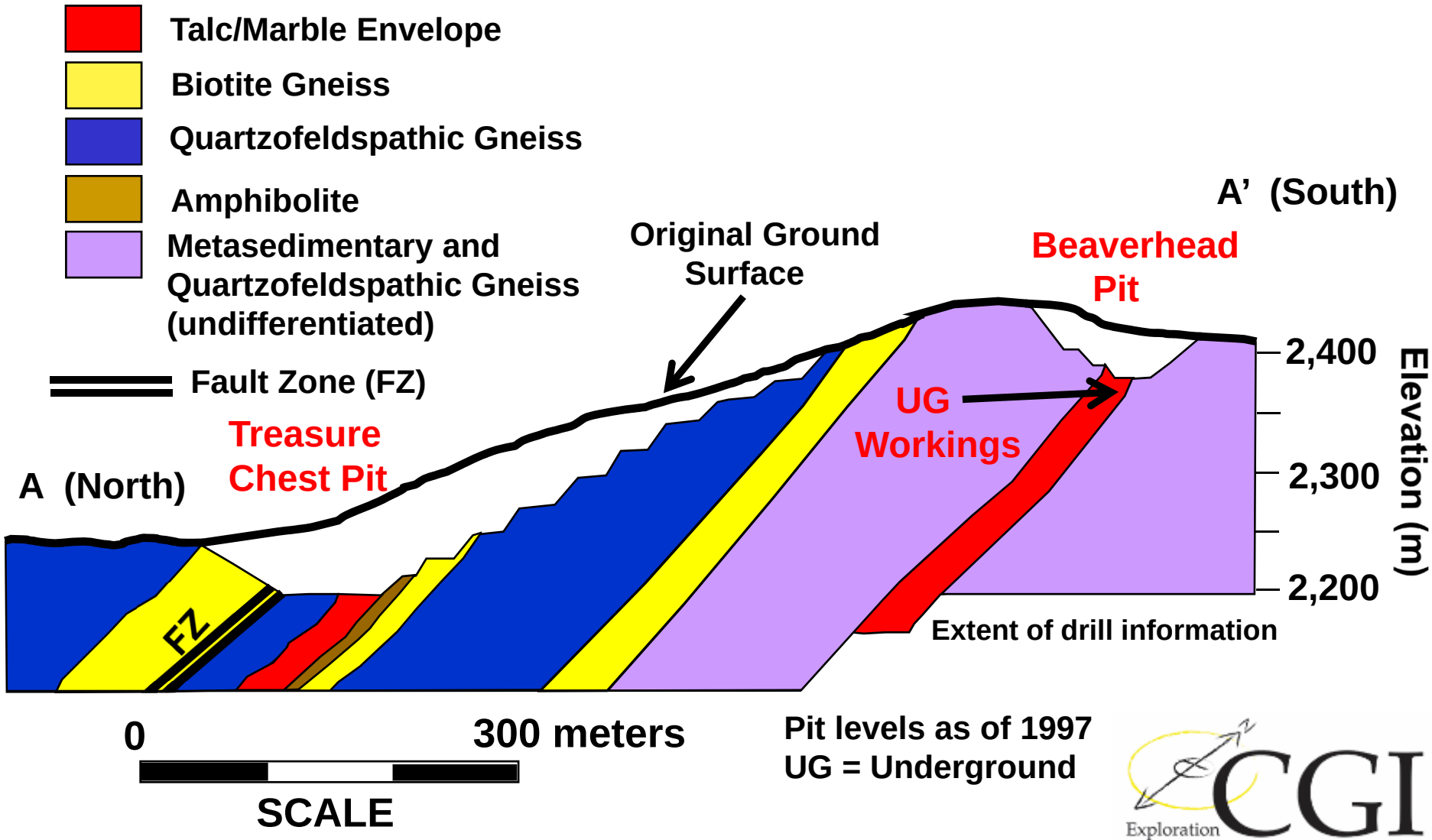
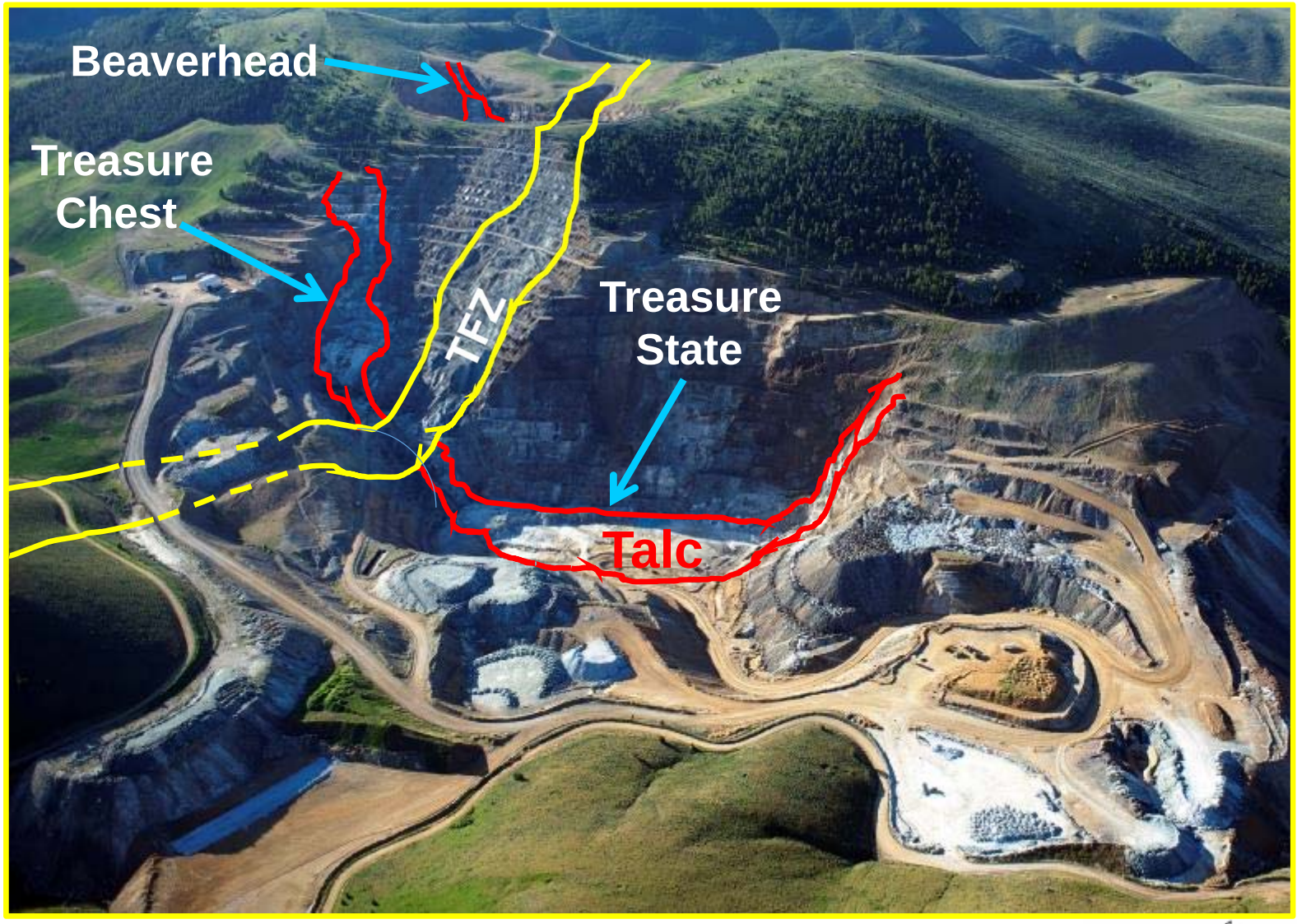
Geologic Cross-Section A-A' at the Treasure Chest and Beaverhead Mines



Treasure Mine Looking South



Talc and marble in red
TFZ = Treasure Fault Zone in yellow

Photo by Julia Gwinn (2011)

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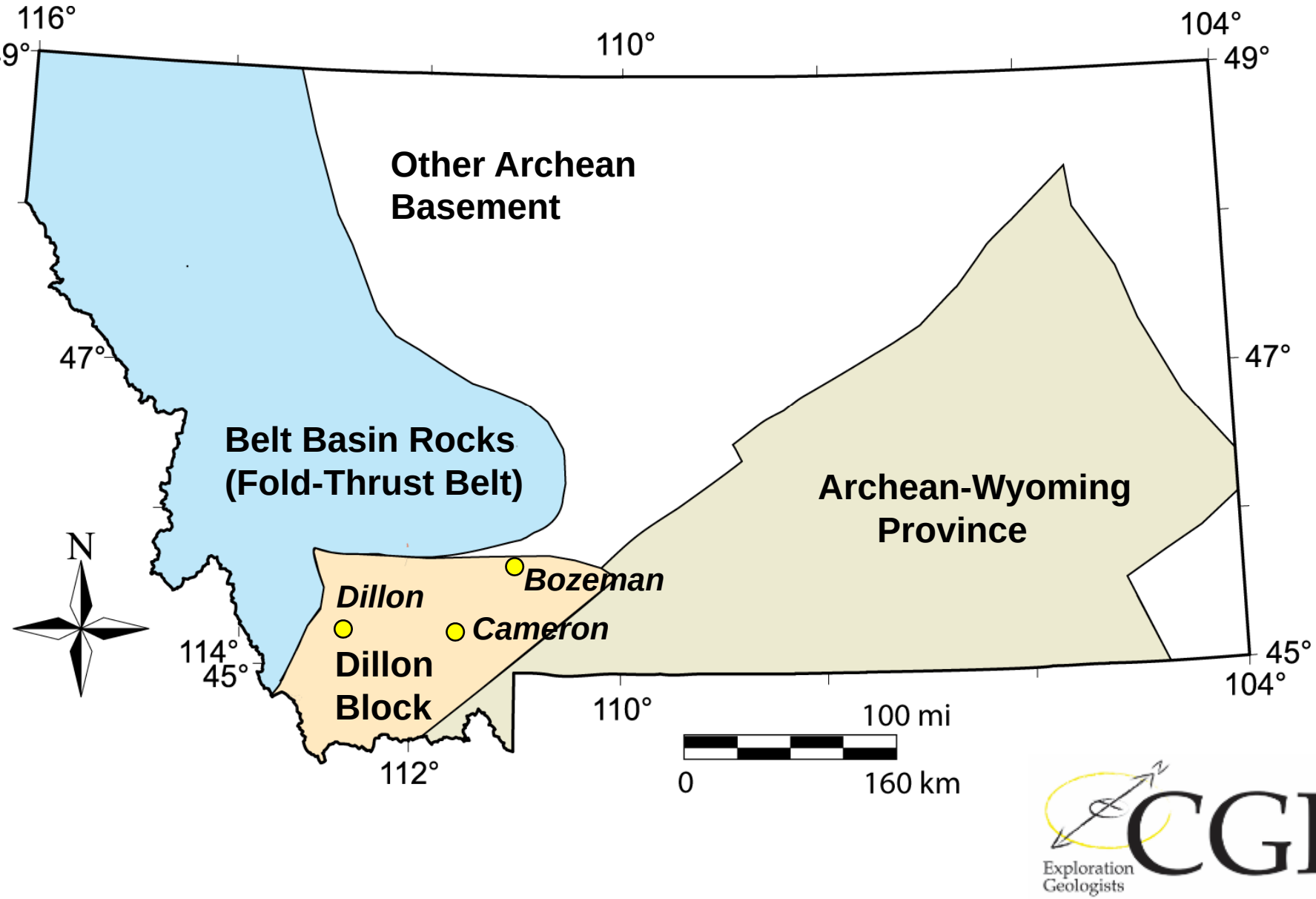
Belt Basin Rocks & Major Tectonic Provinces In Montana



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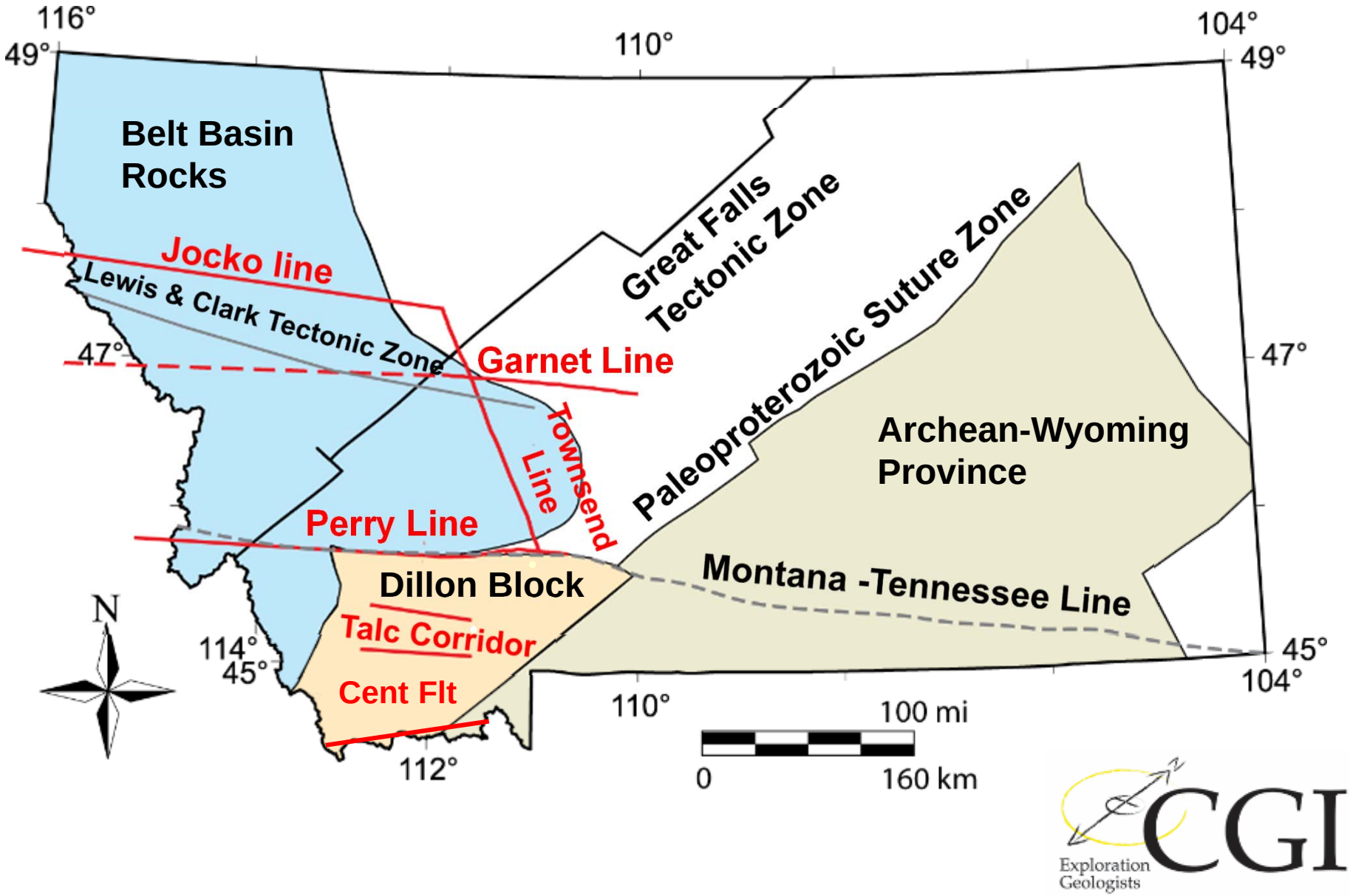
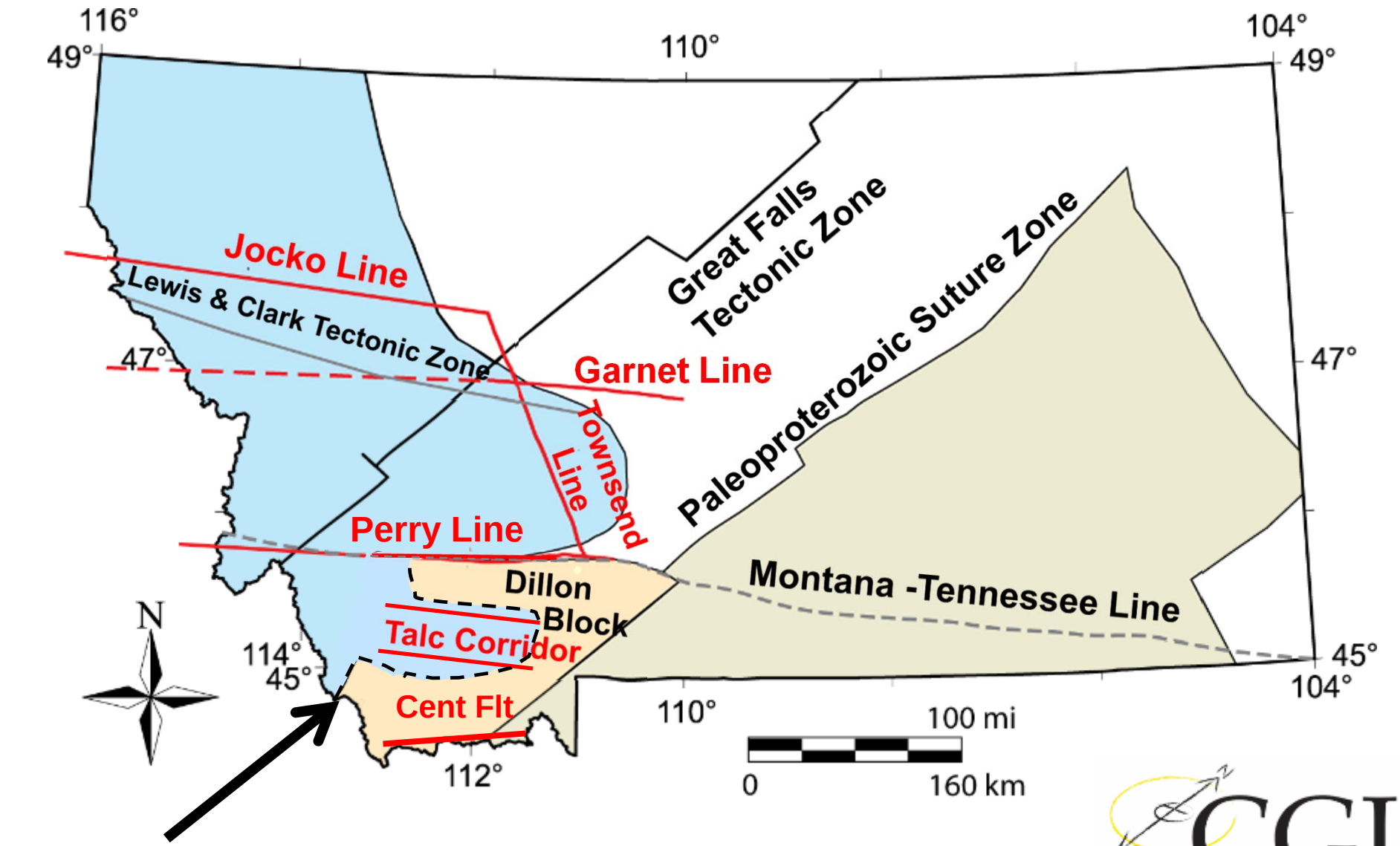
Major Regional Structures of Montana and the Talc Corridor



Inferred Southern Extension of the Belt Basin



Proposed Southern Extension of Belt Basin

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Structural Geology and Implications for the Belt Basin

- The E/W trending Talc Corridor is subparallel to other E/W trending mega structures (Jocko, Garnet, and Perry Lines, Centennial Fault Zone) present in and south of the Belt Basin
- Previous mapping has identified the E/W trending Perry Line to define the boundary between Belt Basin rocks on the north and the Dillon crystalline block to the south
- The talc corridor lies 46 to 80 km south of the Perry Line
- The age of the talc (1.1-1.3 Ga) overlaps and postdates development of the Belt basin (1.3-1.5 Ga)
- The SE extent of the Belt Basin may be inferred to lie 80 to 90 km farther south than previously postulated

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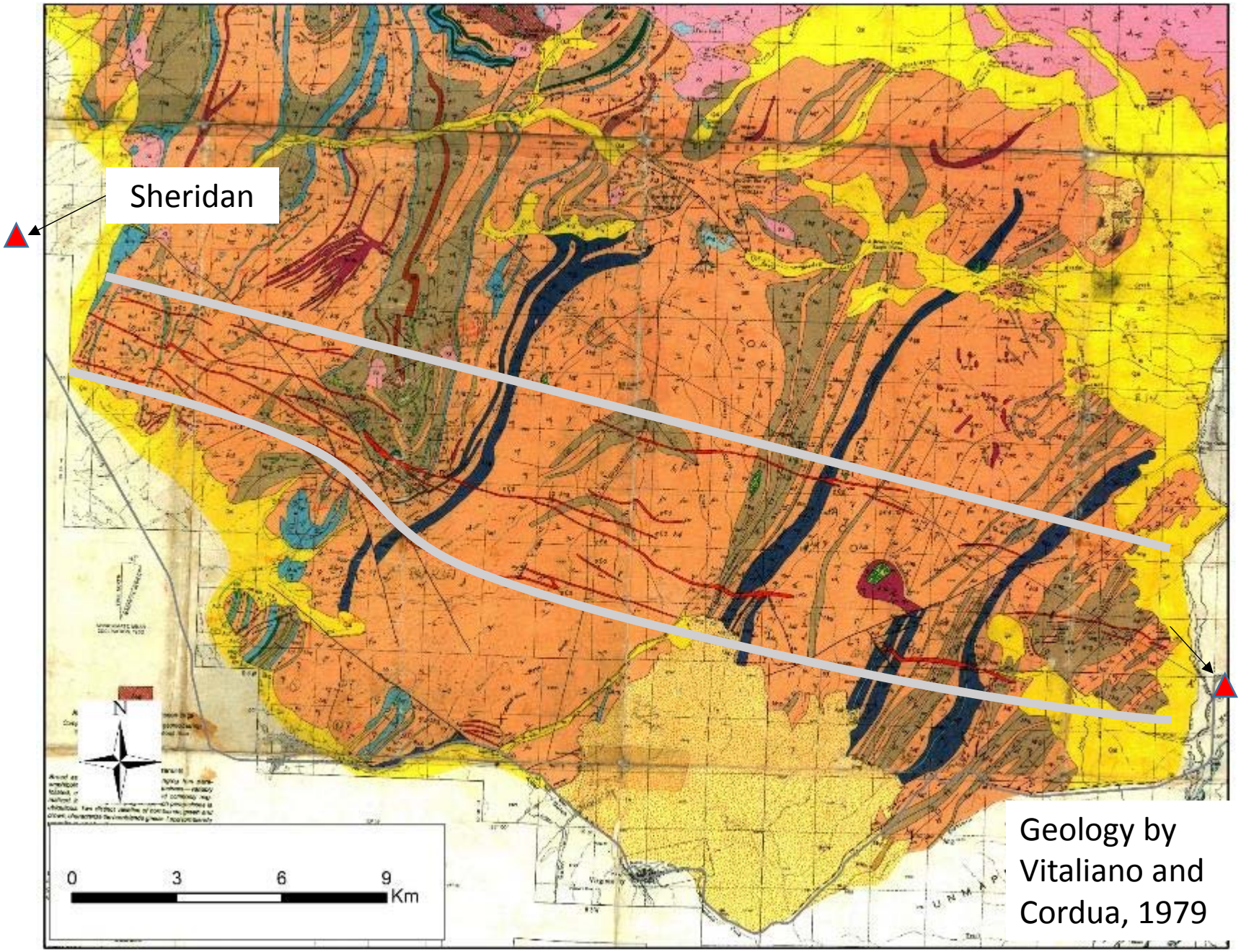
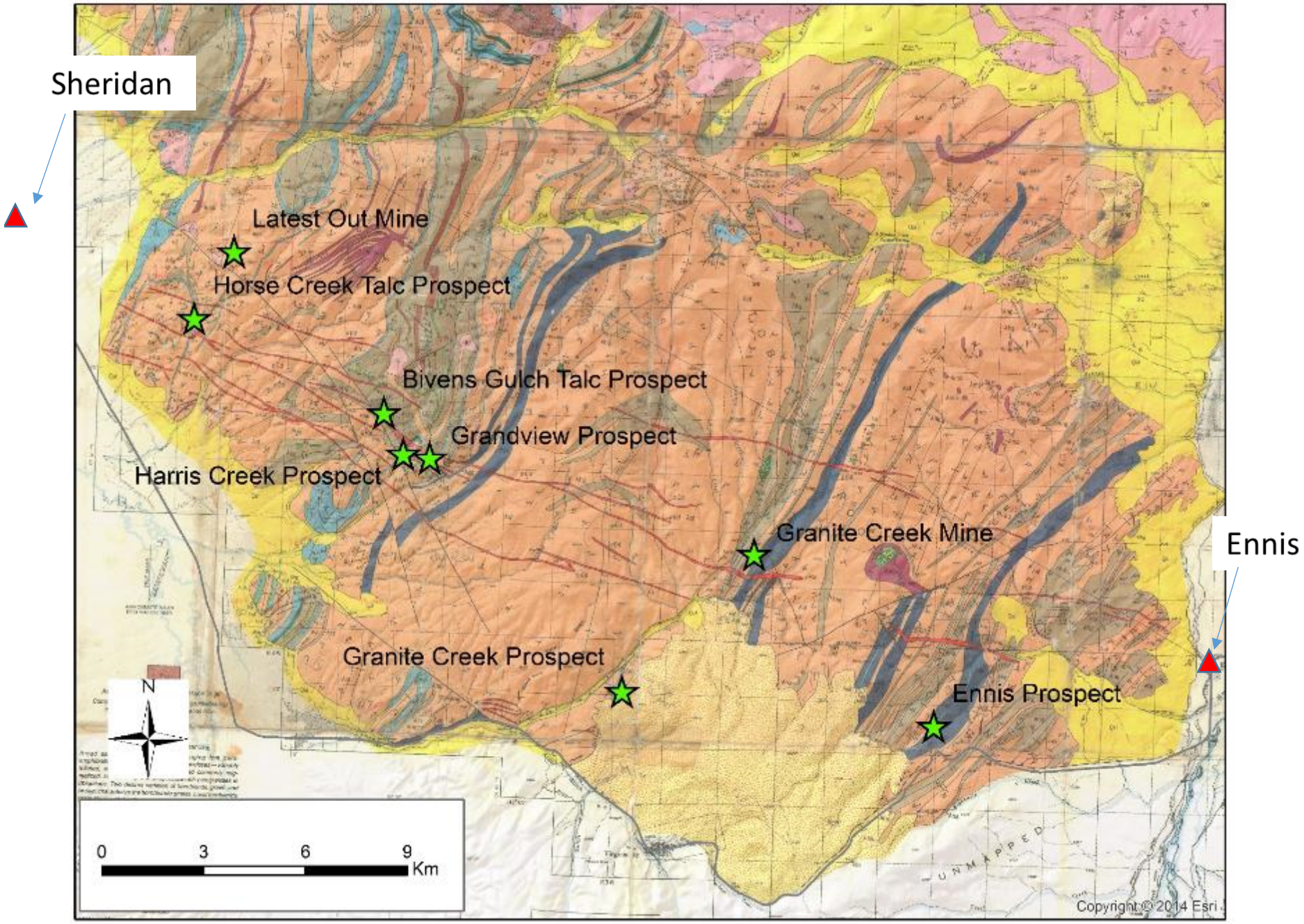
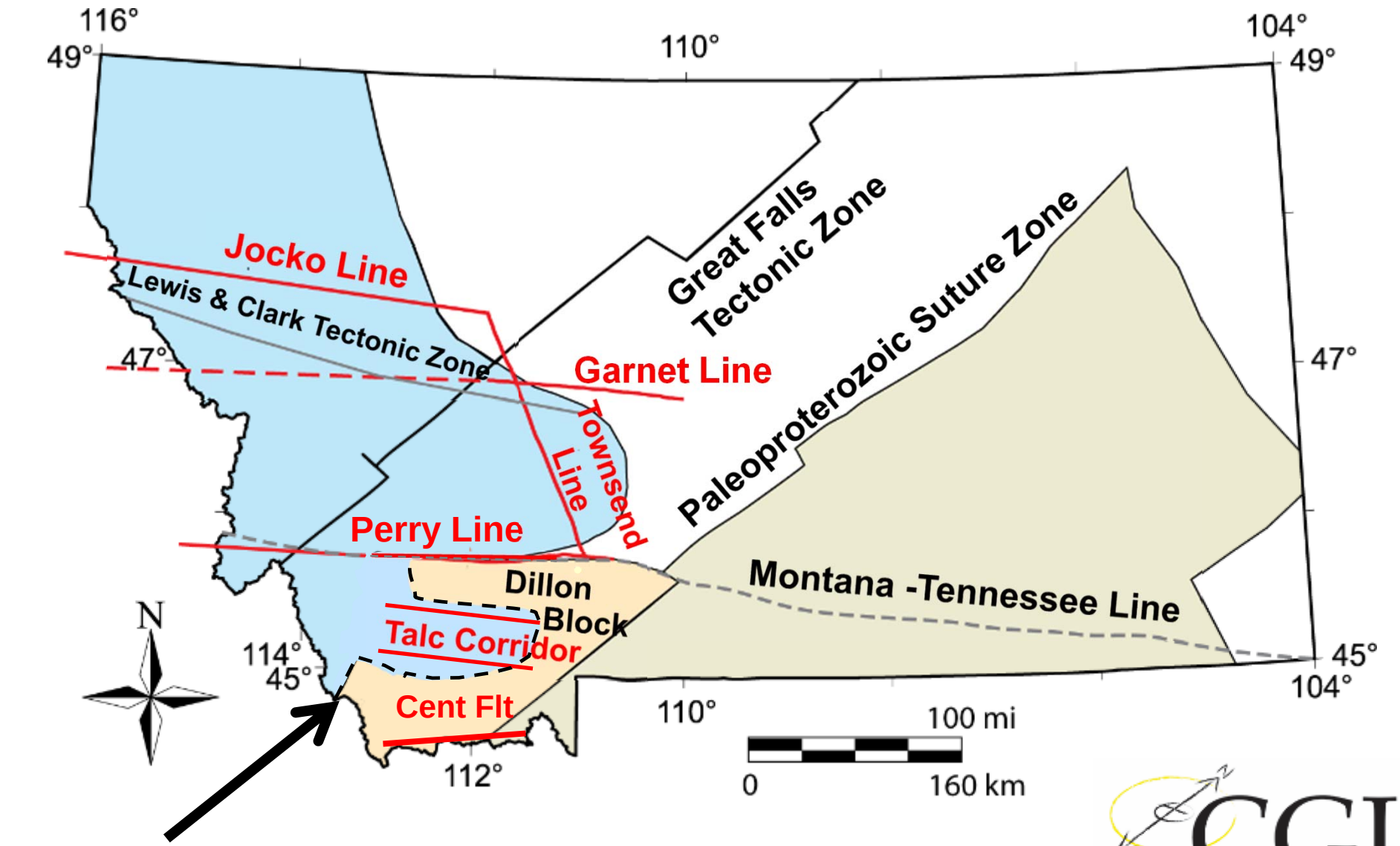
MAFIC DIKE SWARM IN SOUTHERN TOBACCO ROOT MTNS



MAFIC DIKE SWARM AND TALC OCCURRENCES IN SOUTHERN TOBACCO ROOT MTNS



Inferred Southern Extension of the Belt Basin



Proposed Southern Extension of Belt Basin

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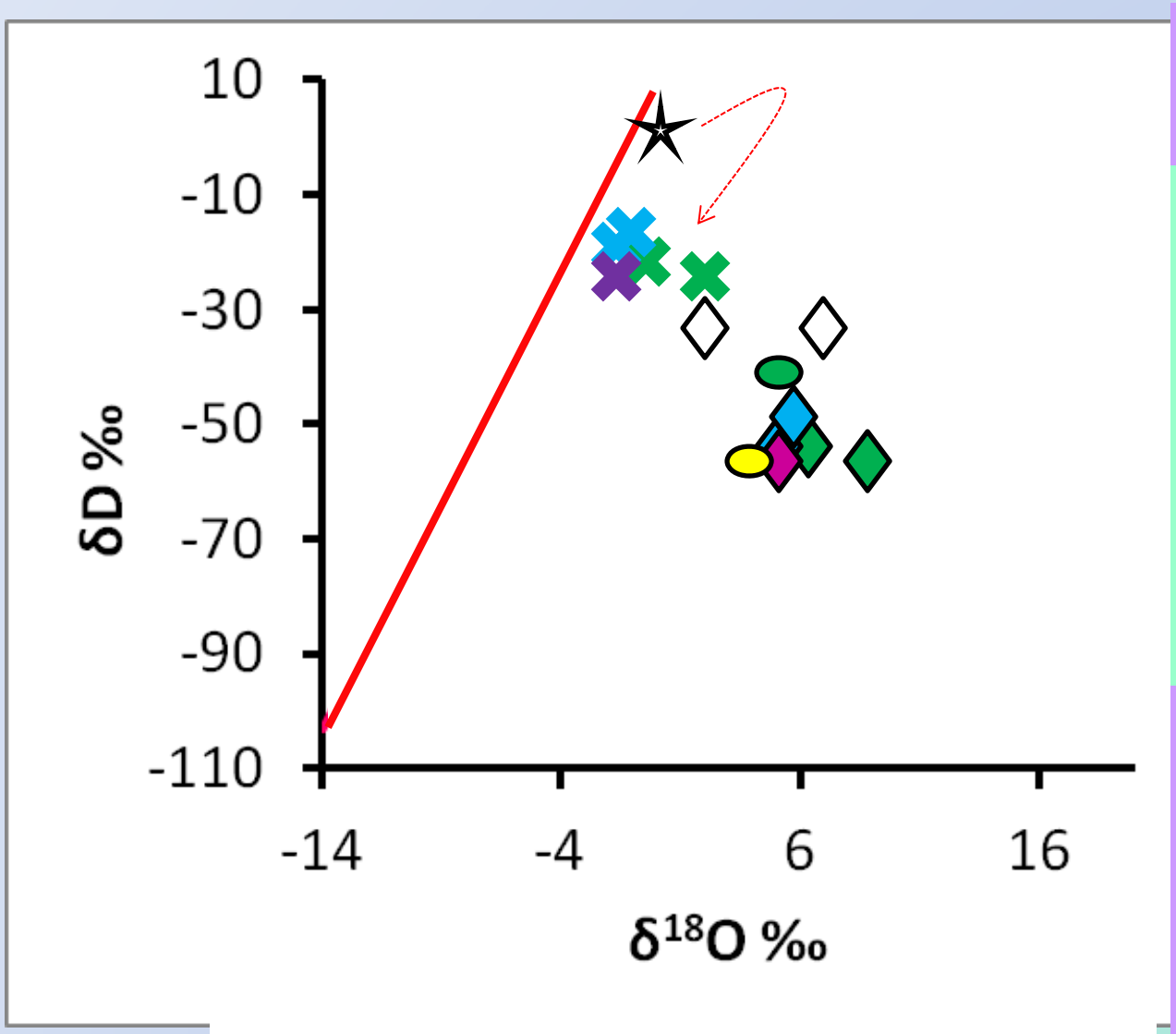
Talc δD and δ18O Range by Yellowstone Mine



Regal American Chemet Treasure

Yellowstone

New low temperature

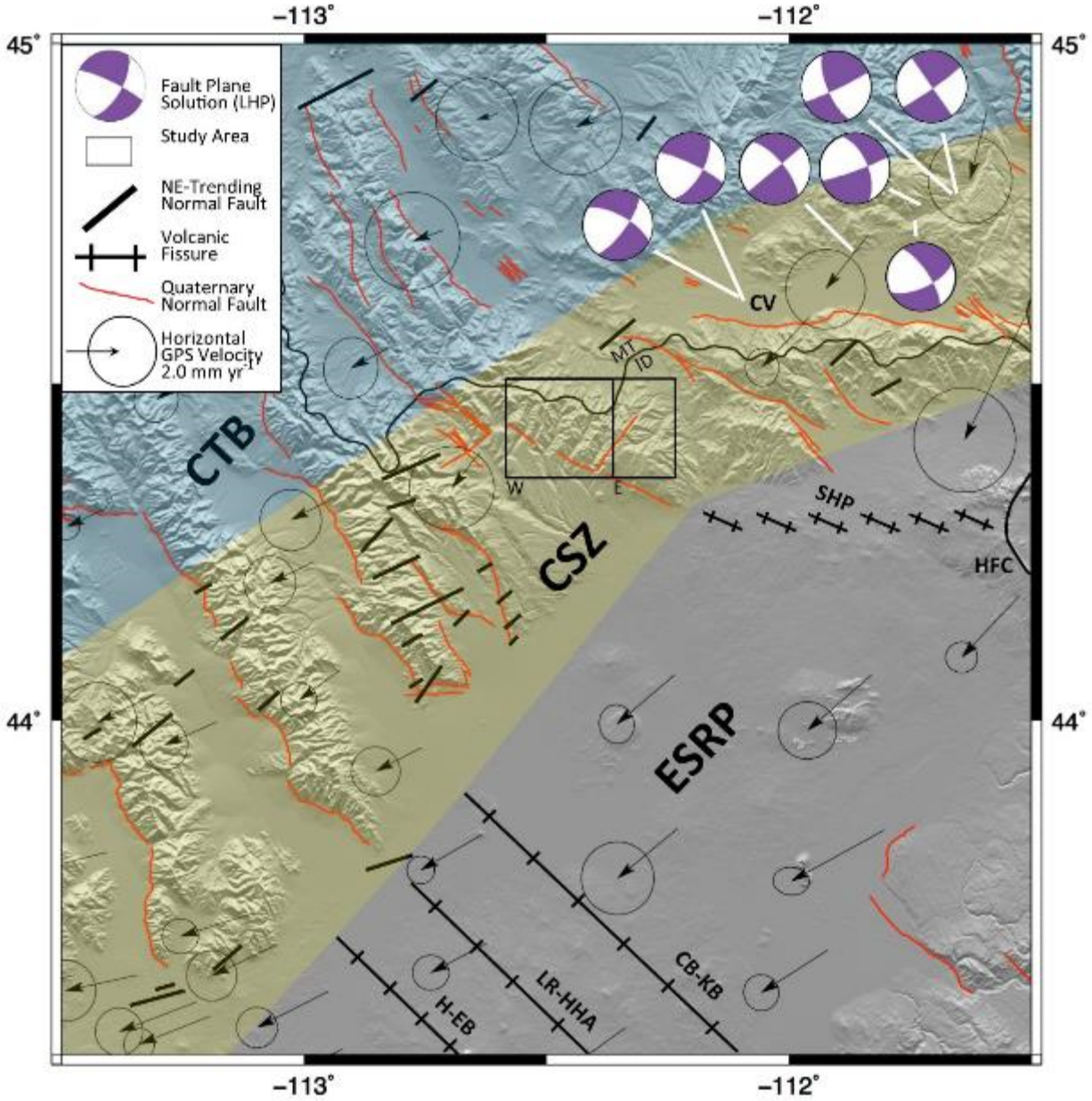
Evolution of sea water to

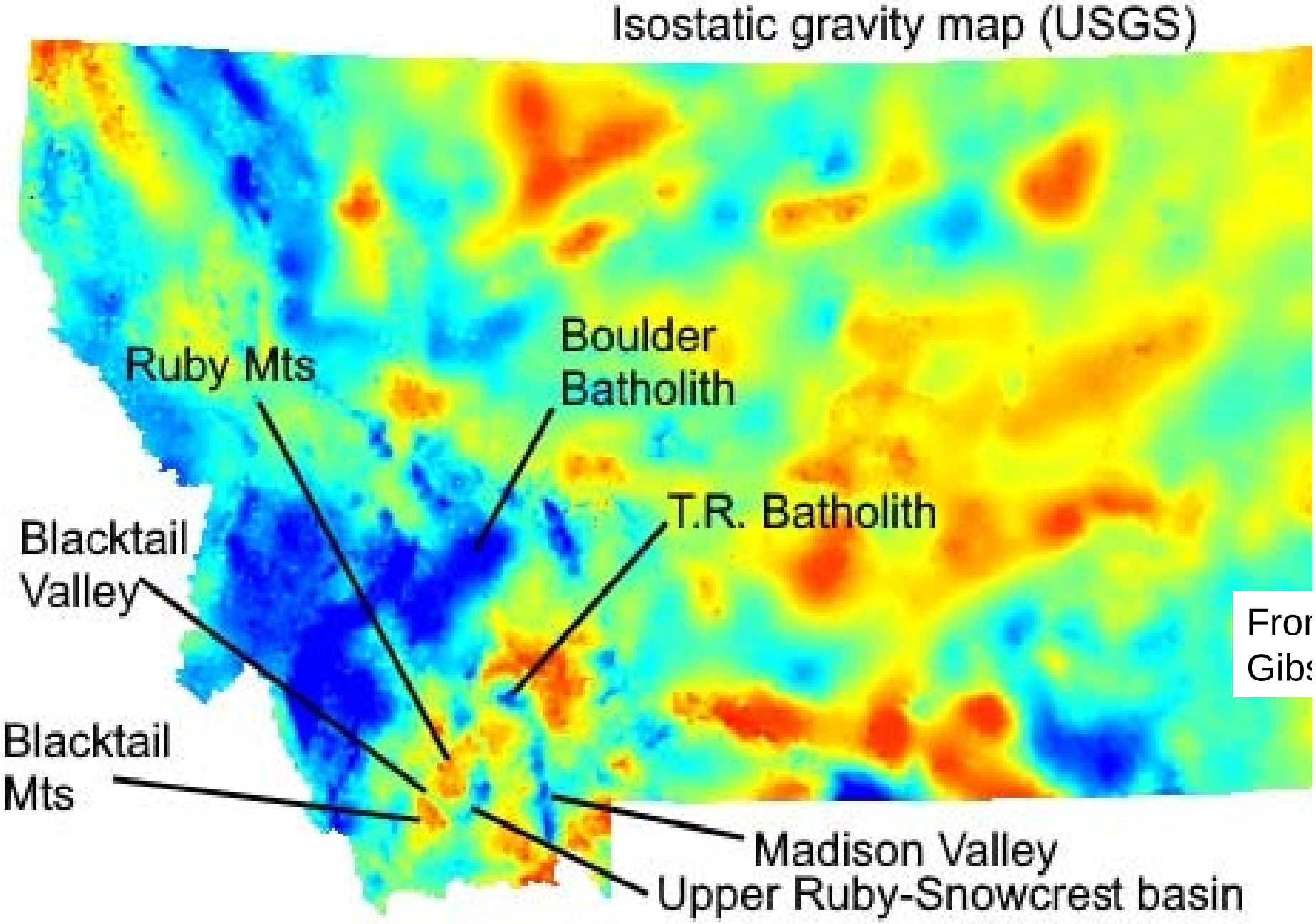
Conclusion: For talc formation, sea water is a minor component. Basin brine is a good isotopic fit and likely plentiful.

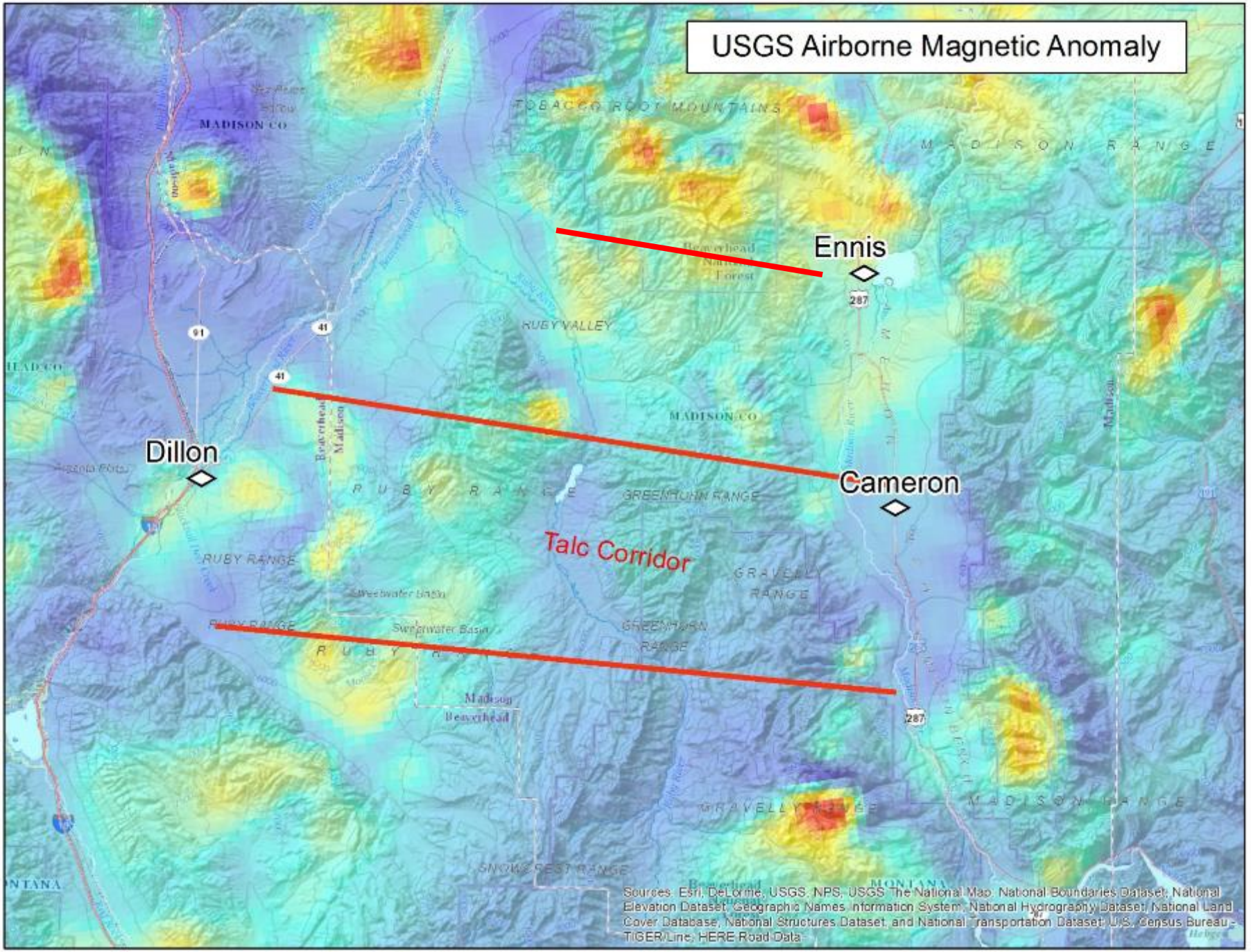
red dashed curve

and δ18O data to estimate δD and δ18O values of talc-forming hydrous fluid

The Centennial Fault Zone (Stuart Parker, 2017)




Isostatic gravity map (USGS)
Ruby Mts
Boulder
Batholith
T.R. Batholith
Blacktail
Valley
Blacktail
Mts
Madison Valley
Upper Ruby-Snowcrest basin


USGS Airborne Magnetic Anomaly
Ennis
Cameron
Dillon
Talc Corridor
TOBACCO ROOT MOUNTAINS
MADISON RANGE
RUBY VALLEY
RUBY RANGE
GREENHORN RANGE
GRAVELLY RANGE
SNOWCREST RANGE
MADISON CO
Sweetwater Basin
Sources: Esri, DeLorme, USGS, NPS, USGS The National Map: National Boundaries Dataset, National Elevation Dataset, Geographic Names Information System, National Hydrography Dataset, National Land Cover Database, National Structures Dataset, and National Transportation Dataset; U.S. Census Bureau - TIGER/Line; HERE Road Data

Southwest Montana Talc Genesis

- Talc forming fluids were derived from mixtures of deeply circulating connate brines, meteoric water and possibly sea water from overlying Belt sedimentary rocks

- Hydrothermal fluids possibly including hot springs ranged in temperature from 188 to 350°C

- Stage 1- Hydrothermal Mg-metasomatism replaced marble with coarse grained dolomite and magnesite along structural conduits
- Stage 2- Volume-for-volume replacement of magnesite/dolomite by hydrothermal talc was followed by deformation and recrystallization of talc

- Local and regional diabase dikes and sills and high geothermal gradient during Belt basin development drove hydrothermal fluids

- Talc formed at levels shallow enough to maintain open space, voids, and fracture filling

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Conclusions

- Proposed Talc Corridor characterized by:
  - East/West trending corridor 65 km long by 25 km wide
  - Contains ~18M tonnes of talc reserves (as of Dec. 31, 2014)
  - Abundant Archean marble as receptive host rocks
  - Talc mines spatially associated with faults & diabase dikes within talc corridor
- The corridor lies subparallel to other E/W deep-seated regional structures in the Belt Basin farther north including the Ennis-Sheridan mafic dike swarm and associated talc prospects
- The corridor likely accommodated differential extension along the southern margin of the Belt Basin within the Dillon basement block and differing domains of mafic dikes reflect differing extensional domains within the Belt basin
- Infer that the southern limit of the Belt Basin lies farther south and east than previously thought

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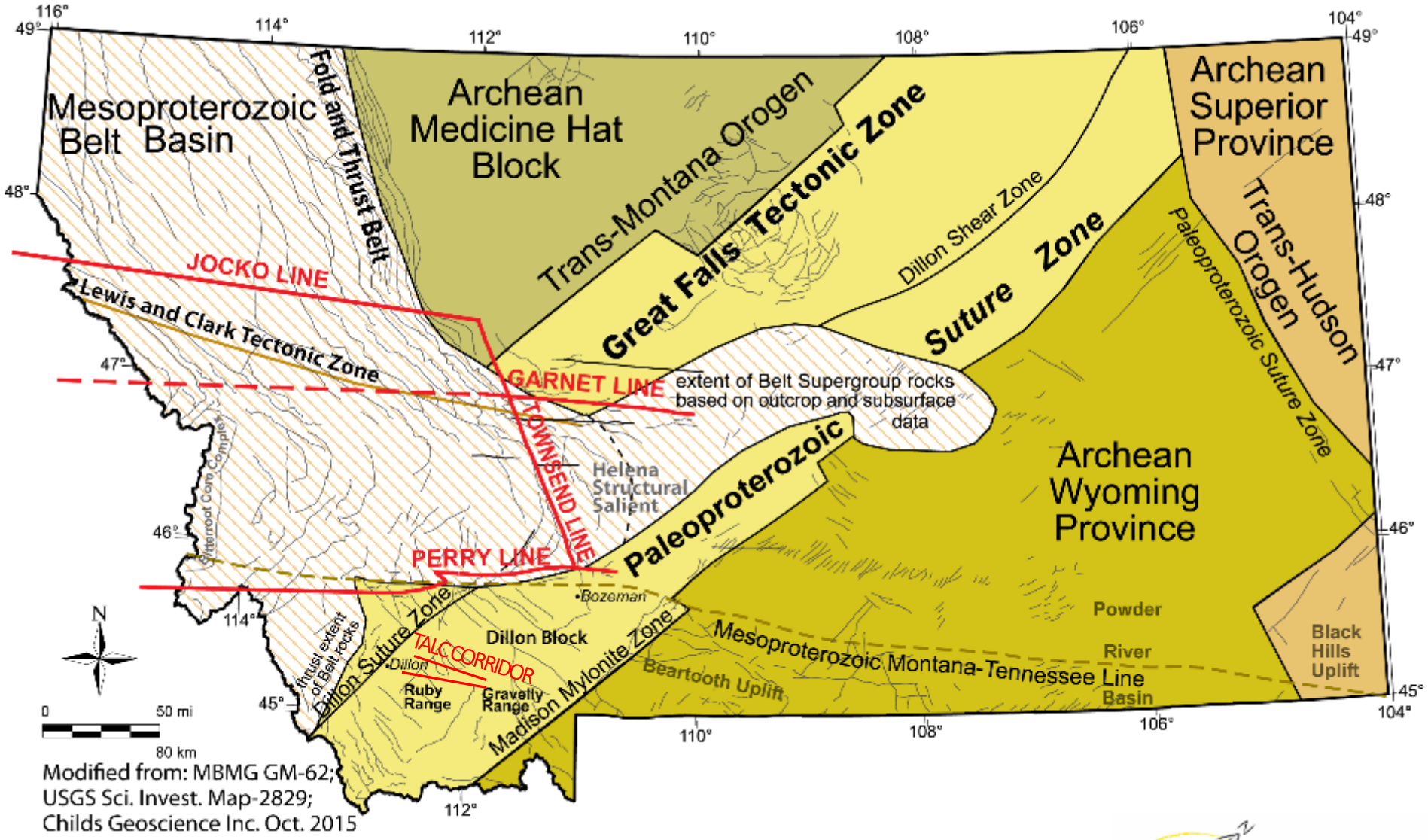
Slide Title



Modified from: MBMG GM-62;
USGS Sci. Invest. Map-2829;
Childs Geoscience Inc. Oct. 2015

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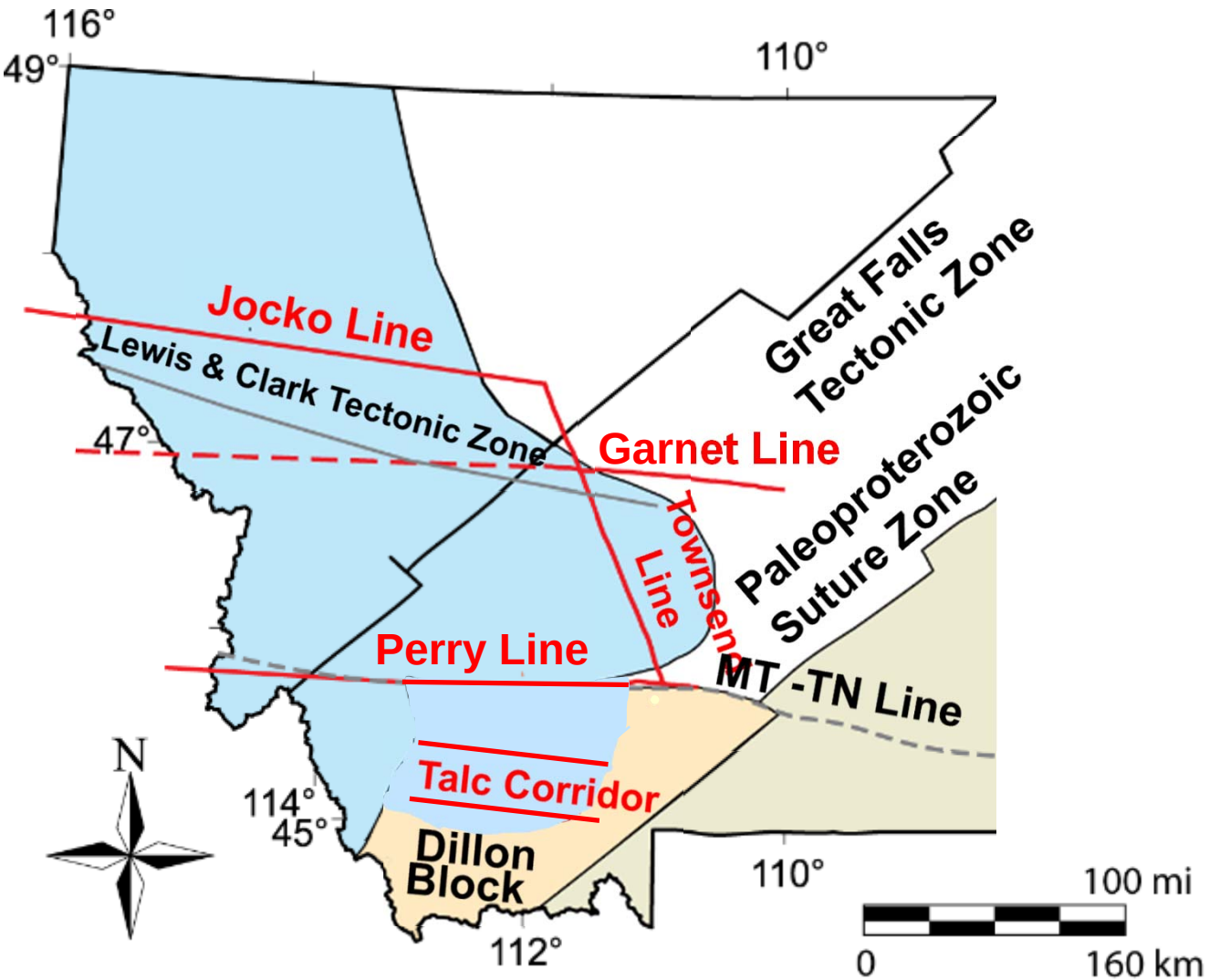
Inferred Southern Extension of the Belt Basin



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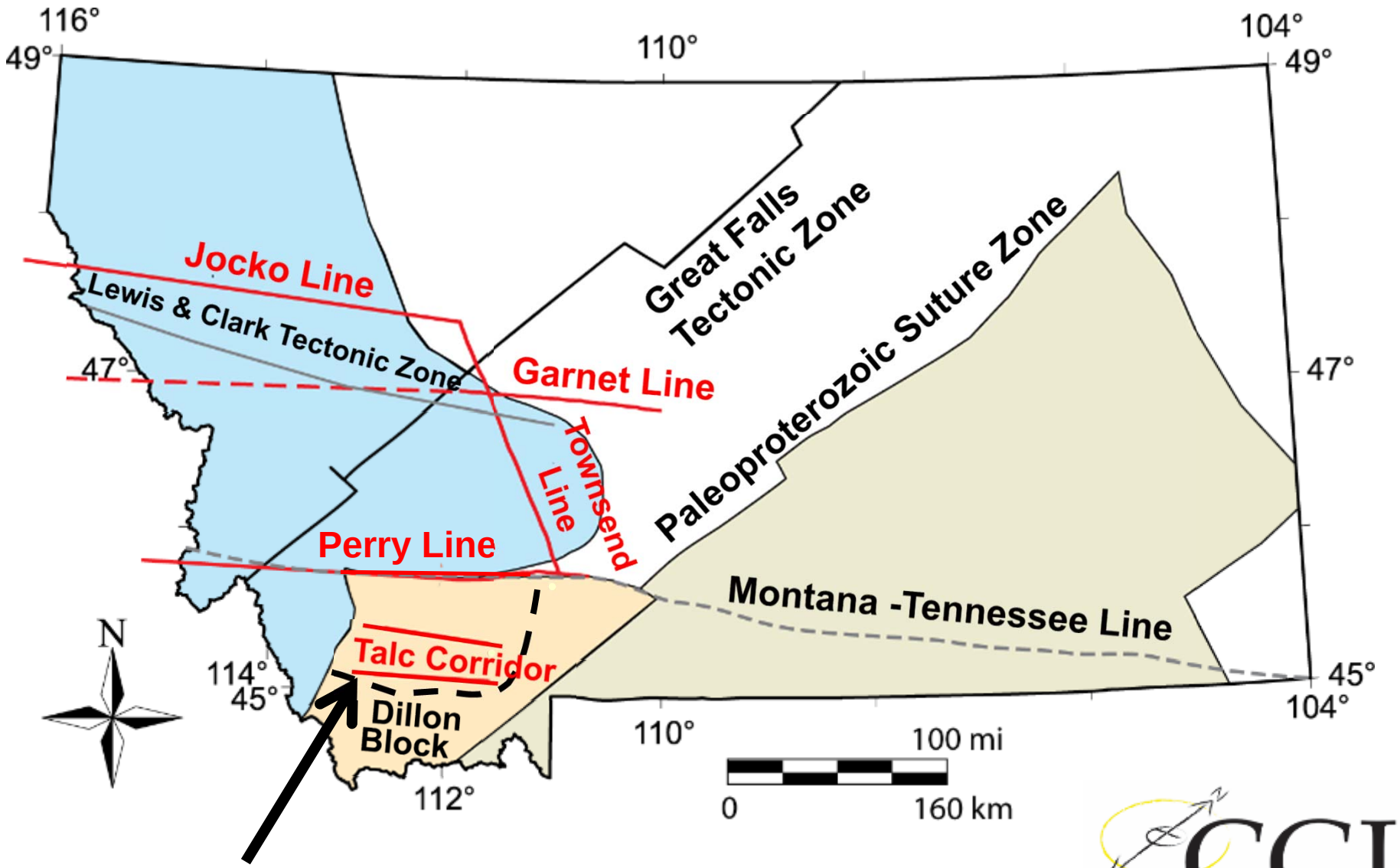
Inferred Southern Extension of the Belt Basin

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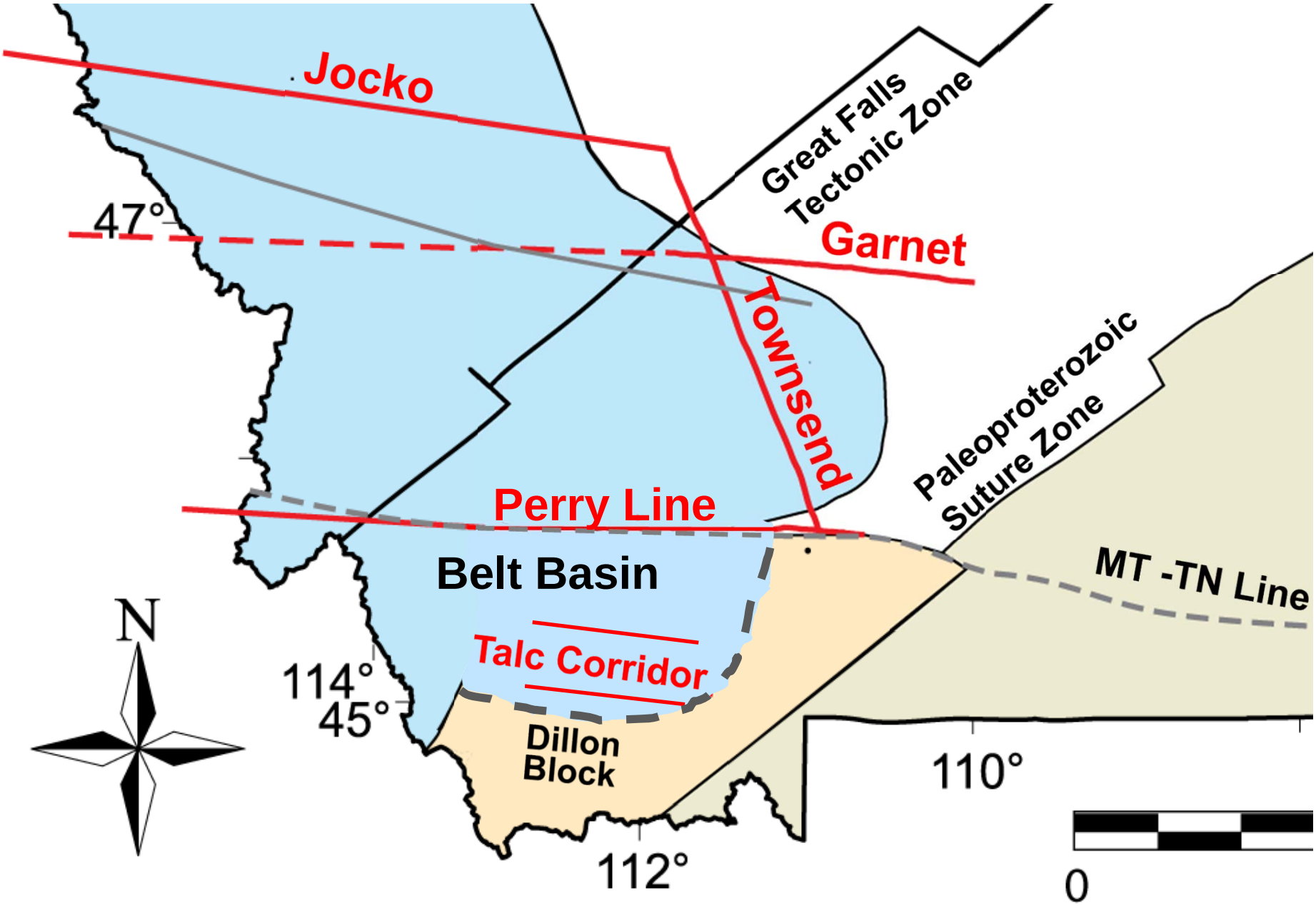
Inferred Southern Extension of the Belt Ba



Talc Occurrences & Host Marble (Underwood, 2016)