World Class Talc Deposits of Southwestern Montana

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Regional Geology of Southwest Montana

Geology after Vuke et al., 2007
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
Talc and Marble Occurrences in SW Montana

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

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

Marble from USGS and MBMG

Yellow = Major highways
Gray = Other roads

Major Talc Occurrences
▲ Past Producer
★ Current Producer
● Resource
✚ Prospect

Talc Corridor
Archean to Early Proterozoic marble
Mafic Dike Distribution in SW Montana

Geology from Harlan et al. (2007)
Yellowstone Mine Geologic Map (Talc in red)

Geology from Cerino (2002)
Yellowstone Mine Talc Distribution

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

Cross Section Looking North

MAP AND SECTION LEGEND

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

from Cerino (2007)
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)
Regal Mine Looking South as of 2007

Photo by Julia Gwinn (2011)
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)
Geologic Cross-Section A-A’ at the Treasure Chest and Beaverhead Mines

- **Talc/Marble Envelope**
- **Biotite Gneiss**
- **Quartzofeldspathic Gneiss**
- **Amphibolite**
- **Metasedimentary and Quartzofeldspathic Gneiss (undifferentiated)**

**Fault Zone (FZ)**

**Original Ground Surface**

**Beaverhead Pit**

**UG Workings**

**Extent of drill information**

**Pit levels as of 1997**

**UG = Underground**

**SCALE**

- **A’ (South)**
- **A (North)**

**Exploration Geologists**
Treasure Mine Looking South

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

Photo by Julia Gwinn (2011)
Belt Basin Rocks & Major Tectonic Provinces In Montana

Belt Basin Rocks (Fold-Thrust Belt)

Dillon Block

Other Archean Basement

Archean-Wyoming Province

Cities:
- Dillon
- Bozeman
- Cameron
Major Regional Structures of Montana and the Talc Corridor

- Belt Basin Rocks
- Great Falls Tectonic Zone
- Paleoproterozoic Suture Zone
- Archean-Wyoming Province

- Jocko Line
- Lewis & Clark Tectonic Zone
- Garnet Line
- Perry Line
- Townsend Line
- Talc Corridor
- Cent Flt
- Dillon Block

Inferred Southern Extension of the Belt Basin

Jocko Line
Lewis & Clark Tectonic Zone
Garnet Line
Townsend Line
Perry Line
Talc Corridor
Dillon Block
Cent Flt

Great Falls Tectonic Zone
Paleoproterozoic Suture Zone
Montana - Tennessee Line

Proposed Southern Extension of Belt Basin
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.
MAFIC DIKE SWARM IN SOUTHERN TOBACCO ROOT MTNS

Geology by Vitaliano and Cordua, 1979
Inferred Southern Extension of the Belt Basin

- Jocko Line
- Lewis & Clark Tectonic Zone
- Garnet Line
- Perry Line
- Townsend Line
- Dillon Block
- Talc Corridor
- Cent Flt
- Montana - Tennessee Line

Proposed Southern Extension of Belt Basin
Conclusion: For talc formation, sea water is a minor component. Basin brine is a good isotopic fit and likely plentiful. Applied to Brady et al. (1998) talc δD 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
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
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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Inferred Southern Extension of the Belt Basin
Inferred Southern Extension of the Belt Basin

- Jocko Line
- Lewis & Clark Tectonic Zone
- Garnet Line
- Perry Line
- Townsend Line
- Montana -Tennessee Line
- Paleoproterozoic Suture Zone

Proposed Belt Basin Southern Extension
Inferred Southern Extension of the Belt Basin

- Jocko
- Garnet
- Perry Line
- Belt Basin
- Talc Corridor
- Dillon Block
- Great Falls Tectonic Zone
- Paleoproterozoic Suture Zone
- MT-TN Line

Map coordinates:
- 47° latitude
- 114°, 45° longitude
- 112° longitude
Talc Occurrences & Host Marble (Underwood, 2016)