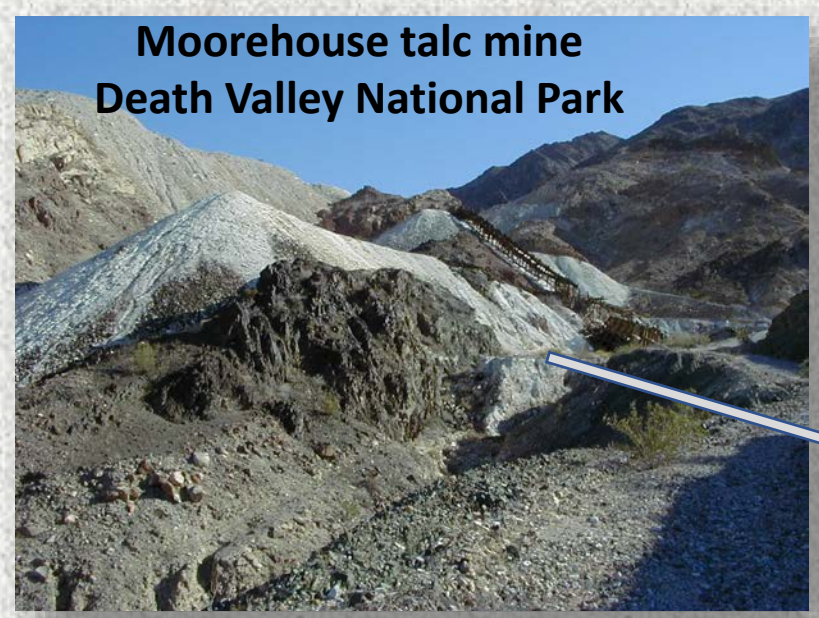
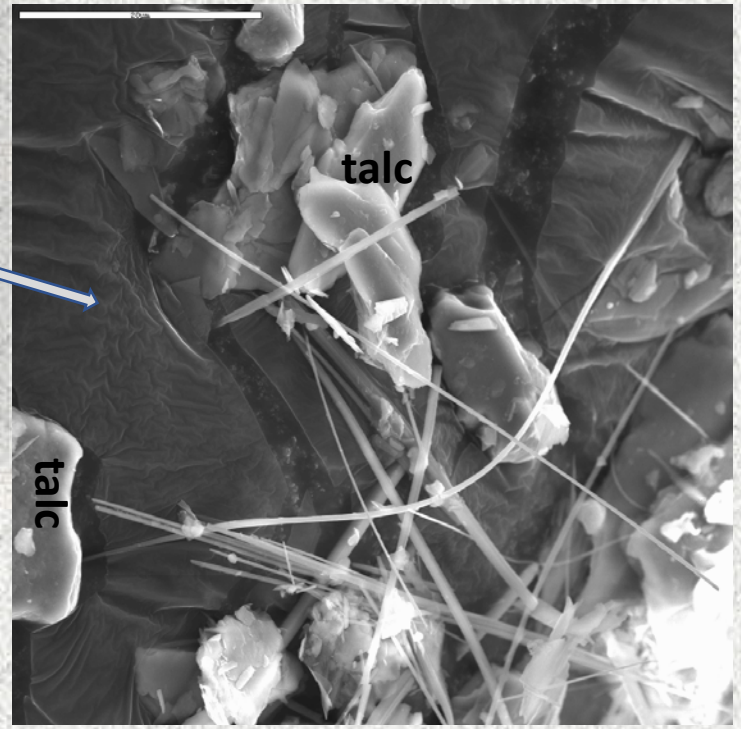
The Mineral Fibers of Potential Concern in Talc



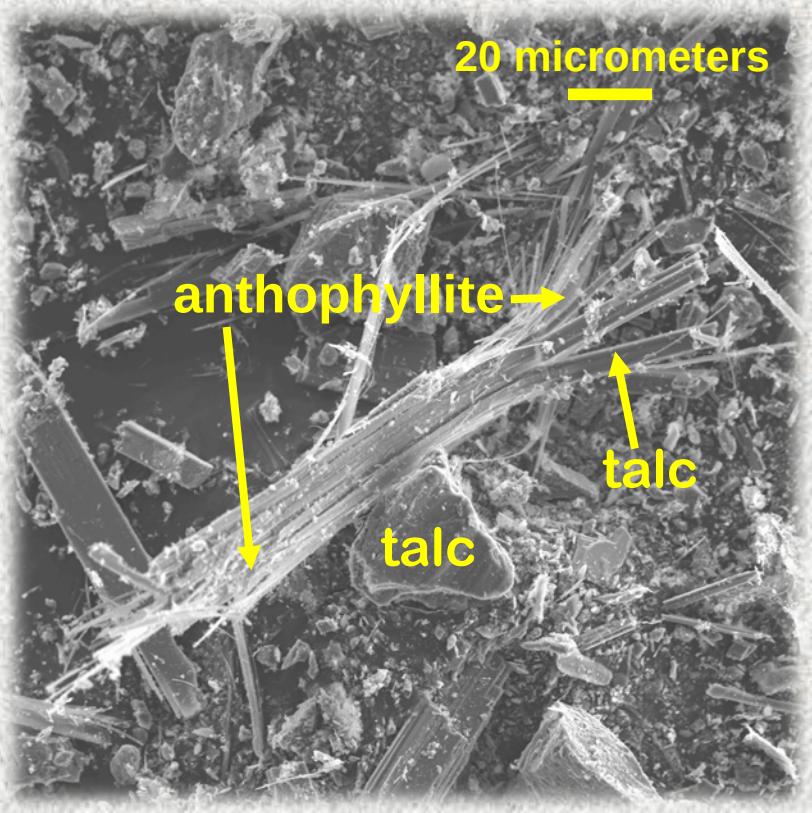
Bradley Van Gosen
U.S. Geological Survey
Denver, Colorado

USGS science for a changing world



Tremolite and
Na-Ca amphiboles

"transitional fibers"



Domestic talc producers

- American Talc Co. – several open pits in the Allamoore district, west Texas
- Barretts Minerals Inc. – Regal mine and Treasure mine, southwest Montana
- Imerys S.A. – Yellowstone mine, southwest Montana, and a mine near Ludlow, Vermont

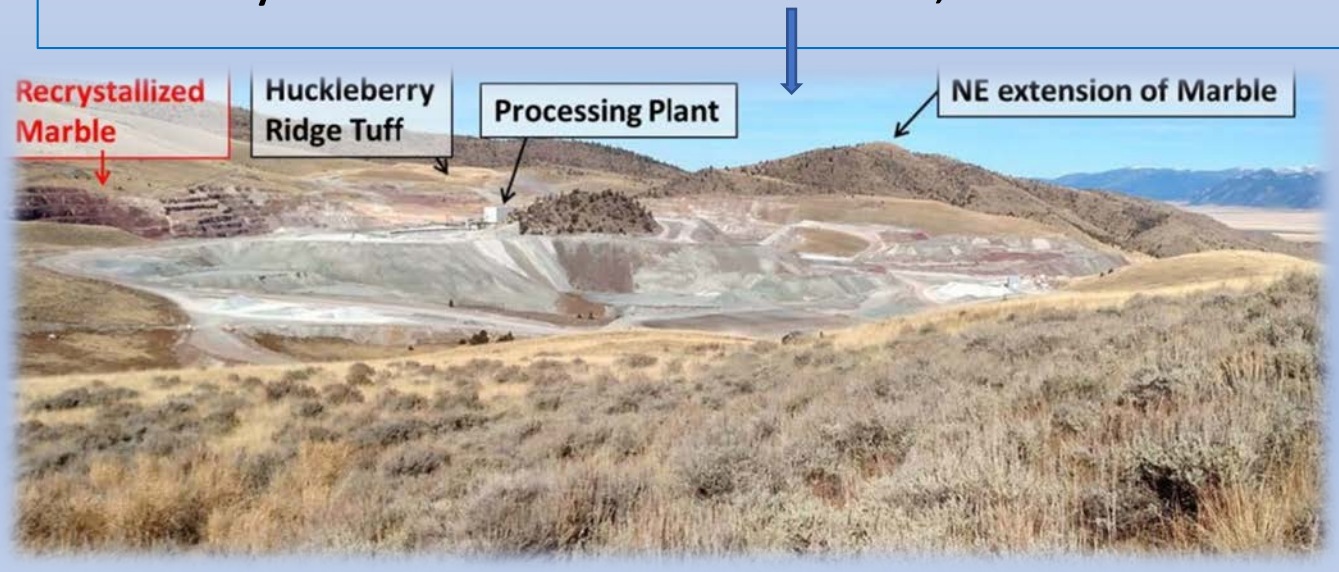


Photo by Childs Geoscience Inc.

Recent production by State

1. Montana
2. Texas
3. Vermont

Domestic talc production and applications

In 2017, total sales (domestic and export) of talc by U.S. producers were estimated to be **540,000 metric tons valued at $108 million**, a slight increase over 2016.

During 2017, talc produced and sold in the United States was used in:

- Ceramics = 20%
- Paint = 19%
- Paper = 15%
- Plastics = 8%
- Rubber = 5%
- Refractories = 4%
- Roofing = 4%
- Cosmetics = 3%

USGS National Minerals Information Center

Exports of talc from U.S producers were 210,000 metric tons

USGS science for a changing world

Talc imports and uses

An estimated 380,000 metric tons of talc was imported in 2017.

In decreasing order by tonnage, likely more than 75% of imported talc was used in ***cosmetics, paint, and plastics applications***.

Including imported talc and domestic production, the U.S. end-uses were thought to be, in decreasing order by tonnage:

Plastics, ceramics, paint, paper, roofing, rubber, cosmetics, and other.

Import sources (2013 – 2016):

Pakistan 35% Canada 28% China 26% Japan 5%

Talc

$Mg_3Si_4O_{10}(OH)_2$

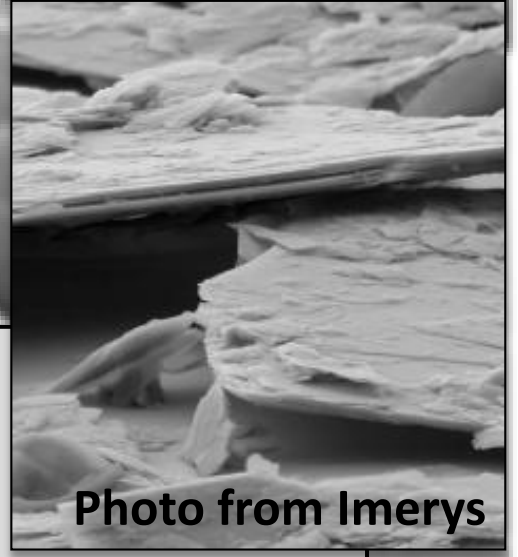


Photo from Imerys

- 1 on the Mohs hardness scale
- Perfect cleavage on {001}, meaning that it is usually platy; however, as we know, there are fibrous varieties.
- Weak bonds between the layers, so that they easily slide past each other, which gives talc its greasy or slippery feel and low hardness.
- Well developed crystals of talc are extremely rare.
- Common impurities include: Ni, Fe, Al, Ca, Na, and H_2O

Amphibole group

Asbestiform riebeckite ("crocidolite")

$\square Na_2(Mg, Fe^{2+})_3Fe^{3+}_2\ Si_8O_{22}(OH)_2$

$Mg/(Mg+Fe^{2+}) < 0.5$

Asbestiform cummingtonite–grunerite ("amosite")

$\square Mg_7Si_8O_{22}(OH)_2$ to $\square Fe^{2+}_7Si_8O_{22}(OH)_2$

Asbestiform anthophyllite

$\square (Mg, Fe^{2+})_7Si_8O_{22}(OH)_2$

$Mg/(Mg+Fe^{2+}) \geq 0.5$

Asbestiform actinolite

$\square Ca_2(Mg, Fe^{2+})_5\ Si_8O_{22}(OH)_2$

$Mg/(Mg+Fe^{2+}) = 0.5 – 0.89$

Asbestiform tremolite

$\square Ca_2(Mg, Fe^{2+})_5\ Si_8O_{22}(OH)_2$

$Mg/(Mg+Fe^{2+}) = 0.9 – 1.0$

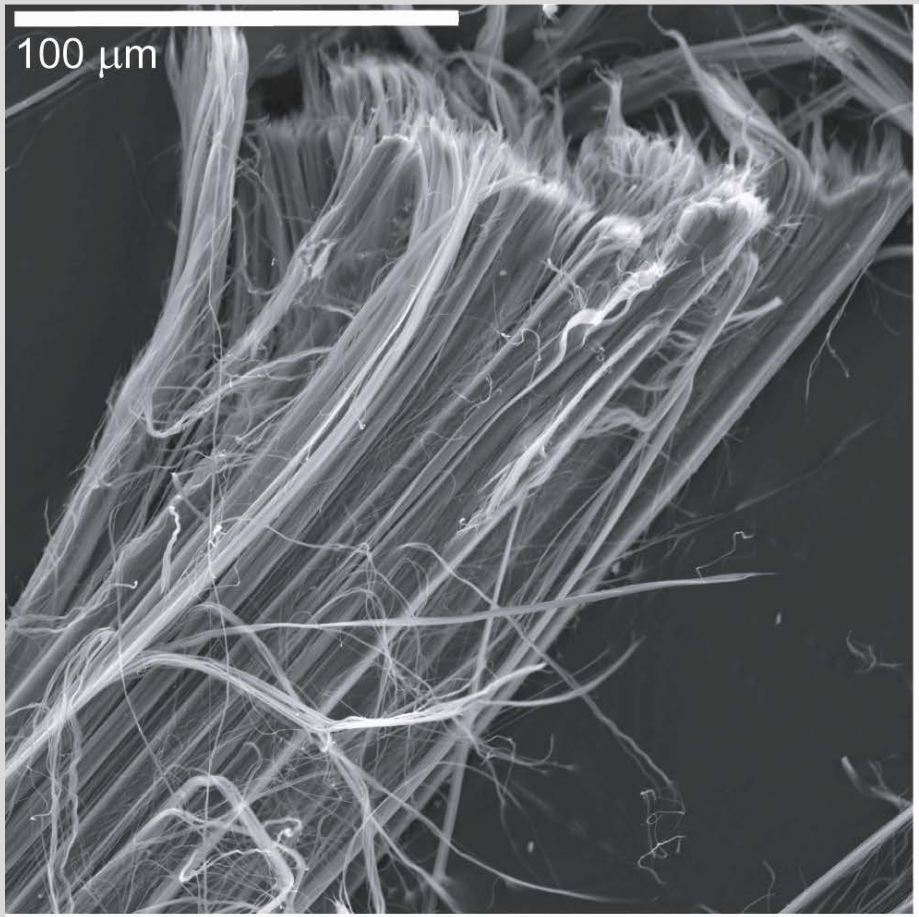
Formulas from Leake et al., 1997, American Mineralogist, v. 82, p. 1019–1037.

☐ Empty "A" site in amphibole structure

Amphibole group

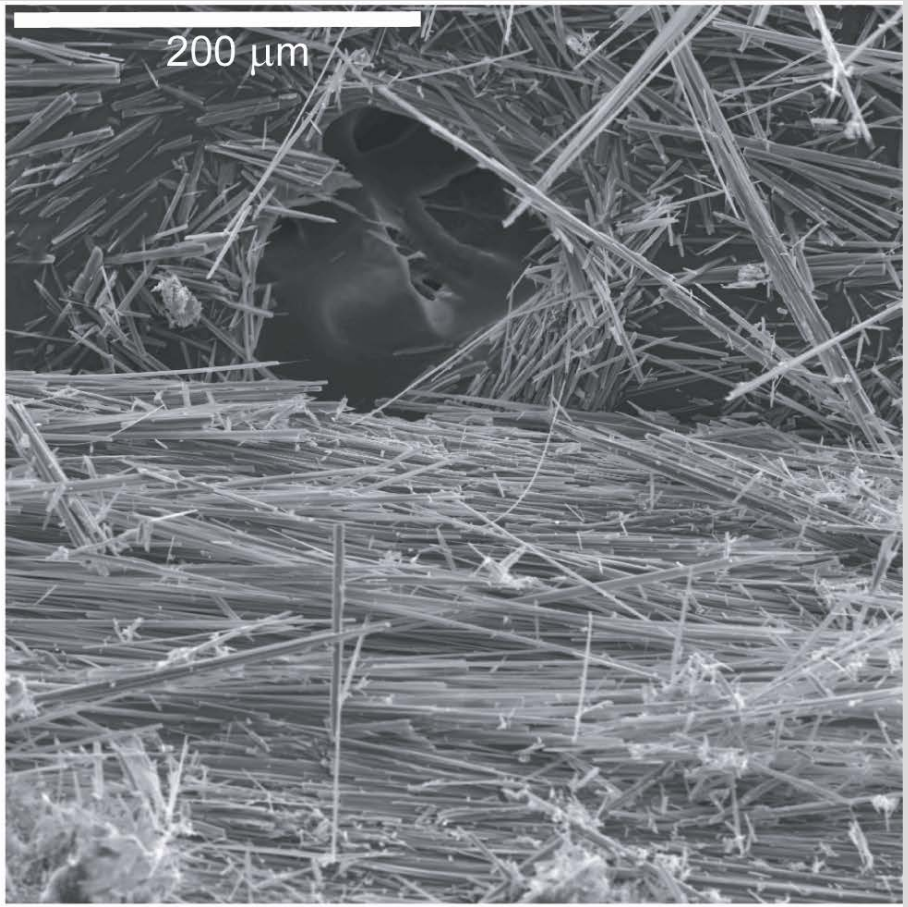
Asbestiform riebeckite ("crocidolite")	$\square Na_2(Mg, Fe^{2+})_3Fe^{3+}_2\ Si_8O_{22}(OH)_2$ $Mg/(Mg+Fe^{2+}) < 0.5$
Asbestiform cummingtonite–grunerite ("amosite")	$\square Mg_7Si_8O_{22}(OH)_2$ to $\square Fe^{2+}_7Si_8O_{22}(OH)_2$

Asbestiform anthophyllite	$\square(Mg, Fe^{2+})_7Si_8O_{22}(OH)_2$ $Mg/(Mg+Fe^{2+}) \geq 0.5$
Asbestiform actinolite	$\square Ca_2(Mg, Fe^{2+})_5\ Si_8O_{22}(OH)_2$ $Mg/(Mg+Fe^{2+}) = 0.5 – 0.89$
Asbestiform tremolite	$\square Ca_2(Mg, Fe^{2+})_5\ Si_8O_{22}(OH)_2$ $Mg/(Mg+Fe^{2+}) = 0.9 – 1.0$



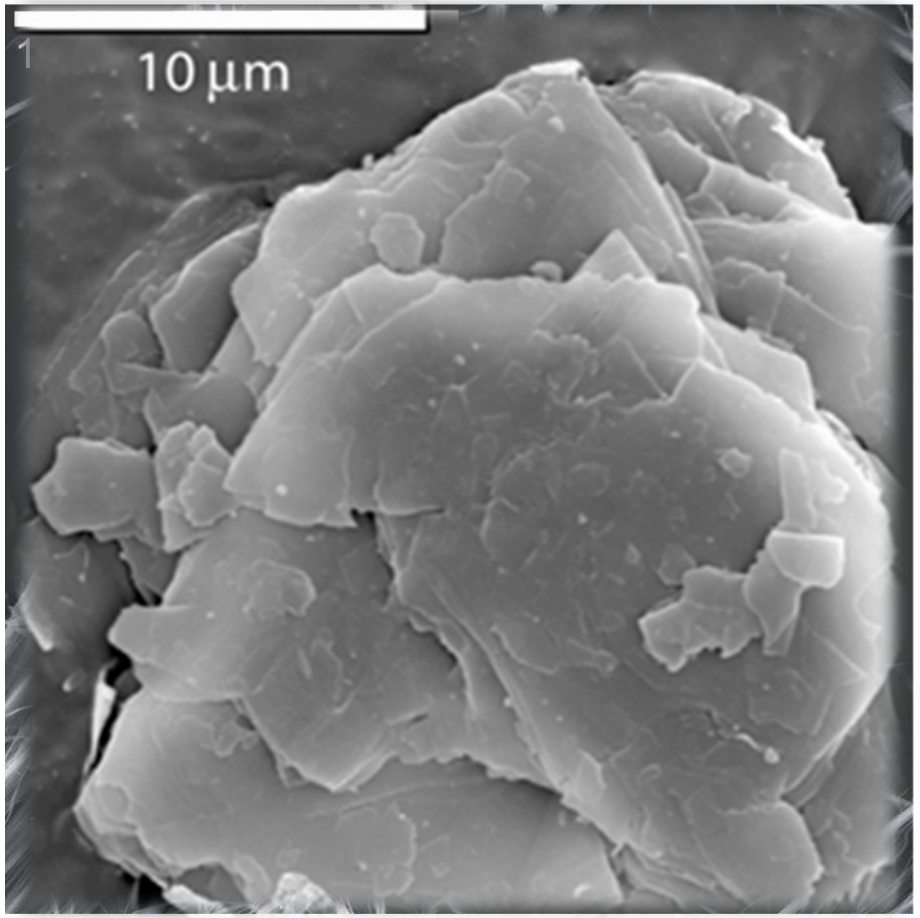
Chrysotile

$Mg_3Si_2O_5(OH)_4$



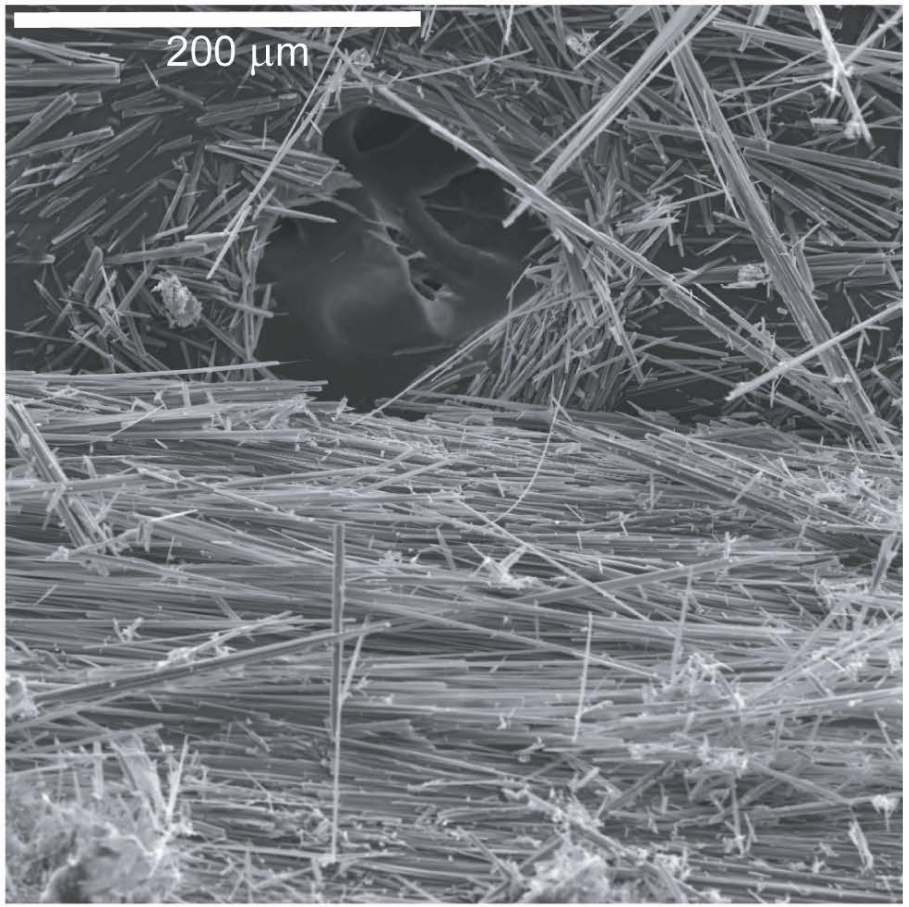
Anthophyllite

$\square(Mg, Fe^{2+})_7Si_8O_{22}(OH)_2$



Talc

$Mg_3Si_4O_{10}(OH)_2$



Anthophyllite

$\square(Mg, Fe^{2+})_7Si_8O_{22}(OH)_2$

Talc formation

Talc is a replacement mineral—
It replaces a preexisting magnesium-rich mineral

Magnesium-rich host rock:

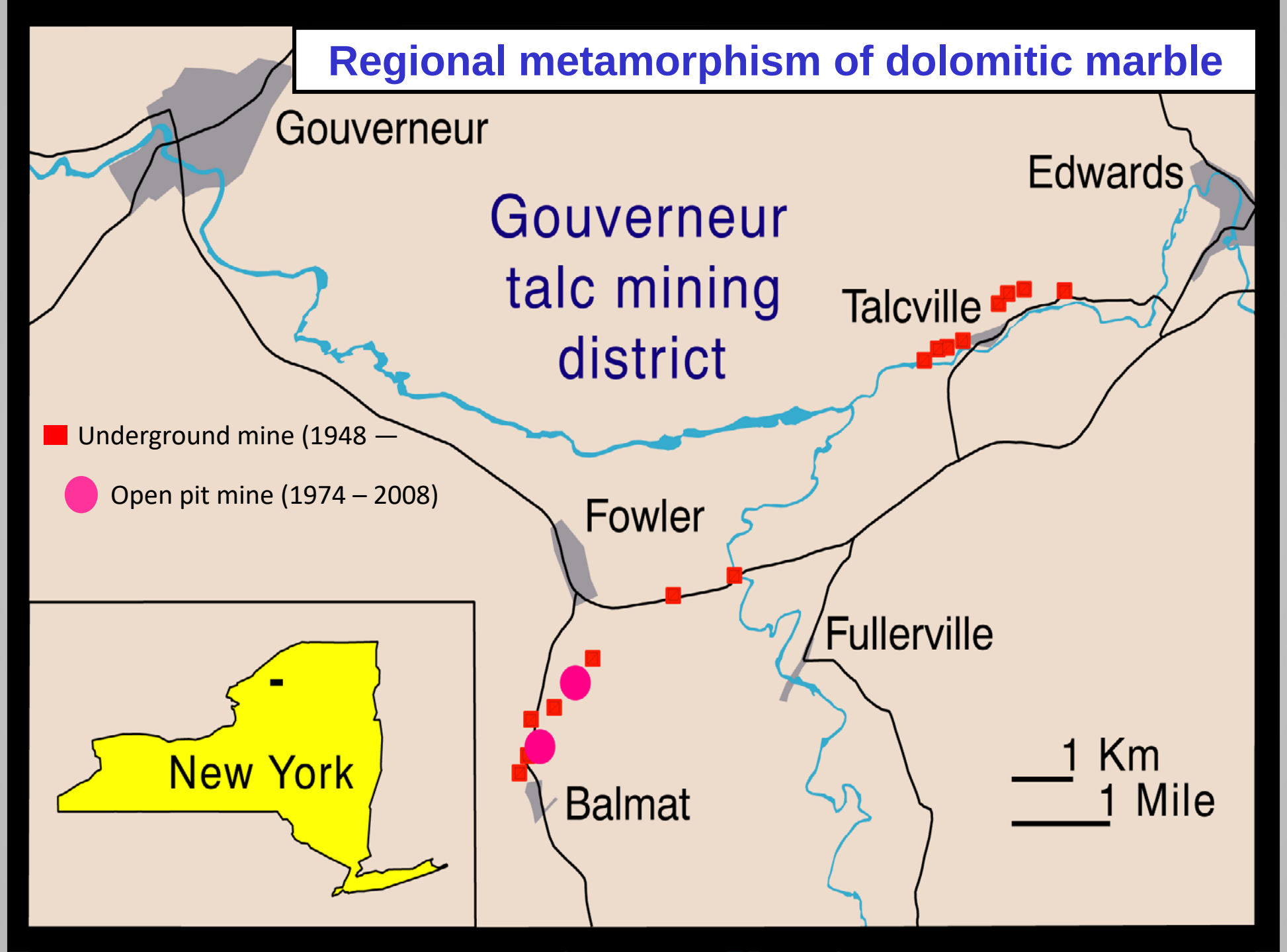
Dolostone – Mg-rich carbonate rocks
Ultramafic rock – Mg-Fe-rich metamorphic rocks

Heated pore fluids (waters) carrying silica in solution

This process can be driven by:

- **Regional metamorphism (tectonics)**
- **Contact metamorphism (igneous intrusion)**
- **Circulation of magmatic hydrothermal fluids (heated by magma at depth)**

Regional metamorphism of dolomitic marble

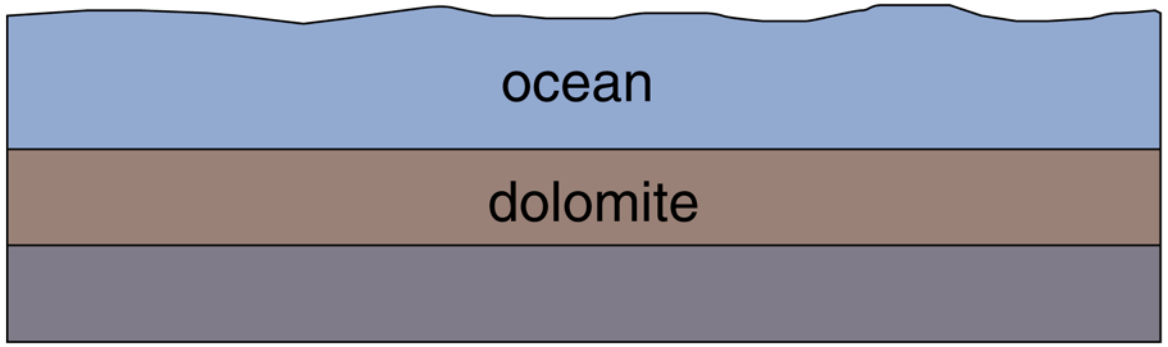


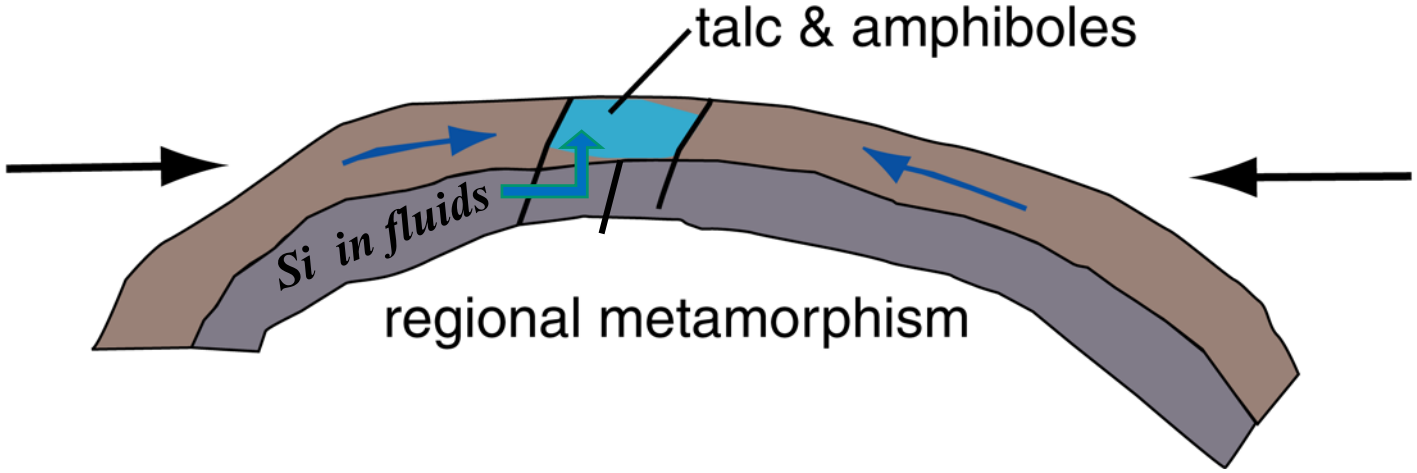
Metamorphosed Dolostones

Dolomite
100% $MgCO_3$

Dolomitic marble

Dolomitic limestone
10 to 50% $MgCO_3$





Dolomite + silica + water → Tremolite + calcite + carbon dioxide

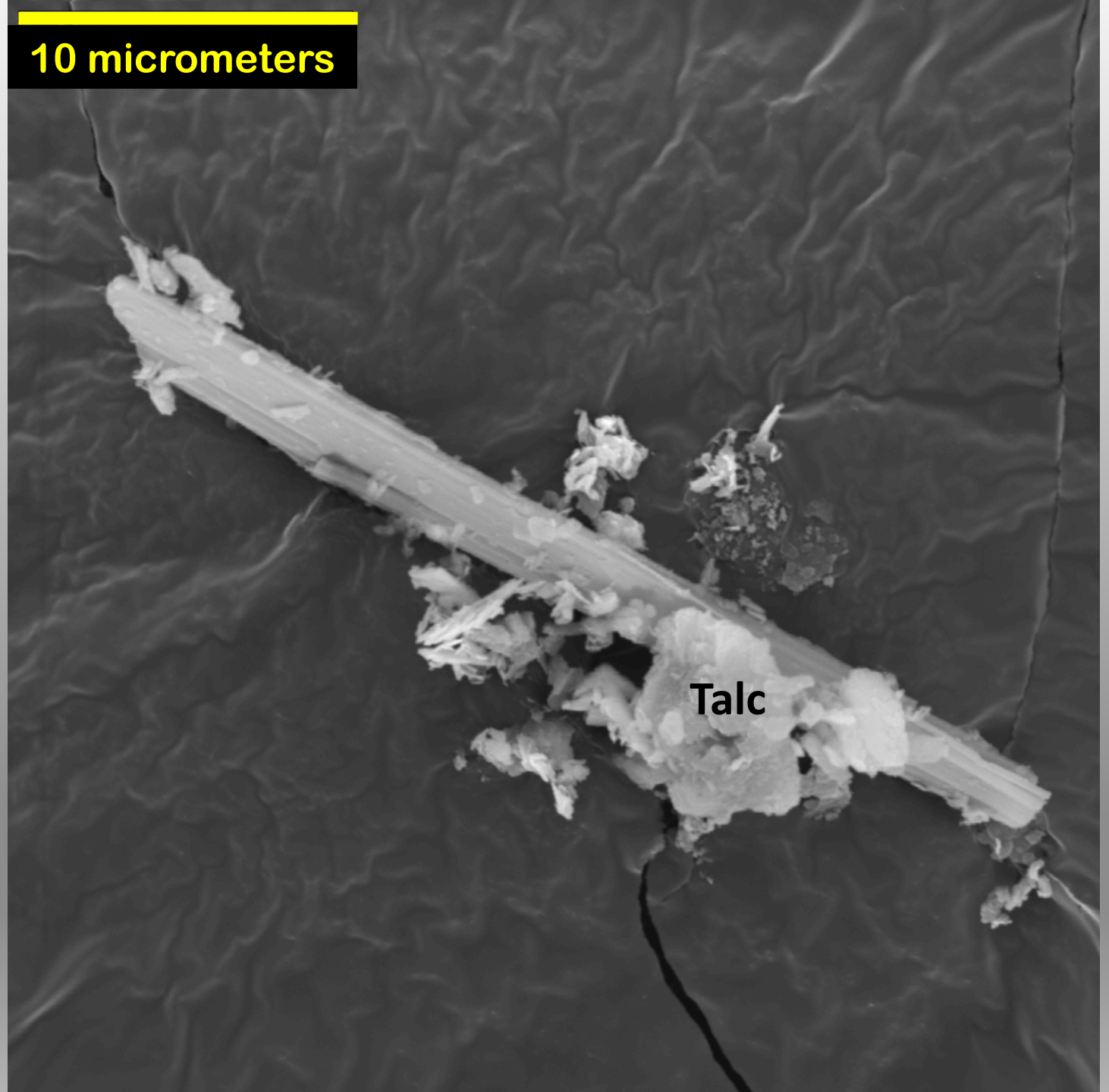
$5CaMg(CO_3)_2 + 8SiO_2 + H_2O \rightarrow Ca_2Mg_5Si_8O_{22}(OH)_2 + 3CaCO_3 + 7CO_2$

Tremolite + dolomite —(in water)→ Anthophyllite + calcite

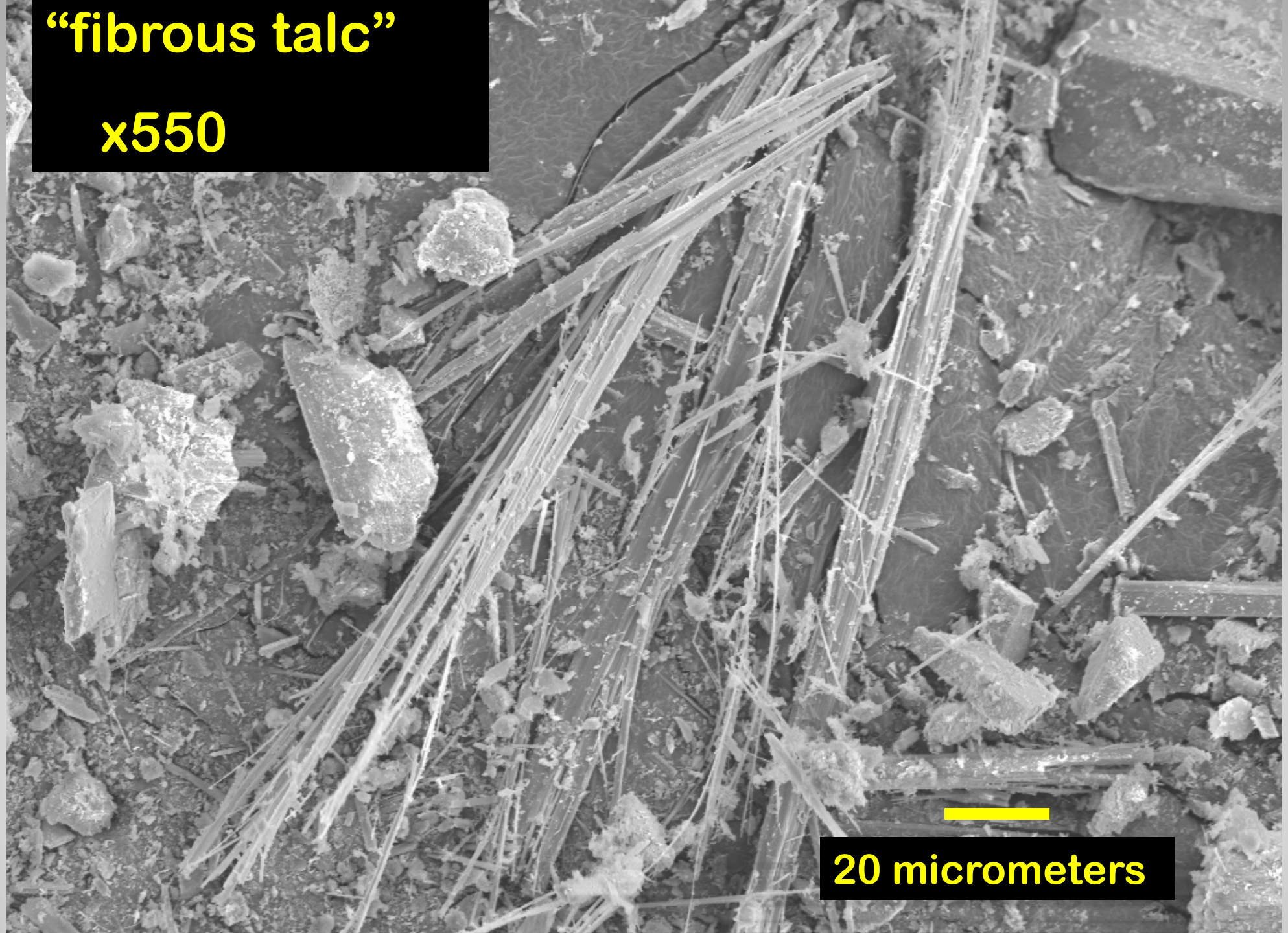
$Ca_2Mg_5Si_8O_{22}(OH)_2 + 2CaMg(CO_3)_2 \rightarrow Mg_7Si_8O_{22}(OH)_2 + 4CaCO_3$

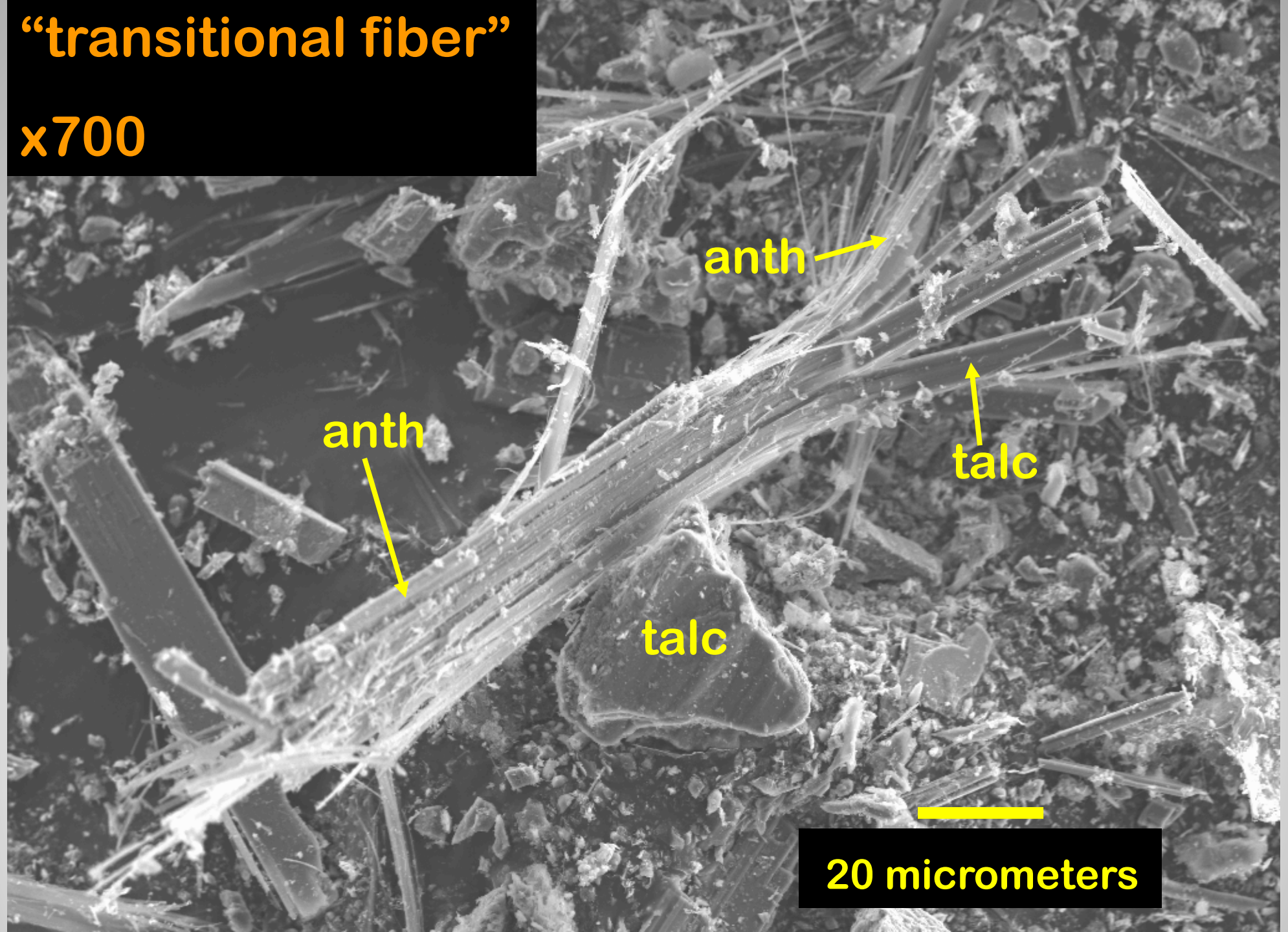
Anthophyllite + silica + water → Talc

$3Mg_7Si_8O_{22}(OH)_2 + 4SiO_2 + 4H_20 \rightarrow 7Mg_3Si_4O_{10}(OH)_2$



Tremolite

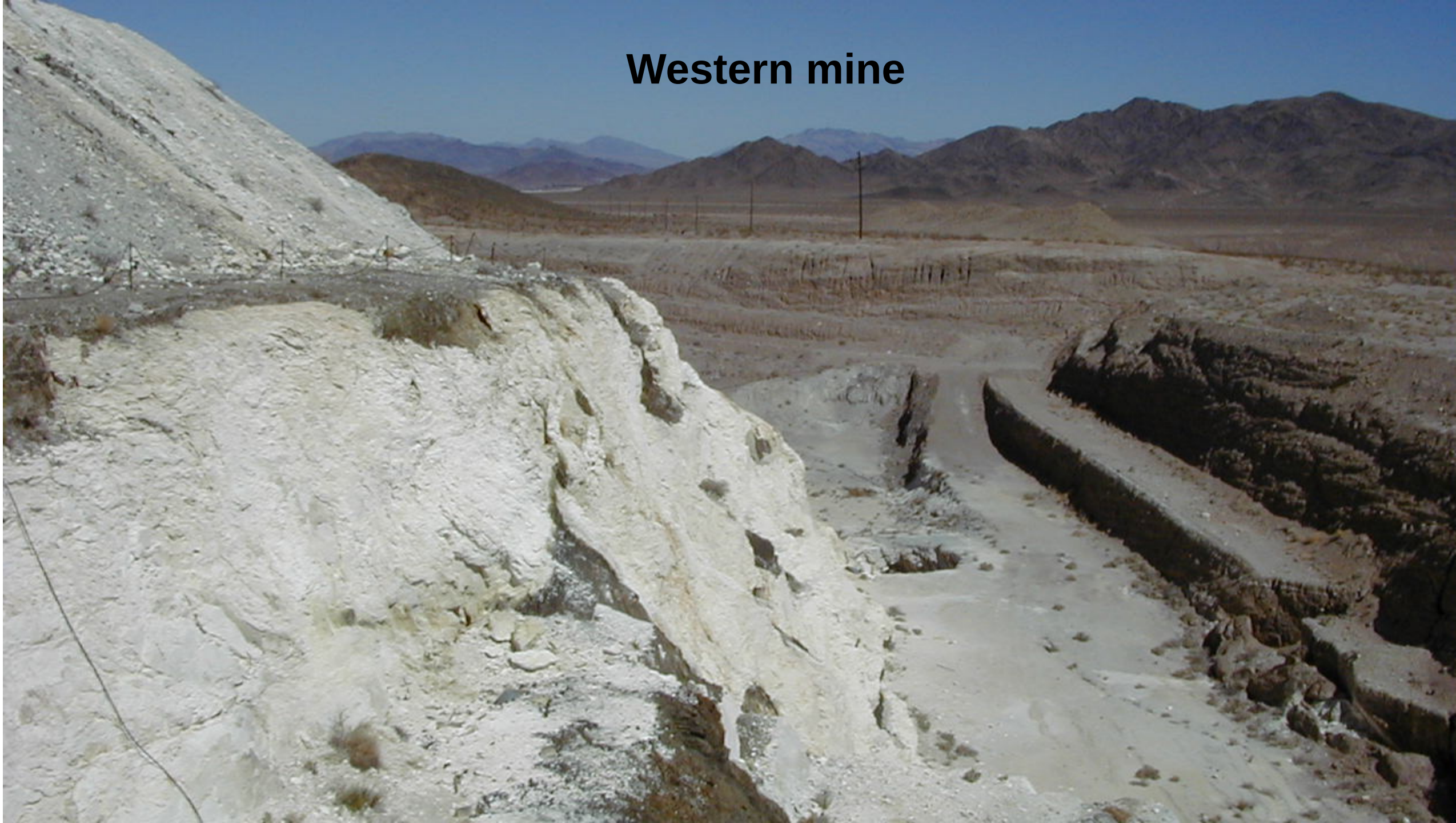

“fibrous talc”
x550
20 micrometers


“transitional fiber”
x700
anth
anth
talc
talc
20 micrometers

Amphibole asbestos-bearing Talc deposits, Southern Death Valley Region, California

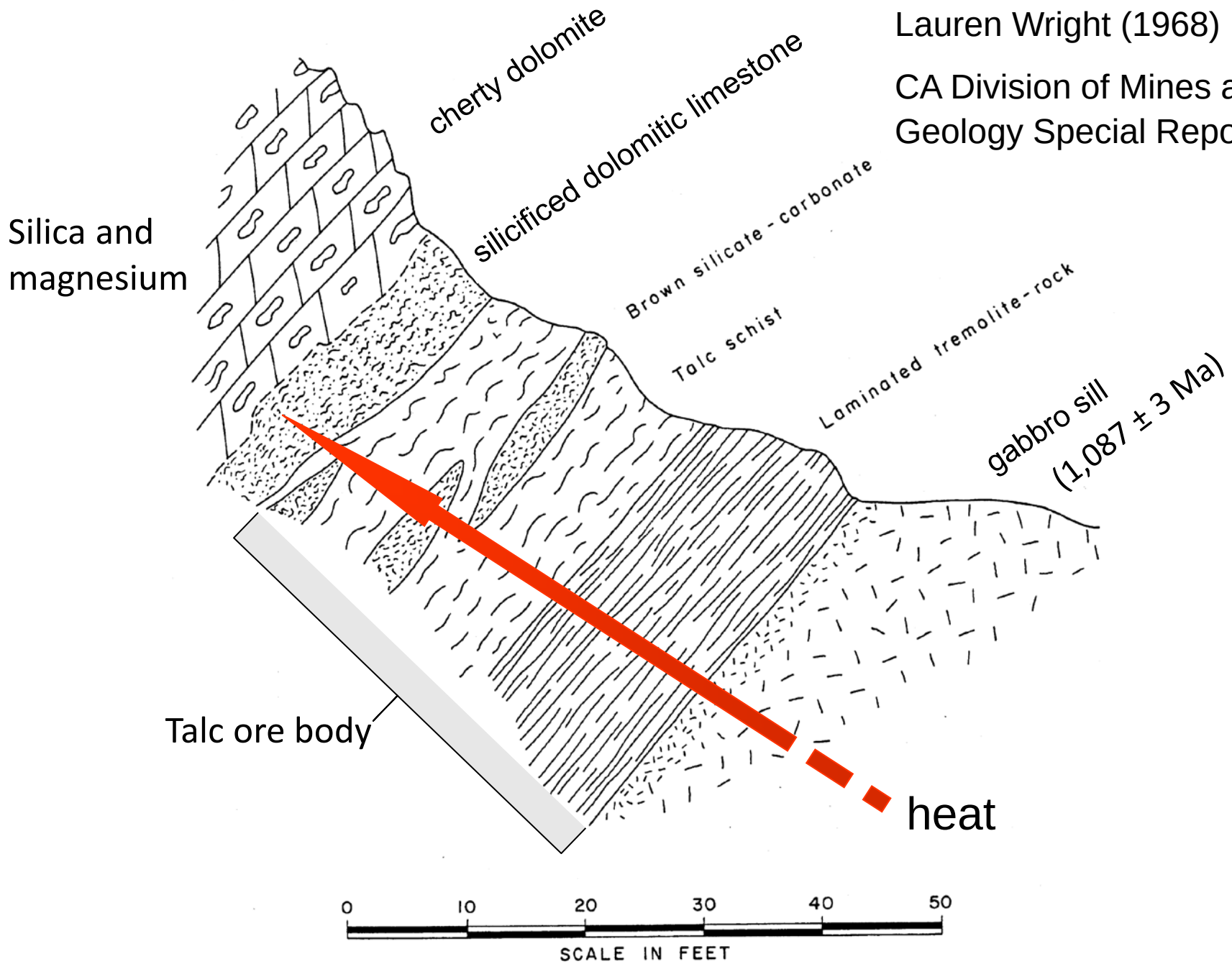

Ibex Hills

Western mine



Lauren Wright (1968)

CA Division of Mines and Geology Special Report 95



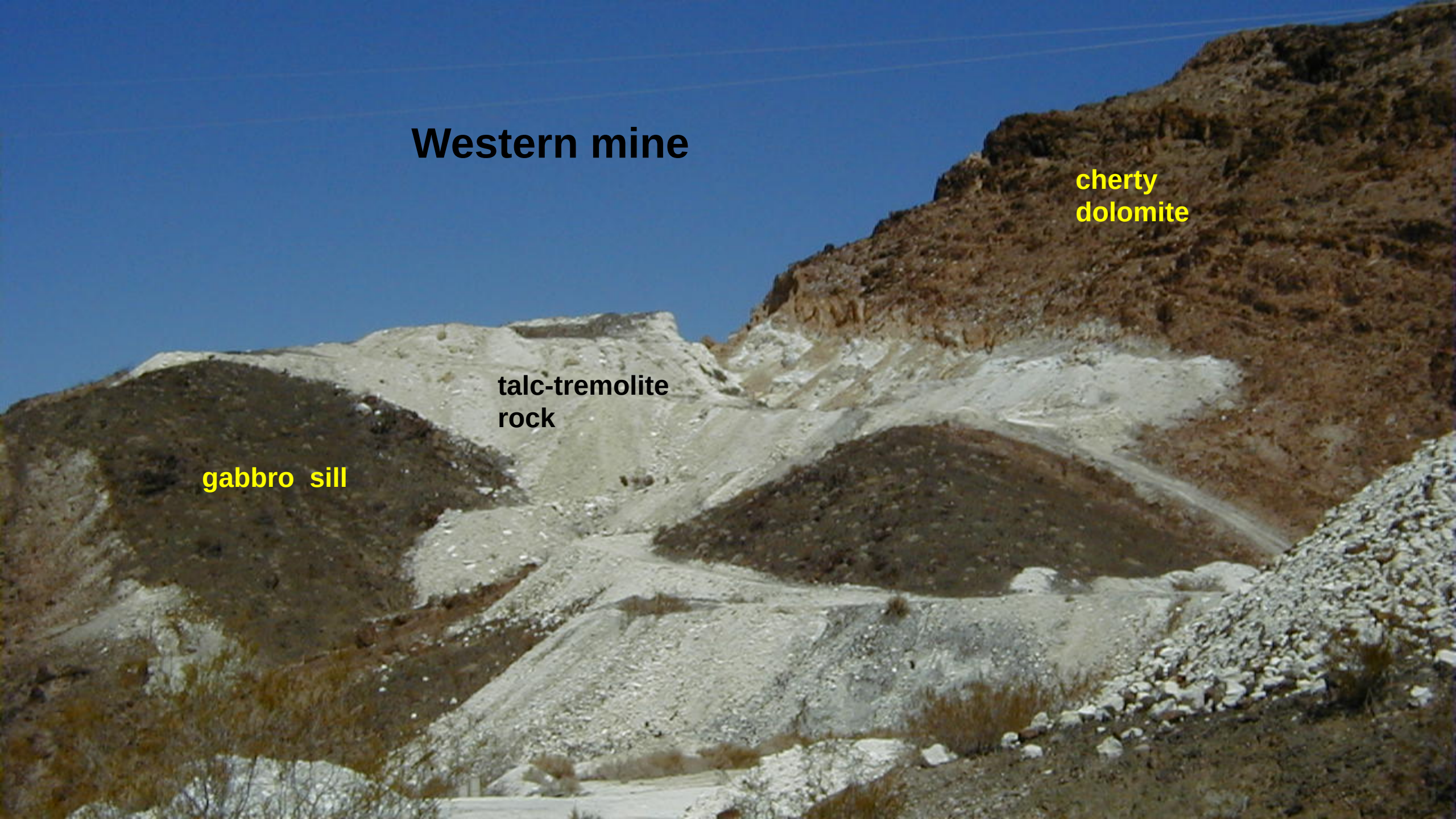
talc

tremolite

calcite

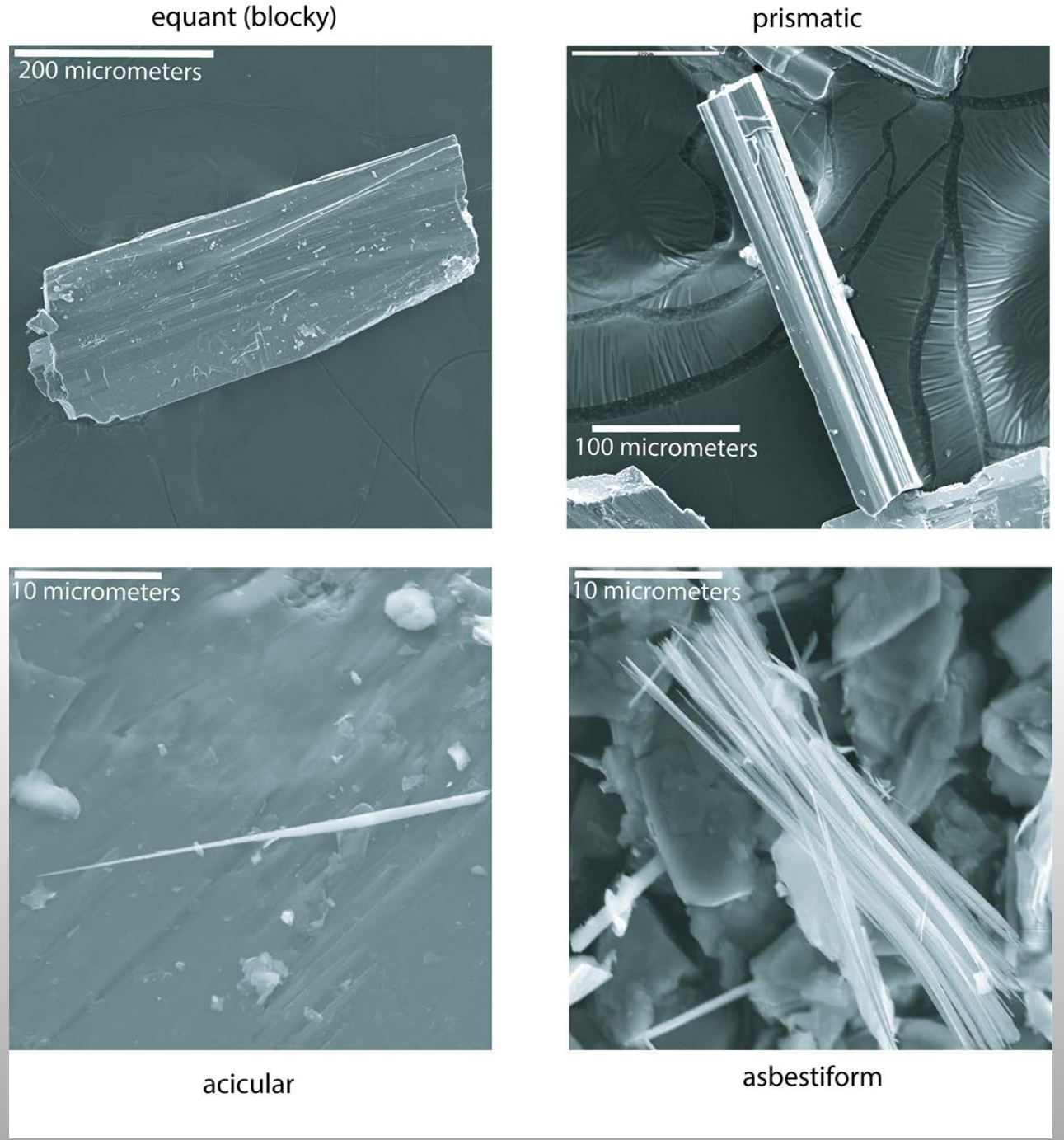
dolomite

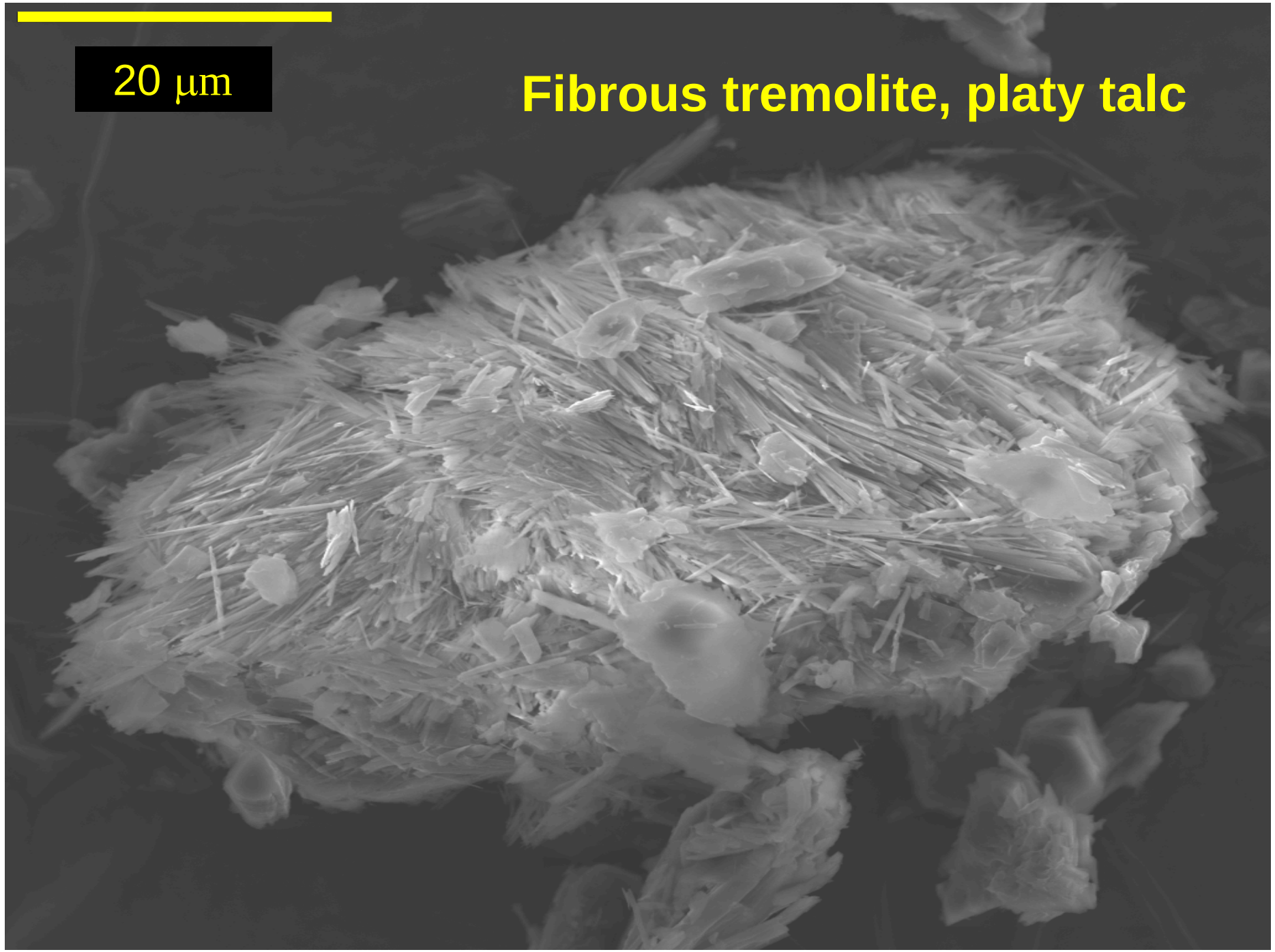
quartz

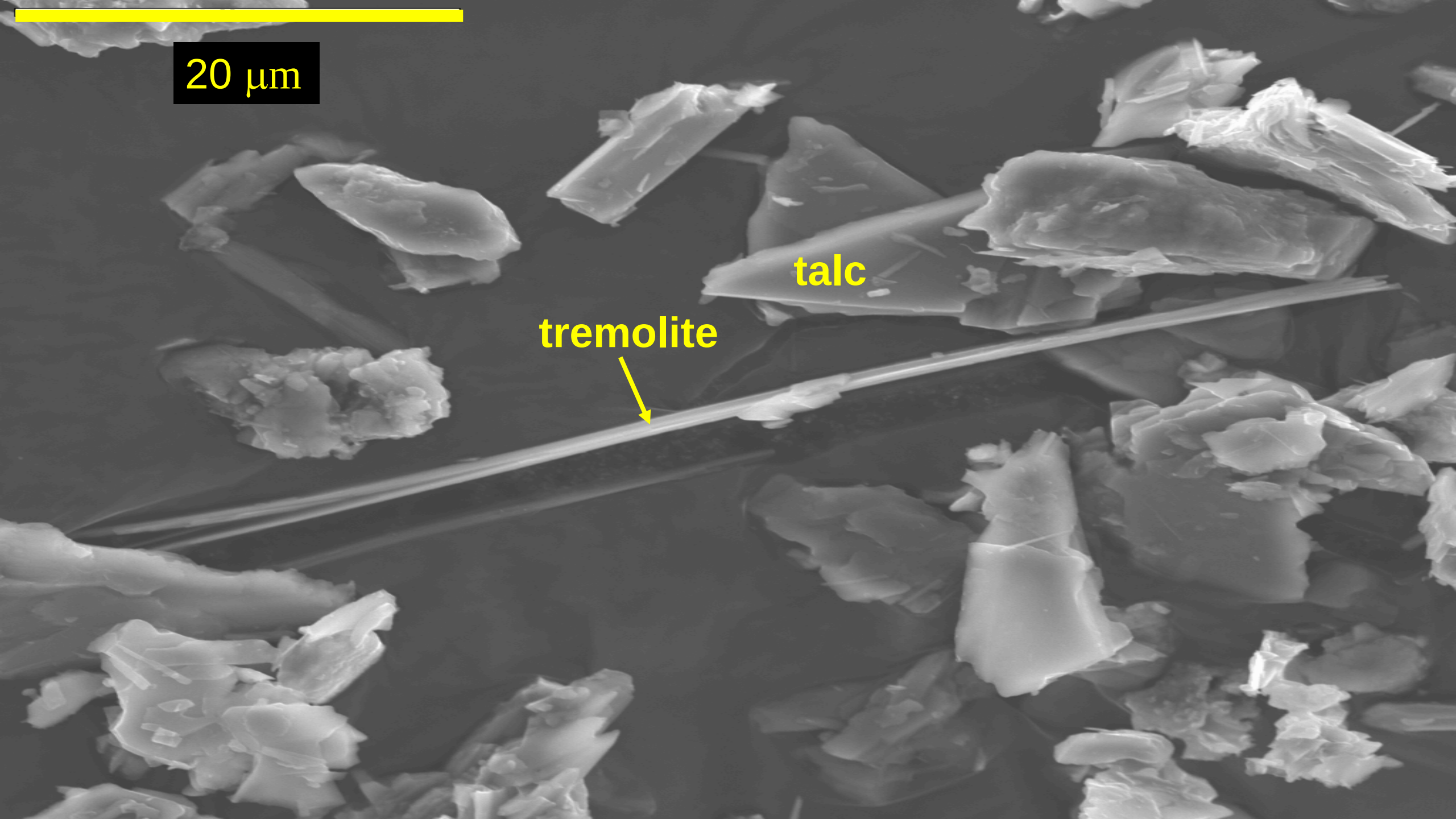

Western mine
cherty
dolomite
talc-tremolite
rock
gabbro sill

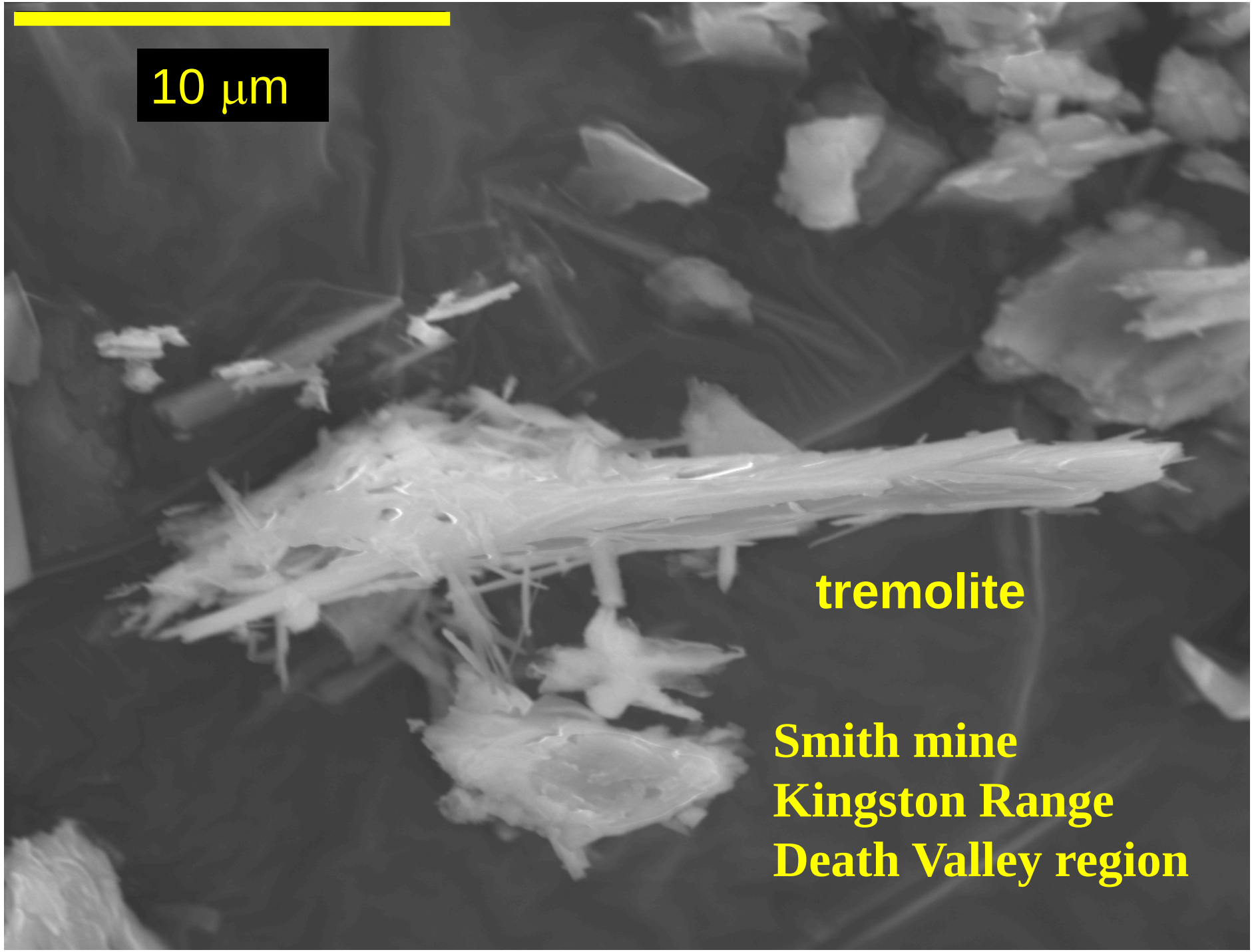

talc-
tremolite
rock
gabbro sill

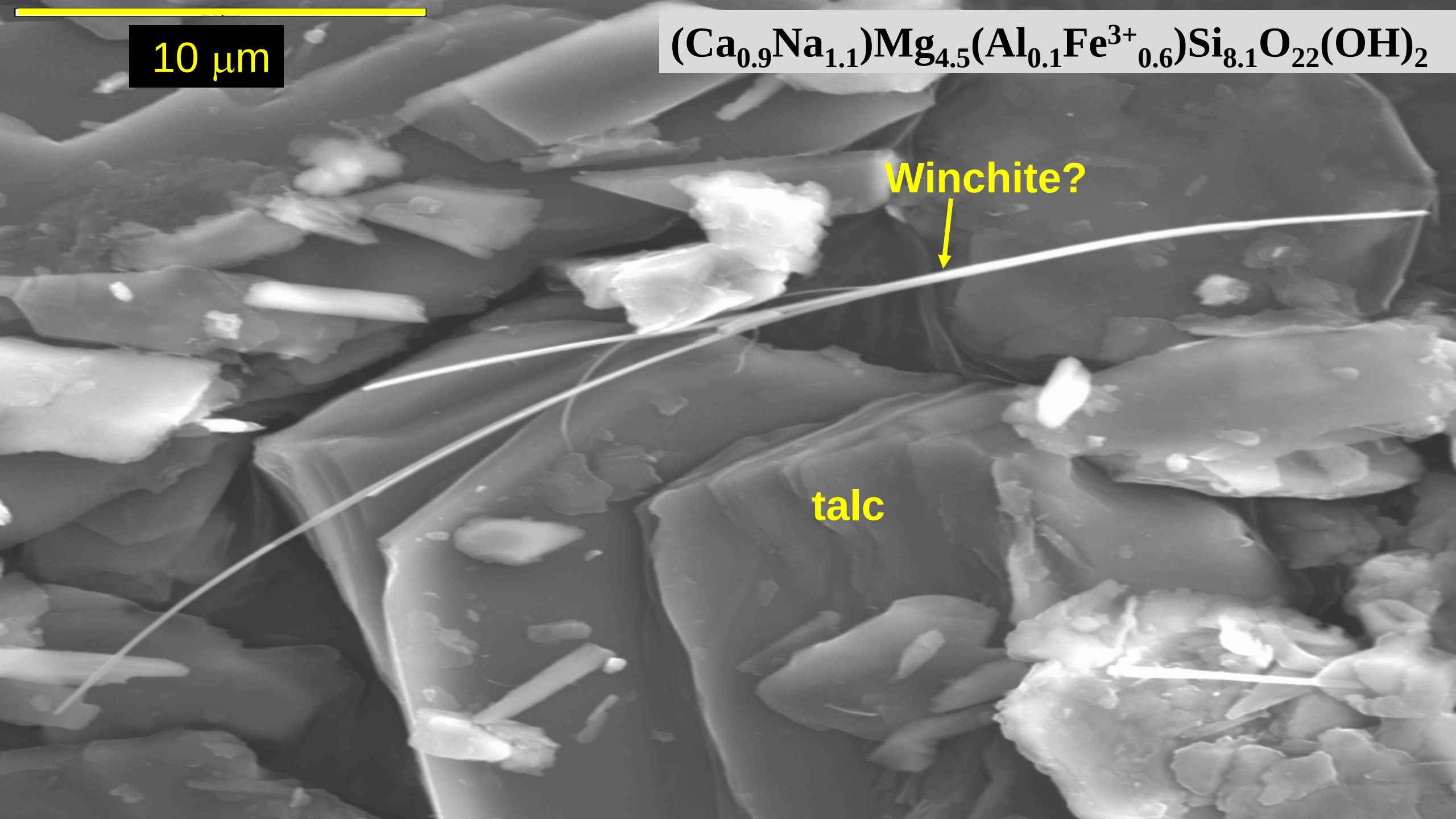
Tremolite in
Death Valley talc

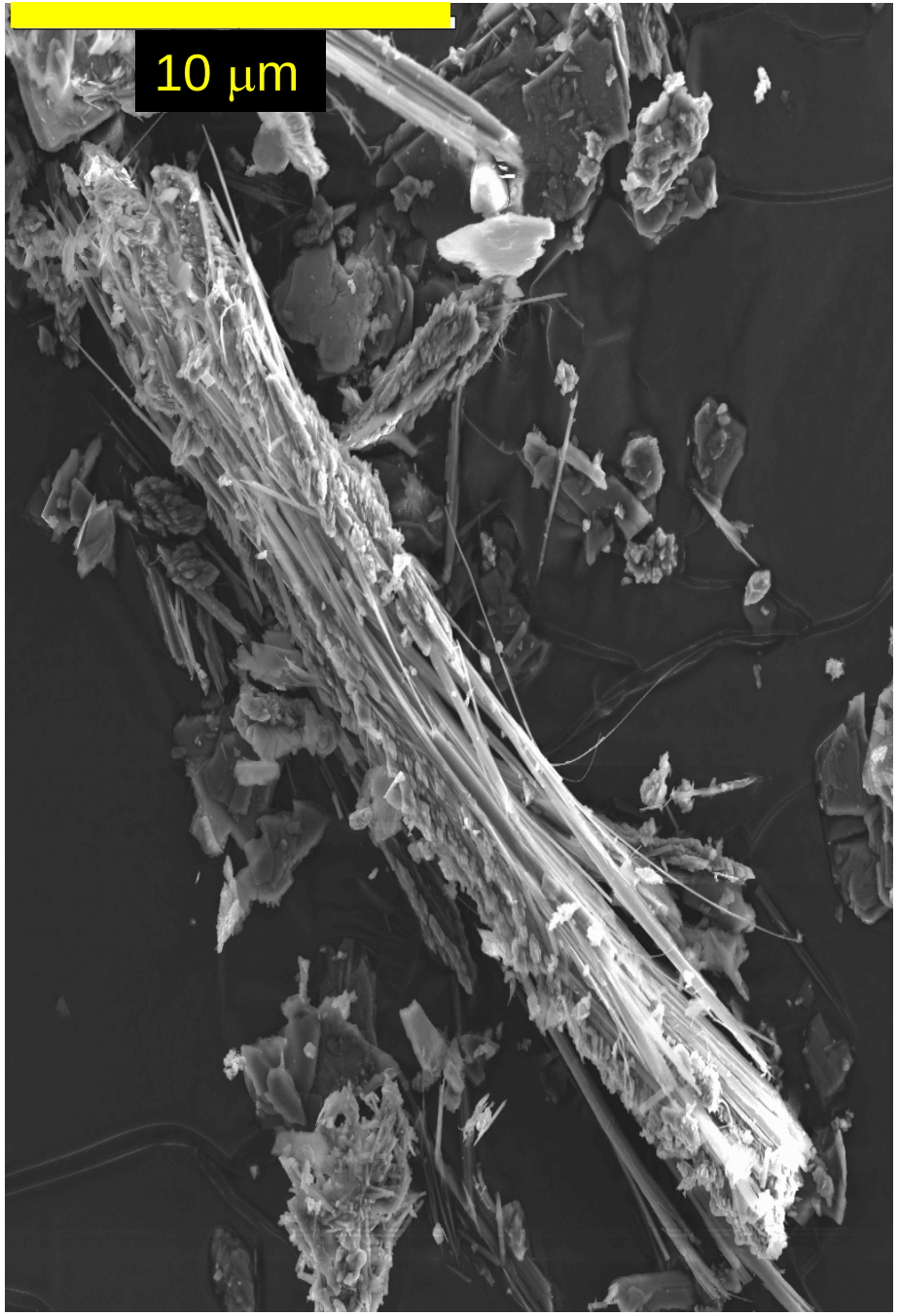



20 μm
Fibrous tremolite, platy talc


20 μm
talc
tremolite


10 μm
tremolite
Smith mine
Kingston Range
Death Valley region

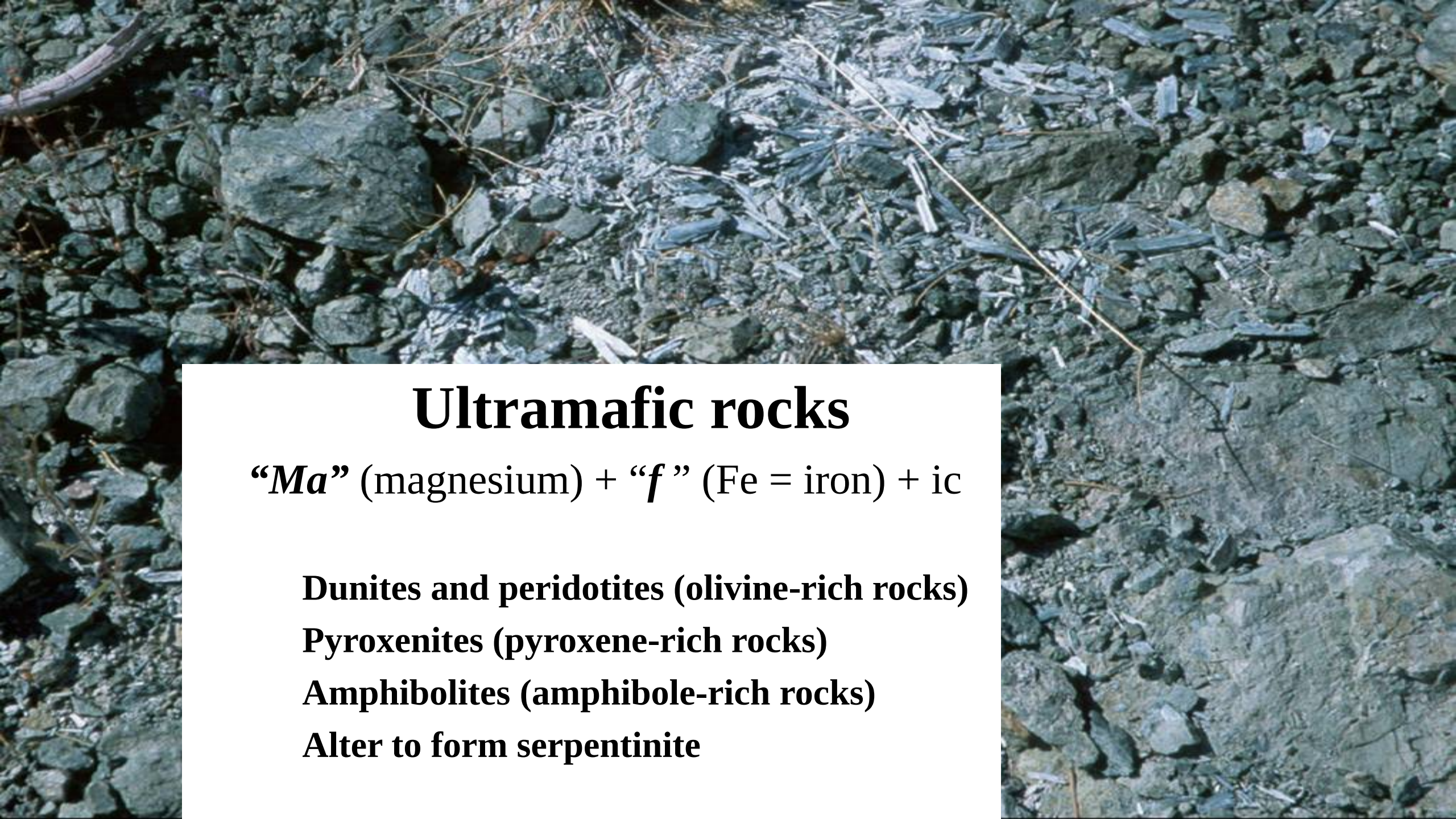

10 μm
$(Ca_{0.9}Na_{1.1})Mg_{4.5}(Al_{0.1}Fe^{3+}_{0.6})Si_{8.1}O_{22}(OH)_2$
Winchite?
talc



Richterite?

$Na_{1.9}Ca_{0.9}Mg_{5.1}Si_{7.8}O_{22}(OH)_2$

Warm Spring Canyon,
Death Valley N.P.



Ultramafic rocks

"Ma" (magnesium) + "***f***" (Fe = iron) + ic

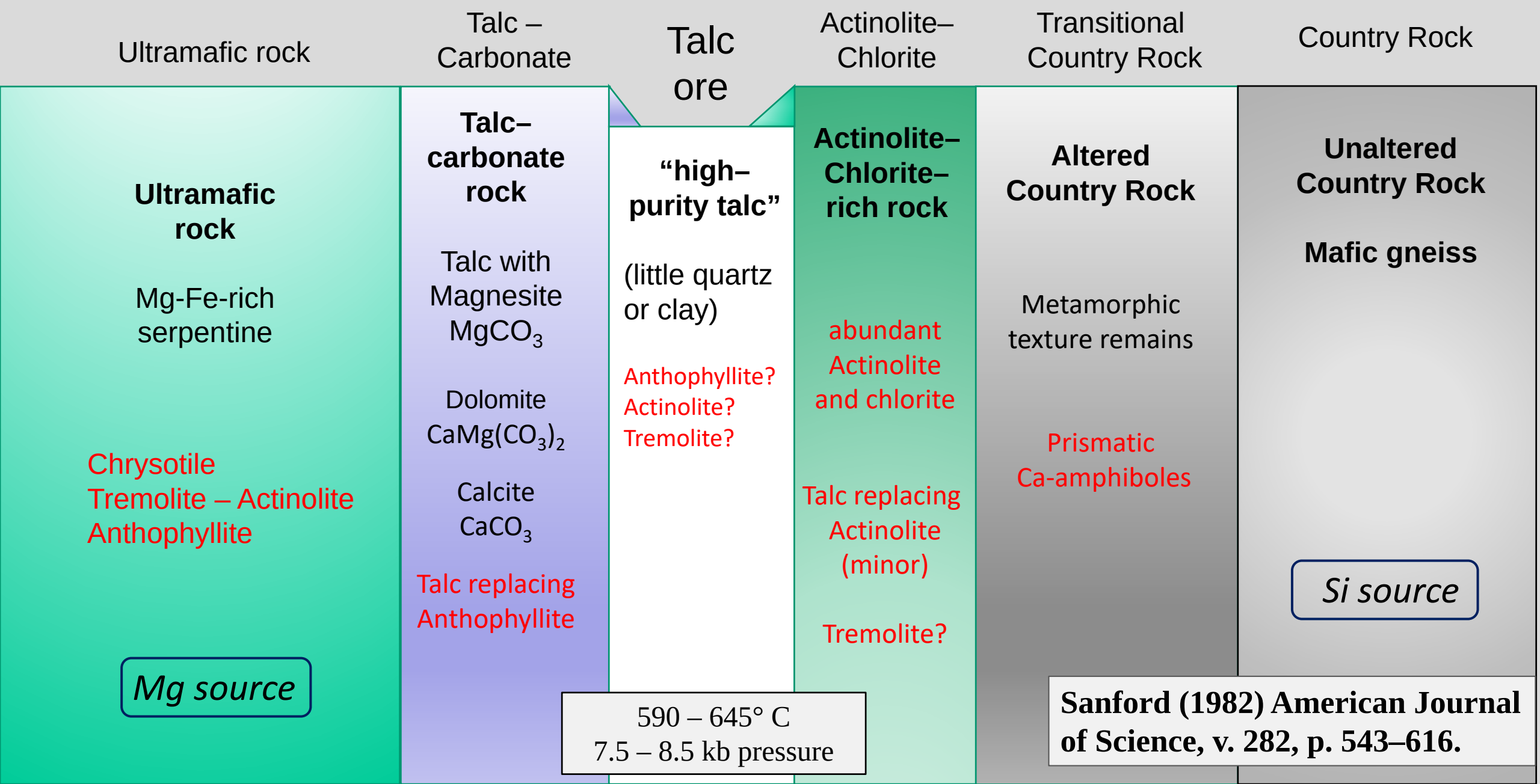
Dunites and peridotites (olivine-rich rocks)

Pyroxenites (pyroxene-rich rocks)

Amphibolites (amphibole-rich rocks)

Alter to form serpentinite

Generalized zonation of a Vermont talc deposit



Sanford (1982) American Journal of Science, v. 282, p. 543–616.

Not all talc is created equal—Another talc deposit type
The good news…..

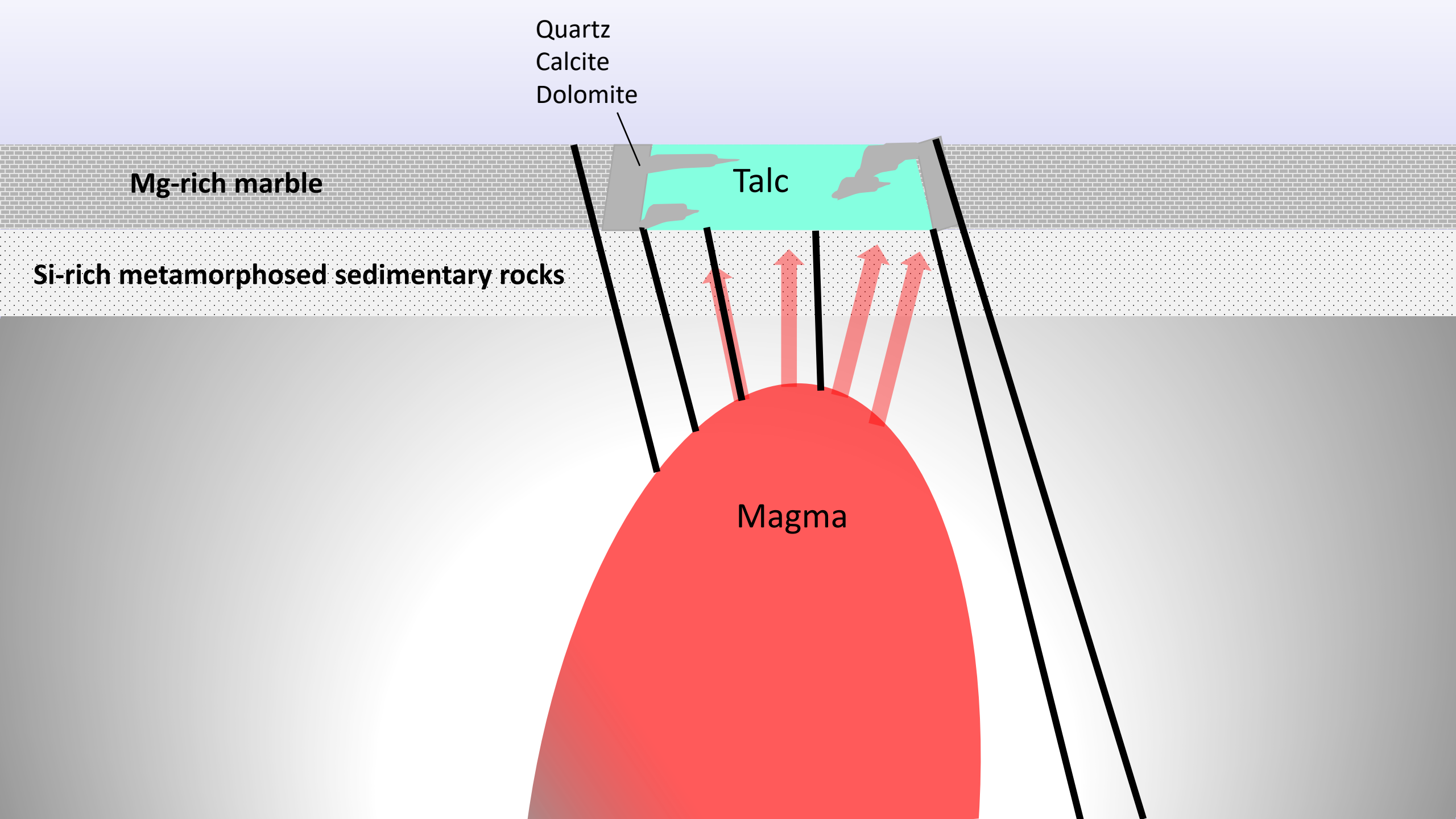
Upward circulation of hot silica-rich fluids, heated by an igneous intrusion at depth, forming large talc bodies by the massive replacement of an overlying dolostone unit (Mg-rich marble)

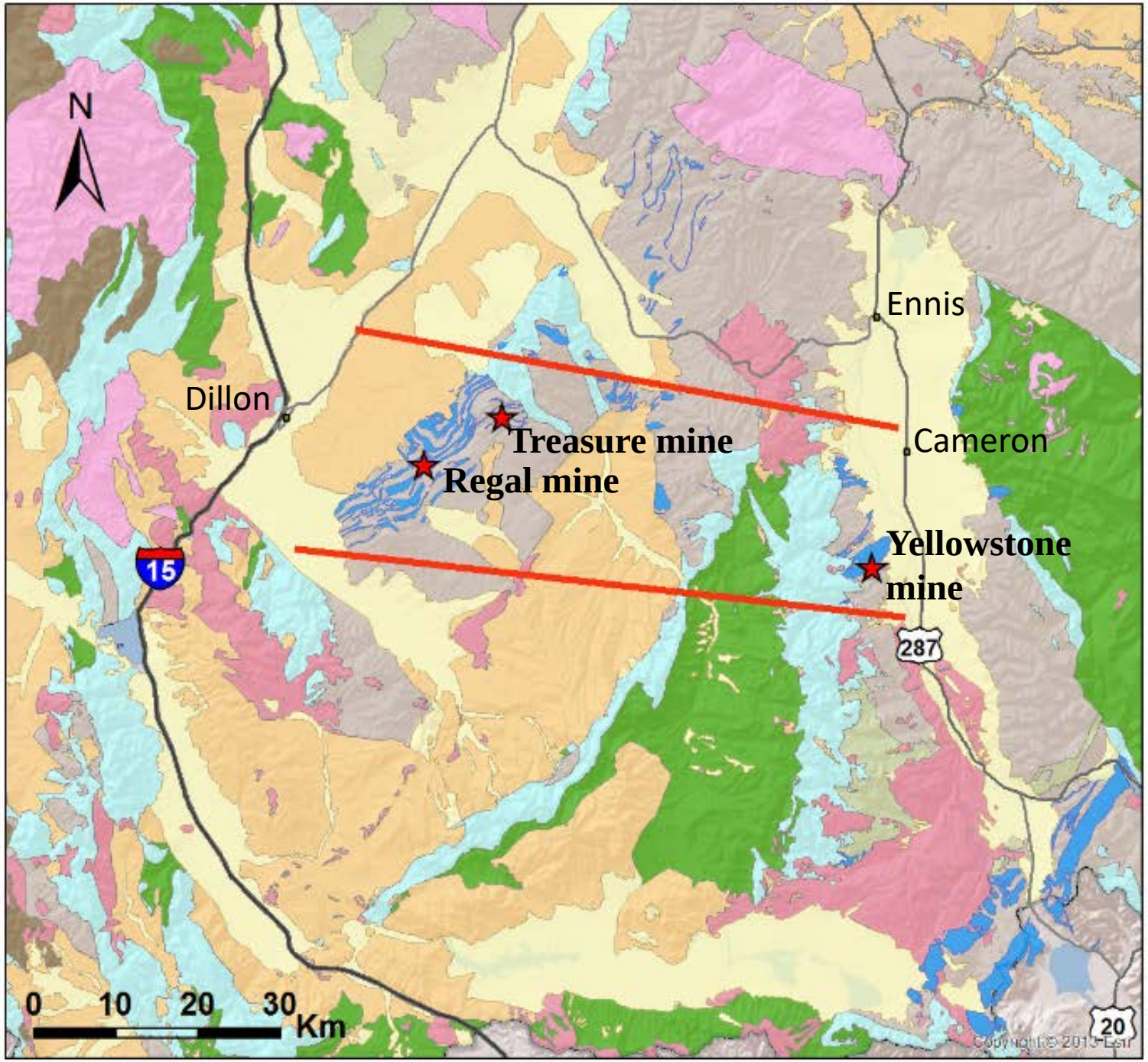
↓

No amphiboles or serpentine are created

Dolomite + silica + water → Talc + calcite + carbon dioxide

$3CaMg(CO_3)_2 + 4SiO_2 + H_2O \rightarrow Mg_3Si_4O_{10}(OH)_2 + 3CaCO_3 + 3CO_2$


Quartz
Calcite
Dolomite
Mg-rich marble
Talc
Si-rich metamorphosed sedimentary rocks
Magma



Active Talc Mines

Talc Corridor

Quaternary Deposits

Tertiary Sedimentary

Tertiary Igneous

Cretaceous Igneous

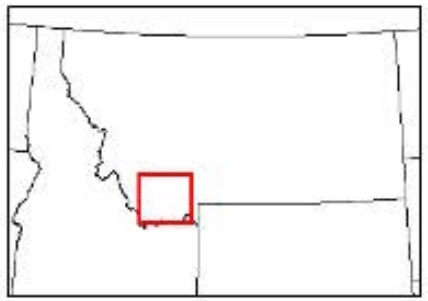
Mesozoic Sedimentary

Paleozoic Sedimentary

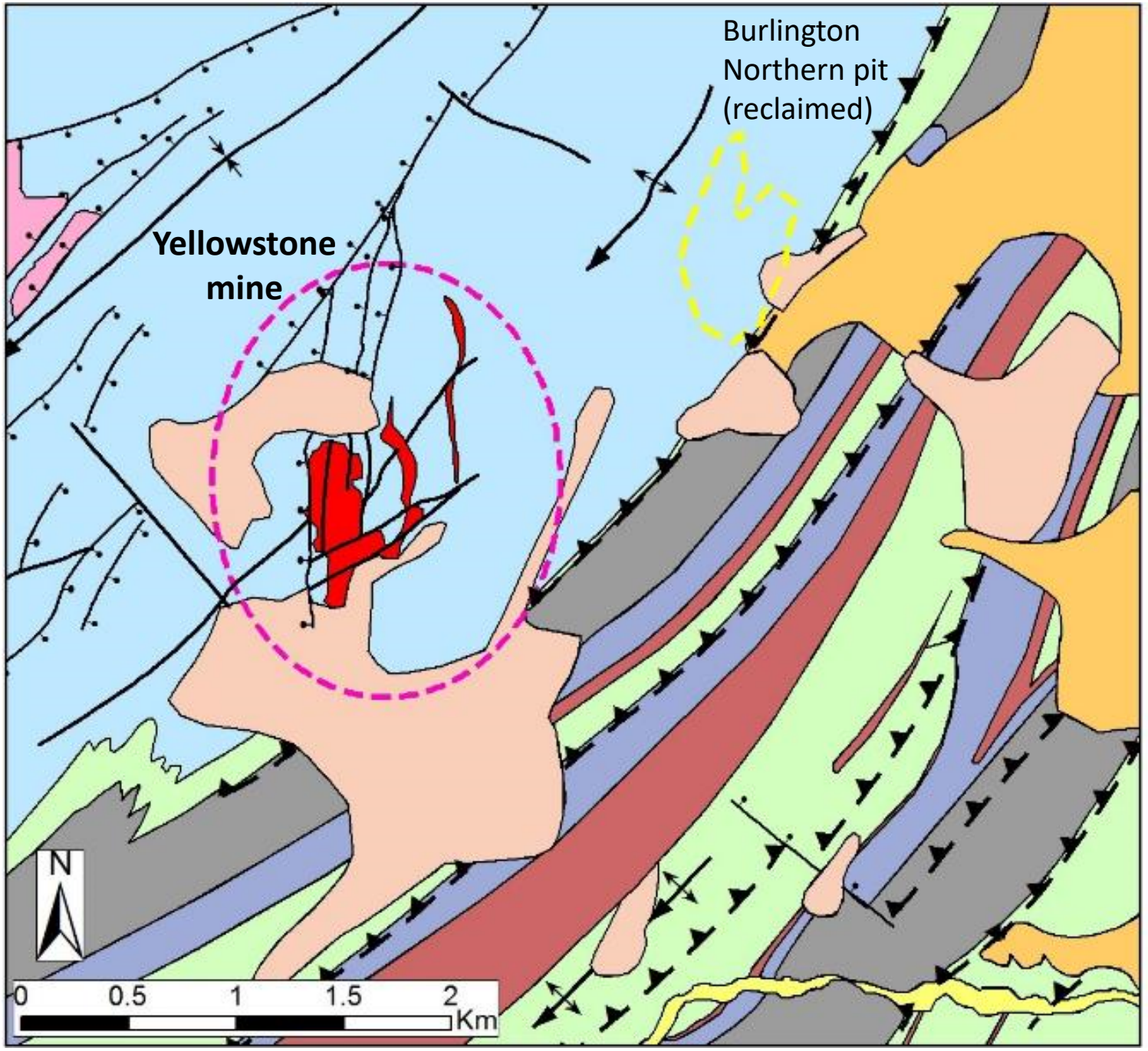
Mesoproterozoic Sedimentary (Belt Supergroup)

Archean Metamorphic

Archean marble



Childs Geoscience Inc.
Bozeman, Montana



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

Childs Geoscience Inc.
Bozeman, Montana


“Yellowstone Talc Mine”
vimeo.com

Tremolite in
Death Valley talc