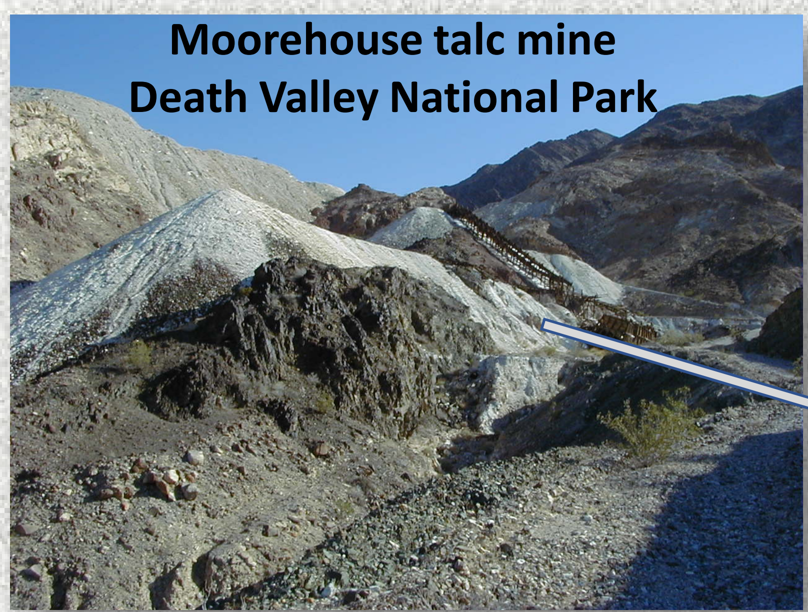
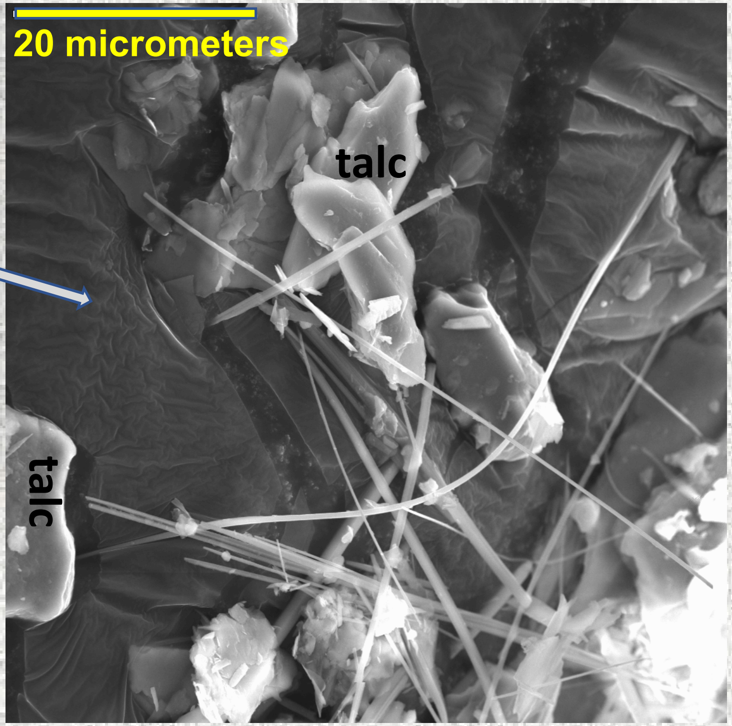
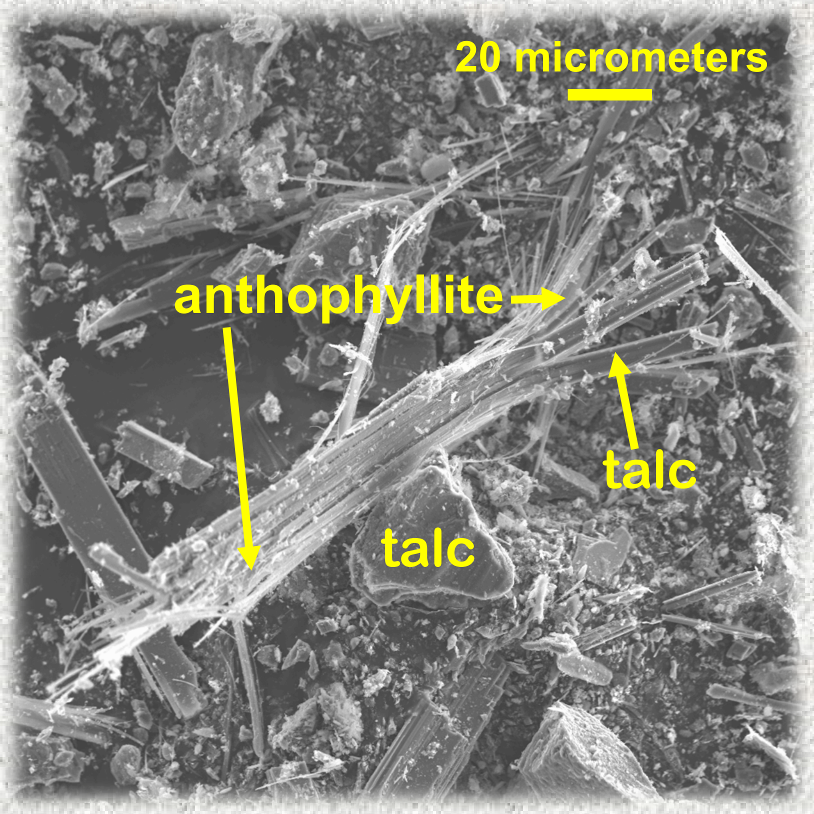
The Mineral Fibers of Potential Concern in Talc—Geology and Mineralogy





asbestiform tremolite
with platy talc

"transitional fibers"



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

USGS
science for a changing world

Domestic talc production and applications

In 2018, total sales (domestic and export) of talc by U.S. producers were estimated to be **540,000 metric tons valued at $117 million.**

During 2018, talc produced and sold in the United States was used in:

- Ceramics = 22%
- Paint = 21%
- Paper = 21%
- Plastics = 8%
- Rubber = 4%
- Roofing = 4%
- Cosmetics = 2%
- Export, insecticides, and others = 18%

Exports of talc from U.S producers were 230,000 metric tons.

USGS National Minerals Information Center

https://www.usgs.gov/centers/nmic/talc-and-pyrophyllite-statistics-and-information

USGS
science for a changing world

Talc imports and uses

An estimated 354,000 metric tons of talc was imported in 2017.
(540,000 metric tons produced domestically.)

Import sources (2014 – 2017)

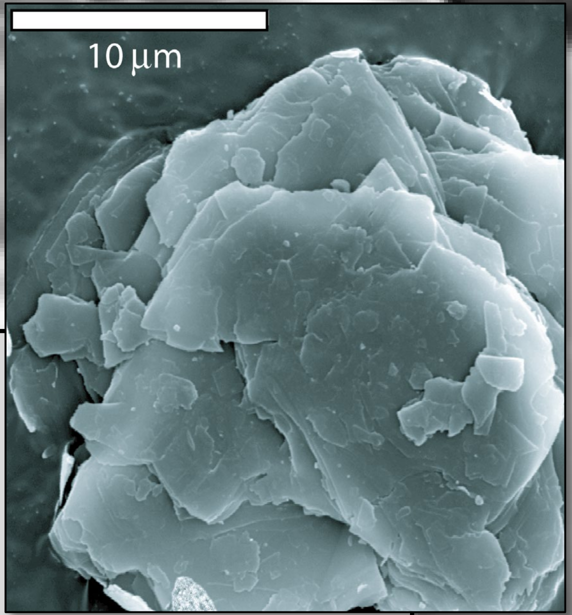
Pakistan 40% Canada 27% China 22% Others 11%

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

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

Talc

$Mg_3Si_4O_{10}(OH)_2$



- 1 on the Mohs hardness scale
- Talc is usually platy, a “sheet silicate”; however, fibrous varieties exist.
- 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 that are visible to the naked eye are extremely rare.

“**<u>Cosmetic talc</u> consists of a minimum of 90% hydrated magnesium silicate**, with remainder consisting of naturally associated minerals such as calcite, chlorite, dolomite, kaolin, and magnesite; **it contains no detectable fibrous, asbestos minerals**.”

[quoted from page 6 of “Safety Assessment of Talc as Used in Cosmetics”
https://www.cir-safety.org/sites/default/files/talc122012tent_faa_final%20for%20posting.pdf

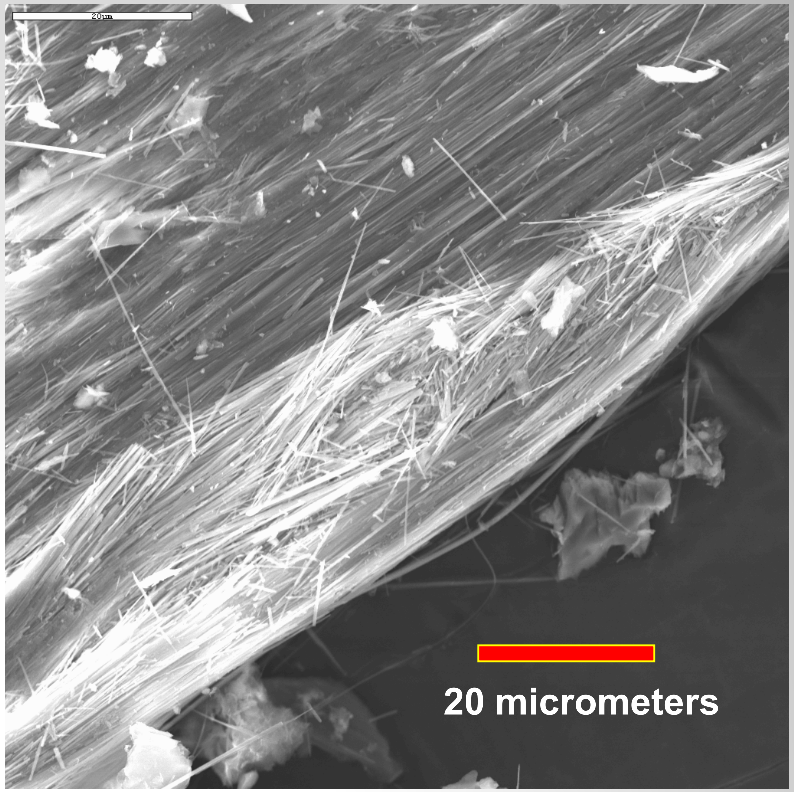
USGS
science for a changing world

“Asbestos”

- Serpentines: chrysotile

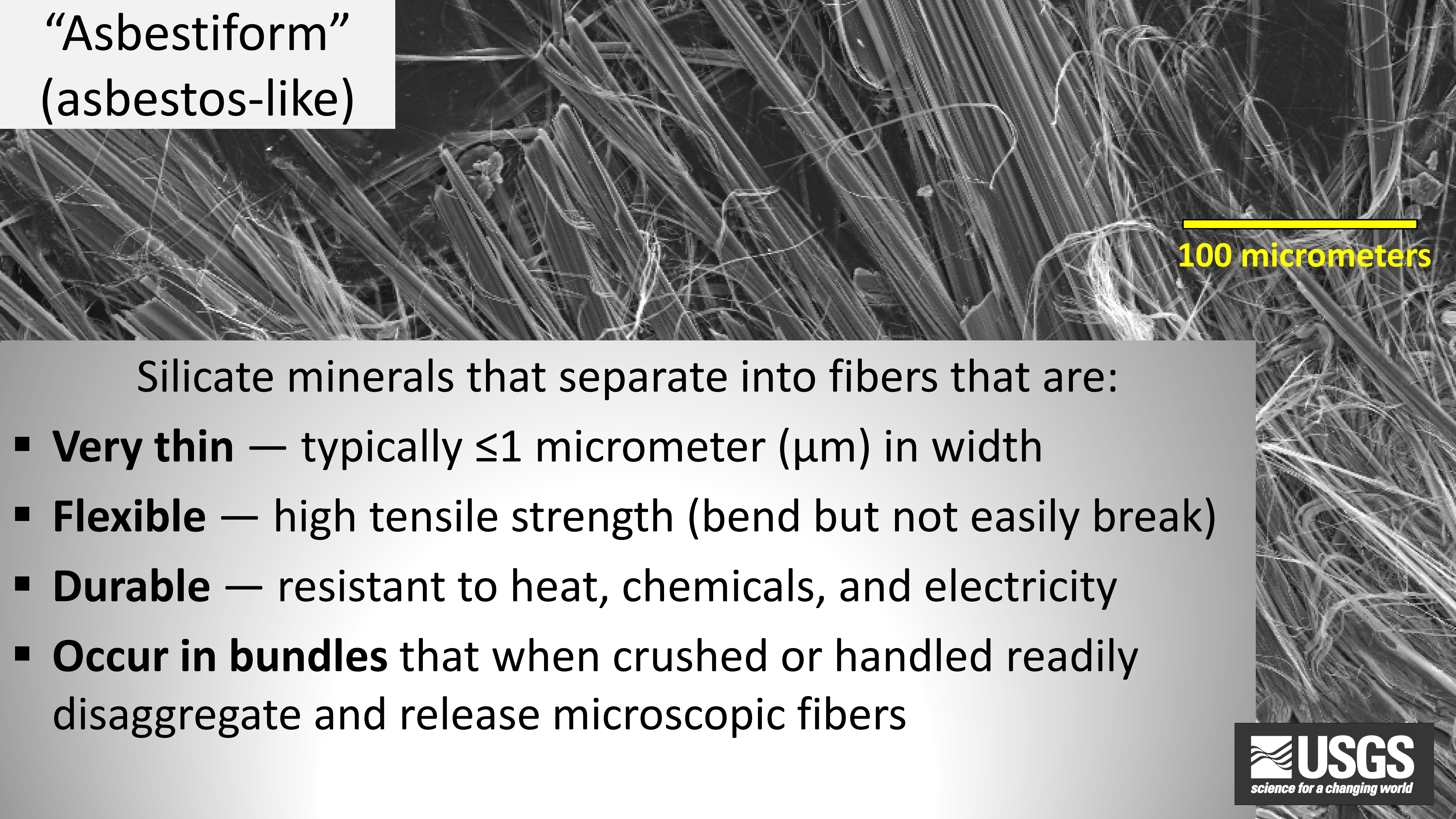
- Five Amphiboles — the *asbestiform* varieties of:
  - tremolite
  - actinolite
  - anthophyllite
  - cummingtonite-grunerite (“amosite”)
  - riebeckite (“crocidolite”)

Tremolite asbestos



USGS
science for a changing world

"Asbestiform" (asbestos-like)



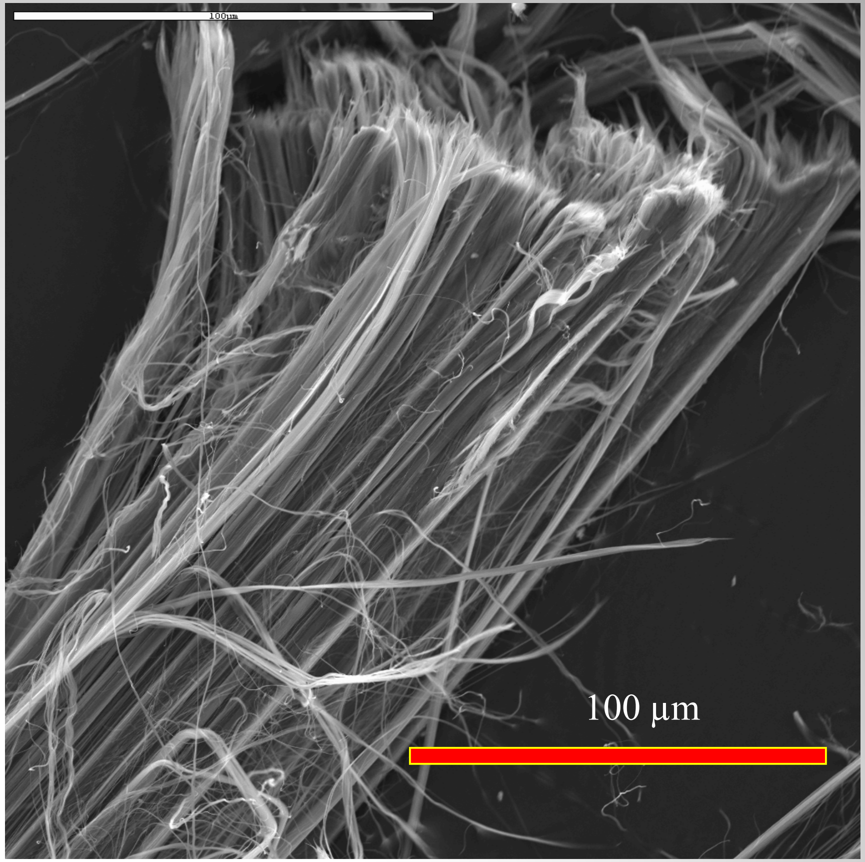
Silicate minerals that separate into fibers that are:

- **Very thin** — typically ≤1 micrometer (µm) in width
- **Flexible** — high tensile strength (bend but not easily break)
- **Durable** — resistant to heat, chemicals, and electricity
- **Occur in bundles** that when crushed or handled readily disaggregate and release microscopic fibers

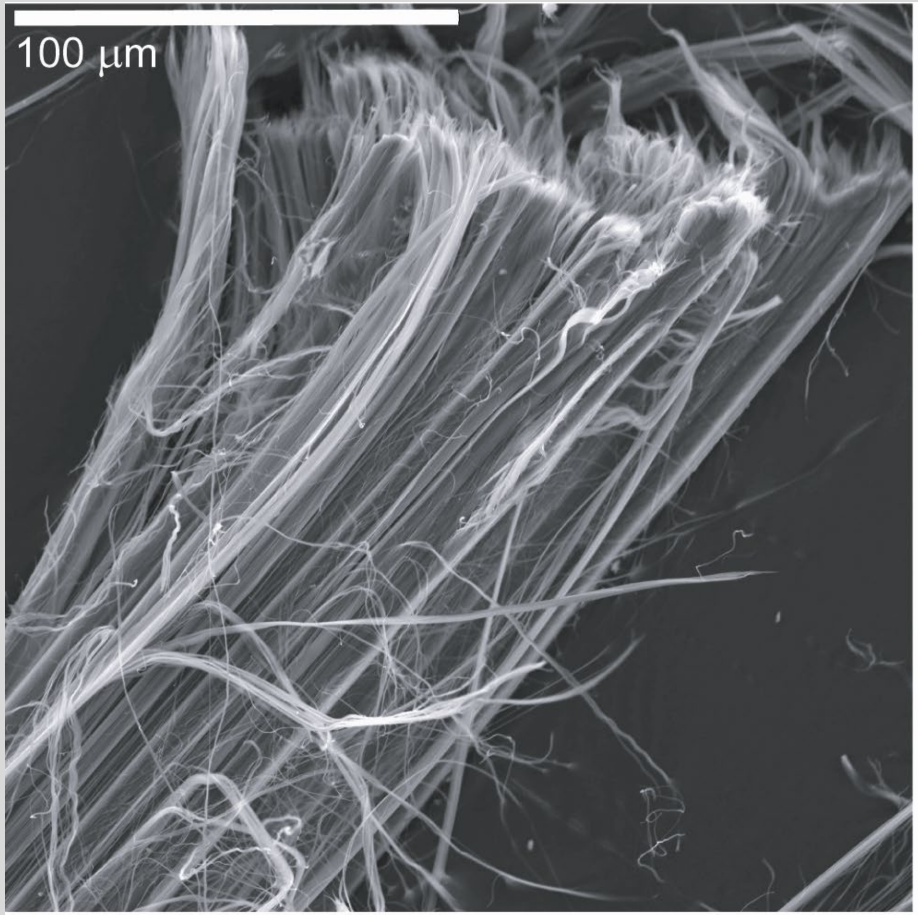
Serpentine mineral group

Chrysotile

$Mg_3Si_2O_5(OH)_4$

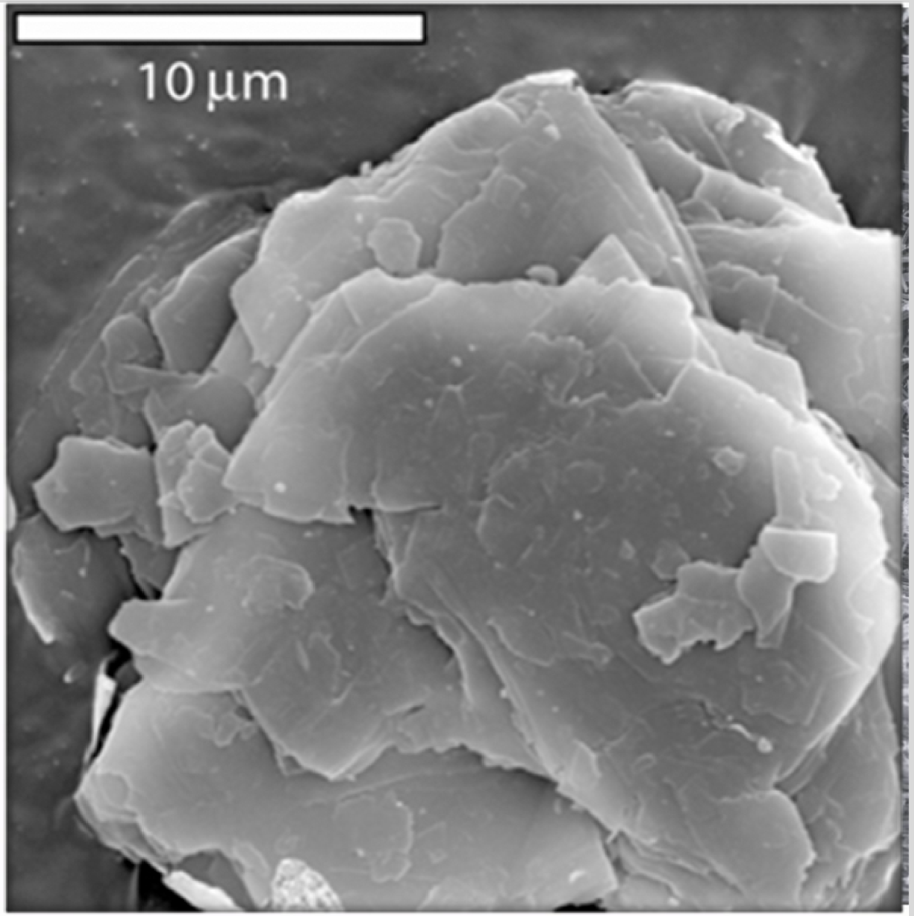


- About 95% of the asbestos produced in the world so far
- About 99% of the asbestos mined today



Chrysotile

$Mg_3Si_2O_5(OH)_4$



Talc

$Mg_3Si_4O_{10}(OH)_2$

USGS
science for a changing world

Regulated asbestos minerals of the Amphibole group

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

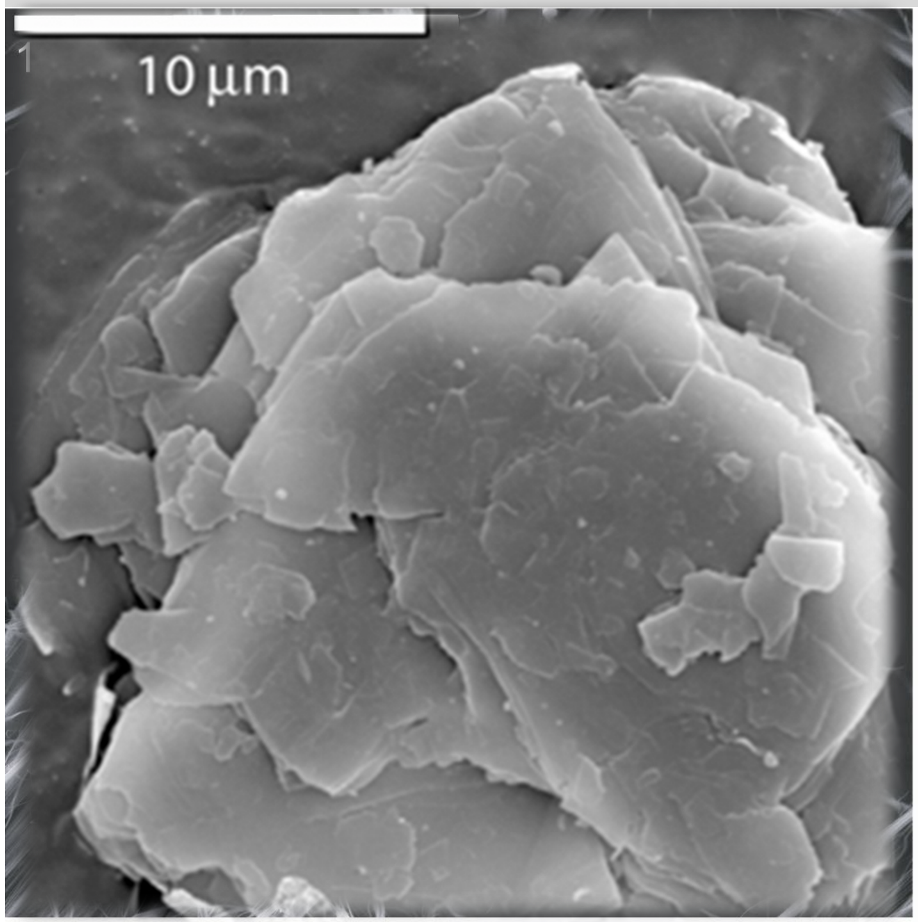
Crocidolite and amosite do not occur in talc deposits

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

Anthophyllite, actinolite, and tremolite can occur in talc deposits

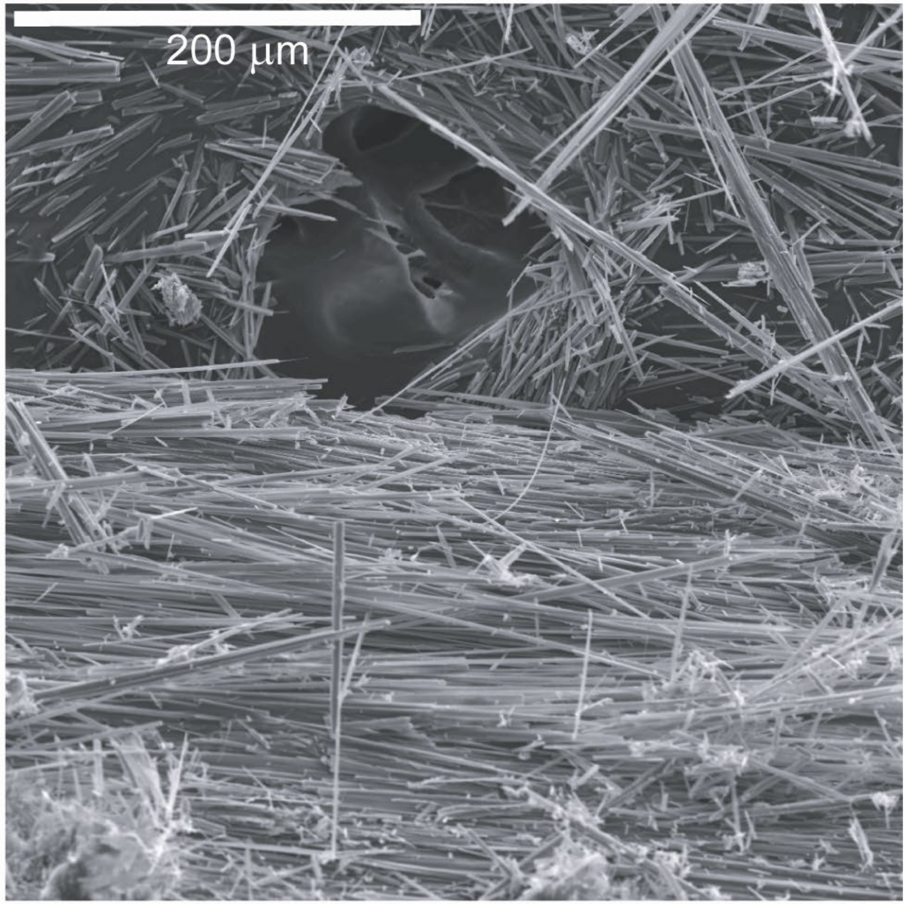
Compositions from: Leake et al., 1997, *American Mineralogist*, v. 82, p. 1019–1037.

USGS science for a changing world



Talc

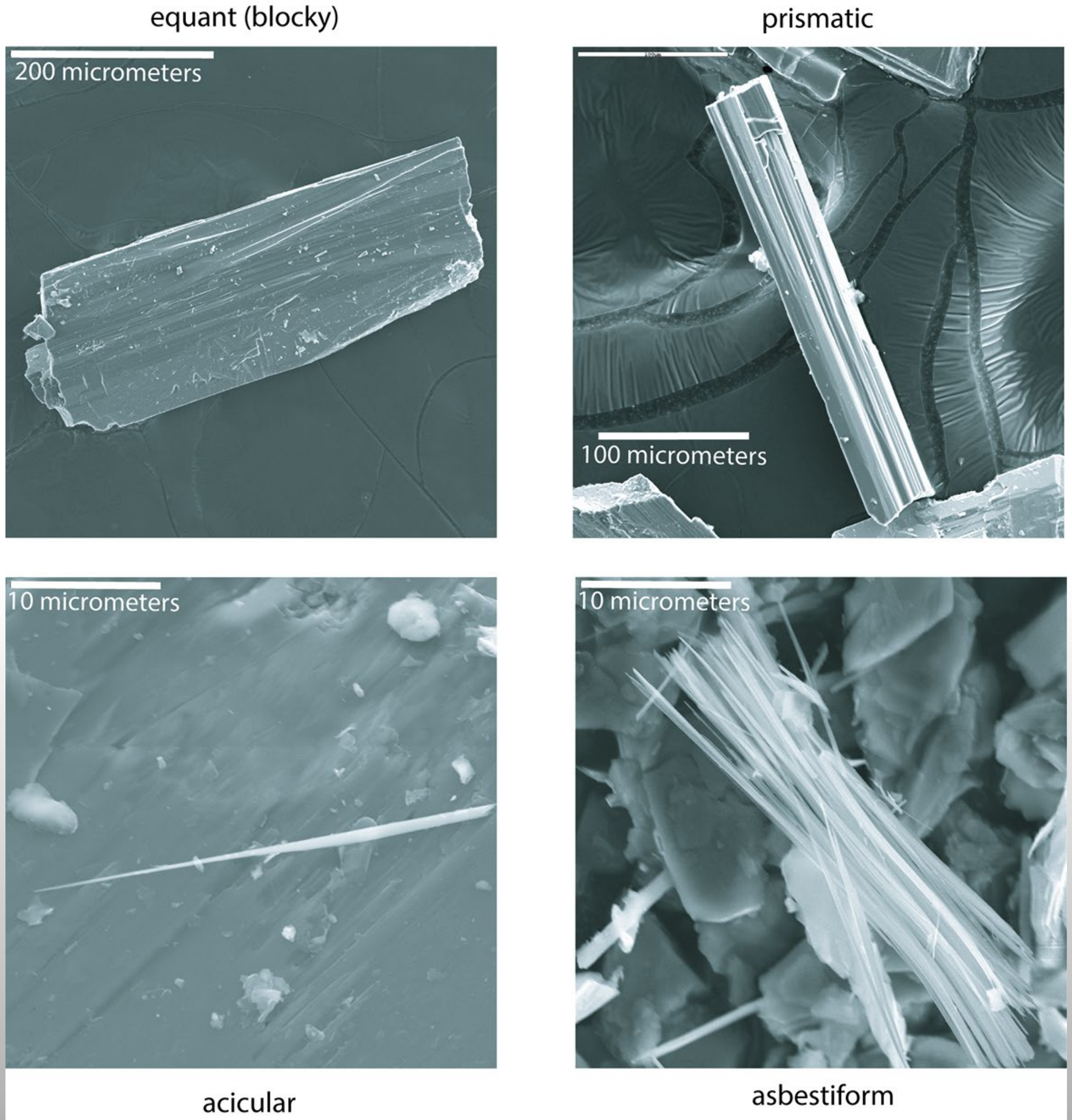
$Mg_3Si_4O_{10}(OH)_2$



Anthophyllite

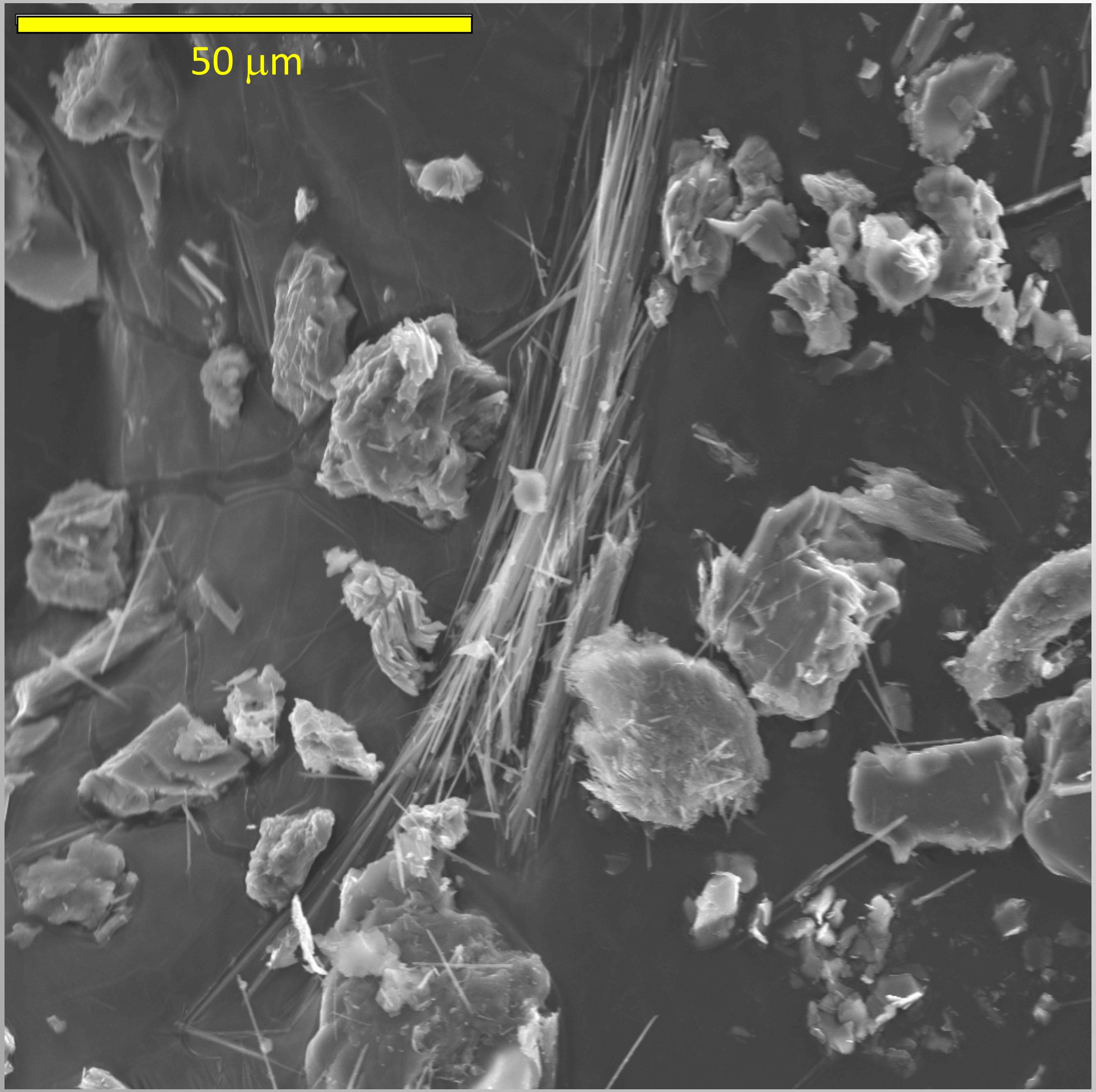
$\square\{Mg, Fe^{2+}\}_7Si_8O_{22}(OH)_2$

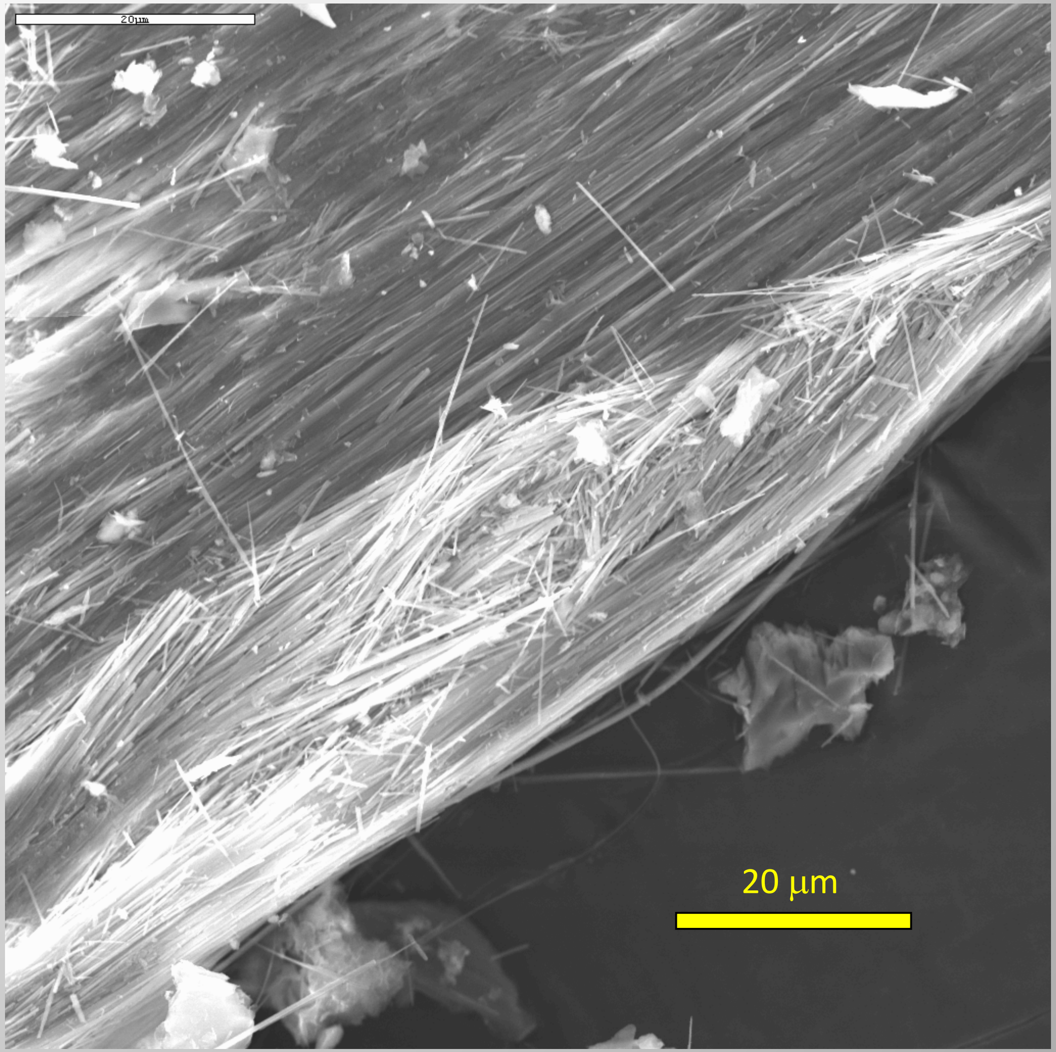
- Variations in amphibole morphology
- Tremolite particles within a single talc deposit (Death Valley region)



USGS
science for a changing world

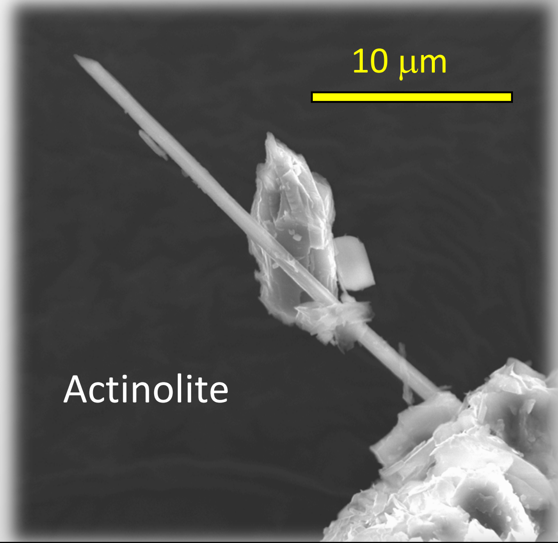
asbestiform tremolite

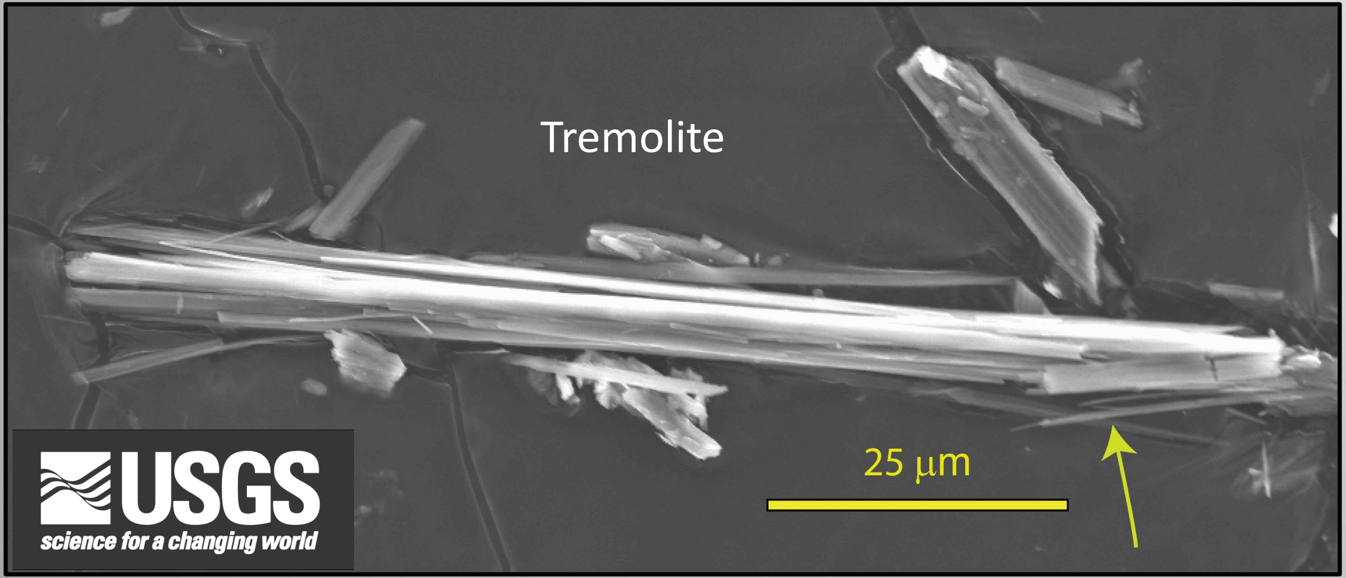


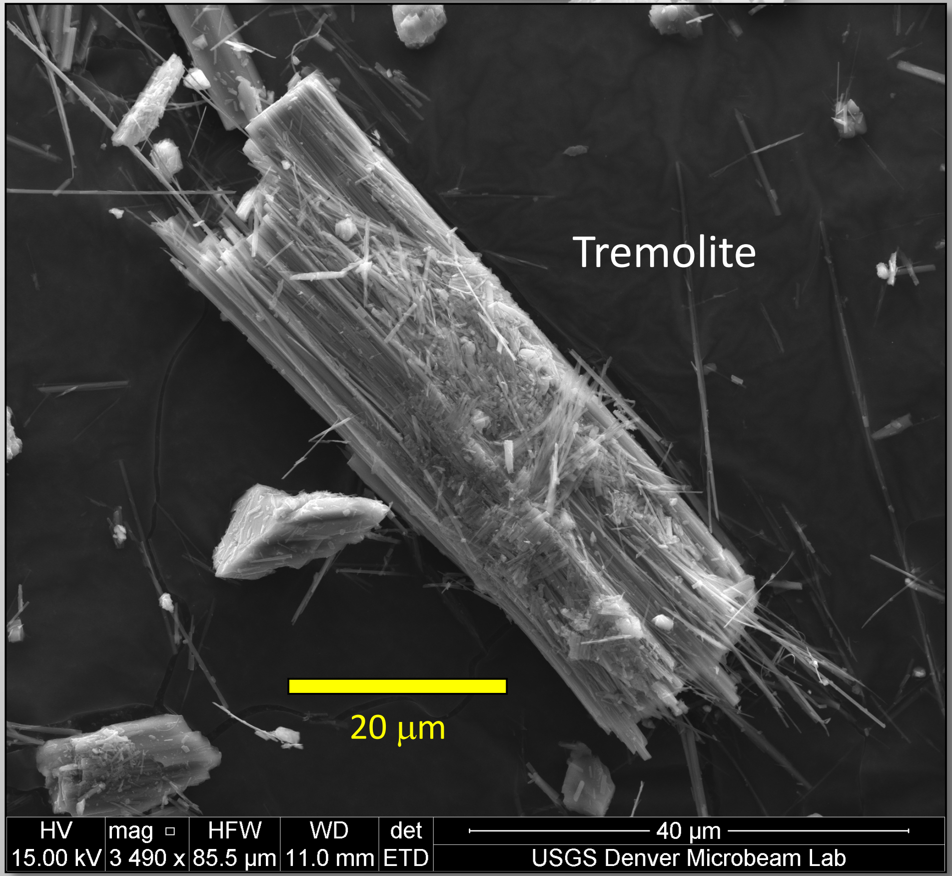


USGS
science for a changing world

“Cleavage Fragments”







Metasomatism

"The process of….capillary solution and deposition by which a new mineral….may grow in the body of an old mineral or mineral aggregate."

To form talc this process is driven by:

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

and you need a
Magnesium-rich host rock:

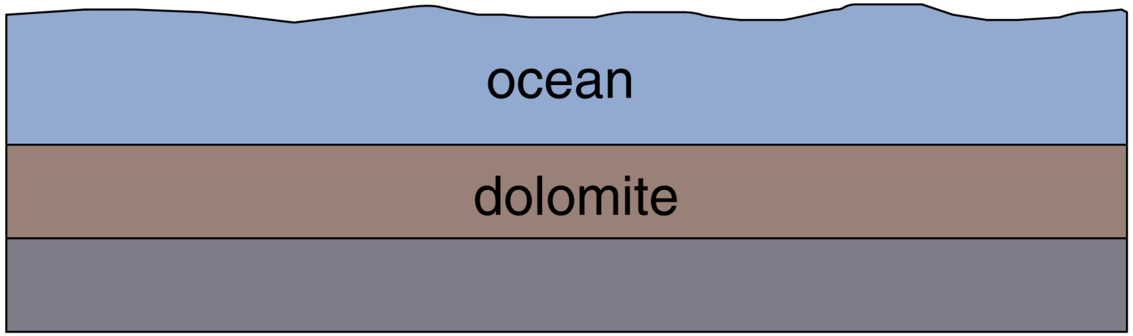
Dolostone – Mg-rich carbonate rocks
Ultramafic rock – Mg-Fe-rich metamorphic rocks

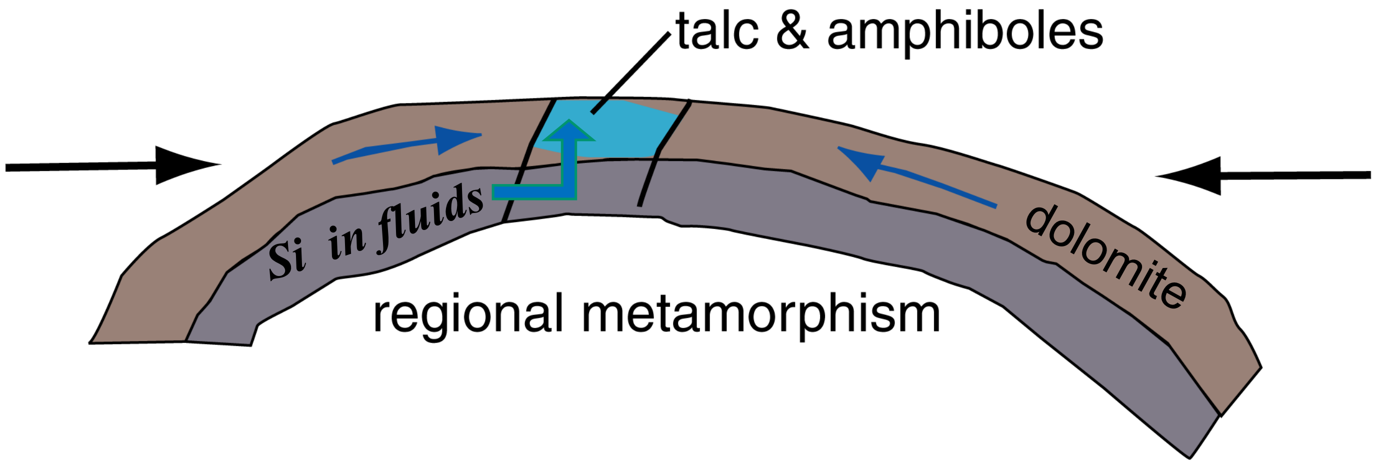
Regional Metamorphism of Dolostones Forming Talc

Metamorphosed Dolostones

Dolomite — Dolomitic marble — Dolomitic limestone

100% $MgCO_3$ — 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

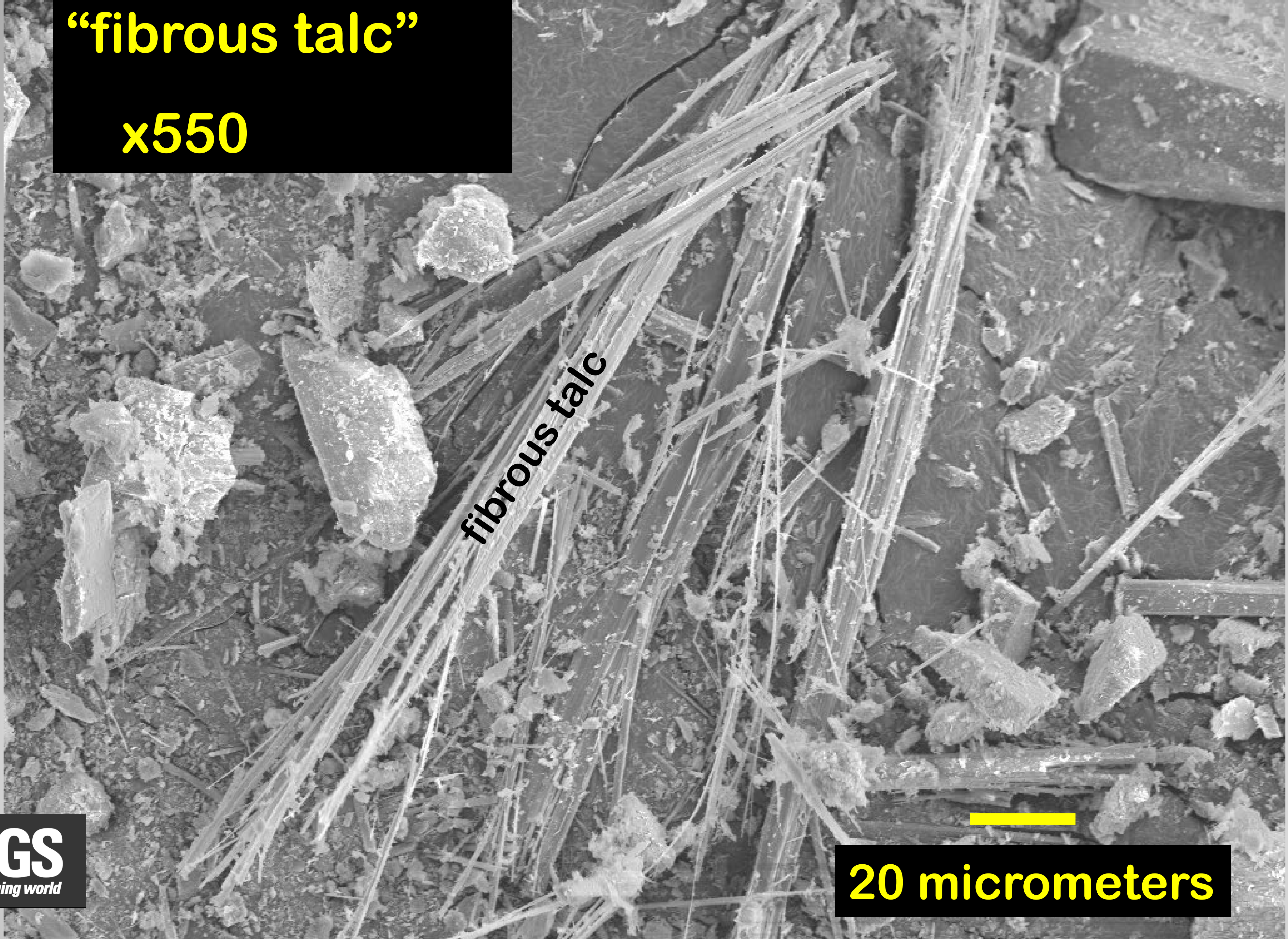
$$3Mg_7Si_8O_{22}(OH)_2 + 4SiO_2 + 4H_20 \rightarrow 7Mg_3Si_4O_{10}(OH)_2$$

Higher temperatures and pressures

↓

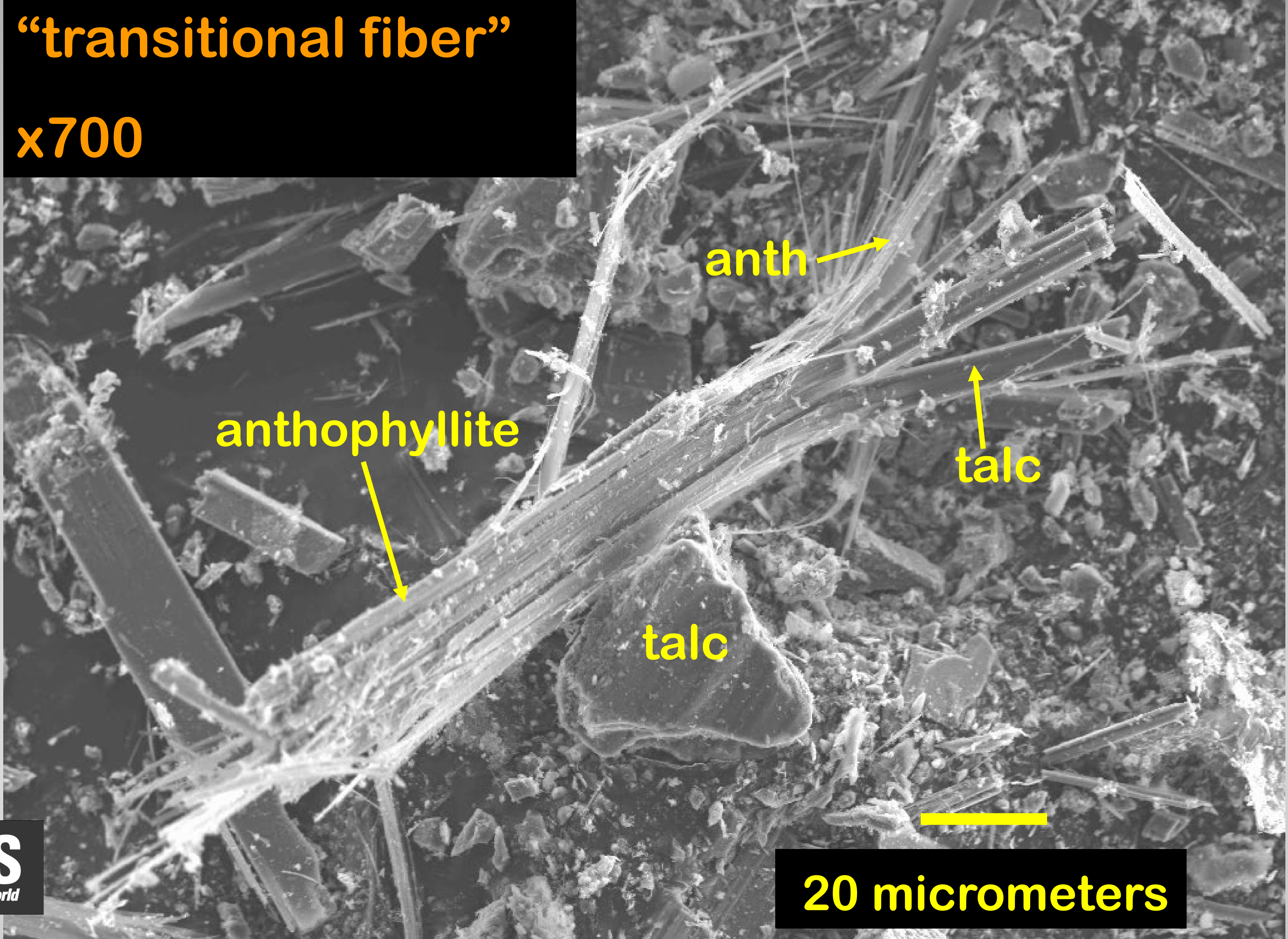
Lower temperatures and pressures

USGS science for a changing world


“fibrous talc”
x550
fibrous talc
20 micrometers
USGS
science for a changing world

“transitional fiber”

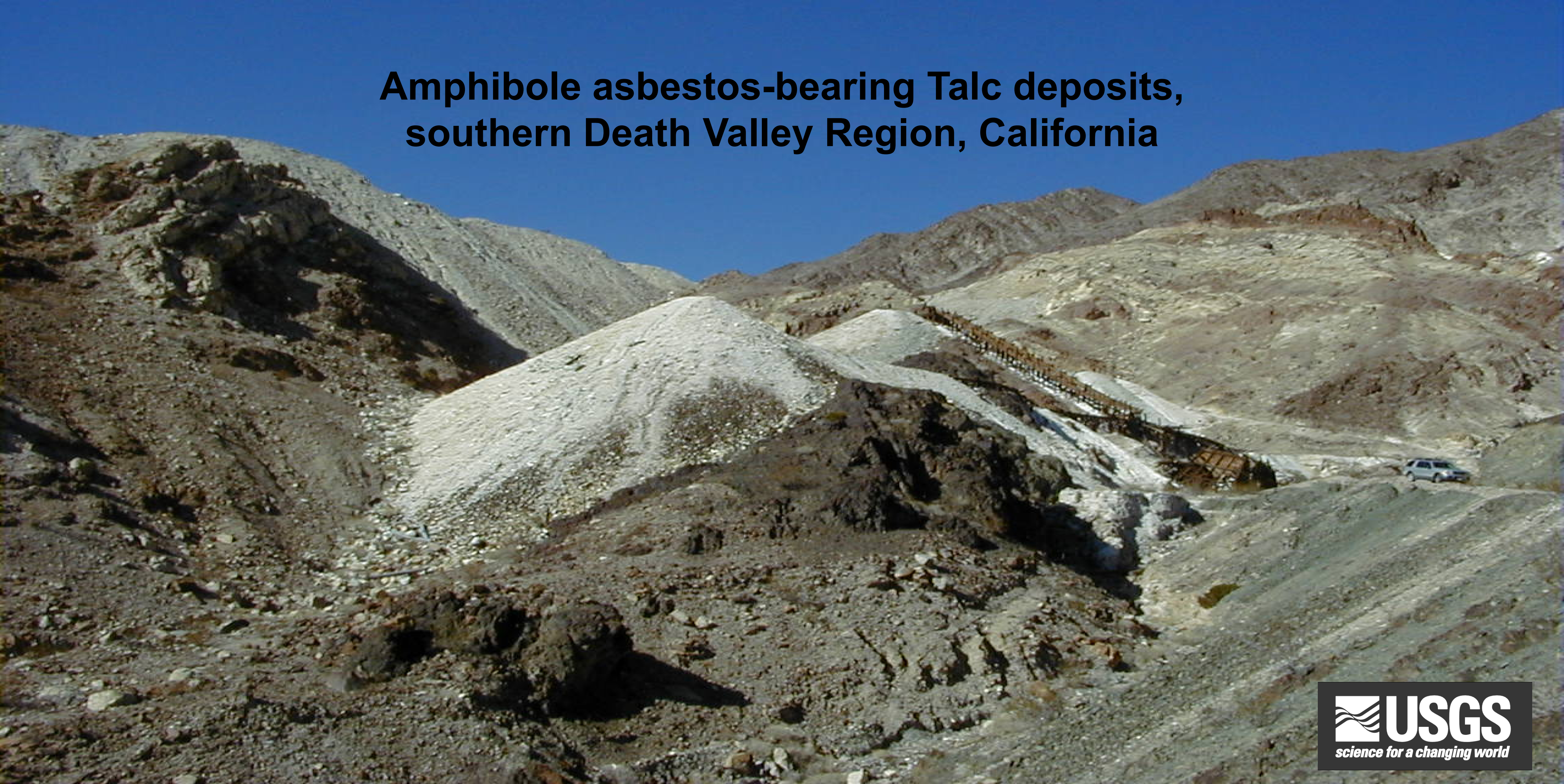
x700

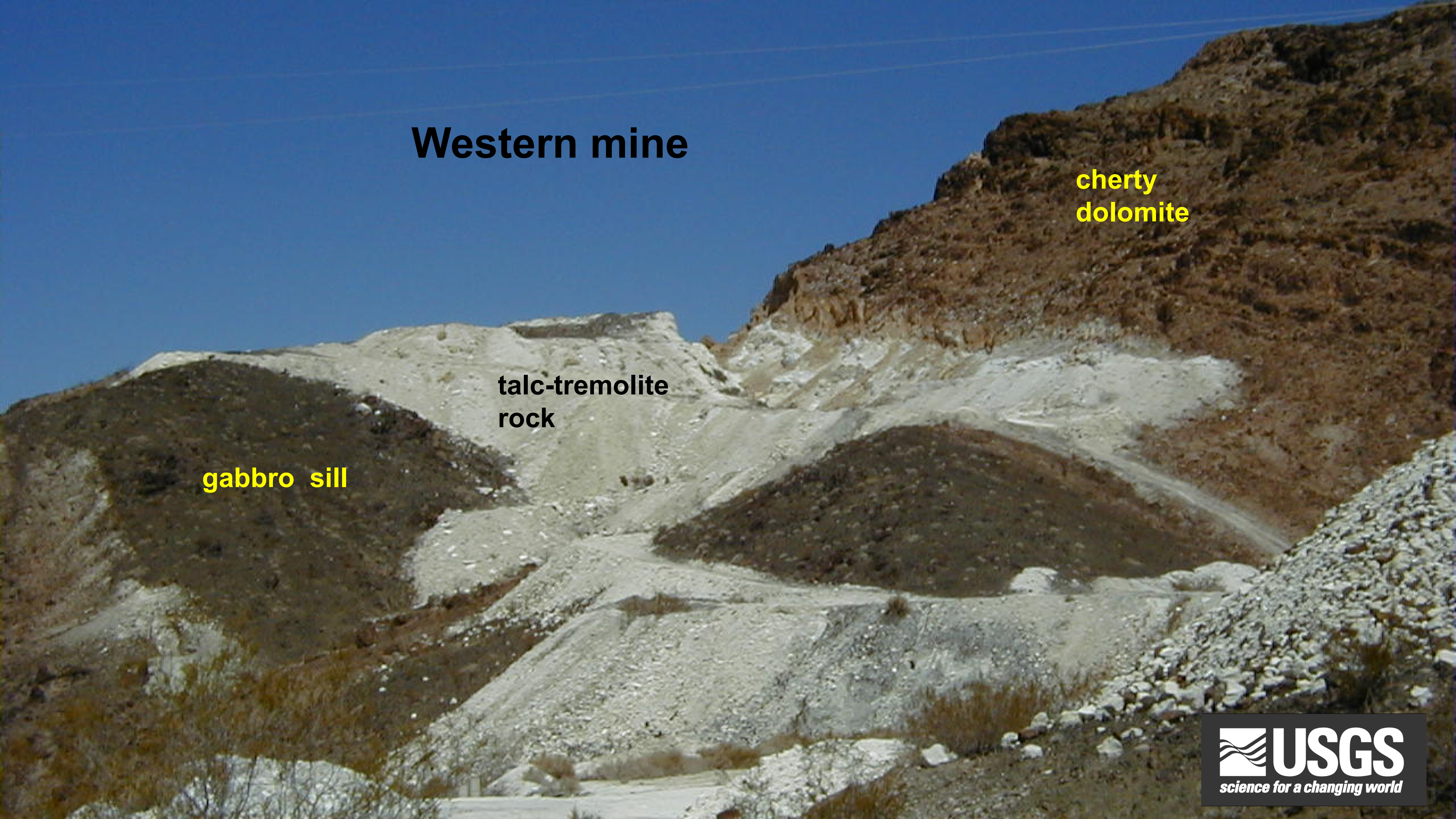


USGS
science for a changing world

Contact Metamorphism of Dolostones Forming Talc

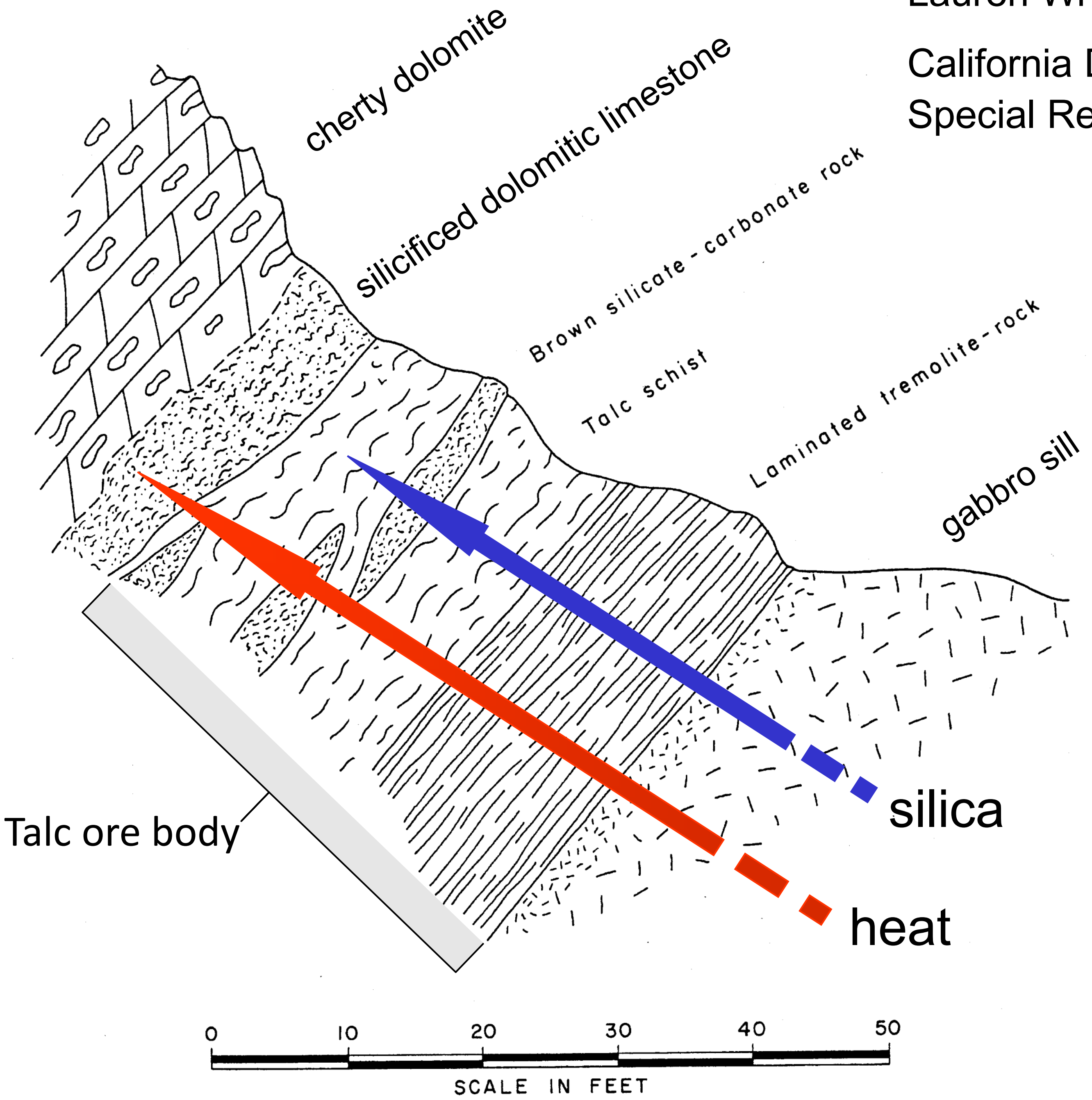
Amphibole asbestos-bearing Talc deposits, southern Death Valley Region, California




Western mine
cherty
dolomite
talc-tremolite
rock
gabbro sill
USGS
science for a changing world

Lauren Wright (1968)

California Division of Mines and Geology Special Report no. 95



talc

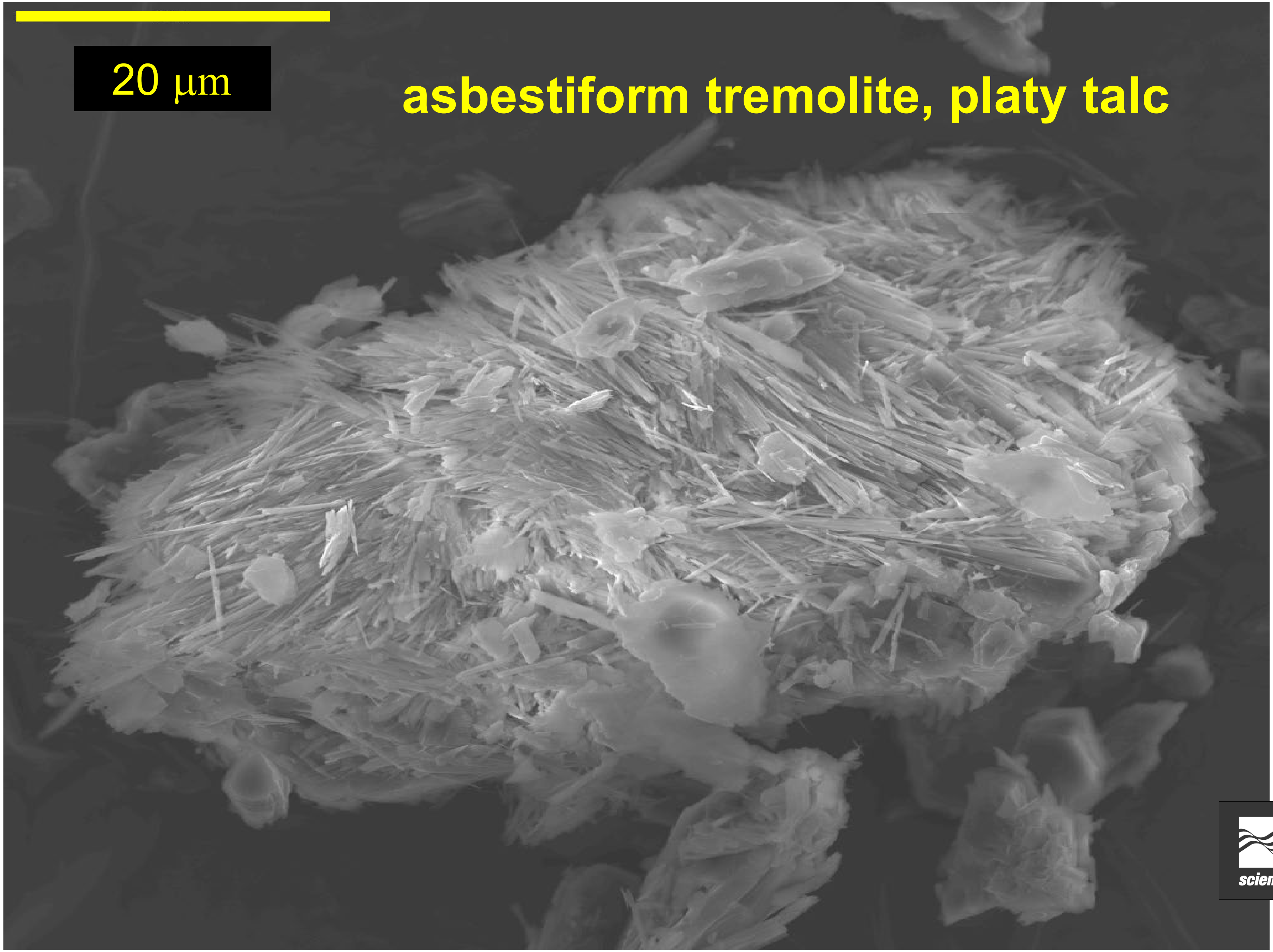
tremolite

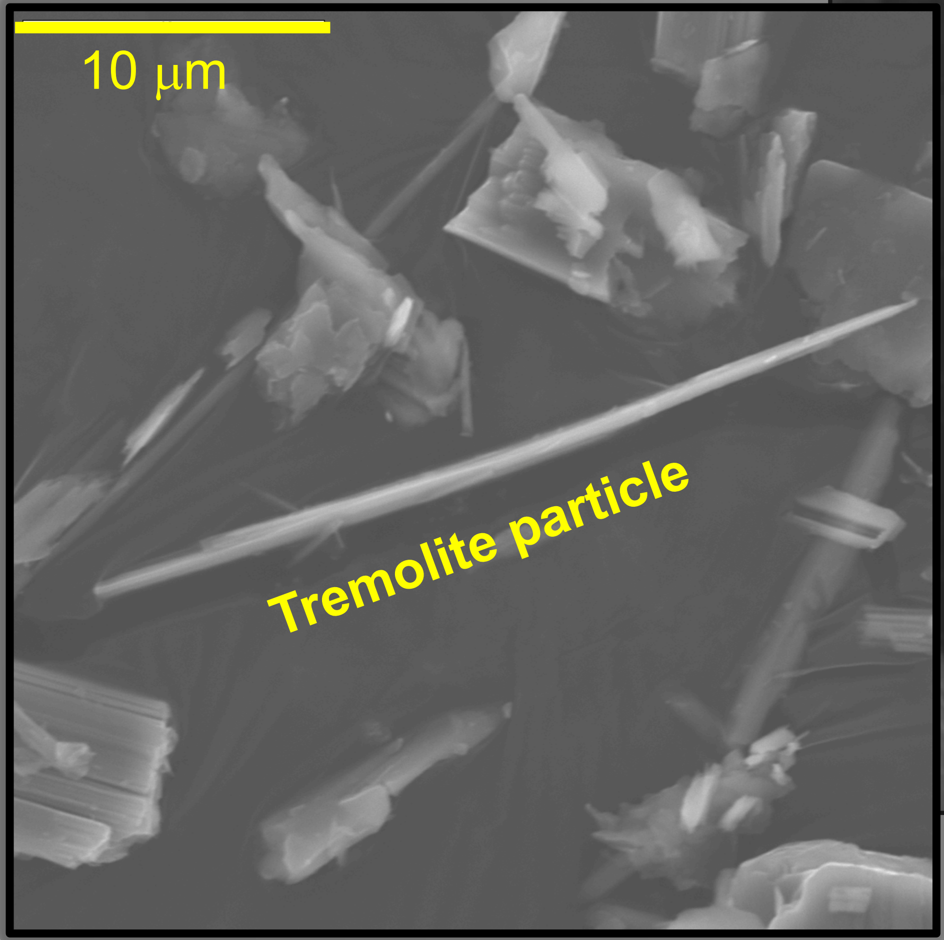
calcite

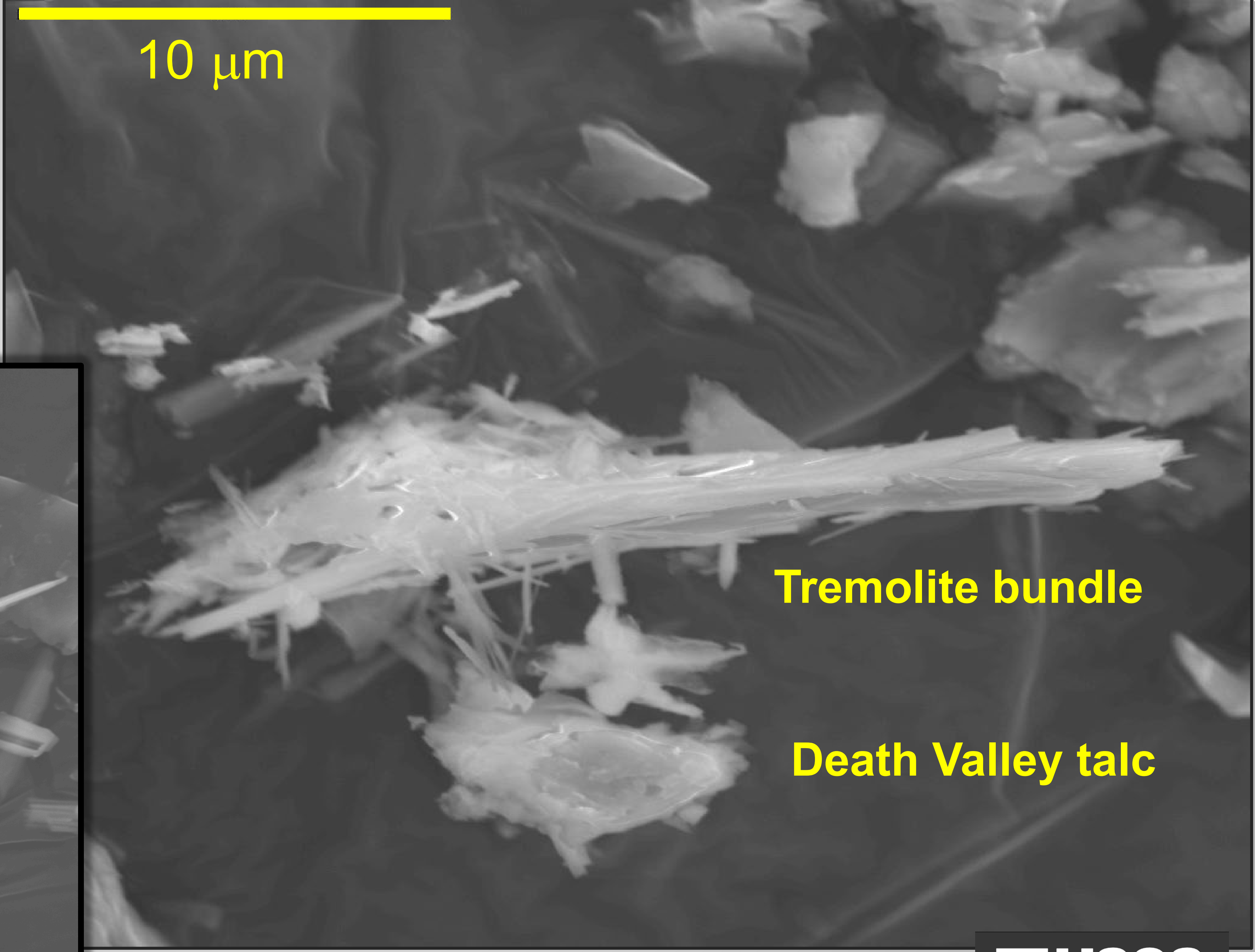
dolomite

quartz

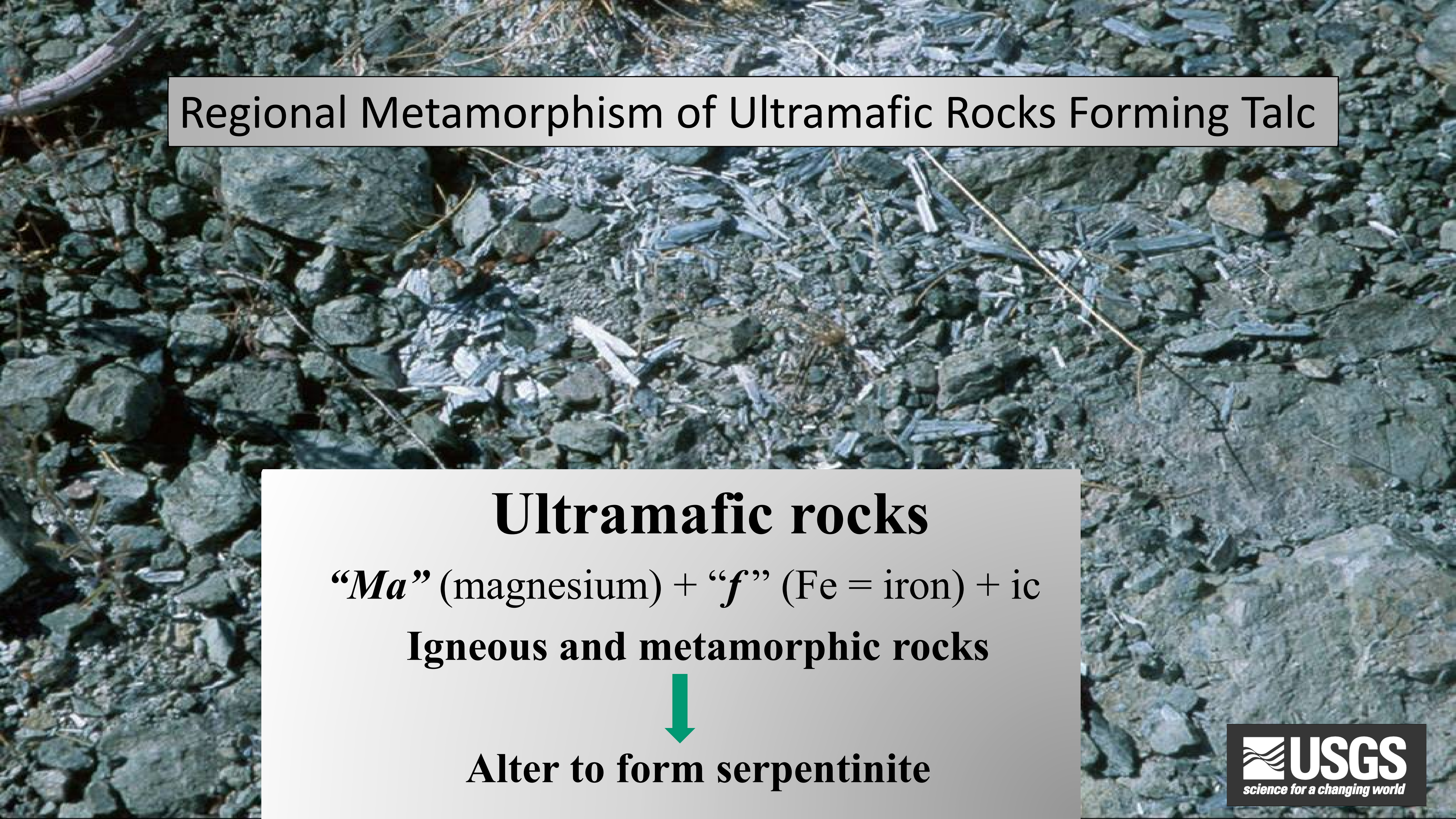

talc-
tremolite
rock
gabbro sill
USGS
science for a changing world


20 μm
asbestiform tremolite, platy talc





USGS
science for a changing world



Regional Metamorphism of Ultramafic Rocks Forming Talc

Ultramafic rocks

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

Igneous and metamorphic rocks

↓

Alter to form serpentinite

USGS
science for a changing world

Generalized zonation of a Vermont talc deposit

Ultramafic rock

Ultramafic rock

Mg-Fe-rich serpentine

Chrysotile
Tremolite – Actinolite
Anthophyllite

Mg source

Talc – Carbonate

Talc–carbonate rock

Talc with Magnesite $MgCO_3$

Dolomite $CaMg(CO_3)_2$

Calcite $CaCO_3$

Talc replacing Anthophyllite

Talc ore

“high–purity talc”

(little quartz or clay)

Anthophyllite?
Actinolite?
Tremolite?

Actinolite–Chlorite

Actinolite–Chlorite–rich rock

abundant Actinolite and chlorite

Talc replacing Actinolite (minor)

Tremolite?

Transitional Country Rock

Altered Country Rock

Metamorphic texture remains

Stubby Ca-amphiboles

Country Rock

Unaltered Country Rock

Mafic gneiss

Si source

Acadian orogeny
~400 Ma
590 – 645° C
7.5 – 8.5 kb pressure

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

Circulation of Heated ("hydrothermal") Fluids Forming Talc Deposits that Replace Dolostones

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)

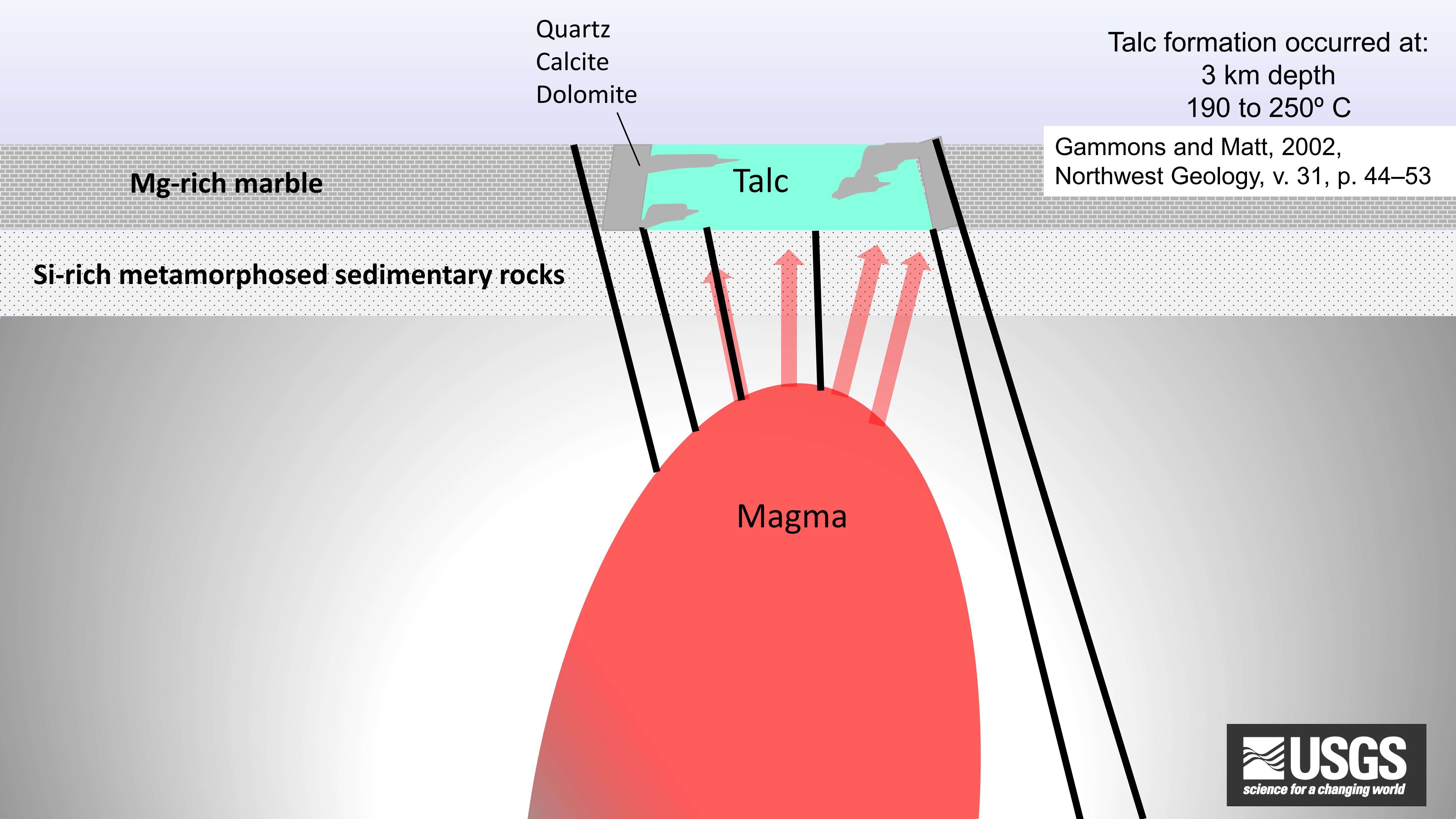
↓

Amphiboles or serpentine are not created

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

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

USGS
science for a changing world


Quartz
Calcite
Dolomite
Talc formation occurred at:
3 km depth
190 to 250º C
Gammons and Matt, 2002,
Northwest Geology, v. 31, p. 44–53
Mg-rich marble
Talc
Si-rich metamorphosed sedimentary rocks
Magma
USGS
science for a changing world


Yellowstone Talc Mine, MT
"Hydrothermal Talc"
1000 ft
Jonny Ridge Rd
© 2019 Google
1566 ft
Google Earth
USGS
science for a changing world

Primary points

- The geologic conditions that formed the talc body controlled the presence or absence of intergrown mineral fibers.
- General consistencies exist between the deposit types that form talc ore bodies with mineral fibers.
- However, all talc deposit types can have some internal variation, which is the nature of mineral deposits.
- All talc ores used in products require detailed mineralogical study so that we can fully characterize and understand them.