The Mineral Fibers of Potential Concern in Talc

Moorehouse talc mine
Death Valley National Park

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

Tremolite and Na-Ca amphiboles

“transitional fibers”

20 micrometers
Domestic talc producers

- American Talc Co. – several open pits in the Allamore 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

Recent production by State
1. Montana
2. Texas
3. Vermont

Photo by Childs Geoscience Inc.
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%

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

USGS National Minerals Information Center
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
\[ Mg_3Si_4O_{10}(OH)_2 \]

- 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 H₂O
**Amphibole group**

- **Asbestiform riebeckite** ("crocidolite")
  \[ \text{Na}_2\text{(Mg, Fe}^{2+})_3\text{Fe}^{3+} \text{Si}_8\text{O}_{22}(OH)_2 \]
  \[ \text{Mg}/(\text{Mg}+\text{Fe}^{2+}) < 0.5 \]

- **Asbestiform cummingtonite–grunerite** ("amosite")
  \[ \text{Mg}_7\text{Si}_8\text{O}_{22}(OH)_2 \text{ to } \text{Fe}^{2+}_7\text{Si}_8\text{O}_{22}(OH)_2 \]

- **Asbestiform anthophyllite**
  \[ \text{(Mg, Fe}^{2+})_7\text{Si}_8\text{O}_{22}(OH)_2 \]
  \[ \text{Mg}/(\text{Mg}+\text{Fe}^{2+}) \geq 0.5 \]

- **Asbestiform actinolite**
  \[ \text{Ca}_2\text{(Mg, Fe}^{2+})_5\text{Si}_8\text{O}_{22}(OH)_2 \]
  \[ \text{Mg}/(\text{Mg}+\text{Fe}^{2+}) = 0.5 - 0.89 \]

- **Asbestiform tremolite**
  \[ \text{Ca}_2\text{(Mg, Fe}^{2+})_5\text{Si}_8\text{O}_{22}(OH)_2 \]
  \[ \text{Mg}/(\text{Mg}+\text{Fe}^{2+}) = 0.9 - 1.0 \]

\[ \square \text{ Empty “A” site in amphibole structure} \]

Amphibole group

Asbestiform riebeckite
(“crocidolite”)
\[ \square \text{Na}_2(\text{Mg}, \text{Fe}^{2+})_3\text{Fe}^{3+}_2 \text{Si}_8\text{O}_{22}(\text{OH})_2 \]
\[ \text{Mg}/(\text{Mg+Fe}^{2+}) < 0.5 \]

Asbestiform

-cummingtonite-grunerite
(“amosite”)
\[ \square \text{Mg}_7\text{Si}_8\text{O}_{22}(\text{OH})_2 \text{ to } \square \text{Fe}^{2+}_7\text{Si}_8\text{O}_{22}(\text{OH})_2 \]

Asbestiform anthophyllite
\[ \square (\text{Mg}, \text{Fe}^{2+})_7\text{Si}_8\text{O}_{22}(\text{OH})_2 \]
\[ \text{Mg}/(\text{Mg+Fe}^{2+}) \geq 0.5 \]

Asbestiform actinolite
\[ \square \text{Ca}_2(\text{Mg}, \text{Fe}^{2+})_5 \text{Si}_8\text{O}_{22}(\text{OH})_2 \]
\[ \text{Mg}/(\text{Mg+Fe}^{2+}) = 0.5 – 0.89 \]

Asbestiform tremolite
\[ \square \text{Ca}_2(\text{Mg}, \text{Fe}^{2+})_5 \text{Si}_8\text{O}_{22}(\text{OH})_2 \]
\[ \text{Mg}/(\text{Mg+Fe}^{2+}) = 0.9 – 1.0 \]
Chrysotile

\[ \text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4 \]

Anthophyllite

\[ \square(\text{Mg, Fe}^{2+})_7\text{Si}_8\text{O}_{22}(\text{OH})_2 \]
Talc

\[ \text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2 \]

Anthophyllite

\[ \Box(\text{Mg, Fe}^{2+})_7\text{Si}_8\text{O}_{22}(\text{OH})_2 \]
## Talc formation

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

<table>
<thead>
<tr>
<th>Magnesium-rich host rock:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dolostone</strong> – Mg-rich carbonate rocks</td>
</tr>
<tr>
<td><strong>Ultramafic rock</strong> – Mg-Fe-rich metamorphic rocks</td>
</tr>
</tbody>
</table>

- 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

underground mine (1948 — )

open pit mine (1974 — 2008)
Metamorphosed Dolostones

Dolomite 100% MgCO₃  Dolomitic marble  Dolomitic limestone 10 to 50% MgCO₃

ocean
dolomite
talc & amphiboles
Si in fluids
regional metamorphism
Dolomite + silica + water → Tremolite + calcite + carbon dioxide

\[ 5\text{CaMg(CO}_3\text{)}_2 + 8\text{SiO}_2 + \text{H}_2\text{O} \rightarrow \text{Ca}_2\text{Mg}_5\text{Si}_8\text{O}_{22}(\text{OH})_2 + 3\text{CaCO}_3 + 7\text{CO}_2 \]

Tremolite + dolomite → (in water) Anthophyllite + calcite

\[ \text{Ca}_2\text{Mg}_5\text{Si}_8\text{O}_{22}(\text{OH})_2 + 2\text{CaMg(CO}_3\text{)}_2 \rightarrow \text{Mg}_7\text{Si}_8\text{O}_{22}(\text{OH})_2 + 4\text{CaCO}_3 \]

Anthophyllite + silica + water → Talc

\[ 3\text{Mg}_7\text{Si}_8\text{O}_{22}(\text{OH})_2 + 4\text{SiO}_2 + 4\text{H}_2\text{O} \rightarrow 7\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2 \]
“fibrous talc”

x550

20 micrometers
"transitional fiber"

x700

anth

talc

20 micrometers
Amphibole asbestos-bearing Talc deposits, Southern Death Valley Region, California
Lauren Wright (1968)
CA Division of Mines and Geology Special Report 95

Talc ore body

Silica and magnesium

Heat

talc
tremolite
calcite
dolomite
dolomite
quartz
Western mine

gabbro sill
talc-tremolite rock
cherty dolomite
talc-tremolite rock

gabbro sill
Tremolite in Death Valley talc

equant (blocky)

prismatic

acicular

asbestiform
Fibrous tremolite, platy talc
tremolite

talc
tremolite

Smith mine
Kingston Range
Death Valley region
Winchite?

\[(Ca_{0.9}Na_{1.1})Mg_{4.5}(Al_{0.1}Fe^{3+}_{0.6})Si_{8.1}O_{22}(OH)_2\]

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

Ultramafic rock
- Mg-Fe-rich serpentine
- Chrysotile
- Tremolite – Actinolite
- Anthophyllite

Mg source

Talc – Carbonate rock
- Talc with Magnesite (MgCO₃)
- Dolomite (CaMg(CO₃)₂)
- Calcite (CaCO₃)
- Talc replacing Anthophyllite

Talc–carbonate rock

“high-purity talc” (little quartz or clay)
- Anthophyllite?
- Actinolite?
- Tremolite?

Actinolite–Chlorite–rich rock
- Abundant Actinolite and chlorite
- Talc replacing Actinolite (minor)
- Tremolite?

Talc ore

Transitional Country Rock

Altered Country Rock
- Metamorphic texture remains
- Prismatic Ca-amphiboles

Si source


590 – 645°C
7.5 – 8.5 kb pressure

Unaltered Country Rock

Mafic gneiss

Ultramafic rock

Country Rock
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

\[3\text{CaMg(CO}_3\text{)}_2 + 4\text{SiO}_2 + \text{H}_2\text{O} \rightarrow \text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2 + 3\text{CaCO}_3 + 3\text{CO}_2\]
Tremolite in Death Valley talc