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

Moorehouse talc mine
Death Valley National Park

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asbestiform tremolite with platy talc

“transitional fibers”

anthophyllite
talc
talc
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
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
$\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$

- 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.
“Cosmetic talc 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”
“Asbestos”

- Serpentines: chrysotile

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

Tremolite asbestos
“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**

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

- About 95% of the asbestos produced in the world so far
- About 99% of the asbestos mined today
Chrysotile
\[ \text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4 \]

Talc
\[ \text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2 \]
Regulated asbestos minerals of the Amphibole group

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

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

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

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

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

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

Anthophyllite
\[ \{\text{Mg}, \text{Fe}^{2+}\}_7\text{Si}_8\text{O}_{22}(\text{OH})_2 \]
• Variations in amphibole morphology

• Tremolite particles within a single talc deposit (Death Valley region)
asbestiform tremolite
“Cleavage Fragments”

- Actinolite
- Tremolite

Scale markers:
- 50 µm
- 10 µm
- 25 µm
- 20 µm

Images courtesy of USGS Denver Microbeam Lab.
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 (100% MgCO₃)
- Dolomitic marble (10 to 50% MgCO₃)
- Dolomitic limestone

Diagram showing the metamorphic process with ocean, dolomite layers, and the formation of talc and amphiboles through 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 → 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
\[3\text{Mg}_7\text{Si}_8\text{O}_{22}(\text{OH})_2 + 4\text{SiO}_2 + 4\text{H}_2\text{O} \rightarrow 7\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2\]

Higher temperatures and pressures

Lower temperatures and pressures
“fibrous talc”
x550

20 micrometers
“transitional fiber”
x700

anthophyllite
anth

talc

talc

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

Contact Metamorphism of Dolostones Forming Talc
Western mine

gabbro sill

talc-tremolite rock

cherty dolomite
Lauren Wright (1968)
California Division of Mines and Geology
Special Report no. 95

Heat
Silica
Talc
Tremolite
Calcite
Dolomite
Quartz

Talc ore body

USGS
Science for a changing world
gabbro sill
talc-tremolite rock
20 µm

asbestiform tremolite, platy talc
Tremolite bundle
Death Valley talc

Tremolite particle

Regional Metamorphism of Ultramafic Rocks Forming Talc

Ultramafic rocks

“Ma” (magnesium) + “f” (Fe = iron) + ic

Igneous and metamorphic rocks

Alter to form serpentinite
**Generalized zonation of a Vermont talc deposit**

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

- **Talc – Carbonate**
  - 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–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

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

\[
\text{Dolomite + silica + water } \rightarrow \text{Talc + calcite + carbon dioxide}
\]

\[
3\text{CaMg(CO}_3\text{)}_2 + 4\text{SiO}_2 + \text{H}_2\text{O} \rightarrow \text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2 + 3\text{CaCO}_3 + 3\text{CO}_2
\]
Mg-rich marble

Si-rich metamorphosed sedimentary rocks

Talc formation occurred at:
3 km depth
190 to 250º C

Gammons and Matt, 2002,
Northwest Geology, v. 31, p. 44–53

Quartz
Calcite
Dolomite
Yellowstone Talc Mine, MT

“Hydrothermal Talc”
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.