Mineral Industry of Minnesota

Figure 23—Mineral industry of Minnesota map and fact sheet explaining where particular geologic materials are found or mined, what they are used for, and other related facts.

QUARRYING
- Dimensional Granite
- Dimensional Limestone
- Crushed Stone

MINING
- Iron Ore & Taconite
- Clay
- Horticultural Peat
- Industrial Silica Sand

IRON BEARING FORMATION

This map does not include construction sand and gravel or mineral exploration.
Sand and Gravel Operations
Rock Quarrying

Crushed Rock

Dimension Stone

Morton Gneiss

Rainbow Rock

Martin-Marietta Waite Park

Quarry Park Waite Park
Lake Superior Green
Katydid Lake Gabbroic Anorthosite

Dimension Stone from the Duluth Complex

Mesabi Black “Granite”

Olivine Leucogabbro
Kasota Stone – Oneota Dolostone

Target Field, Mpls

Paleozoic Stratigraphy of Southern Minnesota

Oneota Dolostone
St. Peter Sandstone

Paleozoic Stratigraphy of Southern Minnesota

Silica Sand Mining
St. Peter Sandstone
Peat Harvesting
Harvesting Yield

- 1 - 2 inches of peat removed each year
- Approximately 1,200 - 3.8 cubic foot bales per acre annually
- A peat deposit, 6 feet thick, will support a horticultural peat harvesting operation for 35 to 40 years
Clay Deposits of SW Minnesota
Iron Formations of the Lake Superior Region

Taconite Ore

Babbitt, MN

Hematite Ore

Ispheming, MI

Natural Ore

Chisolm, MN
LAKE VERMILION GOLD RUSH 1865-1867

In search of rumored iron deposits, State Geologist Eames reports finding GOLD.
VERMILION IRON RANGE
Operation: 1884-1962

“Blue” hematite ore
ORE discovered in 1865, but...

...it was not until completion of CharlemagneTower’s rail line to Two Harbors in 1884 that the first ore was shipped.

Photo source: Iron Range Research Center, Chisholm MN
1850—Discovery

1888—Underground Paulson Mine opened (3 shafts).

1893—Depression/Panic; mine closed.

One car-load of “hand-cobbled” magnetite ore was shipped 1893 via new rail line to Thunder Bay (red).
Rocks of the Mesabi Range differed from those of the Vermilion Range, and therefore didn’t fit the EXPLORATION MODEL:

- Flat-lying layers (Vermilion was steep)
- Deep red (vs steel-blue)
- Soft (vs very hard)
- Wet
1865—Henry H. Eames (State Geologist) canoed St Louis River and Embarrass Lake and reported “immense bodies of the ores of iron; and ascended the Prairie River reporting similar finds. In one year, he unknowingly defined the eastern and western ends of the Mesabi Iron Range.

1890—Edmund J. Longyear sank the first diamond drill hole (near Hoyt Lakes, Mesabi range, MN).

1890—Merritt brothers discovered iron ore near Mountain Iron.

1891-1892—John McCaskill noticed soft ore clinging to tree roots near present Biwabik and sank 65 test pits, all assayed at greater than 65% iron.

1892—first iron ore shipped from Mountain Iron

1892—Frank Hibbing discovered iron ore west of Virginia.

1893—Depression—many unemployed as iron drops from $2.46 to $1.55/ton. “Big money” bail-outs came from names like Rockefeller and Carnegie.

1901—J.P. Morgan forms US Steel Corp., merging the holdings of Oliver, Rockefeller and Carnegie.

1904—Cuyler Adams (with his dog "Una") test drilled iron ore near Deerwood in east-central MN

1907—Labor strike on the Mesabi range for 8 hour days and wages from $1.50 to $2.00/day.

1907-08—Depression—many mines closed forever.

1911—Cuyuna range—shipped iron ore from the Kennedy Mine near Rabbit Lake.

1917—U.S. enters WW I.

1922-24—Experimental taconite plant operated.

1929—Stock market crashed and economic depression began.

1941—U.S. enters WW II.

1953—Largest annual iron ore shipment from Mesabi range of 75,953,215 tons (~76 million tons).

1953—Mesabi range—taconite process developed by Davis, and a pilot plant began at Mountain Iron.

1955—Taconite mining and production successfully begun by Erie Mining and Reserve Mining.
Early 1900s – A World Class Mining District

C.R. Van Hise and C.K. Leith, 1911
USGS Monograph
LAKE SUPERIOR-TYPE IRON FORMATION
BIOGENIC ORIGIN?

STROMATOLITES
(Fossilized Algal Mats)
Evidence of Early Life

Shark Bay, Australia

LTV Mine, MN

Mary Ellen Mine, MN
Mesabi-type Iron Formation

Depositional Environment (~2.0 Ga) - Organically mediated deposition at the margin of the Animikie Basin

Occurrence - Minor structural disruption in northern Minnesota
Natural Ore Mining
Small-scale pits and Underground mining

Hibbing Taconite Mines
Hibbing Taconite is a major economic force in northeastern Minnesota.

- **900 Employees**
- **$56,000,000 Annual Payroll**
- **$110,000,000 Purchases of Goods & Services Annually**
- **$20,000,000 Annual State & Local Taxes**

Hibbing Taconite is managed by Cliffs Mining Company.
History

Iron ore mining on the Mesabi Range began in 1892. At the turn of the century high grade natural iron ores were mined and shipped directly to mid-western or eastern steel mills. However, with depletion of natural ore came awareness that low grade iron deposits would have to be developed to provide for future needs of the steel industry.

In the early 1950's Pickands Mather & Co., working with several major steel companies, began exploring ways of unlocking iron particles from a flint hard rock called taconite. By 1952, a laboratory was established in Hibbing to experiment with taconite ores and develop a flow sheet for commercial operation. Laboratory work was further tested at a pilot plant and in 1957, following a vast construction program, a commercial scale plant began operation near Hoyt Lakes, Minnesota.

Plans for development of taconite reserves in the Hibbing Chisholm area began in the late 1960's. Early feasibility studies determined substantial reserves of taconite. Development and construction of Hibbing Taconite Company began in 1973. The $360 million concentrating and pelletizing operation is designed to produce 8.5 million tons of taconite pellets annually.

Hibbing Taconite Company is owned by: Bethlehem Steel Corporation (70.5%), Steel Inc. (14.7%), and Cliffs Mining Company (15%).

The 24 hour a day, year around operation employs approximately 900 people. About 40% of the total work force is employed in maintenance related jobs.

Mining

Production of iron ore pellets begins with mining. At Hibbing Taconite, over 50 million tons of material must be mined annually to provide raw material for the production of 8.5 million tons of high grade iron ore pellets.

The first stage, after harvesting timber, is surface removal which is followed by drilling. Rotary drills are employed to bore 16” holes to a depth of approximately 55 feet. Each hole is loaded with explosive. Then, under rigid safety controls, the blast is fired. Less than one-half pound of explosives is used for each ton of broken taconite ore.

Broken crude ore is loaded by shovels equipped with 18 and 55 cubic yard dippers and large front-end loaders into large 170 and 240 ton capacity haulage trucks for transportation to the crusher.
Hibbing Taconite's concentrating flow sheet represents the most modern plant design and metallurgical technology in today's taconite industry.

Crude taconite, containing about 20% magnetic iron, is delivered to two 60 x 109 inch gyratory crushers where it is reduced to ten inch chunks and conveyed to a 450,000 ton capacity stockpile which provides surge capacity for milling.

From stockpile, the crude ore is conveyed into one of nine 36 foot diameter autogenous grinding mills, each equipped with two 6,000 HP motors. Water is added and as the ore tumbles it reduces itself to powder fineness (75% -250 MESH). Following two stages of magnetic separation, which extract the high grade magnetite particles and fine screening, a concentrate averaging 66% iron is delivered to the pellet plant.

Waste particles called tailing, along with water, flow by gravity launderers to the tailing basin. This basin is completely contained on land by a series of dams. Tailings settle to the bottom of the basin and the water is reclaimed and pumped back to the plant for repeated use at approximately 120,000 GPM.
In the pellet plant, the concentrate is thickened and all but nine percent of the water is removed by vacuum disc filters. The moist concentrate is mixed with a clay binder called bentonite at a rate of 18 pounds/ton, and conveyed to large rotating drums where it is...

Power consumption is closely regulated throughout the property by power control efficiency equipment. The most modern environmental safeguards have been designed and built into Hibbing Taconite operations.
A Looming Stewardship Question for Minnesotans:
Should we develop this immense copper-nickel-precious metal mineral resource?
THE MIDCONTINENT RIFT

An attempt at continental rifting 1.1 billion years ago
The Concern- Acid Mine Drainage

$$2\text{FeS}_2(s) + 7\text{O}_2(g) + 2\text{H}_2\text{O}(l) \rightarrow 2\text{Fe}^{2+}(aq) + 4\text{SO}_4^{2-}(aq) + 4\text{H}^+(aq)$$
The Role of Sulfur in Concentrating Metals

Most of the world’s metal comes from sulfide minerals

- Chalcopyrite: $\text{CuFeS}_2$
- Bornite: $\text{Cu}_5\text{FeS}_4$
- Chalcocite: $\text{Cu}_2\text{S}$
- Pentlandite: $(\text{Fe,Ni})_9\text{S}_8$
- Sphalerite: $\text{ZnS}$
- Cinnabar: $\text{HgS}$
- Molybdenite: $\text{MoS}_2$
- Galena: $\text{PbS}$
- Cobaltite: $\text{CoAsS}$
Upper Michigan: America’s First Mineral Rush 1844-1972

*of Native Cu*
New Processing Technology for Sulfide Ores

OLD – Smelting

NEW – Hydrometallurgy
United States – The #1 consumer of mineral resources, that produces little for itself

<table>
<thead>
<tr>
<th>Metal</th>
<th>% Mined by US</th>
<th>% Imported for US consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>7.7%</td>
<td>40%</td>
</tr>
<tr>
<td>(Chile 30%), US, Indonesia, Peru</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nickel</td>
<td>0%</td>
<td>54%</td>
</tr>
<tr>
<td>(Russia, Australia, Canada, Indonesia)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cobalt</td>
<td>0%</td>
<td>78%</td>
</tr>
<tr>
<td>(Congo 30%), Zambia, Australia, Canada)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palladium</td>
<td>6.6%</td>
<td>78%</td>
</tr>
<tr>
<td>(Russia 44%), South Africa (38%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Image Description:

The image shows a chart titled "Minerals Imported by the United States". It presents data on various minerals and their sources. The chart indicates the percentage of each mineral that is mined by the US versus the total mining, and the percentage imported for US consumption. The data is sourced from the US Geological Survey. The chart also highlights the countries supplying these minerals to the US.
COPPER

One of the most recyclable metals
Powering cars of the future

Cu in a Standard Car with Combustion Engine
43-55 lbs

Cu in a Prius
80 lbs

Inverter

Battery Pack
PGE – Platinum Group Elements

Pt – Platinum, Pd – Palladium, Os – Osmium, Ru – Ruthenium, Rh – Rhodium, Ir – Iridium

Major PGE Deposits and Targets

- **Stillwater**
  - Pt <5%
  - Pd 90%
  - Rh <5%

- **Sudbury**

- **Duluth**

- **Skaergaard**

- **Voisey's Bay**

- **Fenno-Scandian**
  - Noril'sk
    - Pt 18%
    - Pd 67%
    - Rh 36%

- **Jinchuan**

- **Rincon del Tigre**

- **Bushveld**
  - Great Dyke
    - Pt 74%
    - Pd 24%
    - Rh 60%

- **Munni Munni**

*PGE-reefs in Ultramafic/Mafic Complexes*
*PGE-reefs in Tholeiitic Intrusions*
*PGE as by-product in Cu-Ni Sulfide Deposit*

1997 production numbers
Bushveld Complex
South Africa
Supplying the 70% of the World’s Platinum
Palladium:  
“The Environmental Metal”

Pd Uses

2003 Total: 5260

Other
Jewelry
Electronics
Dental
Chemical
Autocatalyst

Supplied by recovery
The Stillwater Mine (Montana)
Only Precious Metals Mine in the U.S. (owned by Noril’sk Nickel)
Noril’sk, Russia
Cu-Ni-PGE Deposits
Supplies 60% of the World’s Palladium

Sulfide Smelter in Monchegorsk, Russia

In 1998, responsible for 50% of $SO_2$
in the northern hemisphere
Copper and Nickel Resources of the Duluth Complex

WORLD CLASS!

That will be mined....

SOMEDAY

Hulbert & Ekstrand, 2008
Responsible stewardship of mineral resources demands that we make sensible and fair choices of where, how, and when to acquire critical resources we need for today and for the future.