CORE Kids

Program Overview, Metrics and Evaluations

2016-2017

Report Prepared by Peter Voice

The following report is a summary of the activities of the CoreKids program for the academic year 2016-2017. It provides metrics on the numbers of events and contacts that the CoreKids program worked with, as well as feedback from the teachers that hosted CoreKids events in their schools. Presentations given under the outreach initiatives of the CoreKids program, the Department of Geosciences at Western Michigan University, the Michigan Geological Repository for Research and Education and the Mcihigan Geological Survey are also provided.

Report prepared by Dr. Peter Voice

June 28, 2017

COREKIDS 2016-2017 ANNUAL REPORT TABLE OF CONTENTS

CoreKids Overview
And
2016-2017 Events List

CoreKids Program at the Michigan Geological Repository for Research and Education/Michigan Geological Survey

Prepared by Dr. Peter Voice, Director of K-12 Outreach, Michigan Geological Survey

Our Mission: To increase awareness and understanding of Earth, its processes and its natural resources among Michigan's students, teachers and citizenry. We utilize the unique geological resources of Western Michigan University Geoscience Department's Michigan Geological Repository for Research and Education (MGRRE). CoreKids educators carry earth science literacy, science literacy and citizenship messages from university faculty, our sponsors and our partners to the K-12 community and to the public. The program utilizes a mixture of presentations and hands-on activities to promote the understanding of earth science as well as to increase interest in the STEM (Science, Technology, Engineering and Math) fields especially the earth sciences among K-12 students. The majority of our contacts with southern Michigan students have been with higher grade level students who are making decisions about their future and we hope that we can influence some of these students into pursuing careers in the earth sciences. A basic tenet of the organization is to provide programming to schools and non-profit organizations without charge.

Our Current Funding: We thank the Michigan Section of the American Institute of Professional Geologists and the Kalamazoo Geological and Mineral Society for their generous funding support for CoreKids.

We are currently seeking additional funding to support the future activities of the CoreKids Program. We are working on a revision of the MGRRE Portal proposal and will be submitting it in the future to various grant-funding organizations and foundations.

Our Partnerships:

The Cranbrook Institute of Science

The Kalamazoo Geological and Mineral Society

The Michigan Department of Environmental Quality

The Michigan Aggregate Association

The Michigan Basin Geological Society

The Kalamazoo Air Zoo

The University of Michigan Museum of Natural History

The Michigan Mineralogical Society

The Branch County District Library

Michigan State University Museum of Science

We also have the support and partnership of several Teachers associations: The Michigan Earth Science Teachers Association, the Michigan Science Teachers Association, the Michigan Alliance for Environmental and Outdoor Educators and the Metropolitan Detroit Science Teachers Association.

Future Proposals:

1. Develop workshops and continuing education short courses for Michigan teachers. We would use the well cores and samples and production records at MGRRE and allow the teachers to lay their hands on the actual rocks that yield these natural resources such as oil, gas, minerals, metals, and groundwater. This would also allow us to build a stronger collaboration with local teachers associations (Michigan Earth Science Teachers Association, Michigan Science Teachers Association) and promote earth science clubs at their schools.
    a. Progress: (i). Partnership with Steve Kaczmarek (WMU Geosciences) to put together workshop on Chemistry of Earth Materials with an emphasis on X-ray fluorescence. The workshop is tentatively scheduled for August 9th, 2017. (ii). Developed over 2017 a variety of teachers' resources focused on Michigan's Natural Resources – presented a brief workshop at the Michigan Earth Science Teachers Association Annual Meeting and at the Fall Science Update at Grand Valley State University in 2016. Materials are hosted at the Michigan Geological Survey webpage and at researchgate.
2. Develop a pilot MGS-MGRRE online education portal focused exclusively on Michigan energy issues. This portal would develop activities using authentic datasets to guide students through the process by which geologists go from exploration to oil and gas production. As part of portal development, we will engage professional Michigan geologists to work with teachers directly, both in the field and in the classroom. These could also lay the foundation for future mentoring relationships between sponsoring companies and participating schools.
3. Develop additional classroom modules. Several teachers that we have worked with in the past are excited to learn that we now present new modules about natural hazards and shale energy. As a result they are inviting us into their classrooms for multiple events. A wider variety of modules will not only interest more teachers, they will invite us back for more events, and more teachers and students will gain a better understanding of our natural resources and the need to responsibly manage them.
4. Develop an Open House Event twice a year at the MGRRE Facility as a resource for local home school associations and youth groups. A series of hands-on activities are planned centered around Michigan Geology, Michigan Natural Resources, Energy and Fossils. We have already done a pilot version of this idea with the Kalamazoo Geological and Mineral Society and their youth group and it was very well received.

CoreKids Events July 1, 2016 to June 30, 2017

(23 events – School visits, MGRRE tours and Larger Events with Allied Partners and 3 Conferences/Teachers Workshop)

I. Aug. 1st – Kalamazoo Air Zoo
II. Aug. 4th – MESTA Annual Meeting
III. Aug. 29th – Kalamazoo Air Zoo
IV. Sept. 16th – The Gagie School (MI. Geologic Resources Module)
V. Oct. 9th – MSU Museum Fossil Day
VI. Oct. 14th – MAEOE MGRRE Tour (Michigan Alliance for Environmental and Outdoor Educators Annual Meeting)
VII. Oct. 18th – Starr Elementary School (Bill Mitchell – borrowed Core Pumps)
VIII. Oct. 21st – Central Michigan Mineral Show School Day
IX. Nov. 1-2nd – MiCareerQuest Day
X. Nov. 2nd – KGMS Meeting at MGRRE
XI. Nov. 3rd – The Gagie School (Mineral identification)
XII. Nov. 5th – MSU class tour at MGRRE
XIII. Nov. 11th – MESTA Career Day
XIV. Nov. 11th – The Gagie School (Mineral and Rock identification)
XV. Nov. 16th – Fall Science Update Conference, Grand Valley State University
XVI. Dec. 22nd – Kalamazoo Air Zoo joint event
XVII. Jan. 5th – Kalamazoo Air Zoo joint event
XVIII. Jan. 24th – Plainwell Middle School MGRRE visit
XIX. Jan. 26th – Plainwell Middle School MGRRE visit
XX. Jan. 31st – Plainwell Middle School MGRRE visit
XXI. March 8th – Roscommon High School MGRRE visit
XXII. March 23rd – Homeschool event, Bedford, MI
XXIII. March 25th – Kalamazoo Air Zoo Joint Event
XXIV. April 20th – DEQ Earth Day Celebration
XXV. May 5th – 7th – Kalamazoo Geological and Mineral Society Annual Show
XXVI. May 7th - Boy Scout troop, MGRRE tour

CoreKids Frequently Asked Questions

1. Which regions of the state of Michigan does CoreKids go to?

Due to budget constraints, we are currently only able to provide support to our larger events at Mineral Shows and Earth Day events.

2. What is the MGRRE facility?

MGRRE is the Michigan Geological Repository for Research and Education. It is the premier collection of Lower Peninsula Geologic data and archives half a million feet of core rock data. We are part of the Michigan Geological Survey.

3. How many students can your Educators work with during a school trip or MGRRE tour?

Our modules are designed for groups of 30 students. We bring into the classroom all materials that we use including mineral samples and hands-on activities. We encourage schools with multiple sections of the same grade level at each period to schedule more than 1 day of CoreKids visits – i.e. one day for each 6th grade teacher's sections.

At MGRRE we are limited to groups of 25-30 at a time. We have a classroom at the facility that we use for brief presentations and hands-on activities.

4. How can we book a CoreKids Event?

Contact Dr. Peter Voice (peter.voice@wmich.edu or 269-387-8696 or 269-387-5446) to schedule events. He will try to accommodate your group.

5. What modules do you take into the classroom?

We currently have six modules: Michigan Geologic History; Hydrogeology; Shale Energy and Hydraulic Fracking; Michigan Fossils, Natural Hazards and The Environment and Climate Change. The Natural Hazards module is designed as three submodules: Volcanoes; Earthquakes; and Impact Craters. Each module is designed for a 50 minute session and includes a brief presentation and hands-on activities. Michigan Department of Education Grade Level Content Standards have been described for each module and are available on request.

6. Can I schedule more than one CoreKids event for my school or group with different modules?

If we have room in our schedule, we will gladly visit your school or group multiple times during the year presenting different modules.

7. Is there a charge for CoreKids Events?

Our policy is to provide our content free of charge for school visits and MGRRE tours. For MGRRE tours, we cannot cover the cost of transportation to bring your group to the MGRRE facility. We do accept donations to support CoreKids activities.

8. What if my school has a snow day or other cancellation the day a CoreKids event is scheduled?

We will try our best to reschedule the CoreKids event.

Letters of Support

CRANBROOK INSTITUTE OF SCIENCE

April 21, 2014

39221 Woodward Ave.
Mail Correspondence to:
P.O. Box 801
Bloomfield Hills
Michigan 48303.0801
Ph 248.645.3139
Fx 248.645.3050

To whom it may concern:

I am writing this letter in support of the CoreKids K-12 Earth Science Outreach Program. Cranbrook Institute of Science partners with them to provide outstanding learning experiences that supplement and extend learning beyond the classroom.

Coordinated through the Michigan Geological Repository for Research and Education (MGRRE), Core Kids brings an important collection of rocks to public viewing and understanding. Their collection includes thousands of bedrock samples not found anywhere else, and most unique to Michigan. It is truly a one-of a kind storehouse of valuable geological information.

CoreKids does an outstanding job of relating Earth Science concepts to kids and families with fun, engaging activities and demonstrations that use MGRRE samples. These are impactful and memorable experiences for children to widen their knowledge and perspective on how geology relates to our lives and economy.

I have personally witnessed the excellence in interpretation and materials through numerous events: including water festivals and museum fairs. They inspire thousands of students each year about Earth Science and Natural Resources management. This education plays a significant role in shaping the knowledge and understanding of future citizens to build a sustainable society. I look forward to many years of partnership with the CoreKids K-12 Earth Science Outreach Program. Please feel free to contact me if you have any questions. I can be reached by phone at 248-645-3223 or by email at lappel@cranbrook.edu.

Sincerely,

L. Appel

Lisa Appel
Watershed Education Coordinator
Cranbrook Institute of Science

CORE Kids

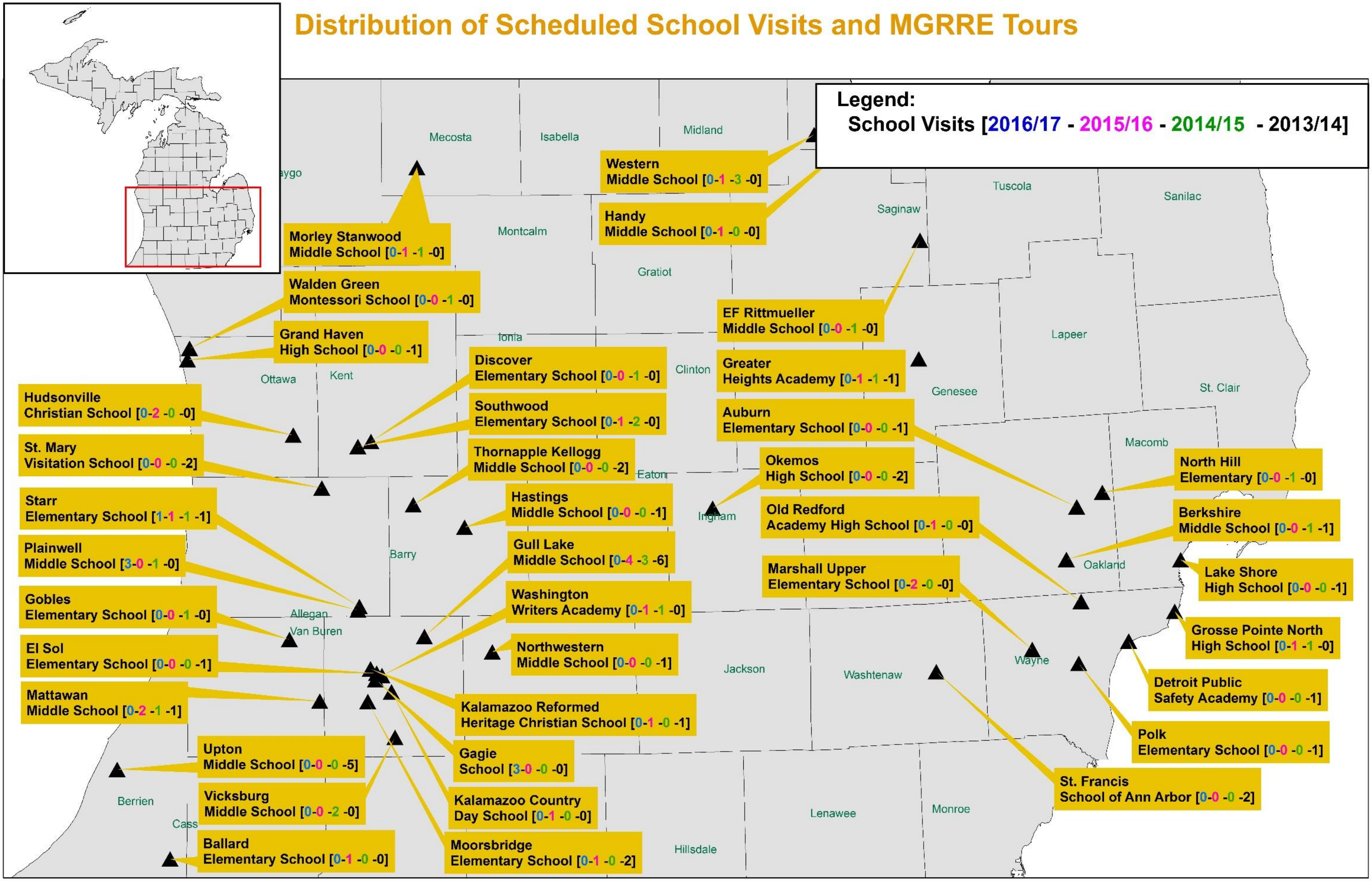
Program Metrics

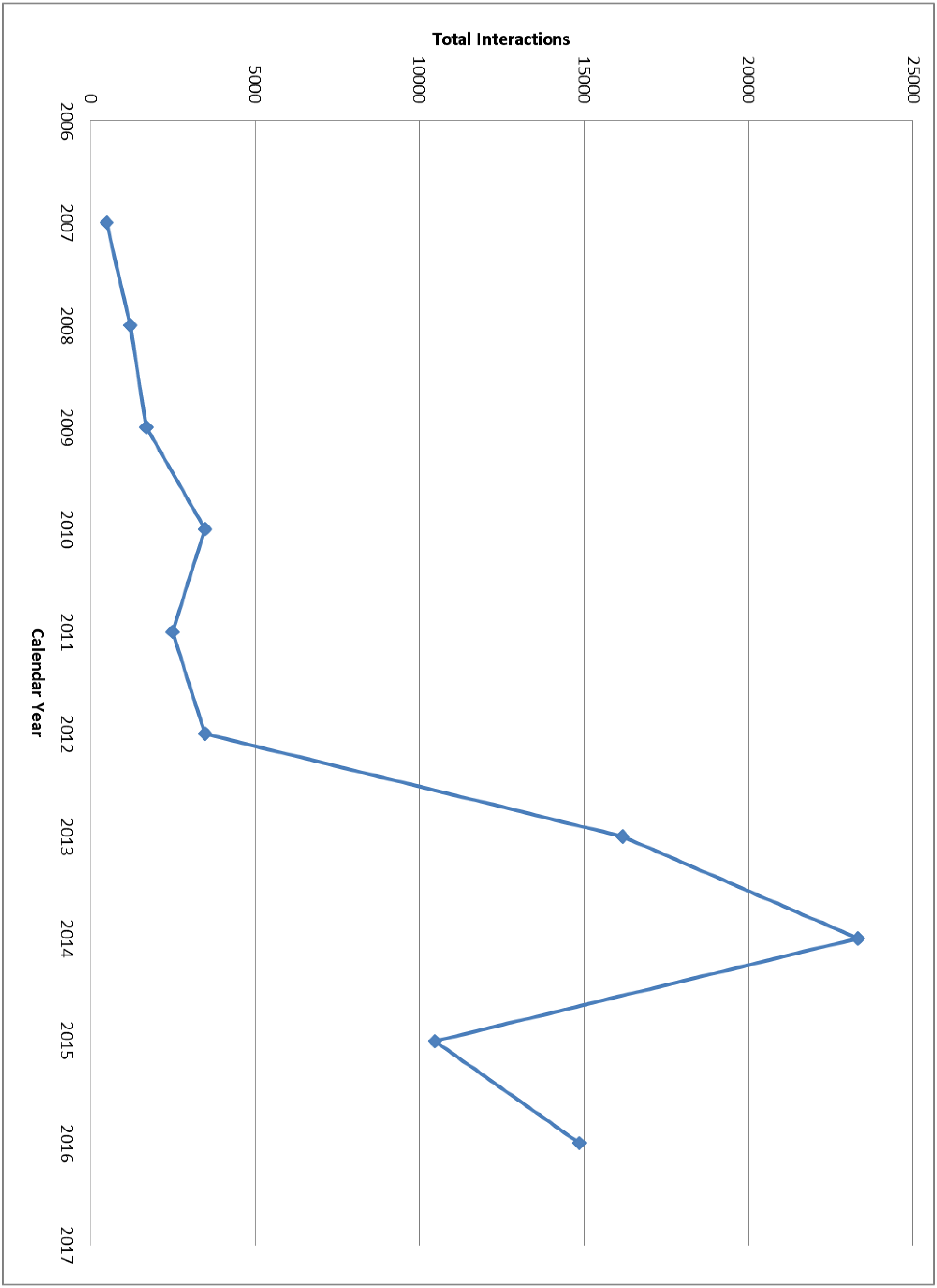
Academic Year	Number of Contacts	Number of Conferences/Teachers Workshops	Number of Events (school visits and allied partner programming)
2013-2014	16,175	7	65
2014-2015	23,329	1	50
2015-2016	10,473	2	45
2016-2017	14,875	3	23

Event Totals July 1, 2016 to June 30th, 2017

Kalamazoo Air Zoo Events	222
MESTA Annual Meeting	20
Michigan Basin Geological Society Meeting	30
School Events	261
MSU Museum Fossil Day	690
MAEOE Field Trip	8
Central Michigan Mineral Show	1,014
MiCareerQuest-Southwestern Career Days	5,000
College Events	38
KGMS Meeting at MGRRE	30
MESTA Earth and Space Science STEM Career Day	400
Fall Science Update	14
Bedford Homeschool Group	10
DEQ Earth Day	2,300
Boy Scout Group	30
KGMS Annual Show	4,808
Total:	**14,875**

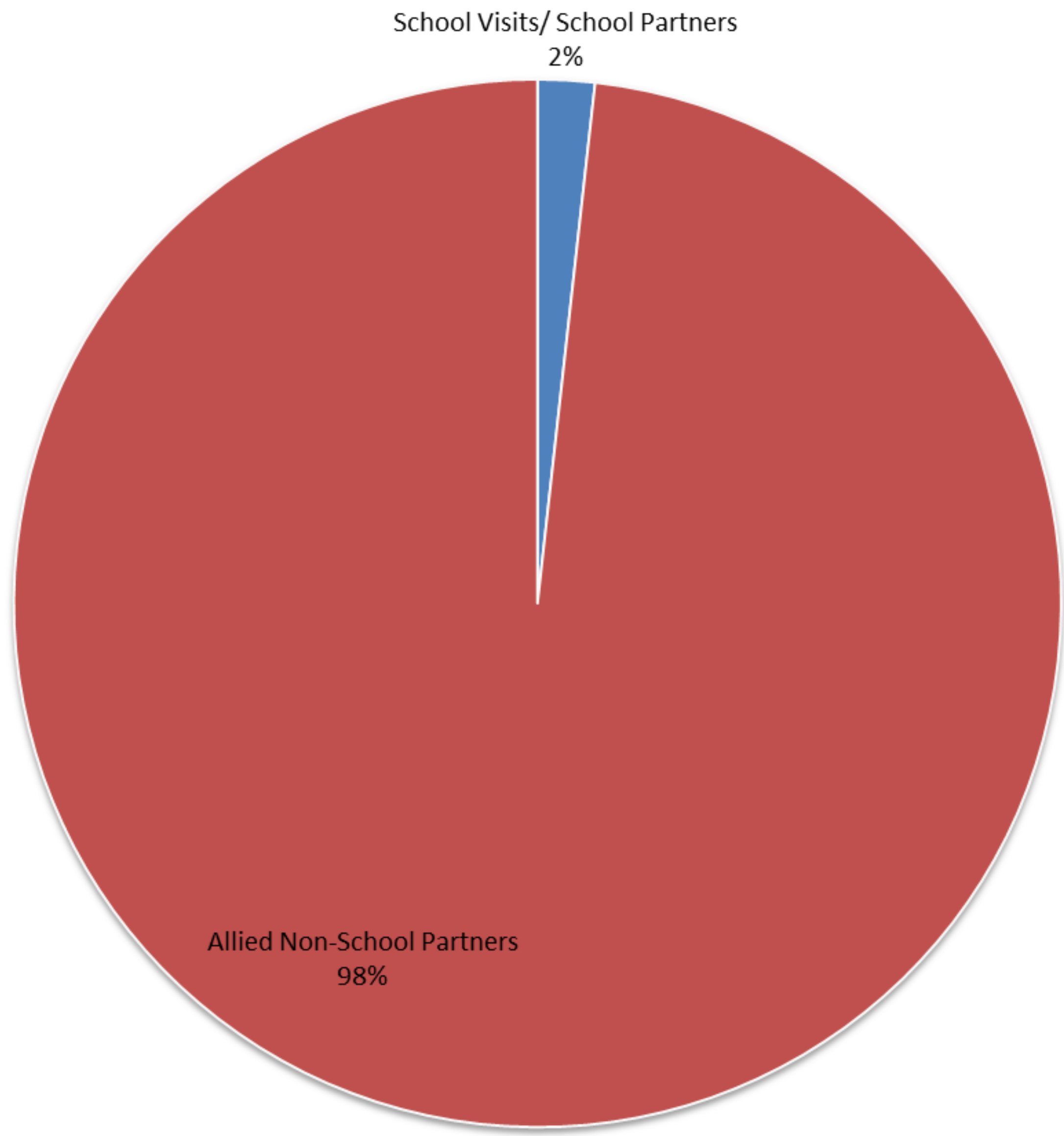
Distribution of Scheduled School Visits and MGRRE Tours

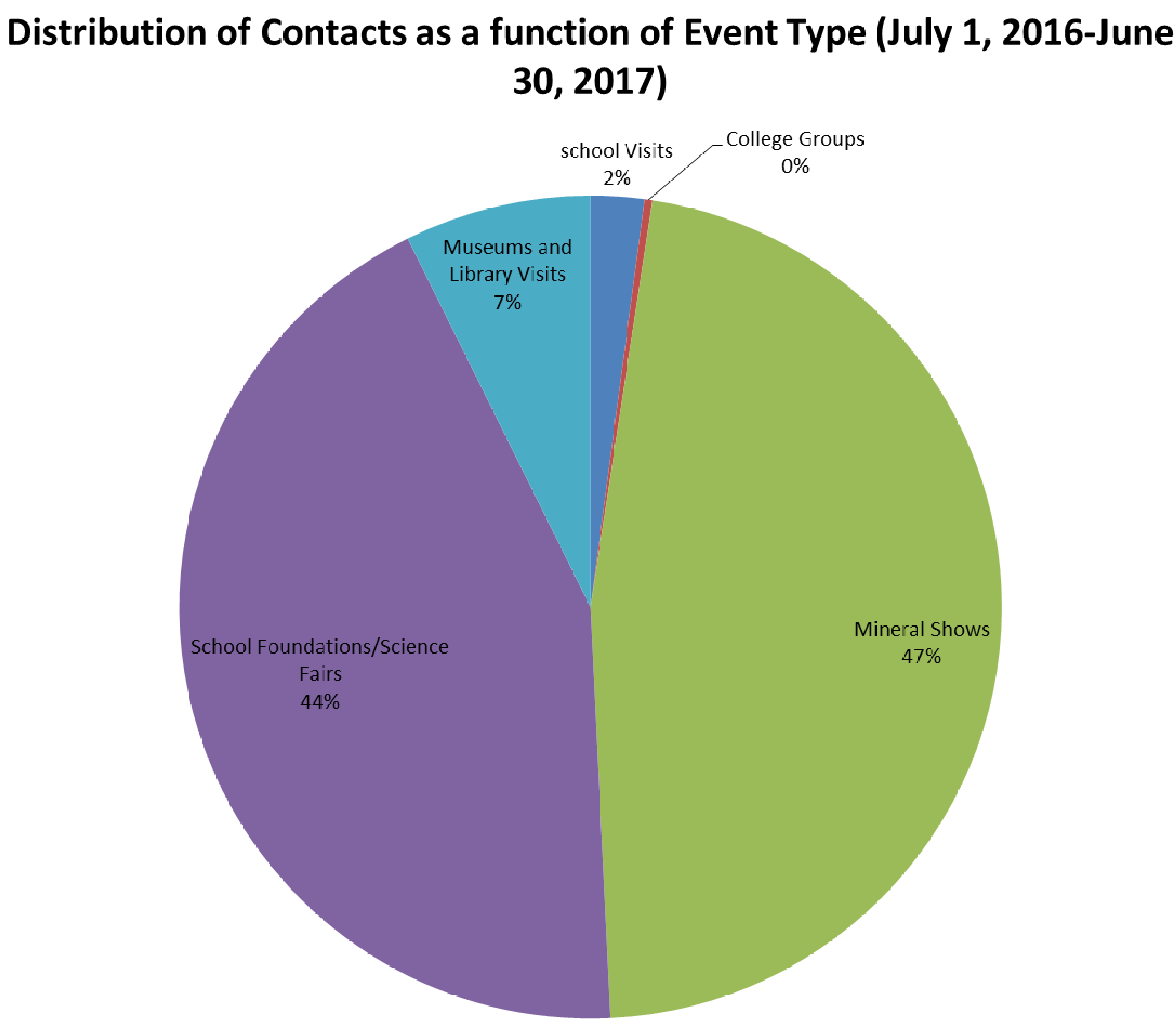




Total Interactions
0
5000
10000
15000
20000
25000
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
Calendar Year

Distribution of Contacts as a function of Event Type (July 1, 2016 to June 30, 2017)




Distribution of Contacts as a function of Event Type (July 1, 2016-June 30, 2017)
school Visits 2%
College Groups 0%
Museums and Library Visits 7%
Mineral Shows 47%
School Foundations/Science Fairs 44%

Module Overviews

Module	Recommended Grade Level	Michigan Department of Education Standards	Description
Michigan Geologic History	2-12	E.ES.03.41, E.ES.03.32, E.ST.04.31, E.SE.06.12, E.ST.06.42, E4.p3A	Discussion of Michigan's Geologic resources in their historical geology context. Emphasis on resources such as Oil and Gas, and Groundwater
Hydrogeology	7-12	E.ES.07.81, E4.1A, E4.1C	Discussion of infiltration rates, porosity and permeability.
Natural Hazards: Earthquakes	6-12	E.SE.06.51, E.SE.06.52, E.SE.06.53, E3.4A, E3.4C, E3.4f	Emphasis is on vibrational energy of earthquakes and its impact on structures.
Natural Hazards: Volcanoes	4-12	E.SE.06.52, E3.1d, E3.4C, E3.4d, E3.4e, E5.4B	Flow rates and magma chemistry are used to classify different types of volcanic eruptions. Volcanoes as natural hazards are explored.
Natural Hazards: Impacts and Asteroids	2-12	E5.p1A, E5.3C, E5.4B, P3.6A, P3.6B	Describes the influence of asteroids on Earth's geologic history.
Shale Energy and Hydraulic Fracturing	7-12	E.ES.03.41, E.ES.03.32, E2.2B, E2.4A, E2.4B, E3.1c, E4.1C	Discussion of conventional vs. unconventional hydrocarbon reservoirs. Explains the process by which hydraulic fracturing occurs.
Michigan Fossils	2-12	E.ST.04.31, E.ST.06.31, E.ST.04.32, E.St.06.42, Ef.3D, E5.4f	Michigan fossils are used to explore Michigan's changing climate as a function of plate tectonics through geologic time. Fossils are used to explore basic ecological principles (food webs, competition, niches).
The Environment and Climate Change	2-12	E.ES.03.52, E.ES.07.41, E1.2B, E1.2f, E1.2g, E2.3A, E2.3d, E2.4B, E5.4A, E5.4e	Module presents an overview of the nature of carbon dioxide gas and the greenhouse effect. The albedo effect is used illustrate the impact of changes in land cover and land use.

1. Michigan Geological History Presentation (Michigan Natural Resources)

The Michigan Geological History Presentation provides an overview of the approximately 3 billion years of Earth Processes that the state of Michigan has experienced with an emphasis on two time periods, the Paleozoic and the Holocene. The presentation illustrates that the climate of Michigan has changed through geologic time with much warmer tropical climates during the Paleozoic and colder glacial conditions in the recent past. The concept of uniformitarianism is defined as one of the paradigms of modern Geology – that processes acting on modern environments are the same processes that acted in ancient environments. Examples are used to illustrate uniformitarianism through comparison of Silurian age reefs in the Michigan Basin and modern reefs in the Bahamas. One of the key aspects of this module is the exploration of the rich variety of natural resources present in the subsurface of the state of Michigan. The students are encouraged to discuss everyday objects that they use and the natural resources that had to go into the production of those objects. Natural resources such as groundwater, oil and natural gas, metallic resources, aggregate (sand and gravel), as well as salt are discussed and placed in the framework of the geology of Michigan. A final topic covered in the module is the idea that rocks have pore space which can be used to store materials like oil, natural gas, and water. A hands-on activity designed to supplement this module is the Core permeability test described below. This presentation is appropriate for grades 3-12 and meets the following content standards:

Michigan Department of Education Grade Level Content Standards covered:

K-7 Standards

E.ES.03.41 Identify natural resources (metals, fuels, fresh water, fertile soil, and forests).

E.ES.03.32 Describe how materials taken from the Earth can be used as fuels for heating and transportation.

E.ST.04.31 Explain how fossils provide evidence of the history of the Earth.

E.SE.06.12 Explain how waves, wind, water, and glacier movement, shape and reshape the land surface by eroding rock in some areas and depositing sediments in other areas.

E.ST.06.42 Describe how fossils provide important evidence of how life and environmental conditions have changed.

8-12 Standards

E4.p3A Describe how glaciers have affected the Michigan landscape and how the resulting landforms impact our state economy.

2. Hydrogeology Presentation

The availability of potable water is a significant problem worldwide. This module was developed to increase awareness in students of issues pertaining to the extraction of groundwater as well as to environmental issues that impact groundwater supplies. The module specifically outlines the distribution of water on the Earth's surface and in its interior. Fresh water makes up approximately 2.5% of the total water on the Earth's surface and much of that water is frozen as glacial ice. The module presenter explores with the students the water cycle and how water molecules move from the atmosphere to the surface as precipitation, from the oceans to the atmosphere through evaporation and the connection between surface waters and groundwater stored in subsurface aquifers. The balance of rainwater (and meltwater) runoff and infiltration is discussed in the context of how groundwater aquifers are recharged. As in the Michigan Geological History module, the properties of porosity and permeability are important concepts explored in this module. The storage space in an aquifer is the pore space between sediment particles that make up the rock portion of the aquifer. The importance of permeability to extraction/production of groundwater is discussed with the students. One final concept that is explored is the contamination of aquifers and how hydrogeologists can study or model the movement of contaminants in an aquifer. A brief discussion of remediation techniques is also described. This presentation is appropriate for grades 7-12. The following content standards are met by this module:

<u>Michigan Department of Education Grade Level Content Standards covered:</u>

K-7 Standards

E.ES.07.81 Explain the water cycle and describe how evaporation, transpiration, condensation, cloud formation, precipitation, infiltration, runoff, ground water, and absorption occur within the cycle.

8-12 Standards

E4.1A Compare and contrast surface water systems and groundwater in regard to their relative sizes as Earth's freshwater reservoirs and the dynamics of water movement (inputs, outputs, residence times, sustainability).

E4.1C Explain how water quality in both groundwater and surface systems is impacted by land use decisions.

3. Natural Hazards

The study of how natural hazards occur is an important component of applied geosciences. Students will gain a better appreciation of the types of natural hazards and the destructive nature of these events. Three different sub-modules have been prepared for this module: Earthquakes, Impacts and Asteroids, and Volcanoes. Each sub-module is designed around a series of hands-on activities and rock samples. The individual sub-modules are designed to fill a 50 minute class period and we bring in all of the materials necessary for the activities.

a. Natural Hazards: Earthquakes

The earthquake sub-module develops for the students an understanding of the behavior of earth materials during an earthquake. The students explore the harmful effects of an earthquake through construction of model cities on different substrates. Earthquakes are put into a plate tectonics context and the forces that generate earthquakes are discussed in the short presentation.

Michigan Department of Education Grade Level Content Standards covered:

K-7 Standards

E.SE.06.51 Explain plate tectonic movement and how the lithospheric plates move centimeters per year.

E.SE.06.52 Demonstrate how major geological events (earthquakes, volcanic eruptions, mountain building) result from these plate motions.

E.SE.06.53 Describe layers of the Earth as a lithosphere (crust and upper mantle), convecting mantle, and dense metallic core.

8-12 Standards

E3.4A Use the distribution of earthquakes and volcanoes to locate and determine the types of plate boundaries.

E3.4C Describe the effects of earthquakes and volcanic eruptions on humans.

E3.4f Explain why fences are offset after an earthquake, using the elastic rebound theory.

b. Natural Hazards: Volcanoes

The volcanoes module is a fun, hands-on module that explores the principle of viscosity and its relationship to the fluid flow dynamics of lava. A classification of volcanoes based on shape and size, magma composition, and eruption style is presented to the students and analog versions of the volcanoes are used to exhibit the viscosity of different lava types. Students work in groups to explore crystallization and cooling rate. A discussion of intrusive versus extrusive igneous rocks, highlights the textural differences observed in these igneous rocks which is a function of cooling rate.

Michigan Department of Education Grade Level Content Standards covered:

K-7 Standards

E.SE.06.41 Compare and contrast the formation of rock types (igneous, metamorphic, and sedimentary) and demonstrate the similarities and differences using the rock cycle model.

E.SE.06.52 Demonstrate how major geological events (earthquakes, volcanic eruptions, mountain building) result from these plate motions.

8-12 Standards

E3.1d Explain how the crystal sizes of igneous rocks indicate the rate of cooling and whether the rock is extrusive or intrusive.

E3.4C Describe the effects of earthquakes and volcanic eruptions on humans.

E3.4d Explain how the chemical composition of magmas relates to plate tectonics and affects the geometry, structure, and explosivity of volcanoes.

E3.4e Explain how volcanoes change the atmosphere, hydrosphere, and other earth systems.

E5.4B Describe natural mechanisms that could result in significant changes in climate (e.g. major volcanic eruptions, changes in sunlight received by the earth, meteorite impacts).

c. Natural Hazards: Impacts and Asteroids

This sub-module discusses the impact that a collision by meteorites or asteroids with the Earth would have on humanity. Basic types of meteorites are described and samples are provided for the students to examine. A brief discussion of orbital dynamics and gravitational attraction sets the stage for a hands-on activity where students simulate impacts on the Earth with different types of impactors (size, density, shape) and incident angles. The shapes of craters are described. Example impact craters in the Midwest region, including the Sudbury impact crater (Ontario) and the Calvin 12 structure (Southern Michigan) are used to illustrate how we can identify deposits related to these events in the geologic record.

Michigan Department of Education Grade Level Content Standards covered:

8-12 Standards

E5.p1A Describe the motions of various celestial bodies and some effects of those motions.

E5.3C Relate the major events in the history of the Earth to the geologic time scale, including the formation of the Earth, formation of an oxygen atmosphere, rise of life, Cretaceous-Tertiary (K-T) and Permian extinctions, and Pleistocene ice age.

E5.4B Describe natural mechanisms that could result in significant changes in climate (e.g. major volcanic eruptions, changes in sunlight received by the earth, meteorite impacts).

P3.6A Explain earth-moon interactions (orbital motion) in terms of forces.

P3.6B Predict how the gravitational force between objects changes when the distance between them changes.

4. **Shale Energy and Hydraulic Fracturing**

This module provides a balanced approach to discussion of hydraulic fracturing and utilizing hydrocarbon resources hosted in shales. Hydrocarbons underpin the world's economy and students need to understand where these natural resources come from that affect their daily lives in so many ways. Permeability and Porosity are used as a starting point for discussion of the differences between conventional hydrocarbon reservoirs and unconventional shale reservoirs. At the end of the session, students will be able to explain the process of hydraulic fracturing and how it is used to extract hydrocarbons from both conventional and unconventional hydrocarbon reservoirs. Students will also be able to list both the positives and negatives of hydraulic fracturing. The module consists of a short presentation and several hands-on activities.

Michigan Department of Education Grade Level Content Standards covered:

K-7 Standards

E.ES.03.41 Identify natural resources (metals, fuels, fresh water, fertile soil, and forests).

E.ES.03.32 Describe how materials taken from the Earth can be used as fuels for heating and transportation.

8-12 Standards

E2.2B Identify differences in the origin and use of renewable (e.g. solar, wind, water, biomass) and nonrenewable (e.g., fossil fuels, nuclear [U-235]) sources of energy.

E2.4A Describe renewable and nonrenewable sources of energy for human consumption (electricity, fuels), compare their effects on the environment, and include overall costs and benefits.

E2.4B Explain how the impact of human activities on the environments (e.g., deforestation, air pollution, coral reef destruction) can be understood through the analysis of interactions between the four Earth systems.

E3.1c Explain how the size and shape of grains in a sedimentary rock indicate the environment of formation (including climate) and deposition.

E4.1C Explain how water quality in both groundwater and surface systems is impacted by land use decisions.

5. Michigan Fossils

The Michigan Fossils module illustrates the diversity of life found in the fossil record of Michigan's sedimentary record. Discussion of how an organism becomes a fossil is presented with hands-on activities that simulate the process of fossilization. At the end of the module, students will be able to define the term index fossil. Specific fossils from Michigan are presented as index fossils that constrain the age of the host sediment. Behavioral and ecological principles are also explored with specific fossils (mastodons and mammoths) as diet and habitat can be inferred from skeletal morphology.

Michigan Department of Education Grade Level Content Standards covered:

K-7 Standards

E.ST.04.31 Explain how fossils provide evidence of the history of the Earth.

E.ST.06.31 Explain how rocks and fossils are used to understand the age and geological history of the Earth (timelines and relative dating, rock layers).

E.ST.04.32 Compare and contrast life forms found in fossils and organisms that exist today.

E.ST.06.42 Describe how fossils provide important evidence of how life and environmental conditions have changed.

8-12 Standards

E5.3D Describe how index fossils can be used to determine time sequence.

E5.4f Describe geologic evidence that implies climates were significantly colder at times in the geologic record (e.g., geomorphology, striations and fossils).

Presentations on the CoreKids program at Meetings

2016: Michigan Earth Science Teachers Association Field Conference

2016: Fall Science Update, Grand Valley State University

Michigan Natural Resources Production Statistics

Resources for Teachers

Prepared by Drs. Peter Voice and William B. Harrison III

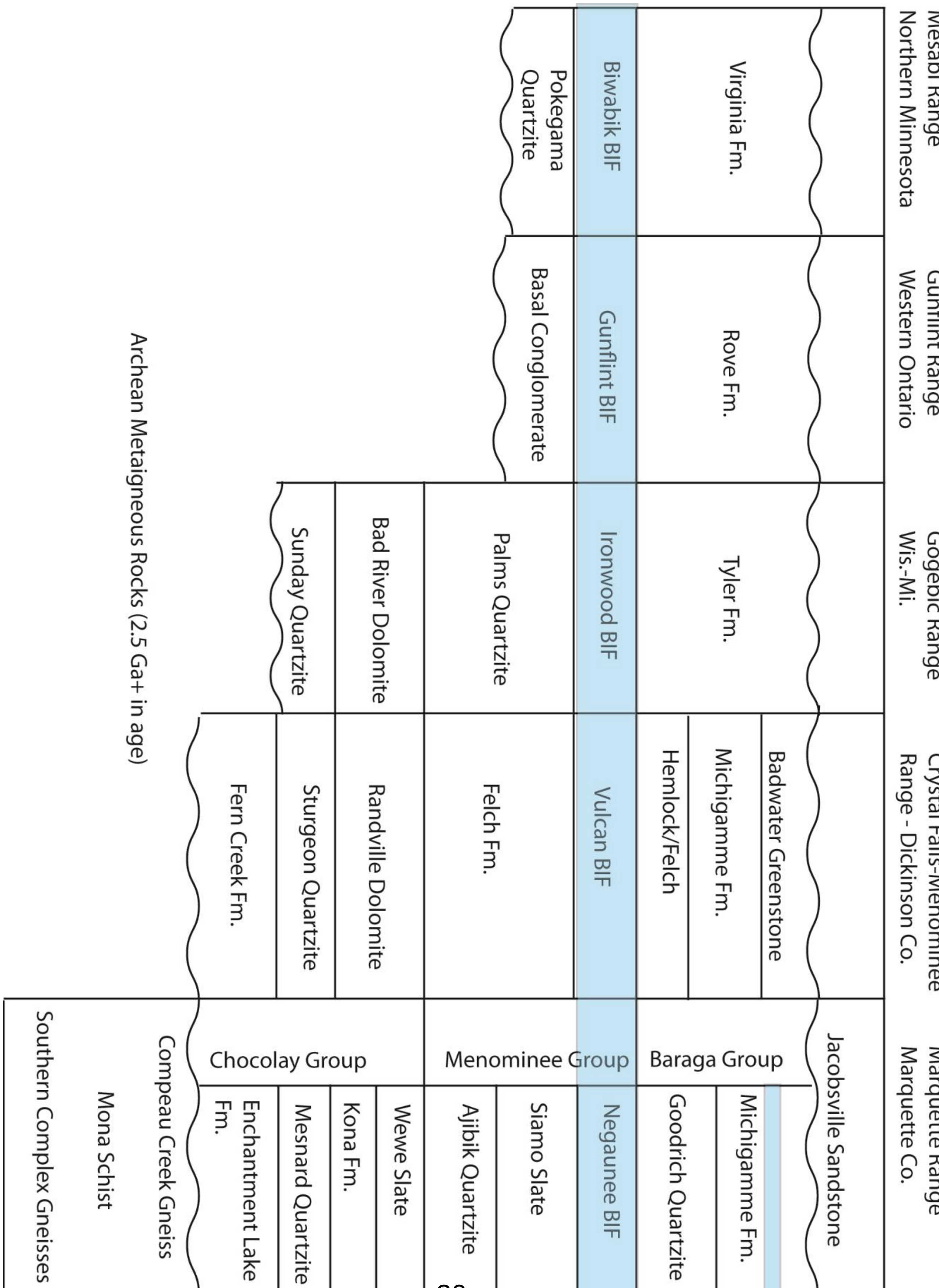
Michigan Natural Resources

- Metallic Minerals
  - Iron Ore (with some associated Manganese)
  - Copper Ore (with some associated Silver, Platinum Group Elements, Zinc)
  - Gold
- Non-metallic Minerals
  - Rock Salt
  - Rock Gypsum
- Aggregate Resources
  - Sand and Gravel
  - Crushed Stone
  - Cement
  - Lime
  - Common Clay and Shale
  - Dimension Stone
- Energy Resources
  - Oil
  - Natural Gas
  - Coal
- Other Resources
  - Aquifers – water
  - Natural Gas Storage (Ranked 1st Nationally!)
  - Proposed CO_2 sequestration storage (currently Pilot Stage)

Natural Resources by Stratigraphic age of host rock

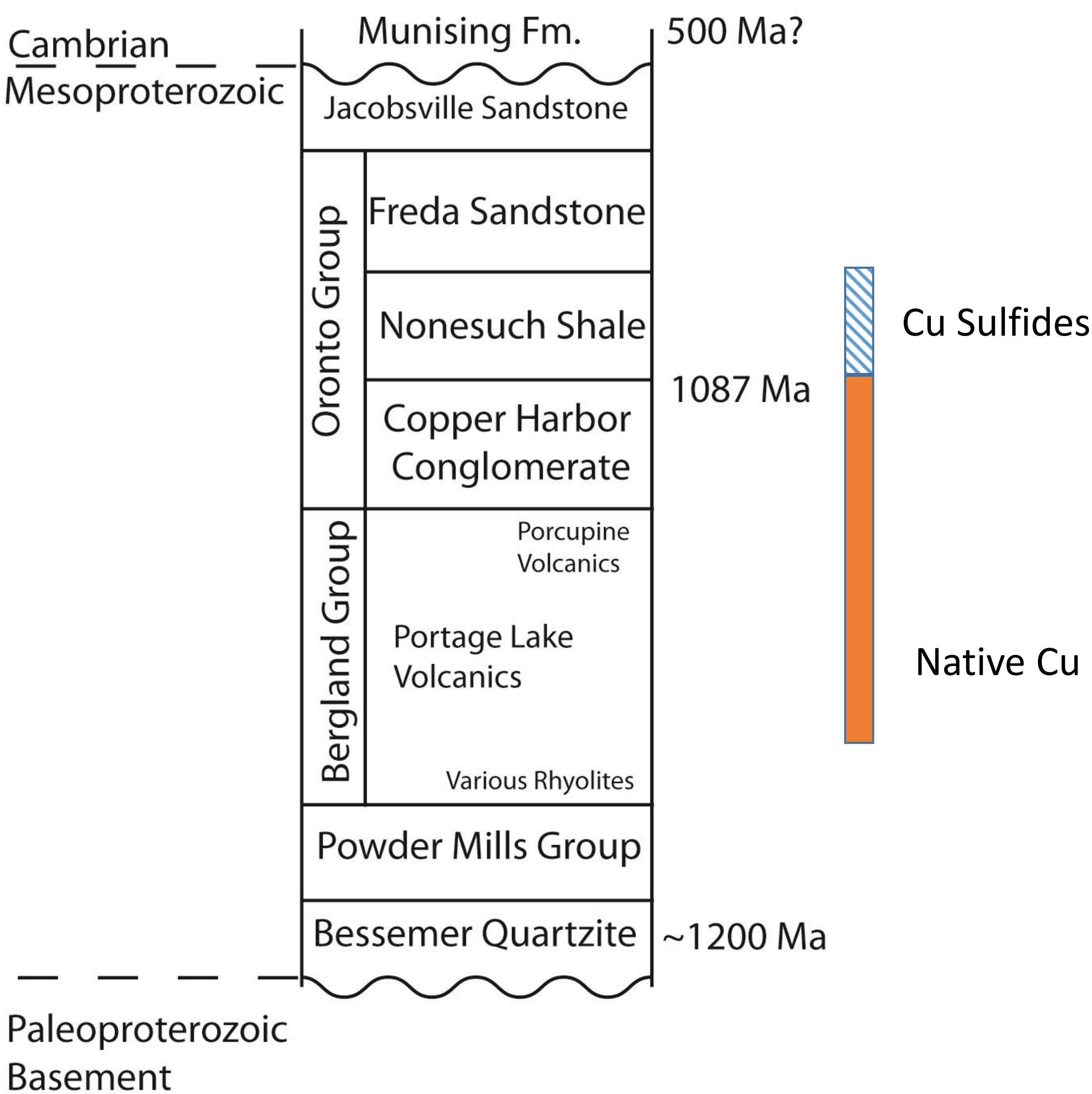
- Precambrian (Paleoproterozoic ~2.3-1.8 Ga)
  - Iron ore
  - Crushed Stone (Kona Dolomite, etc.)
- Precambrian (Mesoproterozooic ~1.1-1.0 Ga)
  - Copper and associated minerals
  - Dimension stone (Jacobsville Sandstone)
  - Crushed Stone
- Paleozoic (542-251 Ma)
  - Oil and Natural Gas (Cambrian-Mississippian)
  - Coal (Pennsylvanian)
  - Crushed stone (Silurian-Devonian)
  - Cement (Devonian)
  - Rock Salt (Silurian) and Brines (Mississippian)
  - Gypsum (Mississippian)
  - Clay (Devonian, Miss.-Pennsylvanian)
  - Aquifers (Cambrian-Pennsylvanian)
- Mesozoic (251-65 Ma)
  - Crushed Stone
  - Aquifer?
- Cenozoic (65 – 0 Ma) – Pleistocene glacial deposits
  - Sand and Gravel
  - Clay and marl
  - Peat
  - Aquifers

Paleoproterozoic Units in the Lake Superior Region
Shading represents horizons with iron formation



Modified from Ojakangas, 1994

Mesoproterozoic Units in the Upper Peninsula



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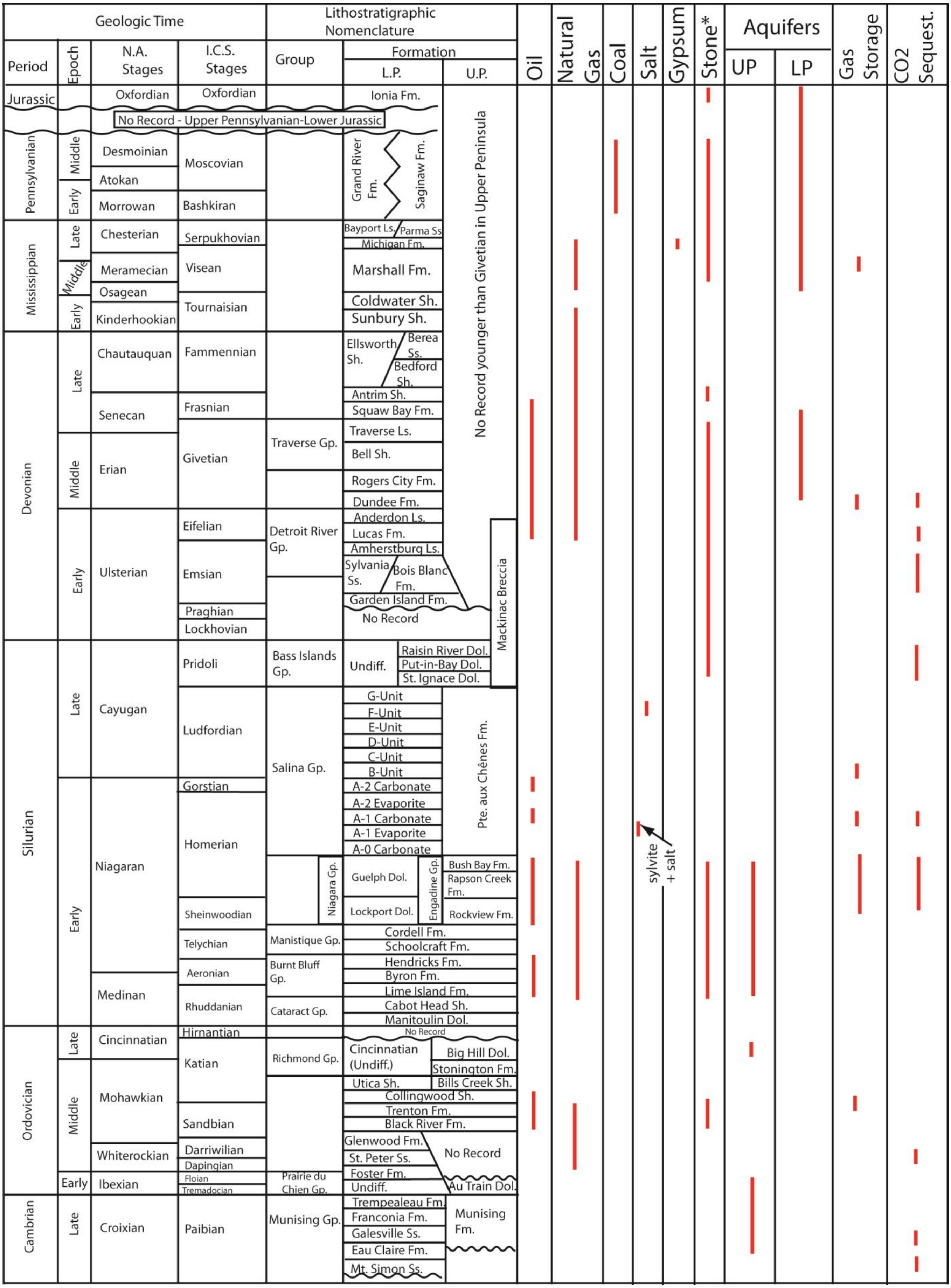
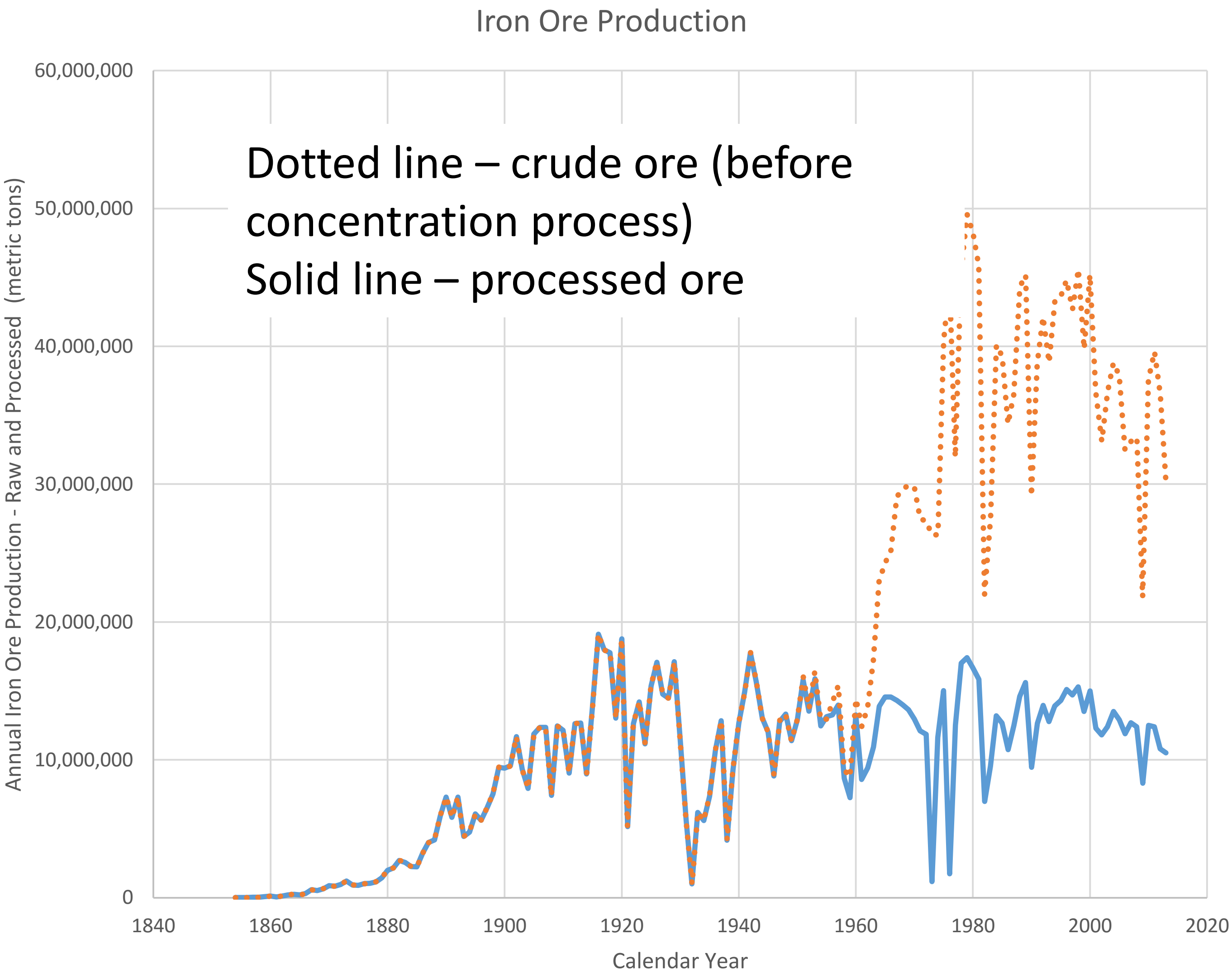
Modified from Mitchell and Sheldon, 2016

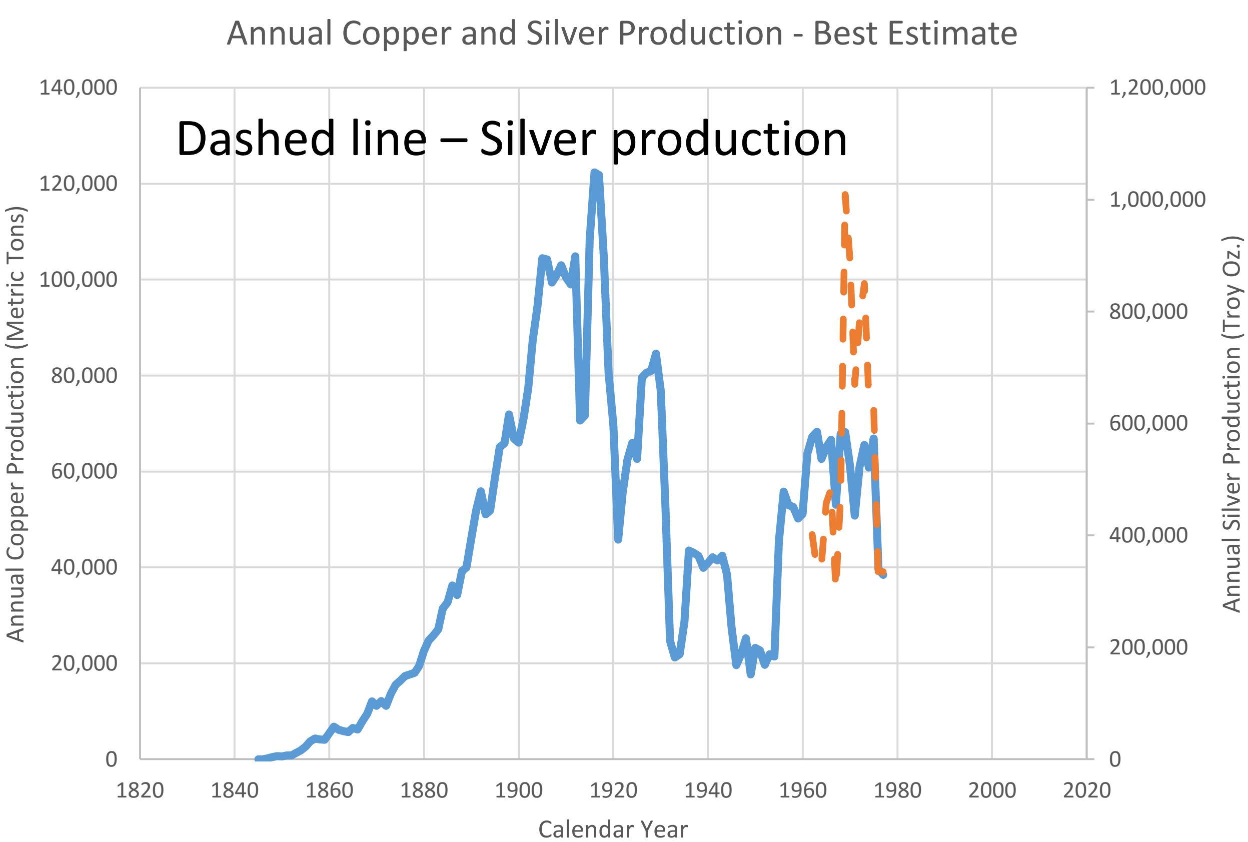
Stratigraphic Distribution of some major resources found in Paleozoic age rocks



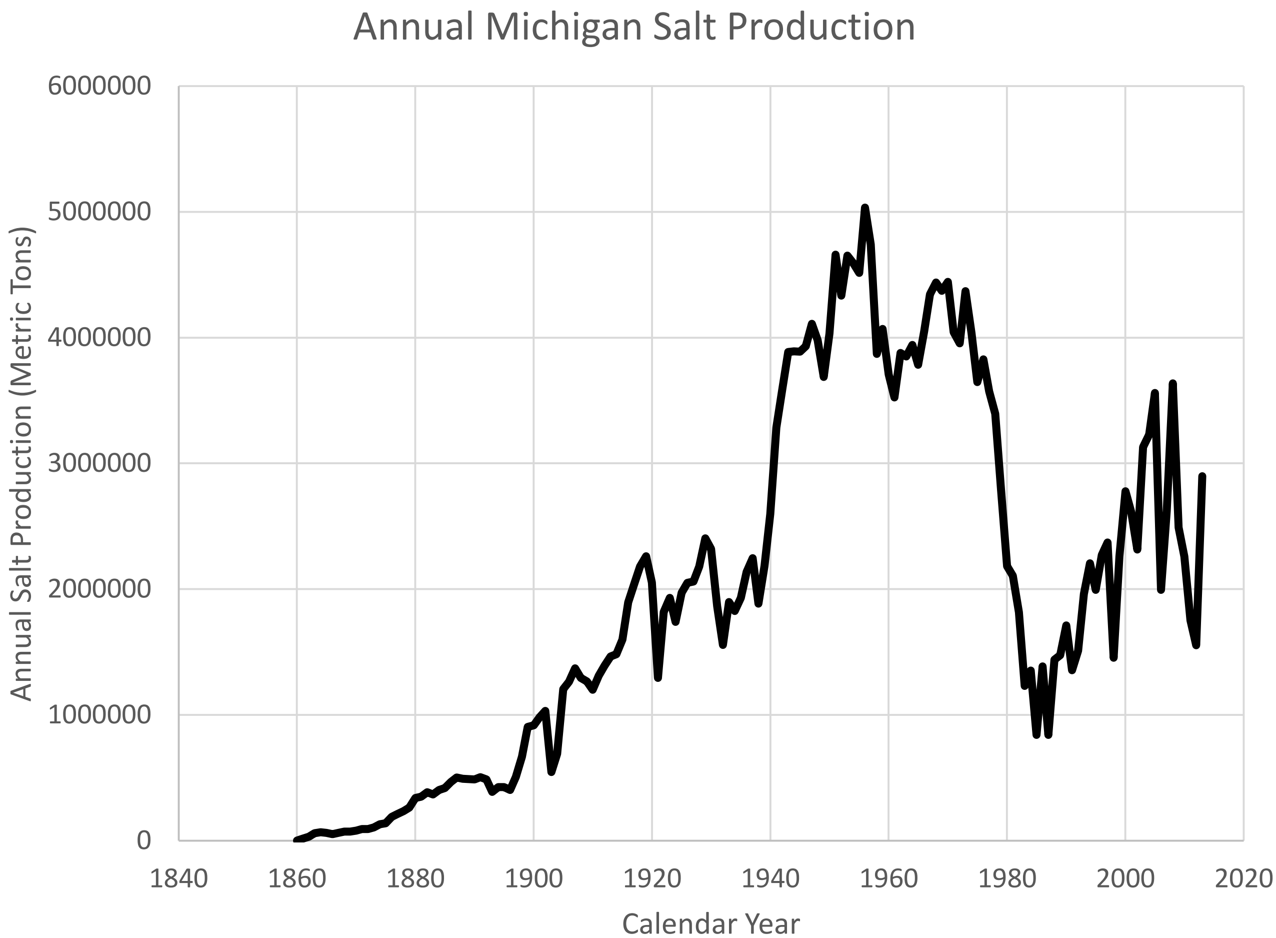
*crushed and dimension stone, clay, glass sands

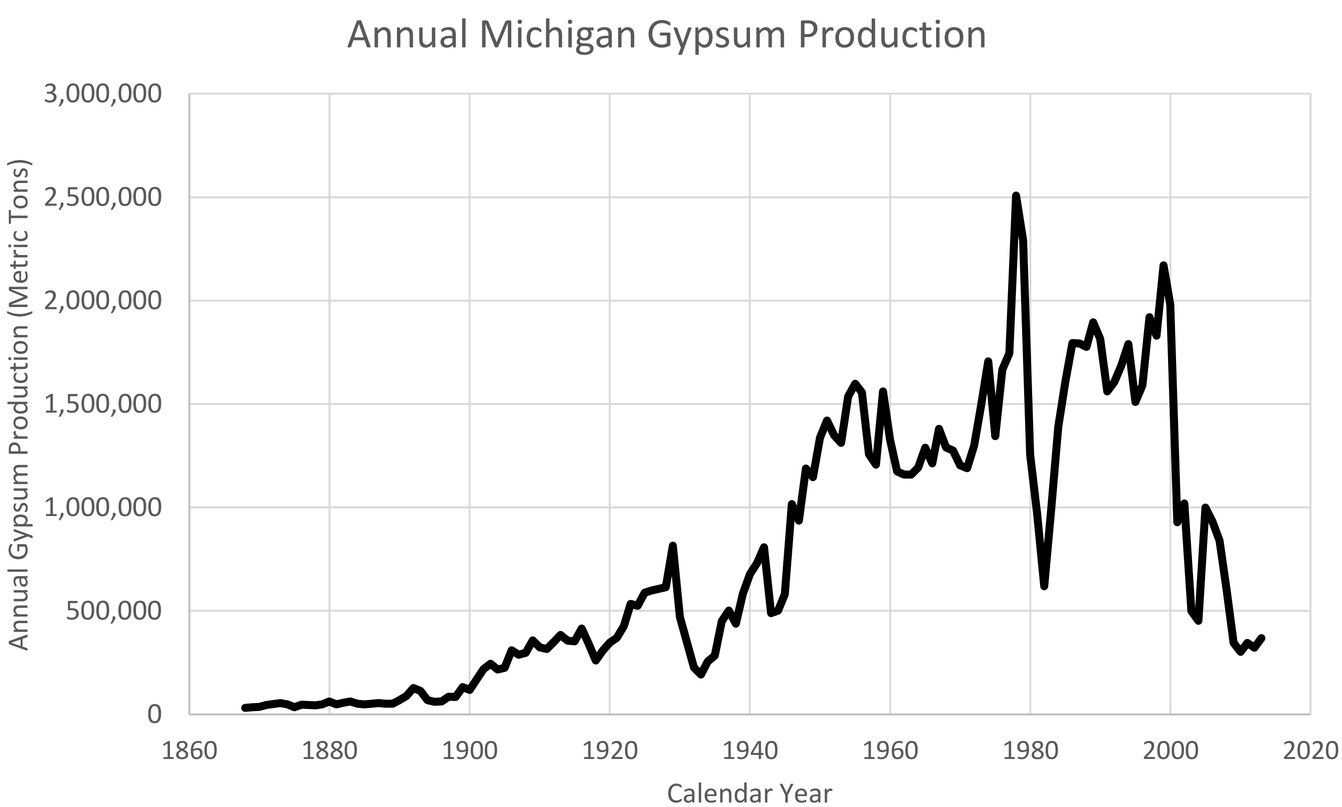
Stratigraphic chart modified from Catacosinos et al., 2000

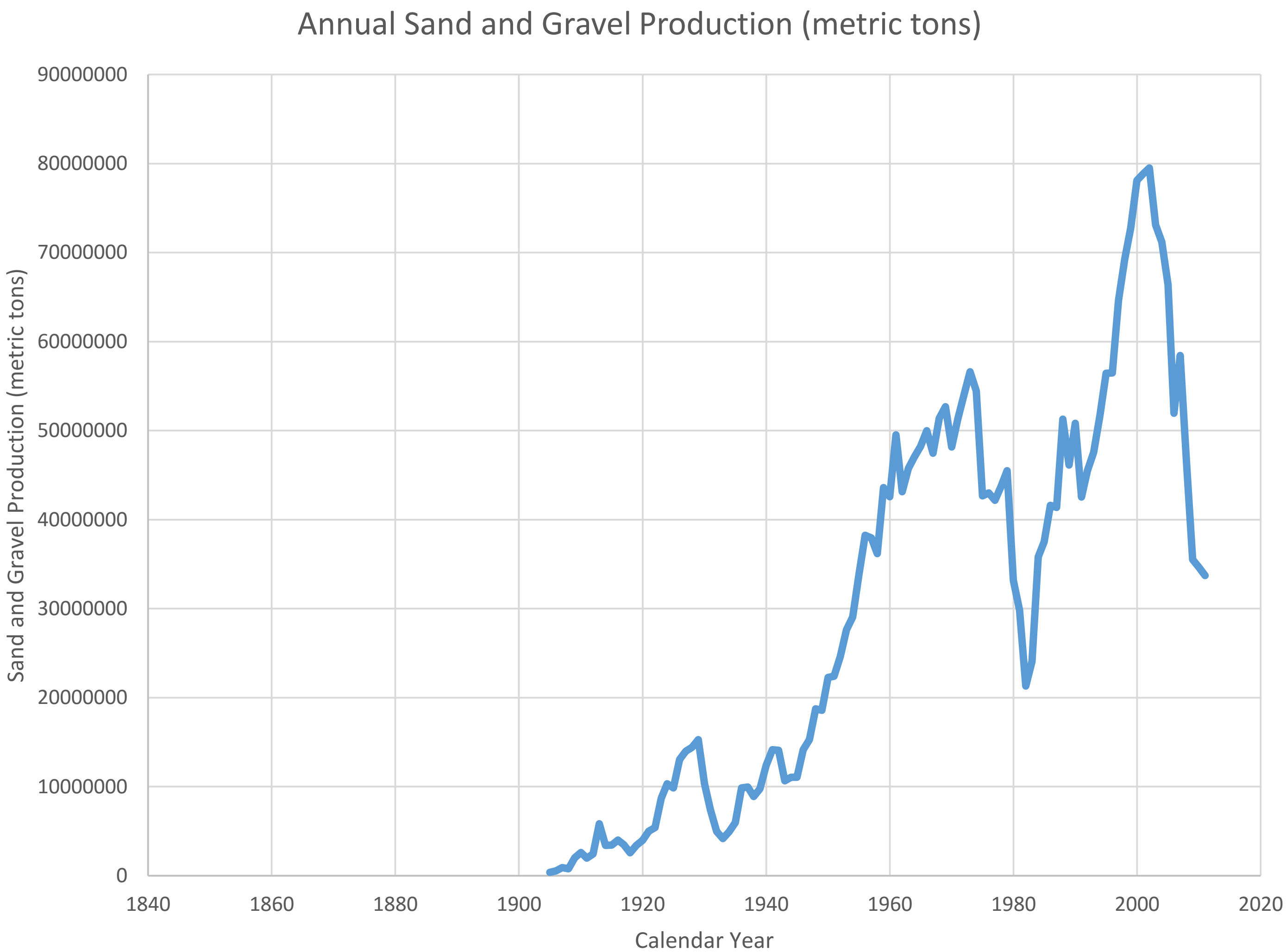

Iron Ore Production
Dotted line – crude ore (before concentration process)
Solid line – processed ore
Annual Iron Ore Production - Raw and Processed (metric tons)
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Calendar Year

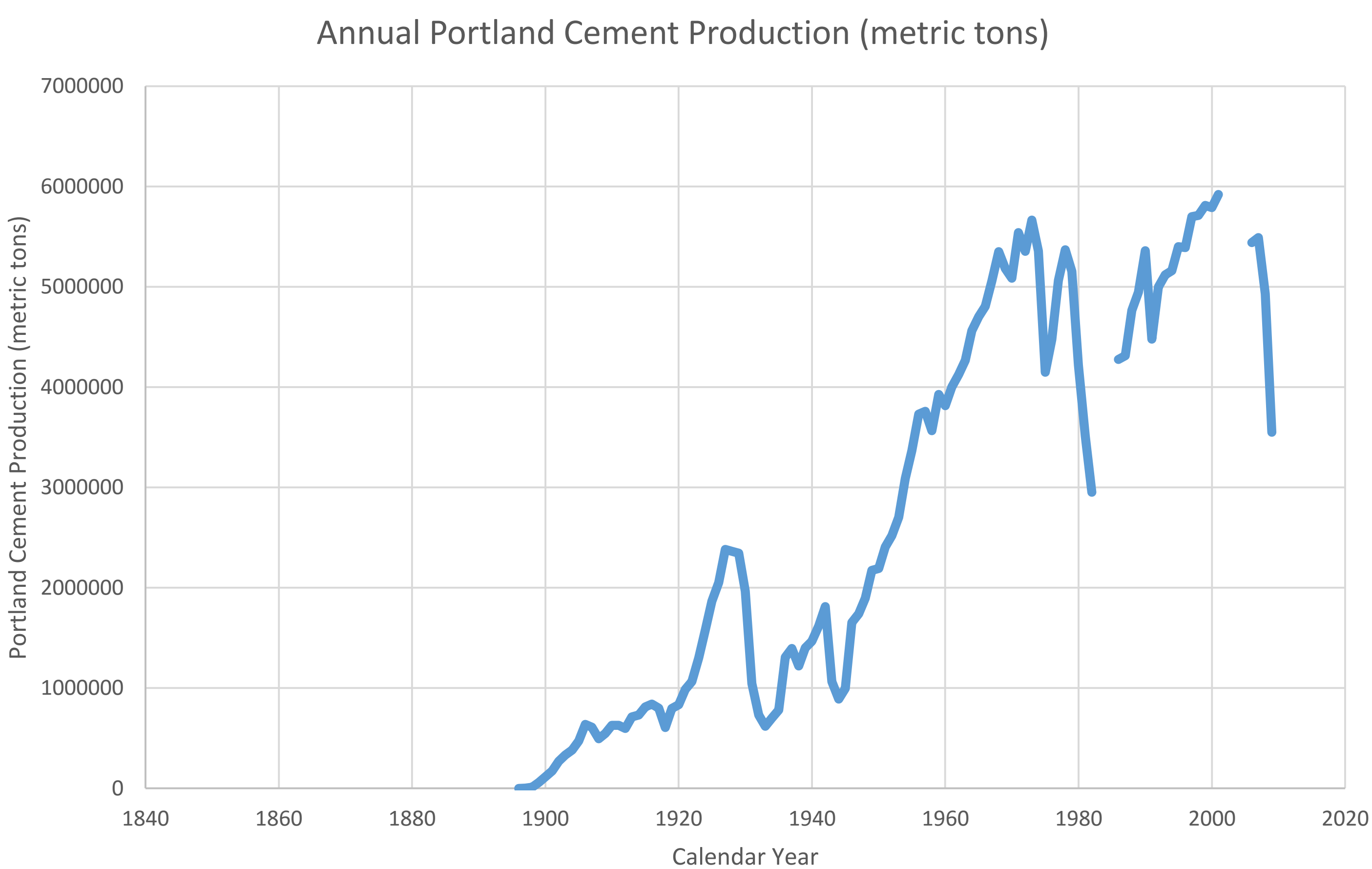

Annual Copper and Silver Production - Best Estimate
Dashed line – Silver production
Annual Copper Production (Metric Tons)
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Annual Silver Production (Troy Oz.)
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
1820
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Calendar Year

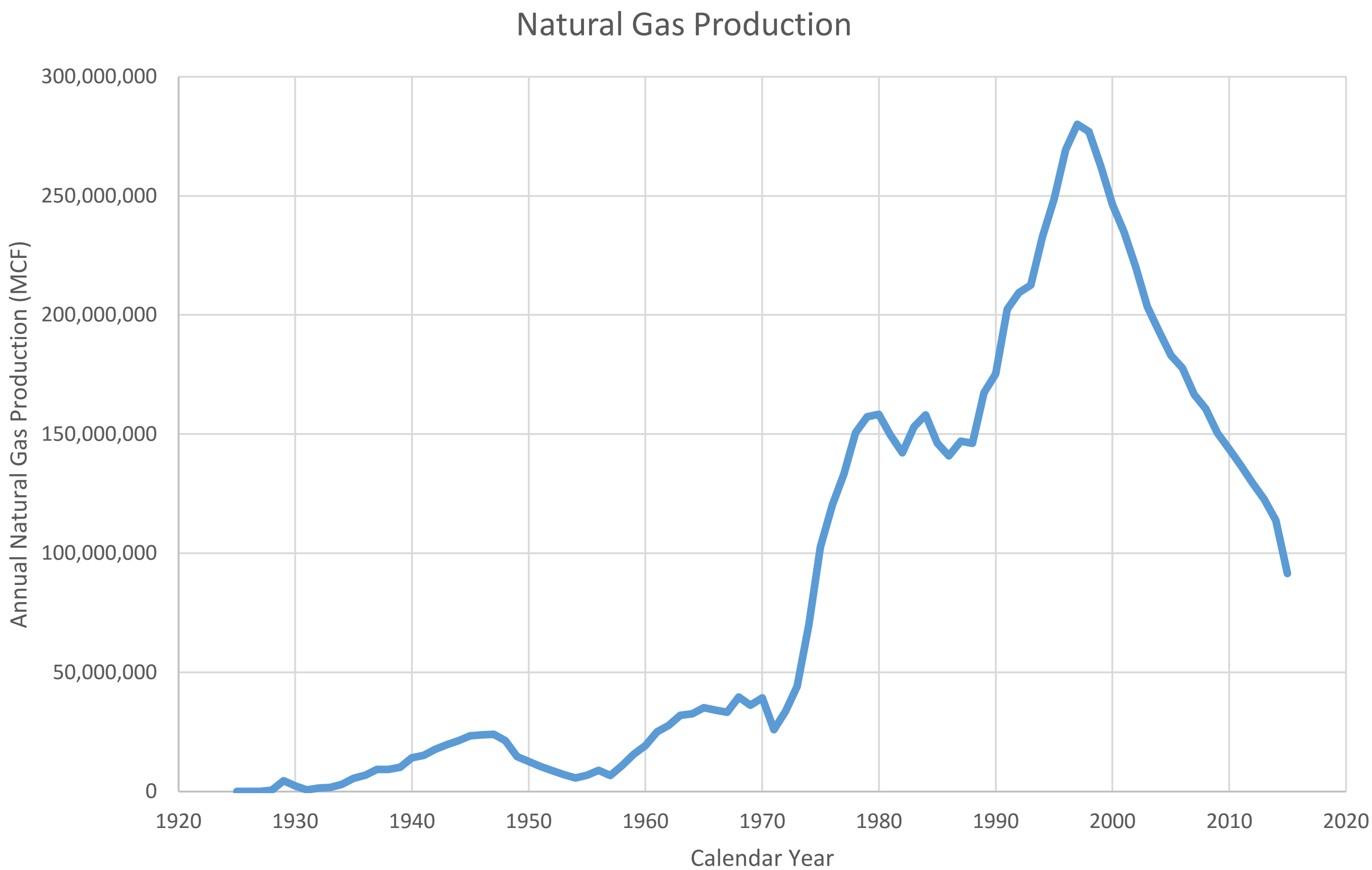
7

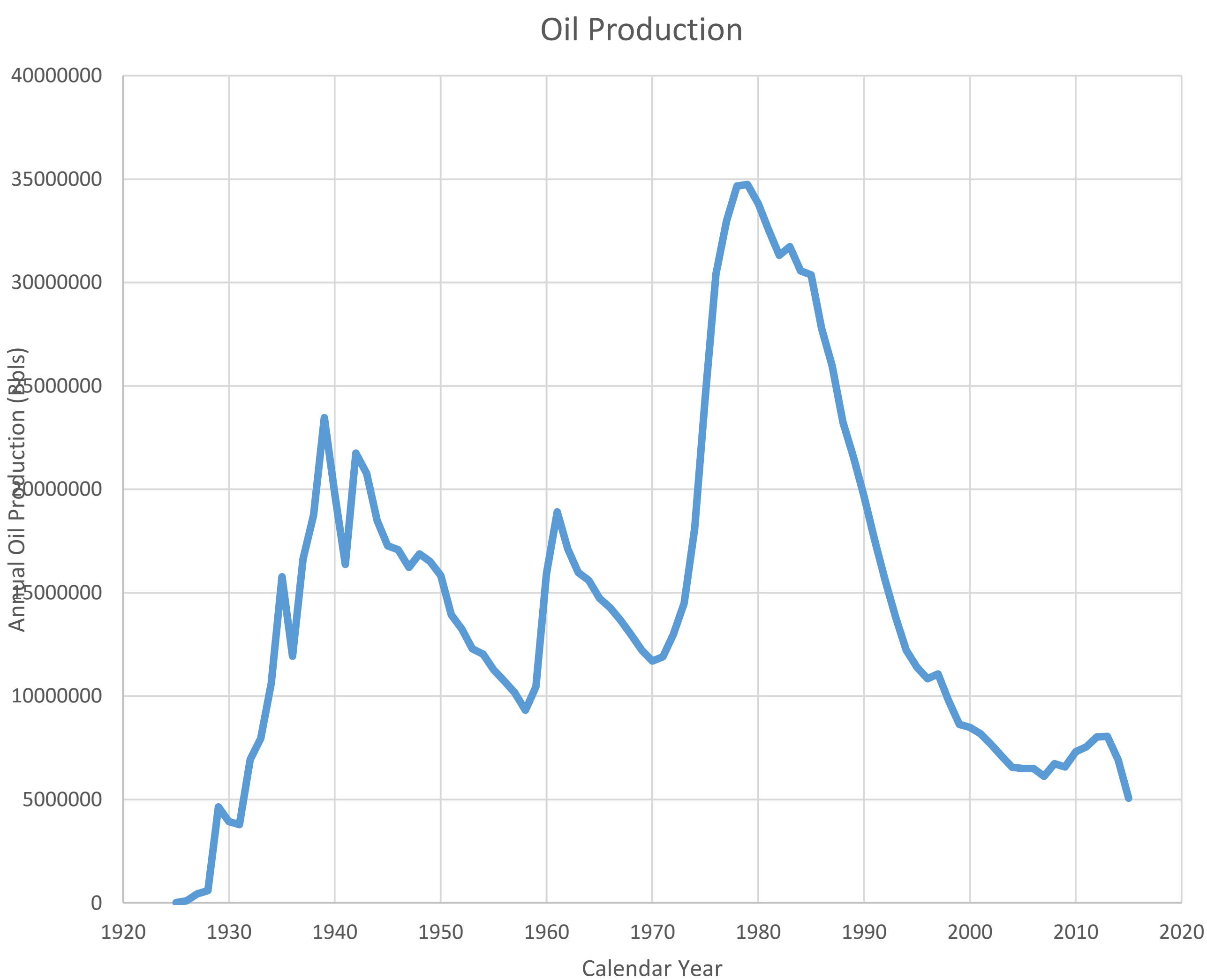

Annual Michigan Salt Production
Annual Salt Production (Metric Tons)
6000000
5000000
4000000
3000000
2000000
1000000
0
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Calendar Year


Annual Michigan Gypsum Production
Annual Gypsum Production (Metric Tons)
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
1860
1880
1900
1920
1940
1960
1980
2000
2020
Calendar Year

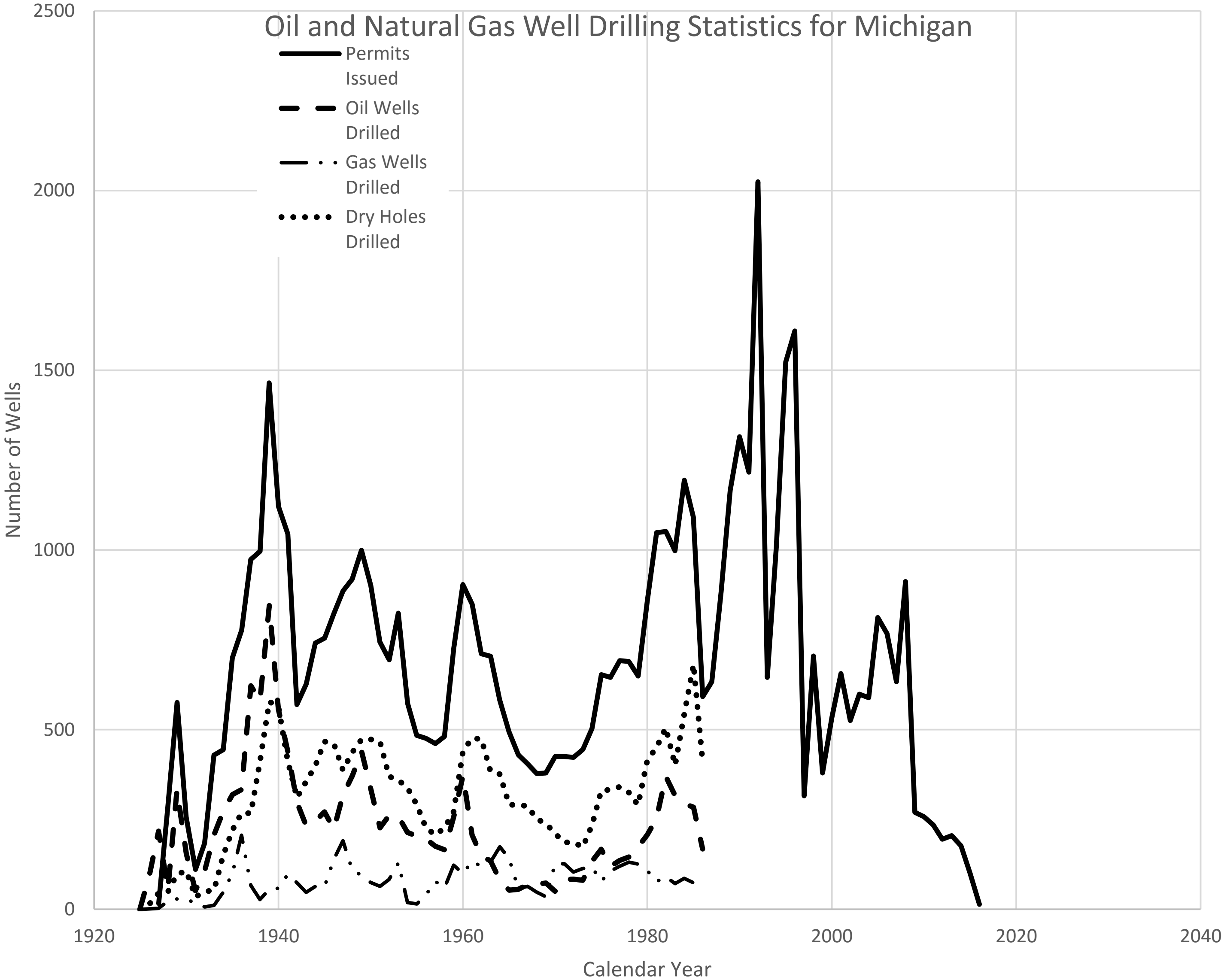

Annual Sand and Gravel Production (metric tons)
Sand and Gravel Production (metric tons)
90000000
80000000
70000000
60000000
50000000
40000000
30000000
20000000
10000000
0
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Calendar Year


Annual Portland Cement Production (metric tons)
Portland Cement Production (metric tons)
7000000
6000000
5000000
4000000
3000000
2000000
1000000
0
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Calendar Year

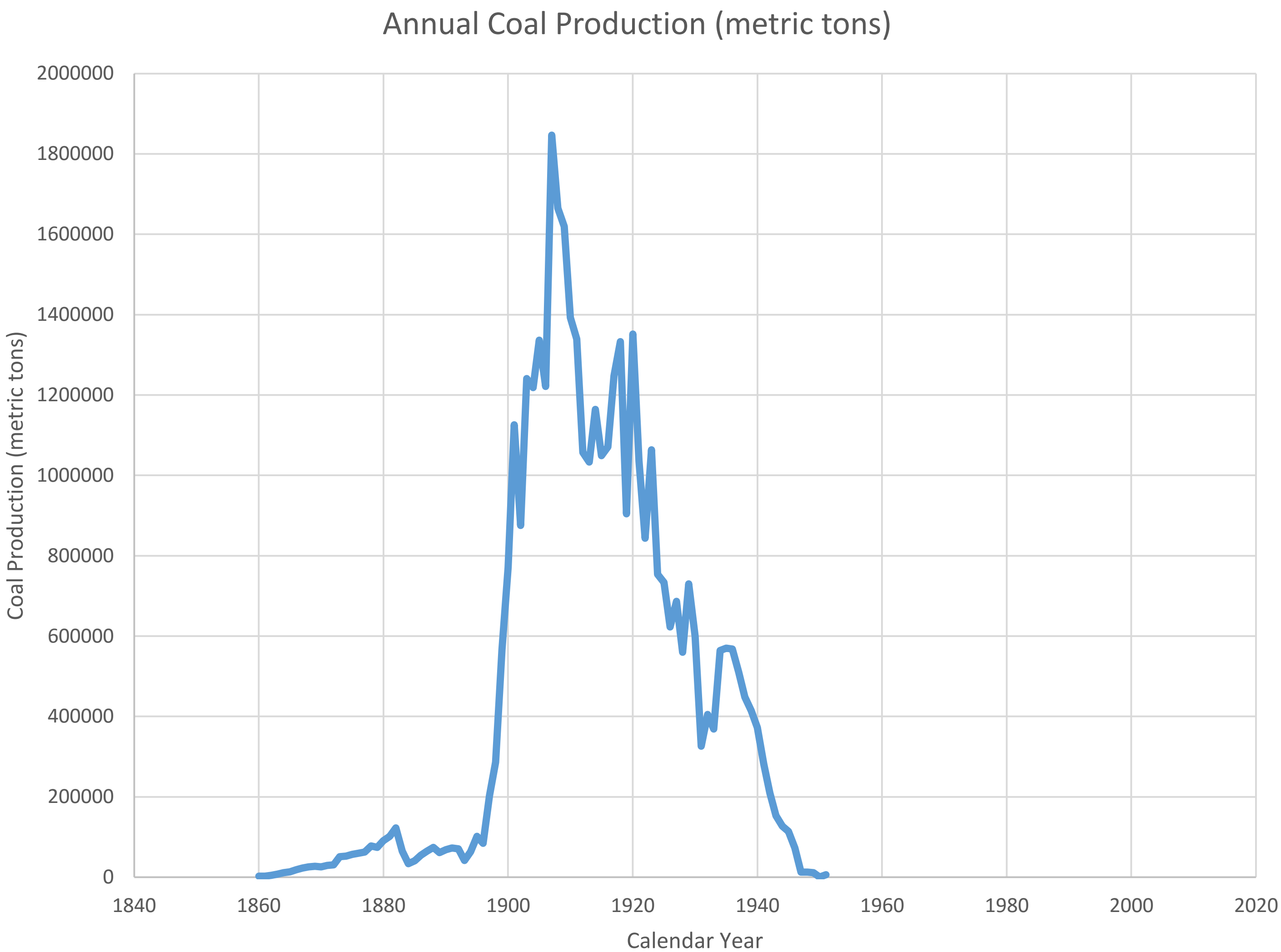

Natural Gas Production
Annual Natural Gas Production (MCF)
300,000,000
250,000,000
200,000,000
150,000,000
100,000,000
50,000,000
0
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Calendar Year


Oil Production
Annual Oil Production (Bbls)
40000000
35000000
30000000
25000000
20000000
15000000
10000000
5000000
0
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Calendar Year

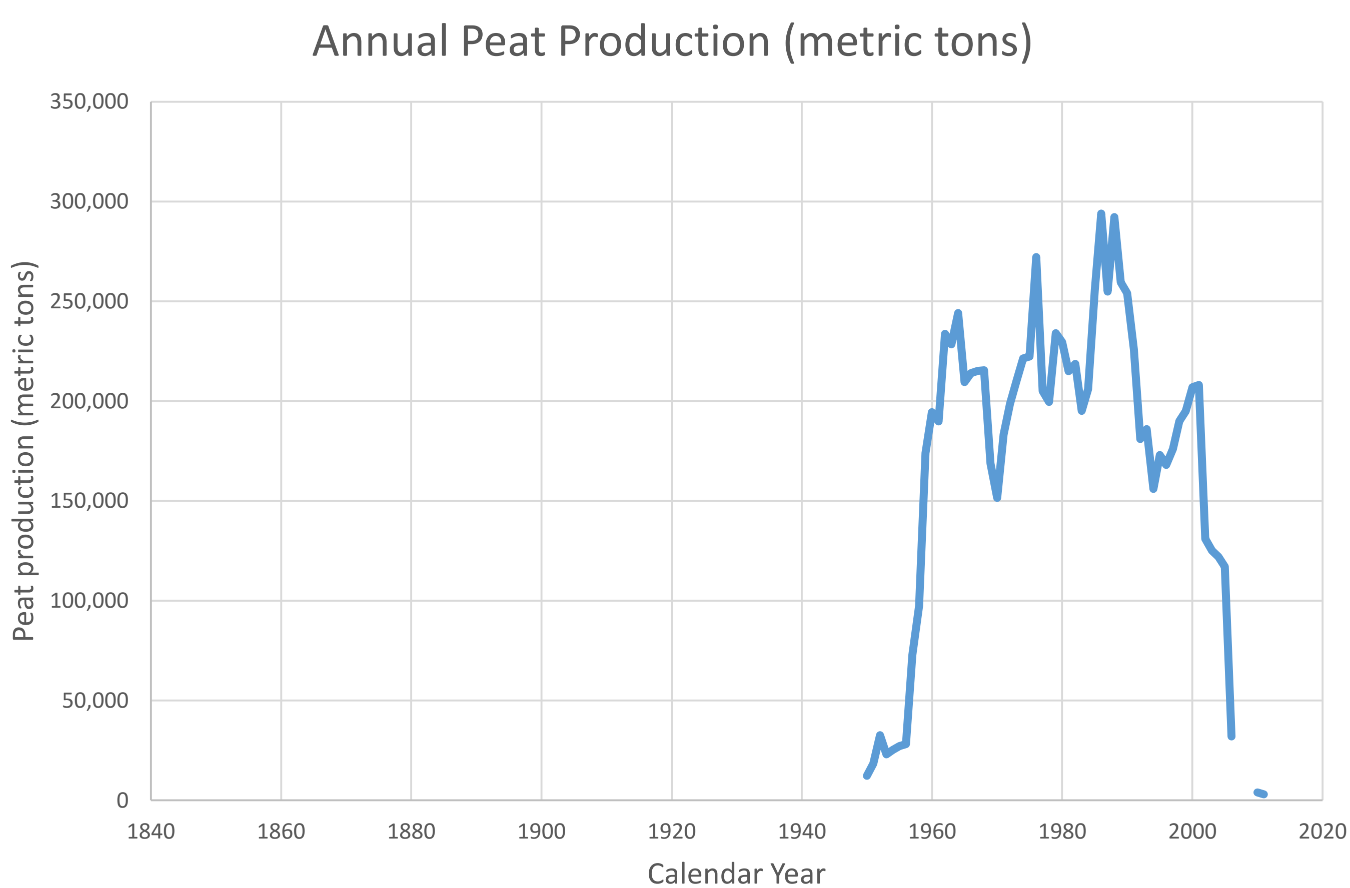
10



- 56,139 total wells drilled (Dec. 2015)
- 61,179 wells permitted
- Producing Wells (Active or Plugged)
  - Natural Gas – 13,087
  - Oil – 14,444
- ~49% of wells drilled produced Oil or Natural Gas
- Total includes Brine disposal/injection wells, Gas Storage wells, mineral wells



Annual Coal Production (metric tons)
Coal Production (metric tons)
2000000
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Calendar Year



Annual Peat Production (metric tons)
Peat production (metric tons)
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Calendar Year

12

Available Production data

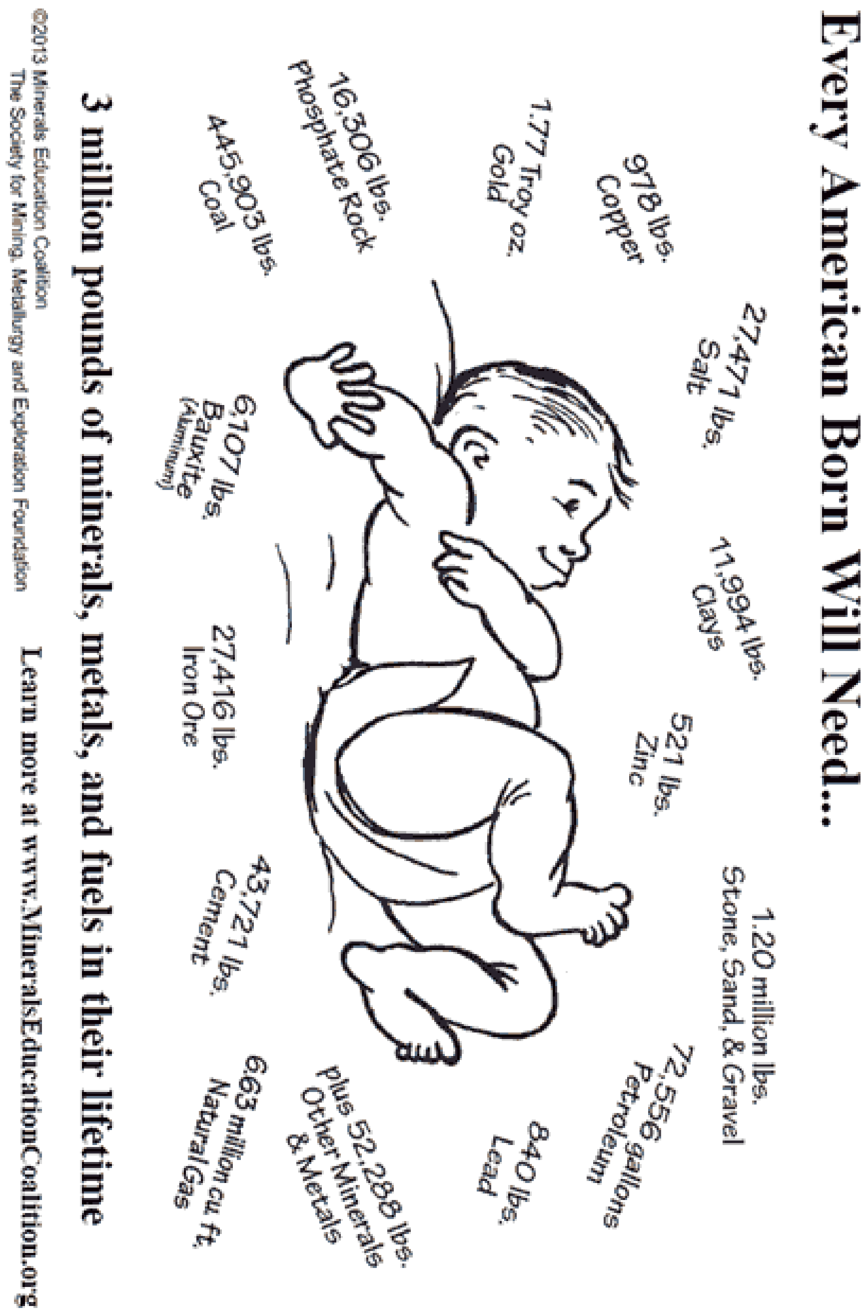
- Excel spreadsheets for the following Commodities are available by request
  - Iron Ore (Crude vs. processed data)
  - Copper Ore
  - Silver Ore*
  - Rock Salt
  - Rock Gypsum
  - Coal
  - Sand and Gravel
  - Portland* and Masonry* Cement
  - Crushed Stone (includes dimension stone)
  - Clay*
  - Peat
  - Coal
  - Lime*
  - Oil
  - Natural Gas

  *limited data – in some years data withheld to protect proprietary information

So What?

Potential Activities for your Students

- Have them look at the raw data
  - All of the commodities have been reported in different units over time, for example:
    - Rock Salt – originally sold as barrels (240 lbs of salt/barrel), then short tons (2000 lbs) and are now reported in metric tons!
    - Unit Conversions
- Making Graphs
  - Ask the students how best to present this data in graph format
- Historical Analysis
  - Are there combinations of resources that might give insight into historical trends?
    - Sand and Gravel, crushed stone and cement – reflect trends in construction
    - Copper and Iron – Industrial Revolution
  - Do peaks and valleys correspond to economic and historical events?
    - How about the Great Recession (2008-2010)?
    - What impact did the Great Depression and World War II have on mineral production?
- Where do we use these commodities in our daily lives?



Plot courtesy of the Minerals Education Coalition

A bit dated now – as this chart does not show the Rare Earth Elements

Estimating the value of produced natural resources from Michigan

- Have students find the average price of a commodity over a year (USGS Mineral Yearbooks are a good source)
- Have them do a summation of the production statistics and multiply by the price

USGS Mineral Yearbooks are here:
http://minerals.usgs.gov/minerals/pubs/commodity/myb/
Organized by:

1. Statistical Summaries – snapshot of annual mineral resource production in the U.S. and the world
2. Domestic Area reports – snapshots of annual production from individual states
3. Commodities reports – snapshots of specific commodities

Commodity	**Estimated Total Production**	**Price (2013 average)**	**Value (2013 dollars)**
salt (metric tons)	308076297.5	$47.24	$14,553,524,294.96
gypsum (metric tons)	109750998.1	$8.83	$969,101,313.12
Processed Iron Ore (metric tons)	1498798582	$104.90	$157,223,971,294.96
Copper (metric tons)	5,886,952	$7,494.39	$44,119,116,598.09
Oil (Barrels)	1336106128	$87.04	$116,294,677,381.12
Natural Gas)	8086818515	$4.15	$33,560,296,837.25
Peat (metric tons)	10008485.22	$25.37	$253,915,270.05
Masonry Cement (metric tons)	10446419.08	$143.00	$1,493,837,928.87
Clay (metric tons)	91038725.08	$12.00*	$1,092,464,701.01
Stone -Crushed + Dimension (metric tons)	2166782102	$4.78**	$10,357,218,448.56
Silver (troy oz.)	8932683	$23.87	$213,223,143.21
Portland Cement (metric tons)	296067256.5	$93.50	$27,682,288,481.08
Lime (metric tons)	41696381.35	$121.10	$5,049,431,781.60
Coal (metric tons)	41957856.91	$84.00 ^	$3,524,459,980.55
Sand and Gravel (metric tons)	3257617928	$7.65	$24,920,777,147.08
		Total:	**$441,308,304,601.51**

*- Common clay average price 2013

**-Average price 2011

^-Average price from 2013 from Statista Coal statistics

Disclaimers

- How was the production data compiled for these charts?
  - A variety of sources were used – old Michigan Geological Survey Publications (pre-1940 data; data from 1948-1977); U.S. G.S. Mineral Yearbooks (1940-1948 and post-1977 data); Coal data from a USGS publication on MI coal (Cohee et al., 1950)
- How was this data gathered?
  - Michigan used to have a state official gather production data
    - Act #9 of 1877 appointed a Commissioner of Mineral Statistics – who gathered production data and published annual reports
    - Act #9 was repealed and replaced by Act #7 of 1911 – which transferred the role of data collection and reporting to the Michigan Geological Survey
    - Act #57 of 1995 repealed Act #7
    - Currently there are no requirements for either the Geological Survey, the DEQ or DNR to collect mineral production data
  - USGS – compiles production data from **voluntary surveys** of individual companies across the country
    - There are no requirements to report data
- How accurate is this data?
  - The available data likely underestimates mineral production.
  - However the trends look right.

Michigan Natural Resources: A survey of Production Statistics

Presented by Dr. Peter Voice

Where did this data come from?

- Sifted through:
  - Older Michigan Geological Survey Annual Statistical Summaries (and predecessor series) – pre-1980 data
  - U.S. Bureau of Mines Annual Reports – pre-1930 data
  - U.S. Geological Survey Mineral Yearbooks – individual commodity reports and Mi domestic area reports (all post-1980 data, and 1940's data)

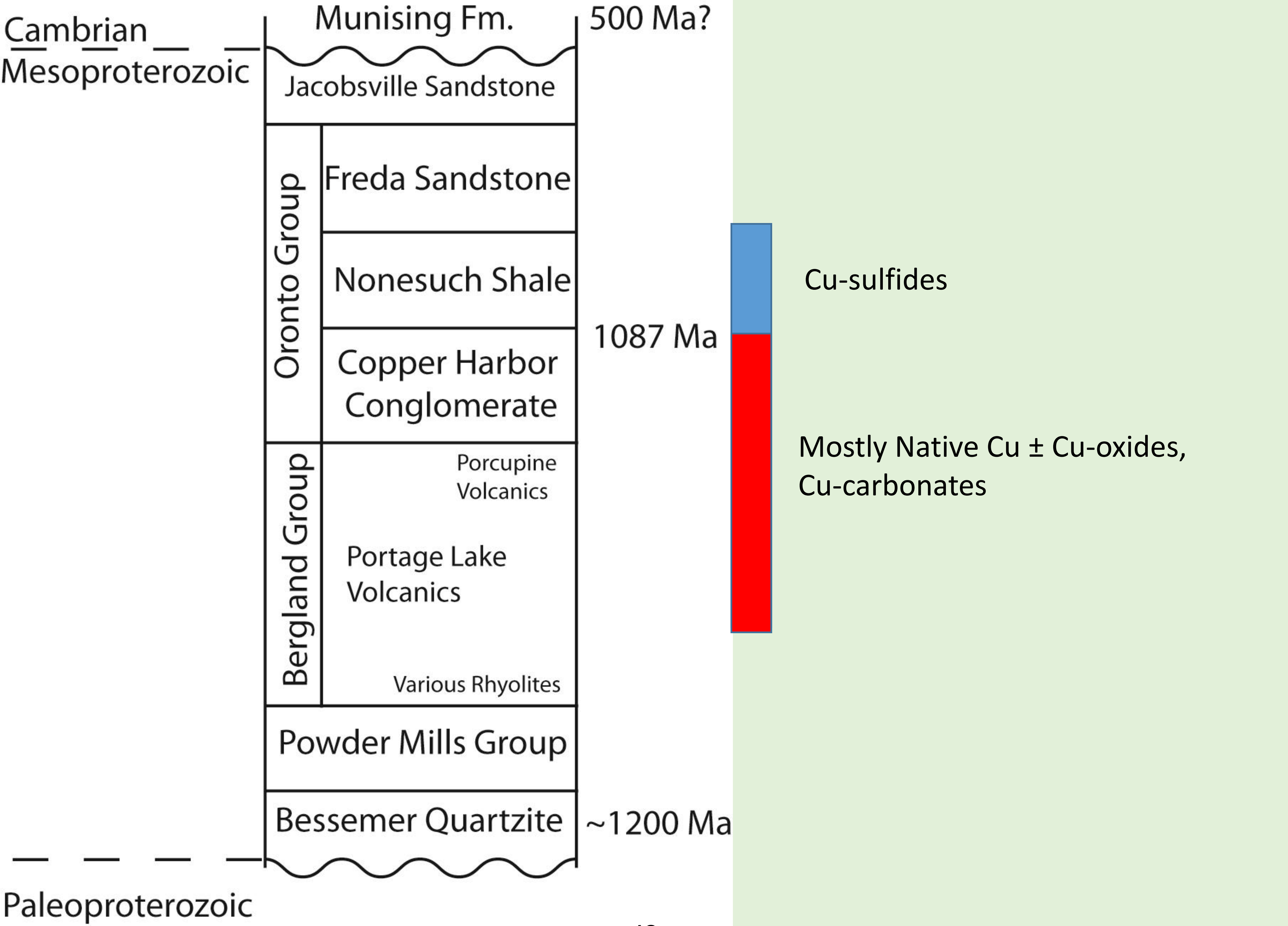
  - Because of the vintage of many of the sources – had to be very careful with units
    - Salt – sold by the barrel (~250 lbs), then in short tons, then in metric tons!

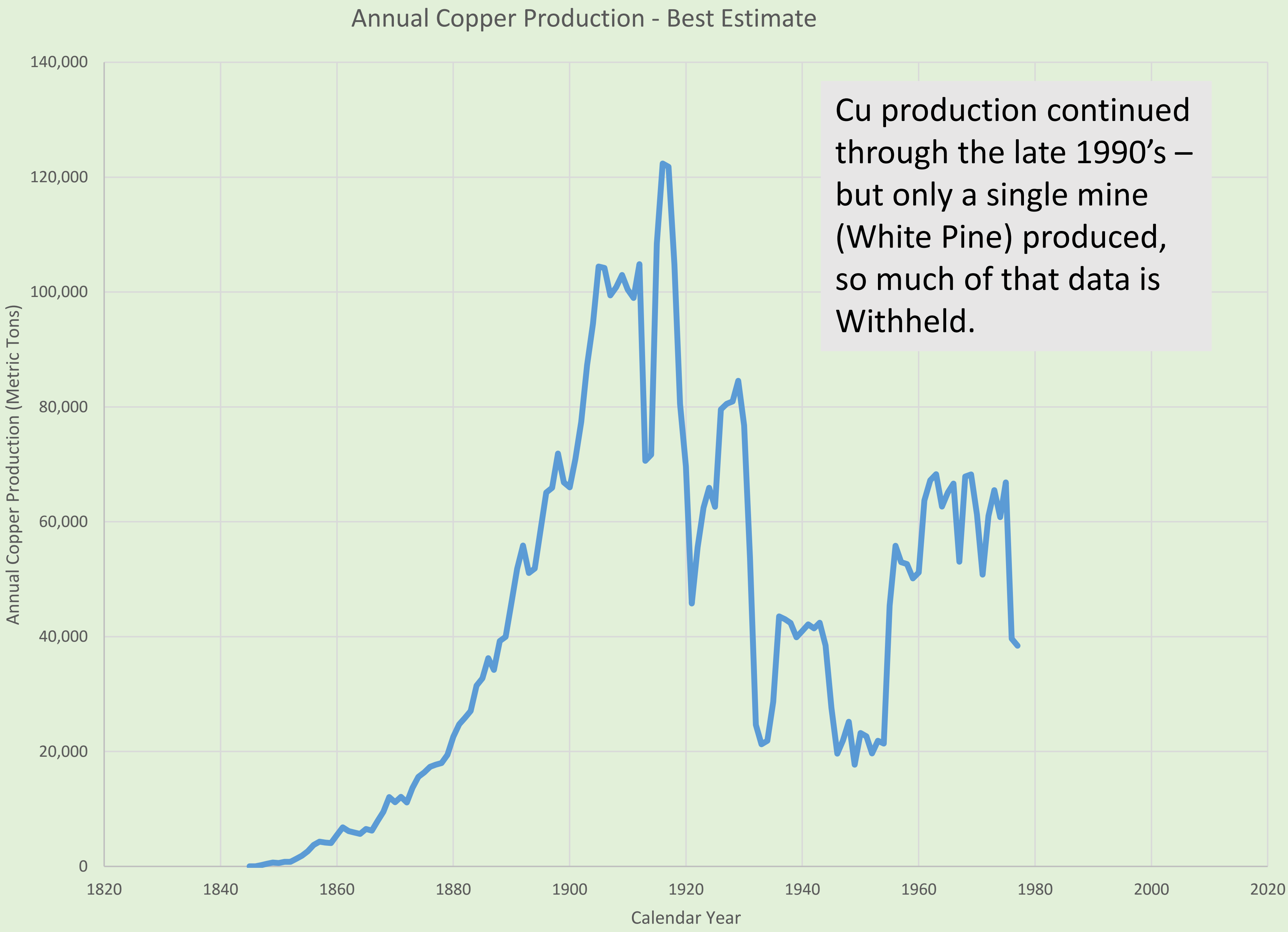
Types of Resources

- Mineral Resources
  - Metallic Minerals
  - Nonmetallic Minerals
- Aggregate Resources
- Energy Resources
- Groundwater

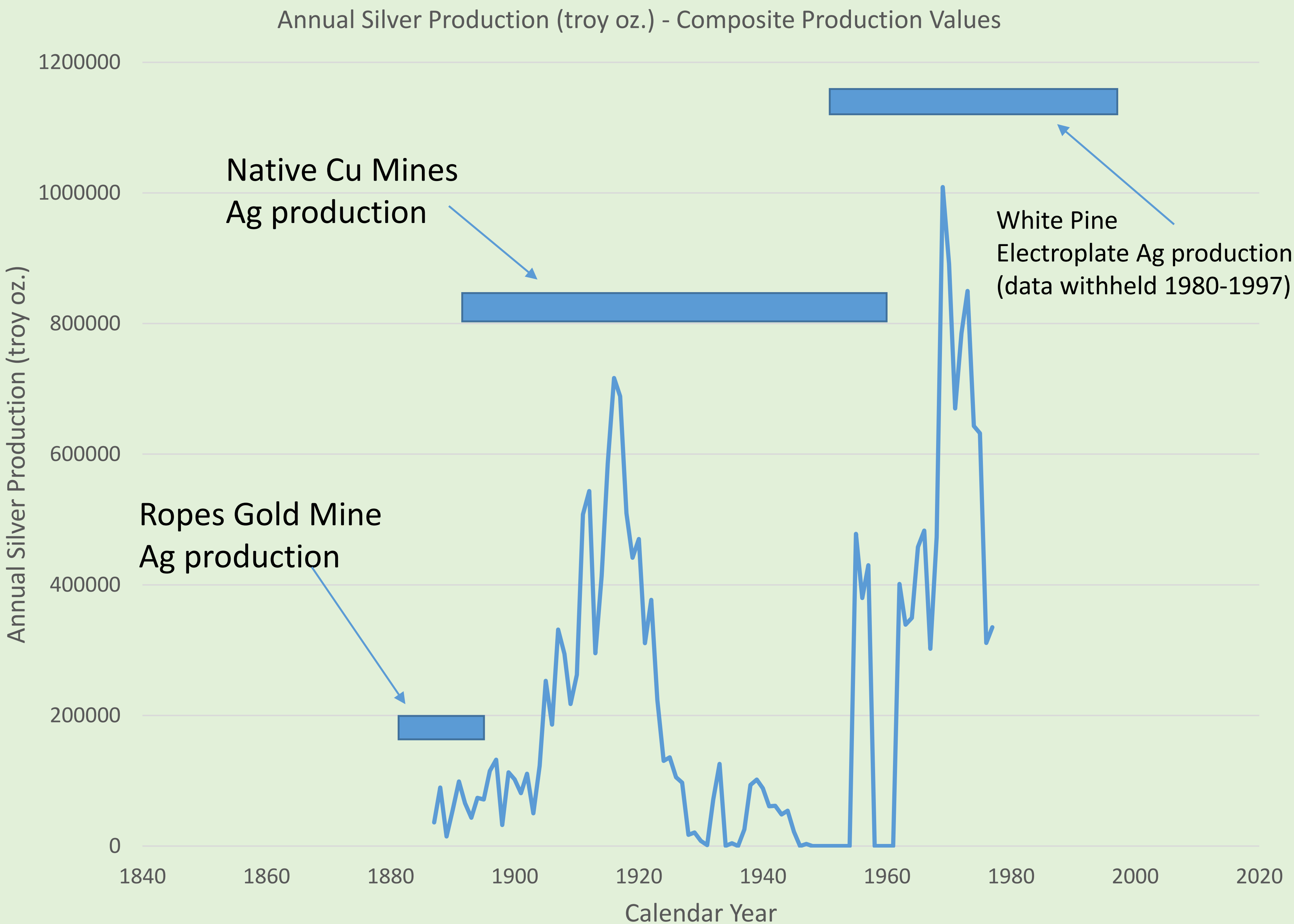
Metallic Minerals

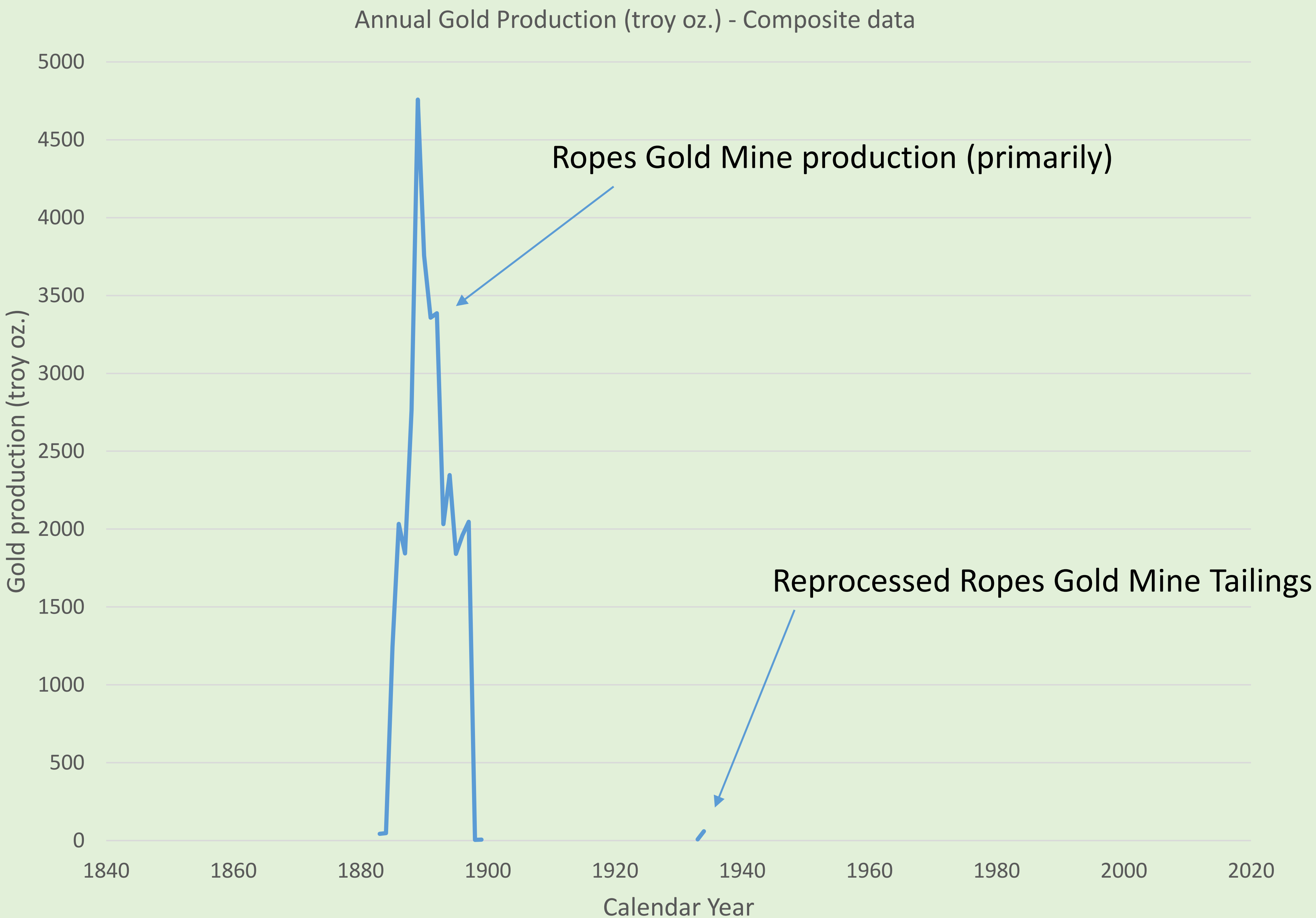
- Upper Peninsula resources (mainly Western UP)
  - Gold – associated with peridotite (olivine-rich rock) – very minor resource
  - Copper (± Silver; Nickel, Zinc, Platinum Group Elements)
    - Keweenaw area and west
    - New Eagle Mine (Cu-Ni, PGE)
    - Back Forty Project (at permitting stage – also has some Zn)
  - Iron Ore (± Manganese)
    - Three major trends – Marquette Range (last mine closing this year); Crystal Falls-Menominee Range; Gogebic Range

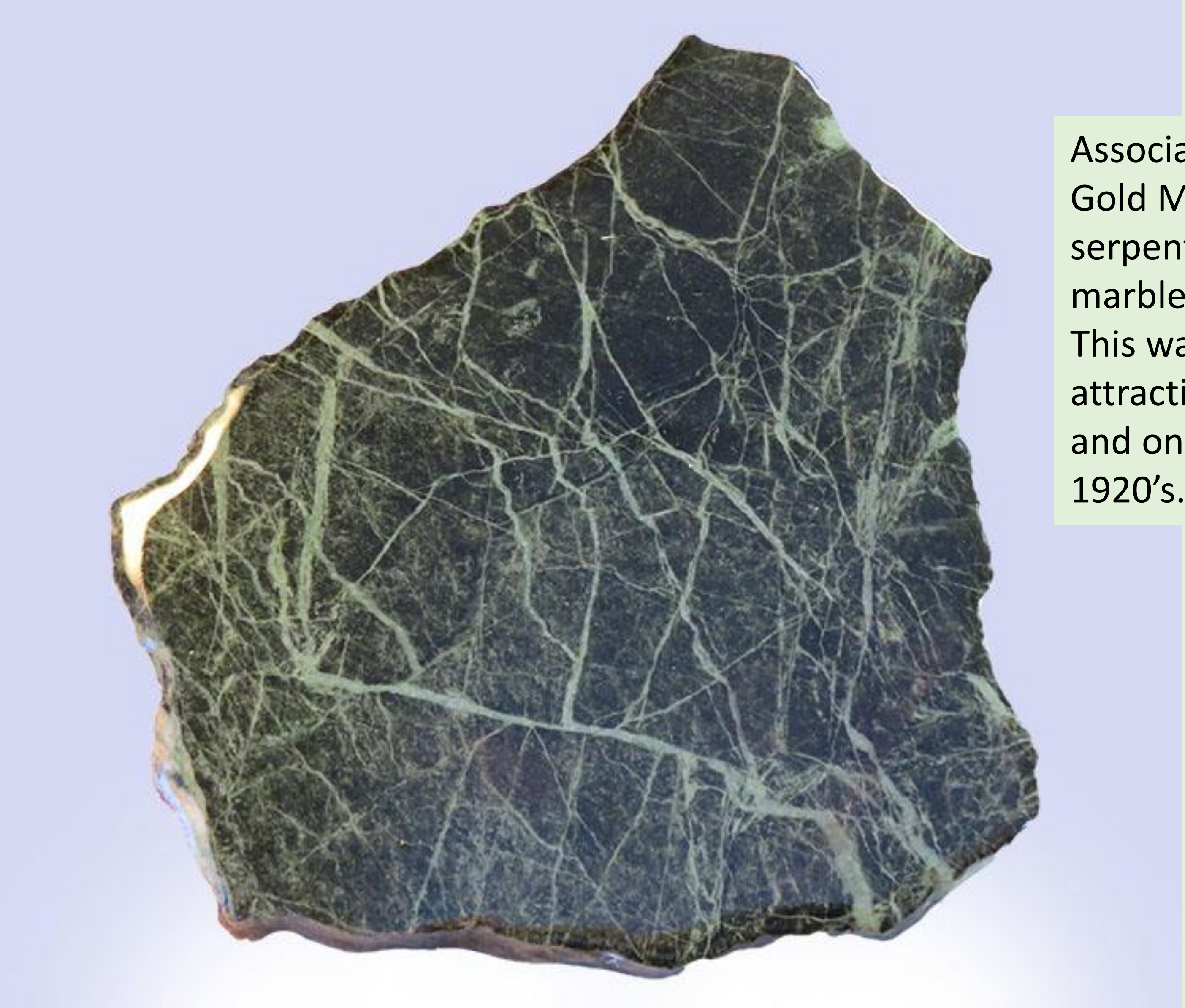

Cambrian
Mesoproterozoic
Munising Fm.
500 Ma?
Jacobsville Sandstone
Oronto Group
Freda Sandstone
Nonesuch Shale
Copper Harbor Conglomerate
1087 Ma
Bergland Group
Porcupine Volcanics
Portage Lake Volcanics
Various Rhyolites
Powder Mills Group
Bessemer Quartzite
~1200 Ma
Paleoproterozoic Basement
Cu-sulfides
Mostly Native Cu ± Cu-oxides, Cu-carbonates



Annual Copper Production - Best Estimate
Annual Copper Production (Metric Tons)
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1820
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Calendar Year
Cu production continued through the late 1990's – but only a single mine (White Pine) produced, so much of that data is Withheld.

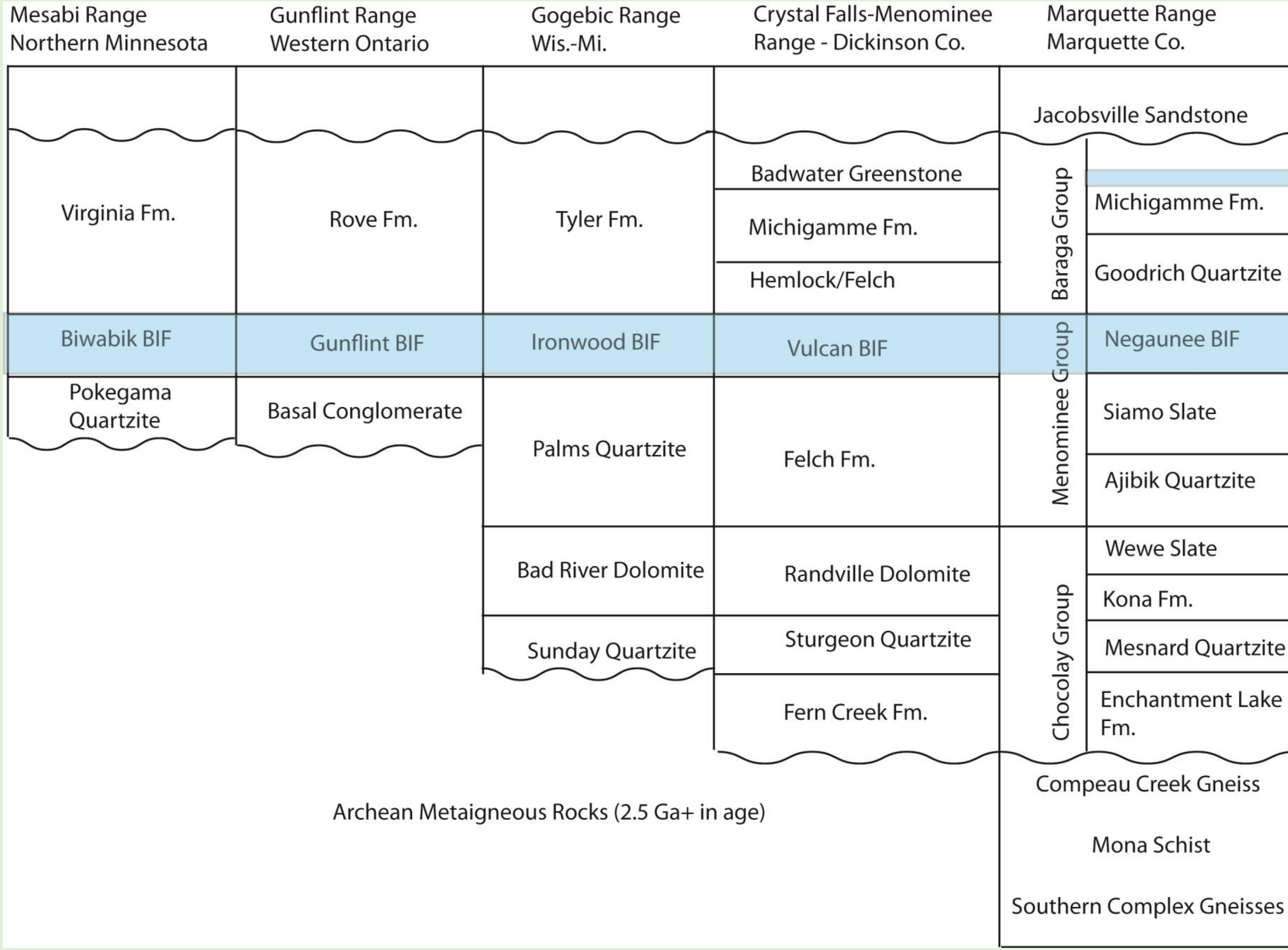

Annual Silver Production (troy oz.) - Composite Production Values
Annual Silver Production (troy oz.)
1200000
1000000
800000
600000
400000
200000
0
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Calendar Year
Native Cu Mines
Ag production
White Pine
Electroplate Ag production
(data withheld 1980-1997)
Ropes Gold Mine
Ag production

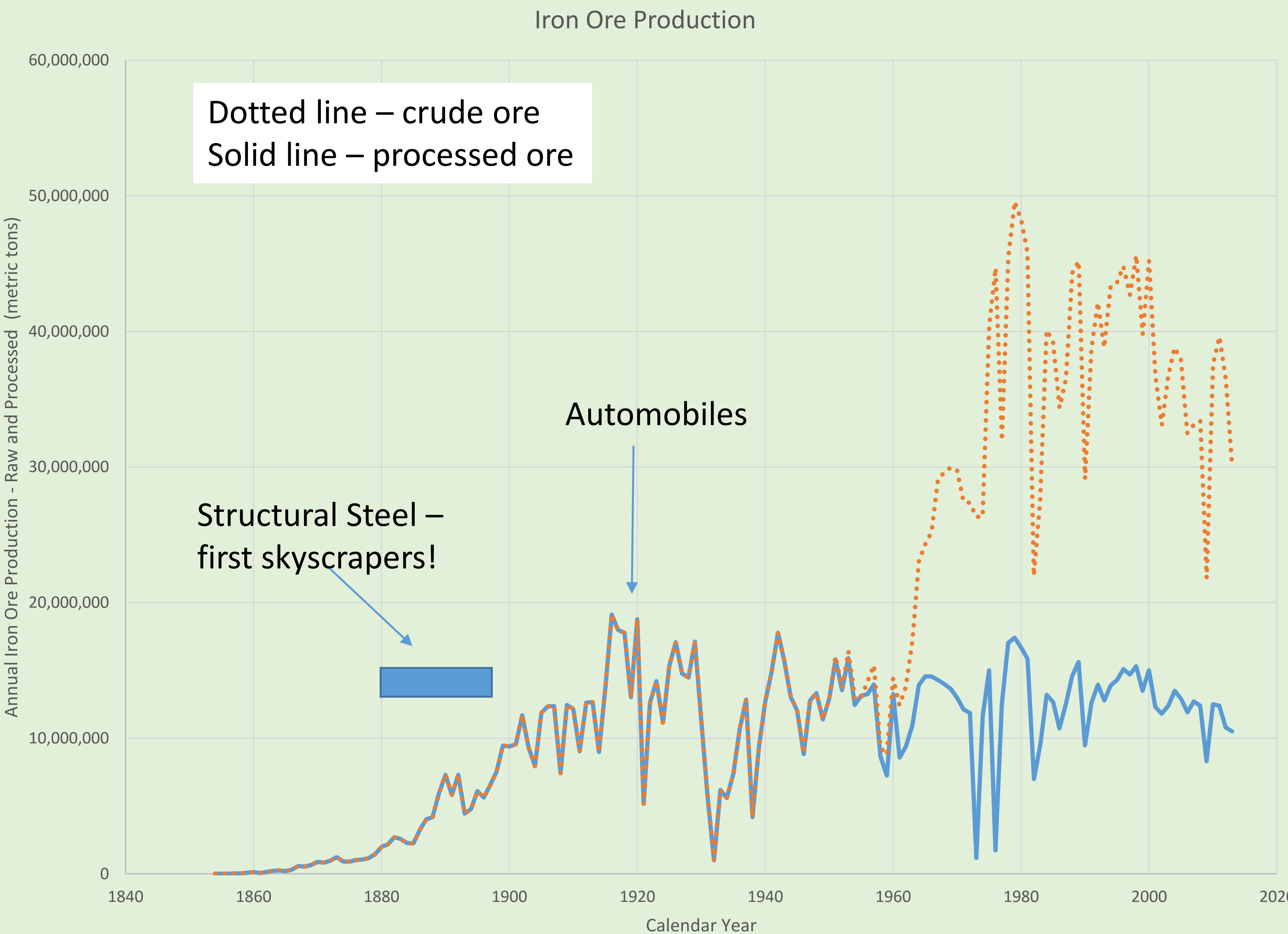

Annual Gold Production (troy oz.) - Composite data
Gold production (troy oz.)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Calendar Year
Ropes Gold Mine production (primarily)
Reprocessed Ropes Gold Mine Tailings



http://dayoopers.com/

Associated with the Ropes Gold Mine area are serpentinized dolomitic marbles, called *Verde Antique*. This was quarried for an attractive dimension stone off and on from the 1880's to 1920's.


Mesabi Range
Northern Minnesota
Gunflint Range
Western Ontario
Gogebic Range
Wis.-Mi.
Crystal Falls-Menominee
Range - Dickinson Co.
Marquette Range
Marquette Co.
Virginia Fm.
Biwabik BIF
Pokegama
Quartzite
Rove Fm.
Gunflint BIF
Basal Conglomerate
Tyler Fm.
Ironwood BIF
Palms Quartzite
Bad River Dolomite
Sunday Quartzite
Badwater Greenstone
Michigamme Fm.
Hemlock/Felch
Vulcan BIF
Felch Fm.
Randville Dolomite
Sturgeon Quartzite
Fern Creek Fm.
Jacobsville Sandstone
Baraga Group
Michigamme Fm.
Goodrich Quartzite
Menominee Group
Negaunee BIF
Siamo Slate
Ajibik Quartzite
Chocolay Group
Wewe Slate
Kona Fm.
Mesnard Quartzite
Enchantment Lake
Fm.
Compeau Creek Gneiss
Mona Schist
Southern Complex Gneisses
Archean Metaigneous Rocks (2.5 Ga+ in age)

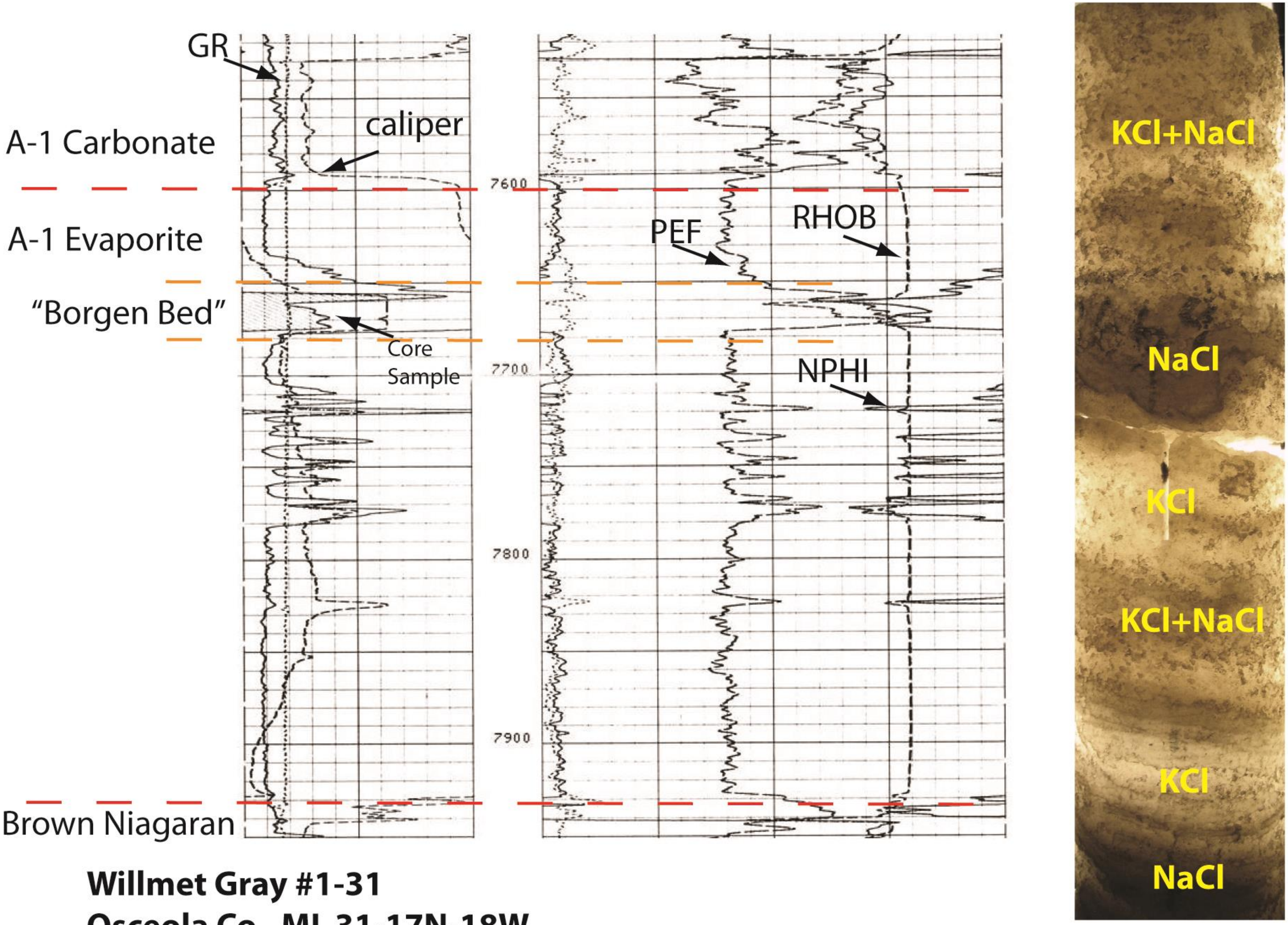

Iron Ore Production
Dotted line – crude ore
Solid line – processed ore
Automobiles
Structural Steel –
first skyscrapers!
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
Annual Iron Ore Production - Raw and Processed (metric tons)
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Calendar Year

Estimated Total Production: Metallic Resources

Commodity	Production
Processed Iron Ore	1,500,000,000 metric tons
Copper	5,887,000 metric tons
Silver	20,530,000 troy oz.
Ferruginous manganese ore	820,000 metric tons
Manganiferous iron ore	516,000 metric tons
Gold	33,600 troy oz.

Nonmetallic Mineral Resources

- Mostly LP production – though historic gypsum production in several rock units in the UP
- Rock Gypsum
- Rock Salt
  - Halite – NaCl salt
  - Sylvite – KCl salt (no active production today; historic production ~160,000 tons per year)
- Brines (Mg, I, Br, Ca, Cl)– data generally withheld – as few operators extract these



Willmet Gray #1-31

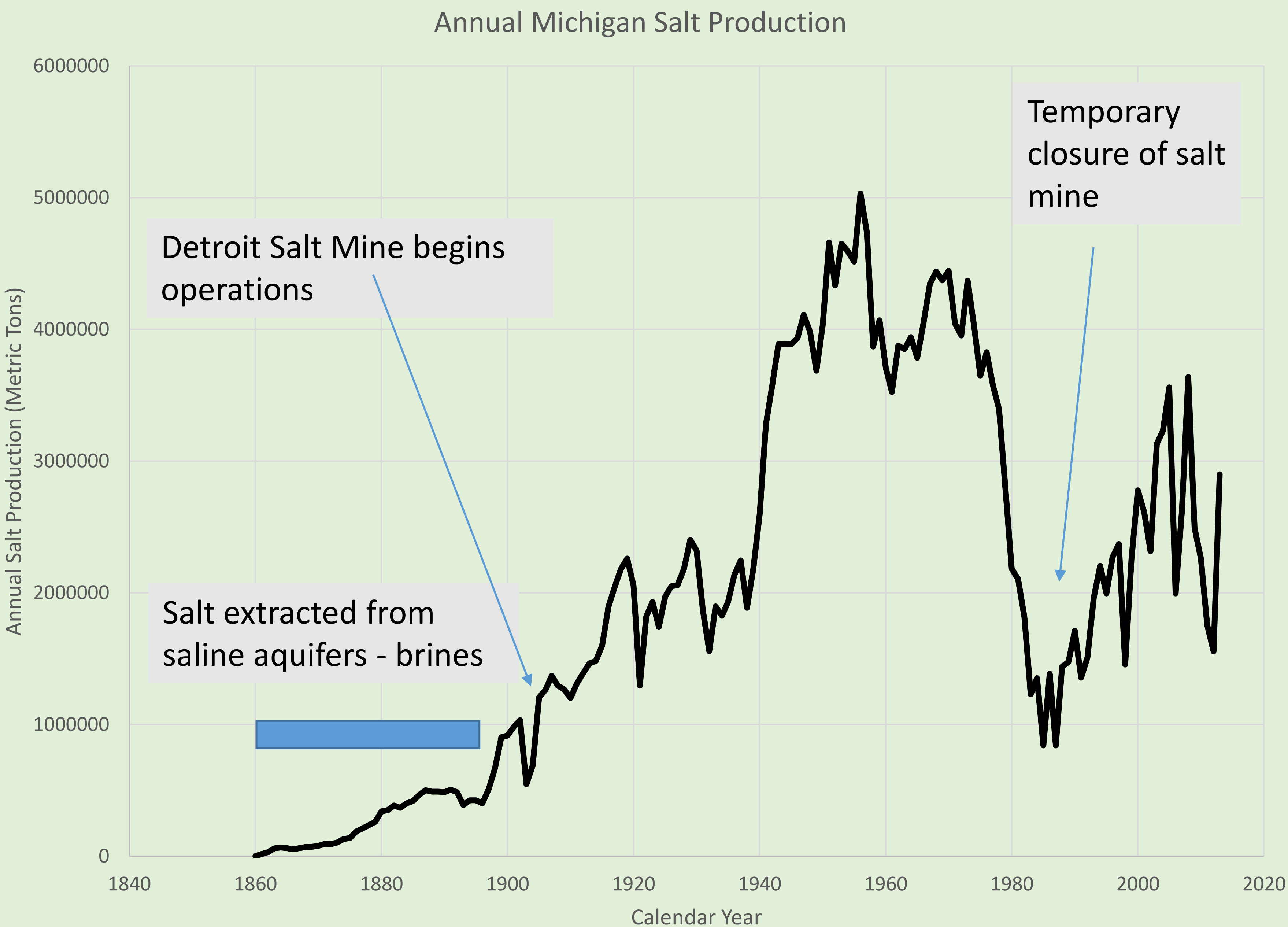
Osceola Co., MI 31-17N-18W

P#: 35800

Core Interval: 2337.4-2337.6 m (7668.5-7669.5 ft)

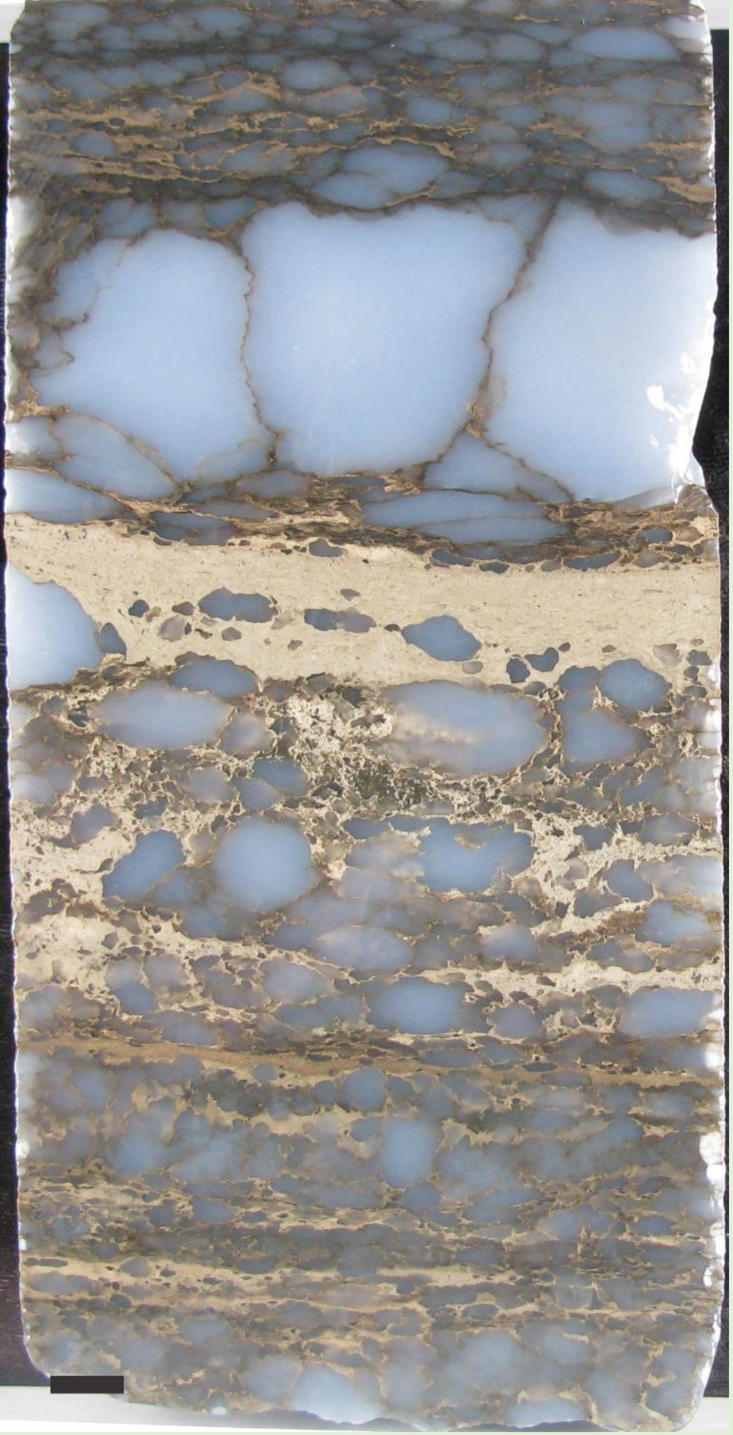
Sample of the C Shale (Salina Group) with secondary red halite cements filling a fracture

Samples of the F Salt (Salina Group) – the unit commercially mined in Detriot



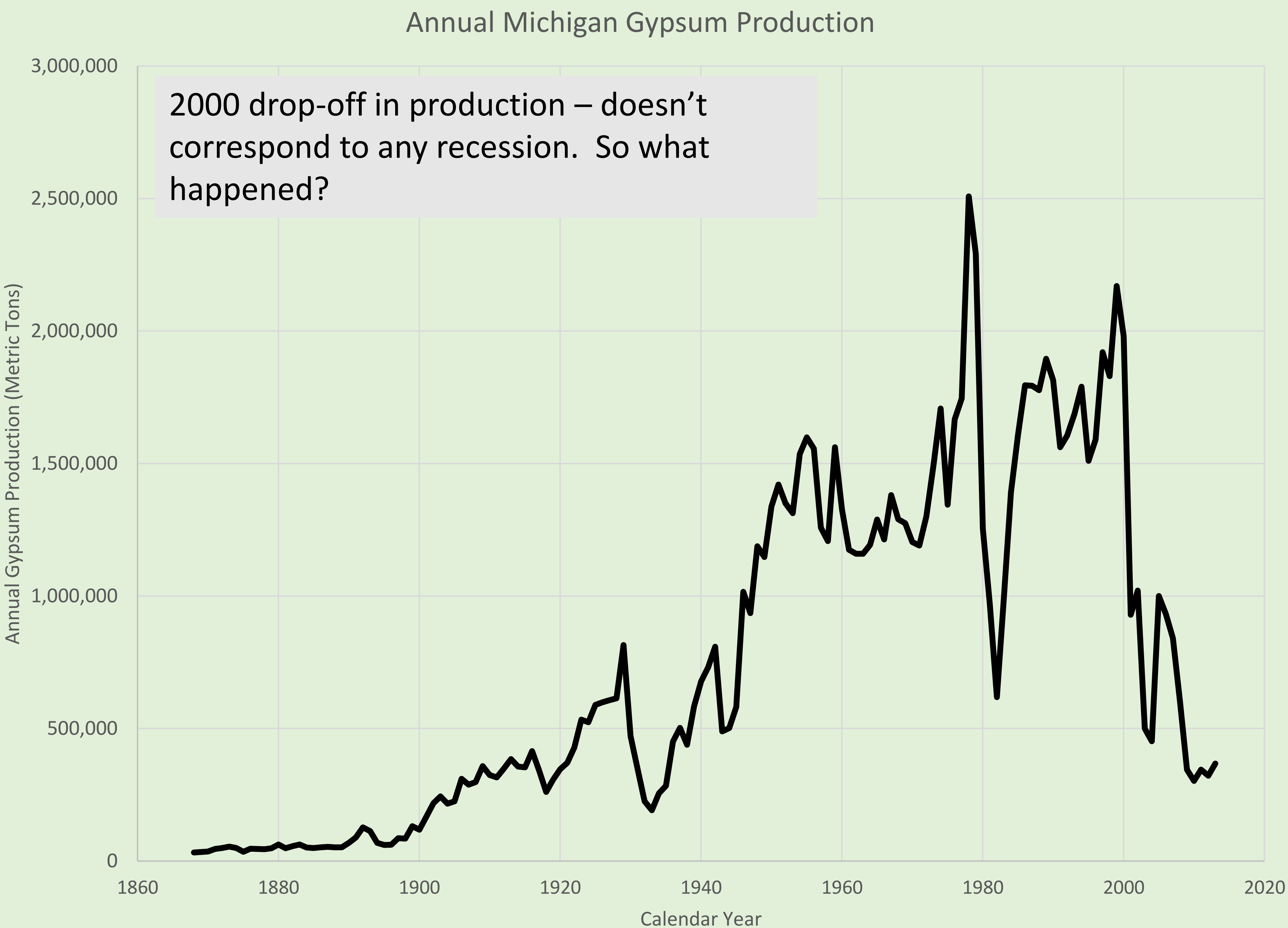
Annual Michigan Salt Production
Annual Salt Production (Metric Tons)
6000000
5000000
4000000
3000000
2000000
1000000
0
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Calendar Year
Detroit Salt Mine begins operations
Temporary closure of salt mine
Salt extracted from saline aquifers - brines

Satin Spar Gypsum – secondary precipitant in the Cabot Head Shale, UP



Anhydrite in the Lucas Formation, Detroit River Group

Anhdyrite in the Michigan Formation – the Michigan Formation was commercially mined in Grand Rapids and is stilled mine at Alabaster.


Annual Michigan Gypsum Production
2000 drop-off in production – doesn’t correspond to any recession. So what happened?
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Annual Gypsum Production (Metric Tons)
1860
1880
1900
1920
1940
1960
1980
2000
2020
Calendar Year

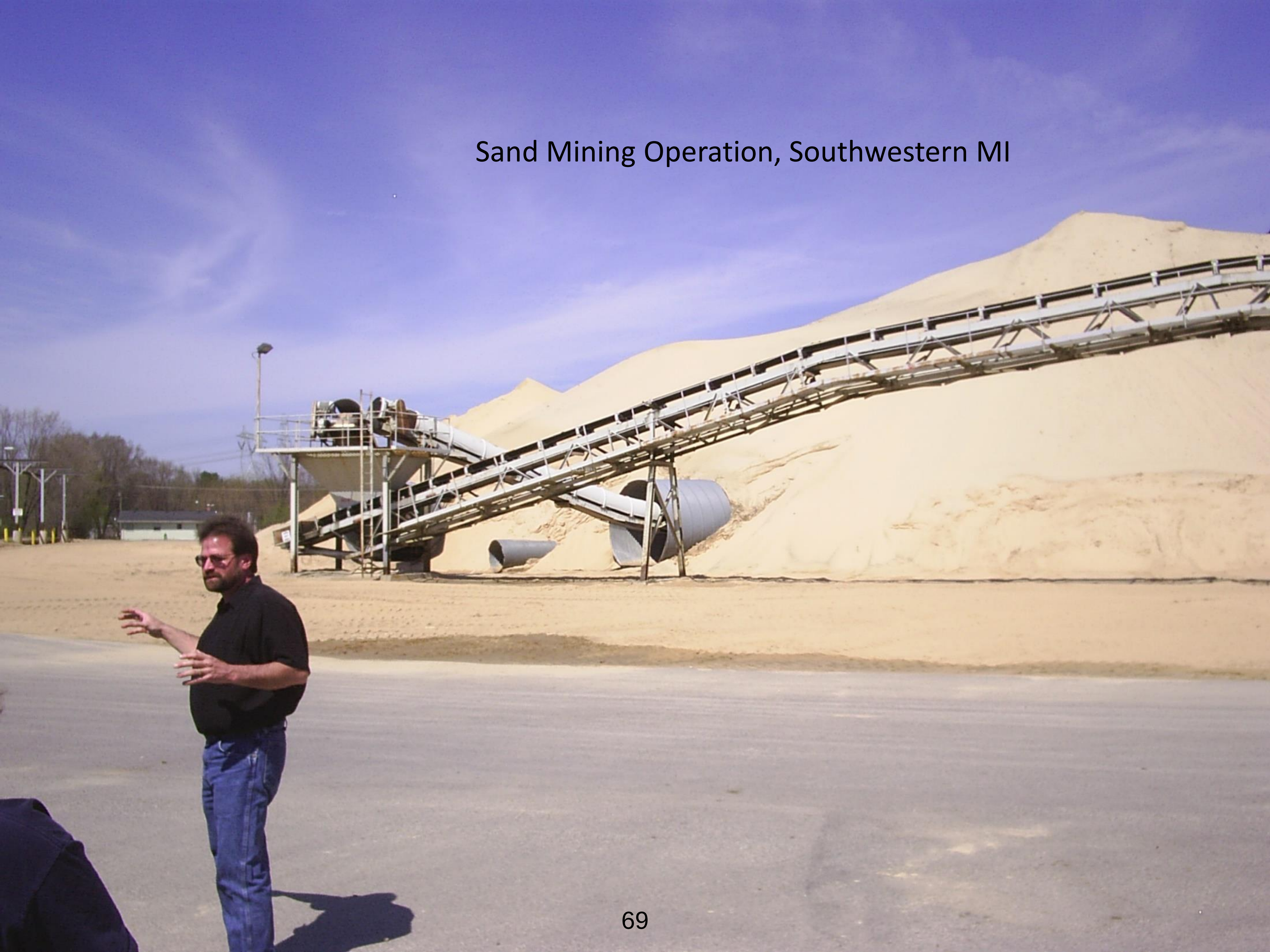
Estimated Total Production: Nonmetallic Minerals

Commodity	Production
Rock Salt	308,000,000 metric tons
Rock Gypsum	110,000,000 metric tons

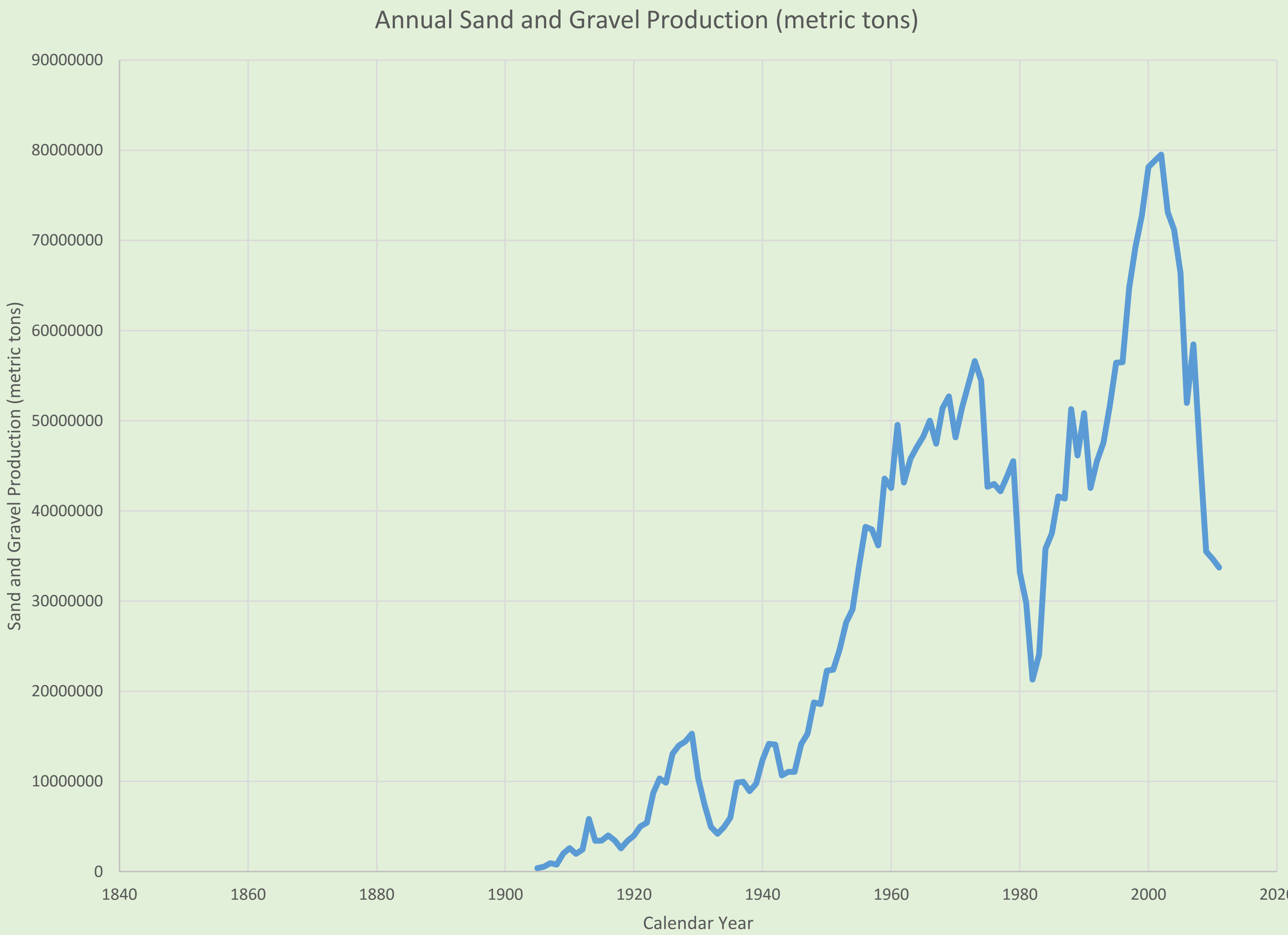
Aggregate Resources

- Mined statewide – though different qualities, and types of materials quarried at different parts of the state
- Sand and Gravel (fill, glass sands, injection mold sands, brick filler, etc.)
- Clay and Shale (bricks and tiles, ceramics)
- Cement
- Lime
- Crushed Stone
- Dimension Stone

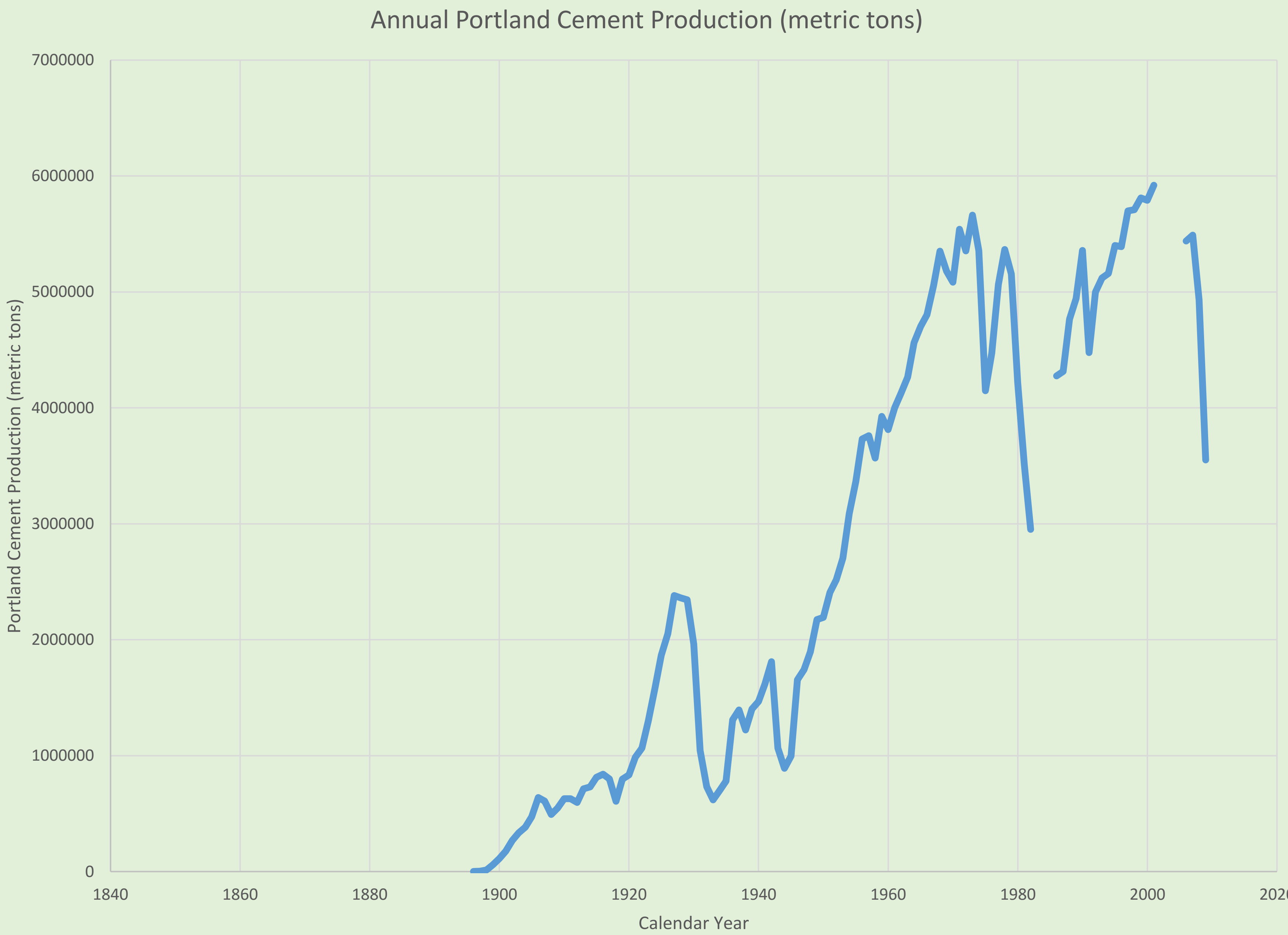

Sylvania Sandstone,
Sylvania Minerals Quarry, Monroe Co.
Glass Sands
Note upper darker layer – glacial till



Sand Mining Operation, Southwestern MI


Annual Sand and Gravel Production (metric tons)
Sand and Gravel Production (metric tons)
90000000
80000000
70000000
60000000
50000000
40000000
30000000
20000000
10000000
0
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Calendar Year

Traverse Group Limestones – Quarried at Charlevoix

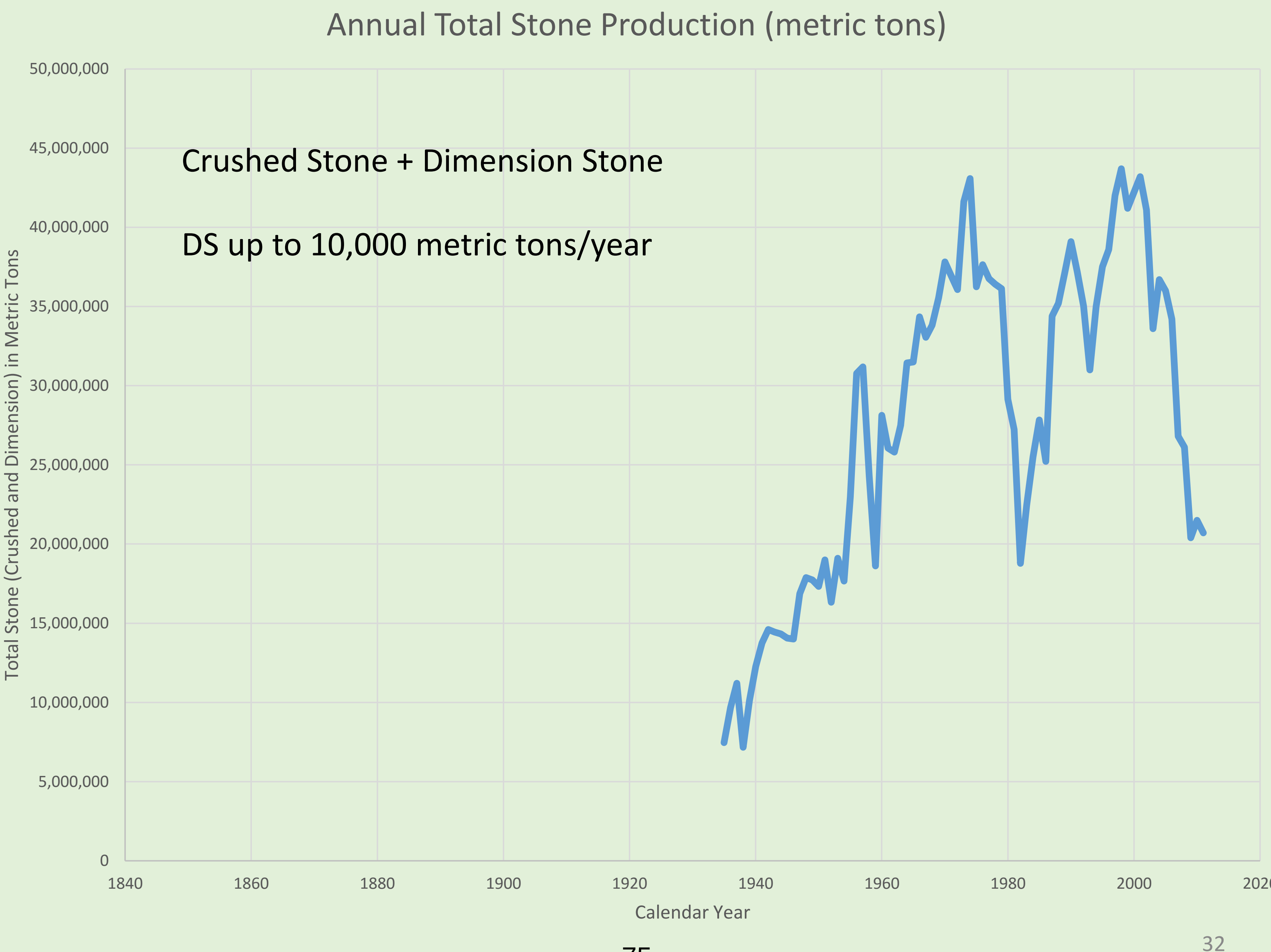


Annual Portland Cement Production (metric tons)
7000000
6000000
5000000
4000000
3000000
2000000
1000000
0
Portland Cement Production (metric tons)
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Calendar Year

Sawheidle Quarry, near Manistique, MI

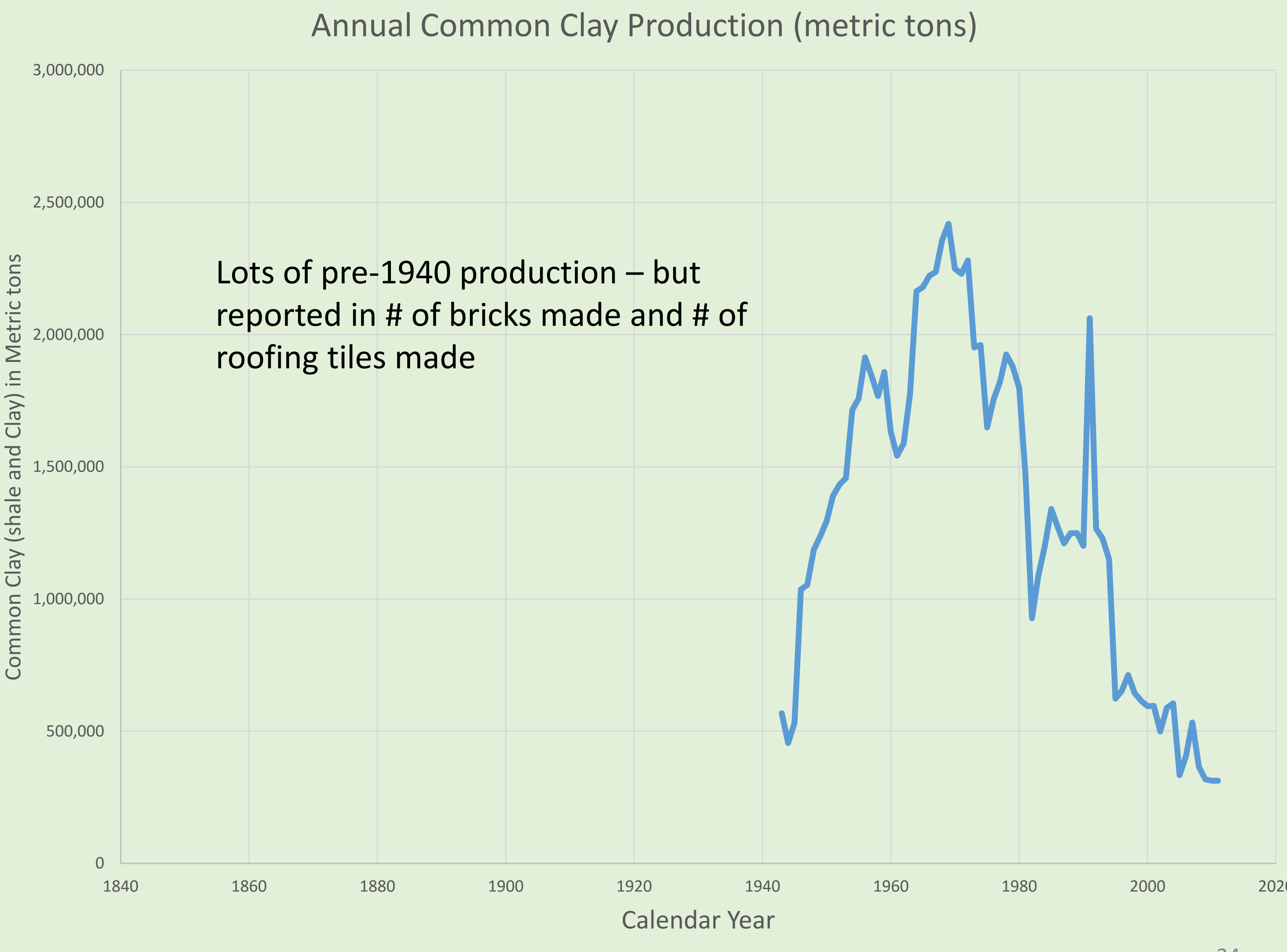
Crushed Rock – Dolomite from the Burnt Bluff Group

Stromatoporoid sponge,
Engadine Dolomite
Drummond Island Quarry
– crushed stone


Annual Total Stone Production (metric tons)
Crushed Stone + Dimension Stone
DS up to 10,000 metric tons/year
50,000,000
45,000,000
40,000,000
35,000,000
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
0
Total Stone (Crushed and Dimension) in Metric Tons
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Calendar Year
32

http://is0.gaslightmedia.com/michigantrailmaps/

Ruins of Lincoln Brick Factory,
Lincoln Brick Park
Grand Ledge, MI

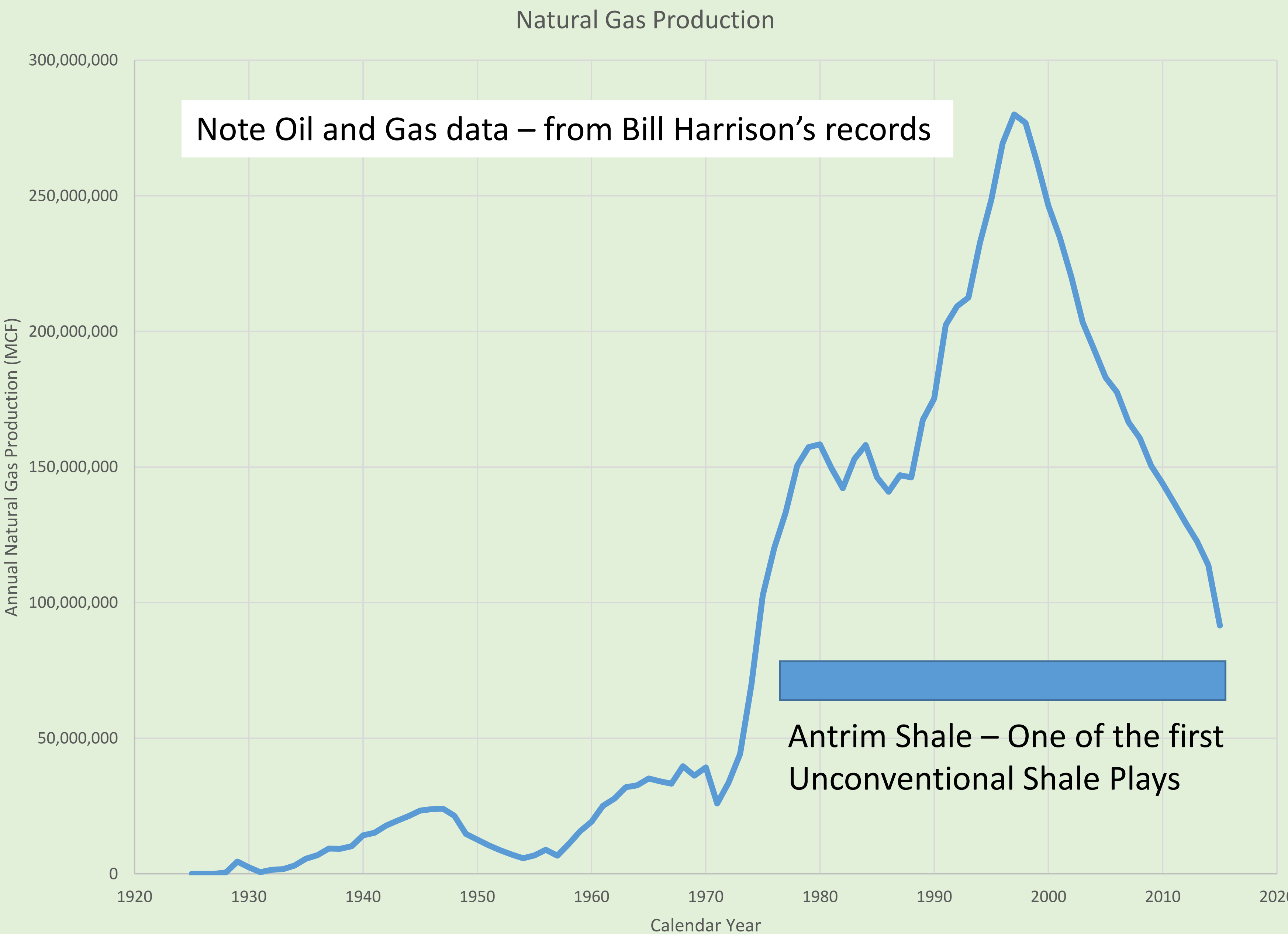

Annual Common Clay Production (metric tons)
3,000,000
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Common Clay (shale and Clay) in Metric tons
Lots of pre-1940 production – but reported in # of bricks made and # of roofing tiles made
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Calendar Year
34

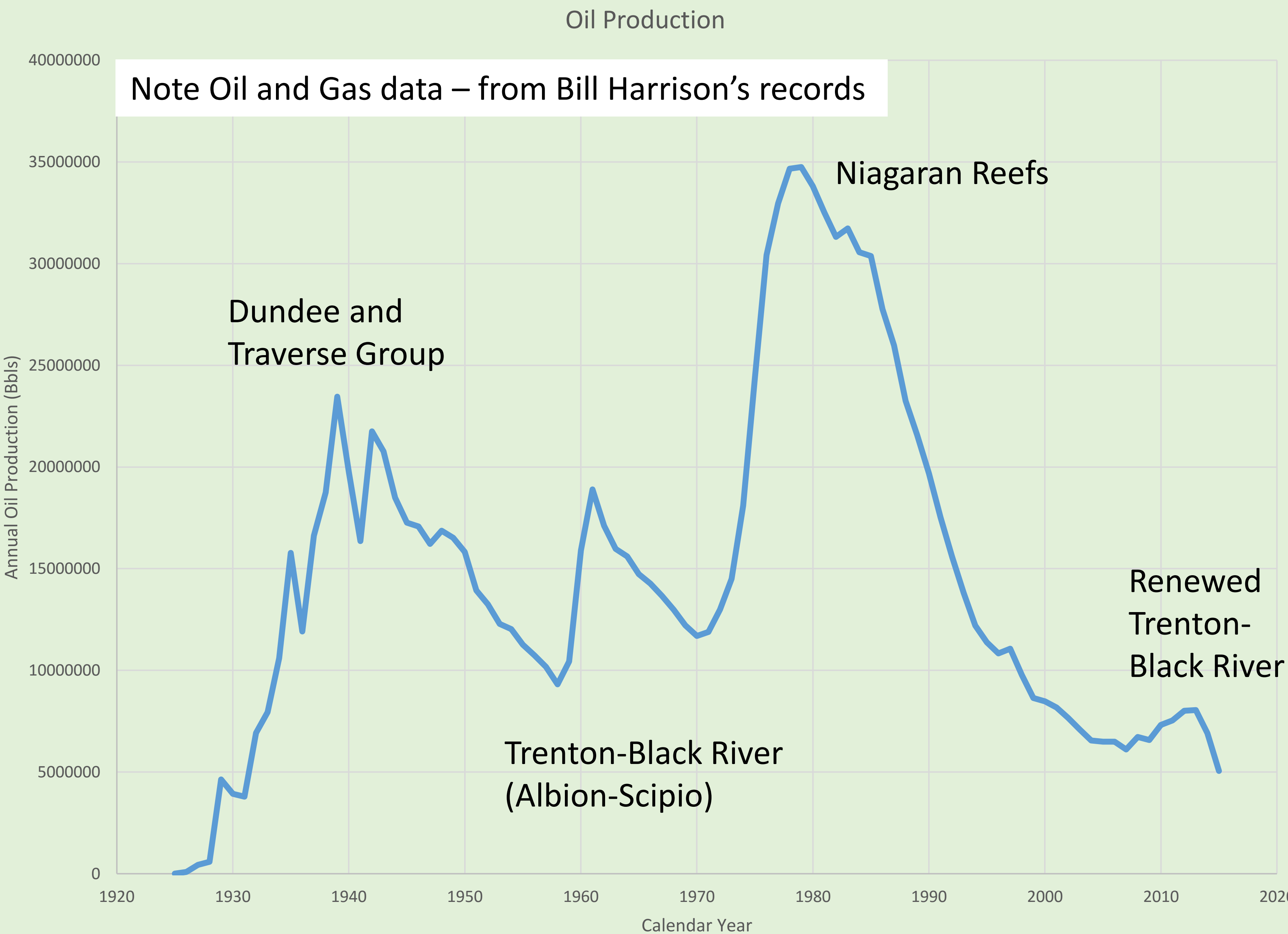
Estimated Total Aggregate Production

Commodity	Production
Masonry Cement	10,500,000 metric tons
Portland Cement	296,000,000 metric tons
Clay	91,000,000 metric tons
Lime	42,000,000 metric tons
Sand and Gravel	3,258,000,000 metric tons
Stone (Crushed + Dimension)	2,166,000,000 metric tons

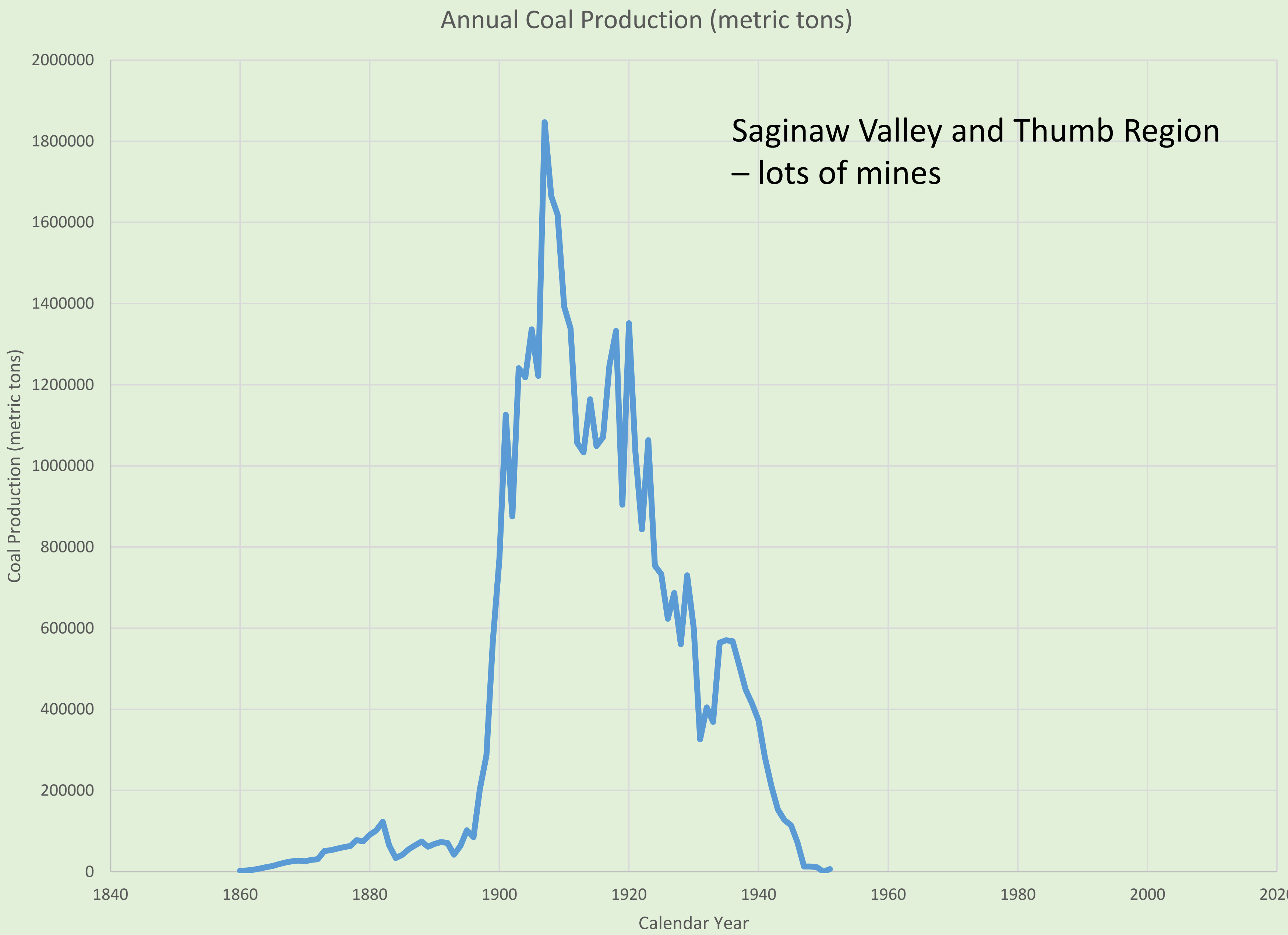
Energy Resources

- Lower Peninsula Resources – some exploration in the UP – but nothing productive
- Oil
- Natural Gas
- Coal (historic production – none today)


Natural Gas Production
Note Oil and Gas data – from Bill Harrison's records
Antrim Shale – One of the first Unconventional Shale Plays
Annual Natural Gas Production (MCF)
300,000,000
250,000,000
200,000,000
150,000,000
100,000,000
50,000,000
0
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Calendar Year


Oil Production
Note Oil and Gas data – from Bill Harrison's records
40000000
35000000
30000000
25000000
20000000
15000000
10000000
5000000
0
Annual Oil Production (Bbls)
Dundee and
Traverse Group
Niagaran Reefs
Renewed
Trenton-
Black River
Trenton-Black River
(Albion-Scipio)
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Calendar Year


Coal Seam – Saginaw Fm., Grand Ledge, MI


Annual Coal Production (metric tons)
Saginaw Valley and Thumb Region
– lots of mines
Coal Production (metric tons)
2000000
1800000
1600000
1400000
1200000
1000000
800000
600000
400000
200000
0
1840
1860
1880
1900
1920
1940
1960
1980
2000
2020
Calendar Year

Estimated Energy Resources Production

Commodity	Production
Oil	1,336,000,000 barrels
Natural Gas	8,086,000,000 cubic feet
Coal	42,000,000 metric tons
Peat	10,000,000 metric tons

Final Thought

- If we had to go back and mine these resources again – at 2013 prices, they would be worth approximately $500,000,000,000

CORE Kids

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