ME589/Geol571/GEOC 589-04D/GEOL 589-04/GEOL 589-04D Advanced Topics

Mineral Deposits in New Mexico

Virginia T. McLemore

Safety

Image from SSR website

Fatal Powered Haulage Accident October 31, 2017

MSHA Investigations - No. 26-02081

John Booker Grab – Safety Share 2/1/2021

Rudimentary Driving Rules While on a Mine Site:

“Haul trucks and other large surface mining vehicles are capable of destroying smaller vehicles that cannot be seen by the operator. Traffic controls, training, and avoiding distractions are key to enhancing safety. “ (MSHA)

- - Communicate and verify with all equipment operators any planned movements and location upon entering or exiting a work area.
- - Ensure all persons are trained to recognize workplace hazards. Specifically, train equipment operators on the limited visibility and blind spot areas that are inherent to the operation of large equipment. Do not drive or park smaller vehicles in mobile equipment's potential path of movement
- - Instruct all operators on the importance of using flags or strobe lights on the cabs of their vehicles to make haulage truck operators aware of their location. Flags must be high enough to be in the view of equipment operators.

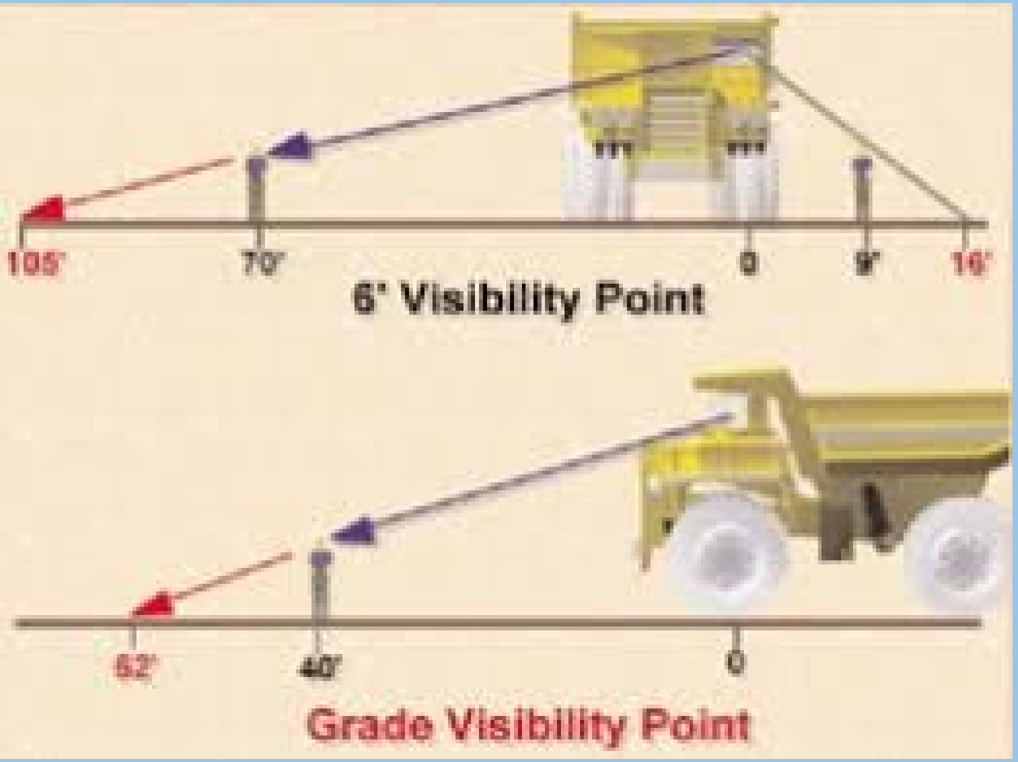


Image from MSHA - Mobile Equipment at Surface Mines

October 31, 2017 Marigold Mine

6:00a.m - Eight new hires meet the mine safety superintendent to begin in-processing and safety training.

1:40p.m - The eight new employees dawned their ppe and got into a van to begin an introductory mine tour with the mine safety superintendent .

1:50p.m - The mine safety superintendent requested permission to go into the pit so the new employees could observe the 2:00p.m blast. They were told that they could go ahead by mine ops, but to be careful because the area was congested with two parked haul trucks.

1:55p.m - The mine safety superintendent got verbal permission to pass one of the parked haul trucks, but did not inform the other haul truck of their approach, and proceeded to park on the right side of the second haul truck.

2:00p.m - The roadblock was set for the blast zone and all vehicles were grounded until the all-clear radio message at 2:05p.m

2:06p.m - The second Haul truck driver honked his horn twice, put the truck into forward gear, released the brake and began to turn sharply to the right. The driver applied the throttle and felt hesitation. The driver heard “481 stop, stop, stop” over the radio and immediately stopped the truck.

2:07p.m - The mine safety superintendent and a new hire did not escape before the loaded (582.25 ton) haul truck crushed the front of the van. The seven other new hires were able to jump out the rear door unscathed.

Complacency kills

- - The van operator, who had over 25 years of mine experience, did not make radio contact and visual contact with the operator of mobile equipment. In addition, the van operator parked in the blind spot of the 340-ton haul truck.
- - In response, SSR updated policies and procedures and developed new training materials, adding information concerning blind spot awareness and communication. Using the updated policies and procedures and new training material, the operator retrained the workforce.

Image of the aftermath of the accident - MSHA

Field Trips

First field trip—Lemitar Mountains

- Volunteer to find best time
  - Afternoon (3-4 hrs)
  - High clearance vehicles (no Durangos)—pickups (2 people)
  - Drivers (me, Haley, Ethan, others?)
  - **Feb 4, 7, 9-11**
- Who will video for those unable to attend?
  - Maybe we can try a Zoom?
- Field trip report required (by yourself or as a team)
  - You are tasked with examining this site and reporting to your boss
  - Is this deposit worth further investigation by your company

Second field trip—Winston area (Monticello diatomite, Winston zeolite mine, Kline kaolin, Taylor Creek tin)

- Feb 19, 2021
  - All day
  - Gravel or paved roads
  - Durangos (3-4 people), pickups (2 people), passenger cars
  - Drivers (me, Haley, Ethan, others?)
- Who will video for those unable to attend?
- Field trip report required (by yourself or as a team)
  - You are tasked with examining these sites and reporting to your boss
  - Are these deposits worth further investigation by your company

Report required

- **If you are not comfortable to attend or you are not feeling well, DO NOT GO**
- Those who can’t go
  - Video on Socorro perlite
  - https://geoinfo.nmt.edu/staff/mclemore/DicaPerl17minmovie.mp4
  - Another video on the web or go on your own trip and photograph or even video

FIELD NOTES

What are field notes?

What are field notes?

- **Done in the field not at camp or office after field work**
- Types
  - Jottings, scratch notes—minimal notes to get you thru, triggers to remind you
  - Diary—personal notes, not for public consumption
  - Log—running account of how you spend your time, what you did, how much you spent
  - Field notes
    - Methodical
    - Descriptive
    - Analytical

Descriptive (facts, observations) and reflective (thoughts)
Can be used in court for legal cases

Field notes

- In field books or field forms or ipad/smart phone or apps
- Pen or pencil or apps?
- Who needs access to field notes?
- Scan field notes or enter into a database
- Bound books vs loose papers vs numbered pages
- Are they required for legal or contract purposes?

Remember—it costs time and money to perform field investigations and it is important to make the best use of that activity

Field Notes

- Not writing down your observations could result in missed data being recorded and lead to inaccurate conclusions about the rocks being studied.
- Field notes allow you to write down descriptions of fossils, minerals, or rocks while they are being collected. This saves time.
- Sketches are also helpful in interpreting geologic events.
- Field notes can be a legal document, and must be saved for future reference.
- Record any deviations from SOPs.

Field Notes

- Record date, time, location, who, weather
- Describe locality, directions, map names
- Sketch
- Photographs
  - Location (lat, long, UTM, datum)
  - Directions
  - Description
  - Direction
  - Relationships
- Other notes, comments, future work, questions

Field Notes

- If you are unsure of the name of a rock, fossil, or mineral, make a description of it, assign a field name or wait until a lab determination is made

- Detailed description
  - Thickness of the beds
  - Describe the rocks
  - Record any fossils or minerals
  - Strike and dip, trend
  - Unique features (layered, cross-bedding, ripple marks)
  - Alteration, mineralization

Field Notes

- Collect samples
  - Date
  - Location
  - Photograph
  - Description
  - Lithology
  - Unit if known
  - Purpose of sampling

Gallinas Mountains Project

Waypoint Entry

Waypoint id: Gal1 | County: Lincoln | State: New Mexico | District id: DIS092

Mine id: NMLI0040 | Date inspected: 8/28/2019 | Geologist: VTM

LOCATION

Latitude: | Longitude: | Coor system: NAD27

UTM easting: 431851 | UTM northing: 3784035 | UTM zone: 13

Township: 1S | Range: 11E | Section: 24, 25 | Elevation:

Location assurance: HHGPSoff | USGS quadrangle: Rough Mountain

Method of obtaining elevation: HHGPSoff | ☑ Where photos taken?

Weather conditions: sunny, warm

DESCRIPTIVE INFORMATION

Sample location: base of Red Cloud dump

Reason for sampling: chemistry, thin section | ☐ Is this legacy data?

☑ Was sample collected? ☑ Is brecciation present? ☑ Is mineralization present?

☑ Is fluorite present? ☑ Is alteration present? ☑ Is hemitization present?

Radiometric reading: 120 cps | Stratigraphy: Yeso sandstone

Visible minerals: fluorite, green mineral

Comments/notes: N20 vertical

MODIFICATIONS

Entered by: VTM | Date of entry: 12/9/2019 | Modified by:

Date of last modification: | Report Source: field

Information needed in field notes to enter in database

Requirements for a 43-101 report

- Item 1: Summary or abstract
- Item 2: Introduction
- Item 3: Reliance on Other Experts
- Item 4: Property Description and Location
- Item 5: Accessibility, Climate, Local Resources, Infrastructure and Physiography
- Item 6: History
- Item 7: Geological Setting and Mineralization
- Item 8: Deposit Types
- Item 9: Exploration
- Item 10: Drilling
- Item 11: Sample Preparation, Analyses and Security

Requirements for a 43-101 report

- Item 12: Data Verification
- Item 13: Mineral Processing and Metallurgical Testing
- Item 14: Mineral Resource Estimates
- Item 15: Mineral Reserve Estimates
- Item 16: Mining Methods
- Item 17: Recovery Methods
- Item 18: Project Infrastructure
- Item 19: Market Studies and Contracts

Requirements for a 43-101 report

- Item 20: Environmental Studies, Permitting and Social or Community Impact
- Item 21: Capital and Operating Costs
- Item 22: Economic Analysis
- Item 23: Adjacent Properties
- Item 24: Other Relevant Data and Information
- Item 25: Interpretation and Conclusions
- Item 26: Recommendations
- Item 27: References

MINING’S INFLUENCE IN HISTORIC CULTURES

Arrowhead clipart from www.firstpeople.us

Critical and strategic minerals will change with time.

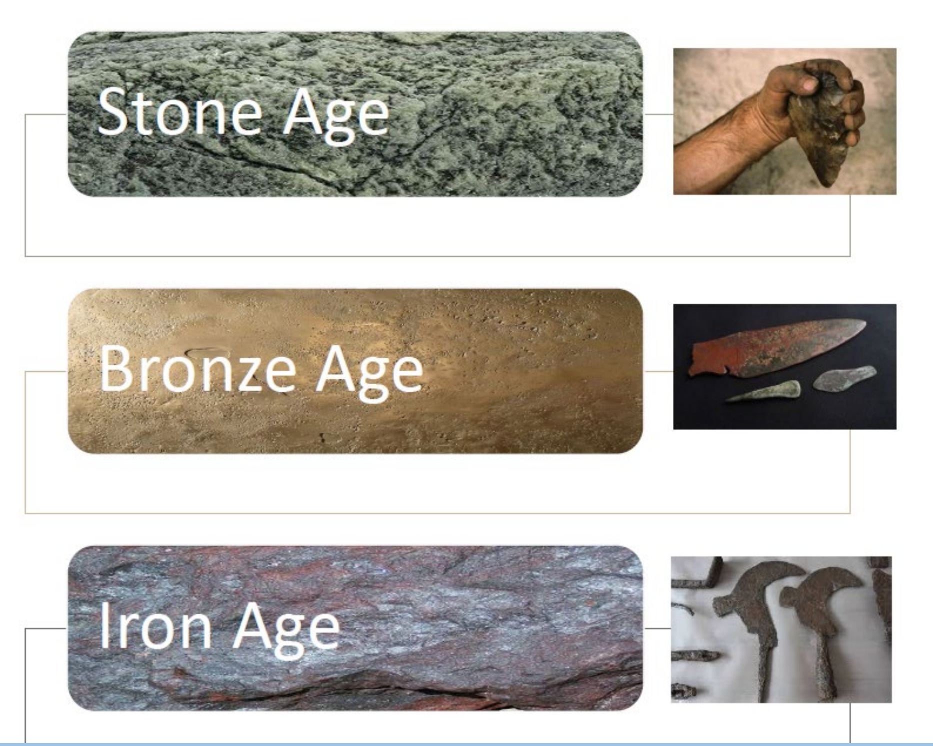
Avatar

Importance of minerals

- Mining began with prehistoric man who wanted to improve their way of life
- Ancient cultures often settled time after time around areas that provided raw materials
- 300,000-100,000 years ago mining of flint in N France and S England
- Throughout history, wars were fought over natural resources

Important Cultural Eras

- Stone Age (prior to 4000 B.C.)
- Bronze Age (4000 to 5000 B.C.)
- Iron Age (1500 B.C. to 1780 C.E.)
- Steel Age (1780 to 1945)
- Nuclear Age (1945 to the present)



- **Early civilisations**: fundamental importance of nonfuel minerals, metals, and materials technology and applications.
  - Stone Age, Copper Age, Bronze Age, Iron Age
  - Discovery of metals: **innovations and applications**
    - Gold (6000 BC), copper (4200 BC), silver (4000 BC), lead (3500 BC), tin (1750 BC), iron (1500 BC), mercury (750 BC)
- **Information Age**: developments in materials science and engineering, mineral exploration, and processing continue to enable and support the development of new technologies

Table 1.1.1. Chronology of Events Related to Mining				
Period—Stage	**Near East—Mediterranean—Africa**	**Central and Northern Europe and Great Britain**	**North and South America**	**Australasia**
BC				c.500,000 Use of fire (China)
Paleolithic		300,000–100,000 Surface mining of flint (N. France, S. England)		
c.20,000	c.40,000 Hematite mined for ritual painting (Africa)	c.30,000 Use of fire, lamps, cave art, hunting with projectiles End of Ice Age		
Late Paleolithic	c.9500 Copper pendant. (Iraq)	c.10,000 Gold ornaments		

Mining Engineering Handbook

When was the first mine?

Certainly after agriculture????

How would you find the answer to this question?

When was the first mine?

- Prehistoric man used chert and flint as tools 450,000 years ago
- Nazlet Khater 4 site, Nile Valley, Upper Egypt 33,000 yr
- British flint quarries
- Krzemionki Opatowskie,Southern Poland
  - Upper Palaeolithic
  - Middle and Neolithic (4500 B.C.)
  - Early Bronze Age

When was the first underground mine?

- Bomvu Ridge, Swaziland
- Hematite
- 40,000 years old
- crude methods of ground control, ventilation, haulage, hoisting, lighting, and rock breakage

http://media.wiley.com/product_data/excerpt/11/04713485/0471348511.pdf

Krzemionki Opatowskie,Southern Poland

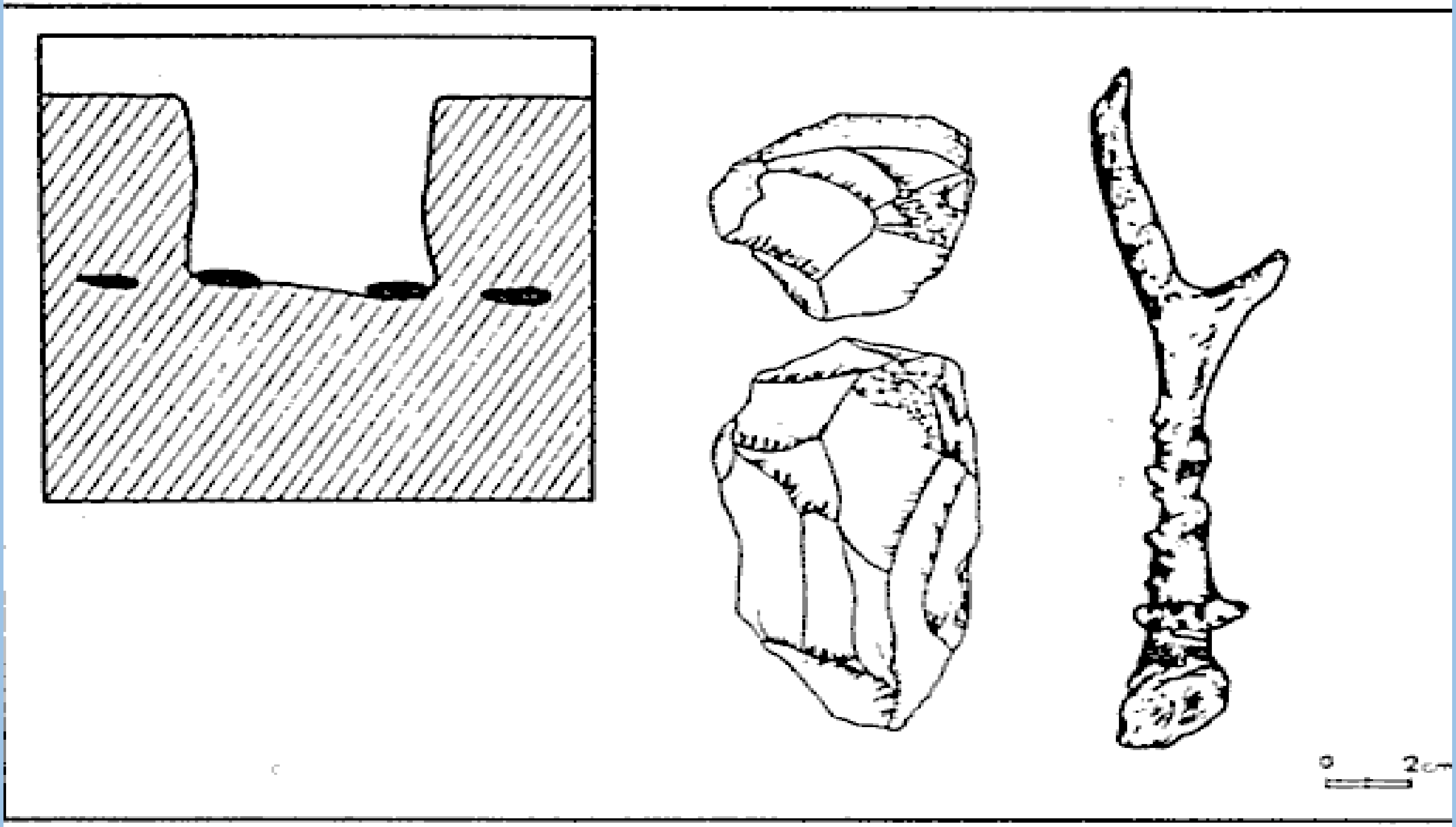


Fig. 1. From the left: scheme of a pit-mine, miner tools.

http://archterra.cilea.it/exhibits/archweb/pocz_gor.htm

Krzemionki Opatowskie,Southern Poland

Photo 22. Widok kopalni filarowej.

Photo 26. Widok kopalni filarowej.

http://archterra.cilea.it/exhibits/archweb/pocz_gor.htm

When was the first mine?

- Prehistoric man used soapstone
- Fleur de Lys quarry, Newfoundland
- Maritime Archaic peoples used it approximately 4,000 years ago

Small Soapstone Vessels from Fleur de Lys.
Soapstone vessels were used as lamps and cooking pots. Lamps were generally used for lighting purposes or for heating suspended cooking pots. Cooking pots were used for cooking meals and were either suspended over an open fire or soapstone lamp or placed directly into an open fire.

http://www.heritage.nf.ca/environment/soapstone.html

Old Testament recognized the land of Ophir (Zimbabwe), which was somewhere in Africa, as a source of gold

African mining sites

- Zimbabwe 20,000 to 26,000 BC
- Swaziland 50,000 BC

http://www.anvilfire.com/21centbs/stories/rsmith/biblical_1.htm

History of mining in southern and east Africa

Ancient mines

World's first underground mine at Lion Cavern, Swaziland; built by San people (20 000-43 000 BP years)

Engraved ochre from Blombos Cave was the first evidence of human art (75 000 BP years)

Iron, copper and tin smelting (c. AD 200)

Venda-type iron smelting furnace from 1888

Traditional products, such as, hoes, arrow heads, and assegais produced until ~1950s

Gold artefact found at Mapungubwe (c. 1220-1270)

Other uses of minerals in ancient societies

- Egyptians replaced water clocks with sand hour glasses
- Greek and Romans made concrete-like structures that are still standing today
- Building stones used in many ancient cultures

Lets look at a commodity in more detail

SALT

- NaCl
- table salt
- essential to life (man 2-5 gr/day)
- salt was used as a preservative, tanning leather, stock, mining
- salt was used to preserve Egyptian mummies

Why is salt important?

SALT

- Trade in salt was very important; salt was valuable enough to be used as currency in some areas.
  - Salt cakes
- The Latin phrase "salarium argentum," "salt money," referred to part of the payment made to Roman soldiers.

- http://www-geology.ucdavis.edu/~gel115/salt.html

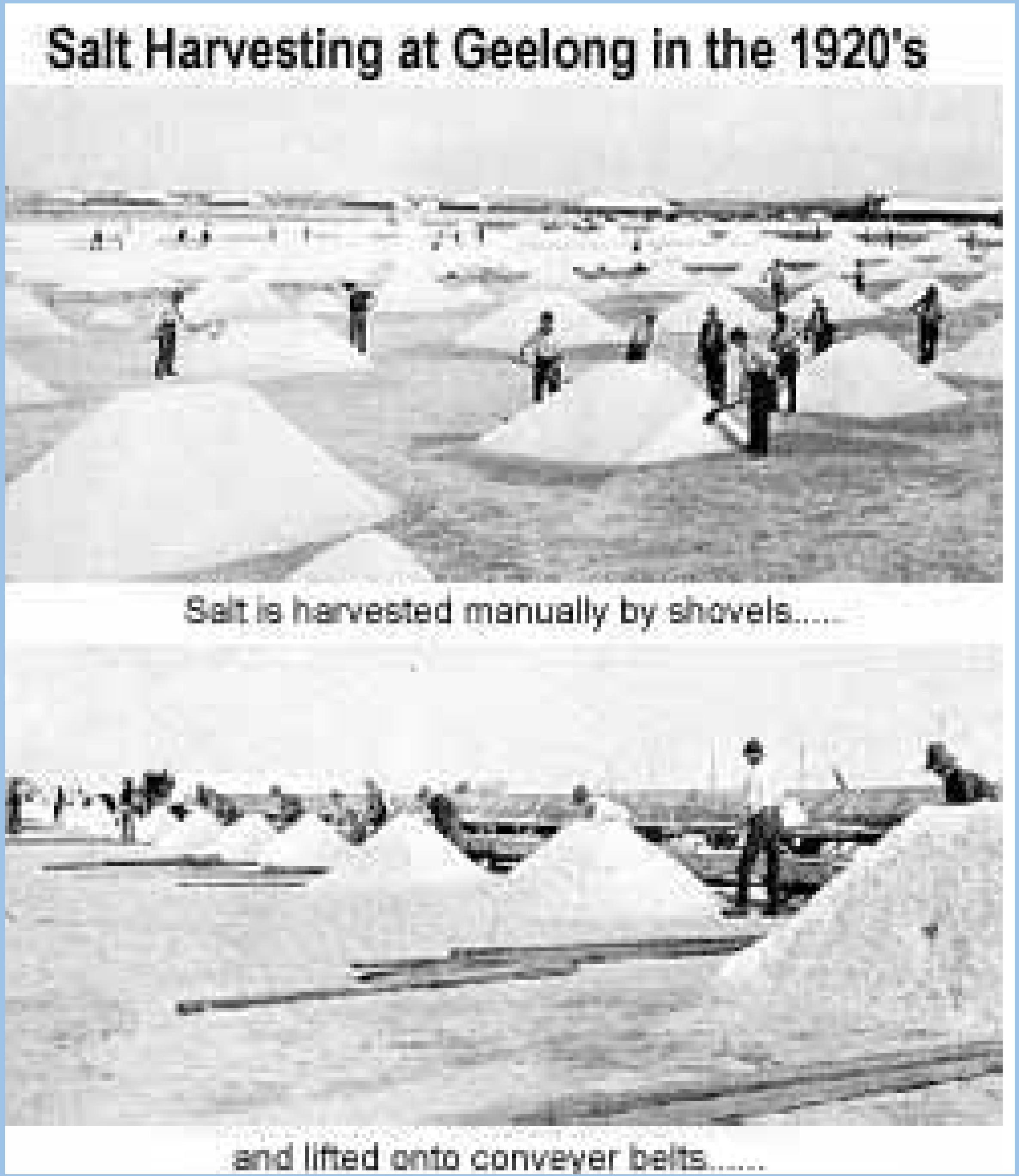
- Greek worshippers consecrated salt in their rituals
- in the Old and New Testaments, covenants were sealed with salt
- Jewish "KASHRUT" [hygiene] tradition and law, involves the dehydration of meat for its preservation
- Catholic Church used salt in purifying rituals
- Buddhist believed salt repeals evil spirits
- Pueblo people worship the Salt Mother

Blocks of pure salt cut from the earth sit stacked in rows awaiting carriers in Taoudenni, as a miner removes earth from his pit mine.

http://www.ask.com/main/metaAnswer.asp?t=ai&s=a&MetaEngine=directhit&en=te&eo=1&o=7039&frames=True&url=http%3A%2F%2Fwww%2Esaltinstitute%2Eorg%2F3%2Ehtml&ac=24&adcat=jeev&pt=The+Salt+Industry&dm=http%3A%2F%2Fwww%2Esaltinstitute%2Eorg%2F3%2Ehtml&io=0&qid=F258E627CA006B41B7CDB7AF2837895D&back=origin%3D7039%26ask%3Dsalt%2Bmining%26search%3Dsalt%2Bmining&ask=salt+mining&dt=030107155051&amt=&pg=1&qsrc=0

Caravans across the Sahara basin carrying salt across the desert to the trading centers of Karta, Bambara, Cairo and Timbuktu.

http://www.cheethamsalt.com.au/



Mining salt in 1920s at The Cheetham Salt mine, Australia

http://www.cheethamsalt.com.au/

The star of David used to crystallise salt in salt pans in Mexico, La Concordia - from "Maya Salt Production and Trade - Antony P. Andrews " courtesy Gertrude Blom.

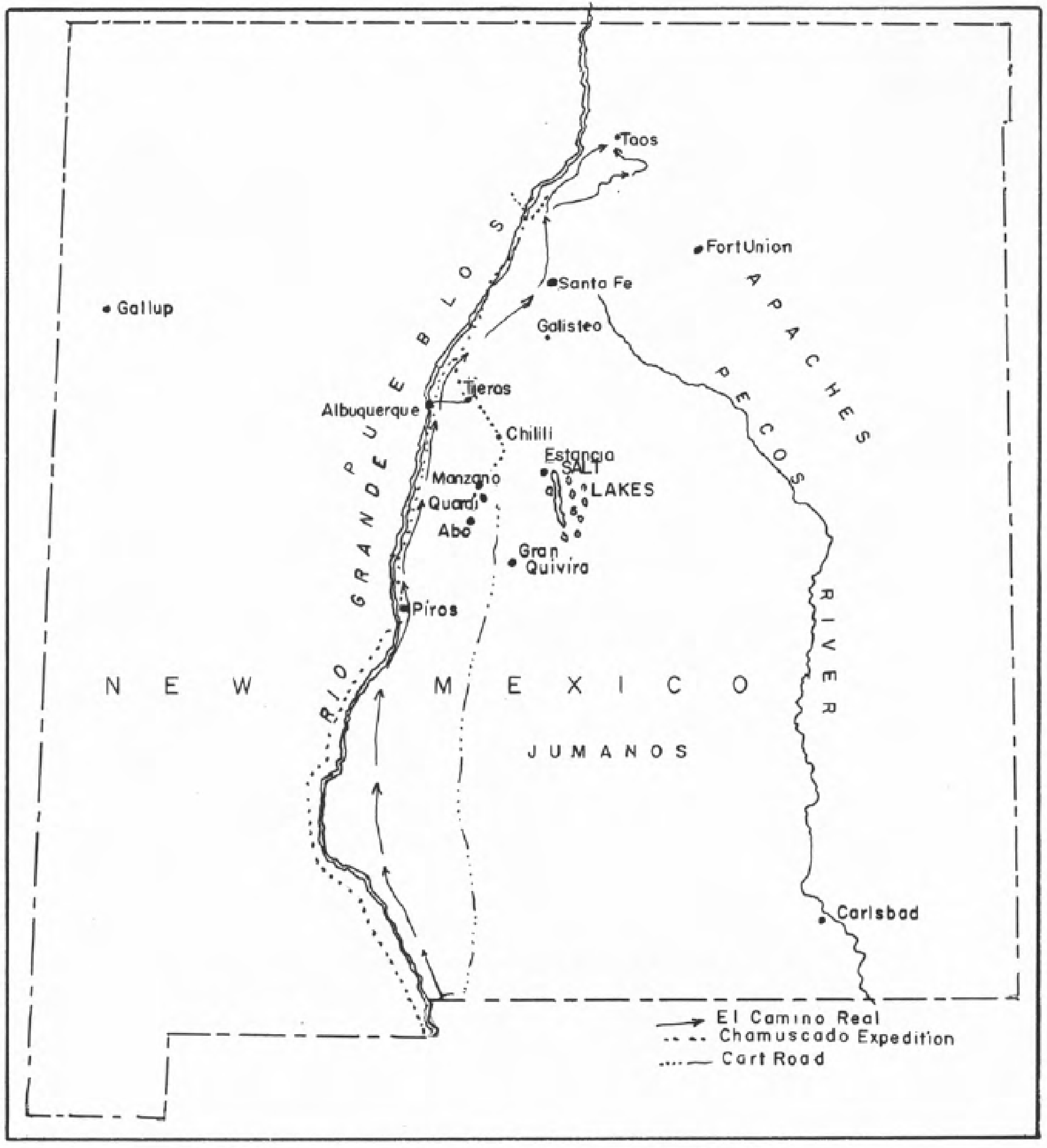
http://salt.org.il/frame_rel.html

Salt in Austria

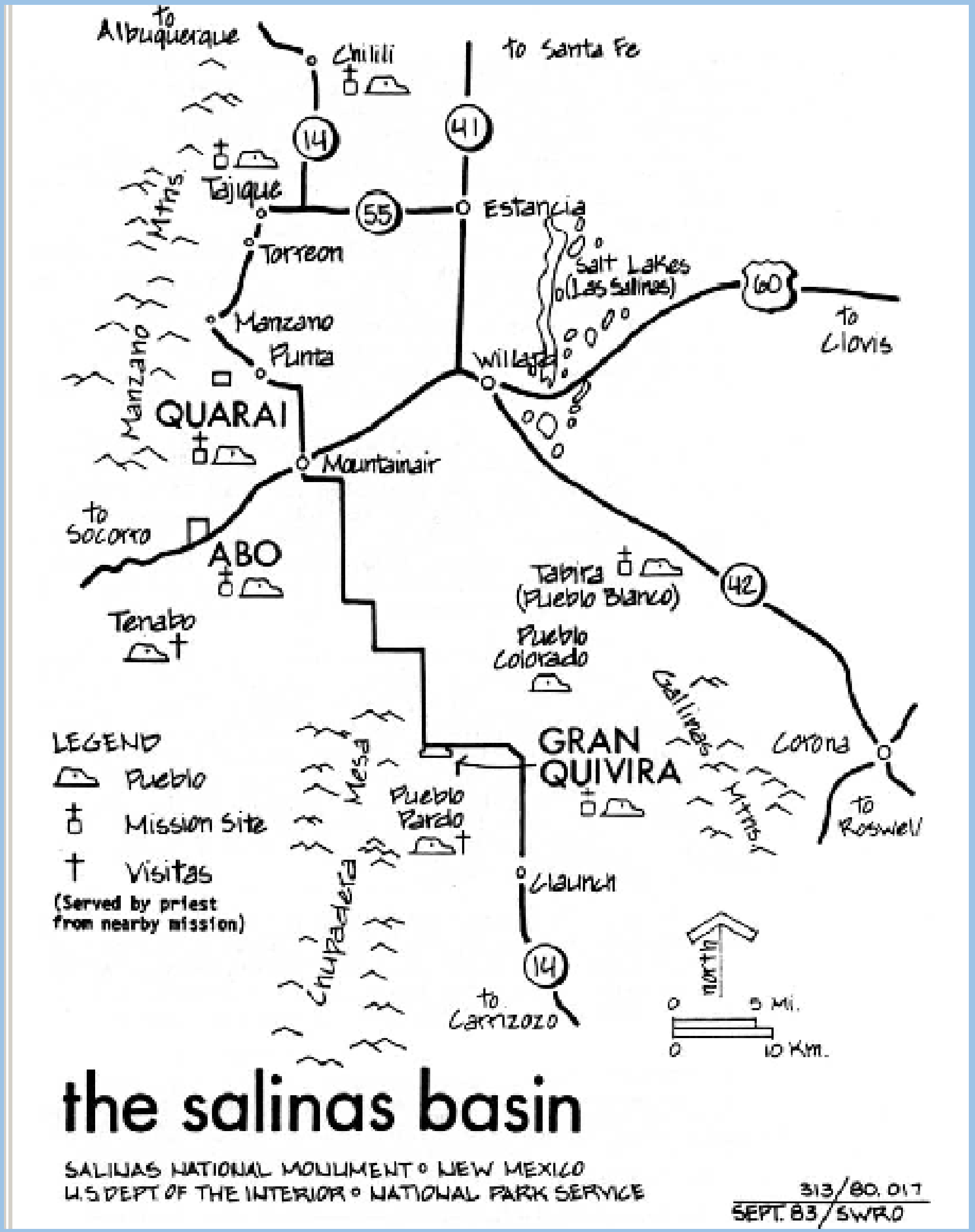
- Heilbad Durrnberg
- 750-150 BC
- 200 people worked the deposits
- wealth of this small settlement is clearly evidenced by the clusters of graves which surrounded the various rectangular houses

Estancia Basin in central New Mexico

- Salt basin, few areas in NM with edible salt
- Tompiro Indians (Abo and Gran Quivira) first to harvest the salt
- Later the peoples of Tijeras, Chilili, Tajique, and Quarai gathered the salt
- Central to Indian Pueblos—Abo, Gran Quivira, Salinas, a total of 10 Piro pueblos
- Important in trade by 13th century
- Spanish conquest in 1581, built churches, and demanded more salt
- The Spanish who settled in the region referred to it as the Salinas Province
- By 1660 Spanish shipped salt 700 mi to Mexico for use in processing silver



Kraemer, 1998)



http://www.nps.gov/sapu/hsr/fig1.jpg

Gran Quivira

Estancia playa, looking northwest

Salt and Silver Processing

- Patio process developed in 1557 in Pachuca, Hidalgo, Mexico
- silver ores crushed in arrastras to a fine slime
- mixed with salt, water, copper sulfate, mercury
- spread onto a patio and allowed to dry in the sun
- silver could then amalgamate with mercury and thus be recovered

Pinos Altos arrastra

End of an Era

- By the late 1670s the entire Salinas district, as the Spanish had named it, was depopulated
  - 1672 Apache raids increased
  - 1671 Famine hit the area
  - Poor harvests
  - By the Pueblo revolt in 1680, the pueblos were abandoned
- Guadalupe salinas, SW of the Guadalupe Mountains, eastern Tularosa Basin, were discovered in 1691, Guadalupe and Lake Lucero deposits supplied salt to the mines
- Salt was still needed and when the Spanish resettled New Mexico, armed escorts frequently traveled to the lakes and mined salt for the rest of the state
- 1821, area near Mountainair in the Manzano Mountains was resettled
  - Some of the orchards from past settlement remained
- Even soldiers from Ft. Craig mined salt from the playas in 1860s
- The coming of the railroad in 1879, ended the salt trade

Modern Era

- Julius Meyer produced salt in 1915 from Estancia Lakes
- Between 1915-1933, several operators
- In 1932 New Mexico Salt Co. mined and marketed 350 short tons of salt and 700 short tons in 1933
  - Sold in 3 grades 85, 92, and 98% pure
  - Vats formed by low dike controlled deposition
  - Used a well to pump water into the vats and allow to evaporate
- In 1931, Carlsbad salt deposits were exploited
- In the 1950s, the Southwestern Chemical Co. attempted to process salt for fertilizer
- Thicker salt beds in Laguna Salina
- Today exploration for Li, Sr, B, Br
- Uranium also is found in the playas (as much as 334 ppb U in waters)

Salt, Societies, and Spirituality: A Tale of Two Cultures.

Tucked away in the middle of New Mexico you'll find Salinas Pueblo Missions National Monument. Its three distinct sites offer a glimpse into a unique time in history—a time entrenched with cultural borrowing, conflict and struggles. These sites continue to stand as reminders of the Spanish and Pueblo peoples' early encounters and prompt exploration of today's interactions among different people.

Virtual Tour of Abó ›

Take a tour of Abó from your home! Abó features a short trail to the picturesque mission ruins.

Gran Quivira ›

Gran Quivira is the most remote of the three sites. If you're interested in visiting excavated Puebloan ruins, you won't want to miss it!

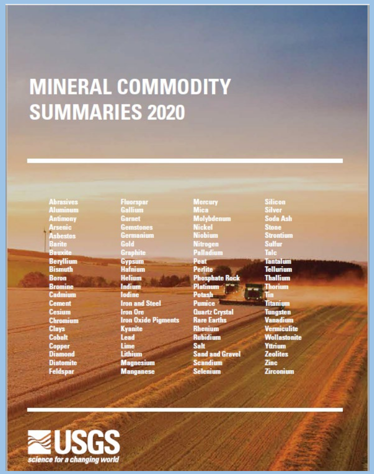
Quarai Virtual Tour ›

Quarai features the most intact church of the three sites and is a wonderful birding location. Learn more about Quarai in this virtual tour.

https://www.nps.gov/sapu/index.htm

Salient Statistics—United States:[1]	2015	2016	2017	2018	2019[e]
Production	45,100	41,700	39,600	[e]41,000	42,000
Sold or used by producers	42,800	39,900	38,200	[e]40,000	41,000
Imports for consumption	21,600	12,100	12,600	17,900	17,000
Exports	830	729	1,120	986	730
Consumption:					
Apparent[2]	63,600	51,300	49,700	[e]57,000	57,000
Reported	52,300	47,800	45,500	[e]48,000	49,000
Price, average value of bulk, pellets and packaged salt, dollars per ton, f.o.b. mine and plant:					
Vacuum and open pan salt	188.87	197.78	211.71	[e]220.00	220.00
Solar salt	102.04	99.69	115.88	[e]120.00	120.00
Rock salt	56.32	56.75	60.41	[e]62.00	62.00
Salt in brine	10.27	8.68	9.49	[e]10.00	10.00
Employment, mine and plant, number[e]	4,200	4,000	4,100	4,100	4,100
Net import reliance[3] as a percentage of apparent consumption	33	22	23	30	29

Recycling: None.



Salt

https://www.usgs.gov/centers/nmic/mineral-commodity-summaries

World Production and Reserves:

	Mine production[e] 2018	Mine production[e] 2019	Reserves[4]
United States[1]	41,000	42,000	Large. Economic and subeconomic deposits of salt are substantial in principal salt-producing countries. The oceans contain a virtually inexhaustible supply of salt.
Australia	12,000	13,000	
Austria	4,900	4,900	
Brazil	7,500	7,600	
Canada	12,000	12,000	
Chile	8,000	9,000	
China	58,000	60,000	
France	5,700	5,700	
Germany	14,000	14,000	
India	29,000	30,000	
Italy	4,100	4,100	
Mexico	9,000	9,000	
Netherlands	7,000	7,000	
Pakistan	4,400	4,500	
Poland	4,400	4,500	
Russia	7,000	7,000	
Spain	4,200	4,300	
Turkey	6,500	6,600	
United Kingdom	4,100	4,100	
Other countries	43,000	44,000	
World total (rounded)	286,000	293,000	

Is salt a critical/strategic mineral?

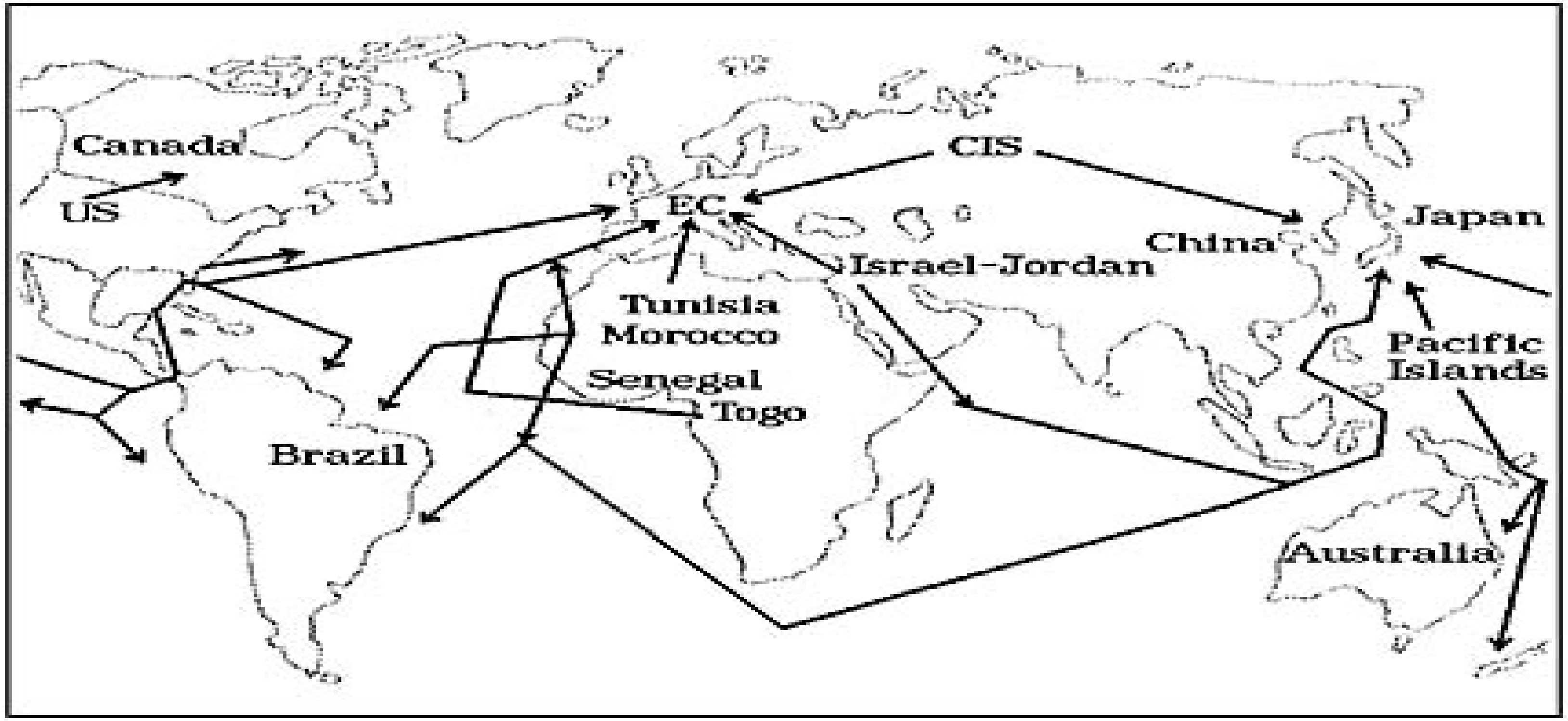
What has changed from Prehistoric times to today?

Need for more commodities

Technology

Global market

Fig. 1. Trade patterns in phosphate rock.



Environmental concerns

Mineral availability

Long term mineral availability (>10 Yr)

- Geologic (does the mineral resource exist)
- Technical (can we extract and process it)
- Environmental and social (can we mine and process it in environmentally and socially acceptable ways)
- Political (how does politics influence)
- Economic (can we mine and produce it at a cost the markets will pay)

Short- and medium-term availability

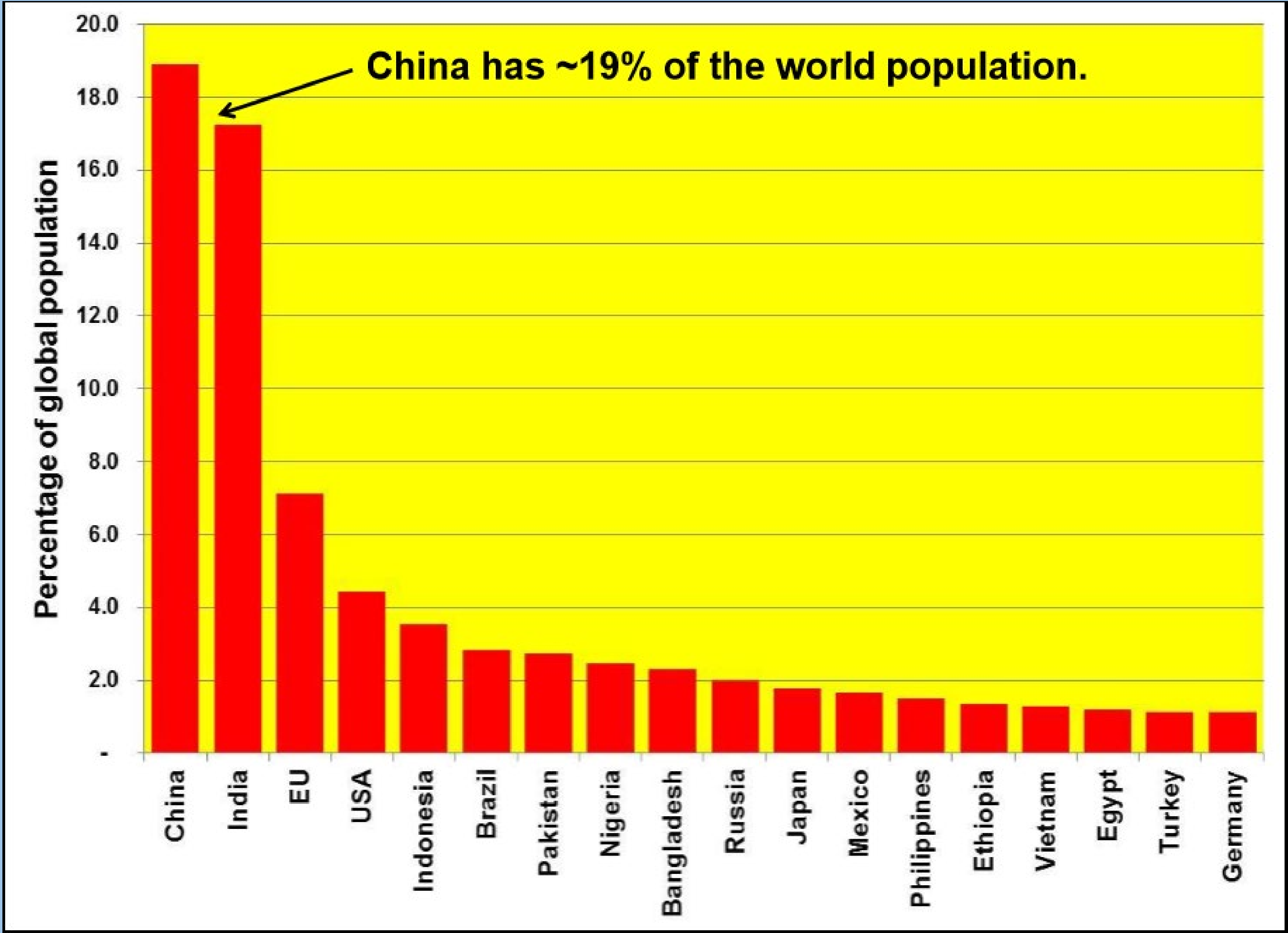
- Significant or unexpected increase in demand
- Small markets
- Production from a small number of mines, companies, or markets
- Minerals whose supply consist significant of byproduct production (i.e. Ga byproduct of bauxite mining)
- Markets for which there is no significant recovery from old scrap

Global challenges

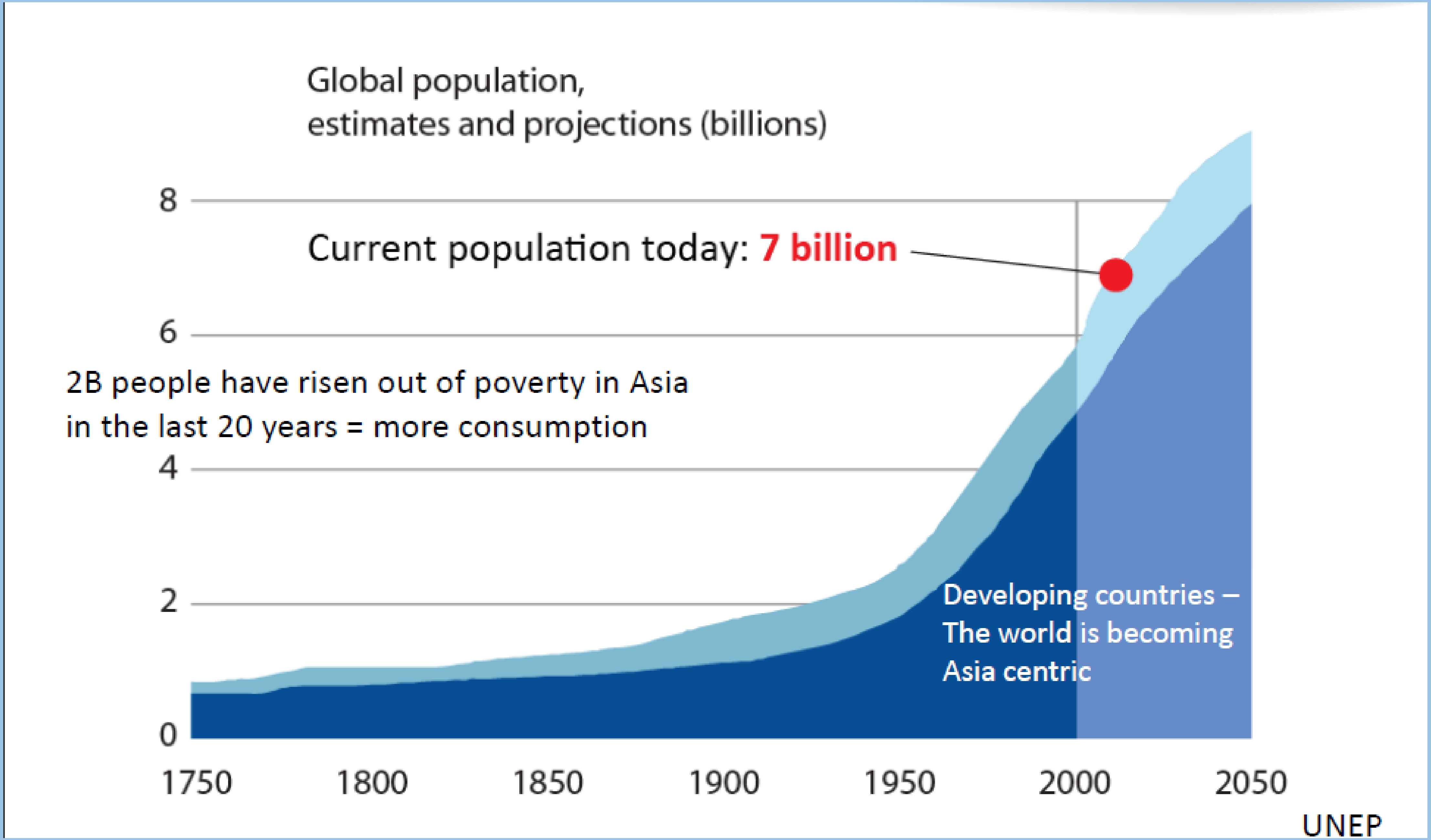
- The small volumes of strategic/critical minerals utilized makes them price sensitive
- New producers need a reliable, long-term buyer
- Long-term buyers require a fixed price, but operating costs are variable
- Monopolies/oligopolies can drive out marginal producers by over-supplying the market until the competition is eliminated

Other factors

- Population
- Food
- Pandemic

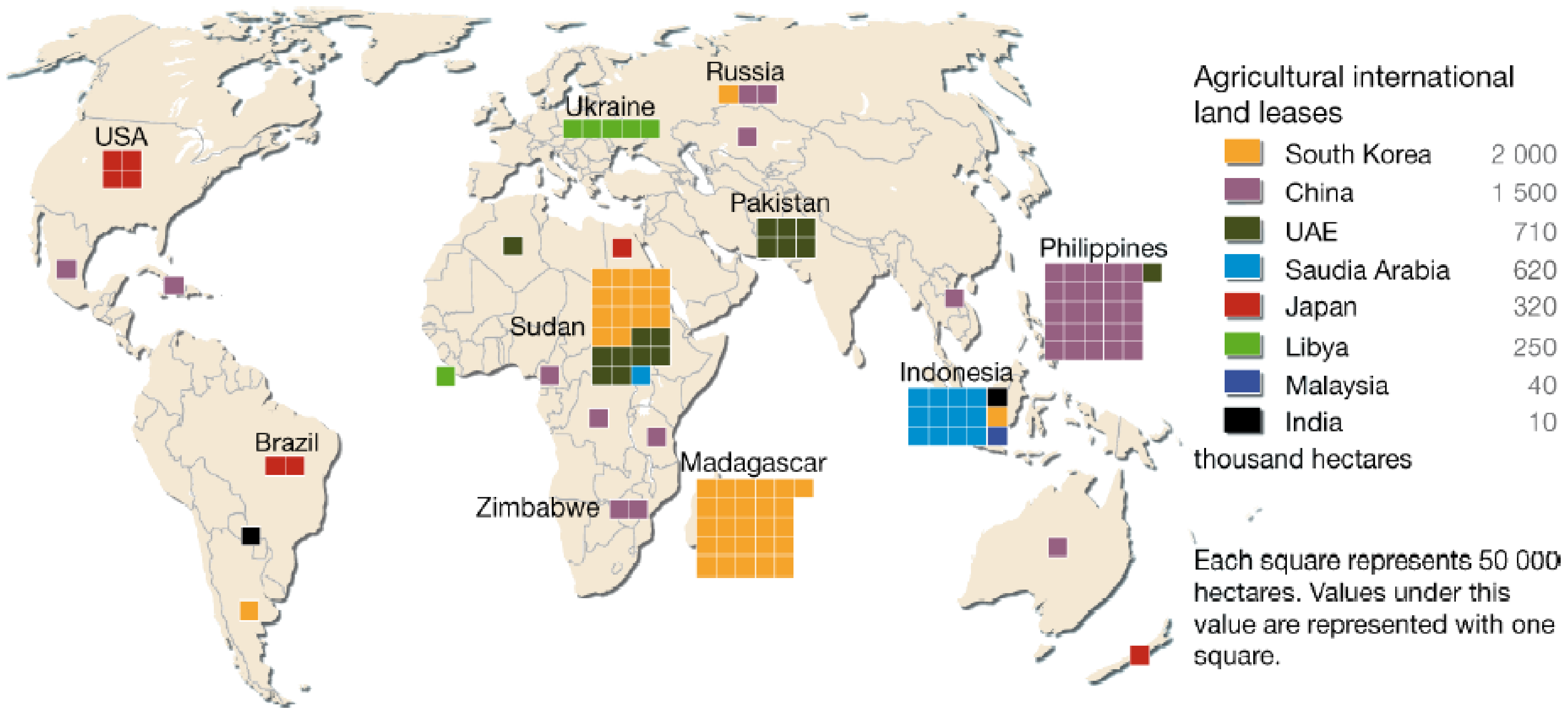


Data from CIA.



http://dnr.alaska.gov/commis/priorities/Slides/Lance_Miller.pdf

Food Security



UNEP

http://dnr.alaska.gov/commis/priorities/Slides/Lance_Miller.pdf

Where will those materials come from?

- Even though there is little danger of material exhaustion, there is a very real danger of supply disruption.
- Critical means you need it, strategic means you don't have it.
- Mineral resource discovery is not automatic – it takes time, money, and training (education) to find new resources
- Even with exploration success – you can decide ***whether*** to mine something but not ***where*** to mine it - mineral deposits are part of nature

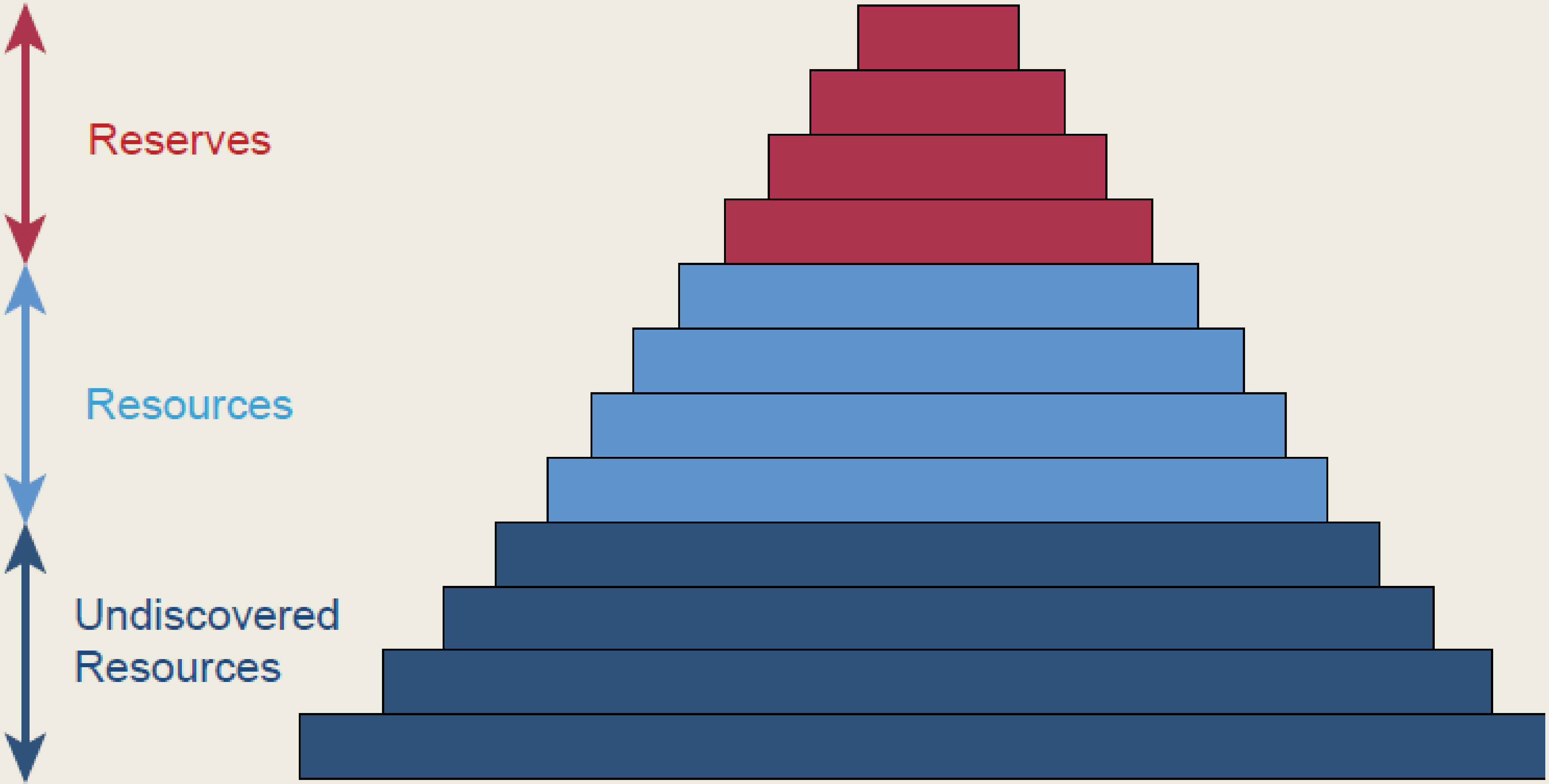
Main Points:

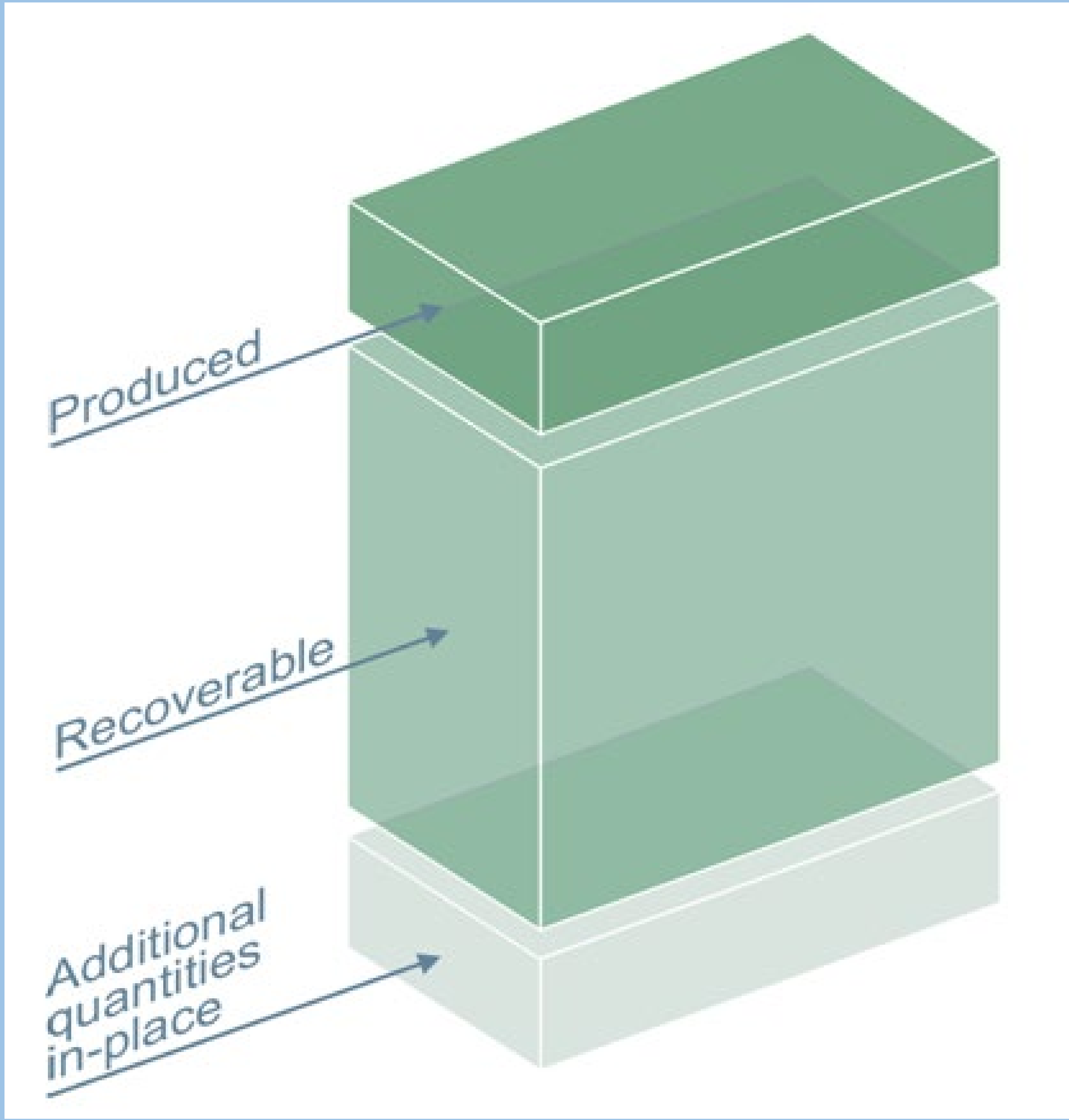
- As world population and standards of living increase, new resources are needed
- Recycling, even if 100% efficient, cannot supply entire need
- More efficient or innovative manufacturing and technology can help, but cannot supply entire need
- "Circular Economy" can help but cannot supply entire need
- Complete life cycle analysis needs to include upstream (exploration, discovery, and production) as well as downstream (manufacturing, recycling, disposal) parts of the materials cycle – education is critical

CLASSIFICATION OF RESERVES AND RESOURCES

Reserves/Resources (1)

Reserves are currently economic occurrences





Initial in place resources

(http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=28&ved=0CGsQFjAHOBQ&url=http%3A%2F%2Fwww.world-petroleum.org%2Fdocs%2Fdocs%2FA-UNFC-FINAL.doc&ei=W7TcUMGdHtGNrQHb54DQCw&usg=AFQjCNHqZM3_ivXShdaHIZC0sGynGlhvTw&sig2=88Yij5U_7KyOR-k9QzGZfA&bvm=bv.1355534169,d.aWM)

Table 1. The UNFC in matrix form applied to coal, uranium and other solid minerals

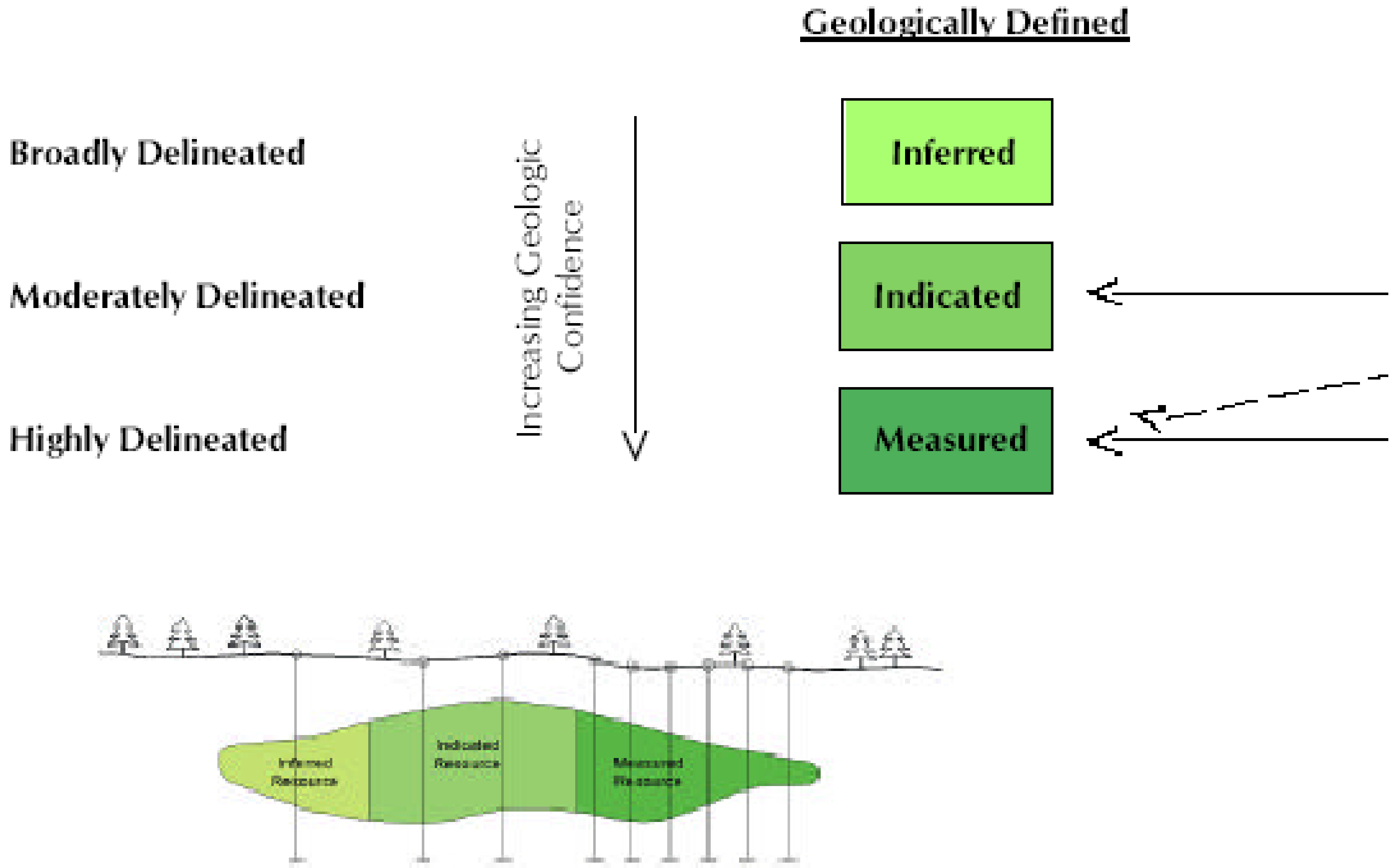
UN International Framework → / National System →		Detailed Exploration	General Exploration	Prospecting	Reconnaissance
Feasibility Study and/or Mining Report		1 (111)	usually		
		2 (211)			
Prefeasibility Study		1 (121)	+ (122)	not	
		2 (221)	+ (222)		relevant
Geological Study*)		3 (331)	3 (332)	3 (333)	3 (334)

Economic Viability Categories:
1: economic
2: potentially economic
3: intrinsically economic (economic to potentially economic)

(http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=28&ved=0CGsQFjAHOBQ&url=http%3A%2F%2Fwww.world-petroleum.org%2Fdocs%2Fdocs%2FA-UNFC-FINAL.doc&ei=W7TcUMGdHtGNrQHb54DQCw&usg=AFQjCNHqZM3_ivXShdaHIZC0sGynGlhvTw&sig2=88Yij5U_7KyOR-k9QzGZfA&bvm=bv.1355534169,d.aWM

RESERVES

- ***Inferred***: That part of a Mineral Resource for which tonnage, grade and mineral content can be estimated with a low level of confidence.
- ***Indicated***: That part of a Mineral Resource for which tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a reasonable level of confidence.
- ***Measured***: That part of a Mineral Resource for which tonnage, densities, shape, physical characteristics, grade and mineral content can be estimated with a high level of confidence.



Geologically Defined
Broadly Delineated
Moderately Delineated
Highly Delineated
Increasing Geologic Confidence
Inferred
Indicated
Measured
Inferred Resource
Indicated Resource
Measured Resource

RESERVES

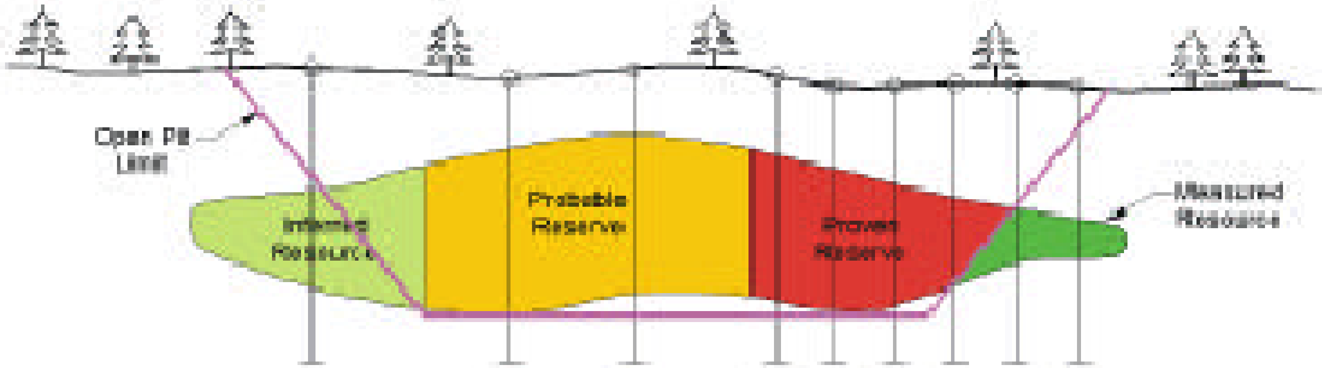
- ***Probable***: The economically mineable part of an Indicated and, in some circumstances, Measured Mineral Resource.
- ***Proven***: The economically mineable part of a Measured Mineral Resource.

Economic Viability Defined

X — reserves have no equivalent of inferred resource

Probable — moderately established viability

Proven — well established viability



Resources

DEFINITIONS OF LEVEL OF RESOURCE POTENTIAL

N **No mineral resource potential** is a category reserved for a specific type of resource in a well defined area.

L **Low mineral-resource potential** is assigned to areas where geologic, geochemical, and geophysical characteristics indicated geologic environment where the existence of mineral resources is unlikely and is assigned to areas of no or dispersed mineralized rocks.

M **Moderate mineral-resource potential** is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence.

H **High mineral-resource potential** is assigned to areas where geologic, geochemical, and geophysical characteristics indicate a geologic environment favorable for resource occurrence. Assignment of high mineral-resource potential to an area requires some positive knowledge that mineral-forming processes have been active in at least part of the area.

DEFINITIONS OF LEVEL OF CERTAINTY

A Available information is not adequate for the determination of the level of mineral resource potential.

B Available information suggests the level of mineral-resource potential.

C Available information gives a good indication of the level of mineral-resource potential

D Available information clearly defines the level of mineral-resource potential.

<table>
<tr><td rowspan="4">INCREASING LEVEL OF RESOURCE POTENTIAL</td><td rowspan="4">U/A
Unknown Potential</td><td>H/B
High Potential</td><td>H/C
High Potential</td><td>H/D
High Potential</td></tr>
<tr><td>M/B
Moderate Potential</td><td>M/C
Moderate Potential</td><td>M/D
Moderate Potential</td></tr>
<tr><td rowspan="2">L/B
Low Potential</td><td rowspan="2">L/C
Low Potential</td><td>L/D
Low Potential</td></tr>
<tr><td>N/D
No Potential</td></tr>
<tr><td colspan="5">INCREASING LEVEL OF CERTAINTY</td></tr>
</table>

FIGURE 48. Classification of mineral-resource potential and certainty of assurance (modified from Goudarzi, 1984).

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Low Potential</td></tr>
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No Potential</td></tr>
<tr><td colspan="5">INCREASING LEVEL OF CERTAINTY</td></tr>
</table>

“A mineral is where you find it. It may not be the most suitable place in the world.”

U.S. Senator Larry Craig, explaining why he is seeking to lift limits on mine waste dumping on public lands

Bre-X

Bre-X Scandal: A History Timeline

- Gold was known from the headwaters of the Busang River in the jungle of Borneo
- 1989 David Walsh flunded Bre-X Minerals, Ltd. as a subsidiary of Breaea Resources Ltd.
- 1993 Walsh bought a property near Busang River, Borneo, Indonesia
- 1994 drilled

http://www.visualcapitalist.com/bre-x-scandal-history-timeline/

Bre-X Scandal: A History Timeline-2

- Contrary to company statements, the Busang core samples had been prepared for assay in the jungle, not in the testing lab
- Security was nonexistent
- Project manager Michael de Guzman was filing gold from his wedding ring and adding the flakes to the crushed core samples, John Felderhof another geologist on site
- De Guzman used realistic ratios of gold to rock and the project kept going
- De Guzman then bought $61k of panned gold from the locals to use in salting
  - Gold was visible and rounded, well worn grains
  - Some had silver depletion along rims, characteristic of placer samples

http://www.visualcapitalist.com/bre-x-scandal-history-timeline/

Bre-X Scandal: A History Timeline-3

- Independent auditors were fooled
- Everyone wanted to invest in the company
- Reported 200 million oz of gold ($240 billion in 2014 prices)
- De Guzman, Felderhoff, and Walsh sold some of their options for $100 million
- 1996 Indonesia revoked their exploration permits
- 1997 a fire destroys many of the sample records

http://www.visualcapitalist.com/bre-x-scandal-history-timeline/

Bre-X Scandal: A History Timeline-4

- 1997 Joint venture established between Indonesia (40%), Bre-x (45%), and Freeport McMoRan (15%)
- Freeport begins due diligence and twin previously drilled holes
- Freeport reports minor amounts of gold
- De Guzman falls to his death from a helicopter on the way to meet Freeport geologists (did he jump or was he pushed?)
- David Walsh died due to brain aneurysm at the age of 52 soon after
- John Feldorhof, chief geologist of Bre-X, made $84 million by selling his Bre-X shares. He moved to the Cayman Islands. He was the only one who was tried in Canada, but found not guilty in 2007

http://www.visualcapitalist.com/bre-x-scandal-history-timeline/

Red Flags

- Only 10-cm length of core retained but industry standard is to retain ½ core
  - Reanalysis failed to find any gold
- Core treated differently (sample preparation, storage, transit)
- Early met tests indicated >90% of gold was recoverable by gravity separation and particle shapes were mostly rounded (vein deposit)
- Sample grades difficult to reproduce

- The movie *Gold* is based on the scandal

GEOLOGY OF MINERALS DEPOSITS

Geology provides the framework in which
mineral exploration
and the integrated procedures of remote
sensing, geophysics,
and geochemistry are planned and interpreted.

Factors important in evaluating a minerals deposit

- Customer specifications
- Distance to customer (transportation)
- Ore grade--concentration of the commodity in the deposit
- By-products
- Commodity prices
- Mineralogical form
- Grain size and shape
- Origin of ore-bearing fluids

Factors—continued

- Undesirable substances
- Size, attitude and shape of deposit
- Process of deposition (replacement, open-space filling)
- Ore character
- Cost of capital
- Location
- Environmental consequences/ reclamation/bonding
- Land status
- Taxation
- Political factors

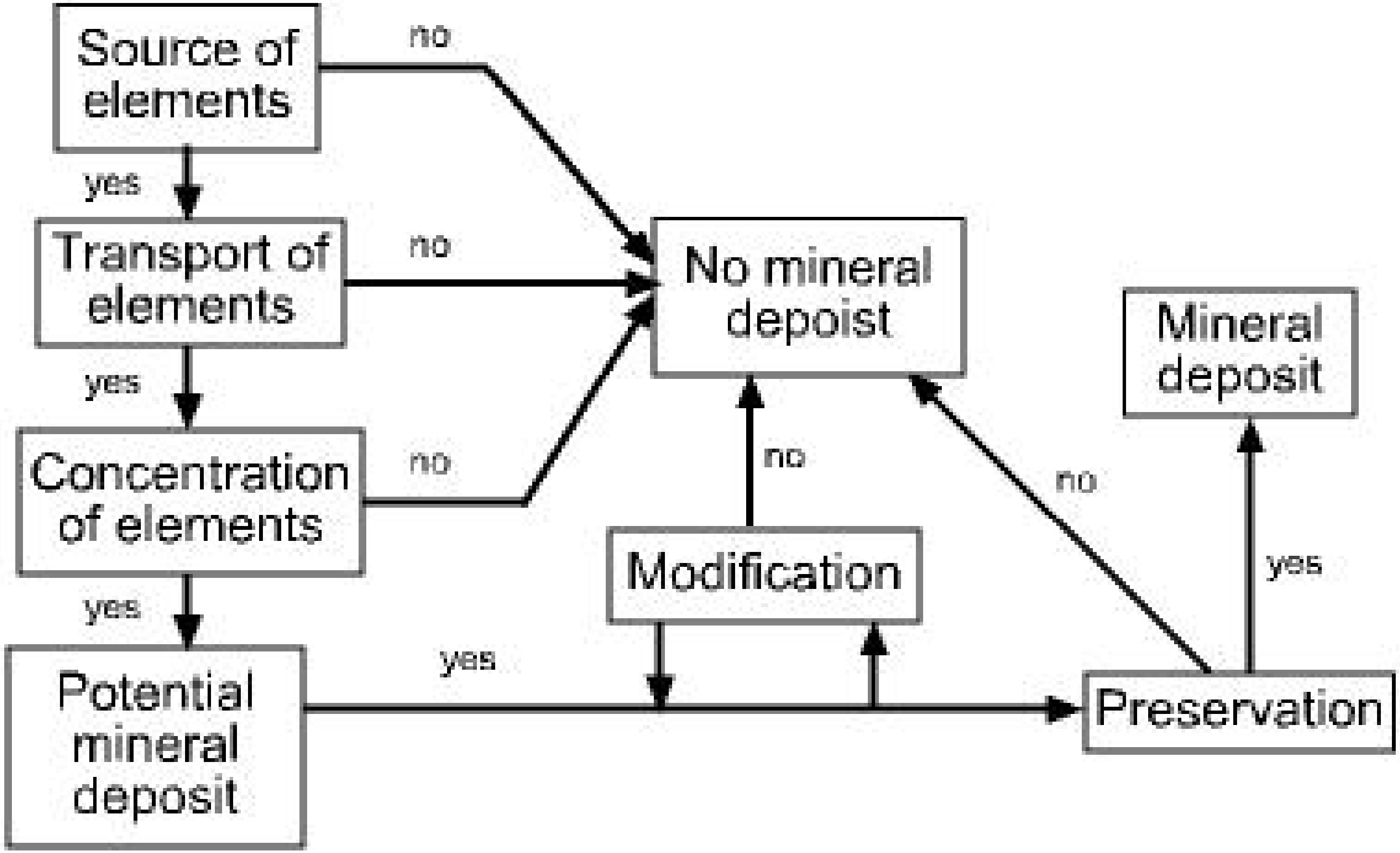


Figure 1. Conceptual model for the formation of a mineral deposit (after Tilsley, 1990).

TYPES OF MINERAL DEPOSITS

Classifications

- Niggli (1929) (historic, considered deposits related to magmatic process)
- Schneiderhohn (1941) (historic, considered deposits related to magmatic process)
- Lindgren (1933, modified 1968) (all types)
- Bateman (1942, revised 1979) (all types)
- Stanton (1972)
- Guilbert and Park (1986)
- Cox and Singer (1986)

Niggli (1929)

I. Plutonic, or intrusive

- A. Orthomagmatic
- 1. Diamond, platinum-chromium
- 2. Titanium-iron-nickel-copper
    - a. Iron-nickel-copper sulfide/arsenide
    - b. Titanium-iron oxide
- B. Pneumatolytic to pegmatitic
- 1. Heavy metals - alkaline earths - phophorus - titanium
    - a. Copper-lead-zinc
    - b. Tourmaline-rutile
- 2. Silicon-alkali metals-fluorine-boron-tin-molybdenum-tungsten
- 3. Tourmaline-quartz
- C. Hydrothermal
- 1. Iron-copper-gold-arsenic
- 2. Lead-zinc-silver
- 3. Nickel-cobalt-arsenic-silver
- 4. Carbonates-oxides-sulfates-fluorides

II. Volcanic, or extrusive

- A. Tin-silver-bismuth
- B. Heavy metals
- C. Gold-silver
- D. Antimony-mercury
- E. Native copper
- F. Subaquatic-volcanic and biochemical deposits

I. Intrusive and liquid-magmatic deposits

II. Pneumatolytic deposits

- A. Pegmatitic veins
- B. Pneumatolytic veins and impregnations
- C. Contact pneumatolytic replacements

III. Hydrothermal deposits

- A. Gold and silver associations
- B. Pyrite and copper associations
- C. Lead-silver-zinc associations
- D. Silver-cobalt-nickel-bismuth-uranium associations
- E. Tin-silver-tungsten-bismuth associations
- F. Antimony-mercury-arsenic-selenium associations
- G. Nonsulfide associations (Iron-manganese-magnesium oxide/carbonate)
- H. Nonmetallic associations (Fluorite-barite-quartz)

IV. Exhalation deposits

Schneiderhohn (1941)

I. Deposits produced by chemical processes of concentration, temperatures and pressures vary between wide limits.

A. *In magmas*, by processes of differentiation.

1. *Magmatic deposits* proper, magmatic segregation deposits, injection deposits. Temperature: 700°-1500° C; pressure very high.
2. *Pegmatites*. Temperature very high to moderate; pressure very high.

B. In bodies of rocks.

1. *Concentration effected by introduction of substances foreign to the rock (epigenetic).*
   a. Origin dependent upon the eruption of igneous rocks.
      i. Volcanogenic, deposits associated usually with volcanic piles. Temperatures 100°- 600° C; pressures moderate to atmospheric.
      ii. From effusive bodies. Sublimates, fumaroles. Temperature: 100°-600°C; pressure moderate to atmospheric.
      iii. From intrusive bodies. Igneous metamorphic deposits. Temperature probably 500°- 800°C; pressure very high.
   b. By hot ascending waters of uncertain origin, possibly magmatic, metamorphic, oceanic, connate, or meteoric. Hydrothermal deposits.
      i. Hypothermal deposits. Deposition and concentration at great depths or at high temperature and pressure. Temperature: 300°- 500°C; pressure very high.
      ii. Mesothermal deposits. Deposition and concentration at intermediate depths. Temperature: 200°-300°C; pressure high.
      iii. Epithermal deposits. Deposition and concentration at slight depth. Temperature 50°-200°C; pressure moderate.
      iv. Telethermal deposits. Deposition from nearly spent solutions. Temperature and pressure low; upper terminus of the hydrothermal range.
      v. Xenothermal deposits. Deposition and concentration at shallow depths, but at high temperatures. Temperature high to low; pressure moderate to atmospheric.
   c. Origin by circulating meteoric waters at moderate or slight depth. Temperature up to 100°C; pressure moderate.
2. *By concentration of substances contained in the geologic body itself.*
   a. Concentration by dynamic and regional metamorphism. Temperature up to 400°C; pressure high.
   b. Concentration by groundwater of deeper circulation. Supergene enrichment. Temperature up to 100°C; pressure moderate.
   c. Concentration by rock decay and residual weathering near surface. Temperature up to 100°C; pressure atmospheric to moderate.

C. In bodies of water.

1. *Volcanogenic*. Underwater springs associated with volcanism. Temperatures high to moderate; pressure low to moderate.
2. *By interaction of solutions*. Sedimentary deposits. Temperature up to 70°C; pressure moderate.
   a. Inorganic reactions.
   b. Organic reactions.
3. *By evaporation of solvents.*

II. Deposits produced by mechanical processes of concentration. Temperature and pressure moderate to low.

Lindgren, 1933)

1. Magmatic concentration. High T and P.
    - I. Early magmatic.
    - A. Disseminated crystallization.
    - B. Segregation.
    - C. Injection.
    - II. Late magmatic.
    - A. Residual liquid segregation.
    - B. Residual liquid injection.
    - C. Immiscible liquid segregation.
    - D. Immiscible liquid injection.
2. Sublimates. Low T and P.
3. Contact metasomatism. Intermediate to high T and P.
4. Hydrothermal processes. T and P conditions from low to high.
    - I. Telethermal
    - II. Epithermal
    - III. Leptothermal
    - IV. Mesothermal
    - V. Hypothermal
    - VI. Xenothermal
5. Sedimentation. Low T and P.
6. Bacteriogenic.
7. Submarine exhalative volcanism. Low to high T and P.
8. Evaporation. Low T and P.
    - I. Marine
    - II. Lake
    - III. Groundwater
9. Residual and Mechanical Concentration. Low T and P.
    - I. Residual concentration.
    - II. Mechanical concentration. Placers.
    - A. Stream
    - B. Beach
    - C. Eluvial
    - D. Eolian
10. Surficial oxidation and supergene enrichment. Low T and P.
11. Metamorphism. Intermediate to high T and P.
    - I. Metamorphosed deposits.
    - II. Metamorphic deposits.

Bateman (1942, revised 1979)

I. Igneous associations

A. Mafic and ultramafic associations

1. Cr-Ni-Platinum Group Elements

2. Fe-Ni-Cu-S-Platinum Group Elements

B. Felsic associations

1. Carbonatite-Rare Earths-Cu-P

2. Anorthosite-Fe-Ti

3. Quartz monzonite-granodiorite-Cu-Mo-S

II. Sedimentary affiliations

A. Fe, B. Mn, C. Limestone-Pb-Zn, D. Sandstone-U-V-Cu, E. Conglomerate-Au-U-Pyrite

III. Marine-Volcanic associations

IV. Vein associations

A. Precious metal-Te, B. Base metal-S, C. Ag-Co-Ni-As

V. Metamorphic Affiliations

A. Contact metamorphism

B. Regional metamorphism

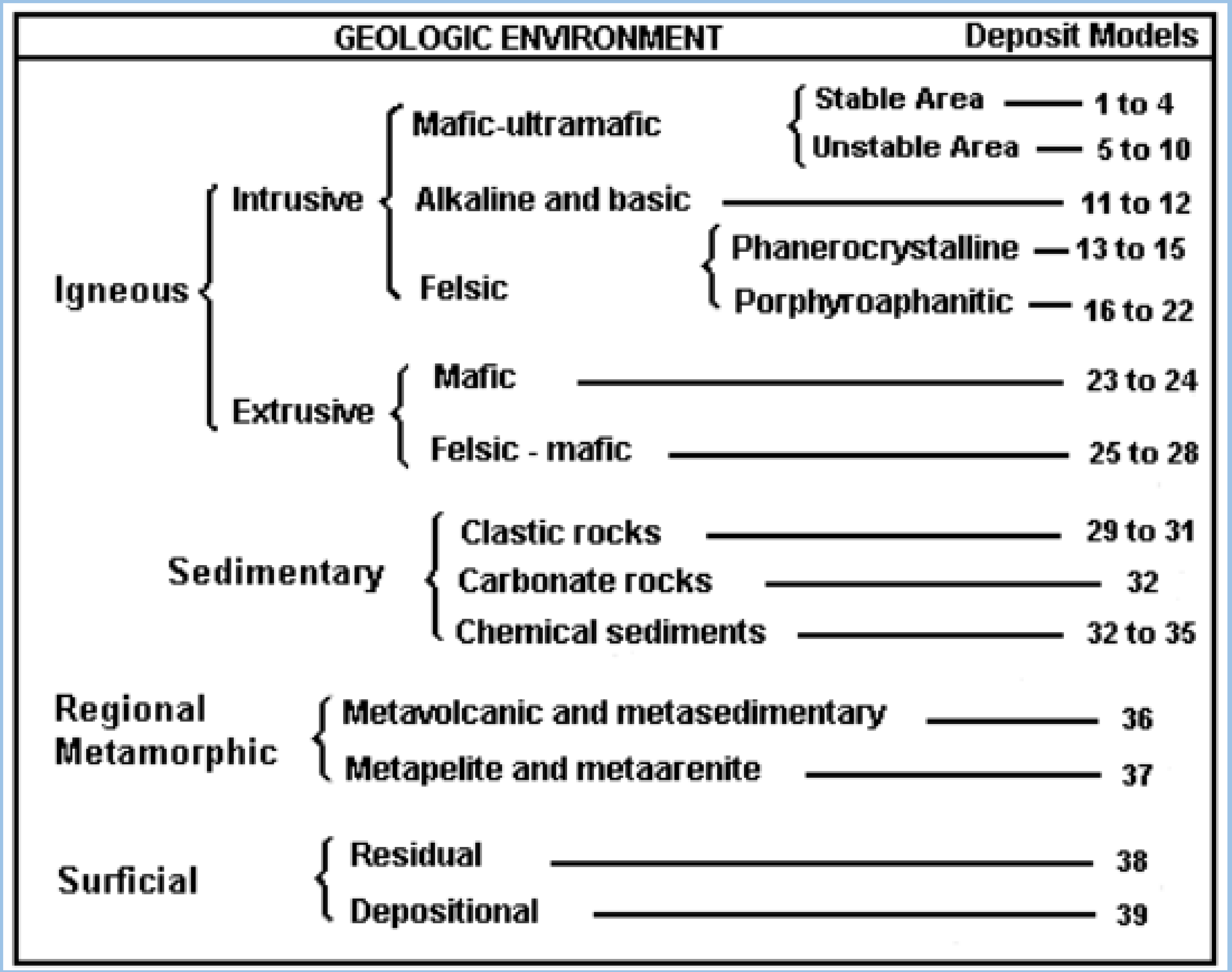
C. Dislocation metamorphism

Stanton (1972)

- I. Mafic igneous rock associations
  - A. Layered mafic intrusions
  - B. Anorthosites
  - C. Kimberlites
  - D. Carbonatites
  - E. Ultramafic volcanic rocks
- II. Oceanic crust associations
- III. Intermediate to felsic intrusion associations
  - A. Igneous iron deposits
  - B. Porphyry base-metal deposits
  - C. Hydrothermal iron deposits
  - D. Cordilleran vein-type deposits
  - E. Pegmatites
  - F. Granitic tin and uranium deposits
- IV. Subaerial volcanic associations
- V. Submarine volcanic associations
  - A. Volcanogenic massive sulfides
  - B. Banded iron formations
  - C. Exhalite gold deposits
- VI. Submarine volcanic-sedimentary associations
- VII. Chemical sedimentation
  - A. Sedimentary base-metal deposits
  - B. Sedimentary iron deposits
  - C. Sedimentary manganese deposits
  - D. Phosphate deposits
  - E. Evaporites
  - F. Manganese nodules
- VIII. Clastic sedimentation (Placers)
- IX. Weathering
  - A. Laterites
  - B. Supergene sulfide enrichment
- X. Regional metamorphism
- XI. Solution-remobilization
- XII. Epigenetic deposits of doubtful igneous connection
  - A. Mississippi Valley type Pb-Zn
  - B. Colorado Plateau type U

C. Unconformity-related U

Guilbert and Park (1986)



Cox and Singer (1985)

SME Mining Engineering Handbook

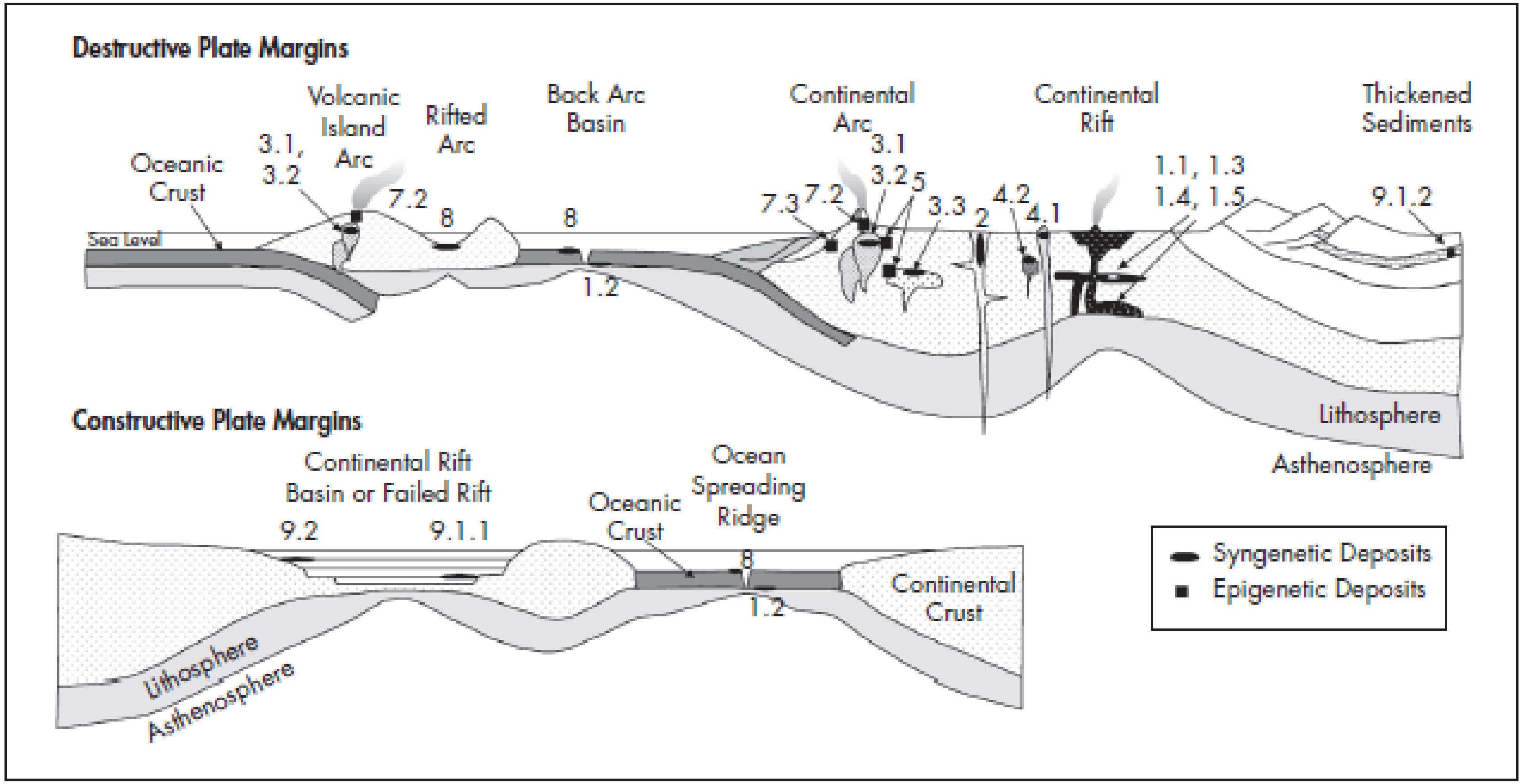


Figure 3.1-1 Plate tectonic settings for key magmatic and hydrothermal deposit types (numbers refer to deposit classes and types shown in Table 3.1-1)

SME Mining Engineering Handbook

Why do we classify mineral deposits?

Why do we classify mineral deposits?

- geological conditions of formation
- how they formed
- where they formed
- exploration

Mineral deposits in New Mexico

ACKNOWLEDGEMENTS

- New Mexico Energy, Minerals and Natural Resource Department
- Company annual reports
- Personal visits to mines
- Historical production statistics from U.S. Bureau of Mines, U.S. Geological Survey, N.M. Energy, Minerals and Natural Resource Department (NM MMD), company annual reports
- Students at NM Tech

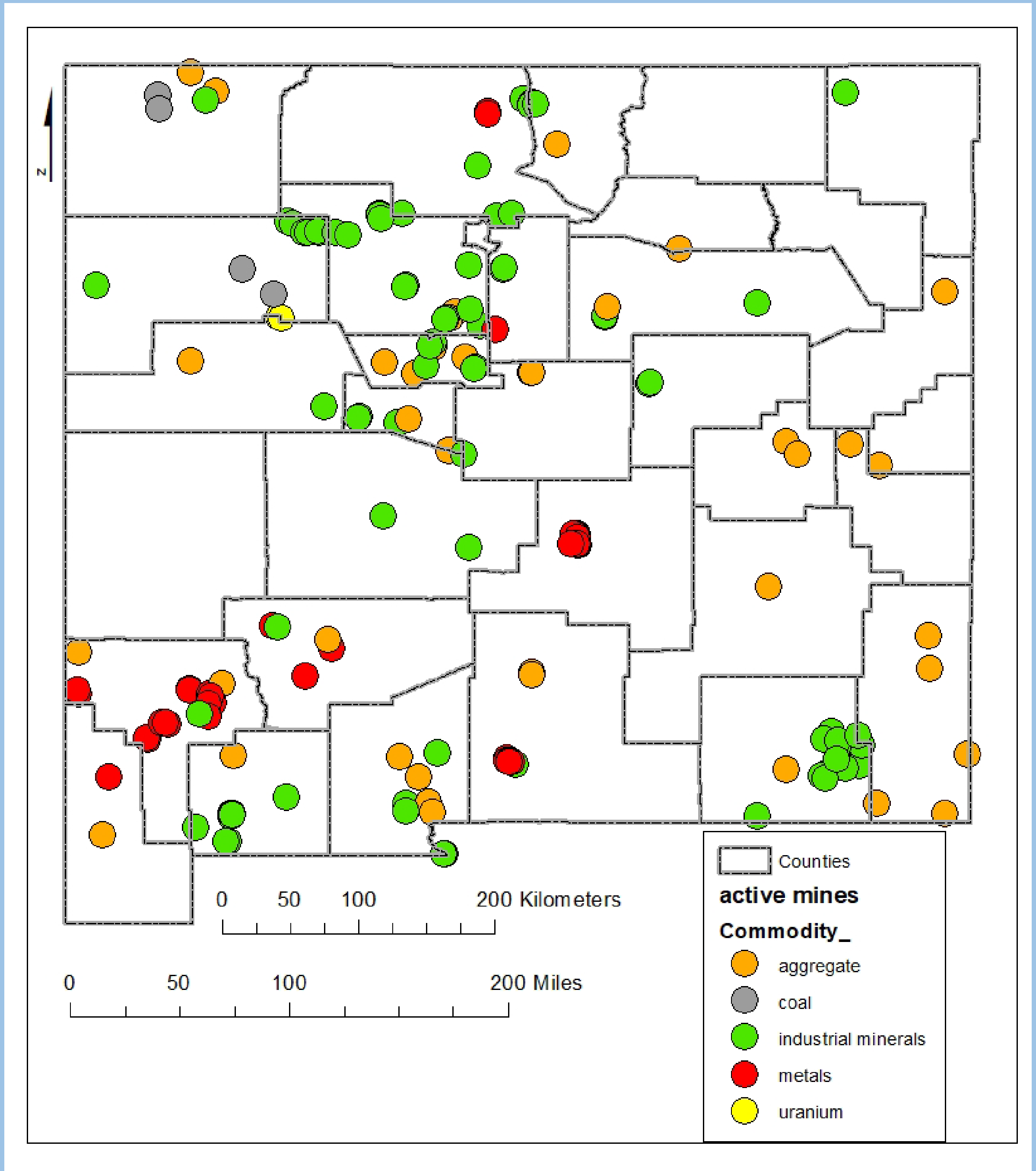
INTRODUCTION

- NM has some of the oldest mining areas in the United States
- Native Americans mined turquoise from Cerrillos Hills district more than 500 yrs before the Spanish settled in the 1600s
- One of the earliest gold rushes in the West was in the Ortiz Mountains (Old Placers district) in 1828, 21 yrs before the California Gold Rush in 1849

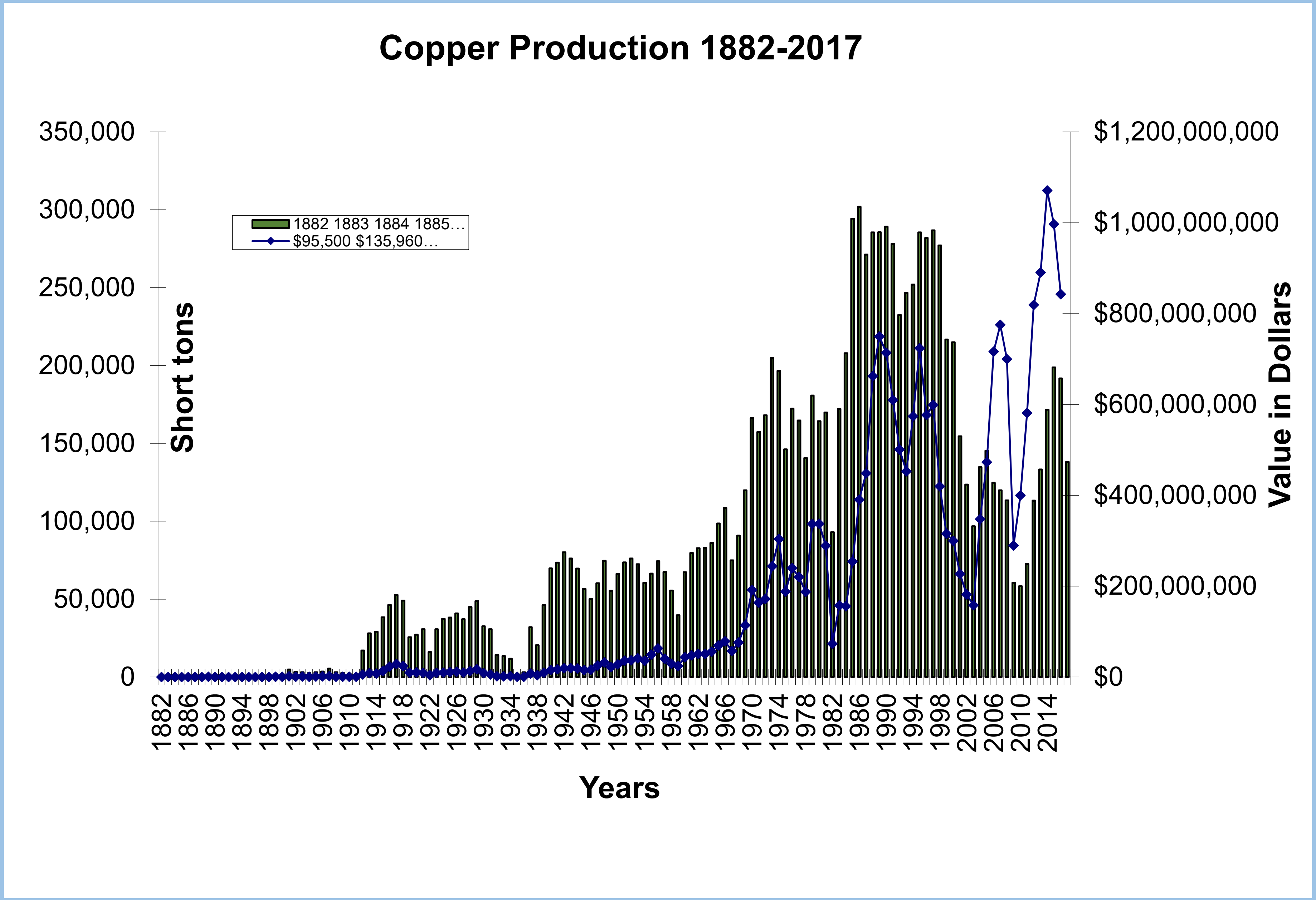
One of the turquoise mines in the Cerrillos Hills district

Active mines 2020

- ~282 active registered mines (NMMMD)
- 4 coal
- 3 potash, 4 potash plants
- 2 copper open pits, 1 concentrator (mill), 2 solvent/electro-winning (SX-EW) plants
  - 2 additional mines in permitting stage
  - Several exploration
- 1 gold mine and 1 mill (on standby)
- 2 iron mines
- 32 industrial minerals mines, 18 mills
- ~236 aggregate/stone



From NM Mining and Minerals Div. database



Copper Production 1882-2017
Short tons
Value in Dollars
Years
1882 1883 1884 1885…
$95,500 $135,960…
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
$1,200,000,000
$1,000,000,000
$800,000,000
$600,000,000
$400,000,000
$200,000,000
$0
1882
1886
1890
1894
1898
1902
1906
1910
1914
1918
1922
1926
1930
1934
1938
1942
1946
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1982
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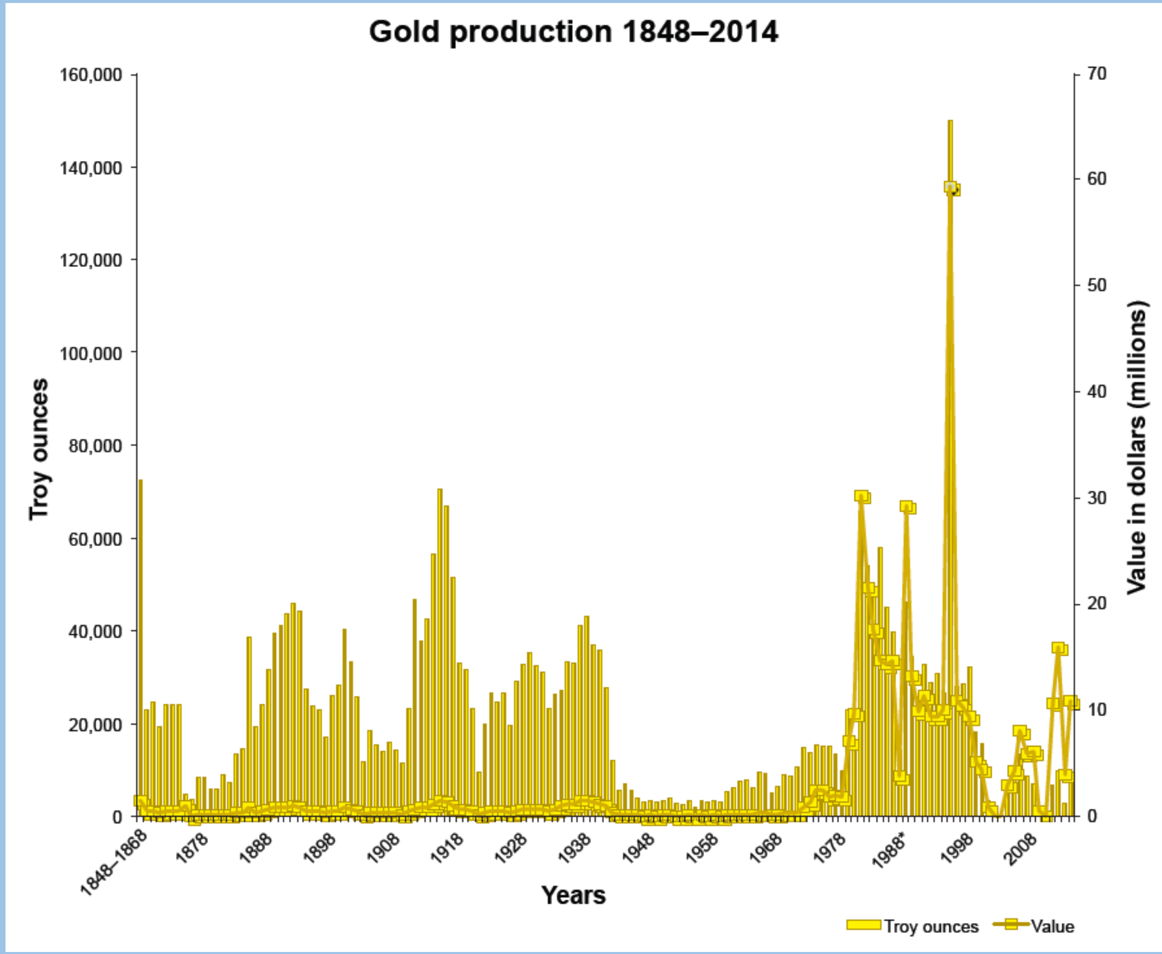
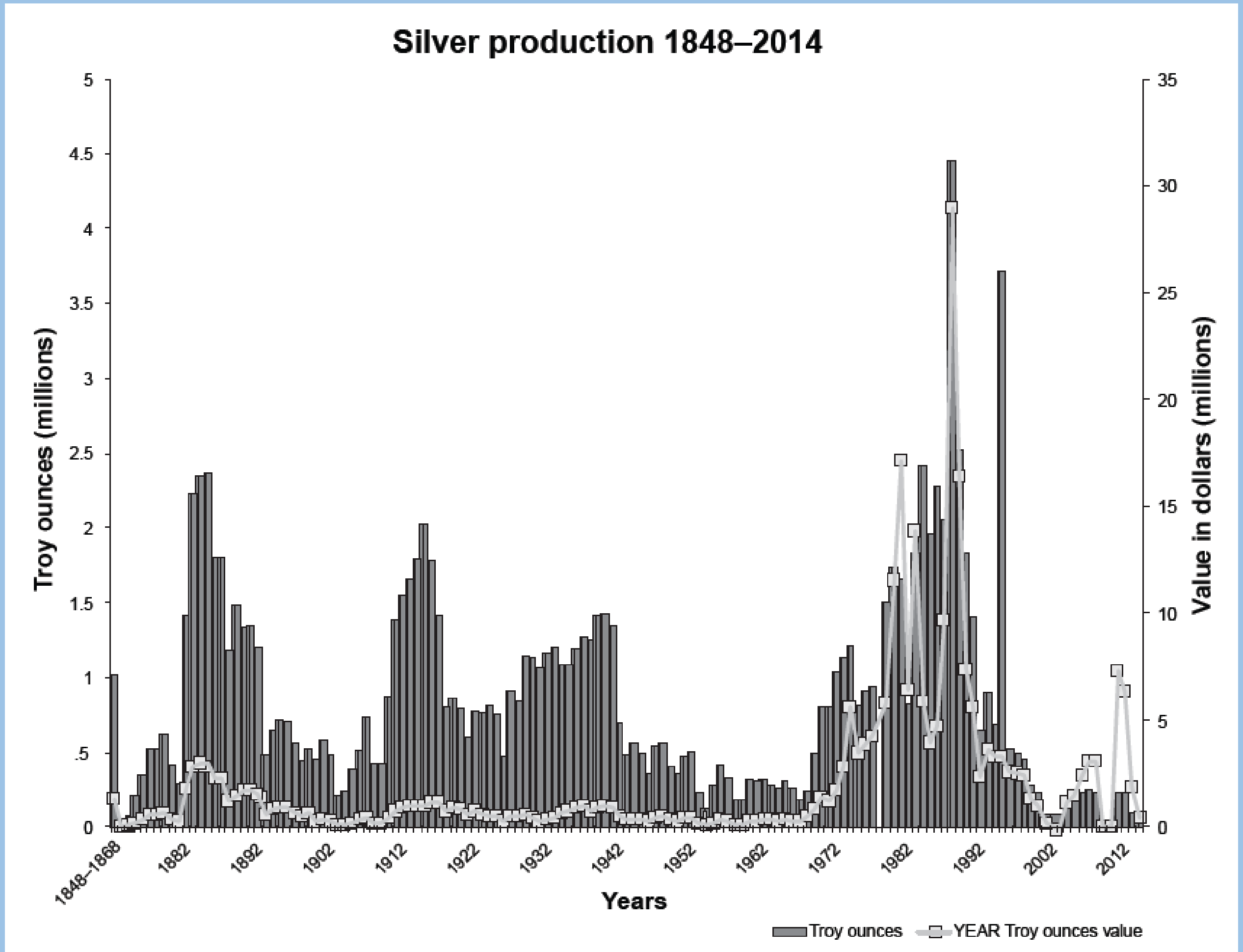
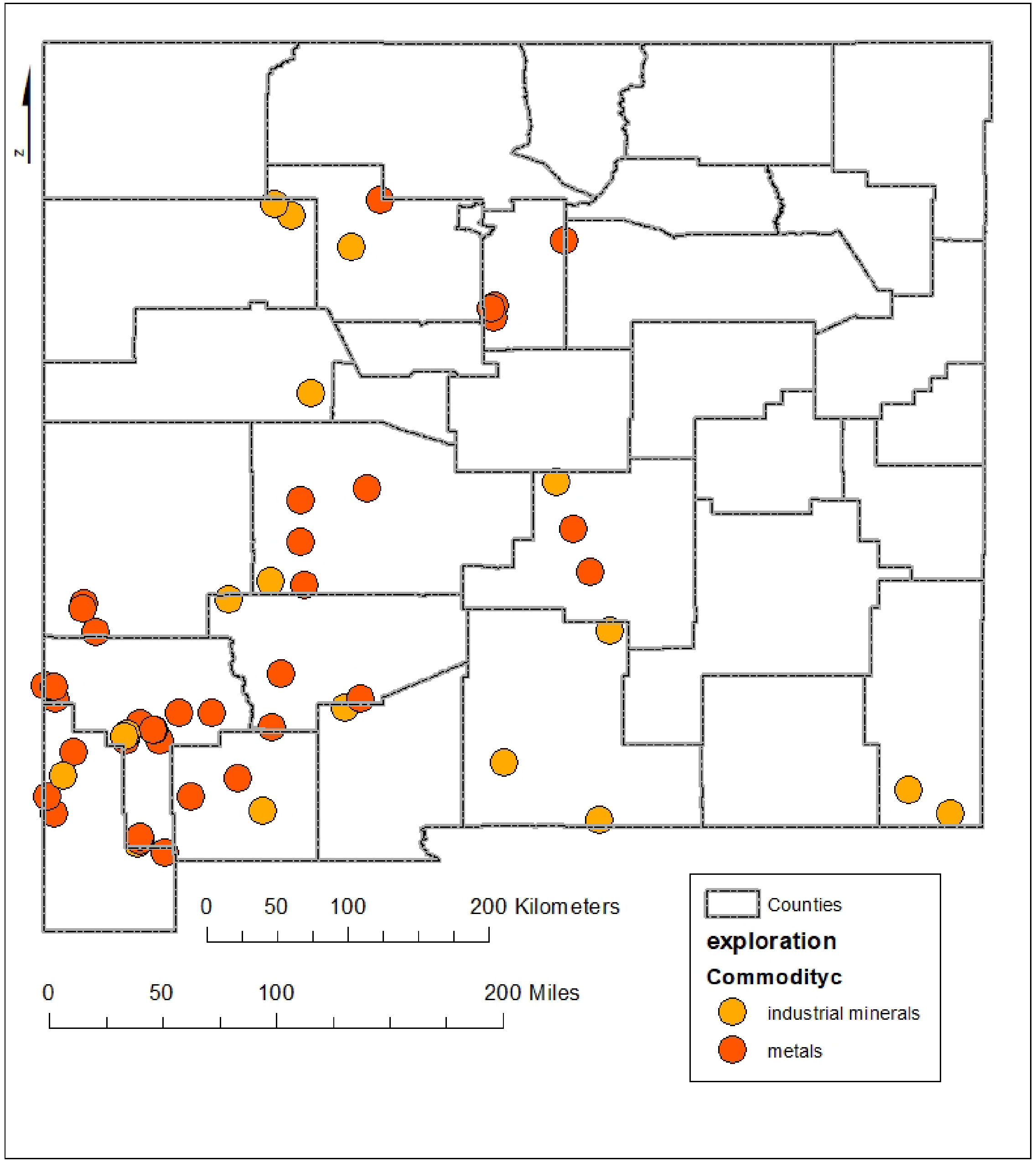
1998
2002
2006
2010
2014


Gold production 1848–2014
Troy ounces
Value in dollars (millions)
Years
Troy ounces
Value
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
70
60
50
40
30
20
10
0
1848–1868
1878
1888
1898
1908
1918
1928
1938
1948
1958
1968
1978
1988*
1998
2008


Silver production 1848–2014
Troy ounces (millions)
Value in dollars (millions)
Years
Troy ounces
YEAR Troy ounces value
5
4.5
4
3.5
3
2.5
2
1.5
1
.5
0
35
30
25
20
15
10
5
0
1848–1868
1882
1892
1902
1912
1922
1932
1942
1952
1962
1972
1982
1992
2002
2012

Exploration Sites 2010-2021



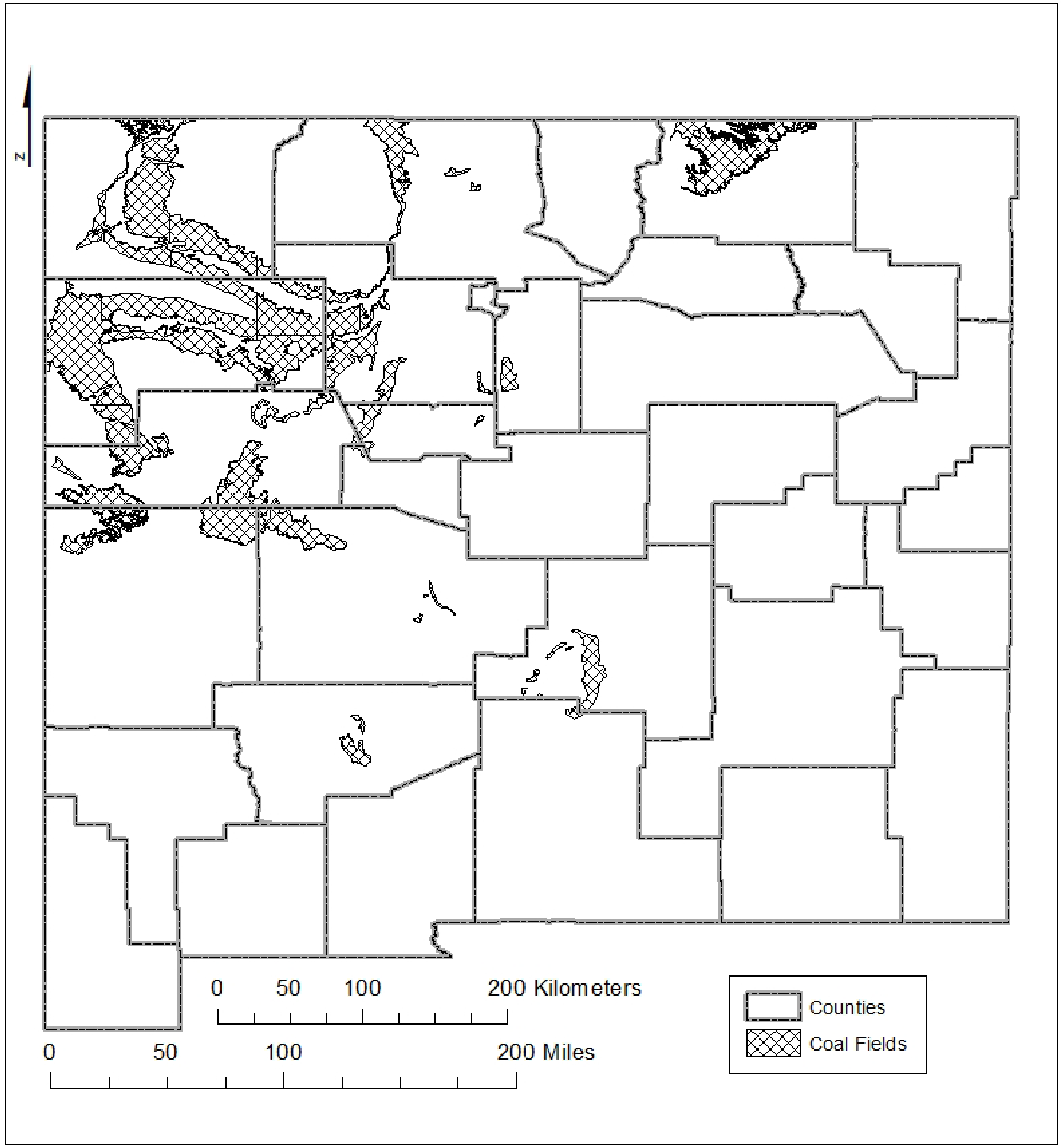
From NM Mining and Minerals Div. and NMBGMR databases, company web sites

Most of these exploration sites have been known for >20 yrs

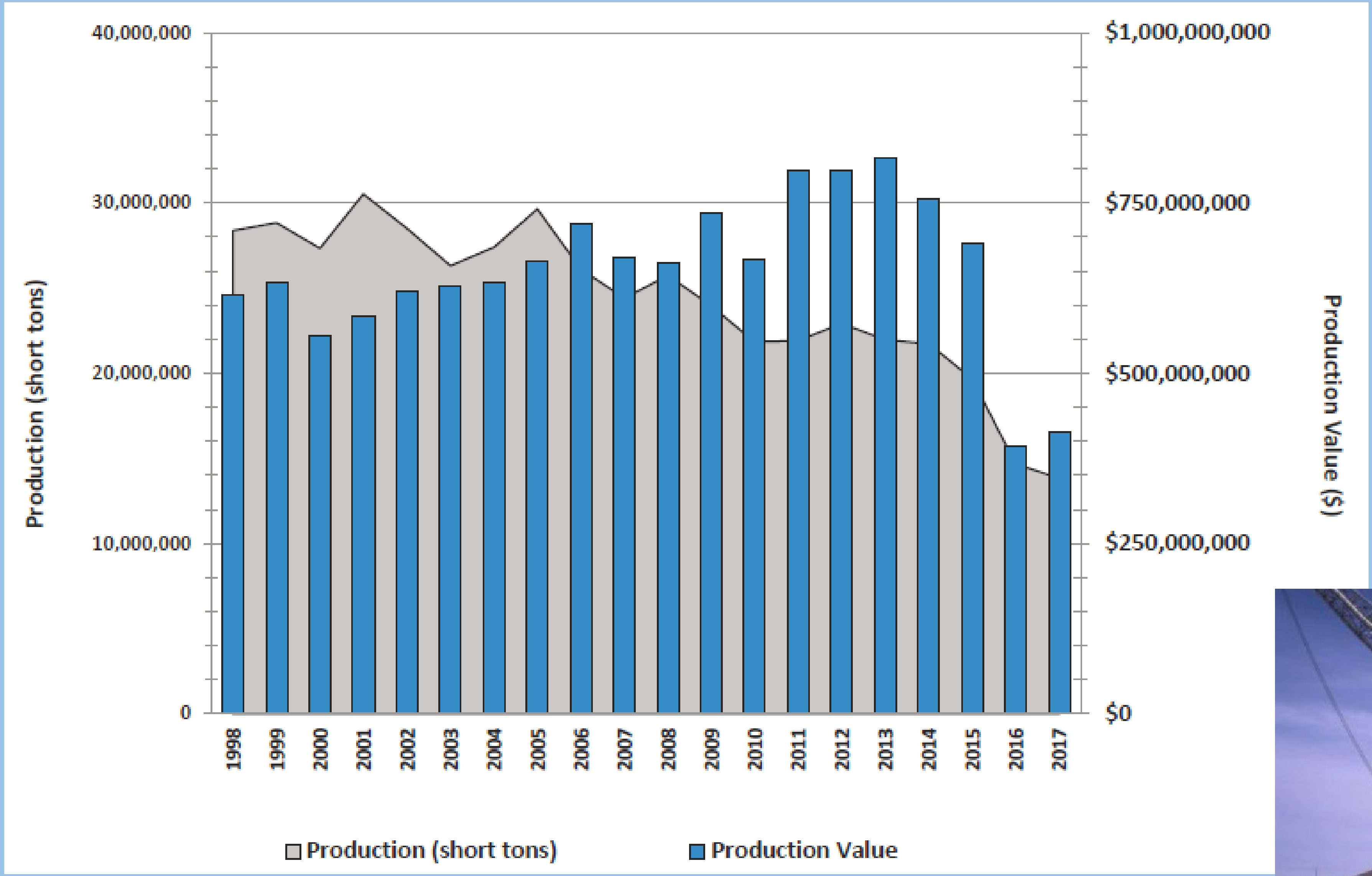
Industrial minerals deposits sometimes can be permitted within a few yrs but not metal mines

COAL

- Fuels 3 electrical generating plants
- 3 surface mines and 1 underground mine in San Juan Basin
- Resources at Raton, Carrizozo
- 12th in production in U.S. in 2018
- 11th in estimated recoverable coal reserves—7 billion tons of recoverable reserves (2005 figures)
- San Juan generating station in the Farmington is scheduled to close in the near future
- ***Coal production is expected to decrease in the near future***



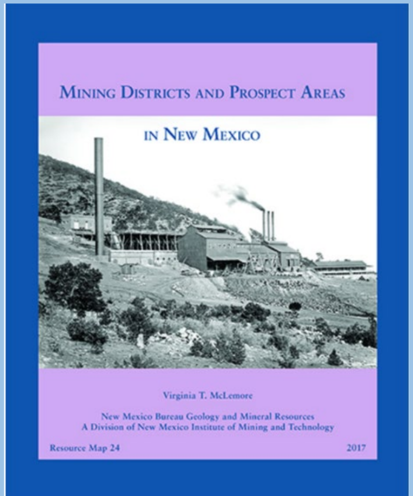
Coal production in New Mexico 1998-2017

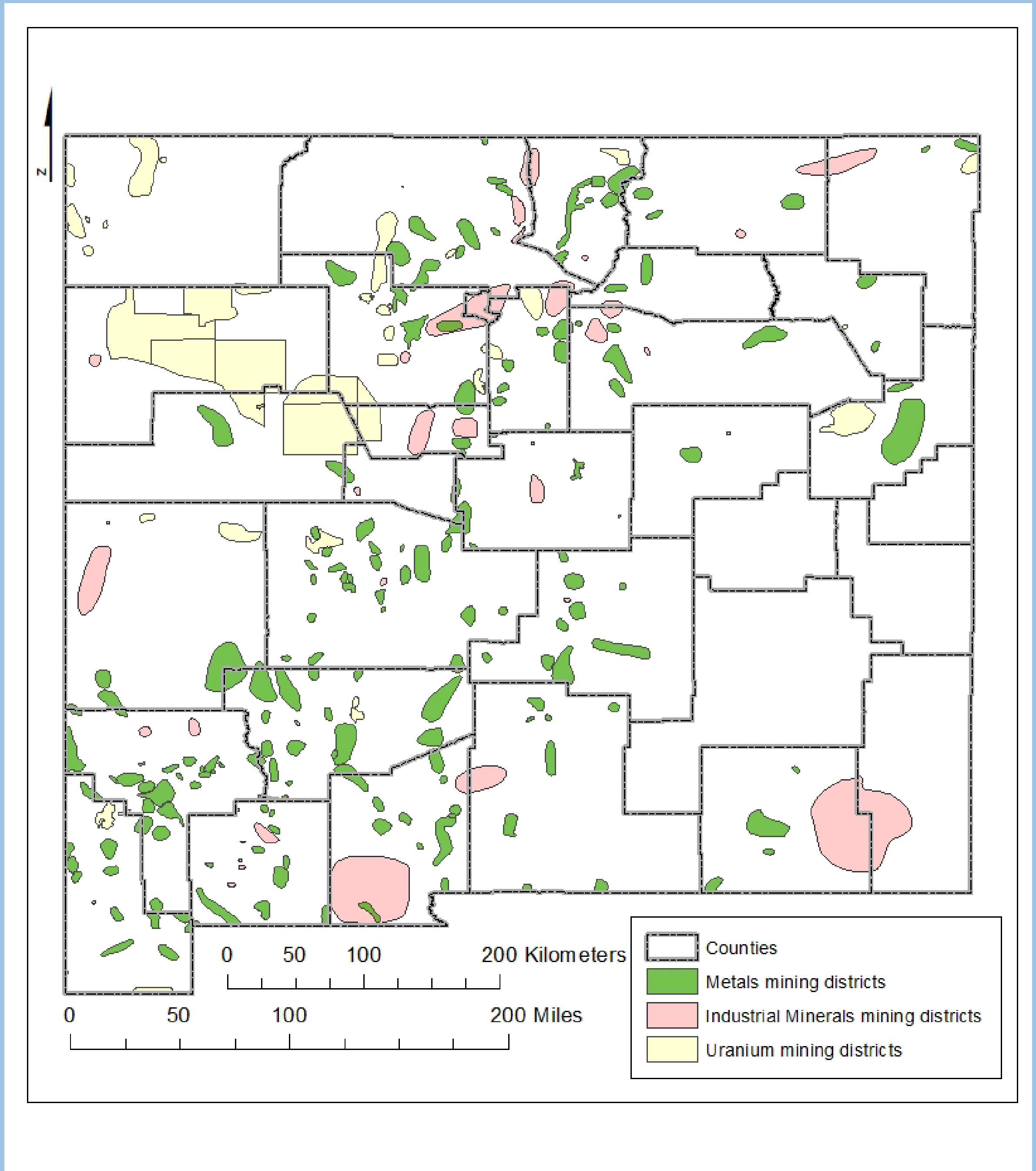


http://www.emnrd.state.nm.us/ADMIN/documents/bw2018AR30Feb.pdf

Mining Districts (production) and Prospect Areas (no production)

- 274 in NM, including coal
- Mining district, coal field, prospect area, or the geographical area as defined by File and Northrop (1966), Shoemaker et al. (1971), North and McLemore (1986), McLemore and Chenoweth (1989), Hoffman (1996), and McLemore (2001)





Mining districts and prospect areas

- Originally defined by the miners themselves
  - During the California Gold Rush in 1849, the Military Governor of California established that gold can be produced from federal land without charge or hindrance
  - Bylaws written and filed in the county courthouse
- 1872 Mining Act validated existing organized mining districts and authorized formation of new mining districts
- Raymond (1870) recognized a mining district as any area of mineral production
- Jones (1904) stated that "*most mining districts in New Mexico are very indefinite in regard to their extent or area*…"
- Lindgren et al. (1910, p. 46) was one of the first to recognize mining districts on the basis of geology

Mining districts and prospect areas

- A mining district is a group of mines and/or mineral deposits that occur
  - in a geographically defined area (such as a mining district or coal field)
  - locally are determined by geologic criteria (distribution of mines and deposits, mineralogy, faults, lithology, stratigraphic horizons, common mineralization processes, age, etc.)
  - has had some mineral production
- A prospect area is an area defined by
  - geologic criteria (distribution of mines and deposits, mineralogy, faults, lithology, stratigraphic horizons, age, etc.)
  - that has had no mineral production

Why are mining districts important in exploration?

Why are mining districts important in exploration?

- Historical
- Production typically reported by mining district not by individual mine
- Guide to exploration
- When you file a mining claim on Federal land you must designate a mining district
- Identifies area of geologically similar settings
- Attract potential investors

Boundaries determined by the miners, locations of mines/deposits, geological characteristics, natural boundaries (rivers, mountains, watersheds), political, and potential investors

Note that many mining districts and prospect areas in New Mexico have more than one type of mineral deposit

Table 1. Estimated total production of major commodities in New Mexico, in order of estimated cumulative value (from USGS, 1902–1927; USBM, 1927–1990; Kelley, 1949; Northrop, 1959, 1996; Harrer, 1965; USGS, 1965; Howard, 1967; Harben et al., 2008; New Mexico Energy, Minerals and Natural Resources Department, 1990–2015). Figures are subjected to change as more data are obtained (these are conservative estimates).

Commodity	Years of production	Estimated quantity of production	Estimated cumulative value ($)	Quantity of production in 2015	Value in 2015 ($)	Ranking in U.S. in 2015
Copper	1804–2015	>11.7 million tons	>21.6 billion	na	na	2
Molybdenum	1931–2013	>176 million pounds	>852 million	na	na	na
Gold	1848–2015	>3.2 million troy ounces	>463 million	20,438 troy ounces	$23,708,980	9
Zinc	1903–1991	>1.51 million tons	>337 million	none	$0	
Silver	1848–2015	>118.7 million troy ounces	>279 million	56,983 troy ounces	$895,610	7
Lead	1883–1992	>367,000 tons	>56.7 million	none	$0	
Iron	1888–2015	>6.7 million long tons	>23 million	na	na	
Fluorspar	1909–1978	>721,000 tons	12 million	none	$0	
Manganese	1883–1963	>1.9 million tons	5 million	none	$0	
Barite	1918–1965	>37,500 tons	>400,000	none	$0	
Tungsten	1940–1958	113.8 tons (>60% WO_3)	na	none	$0	
Niobium-tantalum	1953–1965	34,000 pounds of concentrates	na	none	$0	
TOTAL (excluding coal)	**1804–2015**	**—**	**>23 billion**	**—**	**—**	**15**

Beryllium, tin, antimony, arsenic, vanadium, selenium, tellurium, thorium, REE, titanium, bismuth also have been produced. Na–not available.

Only six commodities have cumulative production from New Mexico exceeding $1 billion: coal, copper, potash, uranium, aggregates, and cement.

Table 2. Types of mineral deposits in New Mexico, in order of perceived age, excluding coal and many industrial minerals deposits (modified from North and McLemore, 1986, 1988; Cox and Singer, 1986; McLemore and Lueth, 1996; McLemore, 1996a, 1996b, 2001). USGS (U.S. Geological Survey) classification from Cox and Singer (1986). PGE=platinum group metals. REE=rare earth elements. *Not described in this chapter but by McLemore and Chenoweth (2016).

NMBGMR classification	USGS classification (USGS model number)	Commodities	Perceived age of deposit in NM
Volcanogenic massive sulfide (VMS)	Volcanogenic massive sulfide (24a,b, 28a)	Au, Ag, Cu, Pb, Zn	1,650–1,600 Ma
Pegmatites	Pegmatite (13a–h)	Be, Li, U, TH, REE, Nb, Ta, W Sn, Zr, Hf	Probably 1,450–1,400 Ma, 1,100–1,200? Ma, some Tertiary
Vein and replacement deposits in Proterozoic rocks (formerly Precambrian veins and replacements)	Polymetallic veins, fluorite veins (22c, 26b)	Au, Ag, Cu, Pb, Zn, Mn, F, Ba	Proterozoic to Tertiary
Proterozoic iron formation	Volcanic hosted magnetite (25i)	Fe, Au	Proterozoic
Syenite/gabbro-hosted Cu-Ag-PGE	Gabbroid-associated Ni-Cu (7a)	Cu, Ag, PGE	Probably 1,450–1,400 Ma, could be older
Disseminated Y-Zr deposits in alkaline rocks	Alkaline complex associated zircon (11c)	Y, Zr, REE, U. Th, Hf	1,100–1,200 Ma
Carbonatites	Carbonatite (10)	REE, U, Th, Nb, Ta, Zr, Hf, Fe, Ti, V, Cu, apatite, barite	400–600 Ma, one about 22 Ma

Table 2. Continued

NMBGMR classification	USGS classification (USGS model number)	Commodities	Perceived age of deposit in NM
Episyenites and REE-Th-U veins	Th-REE veins (10b, 11d)	REE, U, Th, Nb, Ta	400–600 Ma
Sedimentary iron deposits	Oolitic iron (34f)	Fe	Cambrian-Ordovician
Sedimentary-copper deposits	Sediment-hosted copper (30b)	Cu, Ag, Pb, Zn, U, V	Pennsylvanian-Permian, Triassic
Uraniferous collapse-breccia pipe (including clastic plug deposits)	Solution-collapse breccia pipe U deposits (32e)	Cu, Ag, U, Co, Se, REE?	Triassic, Jurassic
Limestone uranium deposits*	None	U, V, Se, Mo	Jurassic
Sandstone uranium deposits*	Sandstone uranium (30c)	U, V, Se, Mo, REE?	Pennsylvanian-Permian-Miocene
Beach-placer sandstone deposits	Shoreline placer Ti (39c)	Th, REE, Zr, Hf, Ti, U, Fe, Nb, Ta	Cretaceous
Replacement-iron	Iron skarn (18d)	Fe	Cretaceous-Miocene (75–50 Ma)
Porphyry Cu, Cu-Mo (±Au)	Porphyry copper (17, 20c, 21a)	Cu, Mo, Au, Ag	75–50 Ma
Laramide, Cu, Pb, Zn, Fe skarn	Skarn (18a, 18c, 19a)	Au, Ag, Cu, Pb, Zn	75–40 Ma
Laramide, Polymetallic vein	Polymetallic veins (22c)	Au, Ag, Cu, Pb, Zn	75–40 Ma
Porphyry Mo (±Cu, W)	Porphyry Mo-W (16, 21b)	Mo, W, Au, Ag, Be, Cu	Probably 35–25 Ma
Carbonate-hosted W-Be replacement and skarn (Mo-W-Be, F-Be, Fe-Mn)	W-Be skarns (14a)	Mo, W, Be, Pb, Zn, Cu, F, Mn	Probably 35–25 Ma
Carbonate-hosted Pb-Zn (Cu, Ag) replacement	Polymetallic replacement (19a)	Pb, Zn, Cu, Ag	75–25 Ma
Carbonate-hosted Ag-Mn (Pb) replacement	Polymetallic replacement, replacement manganese (19a, b)	Ag, Mn, Pb, Zn	75–25 Ma

Great Plains Margin (GPM or alkaline-related) deposits (including veins; gold-bearing breccias and quartz veins; porphyry Cu-Mo-Au; Cu, Pb/Zn, and Au skarns and carbonate-hosted replacement deposits; Fe skarns and replacement bodies; Th-REE-fluorite (with U and Nb) epithermal veins, carbonatites)	Porphyry copper, polymetallic veins, copper skarns, iron skarns, placer gold (17, 22c, 18a,b, 18d, 39a), Th-REE veins (10b, 11d)	Au, Ag, Cu, Pb, Zn, Mo, Mn, Fe, F, Ba, Te, REE, Nb, Zr, U, Th	47–25 Ma
Volcanic-epithermal veins	Quartz-adularia, quartz-alunite, epithermal manganese (25b,c,d,e,g, 26b, 35a)	Au, Ag, Cu, Pb, Zn, Mn, F, Ba	35–16 Ma or younger
Rhyolite/granite-hosted tin (topaz rhyolites)	Rhyolite-hosted tin (25h)	Sn, Be, REE	28 Ma
Tin skarns	Tin skarns (15c, 14b, 14c)	Sn	
Volcanogenic Be (volcanic-hosted replacement, volcanic-epithermal, Spor Mountain Be-F-U deposits)	Volcanogenic Be deposits	Be, F, U	Miocene-Pliocene
Carbonate-hosted Mn replacement	Replacement Mn (19b)	Mn	Miocene-Pliocene
Rio Grande Rift Copper-silver (±U) vein deposits	Polymetallic veins (22c)	Cu, Ag, U	Miocene-Pliocene
Mississippi Valley-type (MVT) (here restricted to Permian Basin)	Mississippi Valley-type (MVT) (32a-d)	Cu, Pb, Ag, Zn, Ba, F	Oligocene-Pliocene
Surficial uranium deposits*		U	Miocene-Recent
Rio Grande Rift (RGR) Epithermal Mn	Epithermal Mn (25g)	Mn	Miocene-Recent
Rio Grande Rift (RGR)barite-fluorite-galena	Fluorite and barite veins, polymetallic replacement (IM26b, c, 27e, 19a)	Ba, F, Pb, Ag, U	12 Ma-Recent

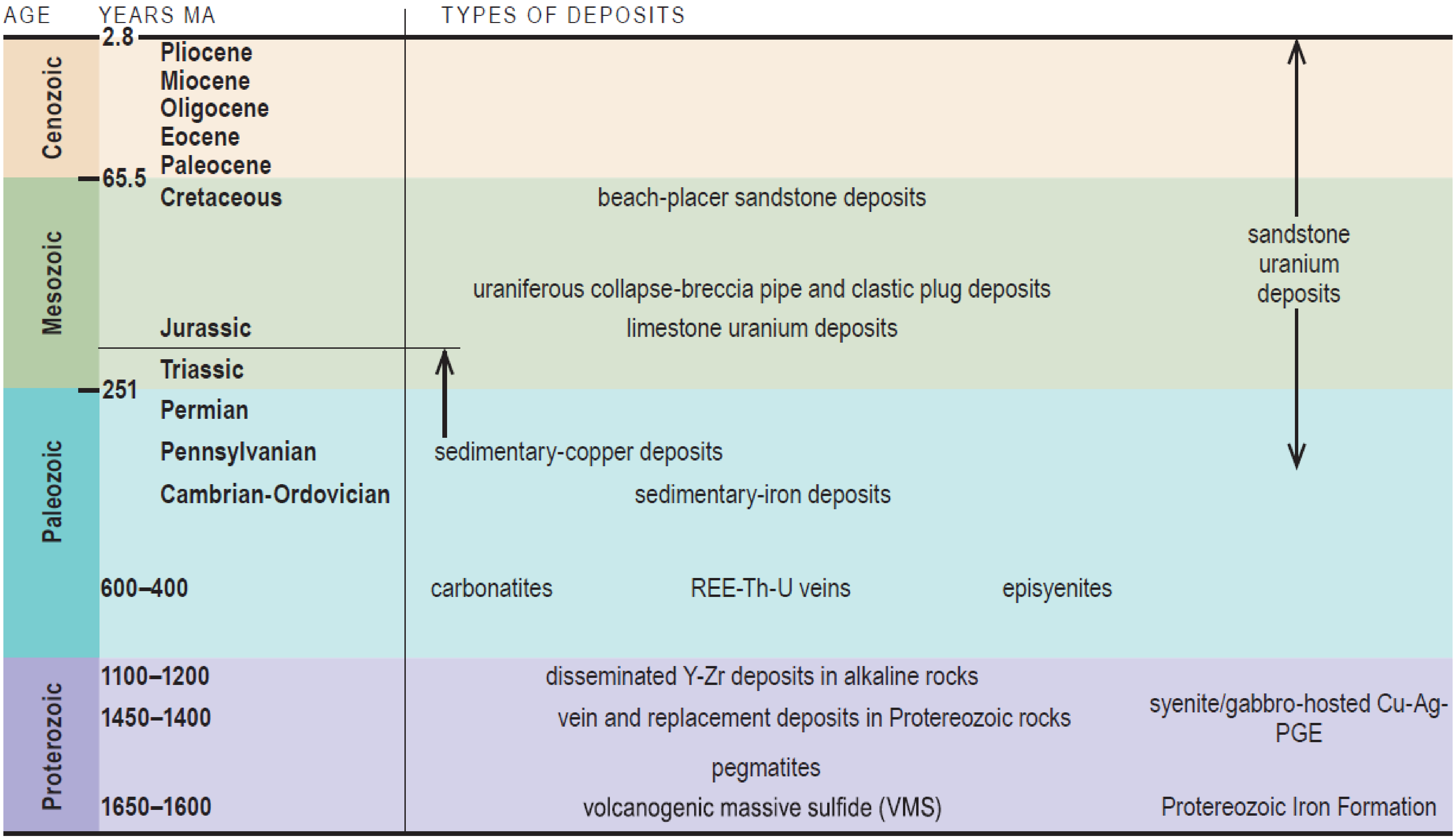


Figure 2. Distribution of Proterozoic-Mesozoic metallic mineral and uranium deposits in New Mexico through time. Arrows delineate the time period sedimentary-copper and sandstone uranium deposits span.

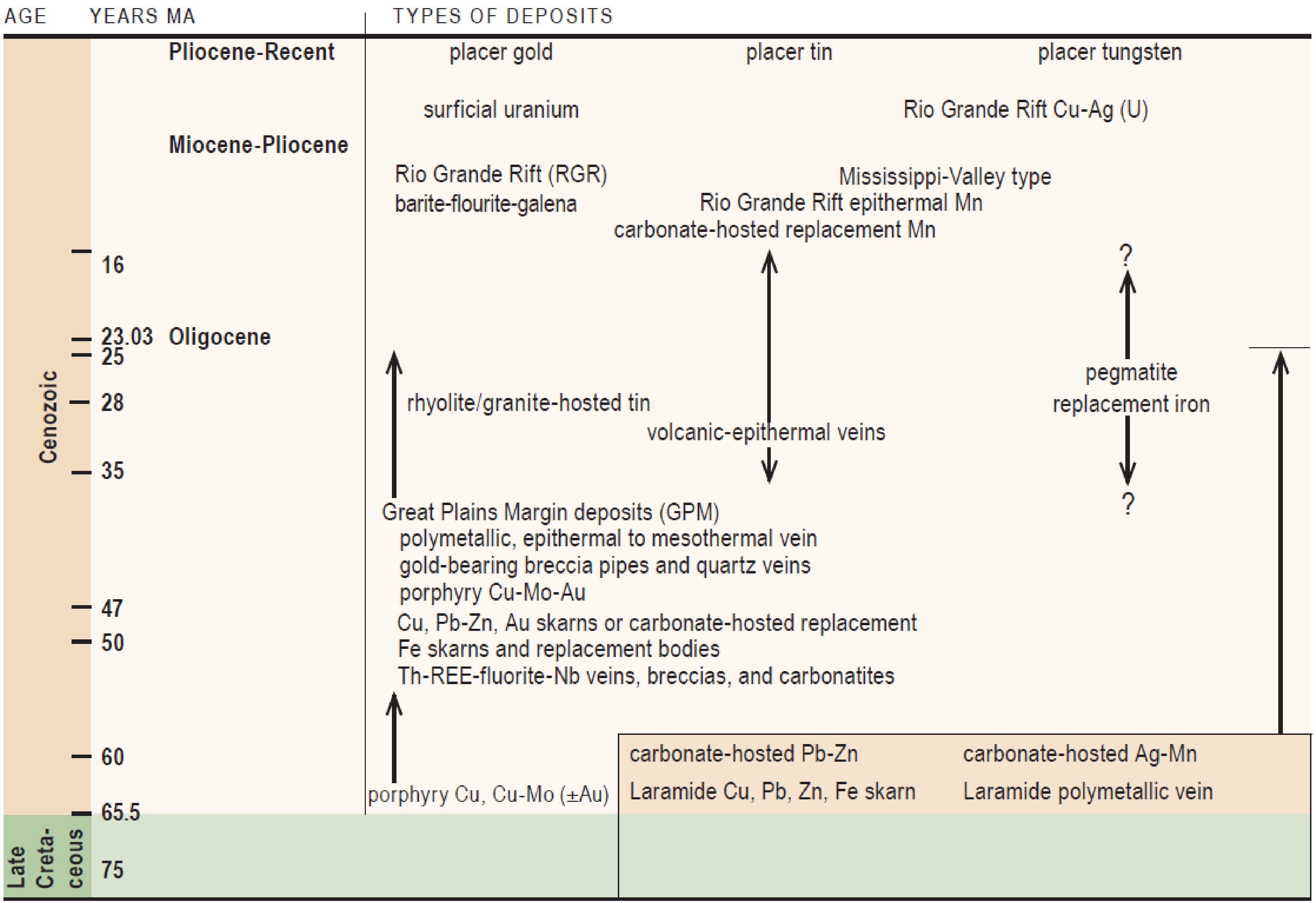


Figure 3. Distribution of Late Cretaceous to Cenozoic metallic mineral and uranium deposits in New Mexico through time.

What are the Mining Issues Facing New Mexico?

Gold King adit

Animas River after Gold King spill

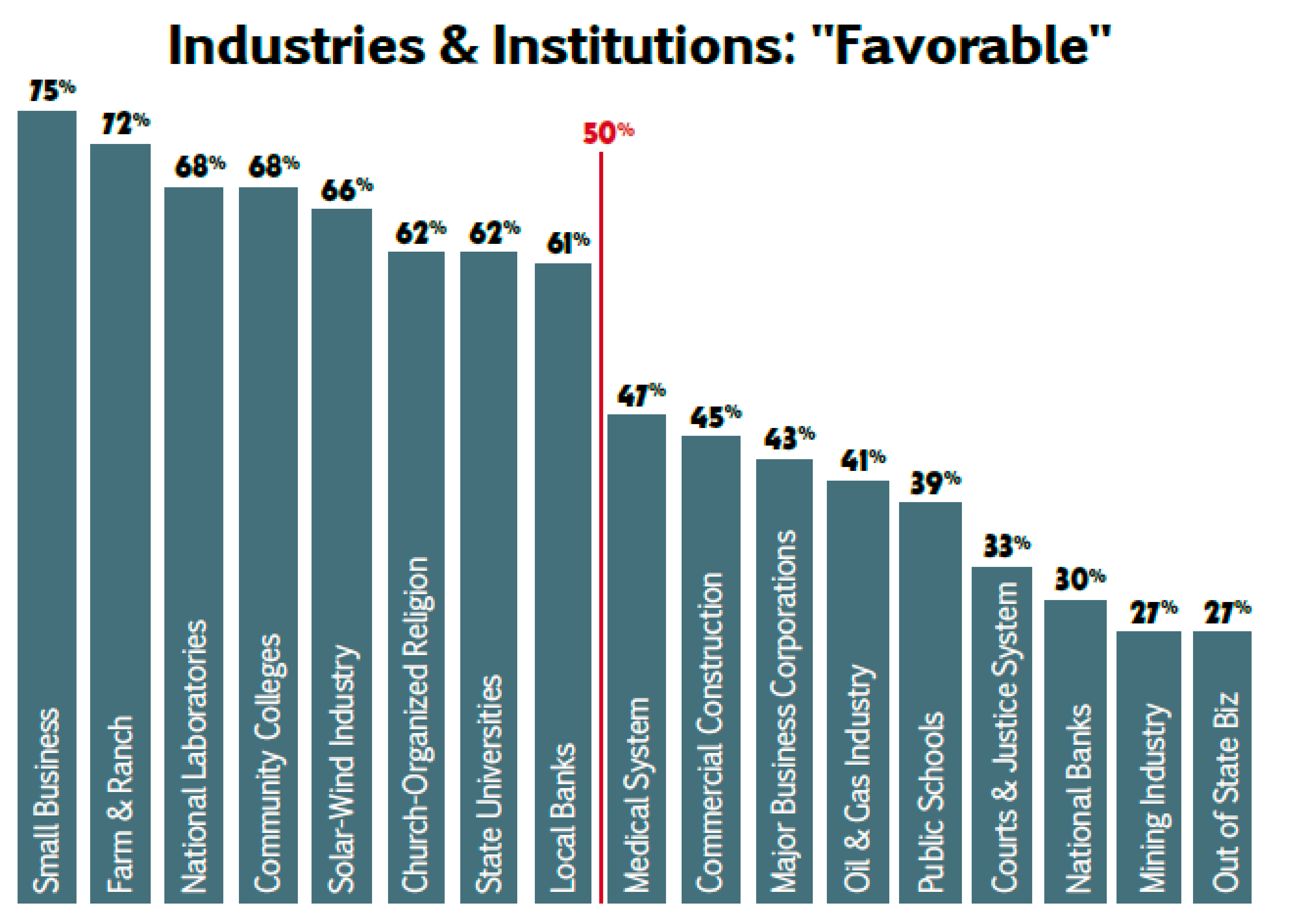
Mining Issues Facing New Mexico

- **Some current mines are reaching the end of their life and will close over the next decade=decreasing minerals production**
- **There are not many new mines to replace them**
- Results in unemployment and decrease in revenues
    - Affects rural economies
    - Affects state revenues

Mining Issues Facing New Mexico

- Mining requires water and their environmental effects must not impact water supplies
- Legacy issues of past mining activities form negative public perceptions of mining
  - Abandoned or legacy mines, especially Grants uranium district and Questa mine
  - Gold King spill
  - Not in my backyard!!!!!!

Mining is viewed as favorable by only 27% of New Mexicans



http://garritypr.com/sites/default/files/uploads/documents/2017_Garrity_Perception_Survey.pdf

Mining Issues Facing New Mexico

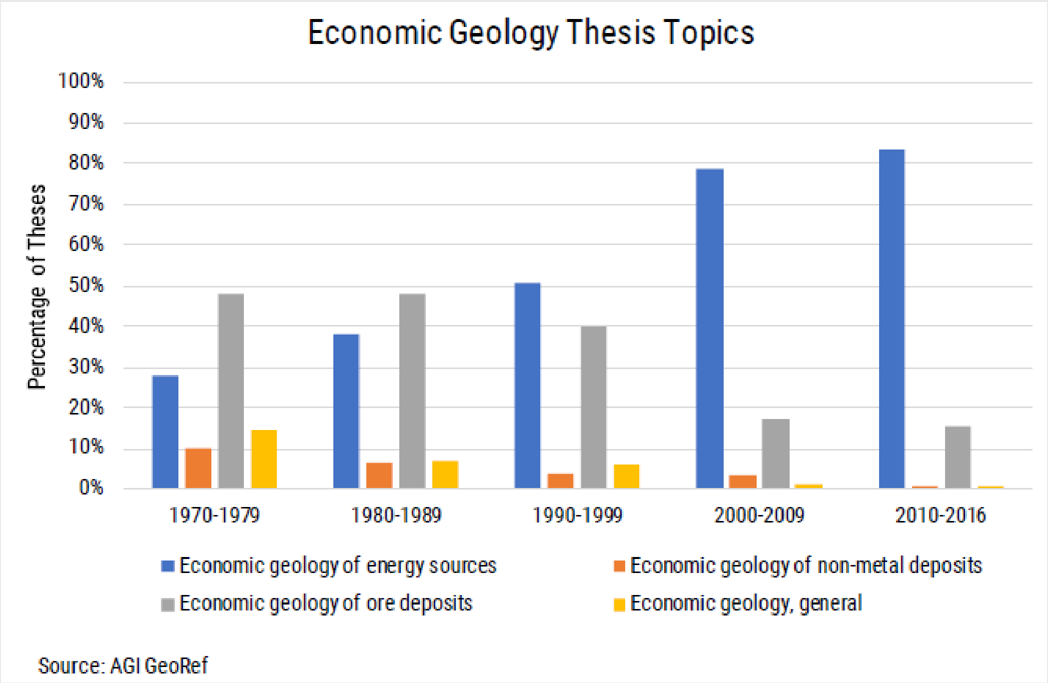
- Many inactive mines still have the potential to contaminate the environment or present a hazard to health and safety
  - Gold King spill
  - AML sites (Abandoned mine lands)
  - Grants uranium district

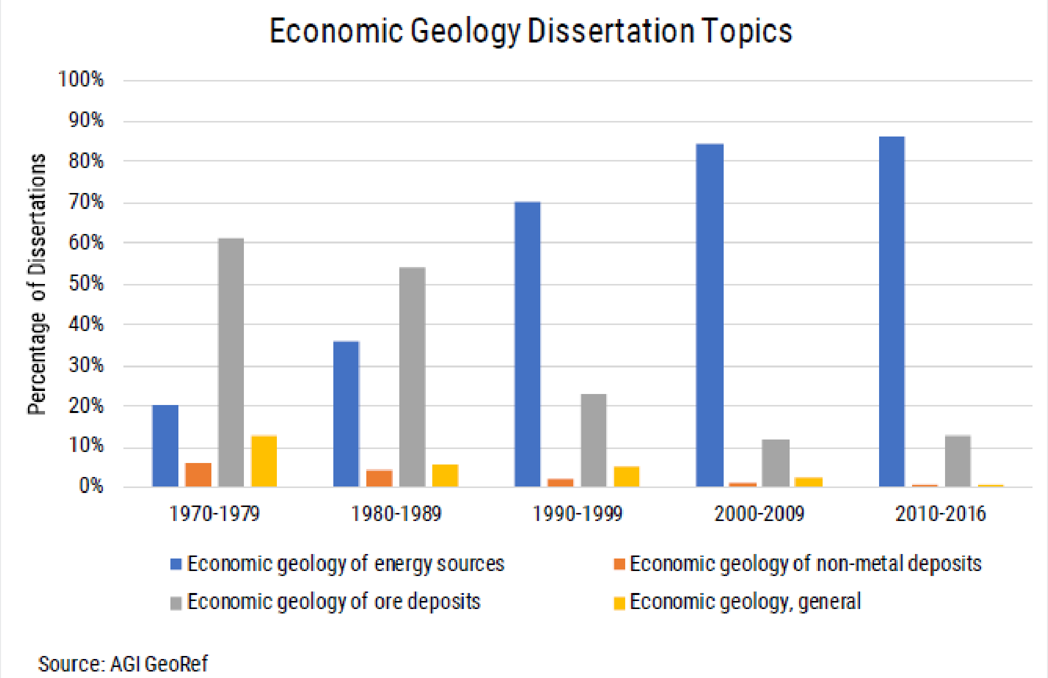
Mining Issues Facing New Mexico

- **Global competition is closing some of our mines**
- Exploration for new deposits often results in drill targets based upon regulatory minimal impact regulations rather than optimum geological criteria
- Permitting for exploration can take longer than exploration funds are available
- Lower prices=closed mines, little exploration

Mining Issues Facing New Mexico

- In some areas conflicts arise between mining and other activities
  - Grants uranium district
  - Otero Mesa
  - Pecos/Tererro mine
  - **Water, don't want a mine in their backyard**
- **Shortage of young geologists and engineers to explore for, develop, mine, permit these commodities and evaluate their effect on the environment—math, science skills critical**





Number of thesis and dissertations on non-energy economic geology has decreased

http://www.multibriefs.com/briefs/aipg/DataBrief_2019_008_EconomicGeologyThesesDissertations.pdf

SUMMARY

- New Mexico has a wealth of mineral resources
- Exploration and permitting takes many years before a deposit can be mined, >10 yrs
- Legacy issues are being addressed
- Negative public perceptions are major issue as is funding
- Global competition is a major threat
- NMBG/NMT research is addressing some of these issues, as well as training future geologists and engineers

Assignment

- Safety
- Read Mineral Resources: Reserves, Peak Production and the Future Meinert et al. https://www.mdpi.com/2079-9276/5/1/14 (be prepared to discuss next week)