North Carolina’s Mineral Storehouse and Emerging Resources

Interstate Mining Commission

Charlotte, North Carolina

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Outline

- Overview
- Value of minerals in the N.C. economy
- Traditional industrial minerals in N.C.
- Emerging resources in N.C. and the 'new stone age'

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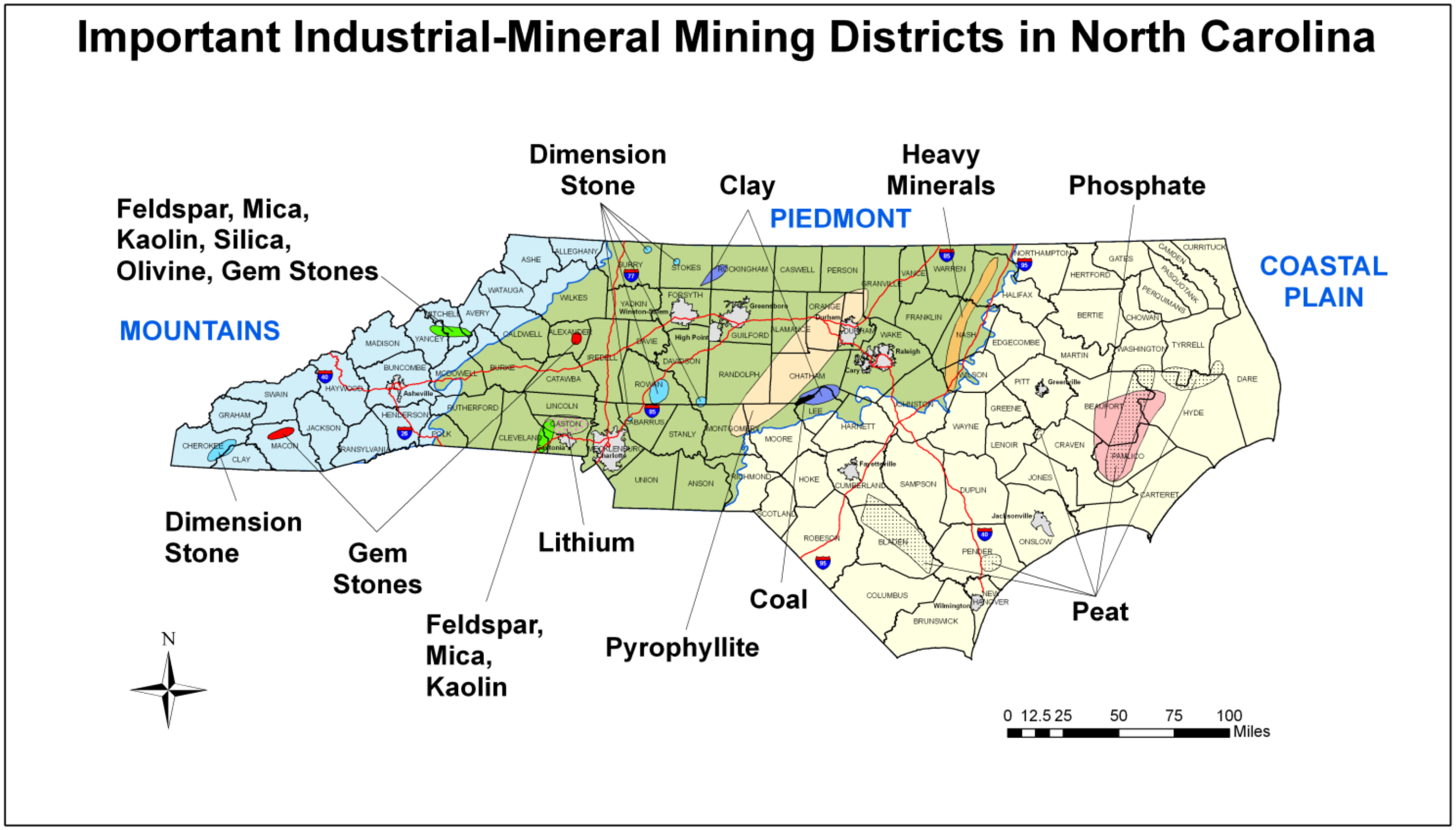
Important industrial mining districts in North Carolina



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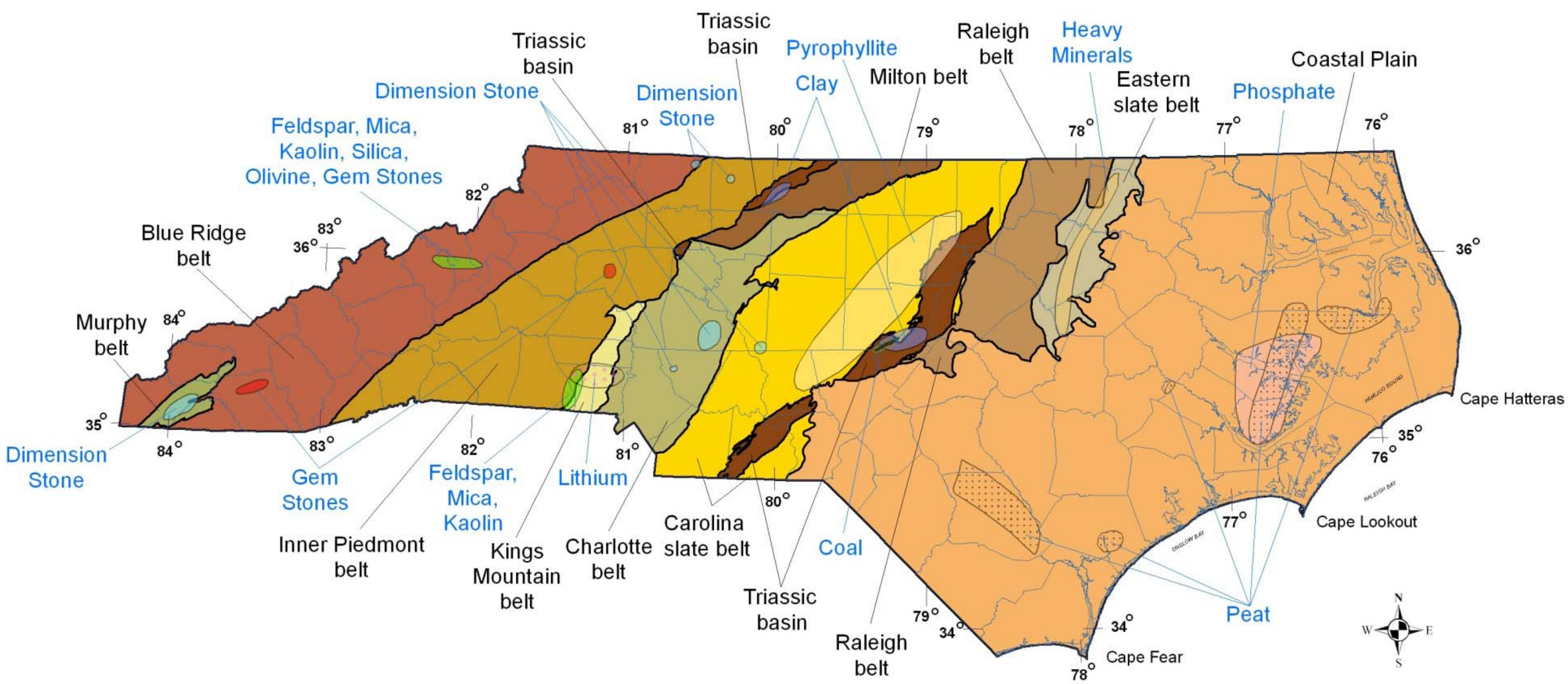
Geologic belts (terrains) of North Carolina

Geologic Belts of North Carolina



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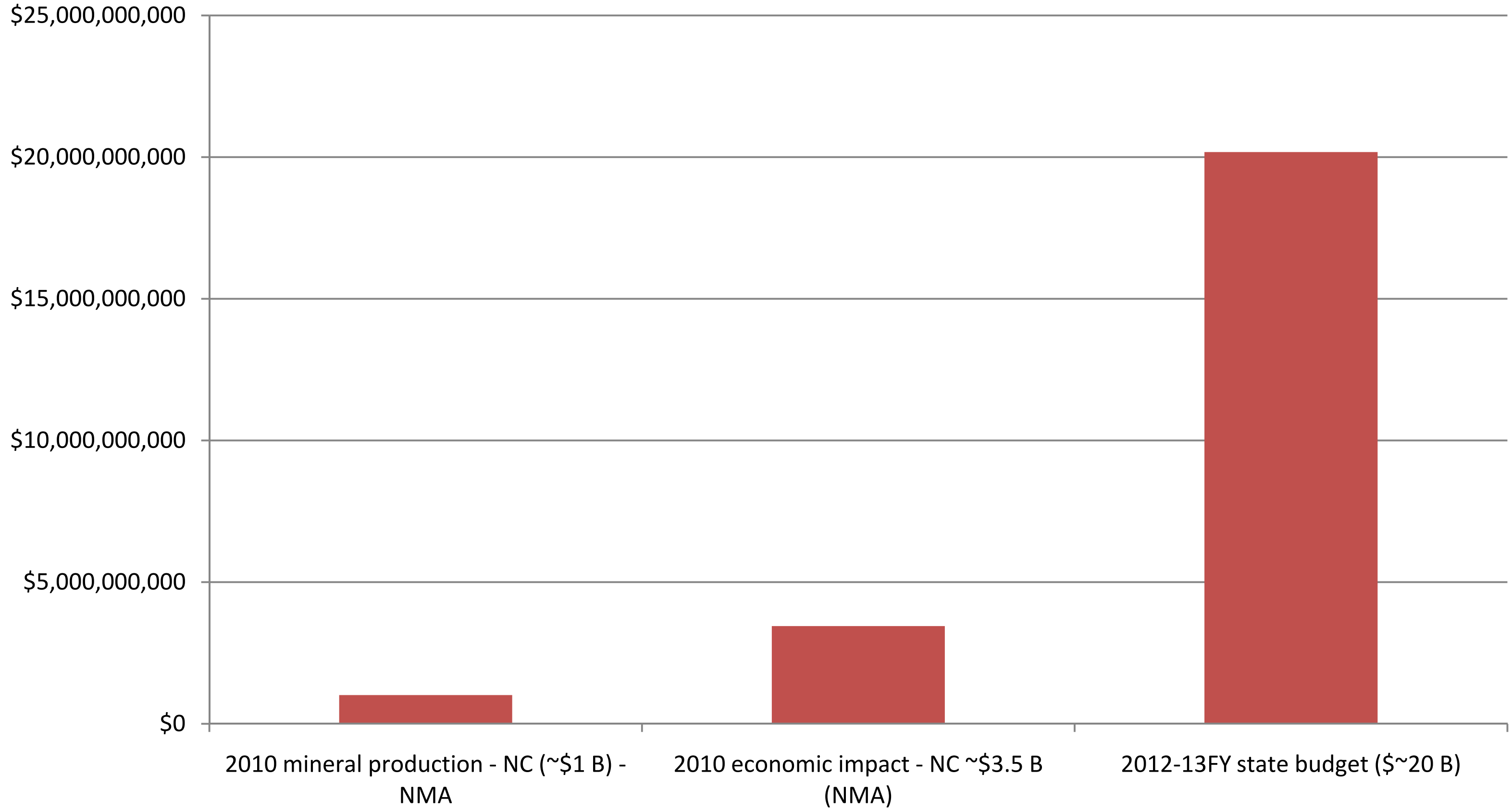
Mining activity and North Carolina's economy



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N.C. Mining Facts

- **Mineral statistics** –
  - The NC Geological Survey in cooperation with the USGS compiles economic mineral information vital to commerce, jobs and national security – a function that needs to be sustained.

- **Mineral processing** –
  - The Minerals Research Laboratory (MRL) of NC State University (Asheville) complements activities of the North Carolina Geological Survey.
  - Statewide tailings study completed by MRL leading to industry interest
  - These two groups throughout the last 60 years have been partially responsible for the development of about $1 billion dollars of mineral revenue.

- **Value added industries –**
  - Several industries provide value added to industrial and metallic minerals including specialty steel production, fiberglass insulation, fiber optic production, gypsum board production (flue gas scrubbing).

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Mining activity and North Carolina's economy

- **Mining activity –**
  - All mining is from 866 permitted active mines that cover 132,033 permitted acres, or only about 0.43 % of the state's ~48,000 square miles of land area (~126,000 square kilometers).
  - This is about $6,980 per permitted acre (USGS 2010).
  - Per capita mineral production is about $92 per year (USGS 2010).
  - A bond ensures reclamation when mining ceases.

- **Minerals and the North Carolina economy** –
  - In 2010 North Carolina ranked 24th among the 50 states in total nonfuel mineral production value ($880,000 thousands) [NMA report $1,013 thousands] accounting for about 1.33% of the U.S. total (USGS 2010).
  - Crushed stone is North Carolina's leading nonfuel raw mineral accounting for about than 70% of the state's total value of nonfuel raw mineral production (USGS Minerals Yearbook advance release 2010)
  - Phosphate rock, sand and gravel (construction), sand and gravel (industrial), and dimension stone are the main commodities.
  - Feldspar, clays (common and kaolin), gemstones (natural), and mica were also produced along with andalusite, pyrophyllite).
  - Nano-technology may prove fruitful in evaluation of tailings.

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Mining activity and North Carolina's economy

- **Minerals and the North Carolina economy in 2010**
  - Mining provided direct employment to 10,230 people and another 27,510 people indirectly for a total of 37,740 jobs
  - The average annual wage was $52,871
  - Payroll earnings and indirect economic activity generated $1.399 million
  - Income and payroll taxes generated ~$686 million
  - Mining operations created $1,013 million of mineral metal and fuel products
  - Indirect revenue accounted for $2,436 million
  - Total economic impact was $3,449 million
  - Mining generated 0.88% of the state's GDP

From National Mining Association, 12 October 2012
URL http://www.nma.org/pdf/states/econ/nc.pdf viewed 7 December 2012

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Mining activity and North Carolina's economy

- **Minerals and the North Carolina economy** *(continued)* –
  - High purity quartz: 90% of the world's high purity quartz is mined and processed in western North Carolina for the electronic industry.
  - Feldspar: 60% of the United States' consumption comes from NC
  - Common clays, mica, olivine, and pyrophyllite produced; the latter two were produced in only one other state and North Carolina.
  - Significant quantities of construction sand and gravel and dimension stone were produced in the State.
  - Metal production in the State, especially that of steel, resulted from the processing of recycled materials or raw materials received from other domestic and foreign sources.

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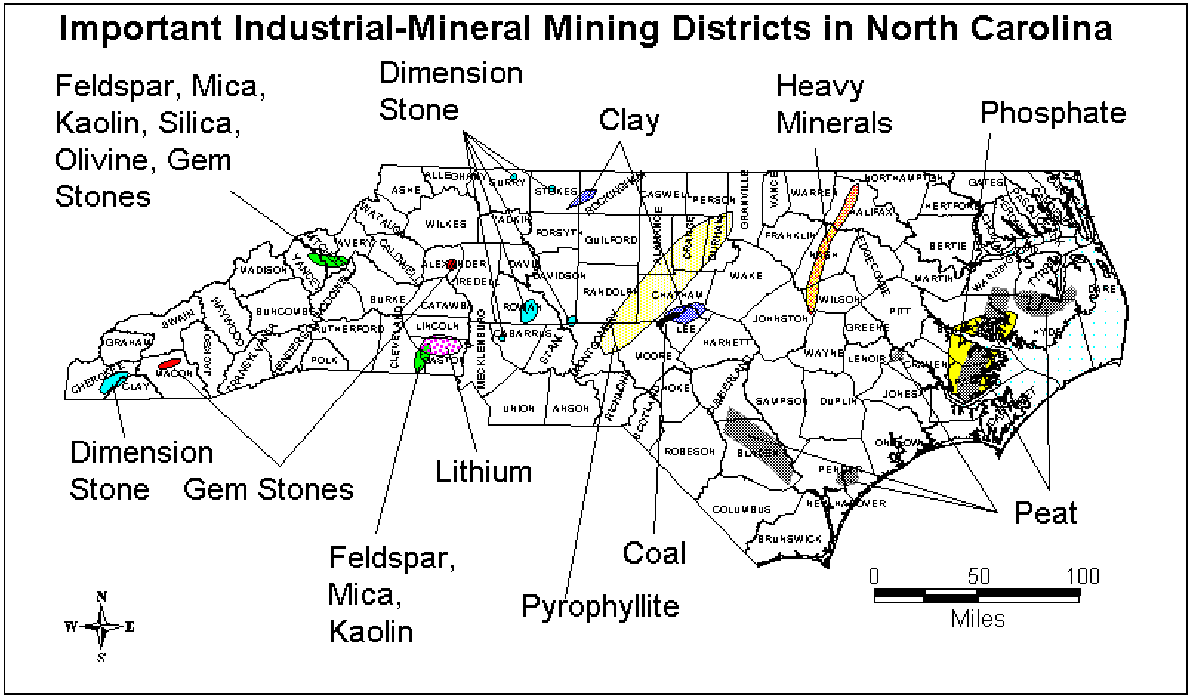
Crushed stone



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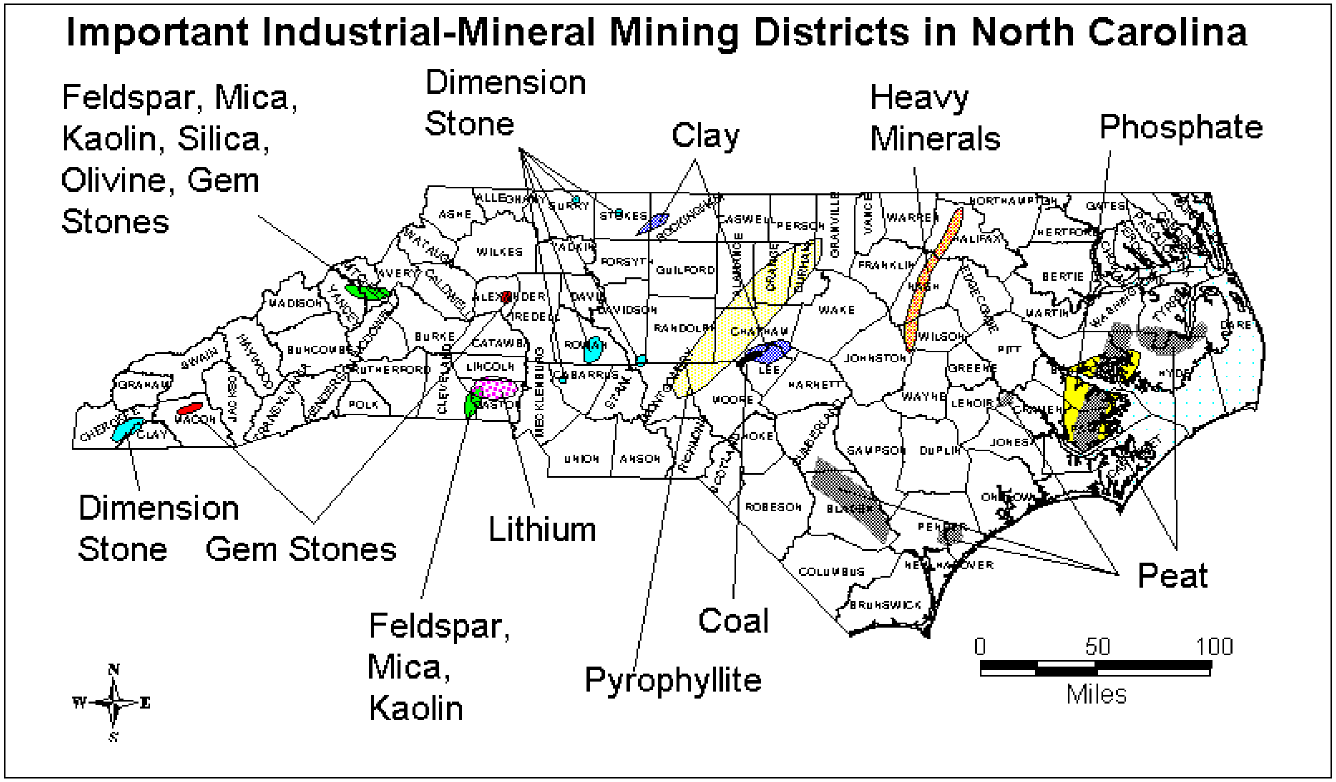
Sand – construction and glass



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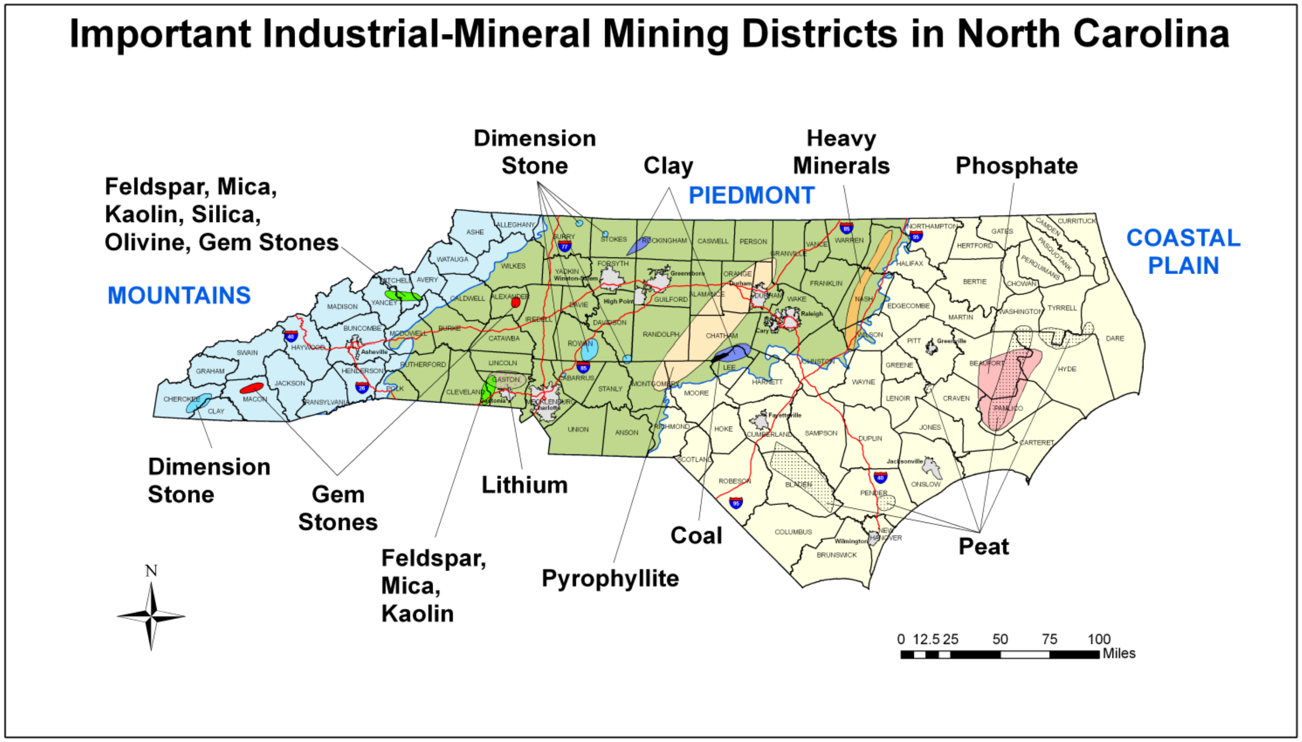
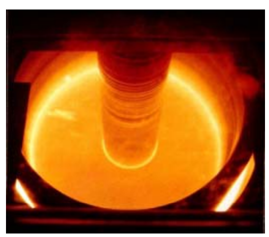
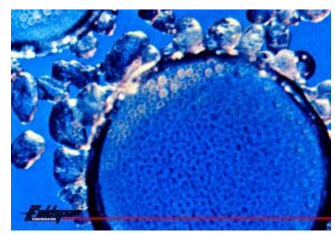
Quartz, feldspar, mica







Note: Deposits are now all foreign-owned: Unimin, and Quartz Corp. (Emery and Norwegian Crystallite venture).

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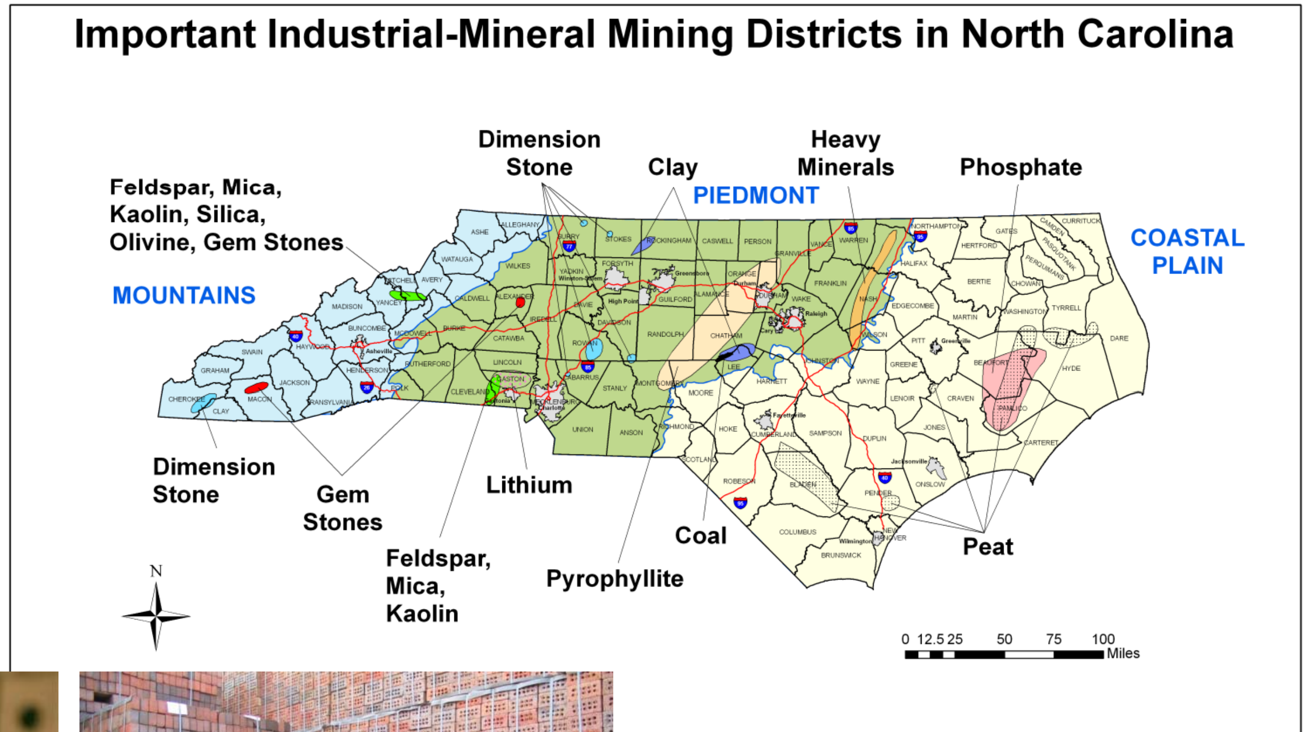
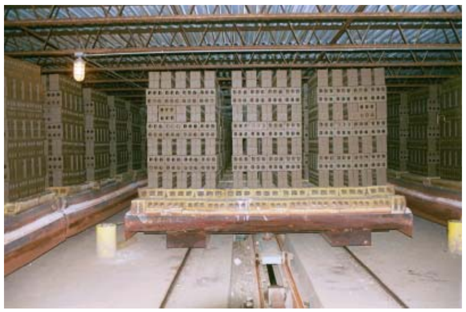
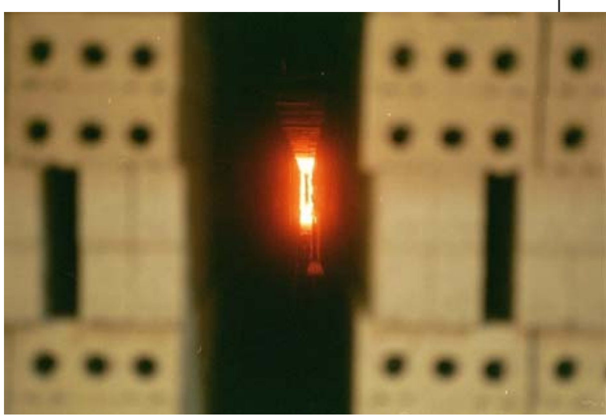
Bricks







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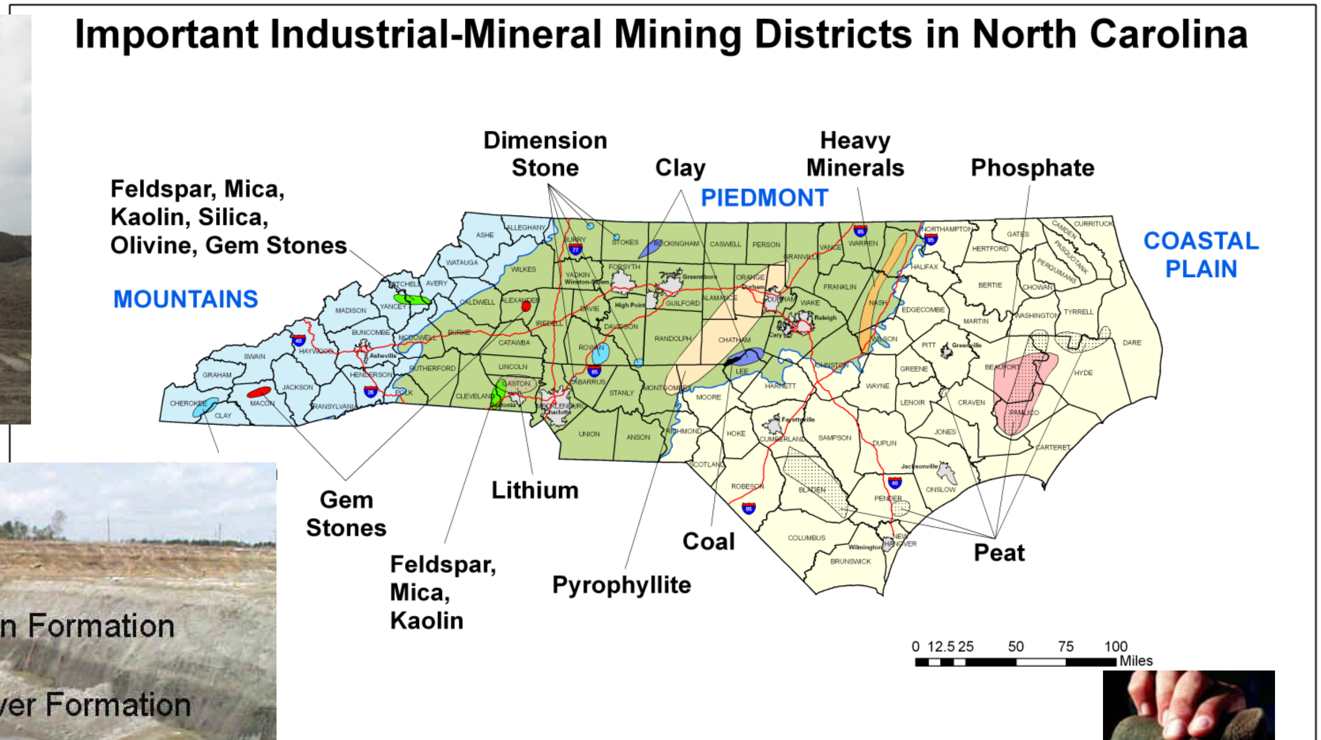
Phosphate



- •Middle Miocene – Pungo River Formation
- •Interbedded phosphatic sands, silts and clays, and phosphatic and non-phosphatic limestones, plus shell hash and coquina

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Phosphate

(From Gilmore, 2006)

- Mining Operations began in 1965.
- 12,800 acres of permitted area.
- The Mine recovers phosphate ore and pumps the ore in a slurry to the Mill where it is upgraded to concentrated phosphate sand.
- The phosphate concentrate is used as a raw material in the production of liquid and dry fertilizers, animal feed products, food grade additives and industrial phosphate chemicals.
- The Aurora operation is the largest vertically integrated phosphate operation in the world today.

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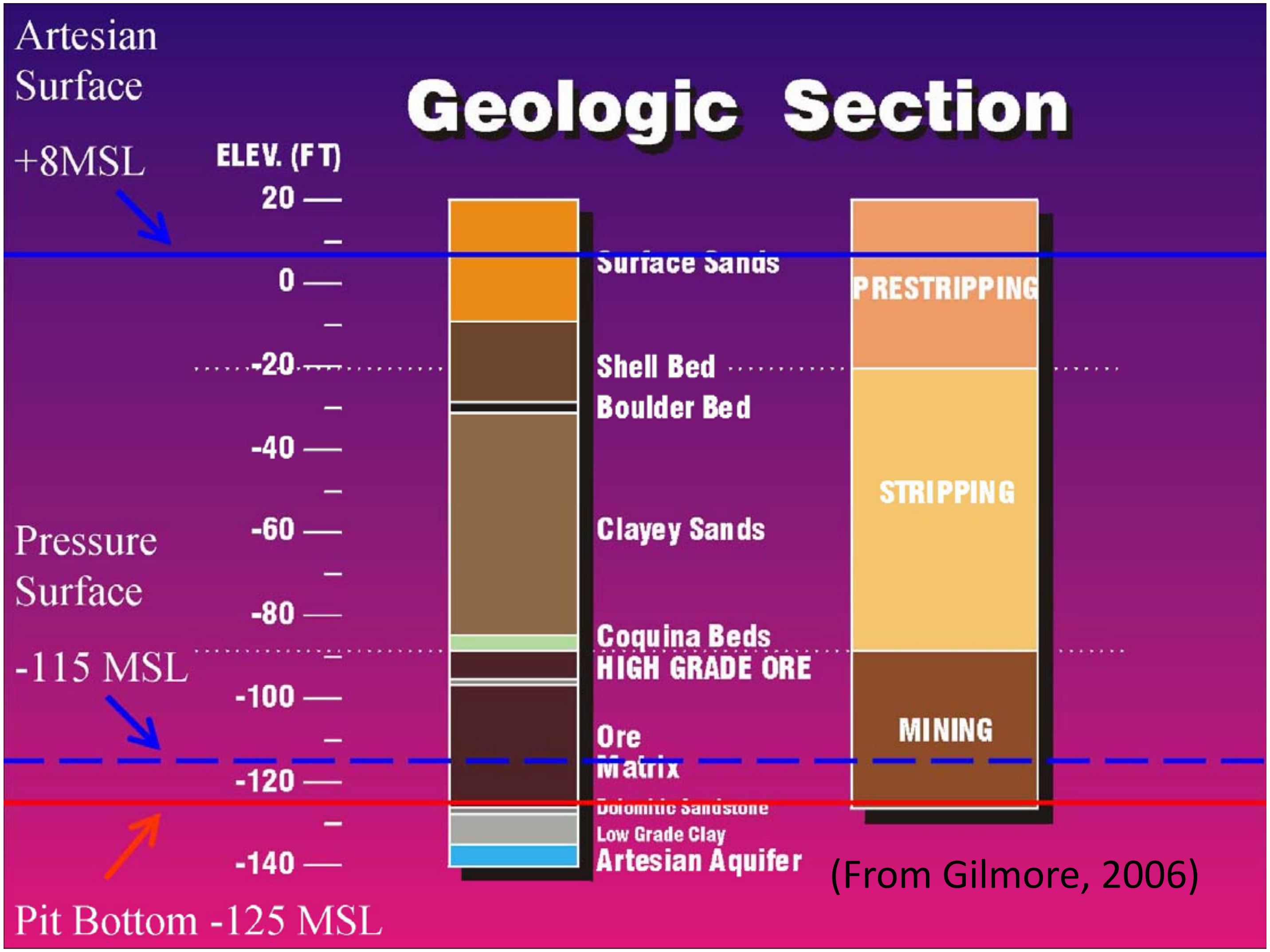
Phosphate



(From Gilmore, 2006)

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Phosphate

From Gilmore, 2006

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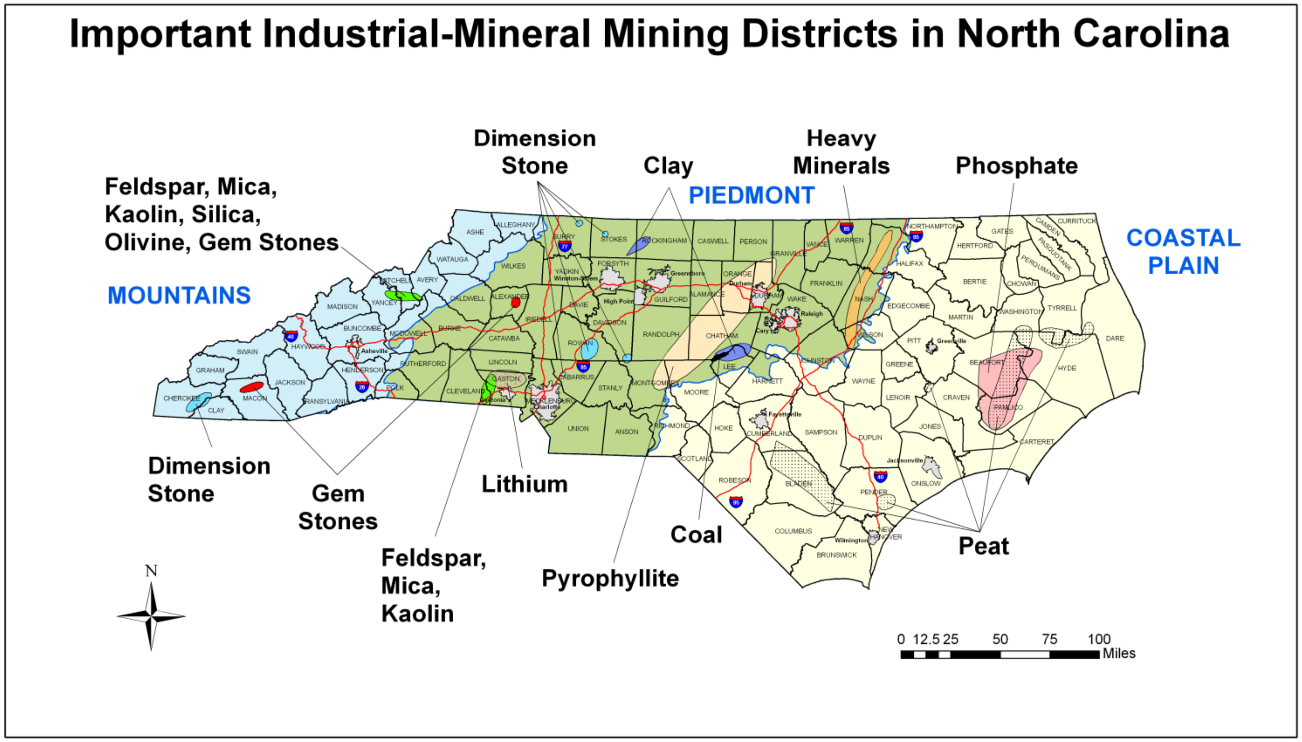
Dimension stone



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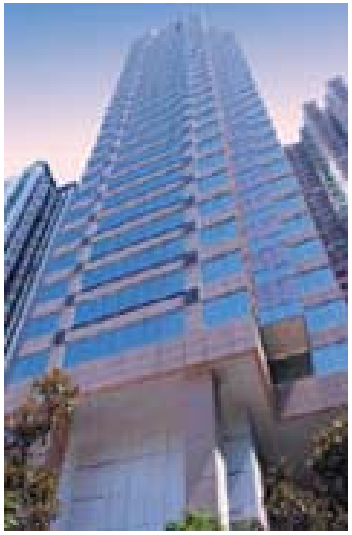
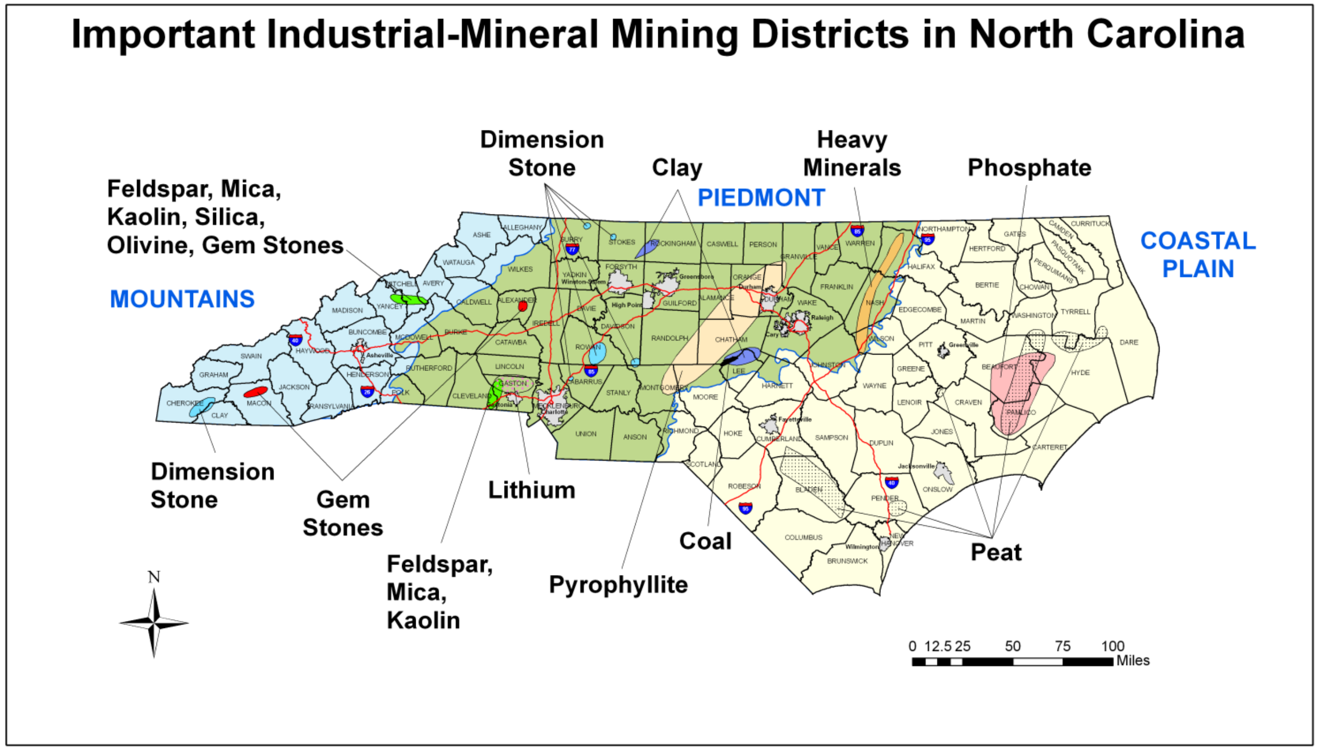
Dimension stone (cont'd)





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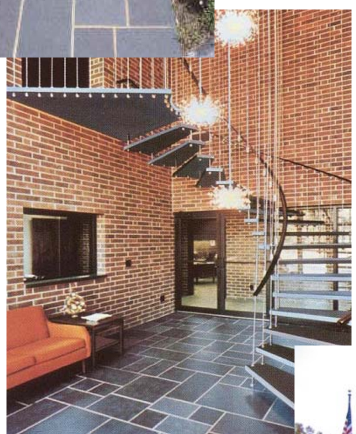
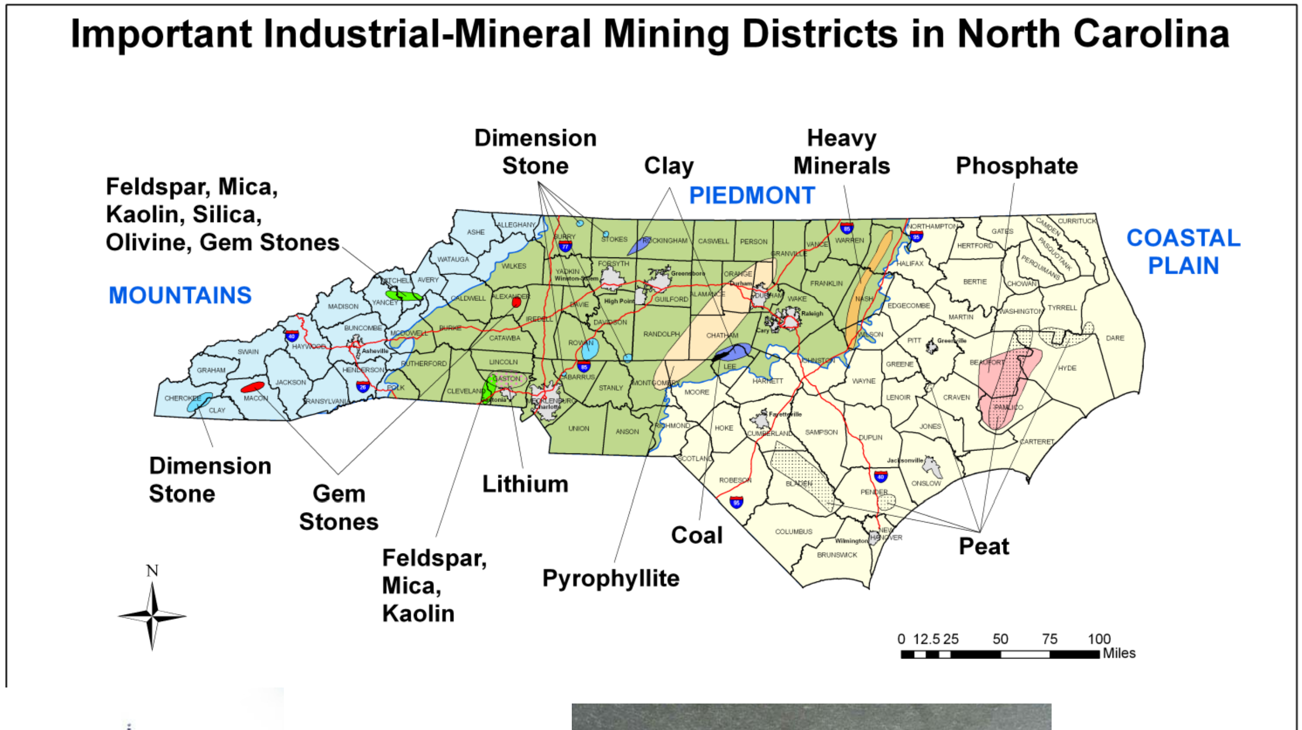
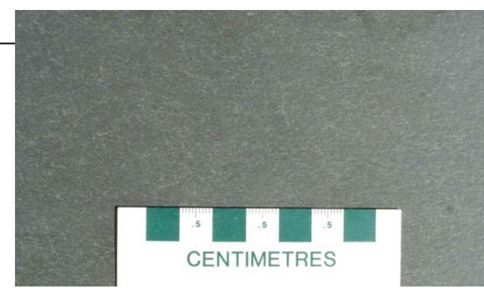
Argillite (dimension stone)







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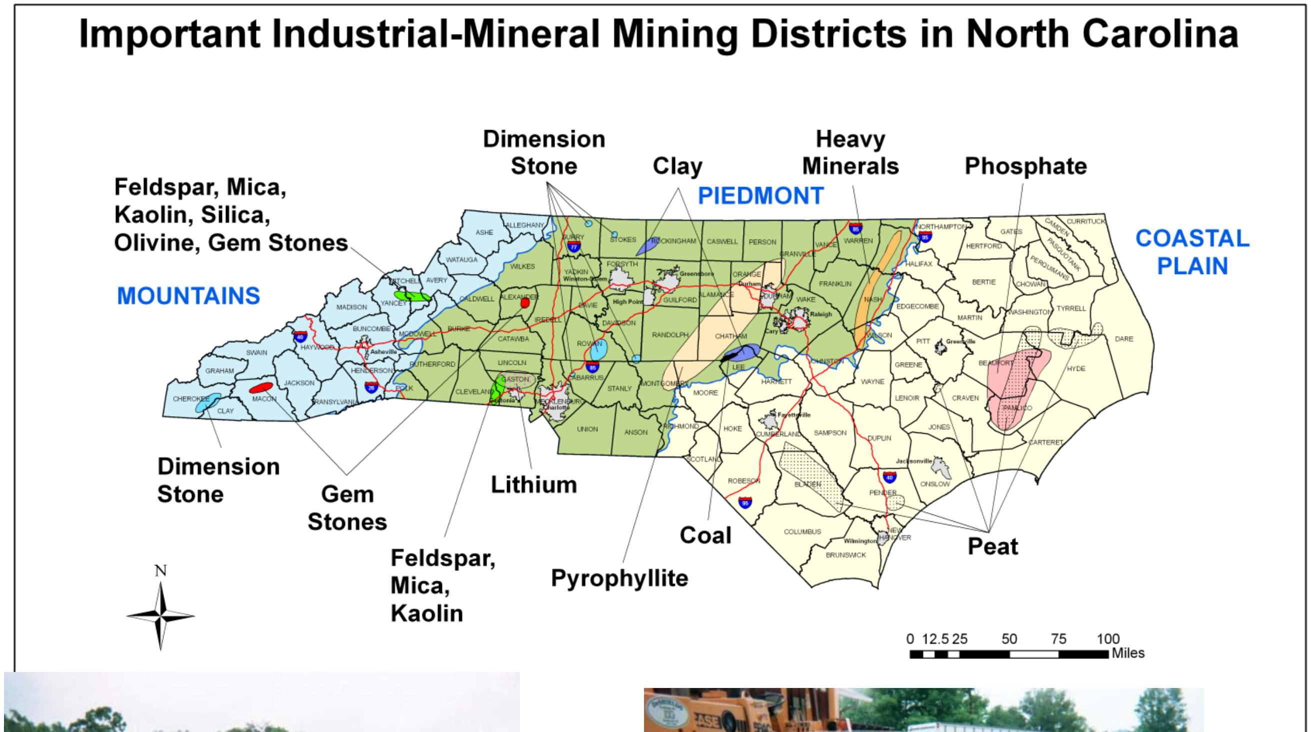
Flagstone



- Typically mylonites
- Includes river cobbles (not shown)

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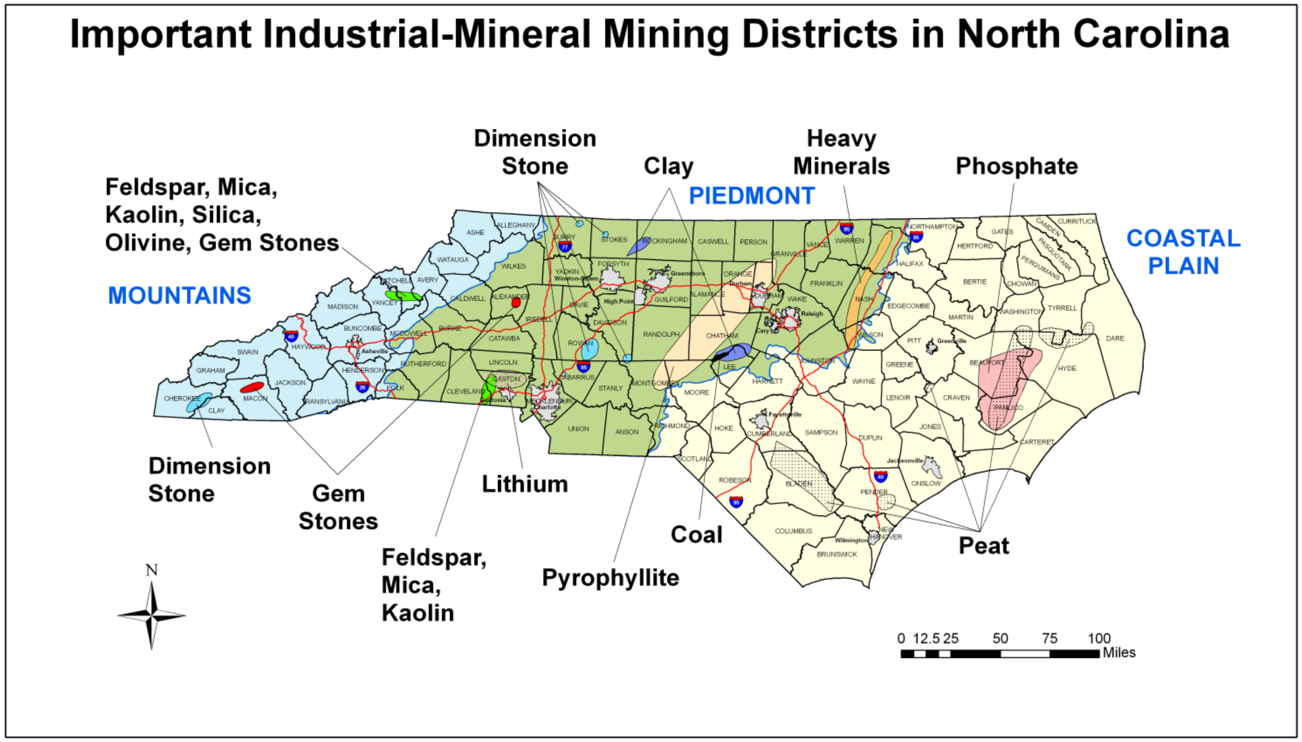
Roofing granules



•Metavolcanic rocks
•Ground and sized
•Coated with different colors (enamel)

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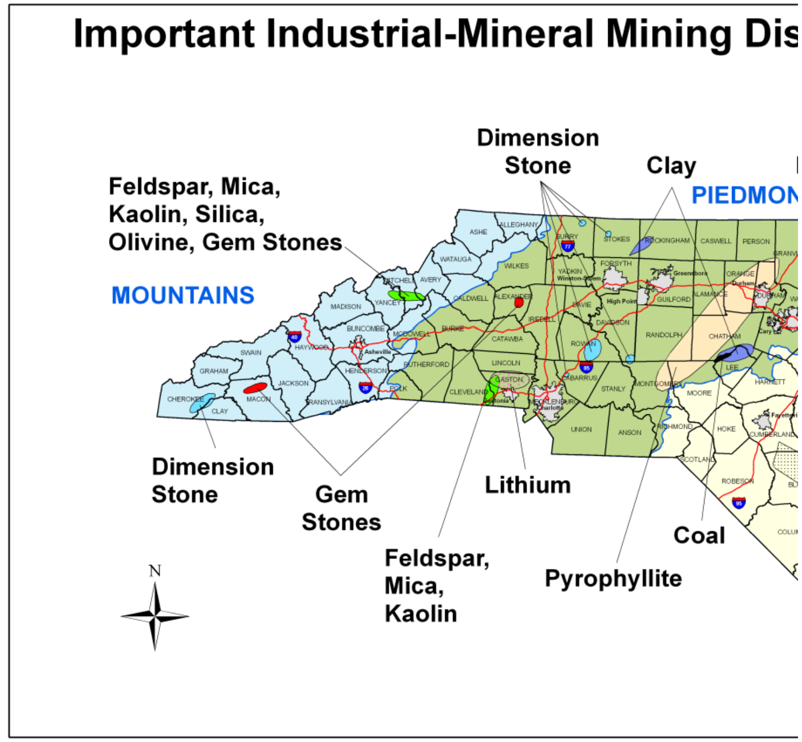
Lithium



- Hard rock silicate resource not currently produced
- Plant processes imported carbonate ore
- Canadian junior explored strike extent to north of present hard rock pit resulting in identification of additional resources along strike to the northeast

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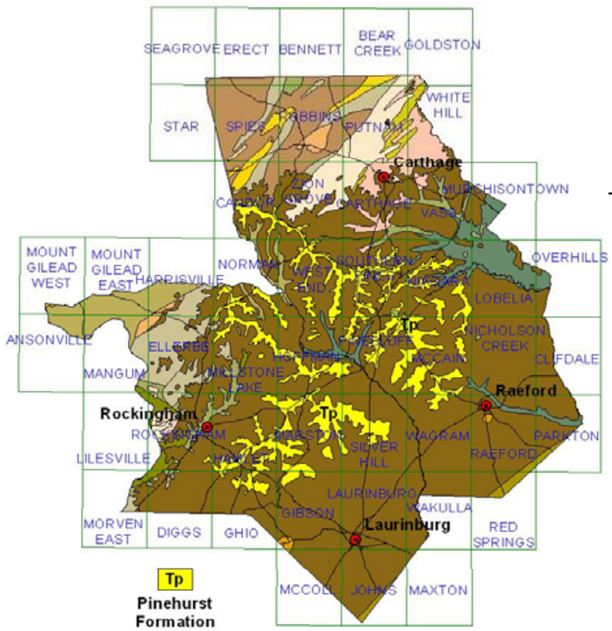
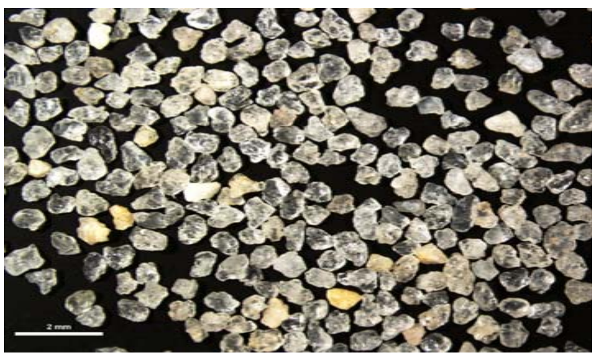
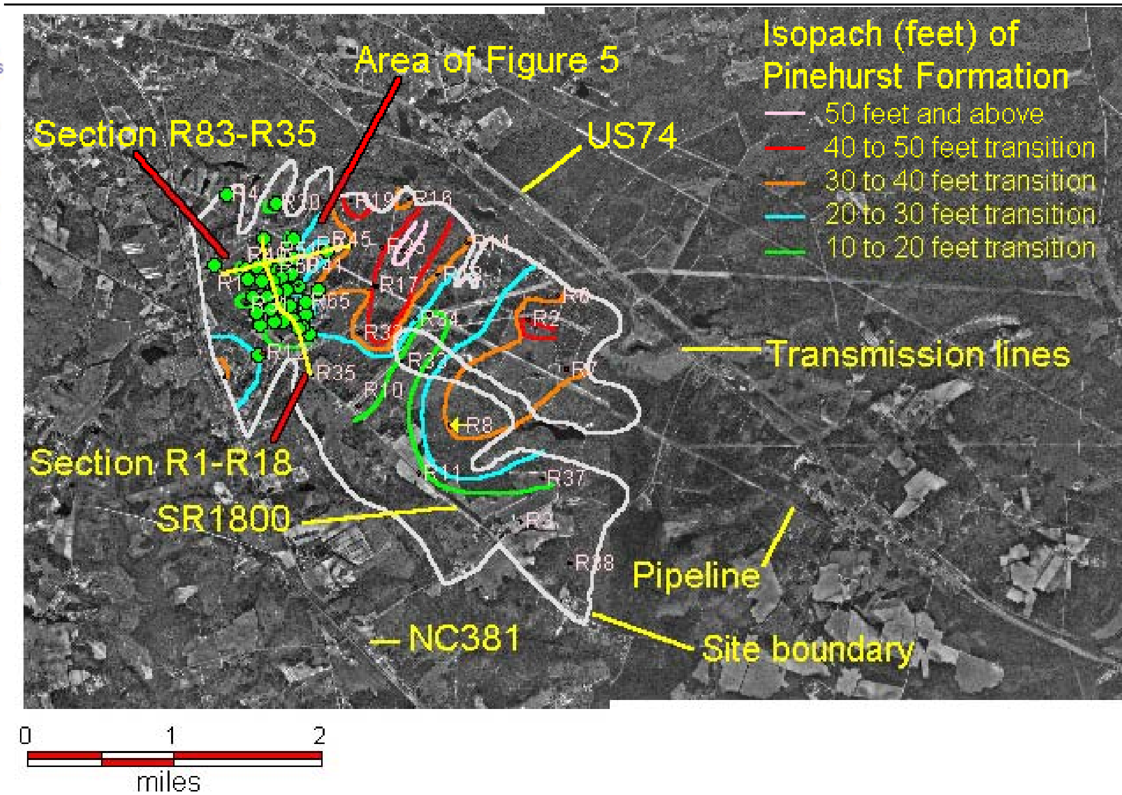
Glass sand







The glass sand product after attrition scrubbing, sizing, and magnetic separation contained 0.13-0.16 % Al_2O_3, 0.02 – 0.04% Fe_2O_3, < 0.01 – 0.02% TiO_2 and traces of other minor elements. Further reduction of impurities will be obtained from separation processes that include flotation. This product is well within the specifications for typical glass sand and is suitable for many glass sand applications.

From: Mensah-Biney, Carpenter, Miller, and Reid, 2005

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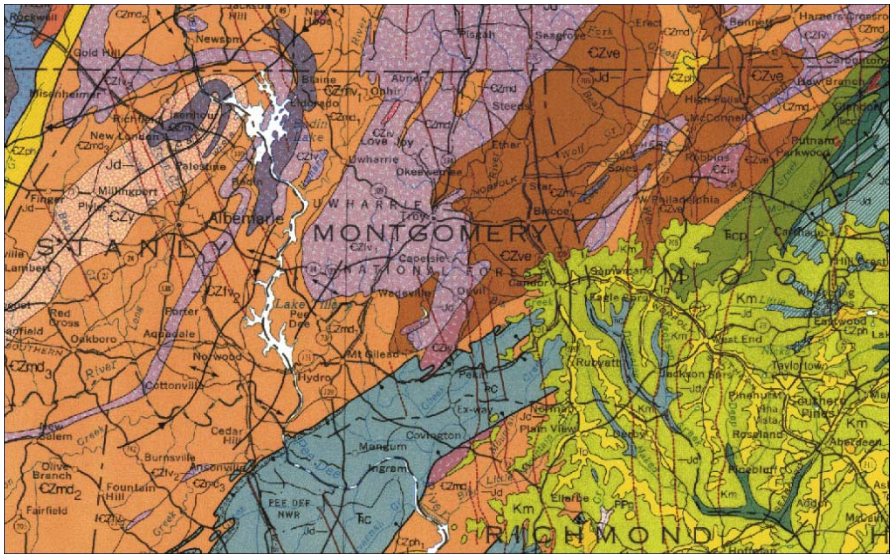
Iota quartz



Preliminary processing evaluation and chemical analysis of the quartz concentrates from the two samples indicated low impurity levels to justify further chemical treatment to produce ultra-high purity quartz. The processing steps involved crushing, grinding to produce 60 x 140 mesh, flotation to remove mica, iron minerals and feldspar impurities, magnetic separation of the clean quartz, sizing and hydrofluoric / hydrochloric acid leach to produce ultra-high purity quartz product (Iota Grade).

From Mensah-Biney and Reid, 2006

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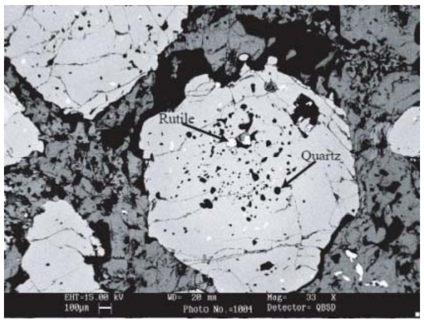
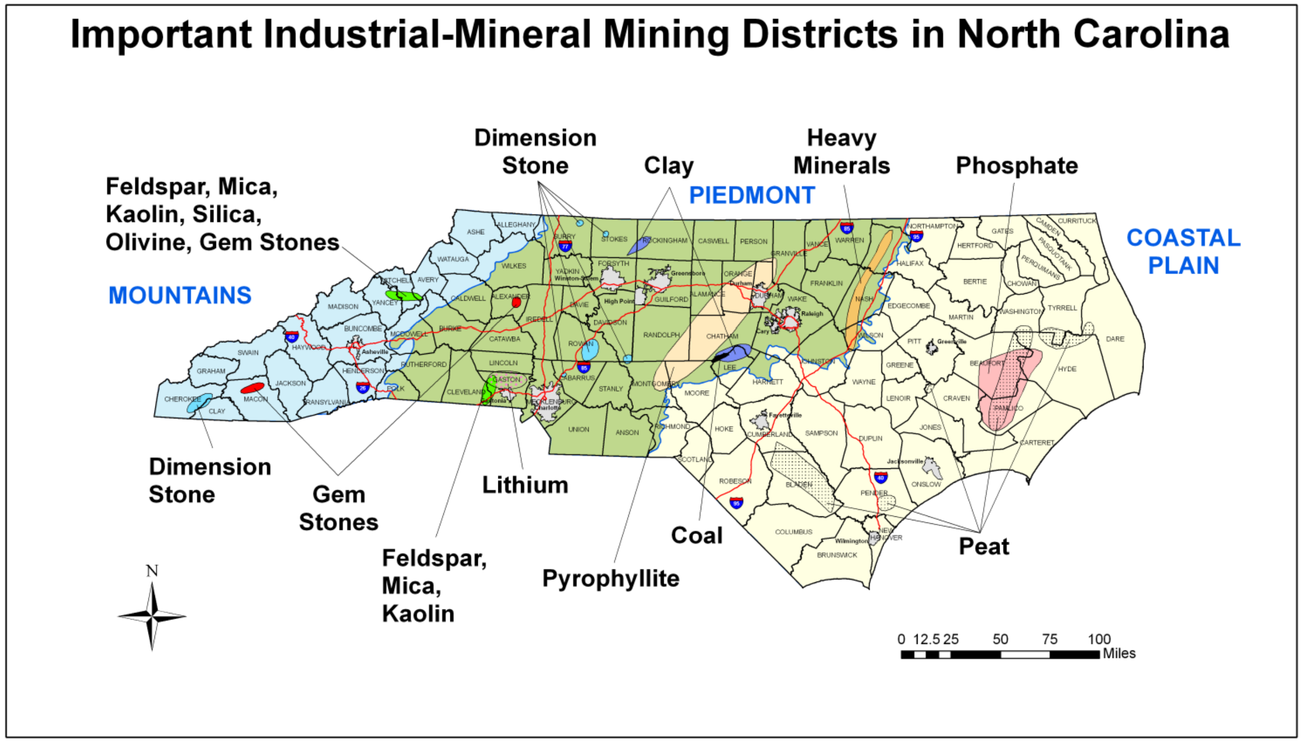
Garnet





•Bakersville metagabbro: 1)water jet cutting application; 2) ~ 36.5 million mt resource potential, pilot plant studies done, 3) ~3 million mt garnet concentrate potential

•From Mensah-Biney and Reid, 2008.

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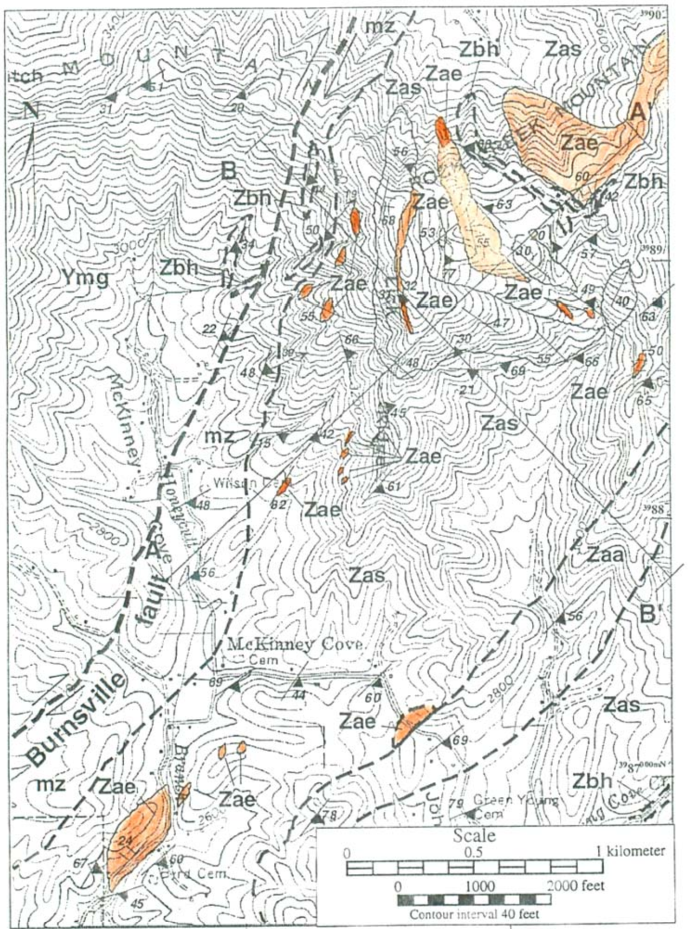
Garnet (abrasive)



Map from Adams, 1995

- Resource: 1,000m x 1,000m x 100m x 3.65 or ~36,500,000 mt
- Recovery (conservative): 10% based on bench scale lab study
- Potential: 3,650,000 mt garnet concentrate

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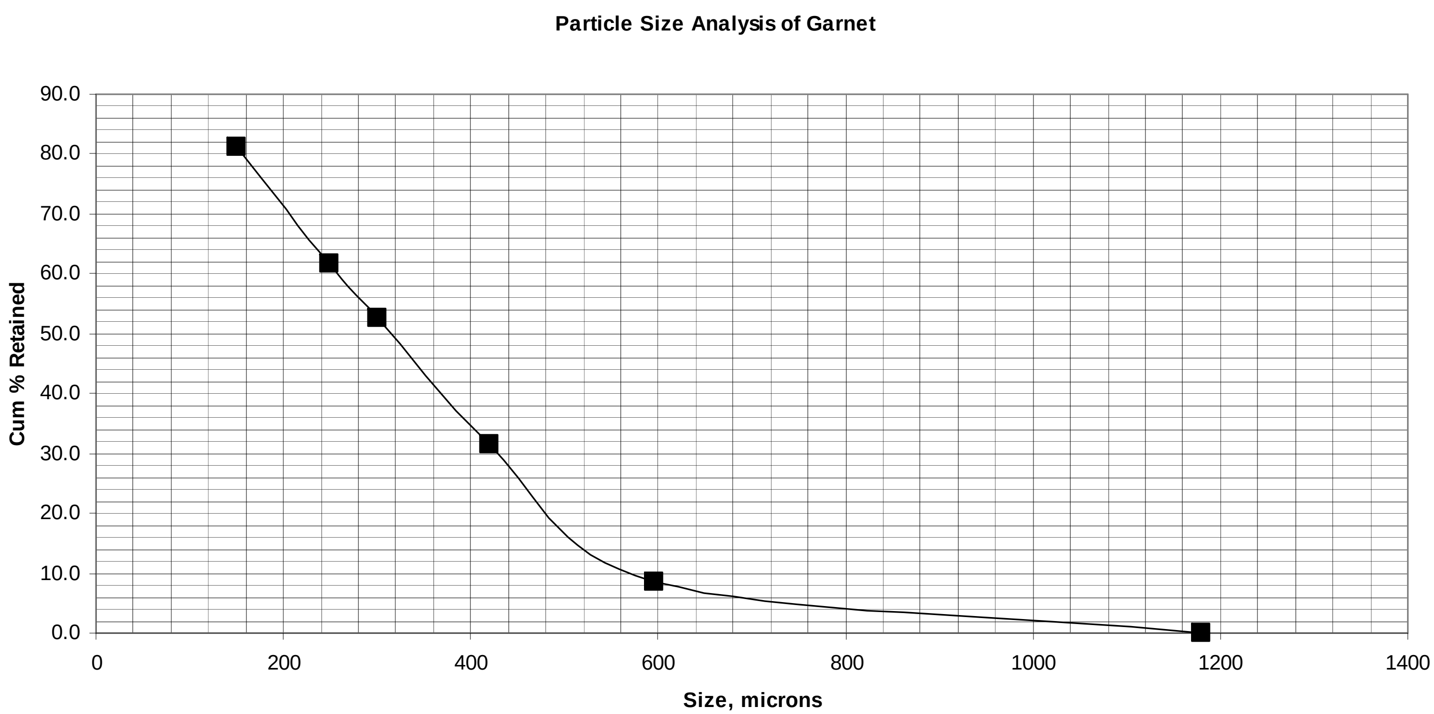
Garnet (abrasive)

- A heavy mineral garnet concentrate, suitable as an abrasive, was produced from a 2 kg sample of garnet-rich material from the Bakersville eclogite, Mitchell County, North Carolina. Use as water jet abrasive.
- The bench scale laboratory process consisted of crushing, grinding, and gravity separation to separate the heavy minerals from the light minerals. The sample was ground to pass US 30-mesh and the minus 30-mesh fraction was subjected to sink float separation using a heavy liquid with density of 2.96 g/cc. The sink fraction (heavy mineral concentrate) composed mainly of garnet was subjected to mineralogical evaluation to determine garnet grade. The results of the heavy liquid separation process indicated that about 85% by weight of the original material reported as heavy mineral concentrate.
- The garnets are red, subhedral, and average 2 mm in diameter. Microprobe compositions are $Py_{32}Alm_{47}Grs_{22}Sps_{<1}$ [rims] and $Py_{27}Alm_{49}Grs_{24}Sps_{<1}$ [cores] (Willard and Adams, 1994)[1].

Garnet (abrasive)



From Mensah-Biney, Baldwin and Reid, 2008

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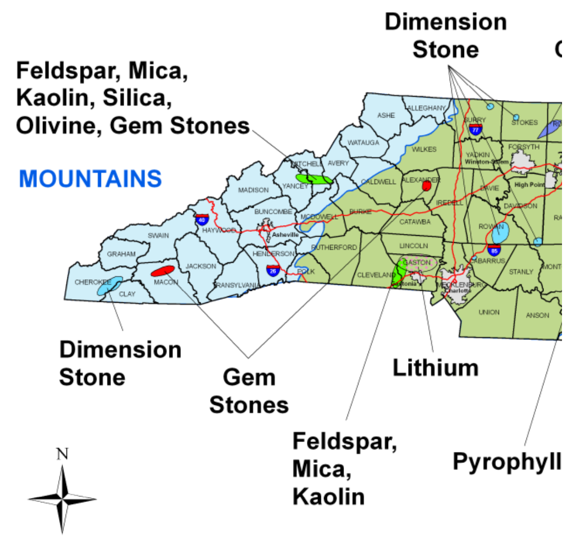
Olivine

Uses

- •Refractory Materials
- •Foundry Materials
- •Blasting Abrasive
- •Future applications may include olivine as a source of Mg for CO_2 sequestration



•Occurs as Isolated Lens in the Ashe Metamorphic Suite
•Associated rocks of the Ashe Metamorphic Suite include: mica schist, mica gneiss, amphibolite, meta-ultramafic rocks, eclogite, rare marble
•Intruded by felsic pegmatites of the Spruce Pine Intrusive Suite
•Contact relations and isotopic ages from associated rocks constrain the age to no younger than Devonian and most likely pre-Ordovician

From Adams, 2006

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Pyrophyllite - andalusite

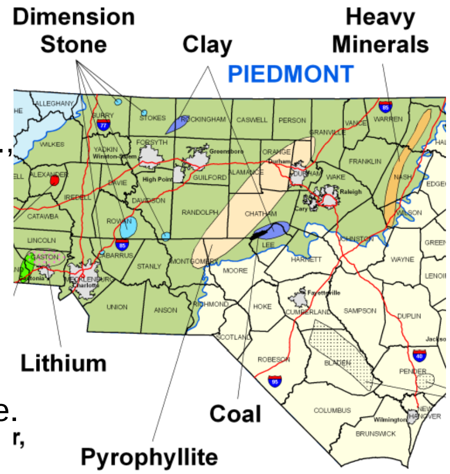
•Close relationship between the pyrophyllite ore bodies and paleohydrothermal centers.

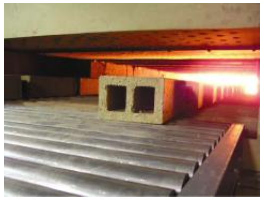
•A large lenses-shaped body of pyrophyllite and andalusite is being exploited by Piedmont Minerals, a division of Resco, Inc., in Hillsborough, North Carolina.

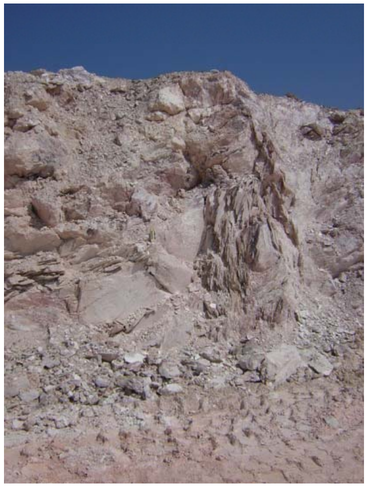
•The ore body contains, pyrophyllite, quartz, andalusite, diaspore, topaz, sericite, lazulite, pyrite, rutile, and secondary phosphate minerals.

•The pyrophyllite and andalusite are processed at the mine site. The high alumina refractory minerals are then transported to Greensboro, North Carolina. In Greensboro a new kiln has started operation to produce refractory bricks and blocks.
•The amount of Al_2O_3 used in the bricks and blocks ranges from 33.3% to 51.1%.

•The pyrophyllite and andalusite are desirable due to their chemical inertness, high dielectric strength, high melting point and low electrical conductivity. The use of the high alumina minerals decreases the thermal expansion and moisture expansion of the product during high temperature service, provides excellent volume stability and resistance to deformation at high temperatures, increases the firing range of the blocks and therefore decreases firing shrinkage, and increases the strength of the fired blocks and bricks.







From Gay, 2006

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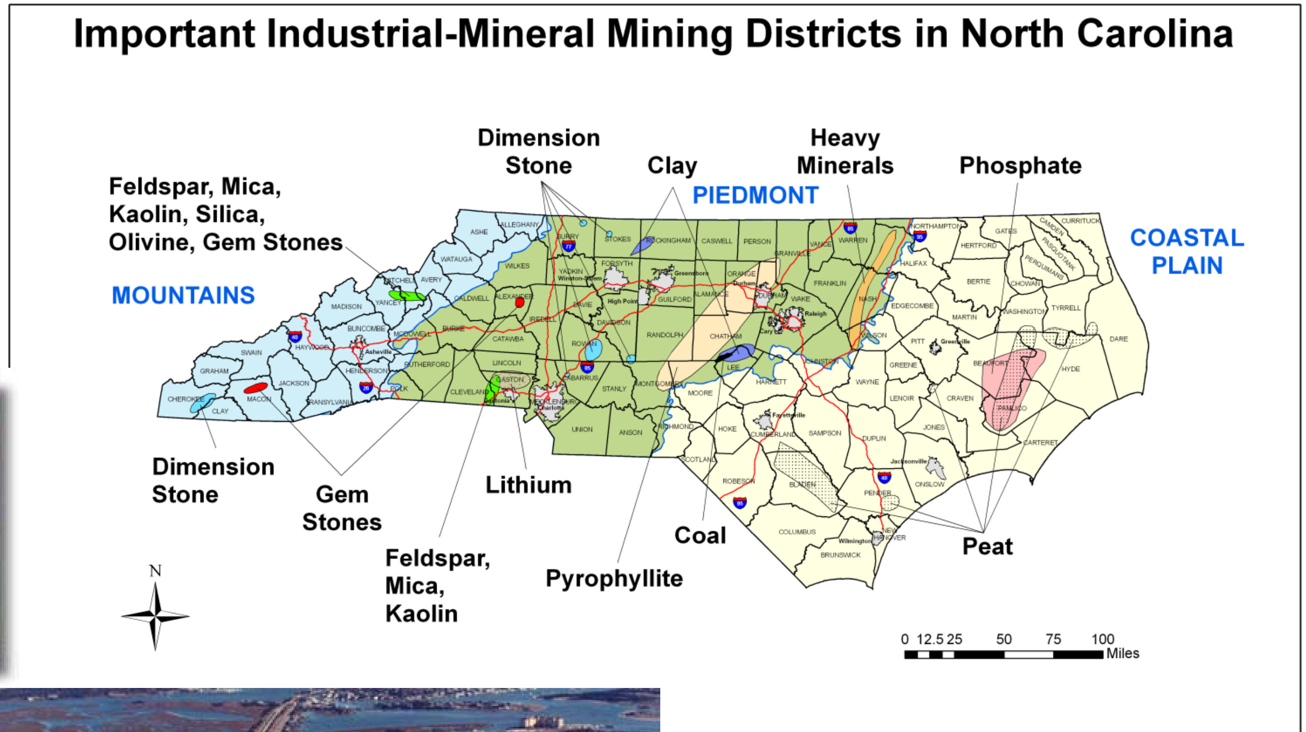
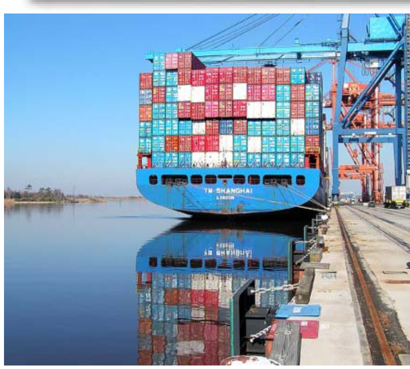
Ports





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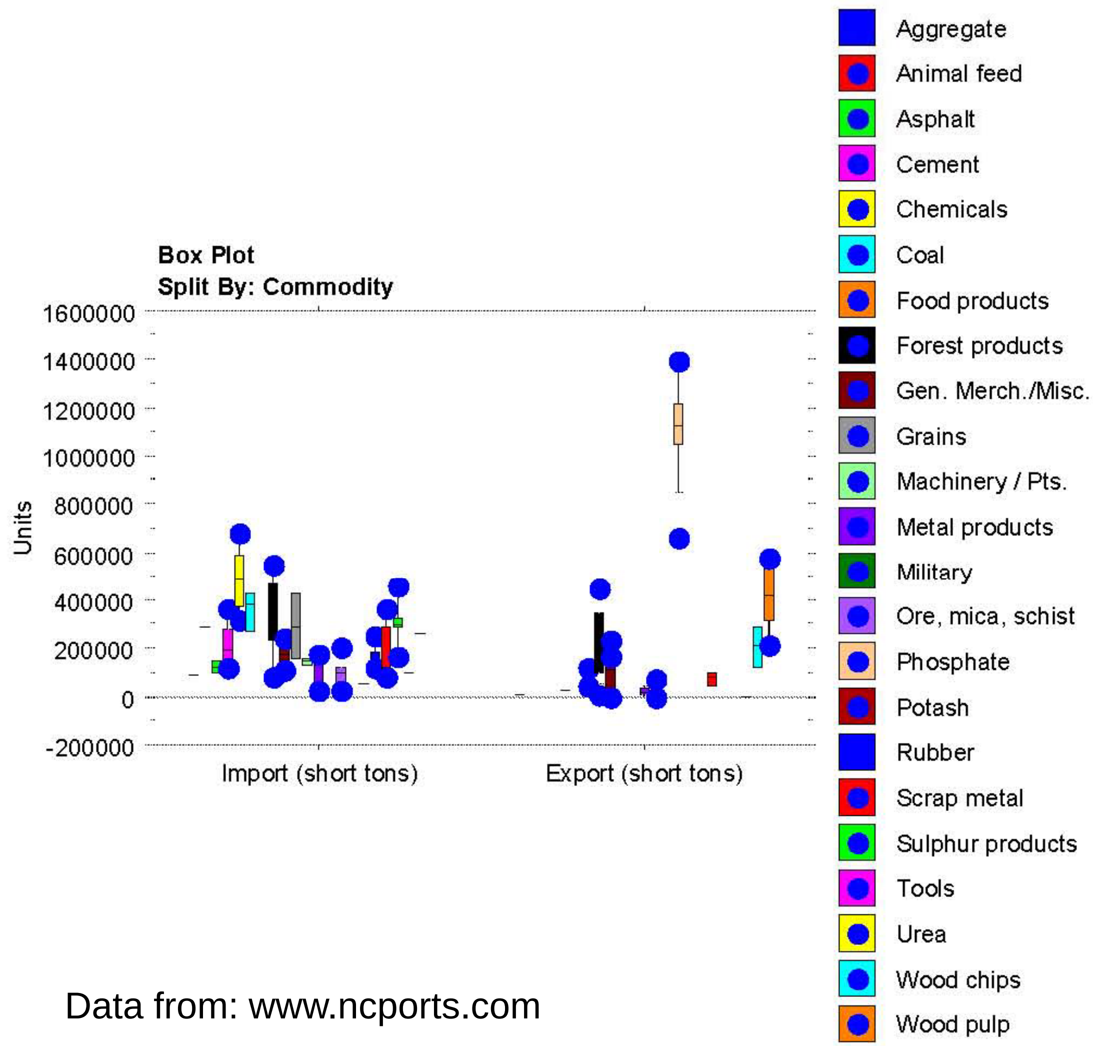
N.C.'s ports import and exports 2003-2012



Data from: www.ncports.com

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Gold

- Stratigraphic control + structural complications
- Resource:
  - World class (Haile – Romarco, S.C.) – advanced stage exploration
  - Ridgeway – mined out, reclaimed
- Biogenic reprecipitation and concentration promoted by biogeochemical sulfide weathering producing thiosulfate complexes with gold and bacteria mediated Redox reactions in streams to precipitate gold (Saunders, 2012).
- Where is the next Haile / Ridgeway?

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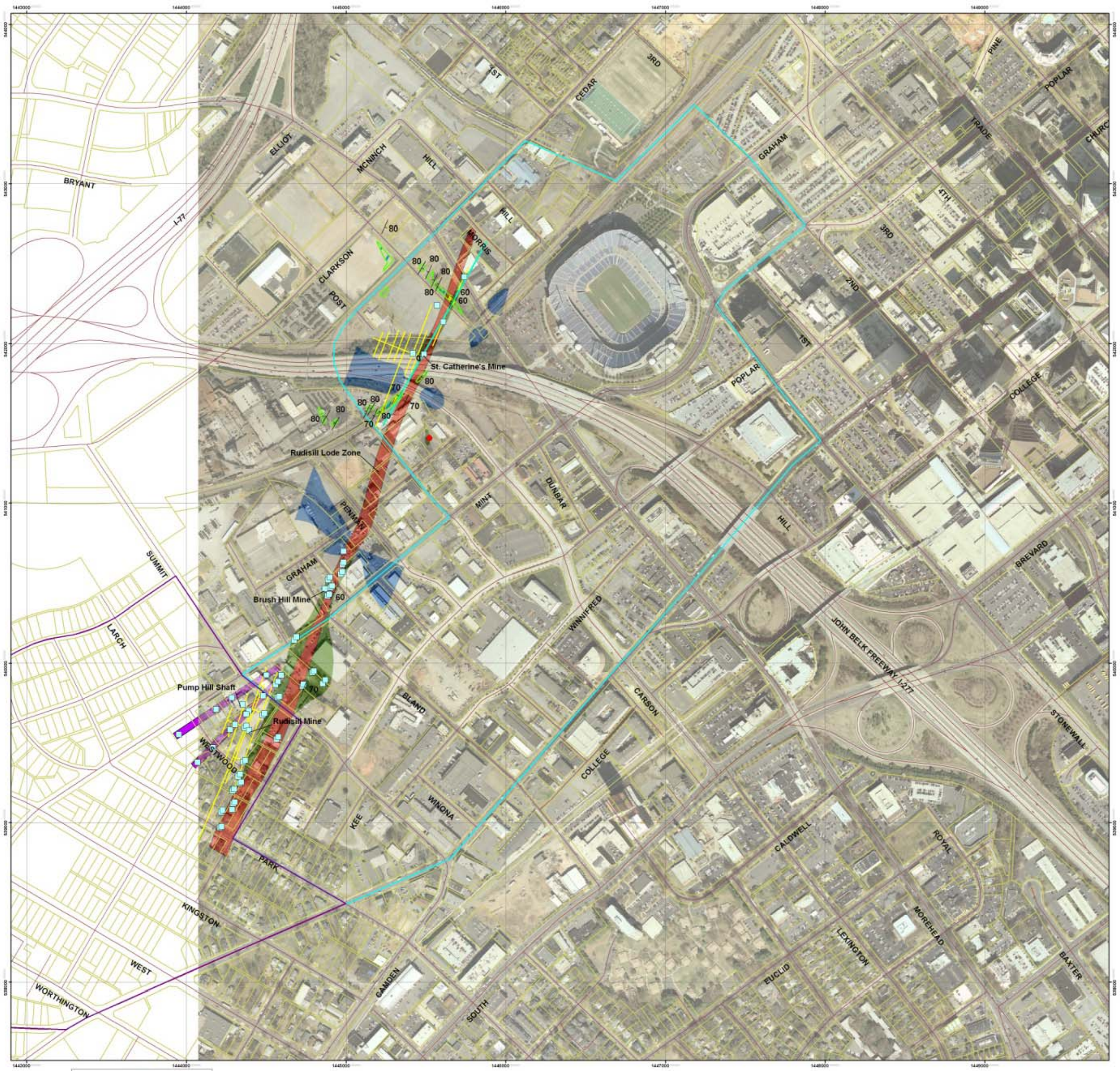
OLD GOLD MINES IN CHARLOTTE, NORTH CAROLINA: A POTENTIAL GEOLOGIC HAZARD FOR DEVELOPMENT



SCALE 1:10,000

North Carolina State Plane NAD 83 meters projection

Funding was provided by the North Carolina Geological Survey and the North Carolina Division of Emergency Management

ABSTRACT

DIGITAL COMPILATION OF ABANDONED GOLD MINE FEATURES IN CHARLOTTE, MECKLENBURG CO., NORTH CAROLINA - CONSIDERATION FOR DEVELOPMENT AND CONSTRUCTION

By

REID, Jeffrey C., and MEDINA, Michael A., North Carolina Geological Survey, 1612 Mail Service Center, Raleigh, NC 27699-1612 and GORETTI, Andy J., Mecklenburg County GIS, Charlotte, NC

Abandoned gold mines were geospatially located in the southwest of the Charlotte city center using historic documents and rediscovered engineering geology reports. The mines and mine workings comprise the Rudisill - St. Catherine's trace of gold mining that ceased nearly 100 years ago. Geospatial compilation of these features can be of considerable assistance to planning large excavations and foundations as the Charlotte city center expands to the southwest and replaces the current warehouse district that is built over these old mine workings.

Today there is limited evidence of previous gold mining except for street names. However, historic reports and rediscovered engineering reports show excavations of considerable extent that underlie warehouses, commercial structures, major transportation corridors and numerous property parcels.

Knowledge of the location of the old gold mines and related workings (including cut and fill areas) will assist foundation engineering studies for potential redevelopment involving large buildings.

Mining features were identified and located from historic library holdings and rediscovered city engineering geology reports. Features were compiled digitally using geographic information systems (GIS) on a high-resolution color aerial photograph of the city center. The rediscovered engineering geology reports identify areas as large as a city block that are so honeycombed below ground from mining to be a concern in land transfer.

Site-specific geotechnical and/or engineering studies are likely to be required on individual property parcels. Mapped features in this study should be considered approximate. However, the identified gold mining trend in conjunction with a property parcel and street base should provide a useful guide for investigations of individual property parcels.

Localized breaching of subsurface workings has been reported in the past and future ones cannot be precluded.

REFERENCES:

Brown, Henry S., and Hoffman, Mary F., August 1978, Gold Mining on the Rudisill Lode and the Development of Charlotte, N.C.: Report prepared for the City of Charlotte by Geological Resources, Inc., 104 p.

Brown, Henry S., and Singeltary, August 1978, Recommendations for actions to commemorate the role of gold mining in the growth and development of Charlotte: Report prepared by Geological Resources, Inc., for the City of Charlotte Community Development Department, 40p.

Carpenter, P. Albert, III, 1976 (reprint, 1993), Metallic Mineral Deposits of the Carolina Slate Belt, North Carolina: North Carolina Geological Survey, Bulletin 84, 89p.

Carpenter, P. Albert, III, 1993, Gold in North Carolina: North Carolina Geological Survey, Information Circular 29, 51 p.

Nitze, Henry B. C., and Hanna, George B., 1896, Gold deposits of North Carolina: North Carolina Geological Survey, Bulletin 3, 193 p.

Pardee, J.T. and Park, C.F., Jr., 1948, Gold deposits of the Southern Piedmont: U.S. Geological Survey Professional Paper 213, 156 p.

Public Works Department / Engineering Division, Charlotte, North Carolina, August 1976, A historical and engineering report on the Rudisill Gold Mine (1826-1938) for The Community Development Department (West Morehead Target Area).

EXPLANATION:

Location of subsurface workings (now all covered by present development) from city engineering reports and historical literature.

- streets
- parcels
- Wilmore N.A.P. area
- West Morehead C.D. Target area
- 80 strike and dip of foliation
- fine grained, dark colored igneous rock. massive to foliated.
- phyllonite (vein?) zone, sheared, altered & silicified.
- outcrop area showing fine to coarse grained, light colored igneous rock. massive to foliated.
- * Rudisill Lode zone - Mostly green to gray phyllite with ore bearing quartz
- cave in
- cave-in
- shaft
- St. Catherine Vein Trace
- tunnel location - known horizontal tunnel
- * tunnel location
- * original surface built up with fill since mining
- * areas of open cut mining and shallow tunnels

* polygons colors appear slightly different due to transparency of the airphoto

Map created by Michael A. Medina and Jeffrey C. Reid

The new gold rush

RESOURCES & RESERVES

2011 OPEN PIT & UNDERGROUND MEASURED + INDICATED RESOURCES AT US$1,200 GOLD [1]

	METRIC TONNES (000s)	g/t	CONTAINED oz Au (000s)
MEASURED	36,894	1.79	2,125
INDICATED	34,277	1.74	1,914
MEASURED + INDICATED	71,171	1.77	4,039
INFERRED	20,125	1.24	801

2010 RESERVES AT US$950 GOLD [1]

	METRIC TONNES (000s)	g/t	CONTAINED oz Au (000s)
PROVEN RESERVE	19,592	2.19	1,382
PROBABLE RESERVE	10,917	1.82	636
PROVEN & PROBABLE RESERVE	30,509	2.06	2,018

(1) From March 13, 2012 Technical Report filed on www.sedar.com on March 19, 2012

WWW.ROMARCO.COM TSX : R

15

Source: Romarco Minerals - 20121128

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The new gold rush

Ridgeway North Pit, looking north from south edge of pit, D. Heron, 1998
Neoproterozoic, large tonnage, low grade, low sulfide Kennecott Ridgeway Au-Ag-Mo
Gold-rich volcanic associated massive sulfide deposit, with syngentic exhalative mineralization overprinted by syntectonic deformation and epithermal alteration – traditional interpretation
Epigenetic origin, formed within a major north-dipping ductile-brittle deformation zone during rapid tectonic evolution associate with collision and amalgamation of the Carolina and Charlote volcanic arc terranes Moye, 2012
Host rocks are immature turbidite of the basal Richtex Formation and complex Au-mineralization and deformation – Moye, 2012

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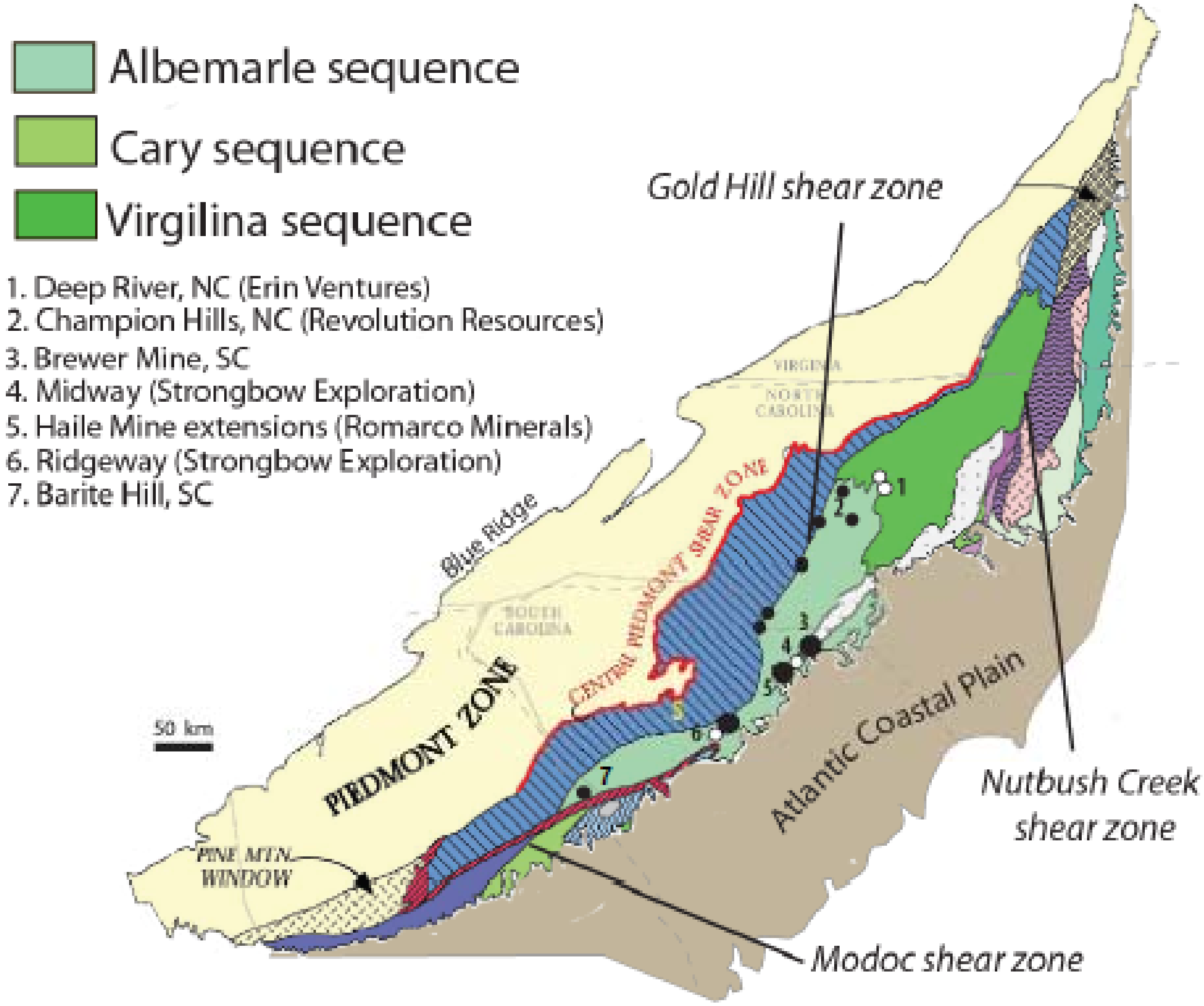
The new gold rush



(after Foley and Ayuso, 2012; Gillon, 2012)

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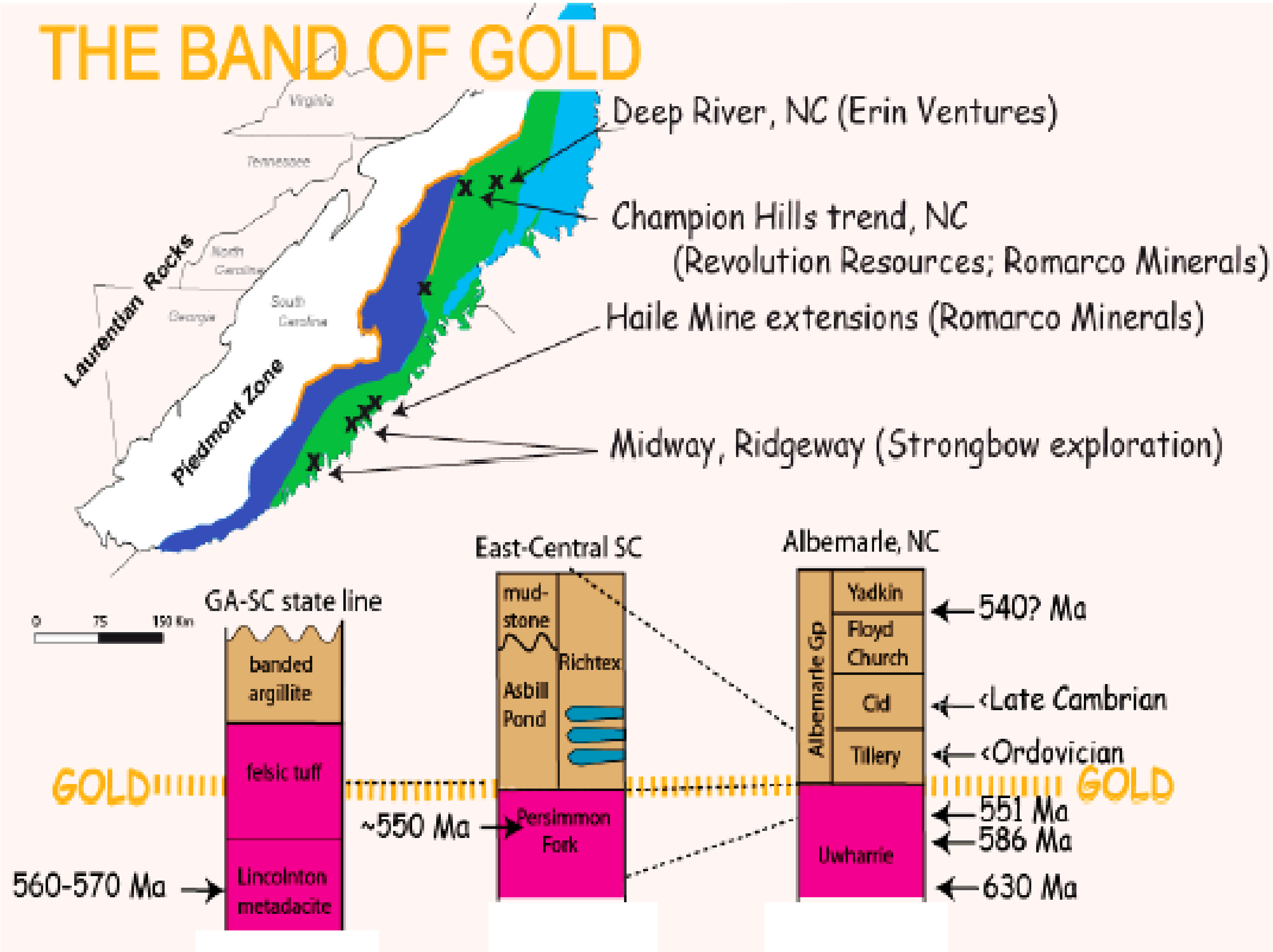

(after Foley and Ayuso, 2012; Gillon, 2012)

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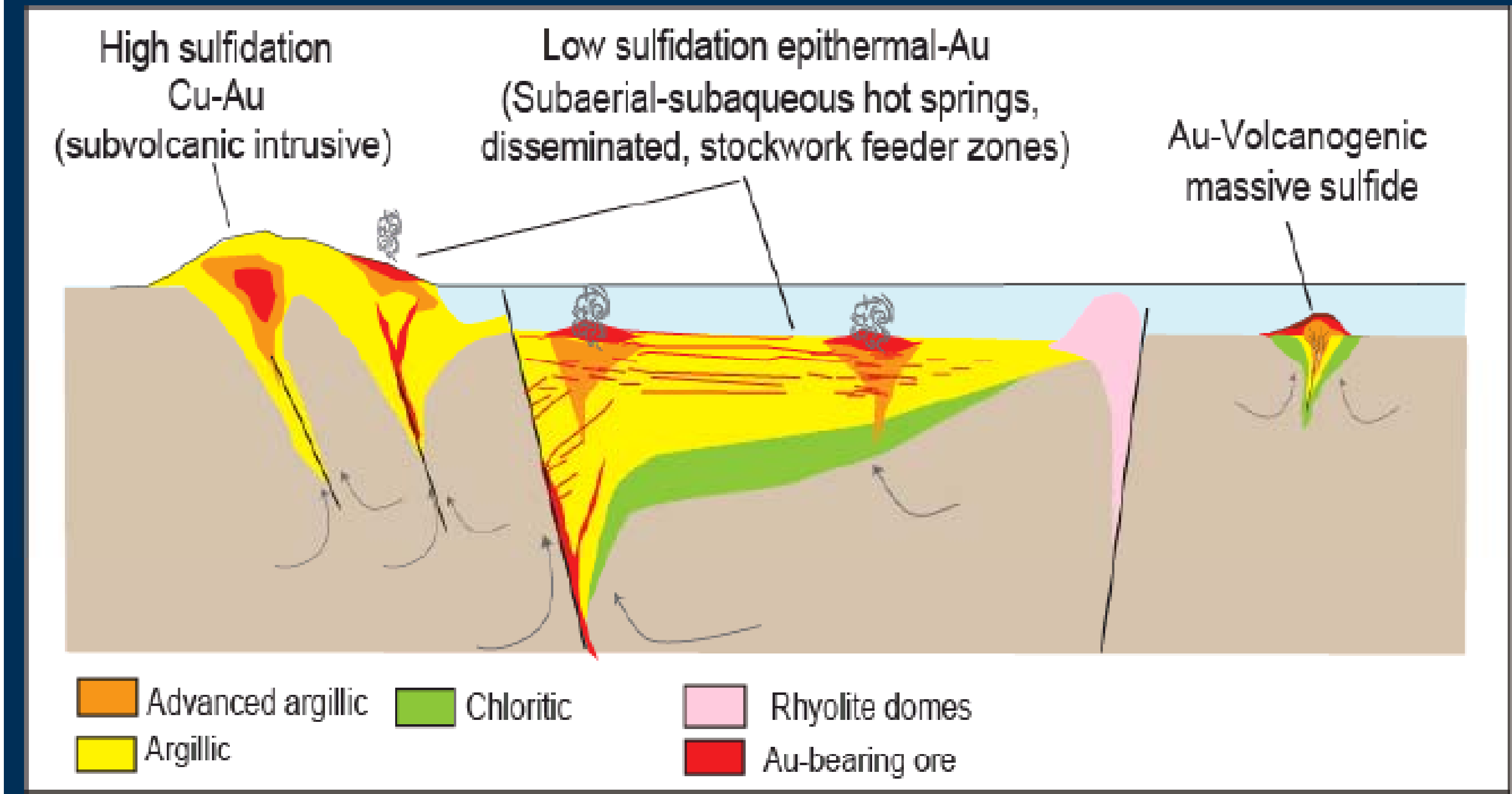
Gold in epithermal deposits



USGS

(after Foley and Ayuso, 2012; Gillon, 2012)

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Wolframite tailings

- Hamme (Tungsten Queen) Mine; Vance Co.
- Wolframite; byproduct fluorite (amount for glass flux? – plant nearby), quartz (quality?) and possibly silver (from galena)
- Resource (tailings)
  - Estimate: 2,038,000 tons @ 0.218% WO_3
  - ~445,500 STU WO_3 (1 Short ton unit [STU] is 20 lbs. Prices around $400 / STU (Ranchers, 1975; Osborne, 2007). WO_3 is 90% tungsten.
- Recovery possible with advanced Knelson and Falcon concentrators – but are these good enough?
- Released from Superfund status (sulfide clean-up).
- Unknown hard rock resources – would need to be dewatered.
- U.S. Corp. of Engineers continue pumping arm of Kerr Lake reservoir to avoid flooding of strategic mineral asset at request of the NCGS.

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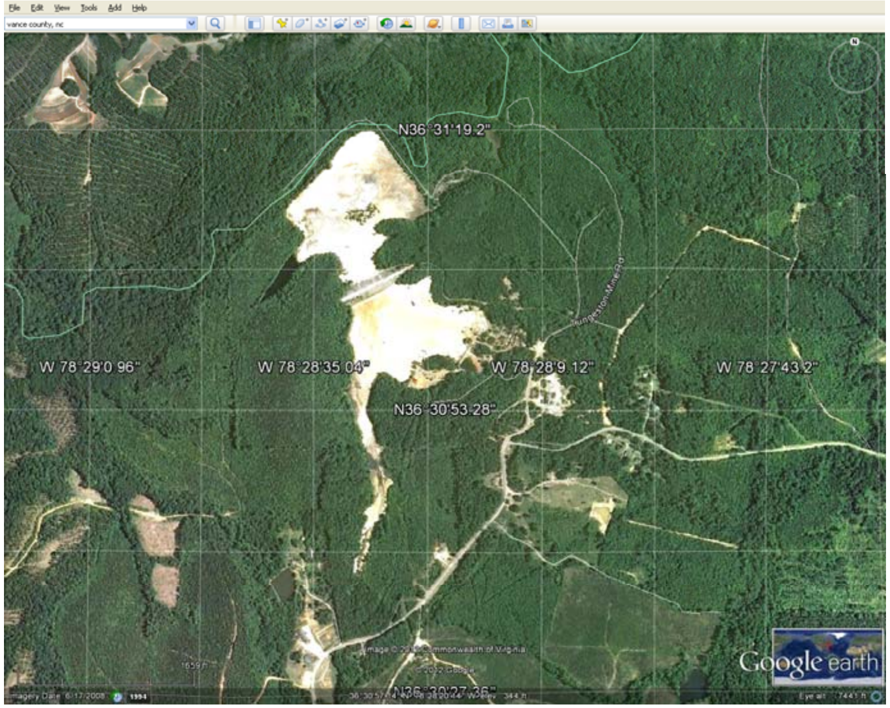
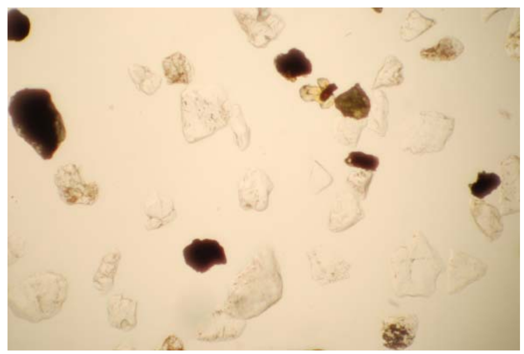
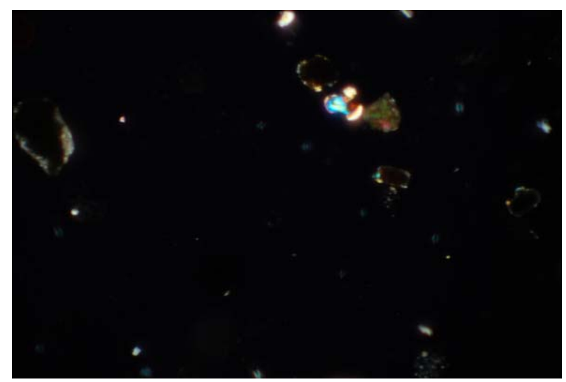




Right – Wolframite and fluorite in heavy liquid sink (cross polarized light). FOV 2.9mm

Left – Wolframite and fluorite in heavy liquid sink (plane light). FOV 2.9 mm.



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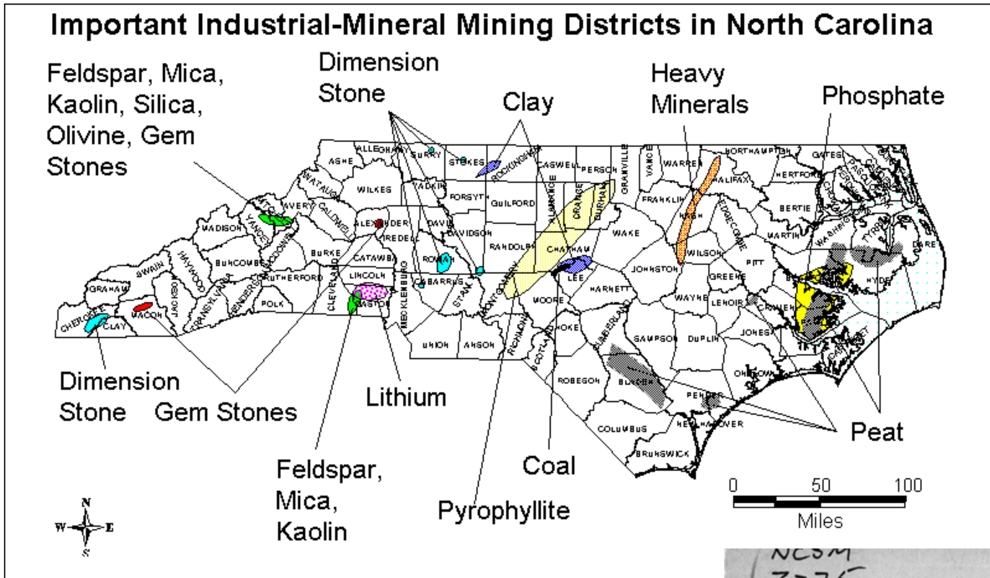
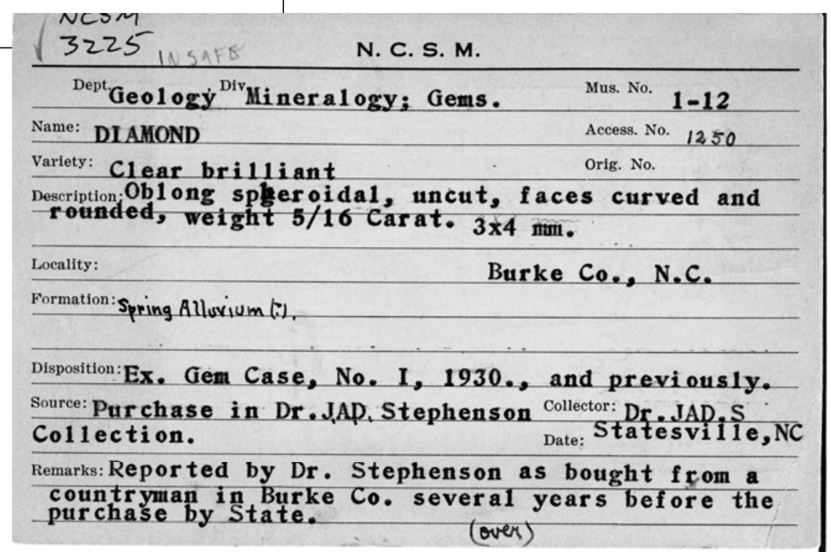
Gemstones





NCSM 3225 IN SAFE

N. C. S. M.

Dept. Geology	Div. Mineralogy; Gems.
Mus. No.	1-12
Name:	DIAMOND
Access. No.	1250
Variety:	Clear brilliant
Orig. No.	
Description:	Oblong spheroidal, uncut, faces curved and rounded, weight 5/16 Carat. 3x4 mm.
Locality:	Burke Co., N.C.
Formation:	Spring Alluvium (?).
Disposition:	Ex. Gem Case, No. I, 1930., and previously.
Source:	Purchase in Dr. JAD. Stephenson Collection.
Collector:	Dr. JAD. S Statesville, NC
Date:	
Remarks:	Reported by Dr. Stephenson as bought from a countryman in Burke Co. several years before the purchase by State.

(over)

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Diamonds

- 13 diamonds reported in the literature; 1 associated with a placer gold deposit.
- 12 in Inner Piedmont, 1 in Eastern ‘slate belt’ rocks associated with a gold placer.
- Kimberlite model has been unsuccessful; ultrapotassic, lamproite model may hold promise.
- Mantle dike emplacement may be associated with CAMP and Pangea rifting, or with subduction features in terrain assembly.
- N.C. produces synthetic diamonds for jewelry.
- Source rock: has not been identified – <u>yet</u> although there are candidate rocks in the Piedmont.

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Emeralds

- Alexander Co.
- 20 largest emeralds from North America.
- Historically weathering material was prospected; for first time hard rock exposed.
- Complex open voids with emeralds and accessory minerals.
- Emerald formation / occurrence poorly understood. One fluid inclusion study in progress.

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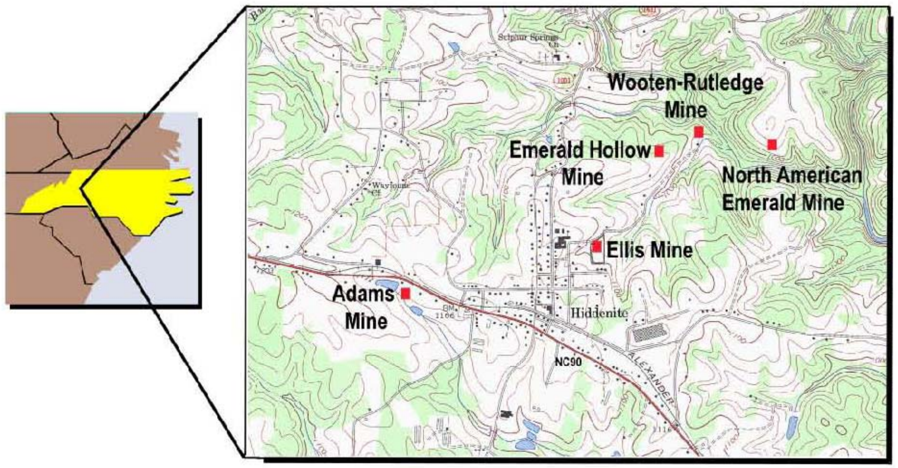
Emeralds



Rank	cts	
1	1,869	Hill Emerald, NAEM mine, 2003, 19.5 cm, HMNS
2	1,686	LKA Emerald, NAEM mine, 1984, 3.8 x 11.4 cm, LKA
3	1,493	Reitzel/Williams/Harwell Twin, Adams mine, 1971, 10.5 x 2.7 cm, (Wilber/Funk), SI
4	1,438	Finger [aka Stevenson] Emerald, NAEM mine, 1969, 5.4 x 7.3 cm, (AGI), LKA
5	1,400	Hill Emerald, NAEM mine, 2007, NAEM
6	1,377	Bolick/Arnold Cluster, Adams mine, 1971, SI, fractured beyond repair
7	1,276	Hidden Emerald, Adams mine, 1886, 7.0 x 4.1 cm, SI
8	1,270	Hidden Emerald, Adams mine, 1881, 21.6 cm, stolen 1950 from AMNH, still missing
9	1,215	Baltzley Twin, NAEM mine, 1970, SI?
10	965	Hill Emerald, NAEM mine, 2006, HMNS
11	934.9	Bolick Twin, Adams mine, 1971, 14.0 x 6.5 x 3.5 cm, (Sharp/Hill-Duncan), HMNS
12	900	Reitzel/Williams/Harwell Twin, Adams mine, 1971, (Morton/Bolick/Barlow), HMNS
13	858	Hill Empress Caroline Emerald, NAEM mine, 1998, SEEC
14	817.5	Baltzley Twin, NAEM mine, 1971, SI?
15	750	Wright Emerald, Ellis mine, 1907, 3.8 x 5.1 cm
16	722.7	Bolick Emerald, Adams mine, 1974, 12 cm, GMNM
17	591	Hill Twin, NAEM mine, 2006, 25.4 cm, NAEM
18	467	Ormond Twin on Goethite, NAEM mine, 1969, 1.4 x 8.9 cm, DA
19	450	Reitzel/Williams/Harwell Emerald, Adams mine, 1971, (Ledford/Tucker), NCMNS
20	433	Reitzel/Williams/Harwell Cluster, Adams mine, 1971, (Ledford), AMNH

From: Wade Edward Speer, 2008

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Emeralds

From: Wade Edward Speer, 2008

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Heavy minerals

- 22.7 million metric tons of heavy minerals @ average grade of 6 wt. percent in 377.8 million metric tons of sand in 19 deposits, upper Coastal Plain, VA and NC.
- Principle minerals: ilmenite (60%), rutile (2.5%), zircon (12.5%), staurolite (8.5%), tourmaline (0.7%), kyanite (3.0%), sillimanite (1.3%) and other – mostly limonite.
- The deposits during the worldwide Pliocene transgressive-regressive event between 3.5 and 3.0 Ma.
- The deposits formed as beach or dune sands during the regressive phase of the event over an elevation of 315 feet to 175 feet.
- From Carpenter and Carpenter, 1991.

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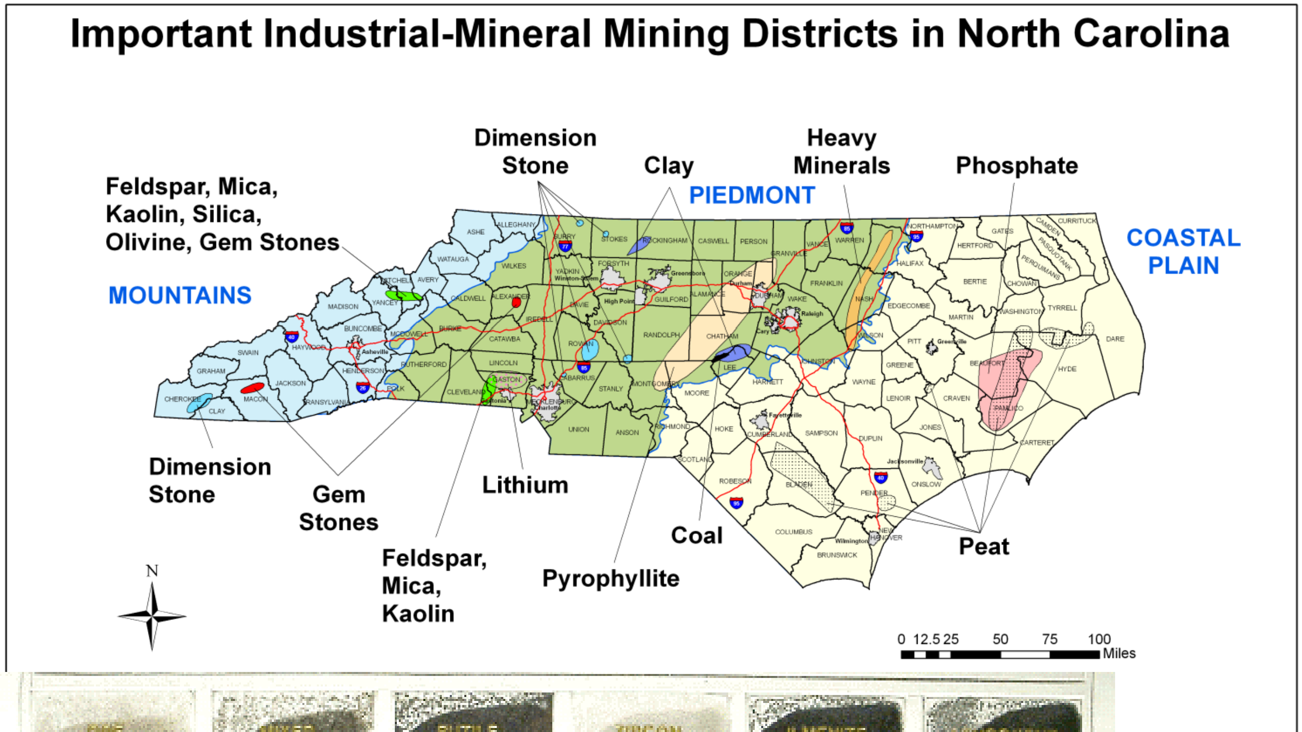
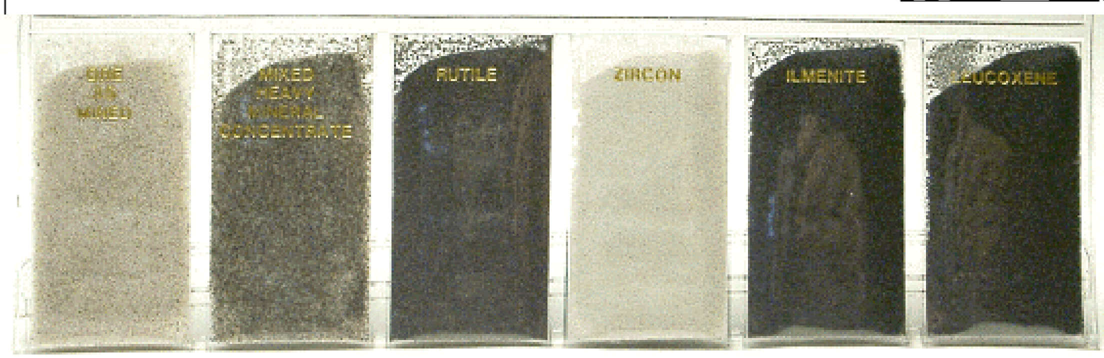
Heavy minerals

- Fall zone
- Elevation controlled
- Pliocene age transgressive—regressive event
- 22.7 million mt – NC and VA – 19 deposits
- Ilmenite ~60%
- Rutile ~2.5~%
- Zircon ~12.5%
- Staurolite ~8.5%
- Tourmaline ~0.7%
- Kyanite ~3%
- Others (limonite) ~11.5%





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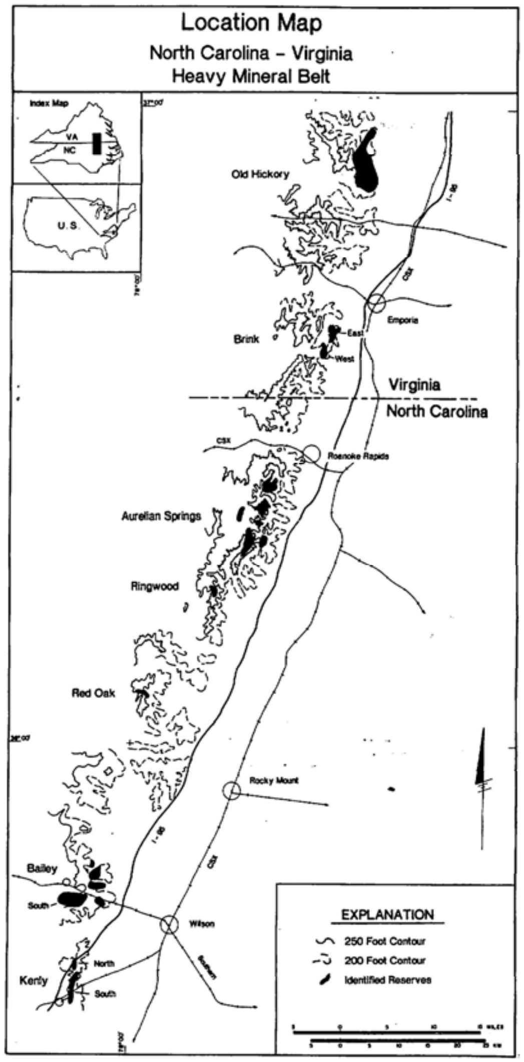
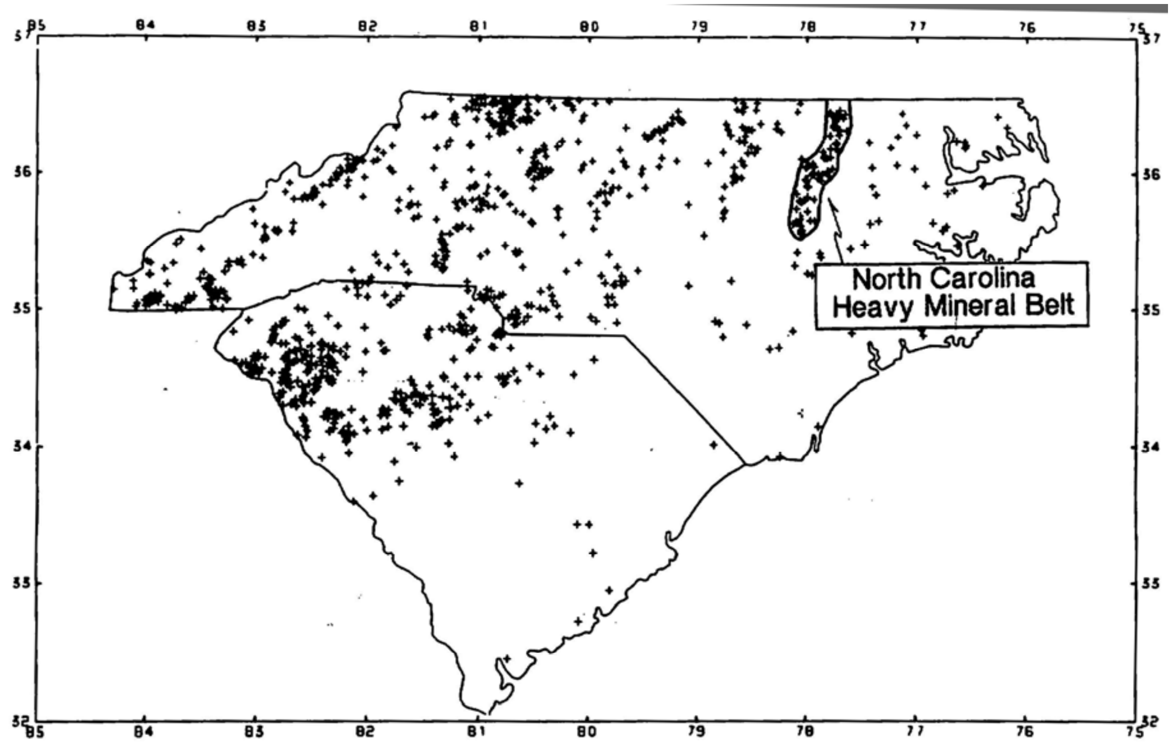
Heavy minerals





From Carpenter and Carpenter, 1981

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Monazite and REEs

- Placer alluvial deposits in N.C. and S.C.
- Focus is REE and Thorium in monazite
- Resource: 13 largest deposits (Overstreet, 1967; Straatz and others, 1979)
  - Thorium ~5,300 metric tons with potential resources 7X that
  - REE oxides ~53,000 metric tons
  - LREE moderately well characterized
  - HREE not well characterized
  - Mineral chemistry limited

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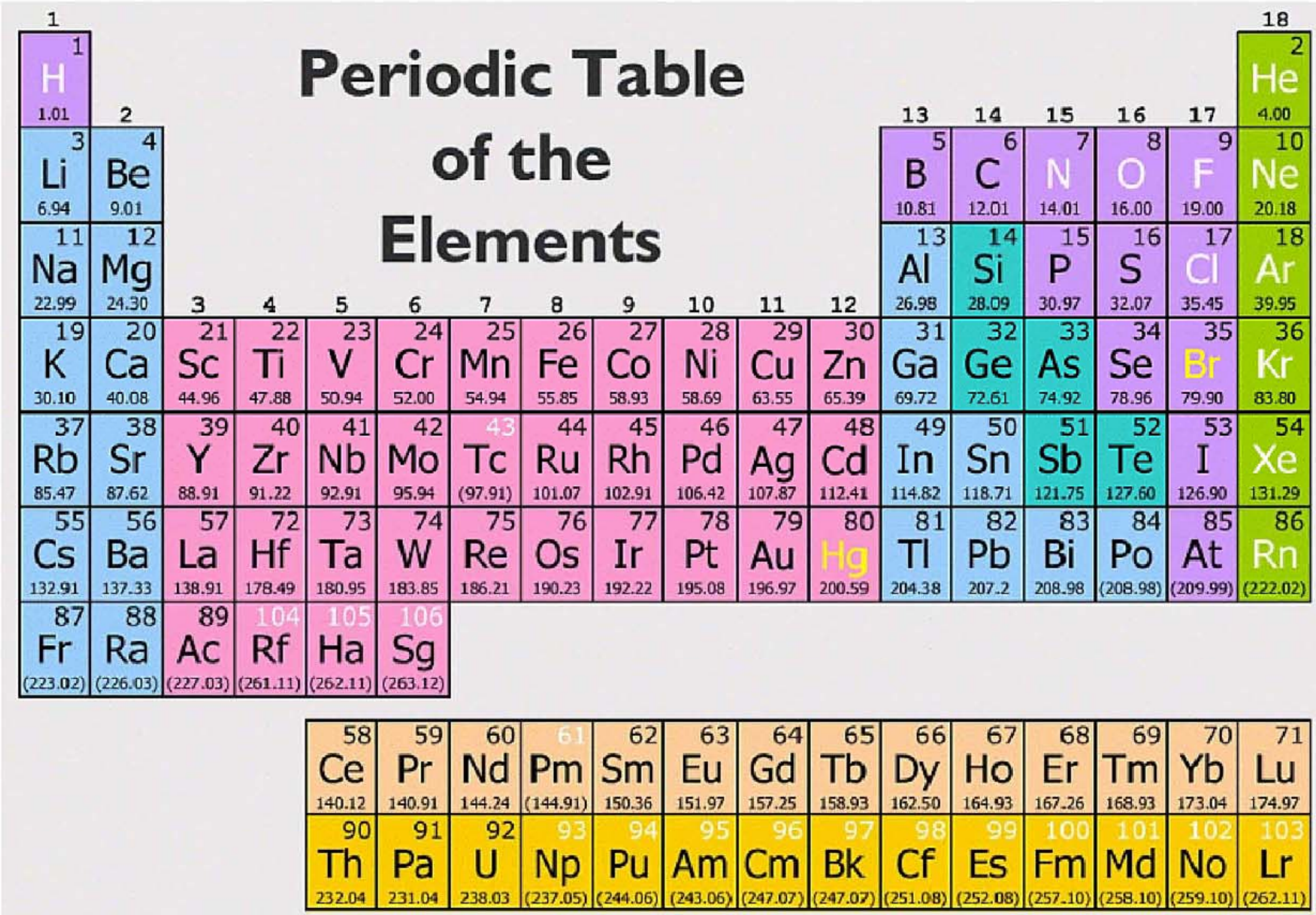

Figure 1. Periodic table of the elements. The rare earth elements comprise 15 elements, which range in atomic number from 57 to 71, including lanthanum (La) to lutetium (Lu). The elements are also commonly referred to as "lanthanides." Yttrium (Y, atomic number 39) is also typically included with the rare earth elements group because it shares chemical, physical, and application properties with the lanthanides.

NURE data available for La, Ce, Sm, Eu, Dy, Yb

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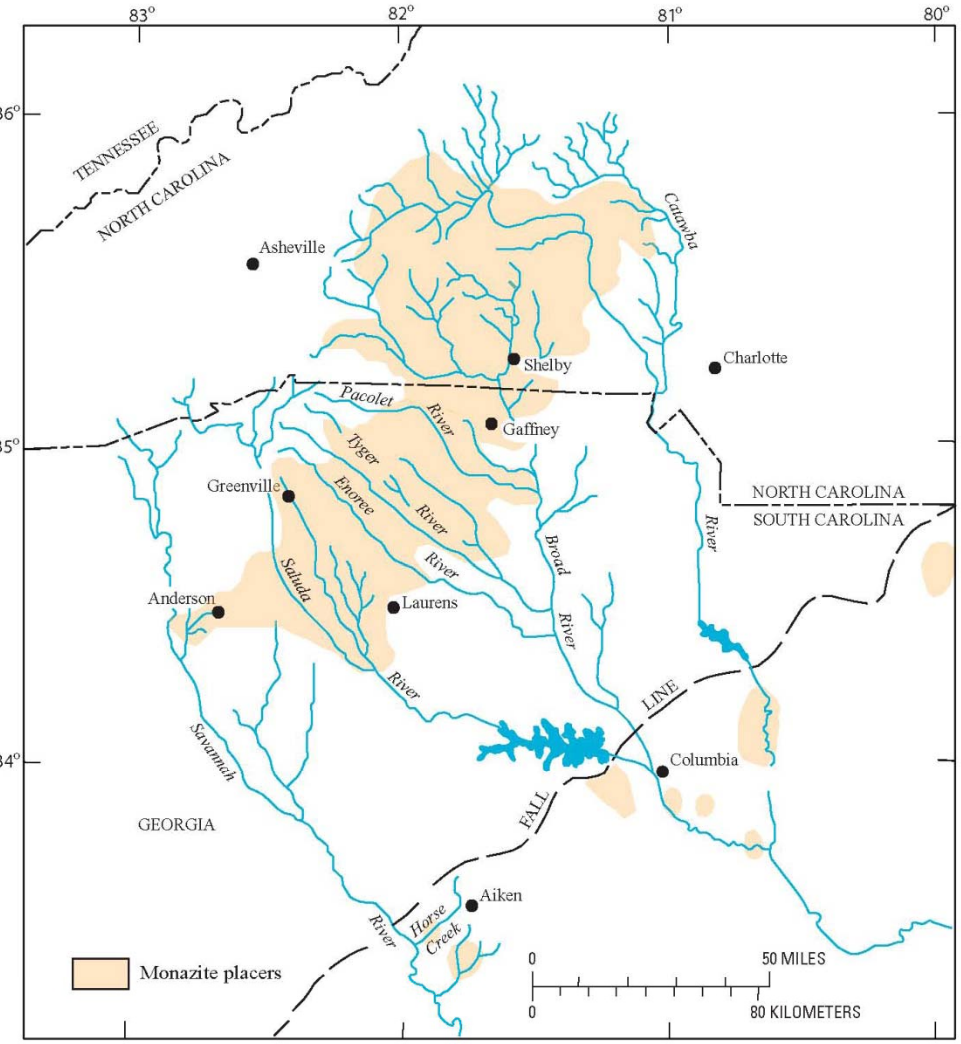
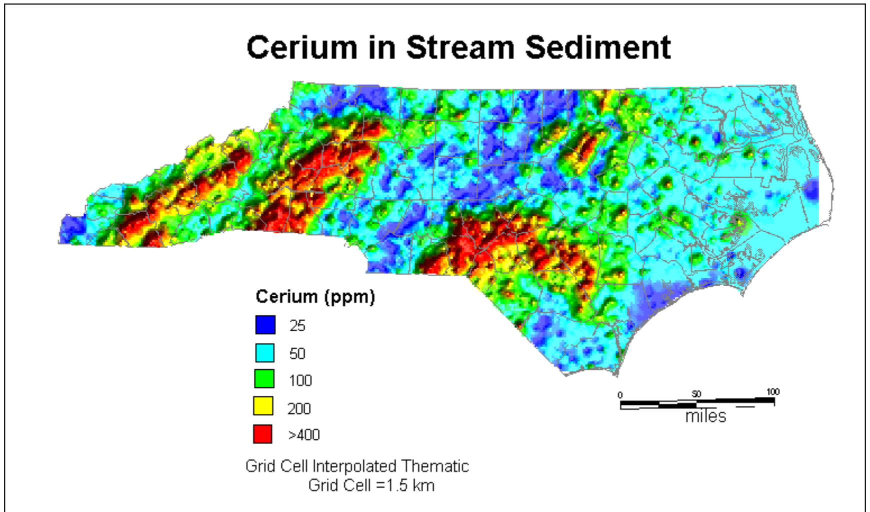
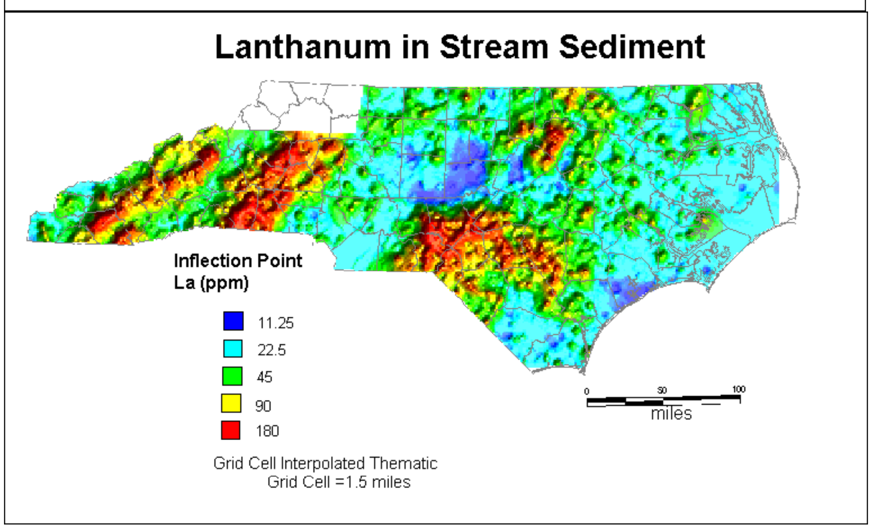
Monazite and REEs

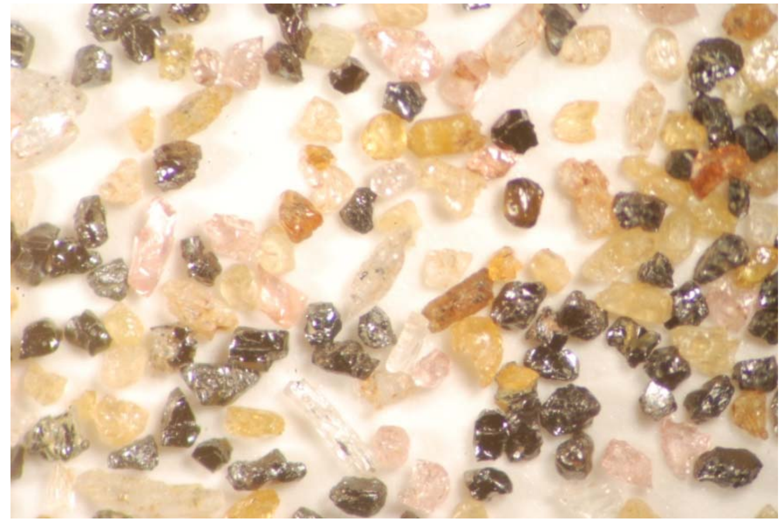


Adapted from USGS, 2010

Monazite placers and REEs







- 52 alluvial monazites ~60-63% total REE oxides and a mean value of 5.67% Th.
- The USGS estimated a resource for the 13 largest deposits in NC and SC to be ~58,400 tons of REE oxide (USGS, 2010).
- HREE content unknown; LREE somewhat known.

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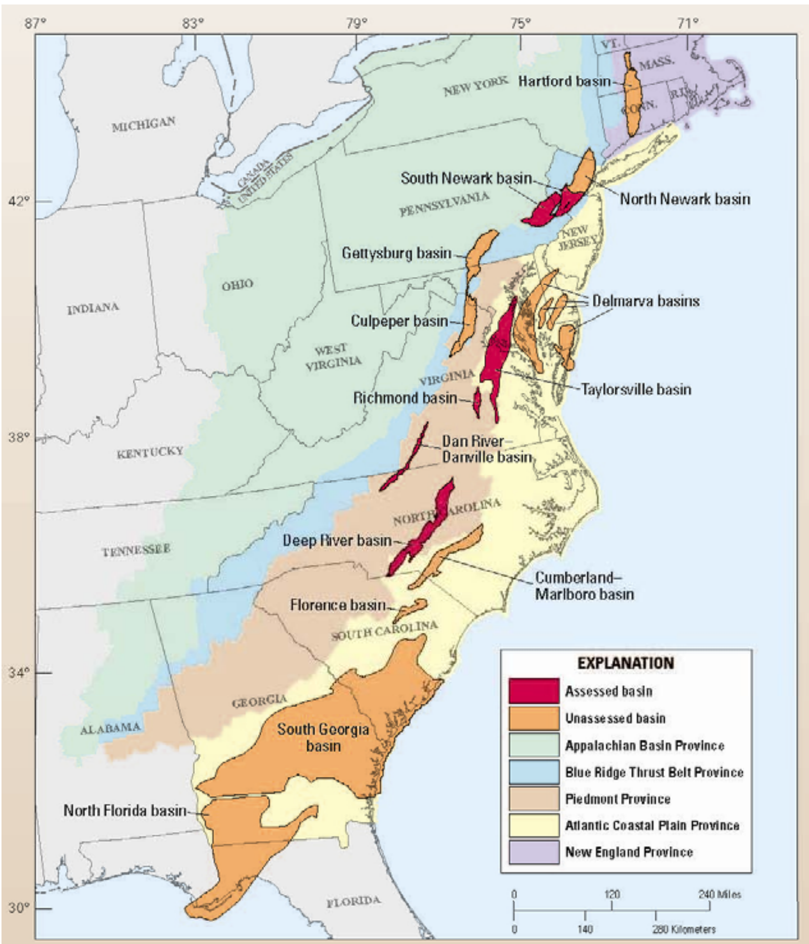
Helium in natural gas



- Two continuous composite total petroleum systems (TPS) in N.C.
- USGS assessed 5 of 14 basins (Fact Sheet 2012-3075)
- North Carolina results:
  - Deep River Basin: 1.66 TCF + 83 MMBNGL; and
  - Dan River-Danville Basin: 49 BCF and NGL?
- New N.C. law legalizes horizontal drilling and hydraulic fracturing (SB 820).
- New N.C. process leading to permitting in 2014.
- Geometry: thick shale sequences, with long strike extent => large volume of source rock / reservoir.

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Helium in natural gas

Total Petroleum System (TPS) and Assessment Unit (AU)	Field type	Total undiscovered resources											
		Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)			
		F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Taylorsville Basin Composite TPS													
Taylorsville Basin Continuous Gas AU	Gas					516	985	1,880	1,064	16	34	71	37
Richmond Basin Composite TPS													
Richmond Basin Continuous Gas AU	Gas					99	194	382	211	4	10	20	11
Newark Basin Composite TPS													
South Newark Basin Continuous Gas AU	Gas					363	785	1,698	876	1	4	10	4
Deep River Basin Composite TPS													
Deep River Basin Continuous Gas AU	Gas					779	1,527	2,990	1,660	35	75	158	83
Dan River-Danville Basin Composite TPS													
Dan River-Danville Basin Continuous Gas AU	Gas					17	42	106	49	0	0	1	0
Total continuous resources						**1,774**	**3,533**	**7,056**	**3,860**	**56**	**123**	**260**	**135**

Helium in natural gas

ISOTECH
ISOTECH LABORATORIES INC
ANALYSIS REPORT

Lab #: 160348 Job #: 11286
Sample Name: Simpson #1 well Co. Lab#:
Company: USGS Reston, VA
Date Sampled: 3/25/2009 Cylinder: 1006
Container: Stainless Steel, 1L
Field/Site Name: NC Triassic Basins
Location: Lee County, NC
Formation/Depth:
Sampling Point:
Date Received: 4/14/2009 Date Reported: 5/13/2009

Component	Chemical mol. %	Delta 13C per mil	Delta D per mil	Delta 15N per mil
Carbon Monoxide	nd			
Hydrogen Sulfide	nd			
Helium	0.223			
Hydrogen	0.0047			
Argon	0.0074			
Oxygen	0.0177			
Nitrogen	45.49			-3.23
Carbon Dioxide	nd			
Methane	51.65	-51.41	-174.8	
Ethane	1.89	-34.60	-151.4	
Ethylene	nd			
Propane	0.501	-29.66	-120.6	
Iso-butane	0.0847	-27.90		
N-butane	0.0814	-28.85		
Iso-pentane	0.0216			
N-pentane	0.0142			
Hexanes +	0.0130			

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 577
Specific gravity, calculated: 0.759

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %. Chemical analysis based on standards accurate to within 2%

ISOTECH
ISOTECH LABORATORIES INC
ANALYSIS REPORT

Lab #: 160349 Job #: 11286
Sample Name: Butler #3 well Co. Lab#:
Company: USGS Reston, VA
Date Sampled: 3/25/2009 Cylinder: 1020
Container: Stainless Steel, 1L
Field/Site Name: NC Triassic Basins
Location: Lee County, NC
Formation/Depth:
Sampling Point:
Date Received: 4/14/2009 Date Reported: 5/13/2009

Component	Chemical mol. %	Delta 13C per mil	Delta D per mil	Delta 15N per mil
Carbon Monoxide	nd			
Hydrogen Sulfide	nd			
Helium	0.218			
Hydrogen	0.0250			
Argon	nd			
Oxygen	nd			
Nitrogen	45.60			-3.32
Carbon Dioxide	nd			
Methane	48.76	-45.11	-178.5	
Ethane	3.86	-36.81	-175.8	
Ethylene	nd			
Propane	1.15	-31.61	-121.3	
Iso-butane	0.0930	-31.96		
N-butane	0.186	-31.25		
Iso-pentane	0.0264			
N-pentane	0.0436			
Hexanes +	0.0366			

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 605
Specific gravity, calculated: 0.778

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %. Chemical analysis based on standards accurate to within 2%

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The 'new stone age'

- N.C.'s industrial minerals warrant revisiting and another look – their production creates jobs, wealth and economic stimulus
- The global demand for industrial minerals coupled with state resources augers well for mineral ventures
- N.C. has extensive mineral resource, geochemical and geophysical databases
- The NC State University's Mineral Research Laboratory (Asheville) offers unique mineral processing capabilities
- N.C. is an industrial minerals storehouse – new resources are on the horizon including nano-technology possibilities
- Industrial minerals are vital to the state's economy and future
- Vibrant international trade involves N.C. minerals

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