Underground Storage of Refrigerated Natural Gas in Granites of the Southeastern U.S.

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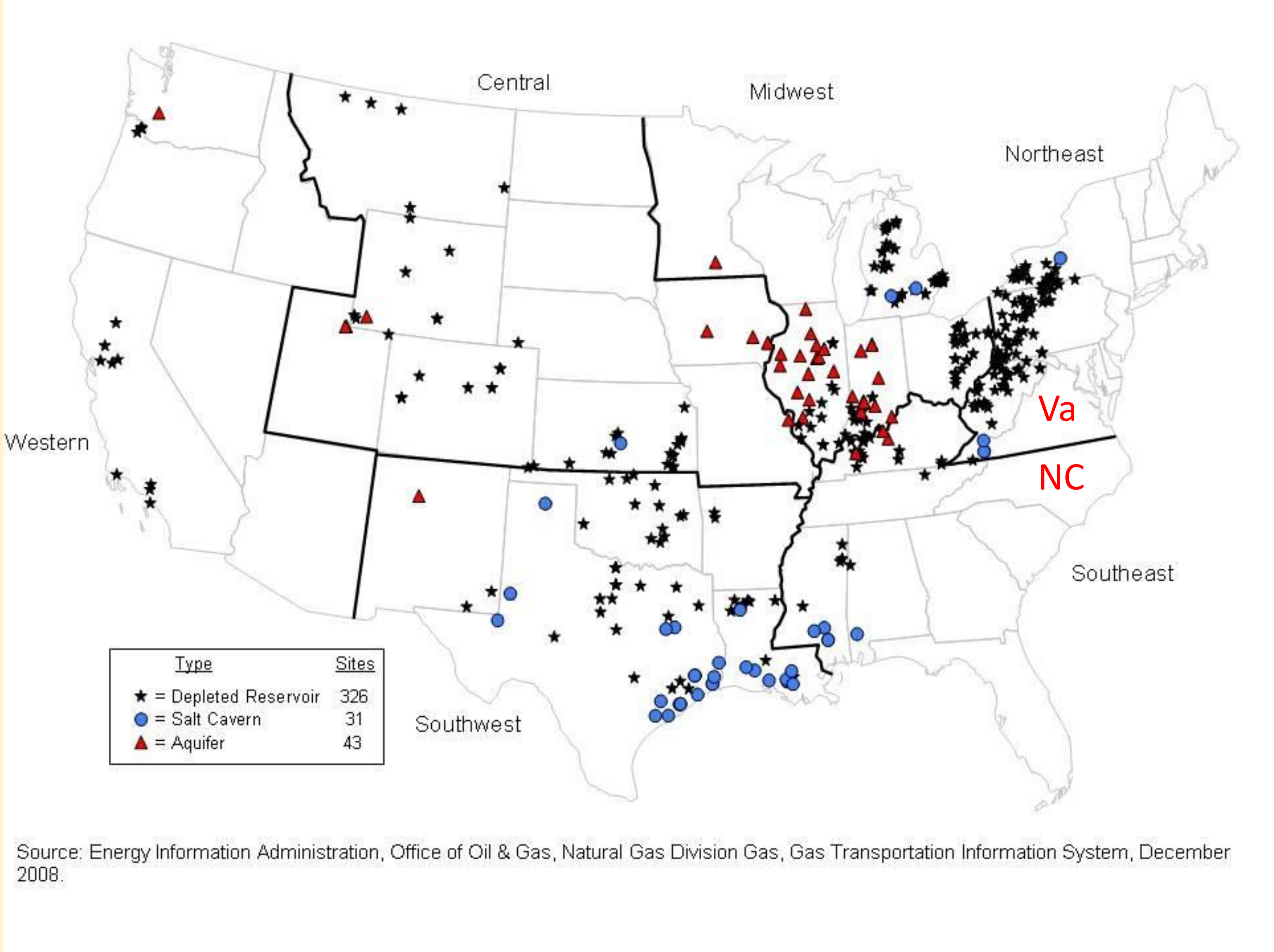
Objectives

- Introduce the concept of storage of refrigerated natural gas in granites.
- Facility design concept introduced.
- Comparison and benefits of mined cavern storage *vs.* LNG plants (including security). This is where caption info from slide 11 would be helpful.
- Examples of potentially suitable ‘granite’ bodies intersecting existing or planned natural gas pipelines are provided.

Topics Covered in This Presentation:

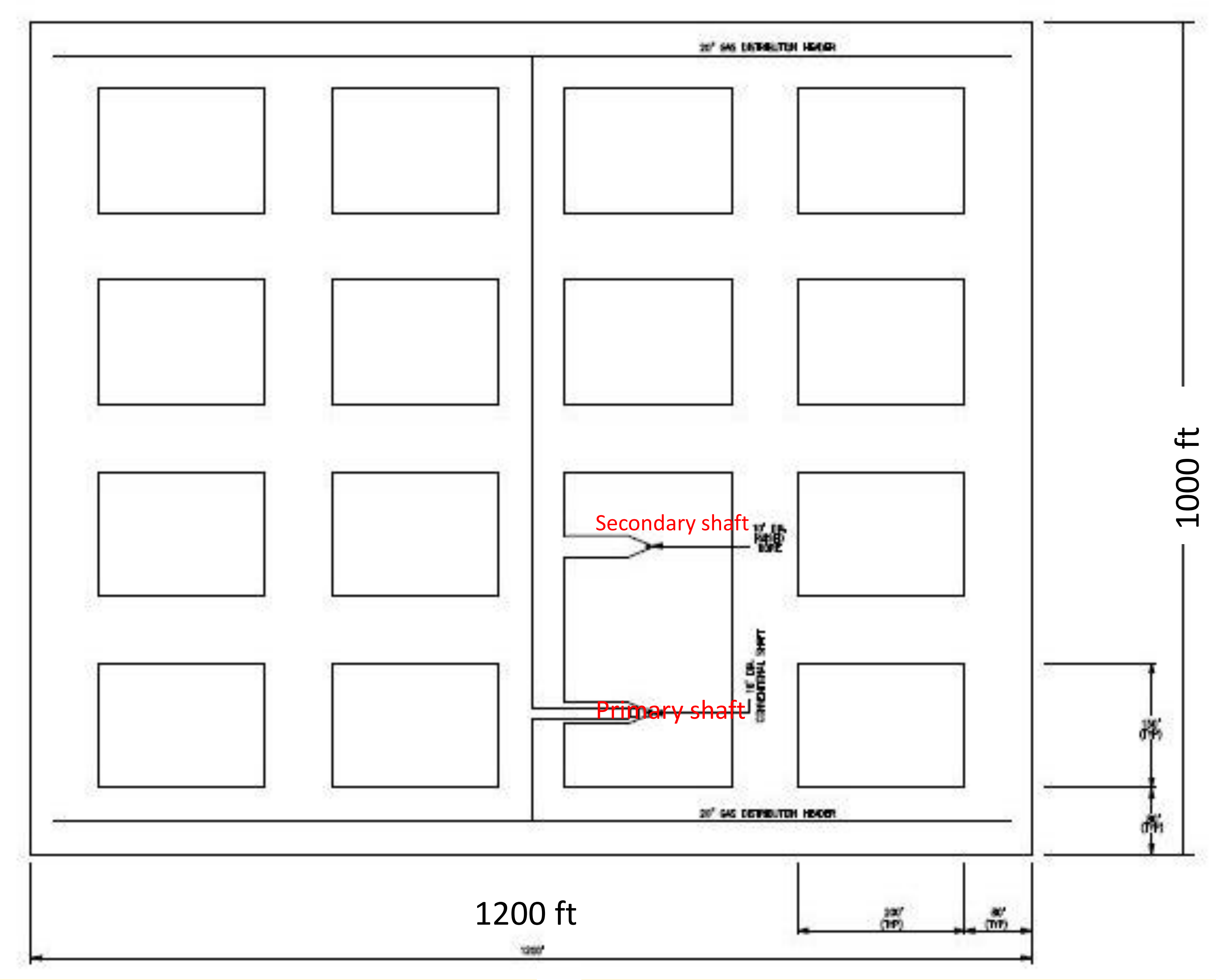
- Distribution of Underground Storage Sites in the U.S. and possible need for additional sites in the Atlantic Seaboard.
- Review of PB-KBB Underground Storage Design for an excavated refrigerated natural gas underground storage site in Granitic rock.
- Existing and proposed major pipelines in the eastern U.S.
- Intersection of major pipelines and granites in North Carolina and Virginia, locations of existing natural gas fired power plants, LNG plants, and population growth maps.
- Relationship between Brunswick County Power Station, Atlantic Coast Pipeline, and Porphyroblastic Biotite Granite in southeast Virginia; and the Sims Granite, Atlantic Coast Pipeline, in Wilson County, North Carolina.



Need for natural gas storage – Southeastern U.S.

According to EIA, natural gas storage is essential as a supply backup and for balancing gas supplies on the pipelines operating in a region. Conventional underground storage sites which include depleted reservoirs, salt caverns, and aquifers are generally absent in the area of this investigation – Virginia and North Carolina.

Under contract to DOE the PB-KBB corporation, in 1998, investigated the feasibility of constructing a room and pillar underground excavation at a Maryland site. They concluded that mined cavity storage can provide high delivery rates and multiple fill – withdrawal cycles in areas where salt caverns are not available.



PB-KBB Design

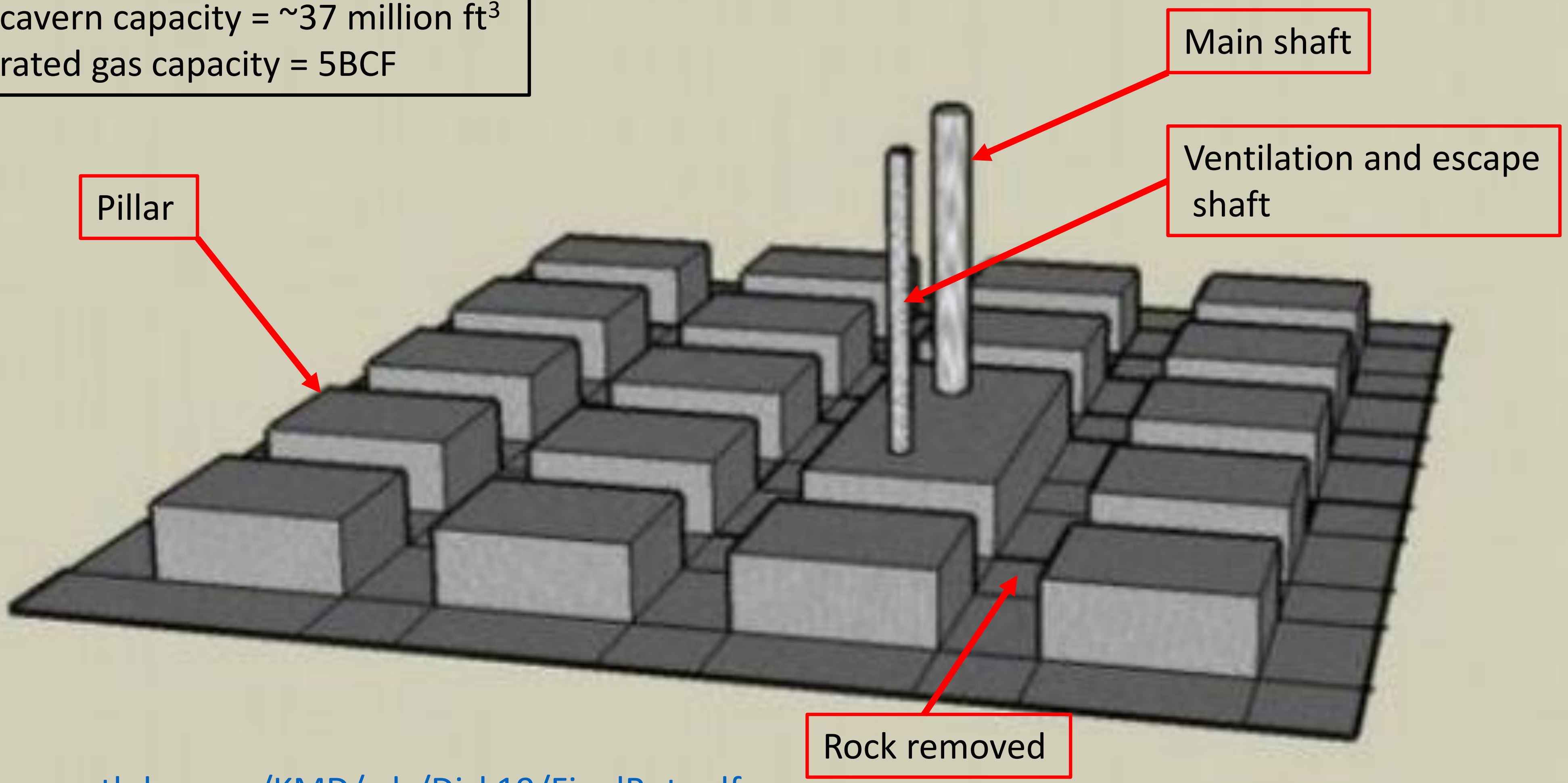
Underground Storage (plan view)

Design features:

Depth – 3000 ft
Volume – 37 million cubic ft
Storage Temperature - -20 degrees F.
Maximum Pressure – 1250 psig
Storage capacity – 5 billion standard cubic ft (BCF).
Plant cost – $178 million or $37.50 per standard thousand cubic ft stored.
Surface footprint – 4 acres with additional 2 or 3 acres for mine shafts and mining operation.
Area of underground development ~ 27 acres.
Shafts – 2 shafts: one 18-20 ft diameter for moving equipment underground and lifting excavated rock during operation; and one 10 ft in diameter to serve for ventilation and escape route in case of accident during construction.

3D Graphic PB-KBB Design – Underground Storage

Mined cavern capacity = ~37 million ft^3
Refrigerated gas capacity = 5BCF



Source:
http://www.netl.doe.gov/KMD/cds/Disk19/FinalRpt.pdf

From PB-KBB Report

<u>General Requirements for Storage Sites</u>

The following are some of the general requirements for storage sites:

- Proximity to transportation systems, such as pipeline, that are to be used for bringing in or shipping out the stored gas to minimize the extent of new pipelines construction. This is of particular importance in areas where approval of new pipeline rights of way is often difficult to obtain.
- More advantageously, and especially for meeting the peaking needs, the storage space would be created near a marketing area, such as a metropolitan area or a strategically located point from which thickly populated areas may be served. Market centers, with their access to multiple pipeline interconnections and supplies, provide a natural platform for gas trading, risk management and opportunity for arbitrage. Storage in Market Center is a multi-purpose resource, such as to support short-term gas loans, gas balancing, and peaking services ("Natural Gas 1996 - Issues and Trends," Energy Information Administration, Dec. 1996).
- Adequate electric power and water supply should be available for storage
- Construction site should be easily accessible
- Congested areas should be avoided, especially environmentally sensitive areas (i.e., natural, state, and local parks, monuments, reservoirs, etc., and areas zoned "residential")
- Suitability of rock for storage - All rock types must be tested locally for site suitability

  (a) The cavern host rock should be as impervious and free of fractures as possible to minimize leakage.

  (b) The rock should be strong enough requiring little or no artificial support of the cavern roof for the given dimensions. Stronger the rock type, the larger the size of the cavern that can be constructed.

  (c) The rock should be uniform and should have little or no jointing, faults and other discontinuities such as shear zone. This impacts the strength of the rock, leakage potential and the dimensions of the underground openings.

  (d) For economic reasons, the rock should be easy to excavate for the shafts and underground caverns.

  (e) The rocks through which the shaft will pass should not be incompetent or be heavy water-bearing, since water control in shaft sinking would require stabilization techniques such as grouting, or freezing, which are expensive.

  (f) Shale and siltstone have been most favorable types of sedimentary rocks because they are impervious, and relatively easy to excavate. However, these rocks require extensive artificial supports, such as roof bolts.

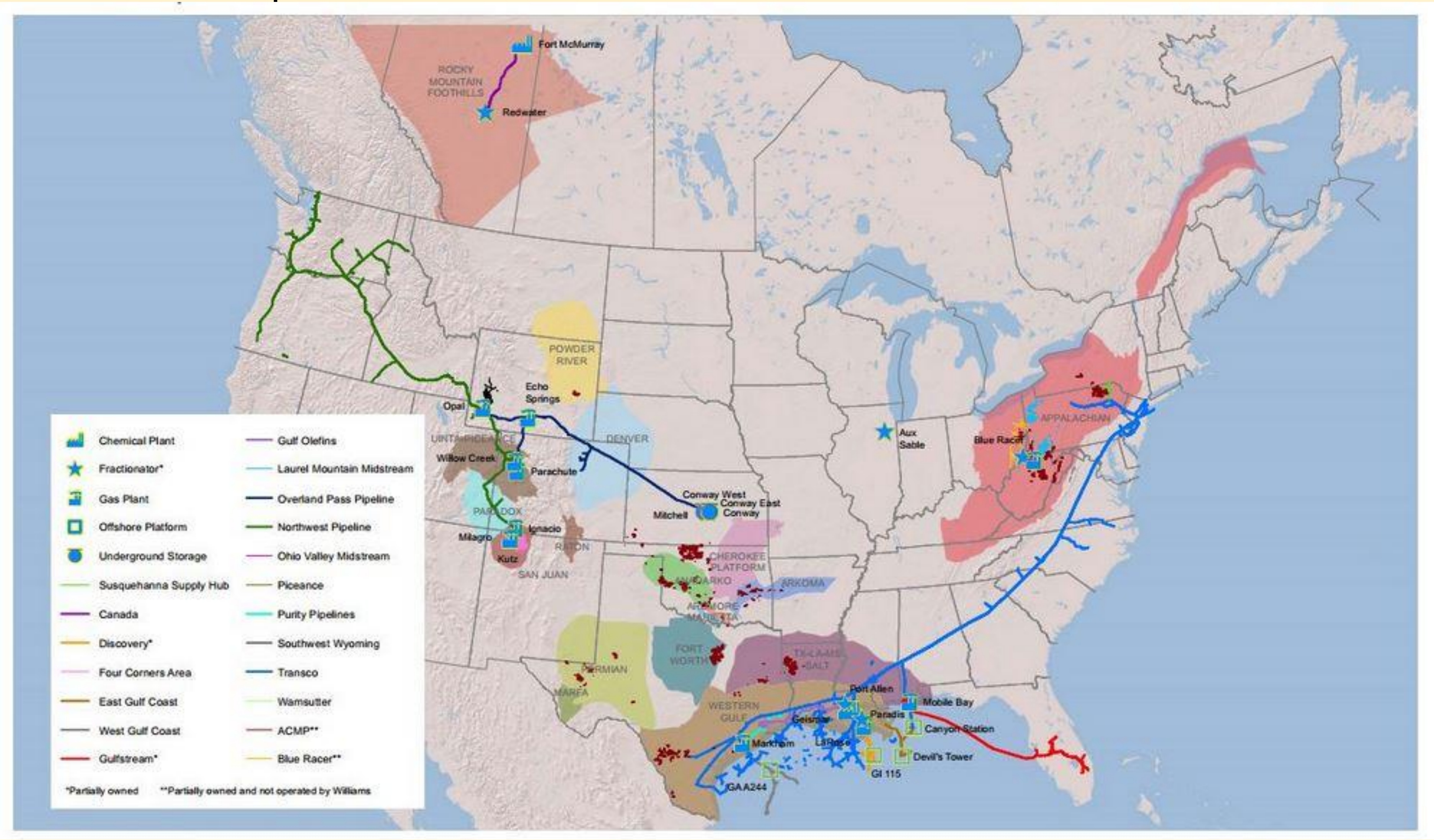
  (g) Igneous and metamorphic rocks are also impervious, could form tight caverns and are strong enough to have self-supporting roofs of the caverns. Large size caverns can be constructed in these types of rocks.

- Availability of space nearby for disposal of the excavated material.
- Sufficient water table to maintain a positive hydrostatic head at the pressures used for storage.

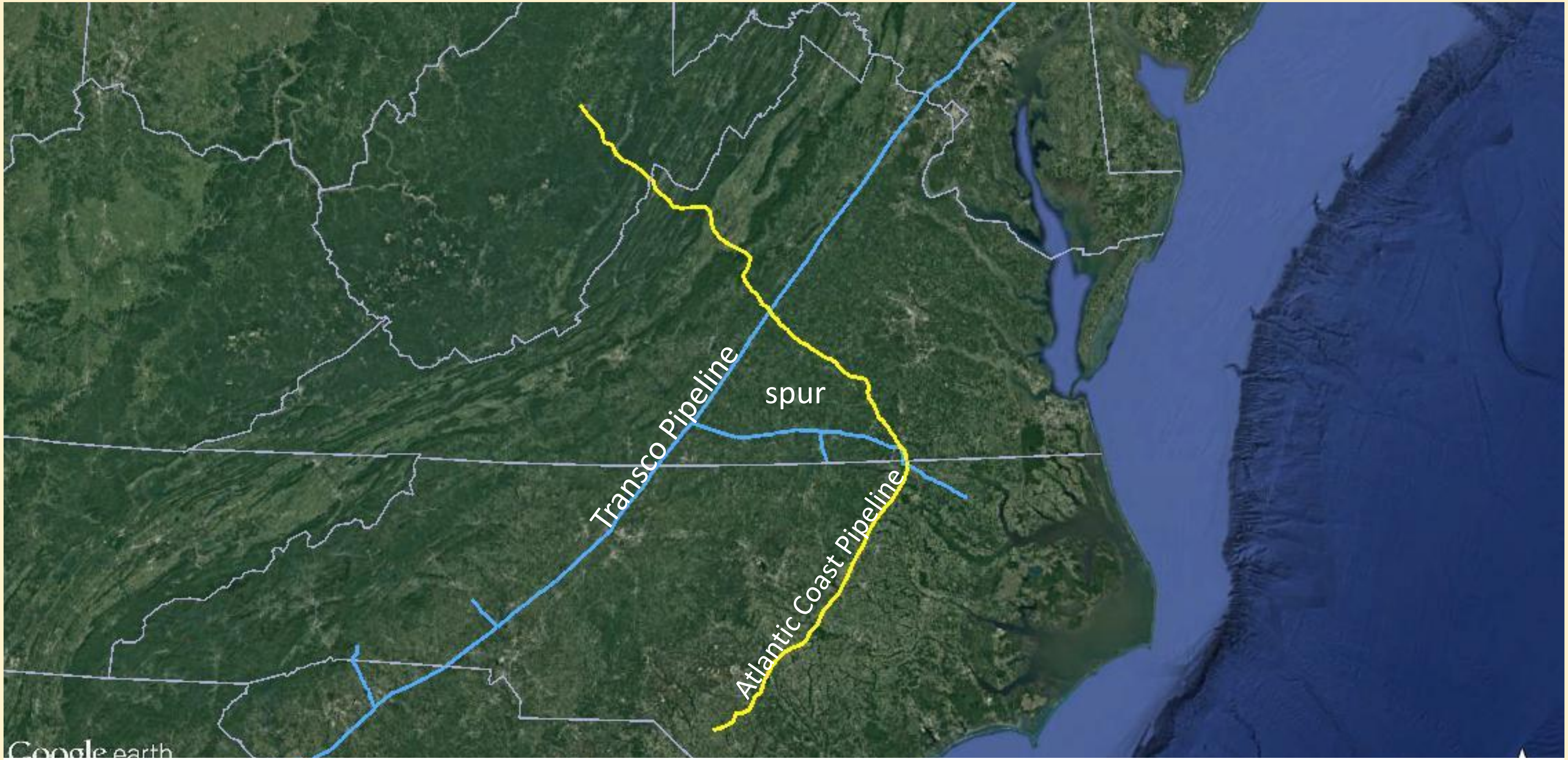
Granitoid rocks are well suited for the type of mined excavation described by PB-KBB. In this study, granites along principal pipelines in Virginia and North Carolina, are investigated using GIS technology – principally Google Earth Pro.

Not mentioned in the PB-KBB statements is the potential for radon accumulation in these excavations. Based on mineralogy, most accessory minerals are resistant to weathering and should not release either radium or radon. Uranium in silicate minerals such as biotite are probable sources of radium and radon in the zone of weathering, but at depths of several thousand feet would not likely release much radon to mined caverns. However, hydrothermally altered granite would be more susceptible to radon release.

Williams Operations and Assets

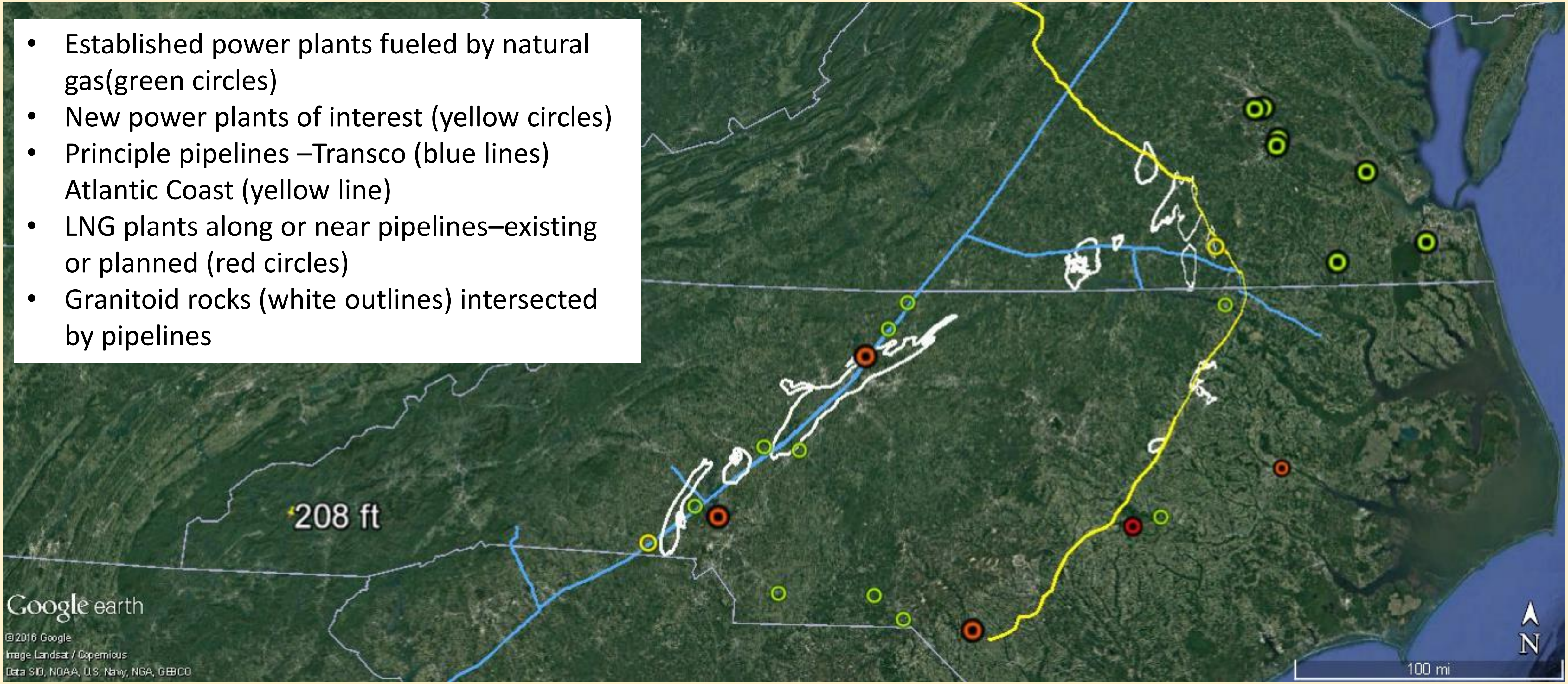


Presently, natural gas is delivered to North Carolina and Virginia from the Gulf Area along the Transco Pipeline.

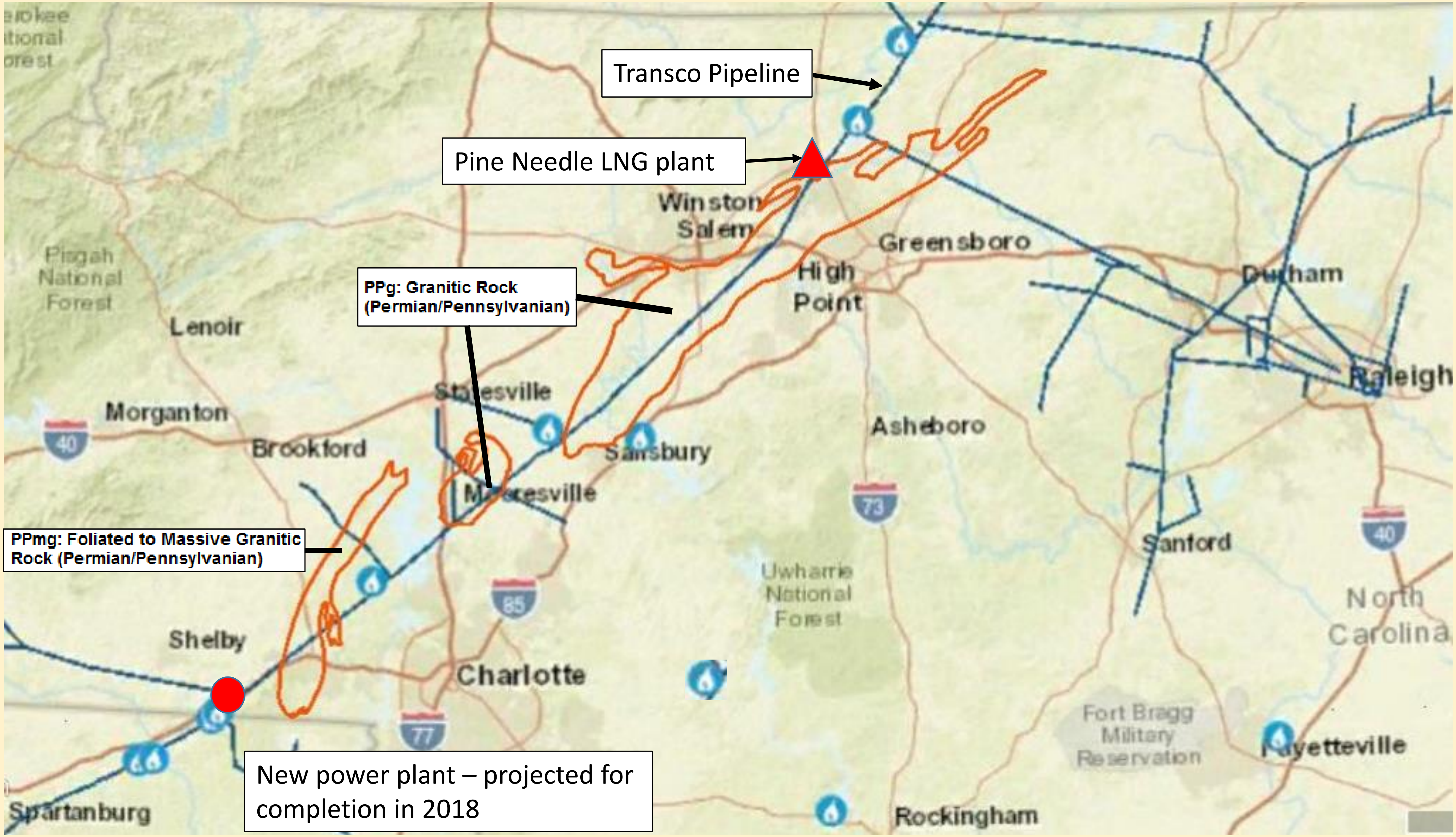


Pipeline Map. Transco Pipeline in blue; Atlantic Coast Pipeline in yellow. The Transco Pipeline has been in existence for many years. The Atlantic Coast Pipeline has only been recently commissioned. It will obtain natural gas from the Marcellus shale in West Virginia, Ohio, and Pennsylvania. Subsequent slides will show these pipelines in relation to granite bodies, LNG plants, natural gas power plants, and population growth maps.

- Established power plants fueled by natural gas(green circles)
- New power plants of interest (yellow circles)
- Principle pipelines –Transco (blue lines) Atlantic Coast (yellow line)
- LNG plants along or near pipelines–existing or planned (red circles)
- Granitoid rocks (white outlines) intersected by pipelines



Currently, LNG plants are considered more viable than Refrigerated Mined Caverns (RMC) in the Atlantic Seaboard. Even though capital costs for LNG plants have more than doubled since 2000 (Songhurst, 2014), capex is still less than for RMC. Another advantage is that LNG plants can be built almost anywhere – those near the coast are built on unconsolidated sediment. RMC requires rocks with special geotechnical properties (certain granites, for example). A principal advantage of RMC is that, like salt caverns, gas can be stored, and removed, more efficiently than LNG plants. Consequently, RMC plants can meet several "peak" demand periods each year, whereas LNG plants have much slower cycle times (some sources indicate 1 cycle/year). Blue dots with black centers are existing power plants.


Transco Pipeline
Pine Needle LNG plant
PPg: Granitic Rock
(Permian/Pennsylvanian)
PPmg: Foliated to Massive Granitic
Rock (Permian/Pennsylvanian)
New power plant – projected for
completion in 2018
Winston
Salem
Greensboro
High
Point
Durham
Raleigh
Pisgah
National
Forest
Lenoir
Morganton
Brookford
Asheboro
Sanford
Uwharrie
National
Forest
Shelby
Charlotte
North
Carolina
Fort Bragg
Military
Reservation
Spartanburg
Rockingham
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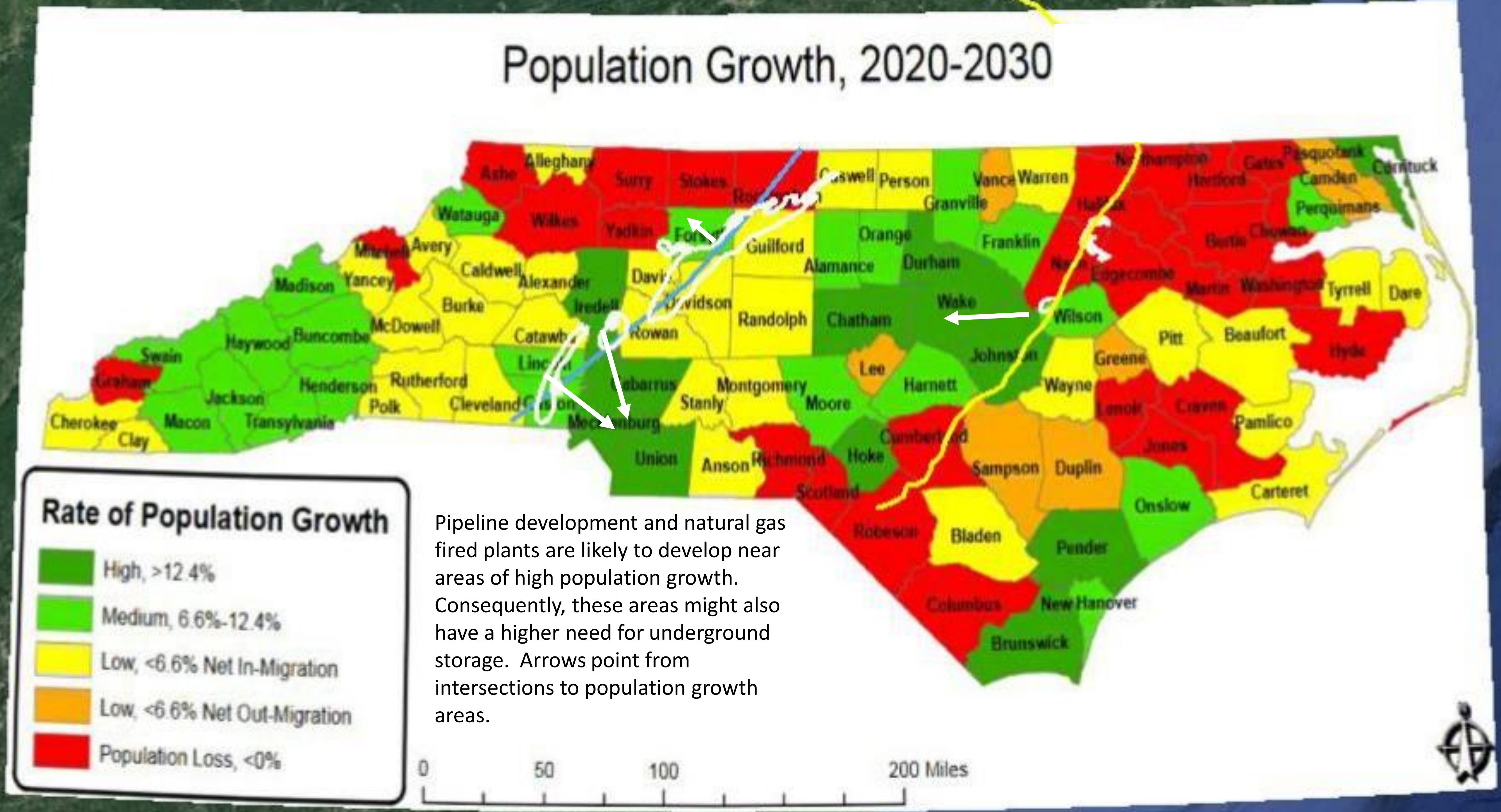
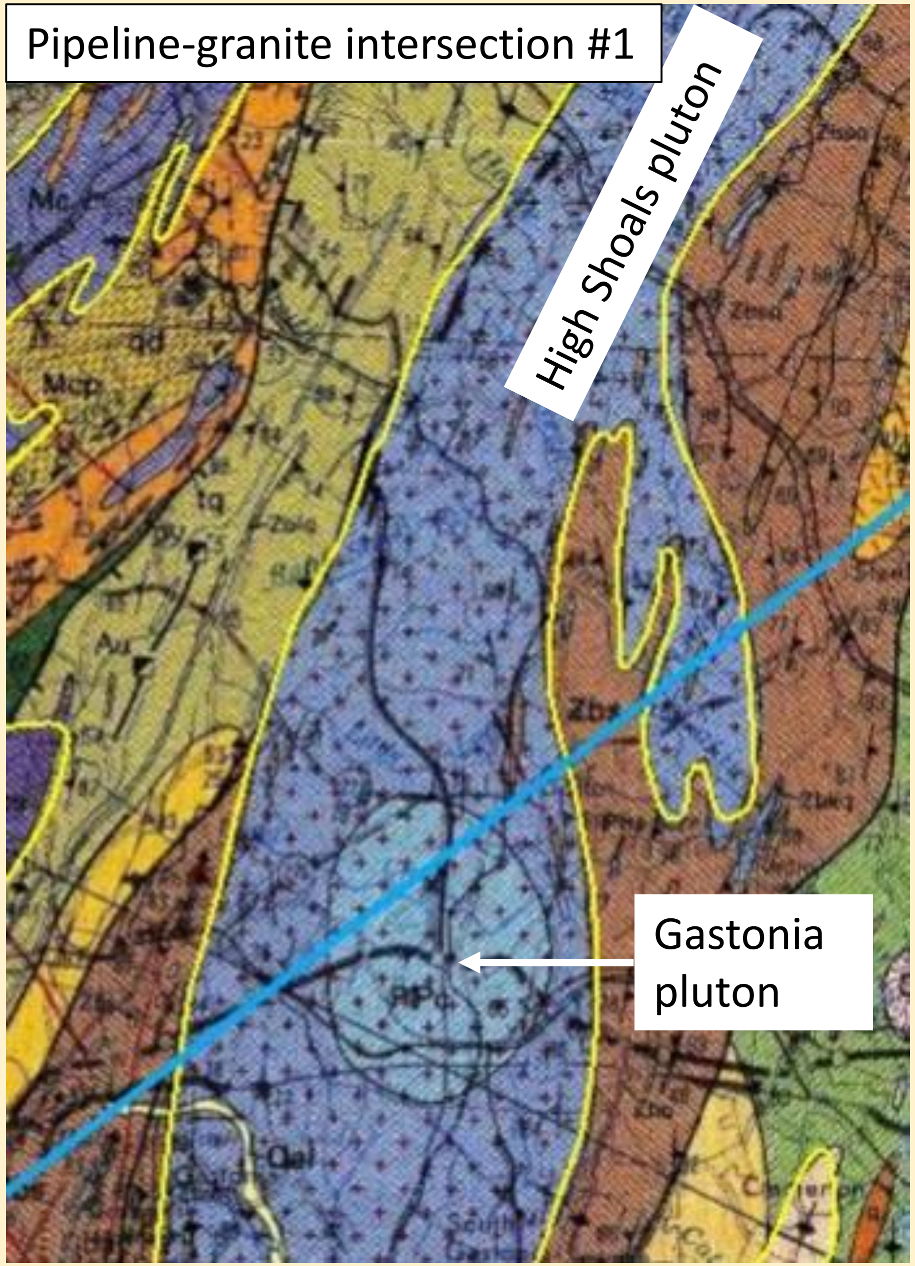
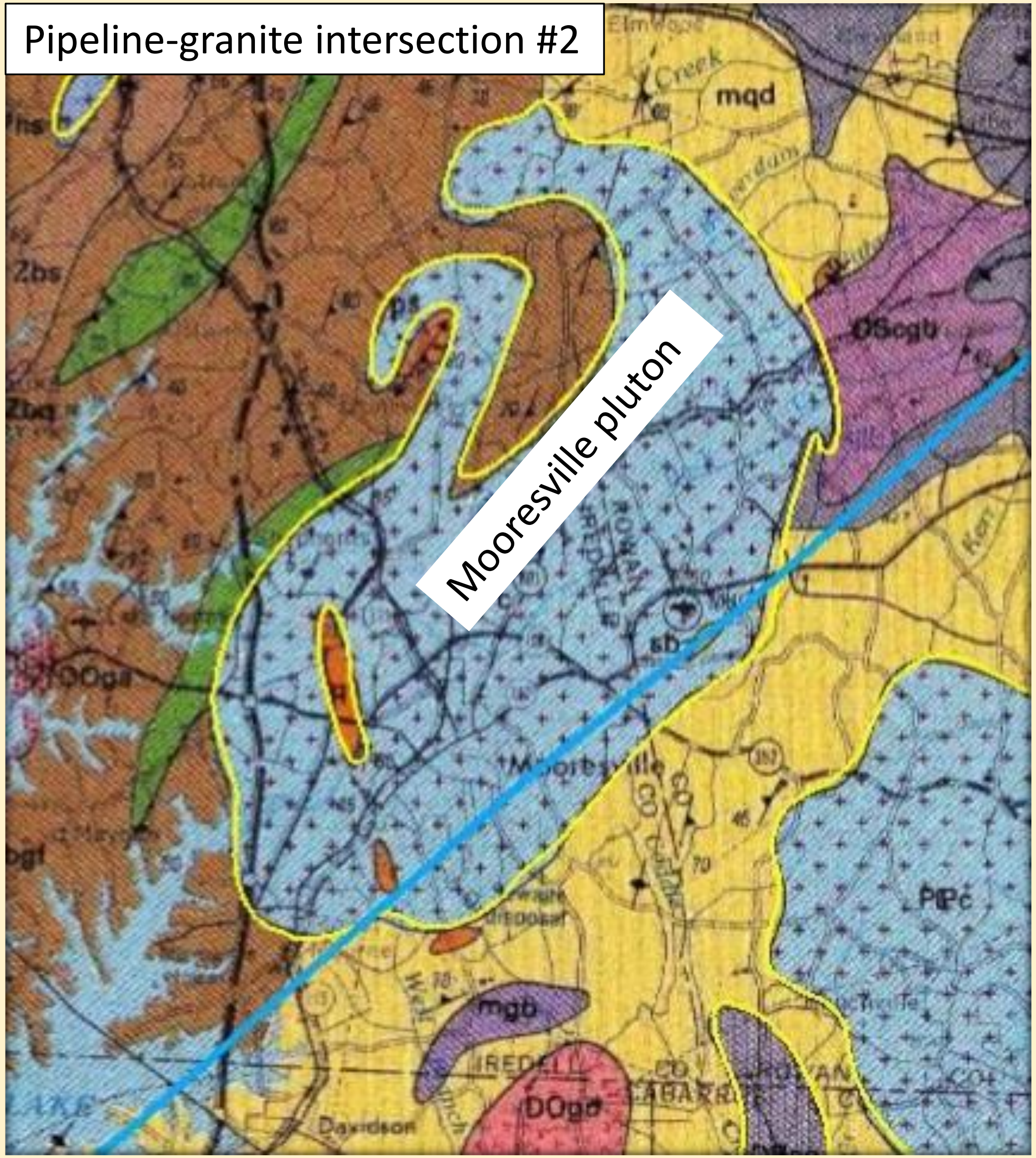
85
73
77

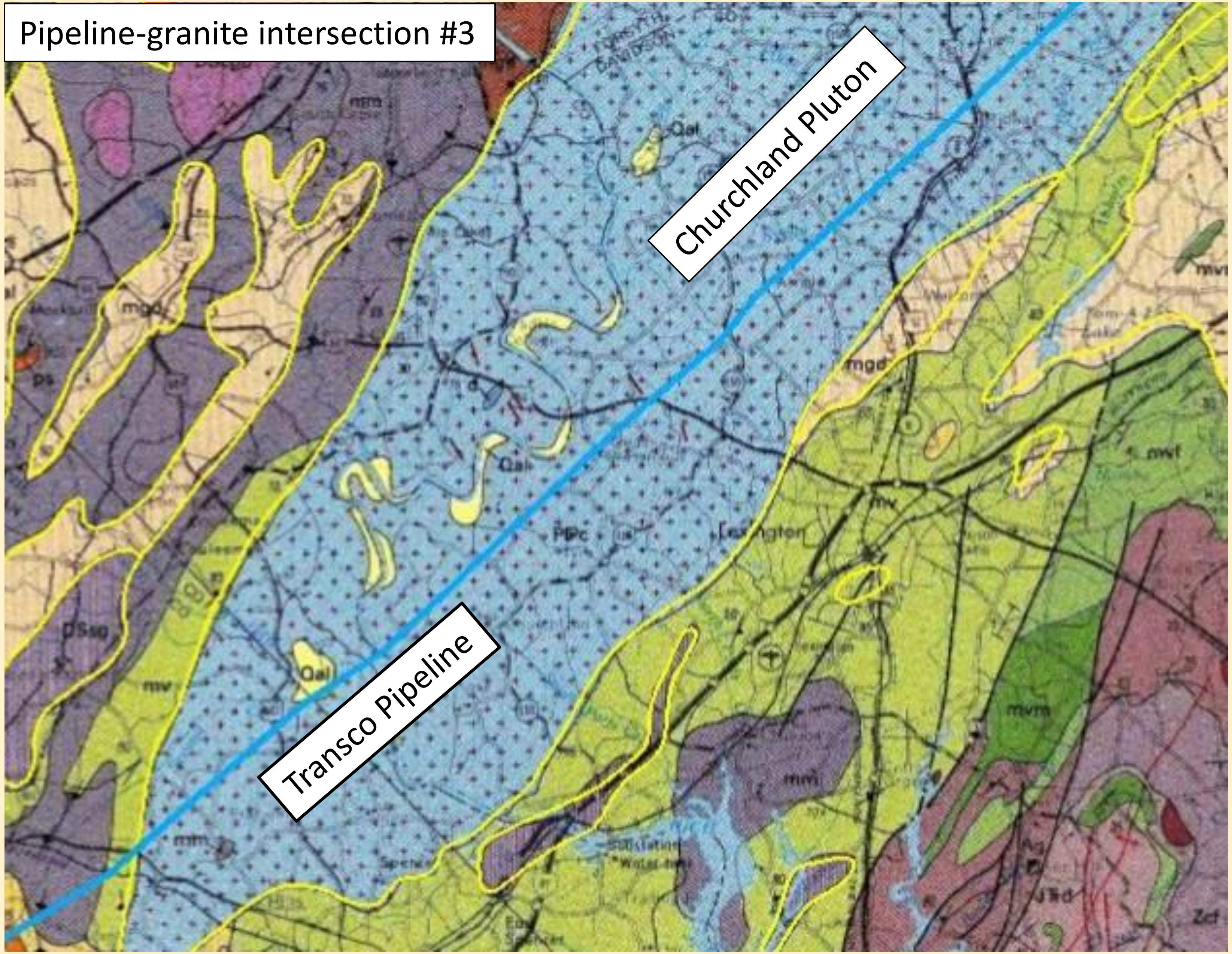


Pipeline development and natural gas fired plants are likely to develop near areas of high population growth. Consequently, these areas might also have a higher need for underground storage. Arrows point from intersections to population growth areas.

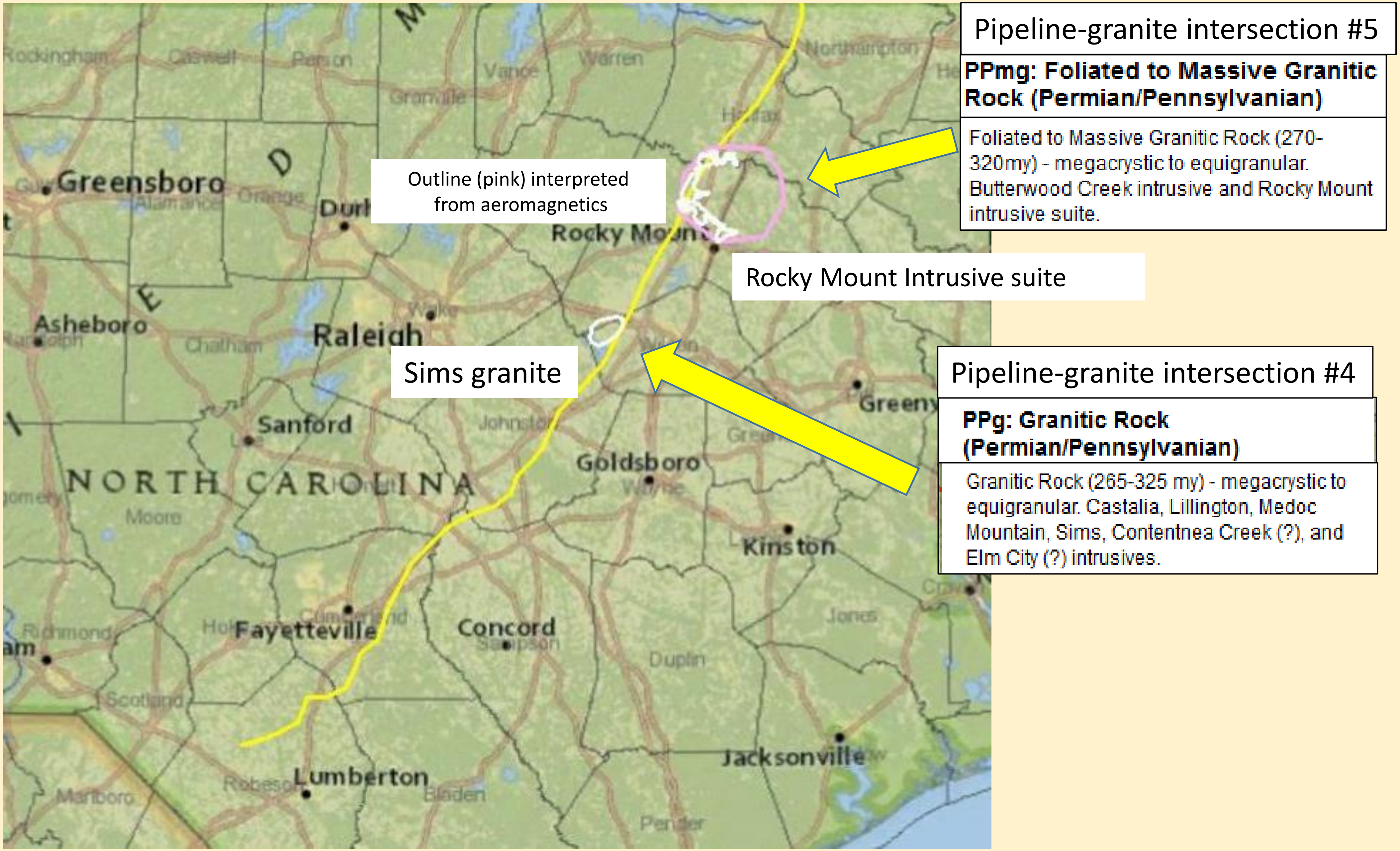




Granites intersecting Transco Pipeline (blue line) from Geologic map of the Charlotte 1 degree x 2 degrees quadrangle, North Carolina and South Carolina.

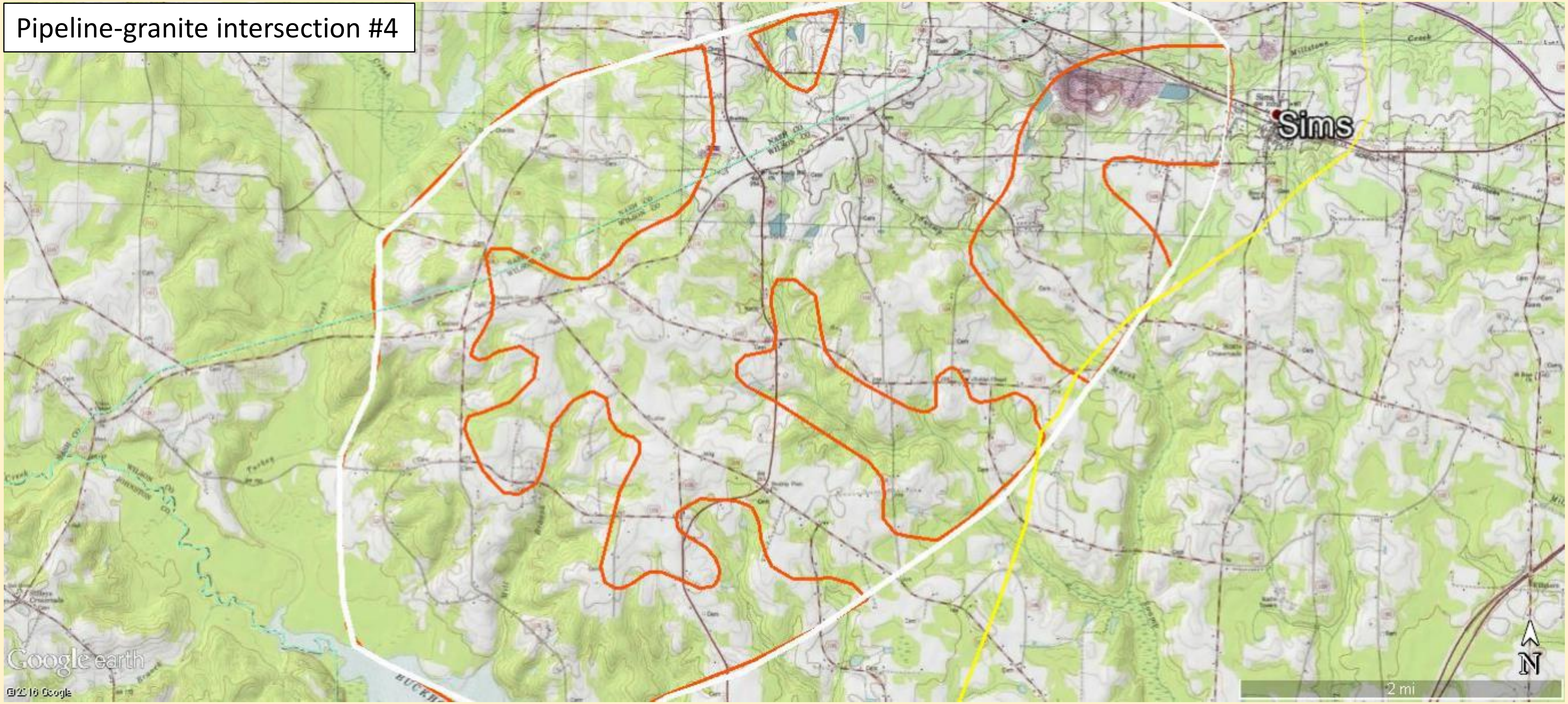


From Geologic map of the Charlotte 1 degree x 2 degrees quadrangle, North Carolina and South Carolina. Intersection of Transco pipeline with granite near Lexington, NC.



Granites (white outlines) intersected by Atlantic Coast Pipeline in eastern N.C.

Pipeline-granite intersection #4



Sims Granite Area. Outline of granite shown in white. Outline of area of granitic outcrops shown in red. Interior areas (not outlined) are an overlap of Coastal Plain sediment. Proposed route of Atlantic Coast Pipeline shown in yellow.

Speer, J.A., 1997, The Sims pluton, Nash and Wilson Counties, North Carolina: North Carolina Geological Survey, Bulletin 97, scale 1:82,000

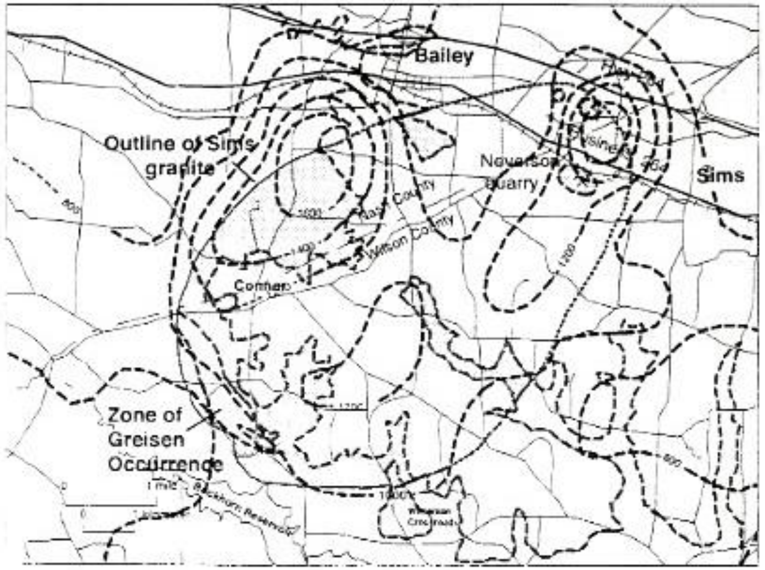


Figure 16. Aeroradioactivity map for the vicinity of the Sims pluton, N.C. (U.S. Geological Survey, 1975). Values are total count gamma ray intensity.

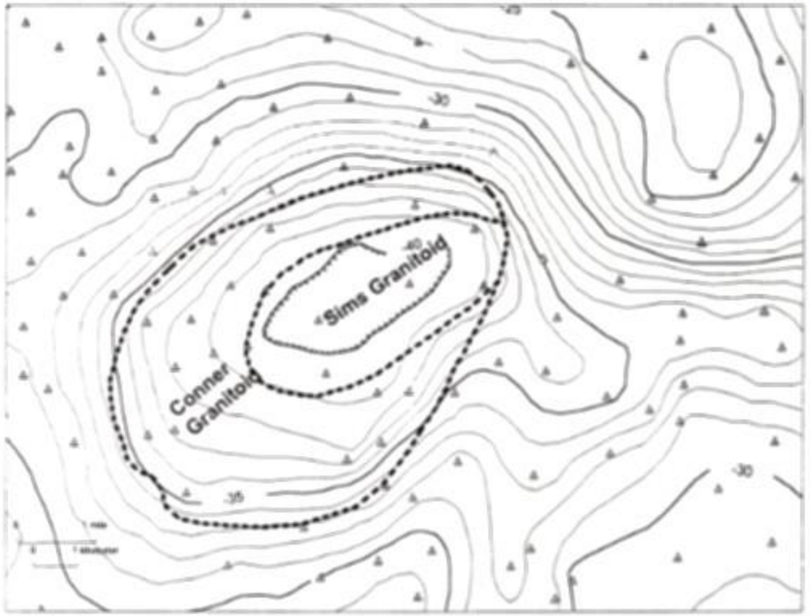
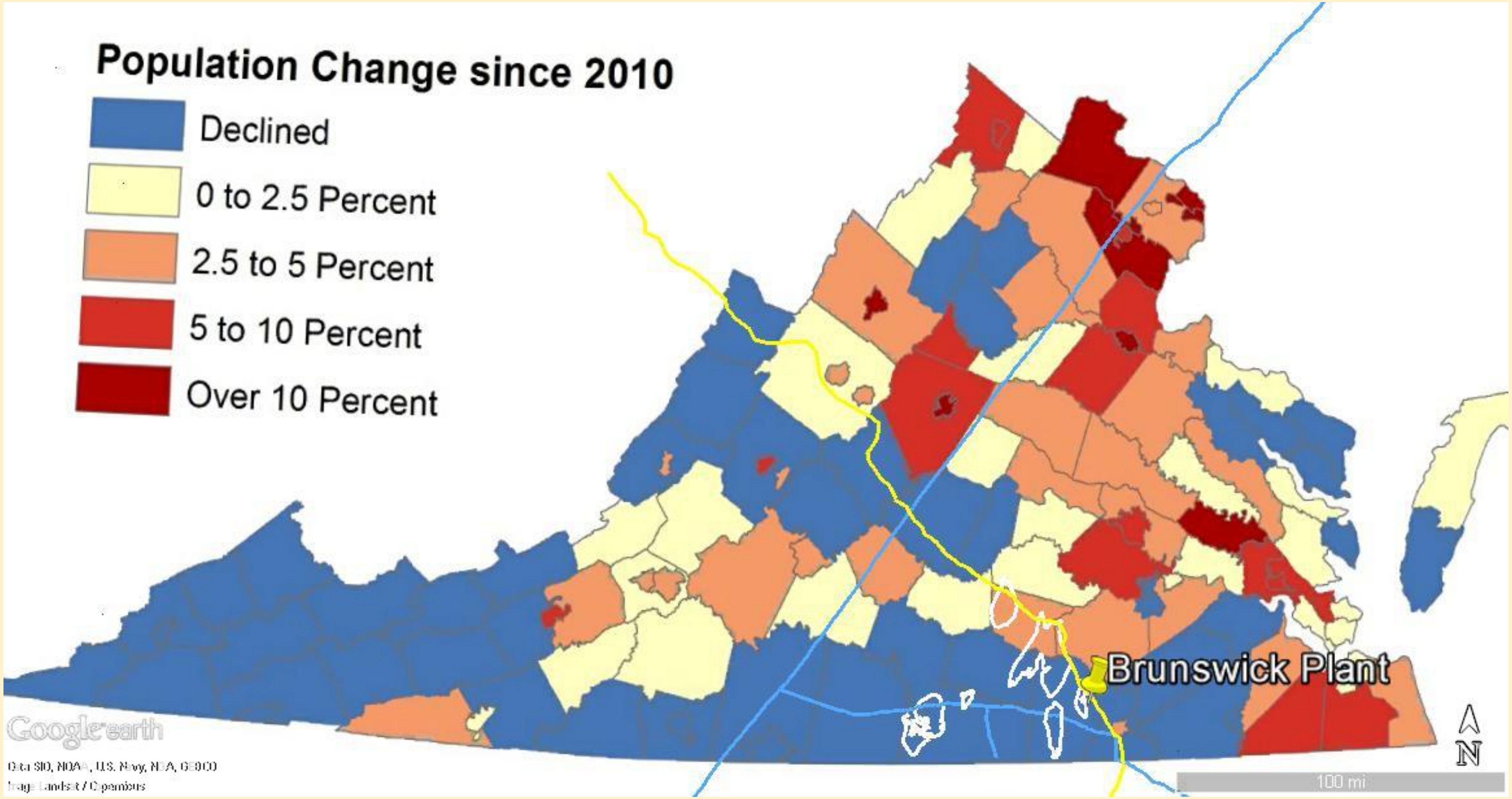


Figure 14. Bouguer gravity anomaly map for the Sims pluton and vicinity (Lawrence, 1996). Shaded triangles indicate location of the observations.

CONTENTS

This publication summarizes just about all information available for the granite body. It serves as a model for the type of information needed for evaluating sites for underground development.



From the standpoint of population growth, the likelihood for underground storage along the Transco spur is less that that along the planned Atlantic Coast pipeline. Relationships at the Brunswick County Power Station (yellow symbol) are quite interesting.

Brunswick County Power Station, Virginia

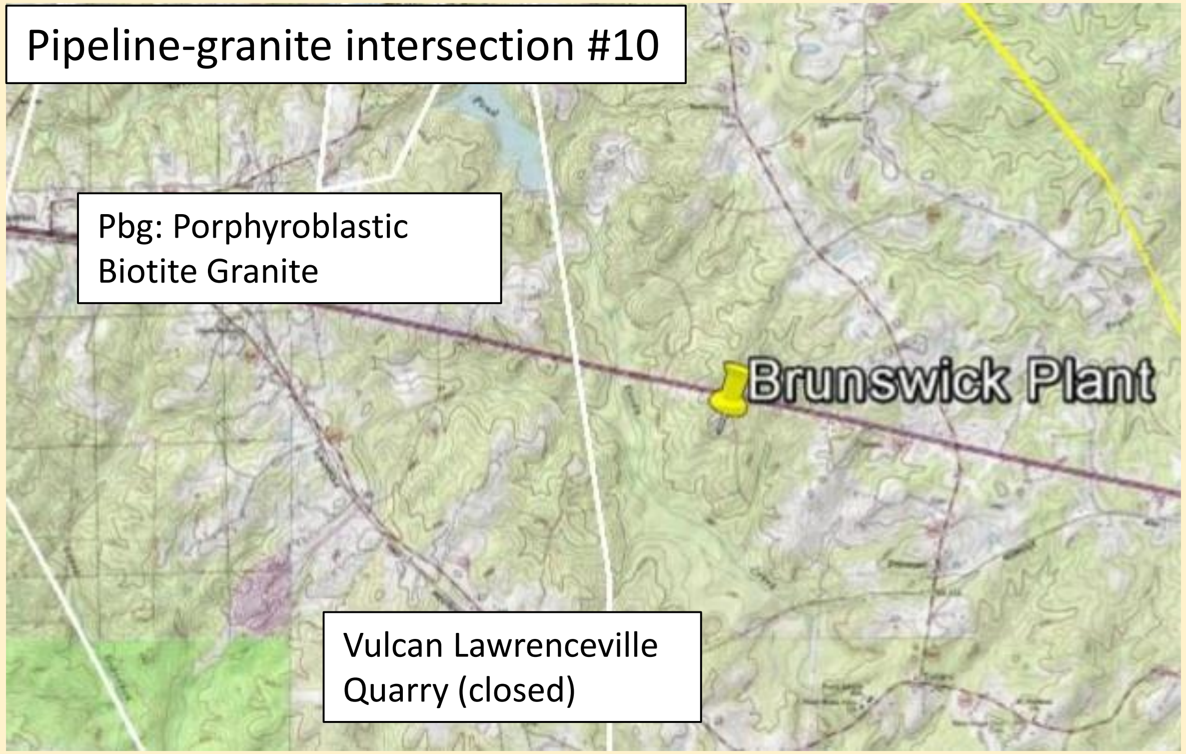
Construction on the $1.3 billion power station began in summer 2013. At the peak of the work more than 1,500 workers were on site. The project was completed ahead of schedule and under budget. Development and construction employs about 380 workers annually and yields about $824 million in economic benefits for the state.

The completed station employs 43 people.

An additional $1 billion in customer savings is expected over the life of the station, compared with the next-best option for supplying power.

Brunswick Power Station is a 3-on-1 combined cycle power station fueled entirely by natural gas. The station uses the latest technology and is among the most efficient power station in the country.

Combined-cycle technology utilizes combustion turbines that are essentially gigantic jet engines. The station has three of the turbines that generate 280 megawatts each. The super heated air from the combustion turbines is used to generate steam that produces another 470 megawatts on a steam turbine.



Relationship between Brunswick County Power Station, Atlantic Coast Pipeline (yellow line), and Porphyroblastic Biotite Granite (white line) on topographic base (left) and Google Earth base (right).

Data from the USGS' National Geologic Map Database

- URL https://ngmdb.usgs.gov/ngmdb/ngmdb_home.html
- Map catalog: https://ngmdb.usgs.gov/ngm-bin/ngm_compsearch.pl
- Project search results along pipeline routes (catalog entries):
  - Scale 1:24,000 = 3
  - Scale between 1:24,000 and 100,000 = 1
  - Scale between 1:100,000 and 500,000 = 22
- All except one citation can be downloaded for use in Google Earth or a GIS system.

Conclusions

There are 11 major pipelines intersections with granite in North Carolina and southern Virginia. If a need for underground storage justifies the higher costs of underground excavations, such as the type described by KB-KBB corporation, these granites may warrant further consideration as underground storage sites.

Initial follow-up evaluation might include the following:

1. Detailed literature search of granites intersected by pipeline,
2. Geological traverses along pipeline intersections and immediately adjacent areas documenting density of fractures and their orientations, and
3. Documentation of parks, schools, subdivisions and potential environmentally-sensitive areas along intersections.

Thank you for your attention

For additional information

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