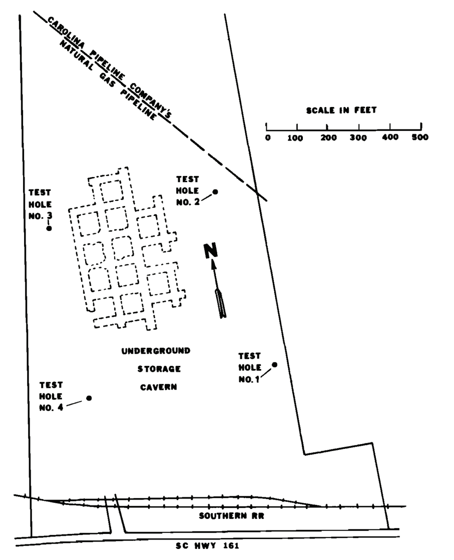
Underground Storage of Refrigerated Natural Gas in Granites of the Southeastern U.S.

North Carolina Geological Survey
Open-File Report 2018-14

Early hydrocarbon (propane) storage in granites - SC and VA (also see bottom center inset)

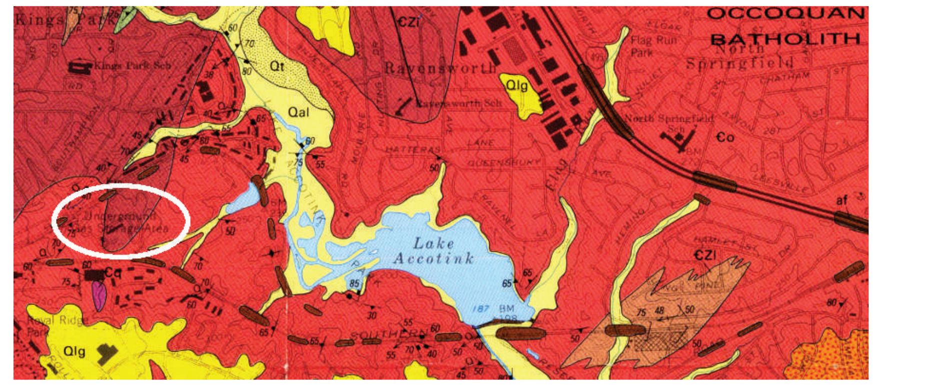


Tirzah, York County, SC - Propane was stored at a shallow depth by the Carolina Pipeline Company. The facility was co-located adjacent to a railroad and a natural gas pipeline. The cavern floor is about 450 ft below ground level. At that depth, where the temperature is 61° F, the natural hydrostatic ground water pressure exceeds the pressure required to contain the propane in a liquid state. Ground water in fractures acts as a seal confining the propane within the excavation. The cavern's storage capacity was 16 million gallons (Nystrom, 1976). The cavern was constructed in a coarse-grained adamellite (Butler, 1976).

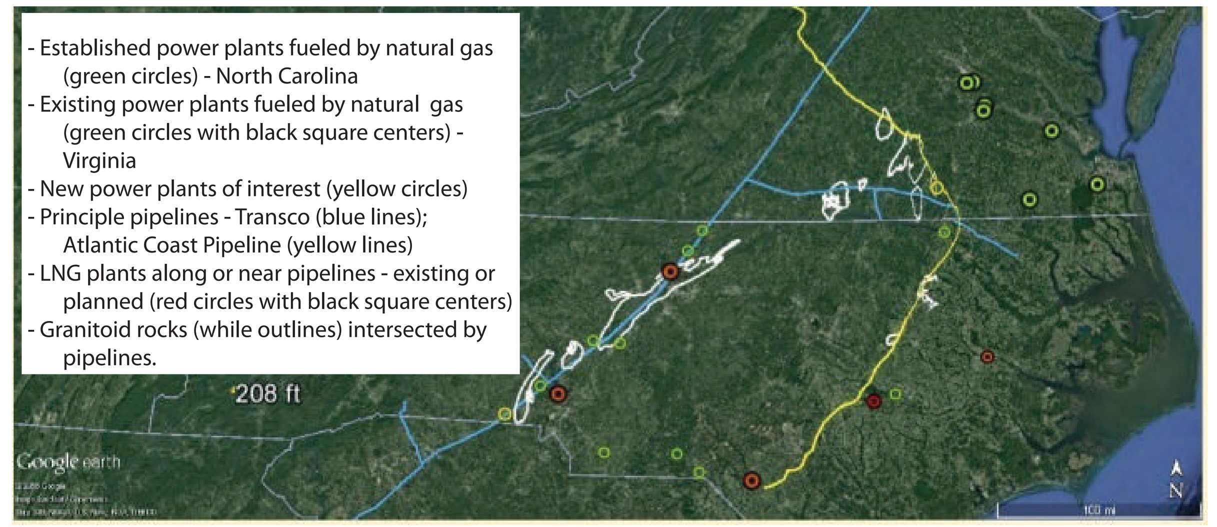
See discussion of fracture closure depths for the Sharon Harris Nuclear power plant in Wake County, North Carolina in box below (The Sharon Harris Nuclear Final Safety Analysis report, U.S. Nuclear Regulatory Commission, September 12, 2012). At the proposed refrigerated gas storage cavern depth of 3,000 ft, all fractures should be closed and sealed. Core drilling and rock testing will be required to confirm site specific conditions and acceptable rock quality.

Fairfax County, VA - In 1962 Washington Gas excavated an underground cavern to store 13 million gallons of Liquefied Petroleum Gas (LPG). The Ravensworth Station reservoir was carved out of the nearly 500-million year old Occoquan granite bedrock west of Lake Accotink Park. The cavern had 25-ft high ceilings and used pillar support. Water leaked into the cavern during construction indicating fractured bedrock. A water cap was used to maintain geostatic pressure. Source: Washington Gas: see URL https://www.washingtongas.com/-/media/d2067877df1e446991e9bece0a1749da.pdf.

Source: http://www.virginiaplaces.org/geology/naturalgasstorage.html

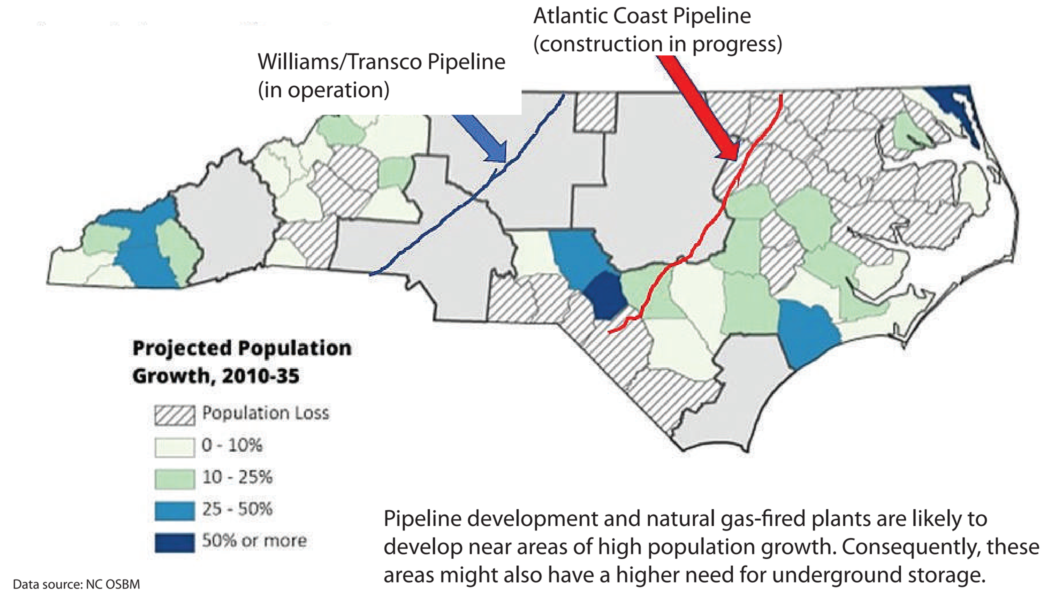


Geologic map of the Annadale quadrangle, Fairfax and Arlington Counties, and Alexandria City, Virginia (1986). See URL https://ngmdb.usgs.gov/Prodesc/proddesc_92836.htm



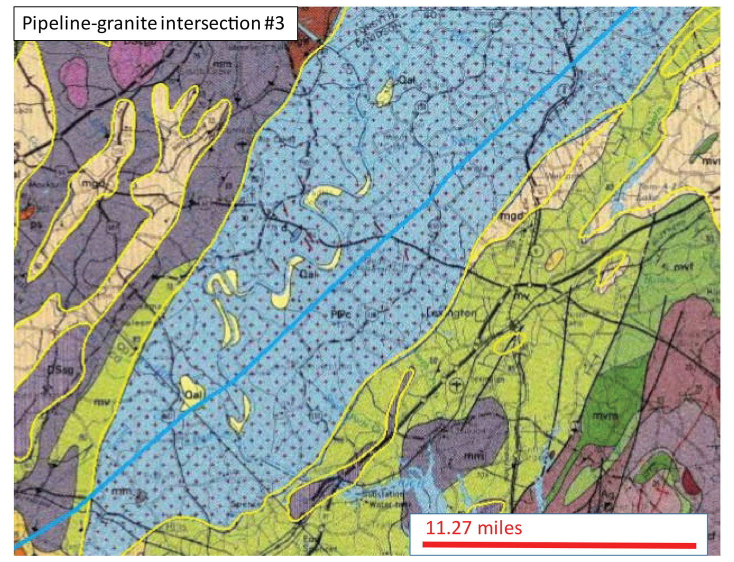
Currently, LNG plants are considered more viable than Refrigerated Mined Caverns (RMC) along the Atlantic Seaboard. Even though capital costs for LNG plants have more than doubled since 2000 (Songhurst, 2014), capex is still less than that for a RMC of equivalent capacity.

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). Green dots with black centers are existing power plants.



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.

North Carolina projected population growth, 2010-2035:
Many counties outside of major metros are projected to lose population.



Intersection of Transco Pipeline (blue line) with granite near Lexington, N.C. Geology from the Geologic map of the Charlotte 1 degree x 2 degrees quadrangle, North Carolina and South Carolina (Goldsmith; Milton, and Horton, 1978) available on-line at URL https://ngmdb.usgs.gov/Prodesc/proddesc_9068.htm.

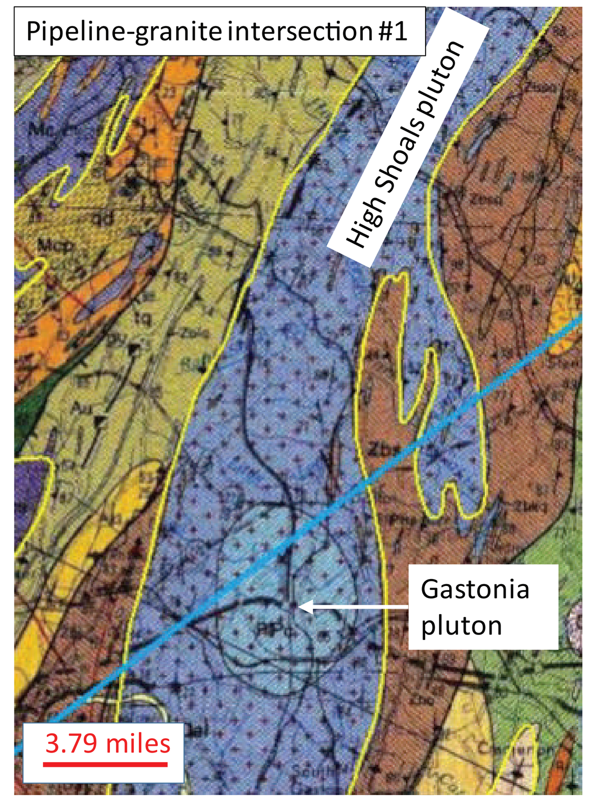
Groundwater and fracture closure depths - area examples

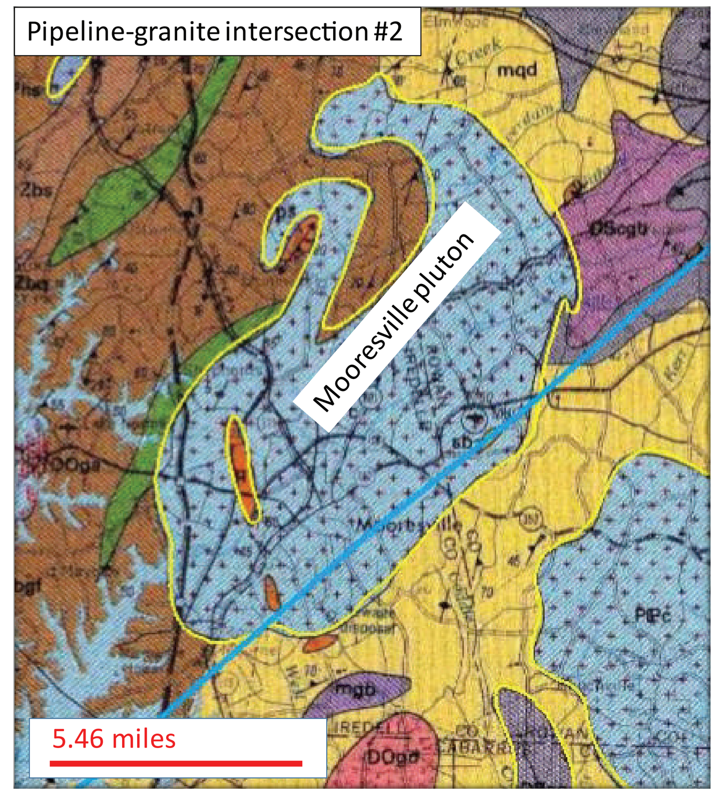
Early mined caverns designed to store propane in Virginia and South Carolina (see above) were constructed at a very shallow depth (nominally ~450 ft. Their design included a water cap to contain the propane using geostatic pressure. Water inflow at Fairfax, VA, cavern indicates fractured bedrock. At the Tirzah (SC) site natural groundwater pressure in fractures acted as a seal to confine the propane in the excavation.

Lu (2010) discussed rock engineering problems related to underground hydrocarbon storage including unlined rock caverns. The Haje underground gas storage in the Czech Republic, the single example cited, is composed of about 45 km unlined tunnels and cross-sections of 12-15 m^2 at a depth of 955-961 m below the ground surface. The groundwater table is 850 m above the caverns (Lu, 2010). The gas and cavern were not refrigerated.

Fracture closure depths were determined as a design criterion to define competent rock as part of the Sharon Harris geotechnical study in extreme southwestern Wake County, North Carolina, at the site of the Sharon Harris nuclear reactor. Results build on similar geotechnical studies at the adjacent parcel nominated to be the site (effort abandoned) for the southeastern regional low level radioactive waste (LLRW) disposal repository. The shallow surface aquifer has many interconnected fractures. However, "these fractures are common to depths of 100 feet below ground surface…, but become less prevalent with increased depth. At depths greater than 400 ft, the fractures are closed and sealed to water flow" (Sharon Harris Final Safety Analysis report, Section 2.5-56, U.S. Nuclear Regulatory Commission, September 12, 2012). Fractures and joint distribution and characteristics were studied for the Sharon Harris and geotechnical investigation (section 2.5-113) and the preceding LLRW geotechnical investigation (Section 2.5-114). Shear wave velocities were a design criterion used as a proxy to define competent rock. The nearby U.S. Geological Survey's Sears #1 well also has shear wave velocities that were used. Fracture closure depths of several hundred feet have been documented by two surface geotechnical investigations (U.S. Nuclear Regulatory Commission, September 12, 2012).

The refrigerated granite cavern storage at a depth of 3,000 ft greatly exceeds the fracture closure depth. Geotechnical site investigations including continuous core drilling are part of a multi-step suitability study for candidate sites. Identified pipeline/granite intersections need to be geologically ranked and geotechnically evaluated.





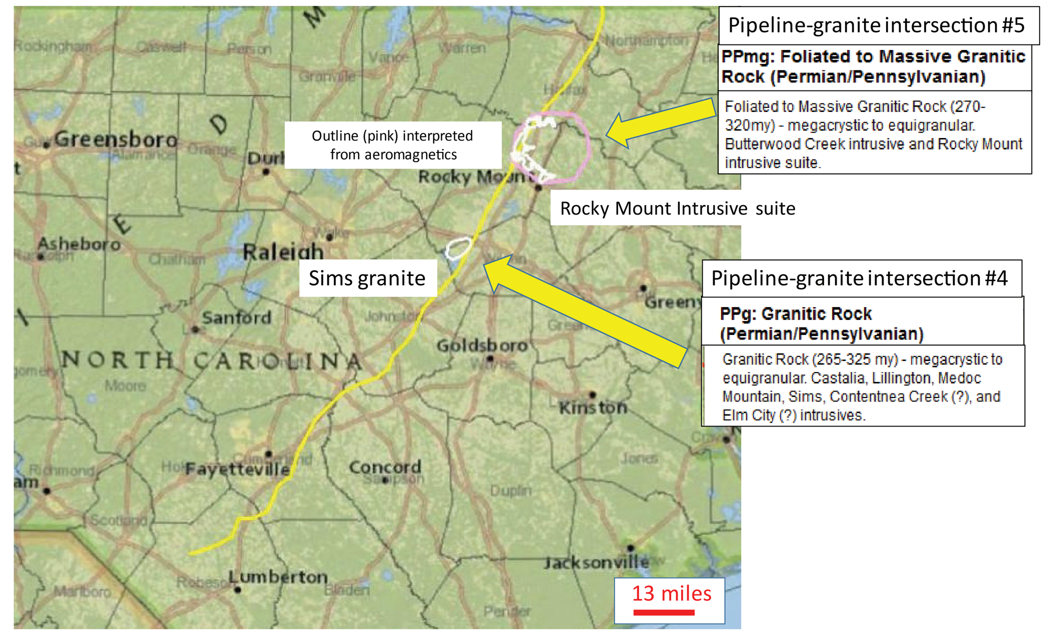
Granites intersecting Transco Pipeline (blue line) from Geologic map of the Charlotte 1 degree x 2 degrees quadrangle, North Carolina and South Carolina (Goldsmith; Milton and Horton, 1978) available on-line at URL https://ngmdb.usgs.gov/Prodesc/proddesc_9068.htm.

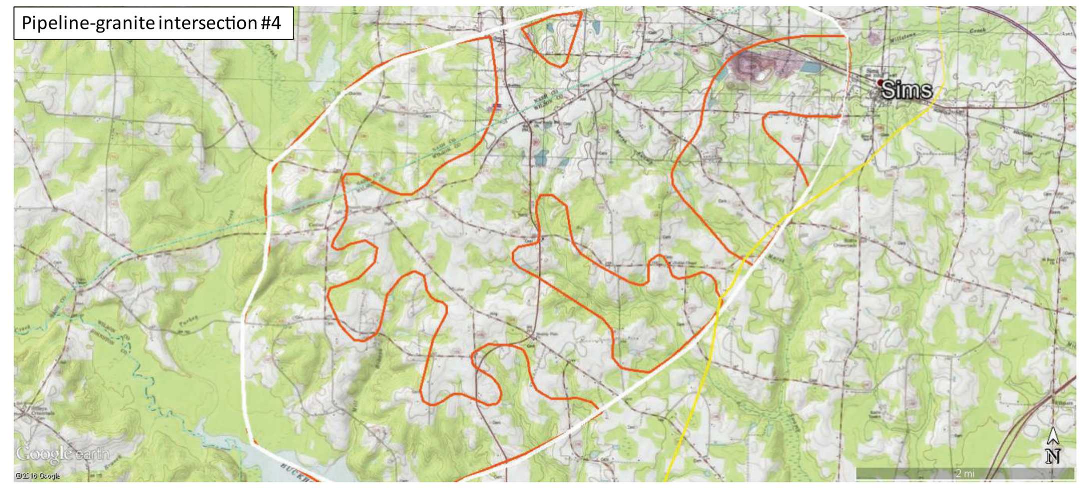
Blue Ridge (Crozet) railroad tunnel: A non-granite propane storage facility, Nelson Co., VA

East portals - Old and new, circa 1959

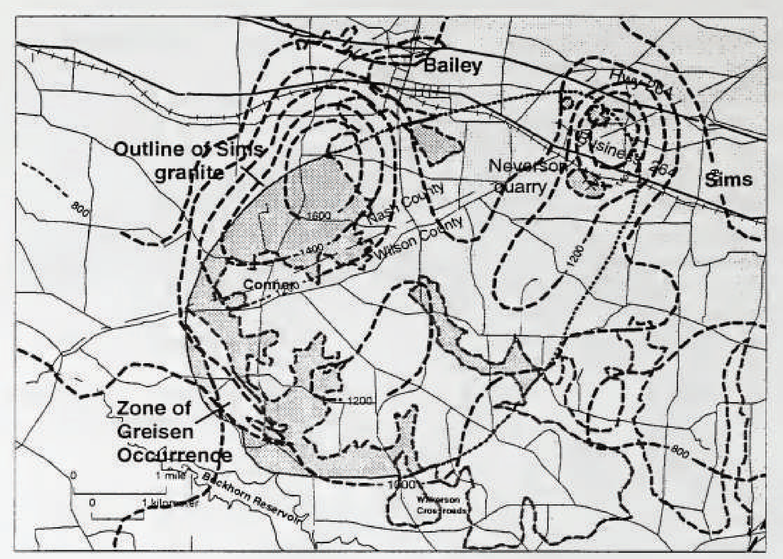
"In the 1950's, a gas company leased the old tunnel for large-scale storage of propane. Two concrete bulkheads, or plugs were constructed. One is 750 ft from the east portal. The other is 1,900 ft from the west portal. The barriers currently remain in place, though the storage plan was cancelled and the interior space never used." (Blue Ridge Tunnel Foundation - http://blueridgetunnel.org/the-blue-ridge-railroad/. Lang (2018) described two dominant fracture sets that may have been the cause for why the space was not used for propane storage. Photographs of the concrete portal plugs are on-line at https://www.steamphotos.com/Railroad-Photos/Abandoned-Railroad-Tunnels/Crozet-Blue-Ridge-Tunnel/. The near surface location precludes a confining water curtain to contain propane and to seal the fractures.

PANEL #2 - Early mined cavern propane storage (SC and VA), and example pipeline-granite intersections in NC and VA.

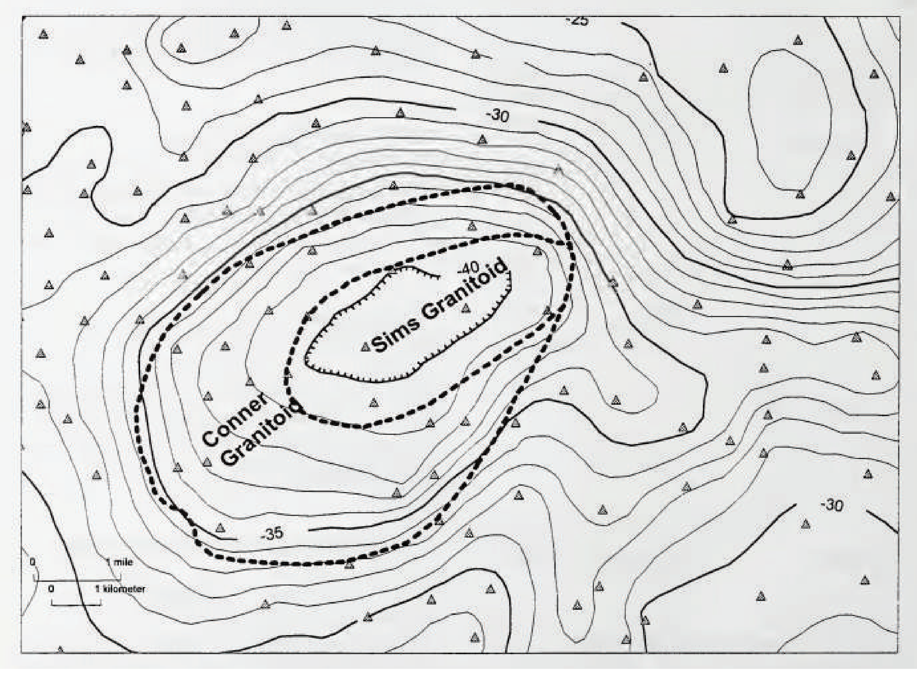




Sims Granite area. Outline of granite is shown in white. Outline of area of granitic outcrops is shown in red. Interior areas (not outlined) are an overlap of Coastal Plain sediment. Proposed route of the Atlantic Coast Pipeline is in yellow. Modified from Speer (1997).

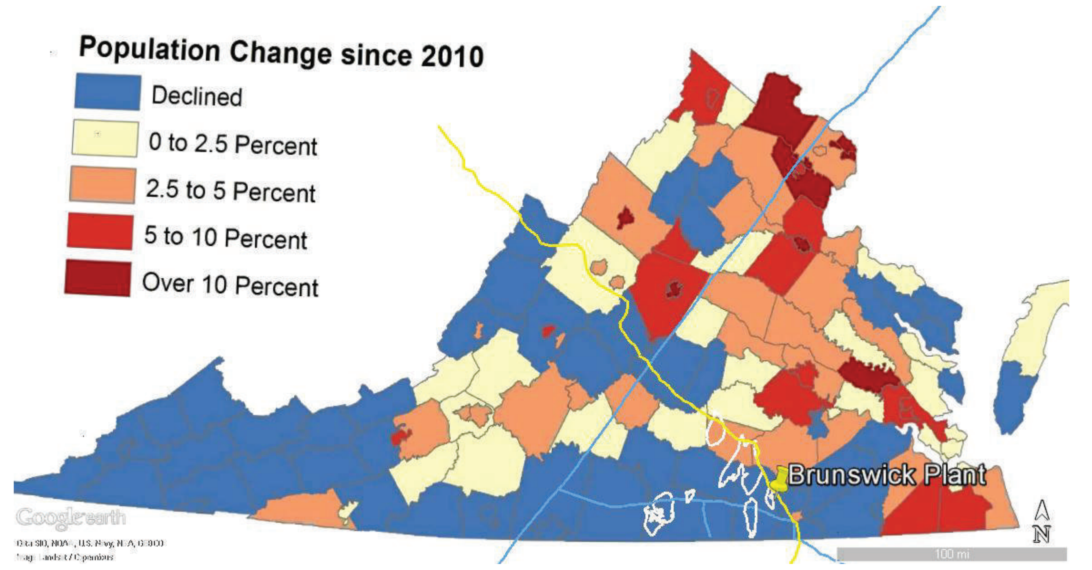


Aeroradioactivity map for the vicinity of the Sims pluton, N.C. (U.S. Geological Survey, 1975). Values are total count gamma ray intensity. From Speer (1997).



Bouger gravity anomaly map for the Sims pluton and vicinity (Lawrence, 1996). Shaded triangles indicate location of the observations. From Speer (1997).

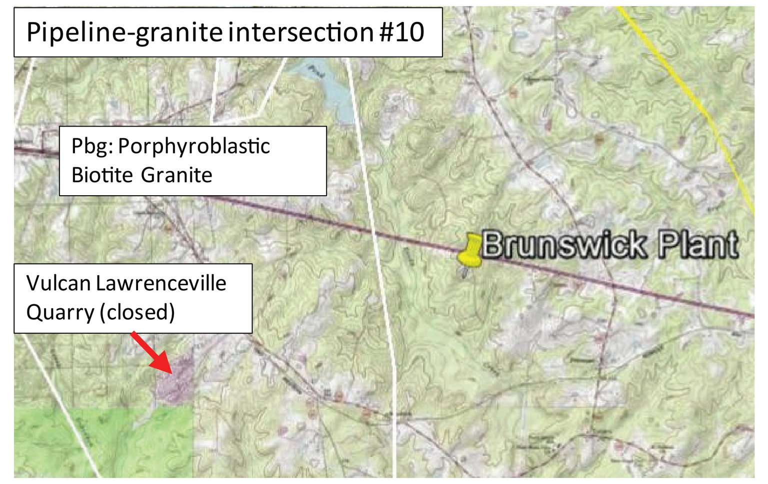
Virginia pipeline-granite intersection examples



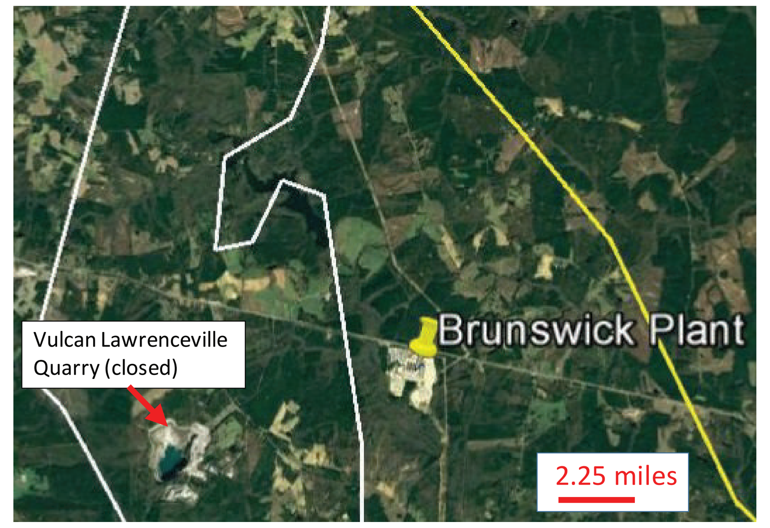
From the standpoint of population growth, the likelihood for underground storage along the Transco spurs is less than that along the planned Atlantic Coast Pipeline (ACP). The Brunswick County Power Station (yellow pin symbol) is located about 2.35 miles from the planned ACP and a potentially suitable granite body.

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 stations 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. Brunswick County Power Station, Virginia – see URL http://www.power-technology.com/projects/brunswick-county-power-station-virginia/..

(a)



(b)



Relationship between Brunswick County Power Station, Atlantic Coast Pipeline (yellow line), and porphyroblastic biotite granite (white line) on a topographic base (a) and a Google Earth base (b). The distance between the Vulcan Lawrenceville Quarry (closed) and the Brunswick power plant is about 2.25 miles.

Discussion and Conclusions

There are eleven major pipeline intersections with granite in North Carolina and southern Virginia identified in this report. If the need for underground storage justifies the costs of underground excavations, such as the type described by PB-KBB corporation, these granites would warrant further consideration as underground storage sites.

Initial follow-up would include: 1) additional literature searches, 2) geological traverses along pipeline-granite intersections and immediately adjacent areas documenting lithologies, discontinuities, and density of fractures and their orientation, and 3) baseline environmental impact studies to identify environmentally-sensitive areas along pipeline-granite intersections.

A mined cavern storing refrigerated natural gas is a means to provide a secured gas supply to maintain the electrical grid during natural disasters or grid failure. Examples of potential natural disasters include weather (hurricanes and flooding), geomagnetic disturbances from solar coronal mass injections. Man made threats include electomagnetic pulse and cyber attacks. Gas-fired steam plants typically have a fuel supply on-site of <1 day (Greene, 2016); the fuel replenishment system is a pipeline. The pace of replacement of coal-fired steam plants with gas-fueled turbine generation plants in the Carolinas with the complete phase out of coal plants in the near future (Duke Energy) is accelerating.

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