Virginiam has three three distinct types of natural gas resource areas (see map on following page):

- **The Western Virginia Coalbed Methane and Noncoal (Shale) Gas Fields**, Located inn the Buchanan, Dickenson, and the northwest corner of Wise County, the western Virginia gas fields are part of the Central Appalachian Devonian Shale Basin, which stretches north from eastern Kentucky to southwestern New York. Prior to the 1930s, coalbed methane was seen more as a hinderance than an energy source and was one of the leading causes of coal mine accidents. To combat methane build-up in the mines, mine operators drilled bore holes to vent off the gas. By 1950, in the 1970s, the US Government began promoting the development and expansion of the methane based natural gas resources. In addition to the noncoal methane deposits in Devonian Shale Formation, there are two primary types of coalbed methane: that which is released during mining operations and collected through a venting system (coal mine methane) and coalbed methane deposits, where the methane is trapped in the unmined coal seams. Coalbed methane deposits are significantly closer to the surface than the shale deposits and are found on the upper slopes rather than in the valleys and the lower slopes. Due to proximity to ground water / drinking water supplies, coalbed methane deposits require vertical wells and do not allow for the use of hydraulic fracturing. Horizontal wells and hydraulic fracturing can be used in the non-coalbed/shale deposits.

- **Marcellus Shale Formation Shale**. The Marcellus Shale Formation extends the length of the Alleghany Range, from Frederick County in the north to Scott and Washington Counties on the Tennessee and North Carolina borders and covers portions of 21 counties and four cities. In addition, the region covers the headwaters for the Potomac, James, New, and a portion of the Big Sandy watersheds. It does not, however, extend into the Blue Ridge, nor does it impact the headwaters of the Roanoke River watershed. Although there has been exploration of the Marcellus Shale reserves in Virginia, it is unlikely that Virginia will experience the scale of resource development found in other areas of the Marcellus and Devonian shale formations. According to the Virginia Department of Mines, Minerals and Energy:

  The Marcellus is the primary target for recent horizontal drilling and hydraulic fracturing in Pennsylvania and West Virginia, where it is thick and buried deeply beneath layers of younger sedimentary rock. In Virginia, the Marcellus is present in relatively shallow belts of folded and faulted rock. Due to this tectonic disturbance, much of the natural gas once present in the Marcellus has probably escaped. A recent study by the U.S. Geological Survey indicates that the Marcellus in that part of Virginia is thermally overmature, meaning that the shale was most likely heated to too high a temperature in the past to preserve economic quantities of gas or oil.

- **Exposed and Buried Mesozoic Basins**. Mesozoic basins, which developed during the Triassic period along the east coast of North America (from South Carolina north to Connecticut), occurred when large blocks of rock with faults on two sides dropped or tilted below the level of a neighboring blocks. The resulting depression filled in with sediment from the upland Piedmon, including organic materials (see the inset on the two maps). The gas fields and coal seams formed in these depressions. Mesozoic basins come in two types: exposed, which are limited to the Piedmont area of Virginia and buried, which are more common in the coastal plain and are covered by a layer of younger sedimentary rock. In total, there are 12 mesozoic basins in Virginia, but only four

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2 The counties with Marcellus Shale Formations include Frederick and the City Winchester, Shenandoah, Rockingham, Highland, Augusta, Bath, Rockbridge, Alleghany and the City of Covington, Botetourt, Roanoke, Craig, Giles, Montgomery and the City of Radford, Bland, Pulaski, Wythe, Tazewell, Smyth, Russell, Washington and the suburbs of the City of Bristol, and Scott. There are currently two local chapters of the League of Women Voters of Virginia located in the Marcellus Shale Region: Montgomery County and Washington County.


3.1 Faults are essentially cracks that occurred at the time the continents formed and are the result of fluctuations in pressure during the Triassic period of the Mesozoic era. As the North American and African plates separated these fissures and cracks developed pushing some of the resulting blocks up and others down or forcing one block to tilt. For more information on the geology of Mesozoic Basins, see *Mesozoic Basins Physiography*, Radford University, 2014; and Charles A. Grimes (2016) "Triassic Basins in
Gas Resources in Virginia, 2016

Western Virginia Coalbed Methane & Noncoal Gas Fields

- Existing Coalbed Methane Fields
- Gas Fields in Noncoal Reservoirs
- Marcellus Shale Distribution
- Exposed Mesozoic Basins (Gas)
- Buried Mesozoic Basins (Gas)
- Plugged Oil & Gas Wells
- Existing Leases
- Chesapeake Bay Drainage Limit
- Hydrology

(Taylorsville, Richmond, Toano, and an unnamed basin in King and Queen County) have been tested for the presence of natural gas. Both the US Geological Survey and the DMME concluded that the mesozoic basins, particularly Taylorsville and Richmond, had natural gas deposits; however, as the DMME noted, only a few of the test wells drilled between 1917 and 1992 indicated the presence of natural gas, and "one well, that was hydraulically fracked in 1968, did not result in a commercially viable flow of gas." 4 The Richmond Basin, which covers portions of Goochland, Henrico, Chesterfield, Powhatan, and Amelia counties, has had a long history of coal mining, which would indicate the presence of natural gas deposits, but exploratory wells drilled between 1930 and 1986 found no "reservoirs of gas or oil large enough to be economically developed." 5 According to Catherine B. Enomoto of the U.S. Geological Survey, Amoco drilled six test wells in the Richmond Basin to explore the potential for coalbed methane. While their test wells indicated the presence of viable natural gas deposits with commercial potential, Amoco abandoned the project after finding that there was no way, given the compexity of the formation, to determine the full extent of either the coal beds or the natural gas deposits. 6 A similary story played out for Texaco in the Taylorsville Basin. While four of the exploratory wells drilled indicated the presence of natural gas deposits, Texaco "did not encounter a reservoir of gas or oil large enough to be economically developed." 7

A further limiting factor in the mesozoic basins is the presence of faultlines and the proximity of the basins to the Central Virginia Siesmic Zone. The Central Virginia Siesmic Zone covers much of the Piedmont area of Virginia, including the northern 2/3rds of the Richmond Basin and the exposed section of the Taylorsville Basin. Until the earthquake in Lousia County in 2011 (which occurred on an unknown faultline), Virginia did not have a comprehensive fault map or GIS fault database, nor did Virginia have adequate recording equipment within 200 km of the epicenter. The GEER report, following the 2011 earthquake, found "a clear correlation between geotechnical conditions (soil applification in soft sediments overly hard rock) and damage, including shaking intensity patterns,...especially in the National Capital Region." 8 In 2014, FEMA awarded Virginia a grant under their Hazard Mitigation progam to "actively assess Virginia's seismic hazards. The project, which is slated to be completed in September 2016, included five key components:

- Development of a comprehensive GIS (geographic information systems) fault database for Virginia;
- Identification of new faults in Virginia using geological field studies and high resolution LiDAR data;
- Development of a comprehensive Virginia earthquake database containing location and damage information;
- General earthquake hazard assessment by overlaying earthquake and fault data with cultural and infrastructure data;
- Presentation of data products to planners and emergency management agencies in seismically active areas to help reduce earthquake hazards in Virginia."

Little is know about the connection between fracking, sedimentary soils and subsurficial geology, and the potential for earthquakes, although there is some indication that fracking may contribute to increased seismic activity. The connection, at this point, is not conclusive, but the potential raises questions about the use of fracking in active seismic zones, including the impact on the groundwater table and on the engineering requirements for fracking operations in active zones.

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4 Ibid.
6 Ibid. Pg. 5.
7 Ibid. Pg. 5