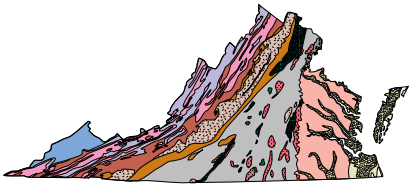
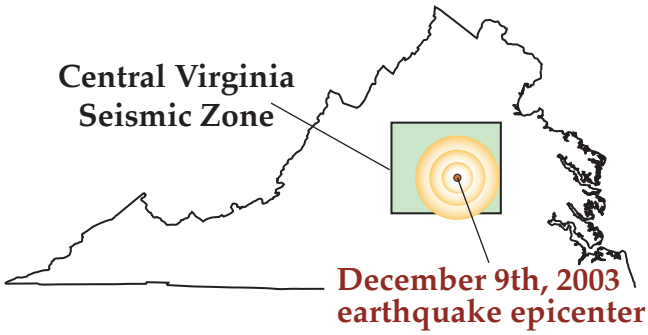


What's New in Virginia Geology
THE GEOLOGY of VIRGINIA

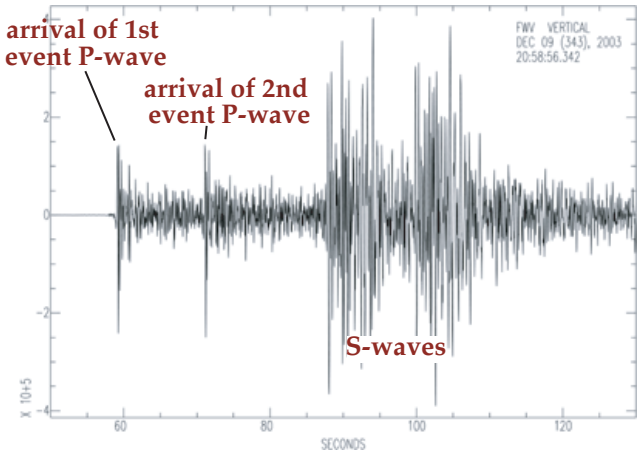
Shaken! Earthquake Rocks Central Virginia

Virginia is located well within the North American tectonic plate and far from active plate boundaries. Given Virginia's modern tectonic setting seismic activity in the Commonwealth is modest, however much of Virginia was jolted by an earthquake at 3:59 p.m. on December 9th, 2003. The quake occurred in the central Virginia Piedmont between Columbia and Goochland Courthouse, approximately 40 miles west of Richmond.



Shaking was felt throughout Virginia and as far as 600 km (450 miles) from the epicenter. The quake caused only minor damage at Bremo Bluff and Kents Store, but rattled the nerves of many. By Virginia standards this was a significant earthquake with a magnitude of 4.5, the largest recorded in Virginia since the widespread use of modern seismic monitoring equipment in the early 1970's. The largest Virginia earthquake in recorded history occurred on May 31st, 1897 in Giles County and is estimated to have had a magnitude of 5.8.

The December 9th quake occurred within the central Virginia Seismic Zone, a region of persistent seismic activity in the Piedmont province covering approximately 8,000 km^2 (~3,000 mi^2). Earthquakes in the central Virginia Seismic Zone are relatively frequent, but generally of small size. This event was located at 37.728° N, 78.087° W, at a depth of less than 5 km (3 miles) and may have occurred due to rupture along the Lakeside fault.



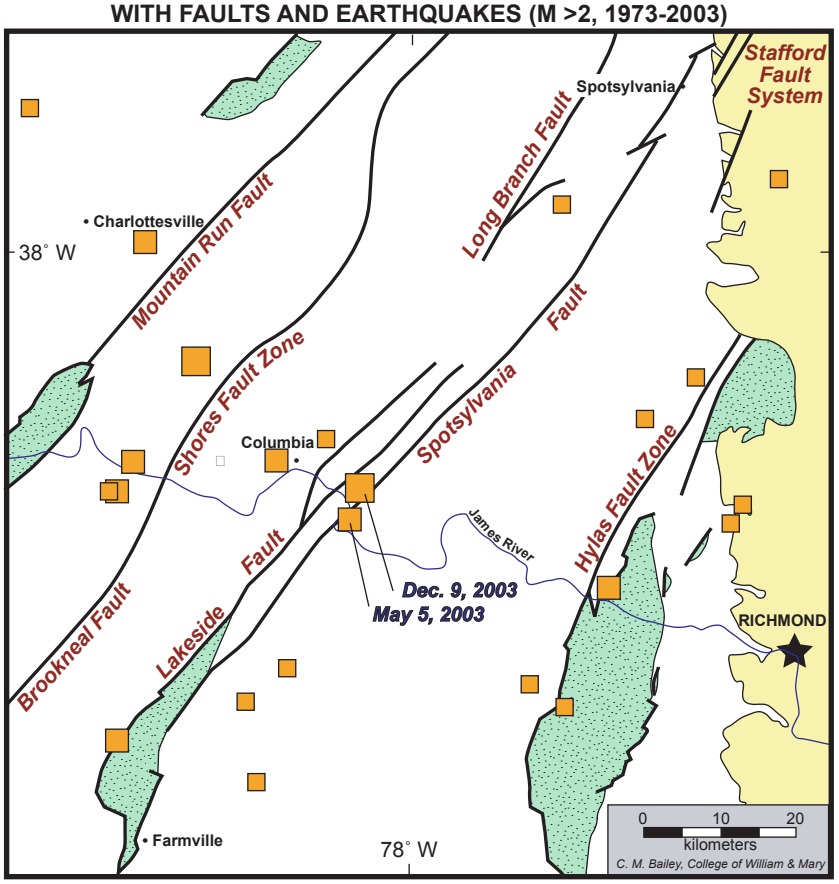
Part of the seismogram trace for the December 9th, 2003 earthquake as recorded by the Virginia Tech Seismological Observatory's Forest Hills, West Virginia seismometer located ~250 km (~160 miles) from the epicenter.
(http://www.geol.vt.edu/outreach/vtso/031209_double.html)

Many observers reported two distinct shaking events. Evidence from seismograms is consistent with two distinct events that occurred approximately 12 seconds apart. The shaking felt by people was caused by the arrival of S-waves and the total duration for shaking from this double event may have been nearly 30 seconds.

The epicenter was originally located in Powhatan County, but seismologists at Virginia Tech re-evaluated seismic wave arrival data and place the epicenter approximately 13 km (8 miles) to the northwest in Goochland County. Seismic waves velocities are controlled by the material properties of the rocks through which the waves travel. Seismic waves radiating outward from this quake travelled through a variety of bedrock before reaching seismometers. The uncertainity in the exact velocity of the seismic waves thereby produces an uncertainity as to the exact location and depth of the quake. This is not unusual for small earthquakes in regions without extensive seismic monitoring equipment.

The Virginia Piedmont is a region of complex geology. During tectonic collision and Appalachian mountain building in the Paleozoic era (550 to 250 million years ago) the Piedmont was the locus of magmatism, metamorphism, and deformation. Rocks currently exposed at the surface were at depths of 10 to 30 km (6 to 18 miles) below the surface during mountain building. Temperatures at these depths were sufficient to cause the rocks to behave in a ductile fashion and flow. Many of the fault zones in the central Virginia Piedmont developed under ductile conditions in the Paleozoic. Some of these faults bound crustal blocks of rocks that originated elsewhere (on other continents or perhaps in New England) and were later accreted onto the North American continent. The Brookneal/Shores fault zone has been proposed by some workers to represent the suture between North American rocks (exposed to the northwest) and exotic rocks sutured to North America. Flow structures in these fault zones indicate material was strongly sheared in a dextral (right lateral) transpressive fashion between 300 and 270 million years ago.

GENERALIZED GEOLOGIC MAP OF THE CENTRAL VIRGINIA PIEDMONT WITH FAULTS AND EARTHQUAKES (M >2, 1973-2003)



Earthquake Epicenters

- M > 4
- M = 3.0 - 3.9
- M = 2.0 - 2.9

data from: Virginia Tech Seismological Observatory and USGS National Earthquake Information Center

Bedrock Geology

- **Cenozoic sediments of the Coastal Plain** sand, silt, clay, and shelly sand
- **Mesozoic sedimentary rocks** arkose, sandstone, siltstone, shale, and coal
- **Proterozoic and Paleozoic rocks** diverse array of igneous and metamorphic rocks

data from: Virginia Division of Mineral Resources and more recent mapping by VDMR and William & Mary Geologists

Photograph of extensively fractured fault rock (breccia) along the Lakeside Fault at Bodatious, Virginia. Photo by Chad Roberts

During the opening of the Atlantic Ocean basin in the Mesozoic era, the ancient supercontinent of Pangaea was rifted apart. In eastern North America this rifting produced normal faults and a series of sedimentary basins on the downdropped fault blocks. In central Virginia, Mesozoic sedimentary rocks crop out in the Barboursville, Farmville, Richmond, Scottsville, and Talyorsville basins. Many of the faults that bound the Mesozoic basins were originally Paleozoic faults reactivated as normal faults in the Mesozoic. This reactivation occurred in the upper few kilometers (miles) of the crust and the style of deformation was brittle. Rocks were pervasively fractured and broken while new minerals were precipitated by fluids percolating through fractures. No major tectonic events have affected Virginia during the past two hundred million years, but geologic evidence indicates that a number of faults in central Virginia have experienced relatively recent movement. The Stafford fault system near Fredericksburg and other faults south of Petersburg offset late Cenozoic Coastal Plain sediments. Cenozoic slip on these reactivated faults appears to have a reverse (hanging wall up) sense of movement.