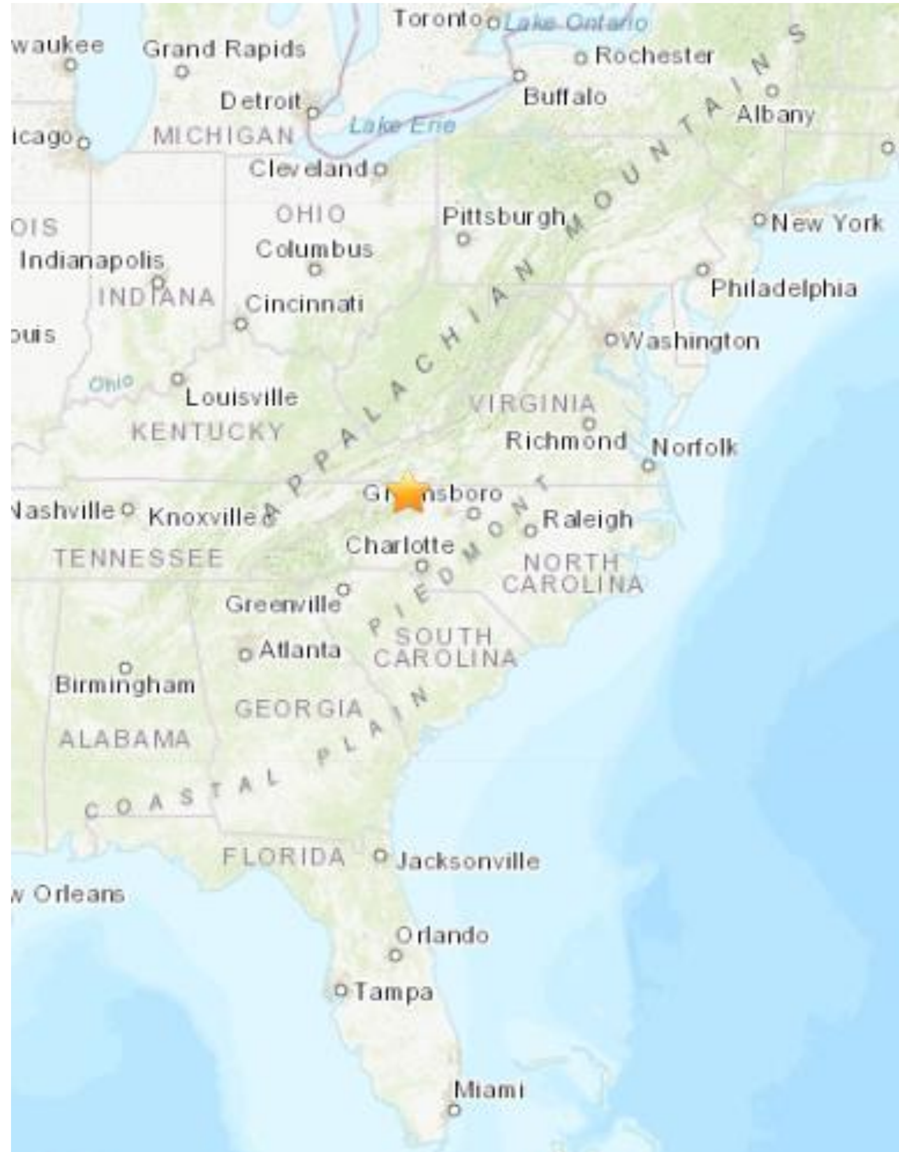
IRIS
Teachable Moments

Magnitude 5.1 NORTH CAROLINA
Sunday, August 9, 2020 at 12:07:37 UTC

A magnitude 5.1 earthquake occurred near Sparta, North Carolina (36.476° N 81.093° W) at a depth of 3.7 km. There are reports of minor injuries and damage.

Earthquake facts from the North Carolina Geological Survey:

- The earliest reported earthquake in North Carolina occurred near Bath on March 8, 1735.
- The largest quake centered in North Carolina was a magnitude 5.2 on February 21, 1916 near Skyland, NC.
- The last damaging earthquake centered in North Carolina was a magnitude 3.5 in Henderson County on May 5, 1981.
- The largest recorded earthquake in the US was a magnitude 9.2 that struck Prince William sound, Alaska on Good Friday, March 28, 1964.
- Alaska and California have the most earthquakes in the US while Florida and North Dakota have the fewest.



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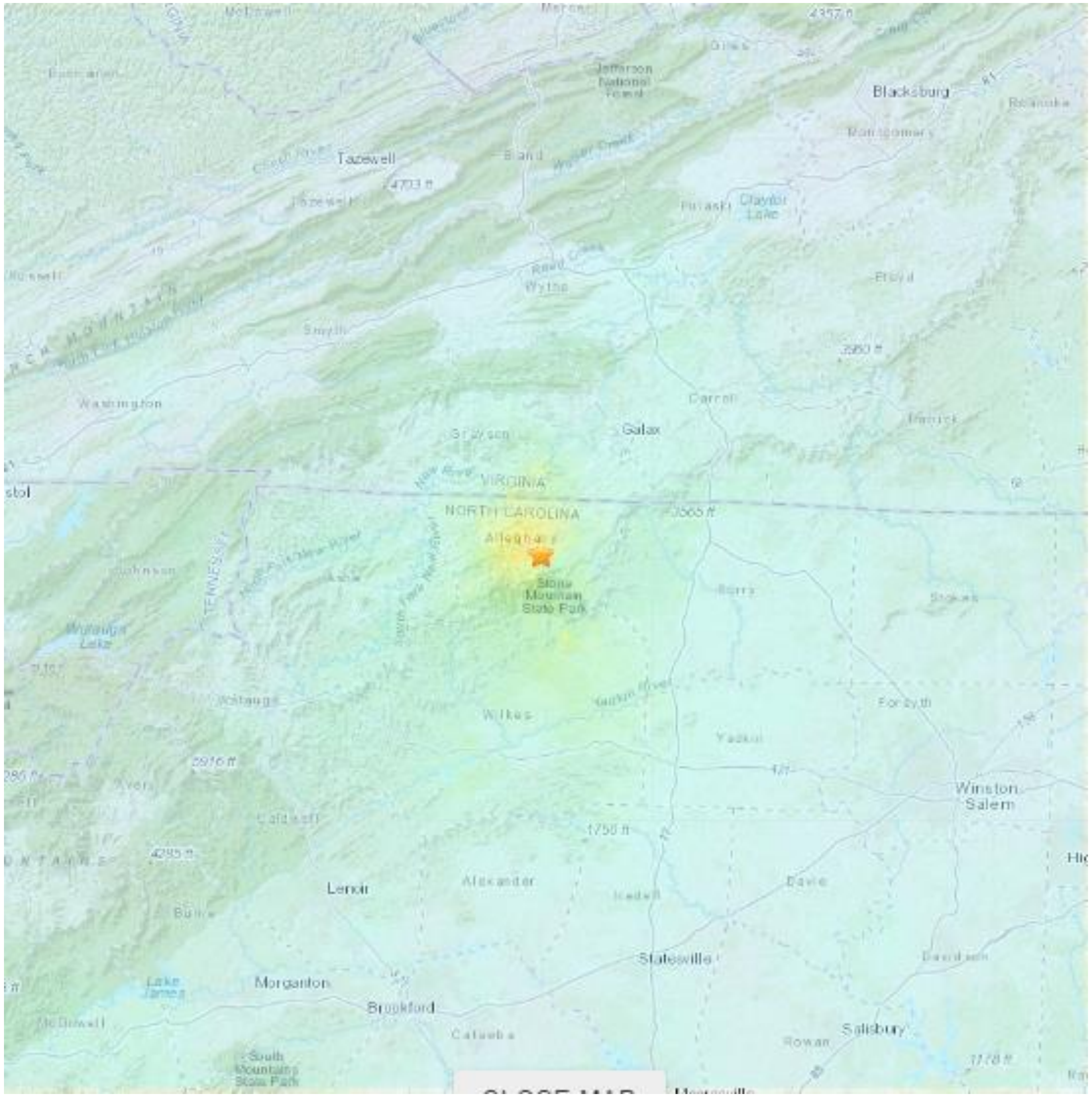
The Modified-Mercalli Intensity scale is a twelve-stage scale, from I to XII, that indicates the severity of ground shaking. Intensity is dependent on the magnitude, depth, bedrock, and location.

This earthquake was widely felt throughout the central Appalachians and coast areas.

Modified Mercalli Intensity	Perceived Shaking
X	Extreme
IX	Violent
VIII	Severe
VII	Very Strong
VI	Strong
V	Moderate
IV	Light
II-III	Weak
I	Not Felt

Image courtesy of the US Geological Survey



USGS estimated shaking intensity from M 5.1 Earthquake

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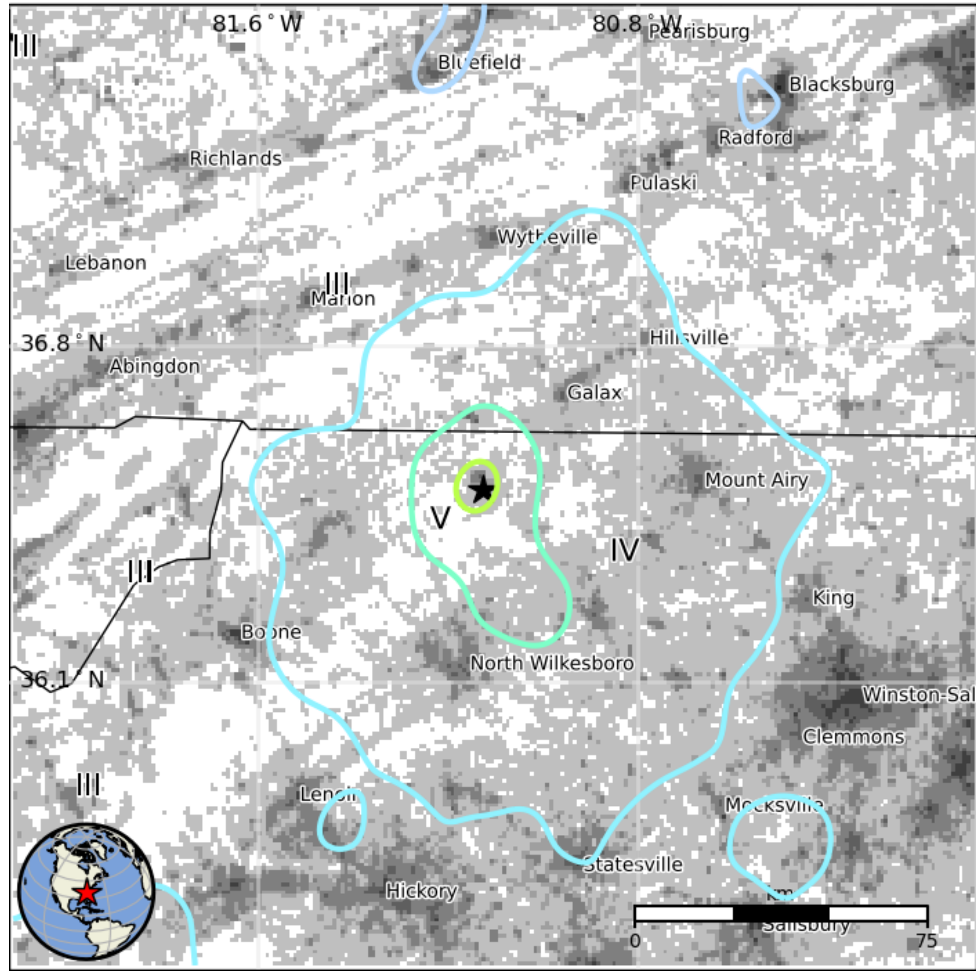
The USGS PAGER map shows the population exposed to different Modified Mercalli Intensity (MMI) levels.

While millions felt this earthquake, approximately 1,000 felt very strong shaking from the earthquake.

I	Not Felt	0 k*
II-III	Weak	1,820 k*
IV	Light	568 k
V	Moderate	20 k
VI	Strong	5 k
VII	Very Strong	1 k
VIII	Severe	0 k
IX	Violent	0 k
X	Extreme	0 k



The color-coded contour lines outline regions of MMI intensity. The total population exposure to a given MMI value is obtained by summing the population between the contour lines. The estimated population exposure to each MMI Intensity is shown in the table.

Image courtesy of the US Geological Survey

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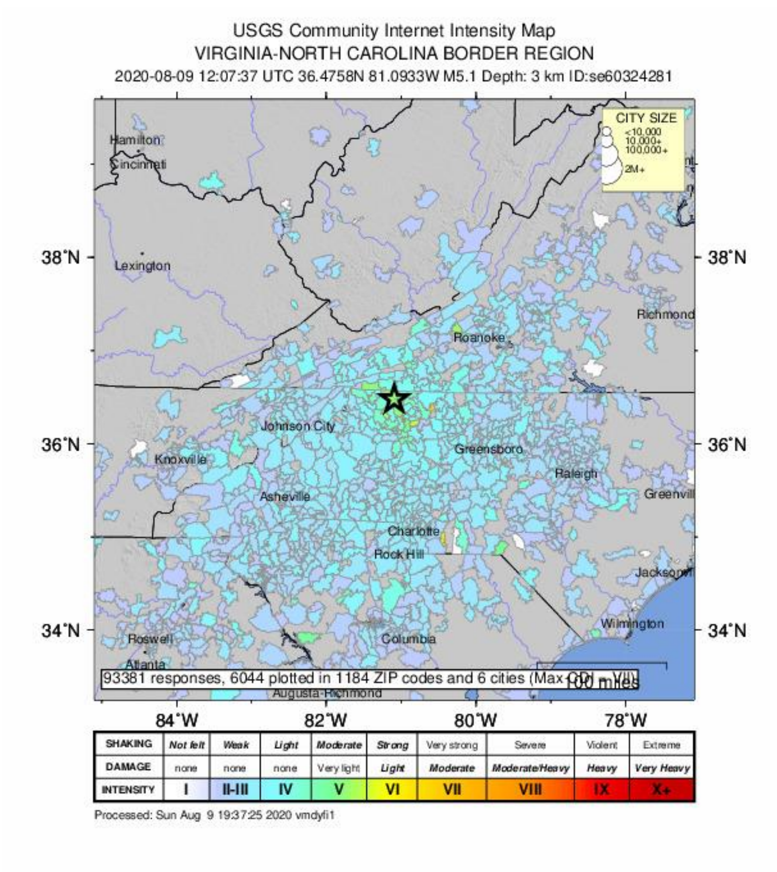
This earthquake was widely felt throughout the central Appalachians and coast areas, from Washington D.C. to Atlanta.

Shaking intensity reported through USGS "Did You Feel It?"



While earthquakes in the eastern United States are less frequent than in the western United States, they are typically felt over a much broader region. Often times, an earthquake can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast. This is due to the ease of wave propagation through the North American Craton (a craton is an old and stable part of the continental lithosphere).

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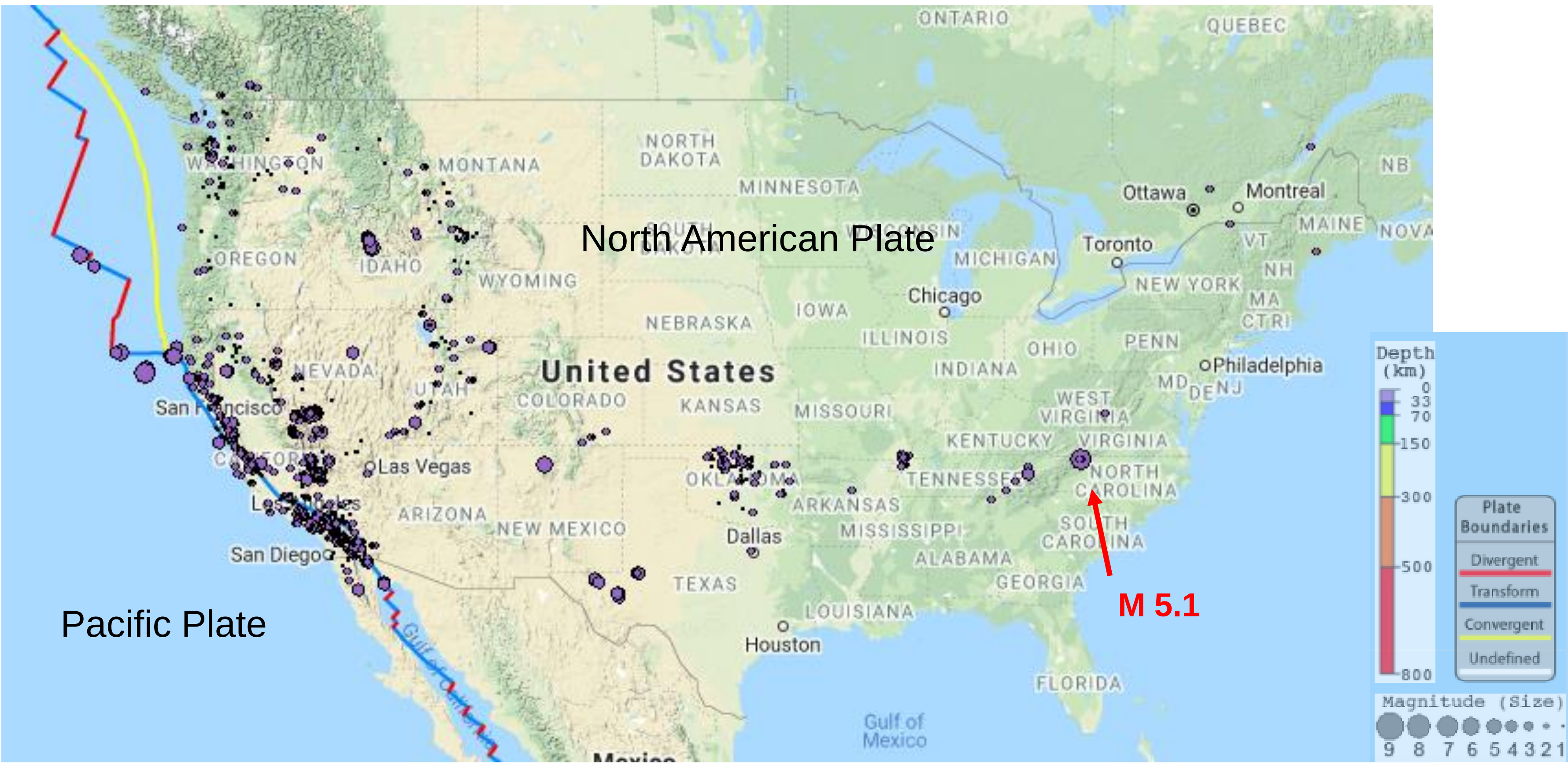
Epicenters of the most recent 4000 earthquakes in the contiguous United States are shown on this map.

This earthquake occurred in the interior of the North American Plate. Such mid-plate earthquakes are known as intraplate earthquakes and are generally less common than interplate earthquakes that happen on tectonic plate boundaries.



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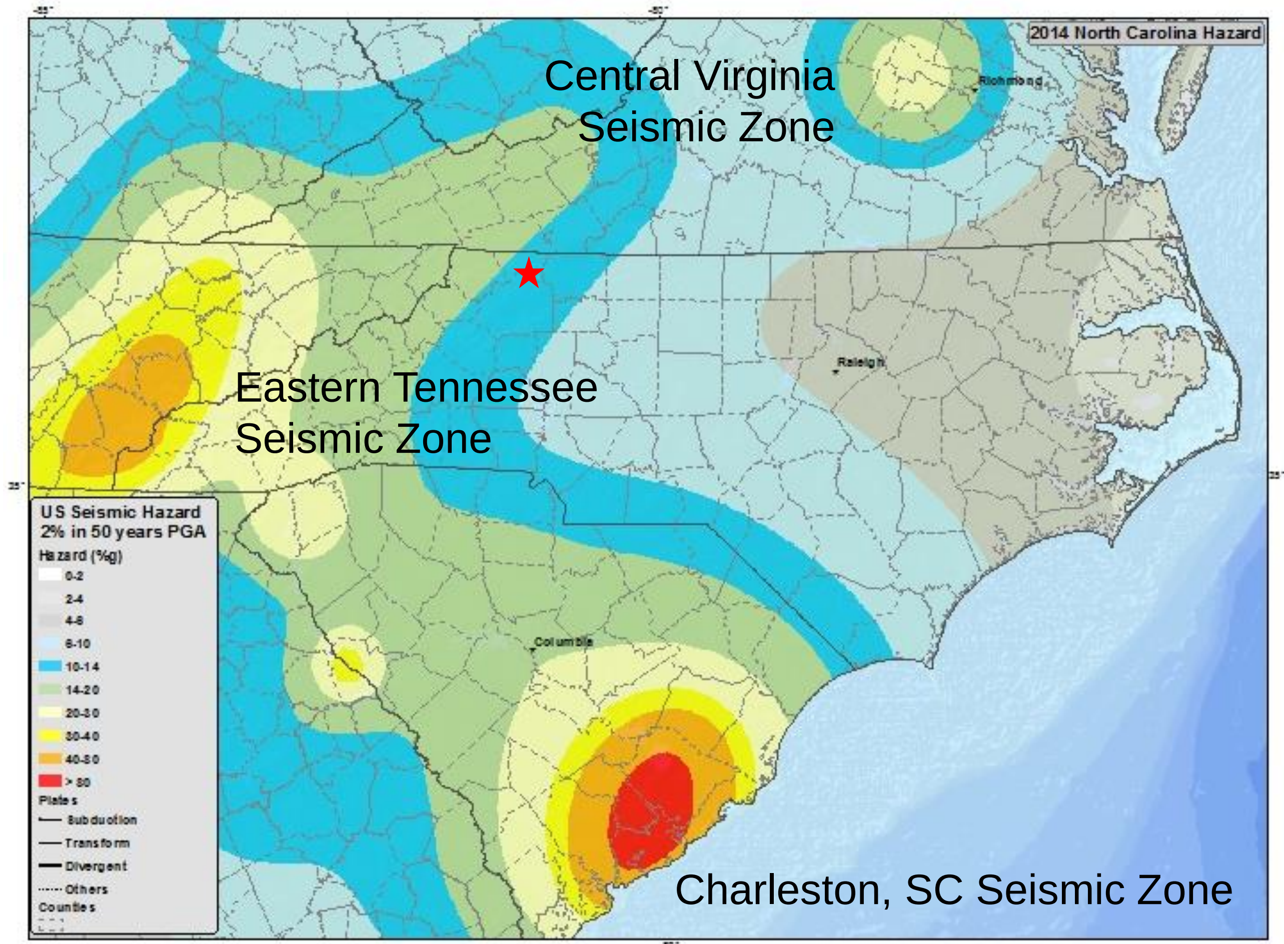
The increased seismic hazard stretching from Tennessee through the edge of western North Carolina into northern Georgia is known as the Eastern Tennessee Seismic Zone. Further to the northeast, the Central Virginia Seismic Zone is shown. The 1886 Charleston earthquake occurred in the Charleston, South Carolina Seismic Zone.

Even though North Carolina and the east coast of the United States experience occasional earthquakes, this area is not a seismically active area like California. Earthquakes are more frequent in the western part of North Carolina, but statewide they are relatively small, random and scattered events.

Generalized Seismic Hazard



Seismic Hazard is expressed as peak ground acceleration (PGA) on firm rock, in percent g, expected to be exceeded in a 50 year interval with a probability of two percent.

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Many faults in the Atlantic Coast and the Appalachian Mountains are inherited from tectonic deformations during the Paleozoic and Mesozoic Eras. The final stage in the formation of the Appalachian Mountains was caused by the continent – continent collision between eastern North America and northwest Africa about 300 million years ago. Then about about 200 million years ago, rifting of North America from Africa during the early breakup of Pangaea began to form the North Atlantic Ocean.

Sediment from erosion of the Appalachian Mountains has been deposited on the Atlantic Coastal Plain burying many of the faults that were active during these previous tectonic episodes. But these old faults can be reactivated to produce the occasional earthquakes in the Atlantic Coast region. These earthquakes are referred to as “intraplate” earthquakes because they are far from present-day boundaries between tectonic plates.

So what force acting on the crust of the Atlantic Coastal Plain can reactivate these old faults to produce the August 9, 2020 North Carolina and August 23, 2011 Virginia earthquakes?

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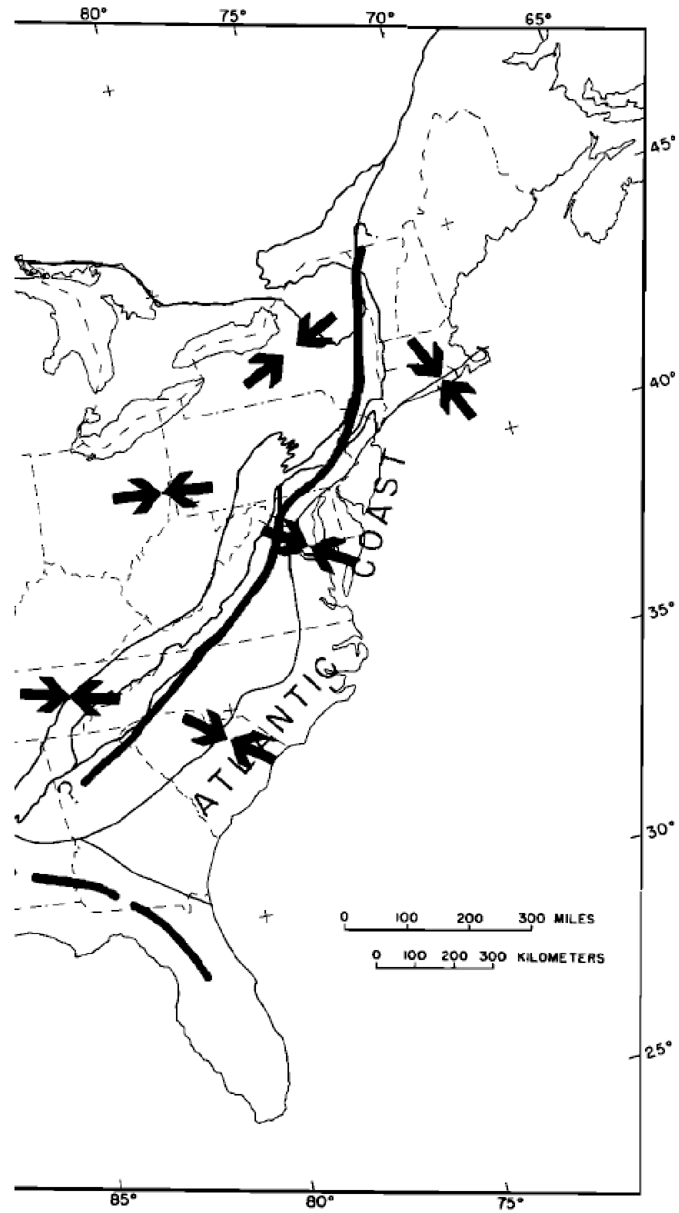
US Geological Survey geophysicist Mary Lou Zoback and her husband Mark Zoback of Stanford University have studied the state of stress in tectonic plates, especially the North American Plate. From hundreds of measurements of stress, they and other researchers have compiled maps of stress provinces in the coterminous Unites States. The Atlantic Coast and adjacent interior portions of an example stress map are shown on the right.

Notice that the direction of compression within the Atlantic Coast regional is oriented roughly in an east – west direction. The August 9, 2020 North Carolina earthquake was produced by thrust faulting with compression oriented northeast – southwest. The August 23, 2011 Virginia earthquake resulted from thrust faulting with compression oriented west-northwest to east-southeast. So the stress released by these two earthquakes is consistent with the broad pattern of stress acting on the Atlantic Coast region.

The next question is where does that east – west compressive stress originate?



M. L. Zoback and M. Zoback, State of Stress in the Coterminous United States, J. Geophys. Res., v. 85, p. 6113-6156, 1980.

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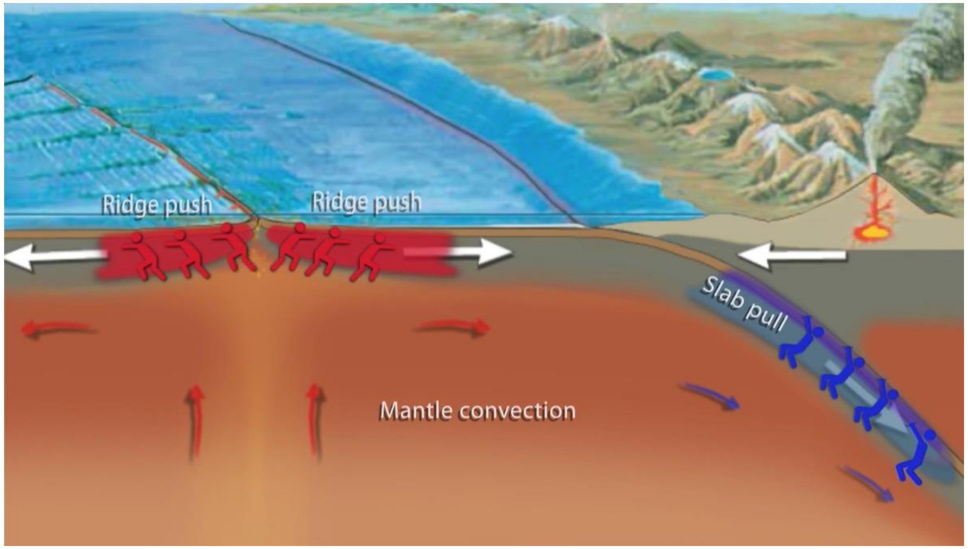
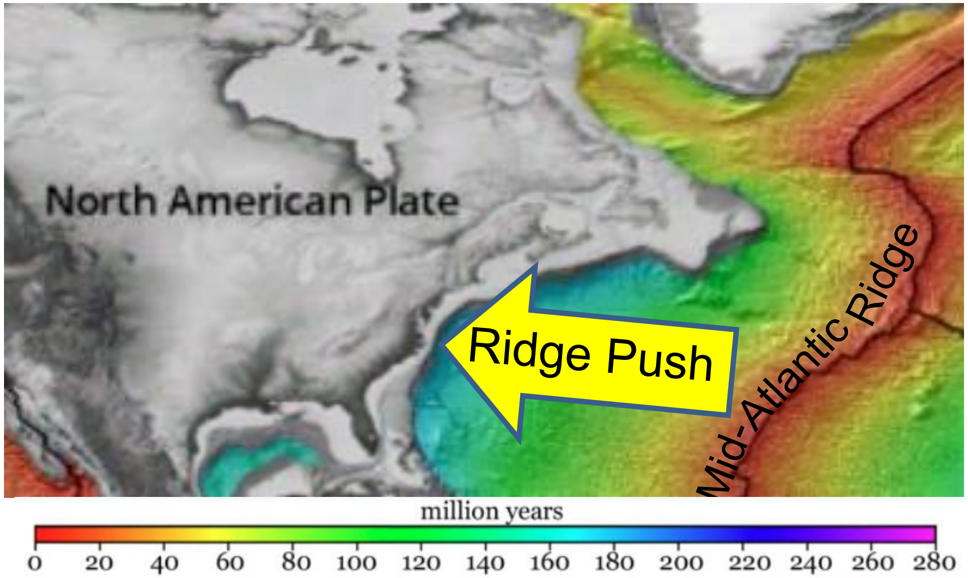
On the scale of world plates, two forces dominate in pushing and pulling plates around.

- One force is ‘slab pull’ or ‘trench pull’ that pulls subducting oceanic plates down into ocean trenches at convergent plate boundaries. The subducting lithosphere is colder and therefore more dense than the surrounding asthenosphere. So gravity pulls down harder on the subducting lithosphere.
- The other force is ‘ridge push’ that pushes plates away from the divergent plate boundaries at spreading ocean ridges. The top of the lithospheric plate is high at the ridge and becomes progressively lower with increasing age of plate. In effect, gravity is pushing the plate away from the ridge. Even 3000 km away from the ridge, the Atlantic Coast experiences the ridge push force from the Mid-Atlantic Ridge.





That force occasionally activates one of the old Atlantic Coast faults to produce an earthquake.

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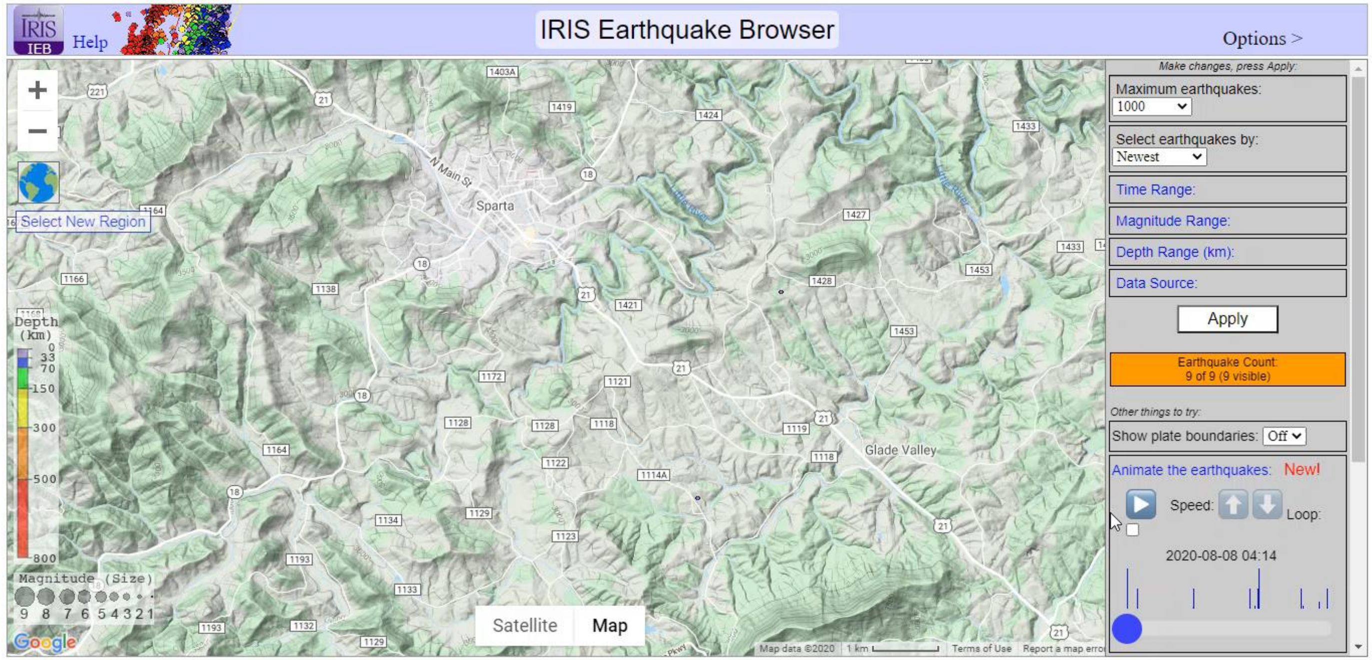
This animation from IRIS's Earthquake Browser shows the small foreshocks ranging from M 2.1 – 2.6 beginning about 25 hours prior to the mainshock. The animation ends with three small aftershocks that occurred in the first hours after this earthquake.



Data from IRIS's Earthquake Browser (www.iris.edu/ieb)

Year	Month	Day	Time UTC	Mag	Lat	Lon	Depth km	Region
2020	08	09	04:43:39	2.3	36.4593	-81.1057	13.7	5 km SSE of Sparta, North Carolina
2020	08	09	05:57:15	2.6	36.4783	-81.0890	4.1	4 km SE of Sparta, North Carolina
2020	08	09	06:06:55	2.2	36.4737	-81.0962	6.3	4 km SSE of Sparta, North Carolina
2020	08	08	11:05:39	2.1	36.4935	-81.0720	9.3	4 km ESE of Sparta, North Carolina
2020	08	08	11:12:32	2.3	36.4652	-81.0862	2.7	5 km SE of Sparta, North Carolina
2020	08	09	12:07:37	5.1	36.4758	-81.0933	3.7	4 km SE of Sparta, North Carolina
2020	08	08	12:35:22	1.8	36.4763	-81.1155	5.9	3 km S of Sparta, North Carolina
2020	08	09	15:58:34	1.7	36.4748	-81.1537	6.5	4 km SW of Sparta, North Carolina
2020	08	08	20:42:28	1.8	36.4625	-81.1323	1.1	4 km SSW of Sparta, North Carolina

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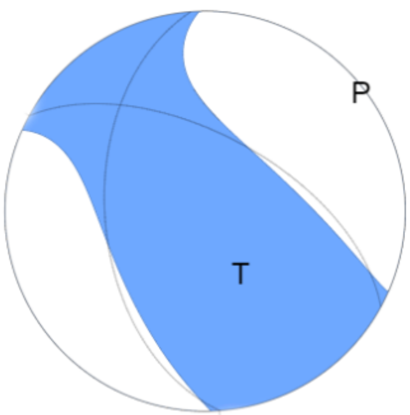
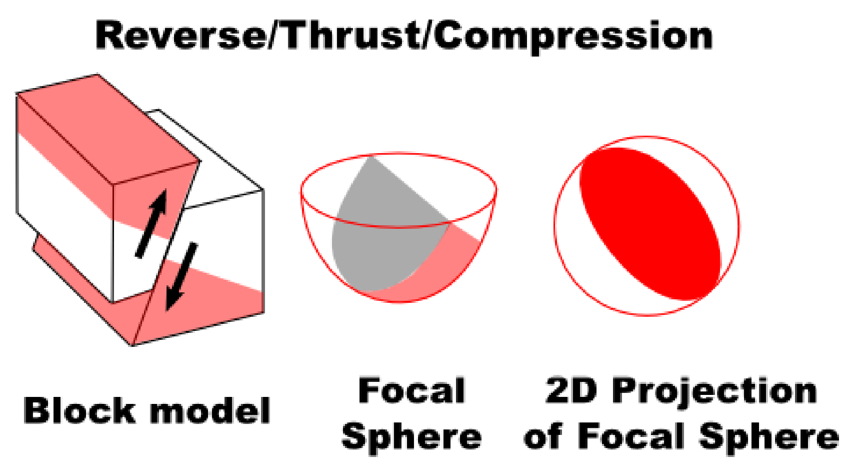
The focal mechanism is how seismologists plot the 3-D stress orientations of an earthquake. Because an earthquake occurs as slip on a fault, it generates primary (P) waves in quadrants where the first pulse is compressional (shaded) and quadrants where the first pulse is extensional (white). The orientation of these quadrants calculated from recorded seismic waves determines the type of fault that produced the earthquake.



USGS W-phase Moment Tensor Solution

The tension axis (T) reflects the minimum compressive stress direction. The pressure axis (P) reflects the maximum compressive stress direction.

In this case, the earthquake location and focal mechanism indicate it was due to slightly oblique thrust faulting within the upper crust of the North American Plate. A thrust fault is caused by compressional forces. Along a thrust fault, one rocky block is pushed up relative to rock beneath the fault.



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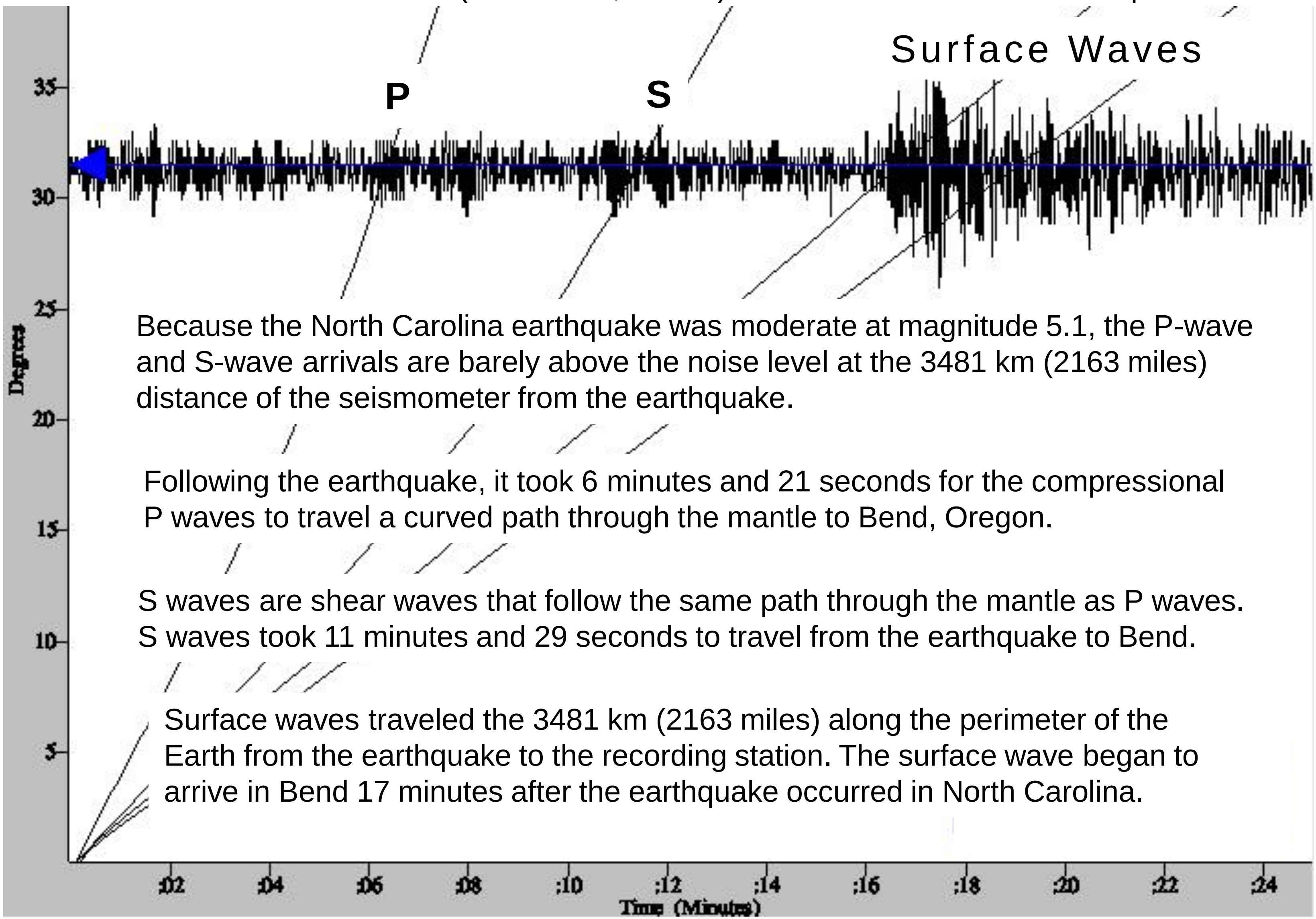
The record of the earthquake in Bend, Oregon (BNOR) is illustrated below. Bend is 3481 km (2163 miles, 31.4°) from the location of this earthquake.



Because the North Carolina earthquake was moderate at magnitude 5.1, the P-wave and S-wave arrivals are barely above the noise level at the 3481 km (2163 miles) distance of the seismometer from the earthquake.

Following the earthquake, it took 6 minutes and 21 seconds for the compressional P waves to travel a curved path through the mantle to Bend, Oregon.

S waves are shear waves that follow the same path through the mantle as P waves. S waves took 11 minutes and 29 seconds to travel from the earthquake to Bend.

Surface waves traveled the 3481 km (2163 miles) along the perimeter of the Earth from the earthquake to the recording station. The surface wave began to arrive in Bend 17 minutes after the earthquake occurred in North Carolina.

Teachable Moments are a service of

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