Report on Elgin-area Earthquakes

July 2022

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EARTHQUAKE NUMBERS

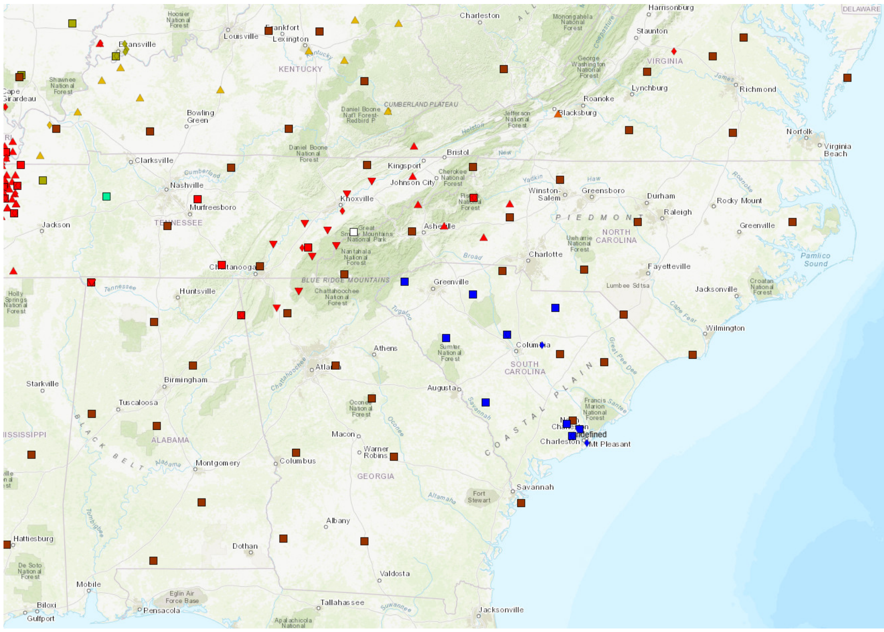

Figure 1. Distribution of earthquake monitoring stations in the southeast.
Source: http://folkworm.ceri.memphis.edu/REQ/html/station.html

As of July 5, more than 56 earthquakes have been located along the I-20 corridor between Elgin and Lugoff since December 27, 2021. This earthquake sequence initiated with a magnitude 3.3 and was followed by four more widely felt earthquakes with magnitudes greater than 3. However, significantly more magnitude 1.3 or lower earthquakes have occurred that were not reported by the seismic network (Figure 1). We know this from a single ANSS seismic station deployed by the South Carolina Seismic Network near Elgin. Because smaller earthquakes are too small to be recorded at other network stations, they cannot be located and therefore are not reported.

EARTHQUAKE SWARMS

The ongoing earthquakes near Elgin are classified as an earthquake swarm. These are groups of earthquakes located close to each other in time and space, but also where the largest earthquake of the group is not significantly larger than the next largest. To date, the five largest earthquakes of this swarm are in the magnitude range 3.3 to 3.6, which is what is expected during an earthquake swarm.

Earthquake swarms are very common and have occurred before in South Carolina. A very long-lasting earthquake swarm occurred in the late 1970s following the filling of Lake Monticello, north of the Columbia. The largest earthquake in that swarm was a magnitude 2.8. During late October-early November 2021 another small swarm (seven earthquakes large enough to be located) also occurred near Lake Monticello. The current earthquake swarm is unusual because of its location (i.e., near Elgin) and that it contains earthquake magnitudes larger than in previous swarms observed in the state of South Carolina.

MAGNITUDE VERSUS INTENSITY

Magnitude measures the energy generated by the release of accumulated strain during an earthquake. When a rock mass reaches a limit (strength of the material) of strain accumulation and can no longer accommodate additional strain, it ruptures, releasing strain in the form of an earthquake. The magnitude of an earthquake is a fixed number for that earthquake. It is a measure of the total energy released. The magnitude scale is logarithmic. A unit magnitude increase represents a tenfold increase in seismic wave amplitude and a 32-fold increase in energy release.

The largest magnitude recorded to date in the Elgin sequence has been a magnitude 3.6. In comparison, the 2014 Edgefield earthquake had a magnitude of 4.1. There were only a few documented examples of structural damage associated with the Edgefield event. A couple of buildings in Edgefield had cracks, and a church near the epicenter had a cracked steeple. But there was no extensive damage.

Earthquake Intensity Scale
Modified Mercalli Intensity (MMI)

INTENSITY	SHAKING	DESCRIPTION
I	Not Felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Weak	Felt quite noticeable by persons indoors. Many people do not recognize it as an earthquake. Standing cars may rock slightly, vibrations are similar to a passing truck.
IV	Light	Felt indoors by many, outdoors by few. At night, some are awakened. Dishes, windows, and doors are disturbed. Sensation like a heavy truck striking a building. Standing cars rock noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Dishes and windows are broken. Unstable objects are overturned. Pendulum clocks may stop.
VI	Strong	Felt by all; many frightened. Some heavy furniture moved. A few instances of fallen plaster. Damage is slight.
VII	Very Strong	Negligible damage to buildings of good design/construction. Slight to moderate damage in well-built/ordinary construction. Considerable damage in poorly built/designed structures. Some chimneys broken.
VIII	Severe	Slight damage to specially designed structures. Considerable damage to ordinary construction, including partial collapse. Damage is great in poorly built structures. Fall of chimneys, columns, monuments, and walls. Heavy furniture overturned.
IX	Violent	Considerable damage to specially designed structures; well-designed frame structures are thrown out of plumb. Damage is great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X+	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures with foundations are destroyed. Rails are bent.

Figure 2. Modified Mercalli Intensity scale.
Source: https://www.usgs.gov/programs/earthquake-hazards/modified-mercalli-intensity-scale

Intensity is a measure of the strength of shaking at a location. The farther from the earthquake's source, the less the shaking (Figure 2), and the lower the intensity. Thus, intensity is not a fixed number but depends on multiple local factors such as earthquake magnitude, distance from source and the local rock types that the earthquake waves propagate through. Note that while magnitude is measured directly from instrument data at the seismic stations, intensity relies on reports from those who felt the earthquake and report it.

The energy released by an earthquake dissipates with distance from the epicenter, and geologic conditions influence the pattern of energy dissipation and thus ground shaking. Boundaries between different rock types and other faults can impede energy transmission. Throughout the Midlands, both rock layers and faults trend in a northeast-to-southwest direction, and this explains the intensity pattern shown by the USGS Did-You-Feel-It maps (Figure 3). These factors are also the reason why many in the Midlands felt the 2011 Mineral, Virginia, earthquake (M5.8).

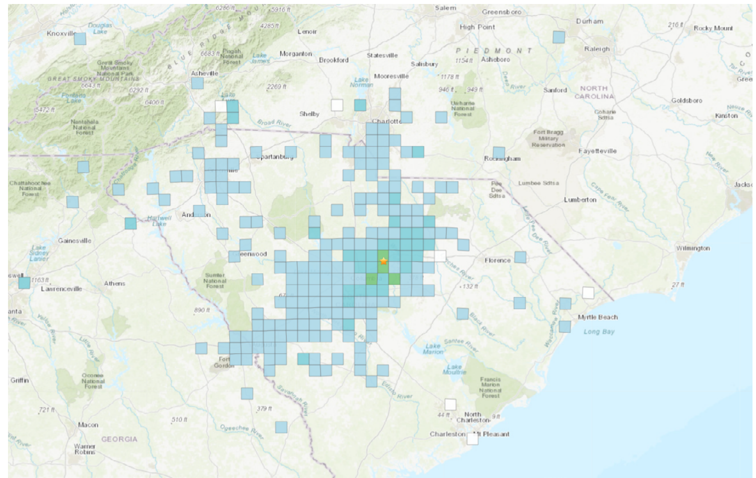

Figure 3. Intensity report from M3.6 on June 29, 2022. Green rectangles are MMI V, dark blue are MMI IV, and light blue are MMI III. *Source: https://earthquake.usgs.gov/earthquakes/eventpage/se60401416/executive*

Intensity maps for the Elgin earthquakes show shaking ranges from moderate (V) to weak (III). A few intensity-V were reported near the epicenters of magnitude 3+ earthquakes. Some intensities of IV are located around the epicenter, and the remainder are III's. All these reported intensities are too small to cause structural damage to buildings; however, there is a potential for material fatigue from repeated shaking events.

EASTERN PIEDMONT EARTHQUAKES ARE NOT RELATED TO THE CHARLESTON SEISMIC ZONE OR ITS EARTHQUAKES

The Elgin earthquakes are occurring along the Eastern Piedmont Fault System (EPFS, Figure 4). This fault system runs northeast to southwest, from Georgia to Virginia. It is not connected to the faults near Charleston. These fault systems are different because they have different characteristics. EPFS is a very ancient fault system with a long history of changing fault styles, inherited structures and fault reactivation. The EPFS formed initially as a ductile shear zone at great depth. It was exhumed during uplift and erosion of the Appalachian Mountains. Many of these ductile shears healed during this time, possibly increasing the strength of the rocks. As the EPFS uplifted, the rock behavior became brittle, and faults formed or reoccupied existing structures. In contrast, the Charleston faults have always been brittle, and they are much younger. At this time, an extensive network system of faults like the EPFS has not been recognized in the Charleston area.

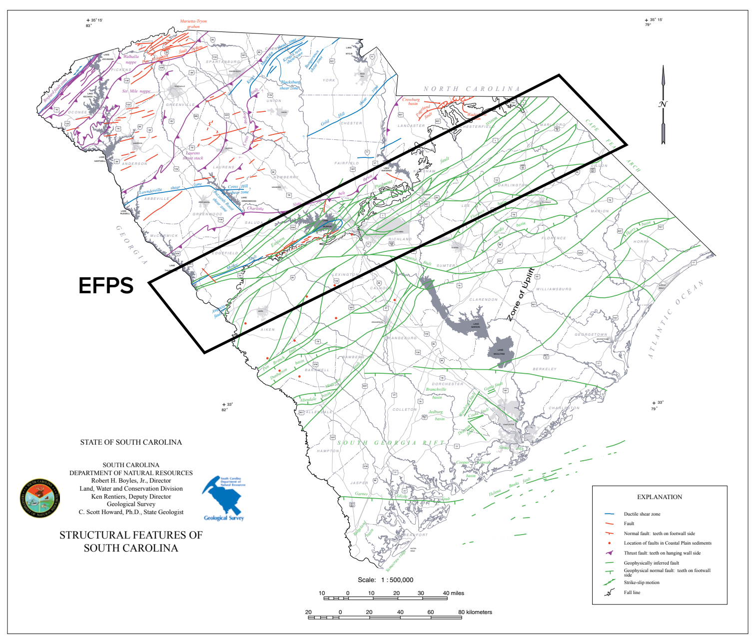

Figure 4. Structural features map of South Carolina. Eastern Piedmont Fault System (EPFS) consists of the green lines inside the black box. *Source: https://www.dnr.sc.gov/geology/pdfs/Publications/GGMS/GGMS4.pdf*

WHY HERE?

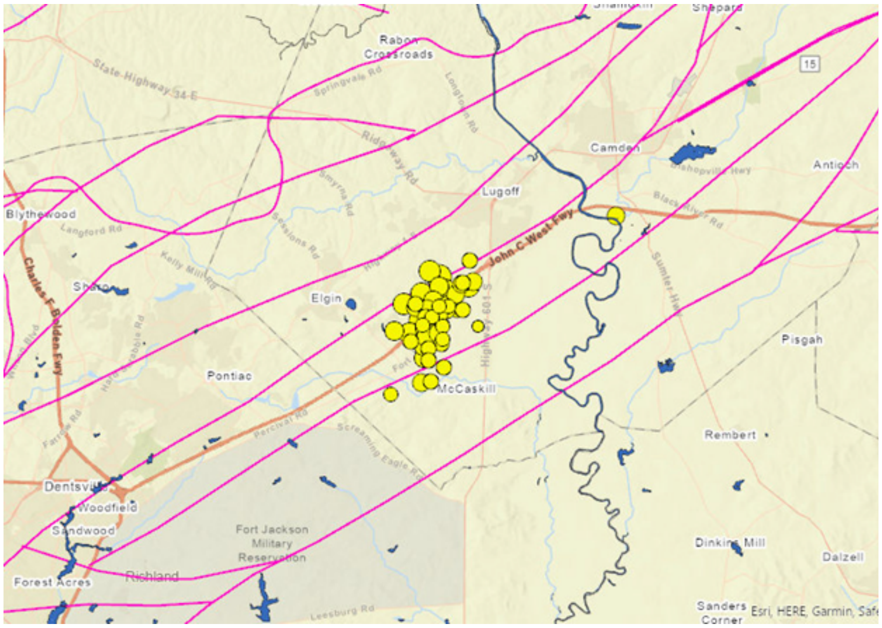

Figure 5. Elgin earthquake swarm displayed with Eastern Piedmont Fault strands.

Why are these earthquakes happening in the Elgin area? The surficial crust of the earth is under constant stress regimes. In the southeastern United States, the principal stress direction is horizontal and oriented approximately east-northeast to west-southwest. The structures in the EPFS exist in this stress regime. Structures parallel to the stress regime are not favorable for faulting. Structures at an angle to the stress orientation are more favorable for faulting. The Elgin earthquakes define a seismogenic zone that is located between two major strands of the EPFS (Figure 5). The earthquakes trend in north-northeast direction. They also appear to occur along several fault planes involved in this swarm.

Focal mechanism studies of the larger (>M3) Elgin earthquakes indicate reverse motion along faults oriented north-northeast substantiating that these are probably small faults in between the larger EPFS faults. Geologic mapping in the Piedmont has recognized this structural relation in many areas of the eastern Piedmont. Note that the focal mechanisms of the Elgin earthquakes fit the general pattern of mainly reverse faulting earthquakes in South Carolina and nearby states; i.e., reverse faulting was also seen in the 2014 Edgefield earthquake, a M3.3 earthquake under Summerville in 2021 and even the M3.9 earthquake in southeastern Georgia in June 2022.

HYDROSEISMICITY

One contributing factor that is being investigated is the concept of hydroseismicity, and the effect of water acting on fault planes. The proximity of the Wateree River, fluctuating river discharges and seasonal precipitation could be contributing to the current seismicity. More studies are needed. But the state of knowledge of other earthquake swarms caused by or affected by water and pore-pressure changes indicates that this issue should be considered.