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(SLIDE 1)-After the recent Asian Tsunami (Japanese for "harbor wave") and its incredible damage to life and property, I began wondering about the possibility of any such risks to the coastal areas of the Carolinas. As a North Carolina native, and an amateur geologist who took some geology at UNC-CH, I began consulting reference books. However, I also consulted with Dr. Michael Oskin, a professor in the Geology dept at UNC-Chapel Hill, and the two state geologists who specialize in understanding geologic hazards to our state: Dr. Jeff Reid here in Raleigh and Dr. Rick Wooten at the Swannanoa geologic field office. So, all this is based in current scientific theory (references at the end of this paper).

-To understand current geologic hazards, we have to talk a bit about the current composition of our Earth. So, let's start at the beginning:

(SLIDE 2) The Earth is approximately 4.6 Billion years old, and weighs approximately 6 sextillion tons (or, 1,000 trillion tons). The Earth's rotation on its axis is a little over a Thousand miles an hour, and moves around the Sun at about 67,000 MPH.
The Earth is not in the shape of a round ball, but is an Oblate Spheroid, eg, a ball that's fat at the outer center, along the equator.

(SLIDE 3) The Earth is comprised of a series of layers, much like a golf ball (if you've ever cut into one) or like an onion, but with 3 layers: Core (inner and outer); Mantle; and Crust. The Outer Core is molten Fe and Ni, at about 6K degrees C, and is responsible for generating the Earth's magnetic field. The top of the crust is called the Lithosphere, a rather lighter and rigid zone of rock, floating above the Asthenosphere, which is hot and semi-solid. The lithosphere, where our cities are, is between 0-40 miles thick, and it comprised of a series of Plates.

(SLIDE 4) -A Plate is a large, rigid slab of solid rock. The earth has approximately 20 or so large or small plates that are moving, and can collide with one another.

(SLIDE 5) This is what caused the recent Asian Tsunami, where the India plate collided with the Burma plate in a process called "Reverse thrust." That is, tension, which had been building for centuries between these two plates, was relieved when the INDIA plate was shoved under the BURMA plate, sending the seawater above upward with such a great force that it created the Tsunami. This plate action was so intense that it both changed the shape of the earth and shortened the length of a day by 3 microseconds.

(SLIDE 6) – Slide 6 is a sonar reconstruction of the sea floor at the point of impact between the Burma and India plates, after the Tsunami. This shows ridges almost 5K feet high. The main collision zone was abt 12,000 beneath the ocean, and the epicenter of the earthquake was abt 24 miles beneath the ocean surface.

(SLIDE 7) The areas we now call North and South Carolina began forming about 1.7 million years ago –They were formed by multiple volcanic island ridges, in what is now the Atlantic, colliding with a land mass to the west, in a back and forth process. To find the original North Carolina, you would have to go 300 miles west of Manteo, to the Appalachian Mountains.

(SLIDES 7 & 8) North and South Carolina are divided into three geologic regions: the Blue Ridge; the Piedmont (French for foot hills); and the Coastal Plan. In North Carolina, the Piedmont occupies the largest area of the state. The second largest region is the Coastal Plain, which runs approximately along the line created by I-95, east to the coast. (In fact, the placement of I-95 is probably due to avoidance of potential for floods). The Coastal Plain, whose elevation ranges from sea level to about 600 ft above sea level, was formed by erosion of the mountains and multiple courses of sedimentation (deposition) laid down by the ocean, when this was all under water. This is most evident in what we call the "Sand Hills" of North Carolina, which once was prime ocean front property. In South Carolina, the largest geologic region of the state is the Coastal Plain. It is so large that it is subdivided into three sections.

-In examining North and South Carolina for geologic hazards that we may need to prepare for, there are four areas of concern: Volcanoes; Earthquakes; Landslides and Tsunamis.

(SLIDE 9) I am happy to assure you that Volcanoes are not a real current threat, but have been active in North and South Carolina in geologic times, particularly non-explosive volcanoes. That is, volcanoes that don't breach the surface and erupt. In fact, Chapel Hill is the remnant of a very old non-explosive volcano. It was formed from the hardened magma, elevating it above the Piedmont floor (Technically, it is known as an Old age monadnock in the Piedmont Peneplain). In the west, Looking Glass Rock and Stone Mountain are old magmatic bodies. SLIDE 9 shows volcanic formation today in Hawaii, where a hot spot of lava melts the rock above (rock melts at abt 1100 to 1600 F) and protrudes to form new land.

(SLIDE 10) shows Mt. St. Helens erupting in the 1980's.

-Earthquakes are another factor to consider in North and Carolina. These earthquakes occur not only due to collision of the major worldwide plates, but also due to changes in faults within the plates. Faults are major breaks in the Earth's crust, within a plate. Everyone has heard of the San Andreas fault in California. There are many faults in North Carolina that are not famous at all.

(SLIDE 11) Nearby, the Jonesboro fault runs in a southwest to northeast direction from the South Carolina line to near Virginia. It runs approximately halfway between Raleigh and Durham. North of Raleigh and North of the Jonesboro fault, the Nutbush Creek fault runs to the Virginia line. Fortunately, as North Carolina is very old geologically and historically, these faults are quiescent. That is, they are at a point of physical stasis, and do not have the built-up tension of other places. One of these places is our sister state, South Carolina (Some of you know that the area of North and South Carolina were one state, in pre-Revolutionary times).

(SLIDE 12) South Carolina has many active faults. The Helena Banks fault off the coast of Charleston in the Atlantic was responsible for 12 minor earthquakes last year. While these recent seismic events have been localized to the Helena Banks fault, geologist believe that the 1886 Charleston earthquake was focused some 15 miles northwest of Charleston, near Summerville on Interstate 26. There, two major faults, the Woodstock Fault and the Ashley River fault converge. Because of the locking together of these two faults southwest of Summerville, this area of South Carolina is designated "...a permanent zone of stress..." (Murphey, p. 195) and destructive earthquakes can be expected there in the future. If an earthquake similar to the 1886 earthquake occurred today (or in the future), "...damage of every kind would surely be catastrophic - affecting millions of people in South Carolina..." and throughout the Southeast. Major cities within a 200 mile radius could expect major damage. These cities would include Savannah, Columbia, Wilmington and perhaps Charlotte. Fortunately, the University of South Carolina has active and intense seismic monitoring stations. Around the Charleston area are seven earthquake monitoring stations, which send data to the United States Geologic Survey in Colorado.

-The Charleston Earthquake of 1886 (which is just a blink in geologic time) was nearly a 7.0 magnitude earthquake. As the land of the East Coast is more rigid than the West Coast, earthquakes here are felt more significantly and at greater distances. Last year, approximately 50 earthquakes occurred in South Carolina. In fact, on February 18th of this year, a magnitude 2.9 Earthquake occurred in Irmo, a suburb of the capitol city, Columbia.

While South Carolina has an active seismological recording network because of this earthquake activity, North Carolina has ceased its statewide monitoring network. However, UNC continues to have two active sites for earthquake monitoring: one in Chapel Hill and the other in Murphy in the far west. Of note, earthquakes can be measured on two different scales. The traditional scale is the Richter scale which is a logarithmic scale measuring energy released (magnitude) (each number represents 30 times the previous number). The modified Mercalli scale actually measures damage. A 1 would mean felt by few, while a 12 would mean total devastation.

(SLIDE 13) However, North Carolina does have earthquake activity that can cause concern to the population: Raleigh was the epicenter of a 2.0 earthquake, a so-called microearthquake. This occurred here in February 11, 1898. More than 20 earthquakes with a magnitude >2, and noticed by the public, have occurred in North Carolina over the last 20 years. For example:

Many residents felt the Dec. 16, 1994 earthquake centered near Winston-Salem. Although it caused audible booms, and shaking felt throughout the Winston-Salem area, it was probably less than a magnitude 3 earthquake.

Widespread reports of shaking are often felt in the Brunswick-New Hanover County area. One such event occurred on February 7, 1995. Research continues into what causes the booms and shaking frequently reported in that area, that are sometimes referred to as the 'Seneca Guns.' Some of these events may be earthquakes, others may not be. Because seismic stations do not detect many of these small events, their origin remains uncertain.

A magnitude 2.6 earthquake occurred near Greensboro on July 12, 1993. Residents reported broken windows, shaking buildings, and being ‘thrown from beds.’

Although there are many faults in North Carolina, they are all thought to be ancient, and none are known to be active. When an earthquake occurs in North Carolina, movement along a fault presumably triggers it. The faults that generate earthquakes here occur at depth, and are not known to have any expression at the ground surface. One of the main reasons that predicting future earthquake locations in the eastern U.S. is so difficult is because scientists have not been able to conclusively identify or locate the faults that cause earthquakes here.

-Landslides have plagued the state due to heavy rain from recent hurricanes.

(SLIDE 14) Some of this is due to the land becoming heavy due to saturation from rain, and the heaviness becoming greater than the cohesion among the molecules, thereby overcoming gravity. Dirt and trees slide down the bedrock.

(SLIDE 15) The North Carolina Geologic Survey has attempted to map specific zones sensitive to landslides. Since 1901, when rainfall from hurricanes or tropical storms has exceeded the threshold of 5 inches in a 24 hour period, the mountains have been plagued with landslides. Historically, major hurricane induced landslides occurred in 1916 and 1942. Most recently, extensive damage with loss of life occurred due to rainfall from Hurricanes Frances and Ivan, from 50 of the 85 recorded landslides they caused. Last September, 5 people were killed and 15 houses were destroyed when a two-mile debris flow (landslide) occurred on Fishhawk Mountain in the Peeks Creek Community in Macon County. The North Carolina Geologic Survey has mapped 450 landslide sites. These are all in the far western counties, adjacent to the Tennessee border. The Geologic Survey is attempting to map all areas of landslide risk, but needs funding from the NC State Legislature. (Hint – write your legislator in support of this.)

(SLIDE 16) shows the very end of a debris field that has moved trees and houses.

(SLIDE 17) -Tsumani-
-On the mid-Atlantic portion of the east coast, Tsunamis are not a big risk. They have occurred recently in the Carribean basin, including Puerto Rico in 1918 and the Dominican Republic in 1946. In fact, there is a Tsunami warning system in Puerto Rico. There, island nations sit atop volcanoes, or are near the earthquake zones under the seas.
Here are possible scenarios that could cause Tsunami damage to the coast of the Carolinas:

-There are a series of submarine ridges off the NC Outer Banks, extending out about 25 miles. These elongate depressions, possibly cracks, were discovered several years ago using bathymetric data and have been postulated as possible indicators of unstable sea floor sediment (i.e., potential submarine landslides). There is the very remote possibility, if these features are, in fact, related to sea floor instability, that large-scale movement of sea floor landslides could trigger tsunamis that could affect the east coast of the U.S. These elongate depressions could, however, be methane gas escape features, and not related to unstable slopes. Apparently, the Woods Hole Oceanographic Institute plans further investigation of these features using submersibles.

However, if these are ridges, and if these ridges were to collapse, it could cause a wave over 20 feet high to sweep over the Outer Banks, and with as much destructive force as a Category 5 hurricane. Fortunately, the odds of this are minimal or less.

-A Tsunami also could result from a meteorite falling in the Atlantic, off the North or South Carolina coast. Throughout history, meteorites have fallen to the earth, causing great damage, perhaps even the Ice Age. However, debris from outer space falls almost daily, and each year almost 9000 tons of space debris falls to the earth. One of the largest impact craters from asteroids is the Manicouagan Crater in NE Canada, that is 43 miles across. Thanks to the friction created by our atmosphere, these objects usually burn up before causing significant damage to the earth.

-The final possibility is that of a Tsunami caused by a volcano-generated landslide in the Canary Islands. In this scenario, a landslide on Cumbre Vieja volcano could result in a 60 foot Tsunami to much of North, Central and South America. This is a virtual reality. It will happen. However, scientists can only say that it will most likely happen sometime in the next 5,000 years. Hopefully, not in our lifetime.

-So, in conclusion, I hope I have given you some information to make geology (the study of the earth) as interesting and exciting as the study of other natural phenomena impacting our great state.

-Again, I want to thank the folks who have reviewed this material or have added information. I want to thank Dr. Mike Oskin, professor of geomorphology and neotectonics at the UNC Chapel Hill Dept of Geology (where I took courses years ago); Drs. Jeff Reid and Rick Wooten, geologists with the North Carolina Geological Survey, who specialize in analysis of geologic hazards; and the United States Geologic Survey.

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-Visit the North Carolina Natural Science Museum, off Jones Street in downtown Raleigh, NC