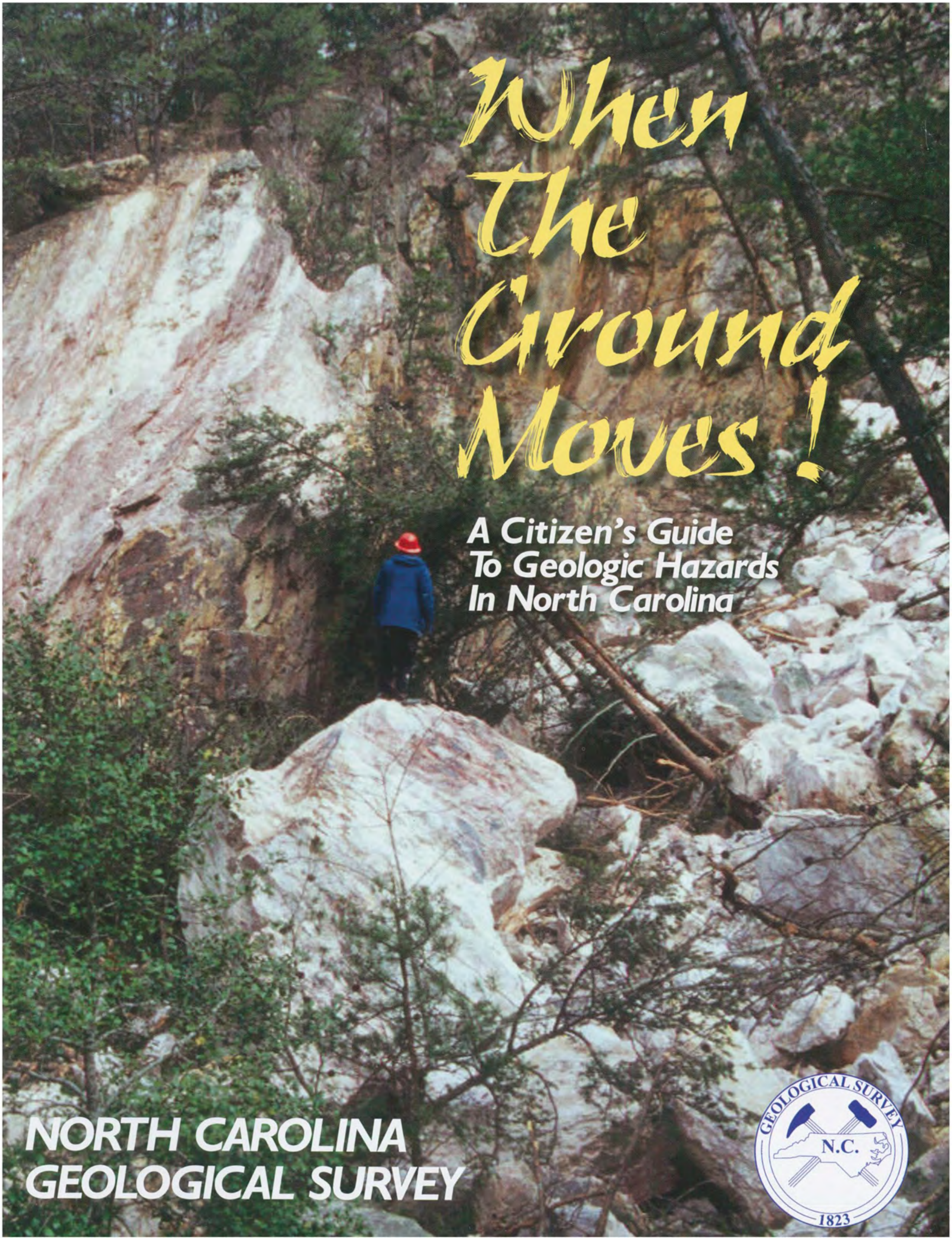

When The Ground Moves!

A Citizen's Guide To Geologic Hazards In North Carolina

NORTH CAROLINA GEOLOGICAL SURVEY

GEOLOGICAL SURVEY N.C. 1823

Front Cover: Rockfall at Occoneechee Mountain State Natural Area, Eno River State Park. Above: Photographs of Topsail Island, before and after Hurricane Fran, September 1996. Photo Courtesy of United States Geological Survey.

When the Ground Moves!

A Citizen's Guide to Geologic Hazards in North Carolina

Information Circular 32

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Division of Land Resources

Department of Environment and Natural Resources

State of North Carolina
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Department of Environment and Natural Resources
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Raleigh, North Carolina

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A Citizen's Guide to Geologic Hazards in North Carolina

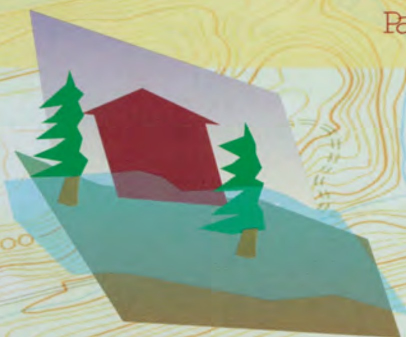
Landslides

Page 1

Many factors can cause rock and soil to move downhill. Sometimes the movement is slow, but it is often fast and can destroy homes or cover highways. Look further to find out more about landslides in North Carolina.

Coastal Hazards

Page 7



The North Carolina coastline is vulnerable to flooding and erosion from coastal storms and sea level rise. We cannot stop these natural forces but we can identify where we are most vulnerable and make plans to minimize risk to life and property.

Sinkholes

Page 11

These phenomena don't just happen in Florida. North Carolina has its share of sinkholes because of a particular type of rock and human activity.

Abandoned Mines

Page 13

We have a rich history of mining and hundreds of old abandoned underground mines exist in North Carolina. We know where a lot of them are, but not all, and that can be a problem.

Earthquakes

Page 15

Do earthquakes occur in North Carolina? Yes, North Carolina experiences earthquakes originating from within the state and surrounding states. Check out our earthquake map and you may be surprised at where the shaking is going on.

Introduction

Natural disasters happen frequently on our planet and North Carolina is no stranger to these events. Many of these natural phenomena are directly related to the wide variety of rocks, soil and natural settings in North Carolina. From the mountains to the sea, our state's many unique environments are affected by the interactions of natural processes and human activity.

Now, more than ever, geologists need to understand these complex geologic hazards as our state continues to grow and develop. The North Carolina Geological Survey is currently investigating many of these hazards. The result of this research will aid in the planning and developing of communities, reduce the risks to public safety and minimize the impact on our state's infrastructure.

Which of the Following Types of Geologic Hazards Occur in North Carolina?

Earthquakes / Sinkholes / Landslides / Mine Collapses / Hurricanes

If you think all of these geologic hazards occur in North Carolina.

You Are Right !!!

The Slippery Slope of... Landslides

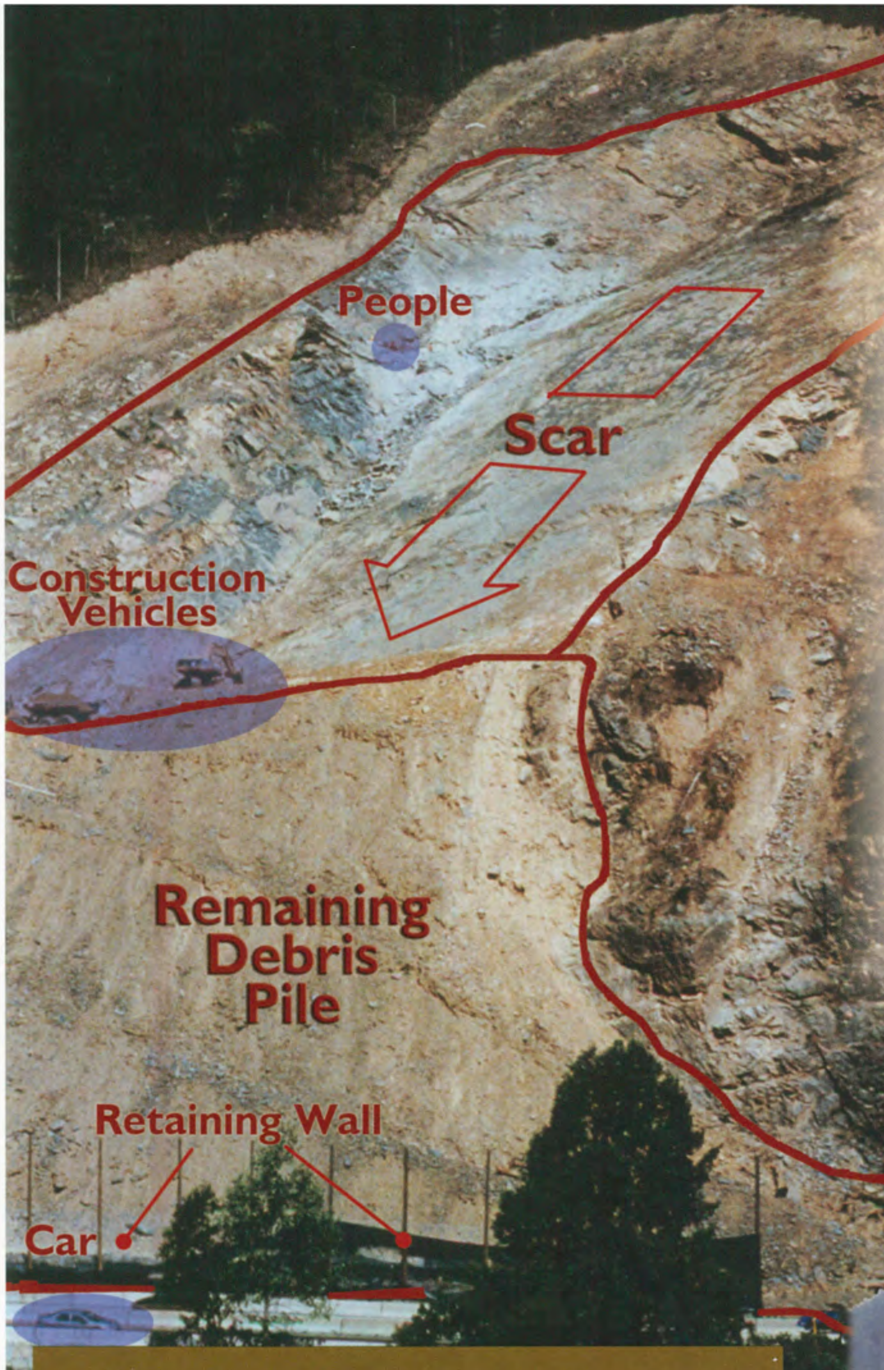
Landslides are most common in the mountain region of our state because of the steep slopes. The Piedmont and Coastal Plain regions also have landslides that are commonly related to human activity, such as making a road cut too steep. Large rainstorms, hurricanes, freeze-thaw processes and human activities all can trigger landslides. There are many types of landslides made of different types of material that travel at different speeds. Some landslides only consist of soil, called an earthslide. Some are a mixture of soil, rock, trees and mud, called a debris flow. Other landslides contain only rock, called a rockfall or rockslide. The speed of a landslide can vary greatly depending on the weather, rock and soil conditions. Landslides can creep along at barely perceptible rates or can move faster than a human can run. In 2003, the Blue Ridge Parkway was partially covered by a rockslide that left a huge boulder in the road (fig. 1).

BELIEVE IT OR NOT

Geologists have many names for landslides such as earthslide, debris flow, mudflow, earthflow, rockfall and rockslide. Each name describes a different type of landslide.

Figure 1

Boulders on the Blue Ridge Parkway from the April 24, 2003, rockslide near Potato Field Gap, northeast of Asheville. The 165-ton boulder is being broken down to fit into a dump truck.



Landslides can be very small, like those on the side of a ditch, or they can be as large as a mountainside, like the one that occurred in July 1997 along the Pigeon River Gorge that covered I-40 by a rockslide (fig. 2). This rockslide was caused, in part, by the nature of the underlying rock. Most rock formations have layers similar to a stack of books. If you tip a stack of books they will slide off each other just as tilted layers of rocks can slide off a mountainside. The layers of rock are planes of weakness. The planes of weakness are where the landslide separates from the side of the mountain. Geologic maps show how these planes are oriented and the maps can be used to plan transportation and community development.

Figure 2

Scar from the 1997 rockslide along I-40 in the Pigeon River Gorge. This rockslide closed the highway for more than 20 days. In this photo, clean-up efforts have removed most of the debris pile, a retaining wall has been constructed and I-40 has been reopened. Photo courtesy of NCDOT.

It is difficult to tell where a landslide has happened before because plants and trees overgrow the area, but it is important to study these areas so people do not build in harm's way. The apartment complex in Maggie Valley (fig. 3) is built on old landslide and stream deposits at the base of the mountain. The landslide deposits have accumulated because of recurring landslides and where they have happened in the past, they can happen in the future.

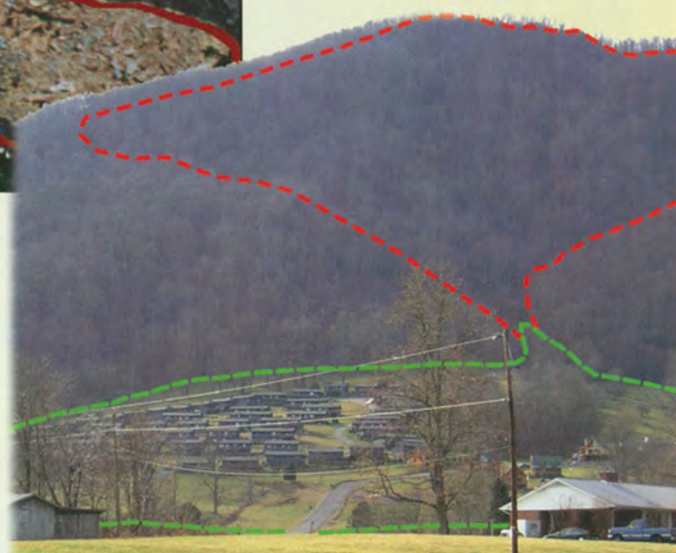


Figure 3

An apartment complex in Maggie Valley is built on landslide and stream deposits (green outline) originating on the hillside (red outline). The landslide deposits have accumulated because of recurring landslides.

The trained eye of a geologist can discover hints that the land is currently moving and uncover clues as to where it has moved in the past. Evidence that the land is moving include cracks that appear when the land is slowly pulling apart from the hillside. These cracks are called tension cracks. With time, the ground on one side of the tension crack may slide downhill forming a scarp (figs. 4 and 5). If the ground moves far enough, it will leave a mark called a scar (see fig. 2). A fresh scar will usually have a lighter color and no vegetation compared to the surrounding slopes.

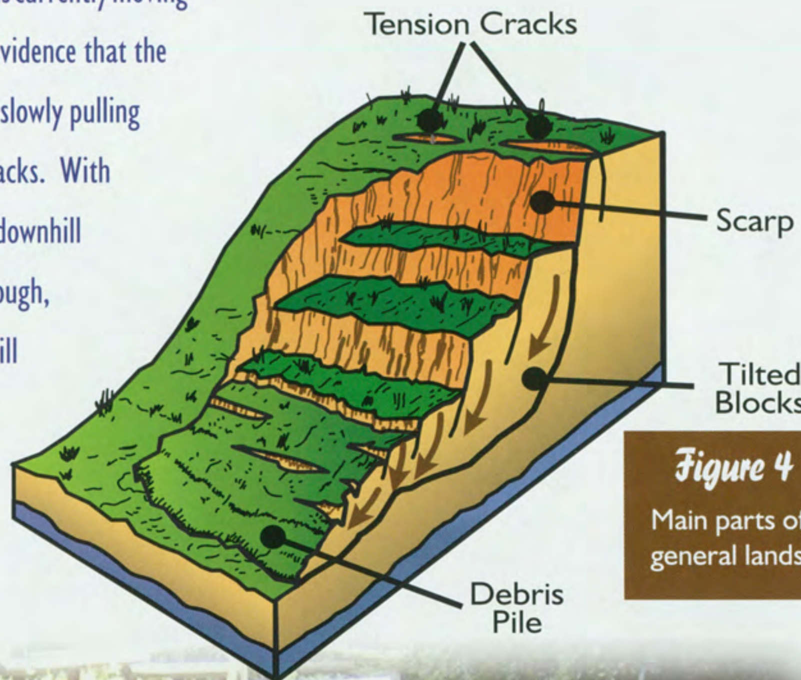


Figure 4

Main parts of a general landslide.

Figure 5

This is where a debris flow, a type of landslide, was triggered in Henderson County by heavy rainfall from the remnants of Hurricane Frances in 2004. Tension cracks indicate areas of the ground have pulled away from the hillside. Scarps indicate areas that have already dropped down; with time, tension cracks in the pavement will likely become scarps.

Another clue that the land is moving is trees growing at an angle or with bent trunks (fig. 6). Trees growing on the side of a hill normally grow straight up. If the land is slowly moving downslope, the trees will lean, but keep trying to grow straight towards the sun. This process results in their bent growth pattern and indicates the trees are slowly sliding down the hill on top of the landslide. This should be a warning that the land may move substantially with the next large rainstorm.

Figure 6

Tree showing curved growth. The curved growth pattern indicates the tree is growing on top of a slowly moving landslide.

A landslide can carry a lot of debris (fig. 7). This debris flow took the bark off the tree 10 feet above the ground indicating the flow was about 10 feet deep at that point. It also carried the large boulder downhill, bringing it to rest next to the tree. A landslide can leave a trail of destruction and debris along its path and a pile of debris at the end of its journey.

Figure 7

A nearly 5-ton boulder moved by a debris flow. The yellow arrow indicates the mud mark left by the debris flow. The flow at that point was about 10 feet thick.

Hurricanes in the Mountains – Hurricanes not only affect the coast, they can move inland and drop tremendous amounts of rain. A single hurricane can substantially affect a large area. If consecutive storms hit an area within a short period of time, the results can be devastating. Such an occurrence happened when the remnants of Hurricanes Frances and Ivan passed through the North Carolina mountains within a two-week time span in September 2004.

Figure 8

The Peeks Creek debris flow moved boulders larger than 16.5 tons. Only a small fraction of the debris is shown here.

In 2004 the Peeks Creek community in Macon County, North Carolina, experienced one of the largest landslides to hit the North Carolina mountain region in decades. Tons of water, mud, rocks, trees and other debris traveled for more than two miles (fig. 8). The debris flow was 30 feet deep and 250 feet wide at some points and traveled downhill as fast as 33 miles per hour. The debris flow destroyed or heavily damaged 15 homes (fig. 9) and five fatalities, including an unborn child, were reported. The debris flow happened as the remnants of Hurricane Ivan moved through the area approximately one week after the remnants of Hurricane Frances.

Figure 9

The Peeks Creek debris flow pushed this two-story home 30 feet off its foundation. The piles of debris to the right of the house are the remnants of an adjacent house that was destroyed.

The large amount of rain falling on steep, unmodified slopes in such a short period of time triggered the more than two-mile long debris flow. Ivan dropped between 4 to 6 inches of rain, with higher elevations receiving 10 or more inches of precipitation. This rainfall was in addition to the remnants of Hurricane Frances that dropped 6 to 10 inches of rain, with many areas receiving greater than 10 inches. This landslide was most likely because of steep slopes, shallow soil and large amounts of rain. Mountain counties were hard hit by these back-to-back events with destruction to property and transportation routes throughout the region (figs. 10 and 11).

Figure 10

In a subdivision in Watauga County, one home was destroyed and eight condemned for occupancy by landslides related to Hurricane Frances in 2004.

Figure 11

This landslide, caused by Hurricane Ivan in 2004, destroyed this home in Starnes Cove, Buncombe County. Photo courtesy of the Asheville Citizen-Times online edition.

It is very difficult to determine exactly when and where a debris flow, or any type of landslide, will occur. Hurricanes triggered widespread debris flows in the North Carolina mountains in 1916 and again in 1940. A strong tropical depression in 1977 also triggered numerous debris flows. Although many debris flows occurred in remote areas, these and other types of landslides caused fatalities in 1916, 1940, 2003 and 2004. Debris flows and other landslides have occurred in the past, and will occur in the future in the North Carolina mountains.

Things to consider:

Human activity can contribute to the number and severity of landslides throughout our state. When humans cut into hillsides and mountainsides, the slopes are sometimes too steep, making it easier for the land to slide downhill.

How this affects you:

One example of the direct and indirect costs of landslides is the Pigeon River Gorge rockslide along I-40 (see fig. 2). Road repair and stabilization costs exceeded $10 million. Indirect costs, such as interruption of business, commerce and tourism because of lengthy detours, probably exceeded $5 million.

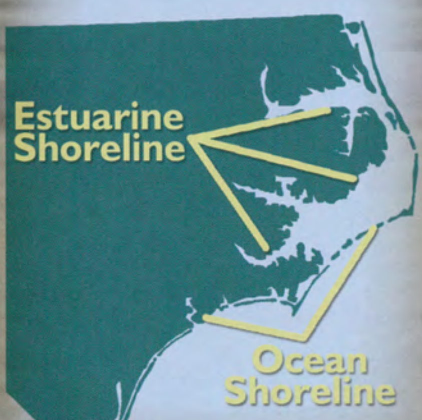
Surf's Up!

Coastal Hazards

Storms- The North Carolina coastal zone includes barrier islands, sounds and estuaries. These areas are vulnerable to flooding and erosion by waves and high water driven by coastal storms. There are several types of shorelines including sandy beaches, swamp forests, bluffs and marshes. The narrow strand of sand known as the barrier islands is particularly vulnerable to these forces. Waves and currents continually shape this coastal landscape. No other part of North Carolina is more geologically active. Much of the change is slow and barely perceptible on a daily to yearly basis, but storms (figs. 12A and B) often cause very significant changes in a matter of hours (see fig. 13).

BELIEVE IT OR NOT

North Carolina has an ocean shoreline about 330 miles long and an estuarine shoreline that is approximately 4,000 miles long. That is a tremendous amount of shoreline that is vulnerable to flooding and erosion from coastal storms and rising sea level.



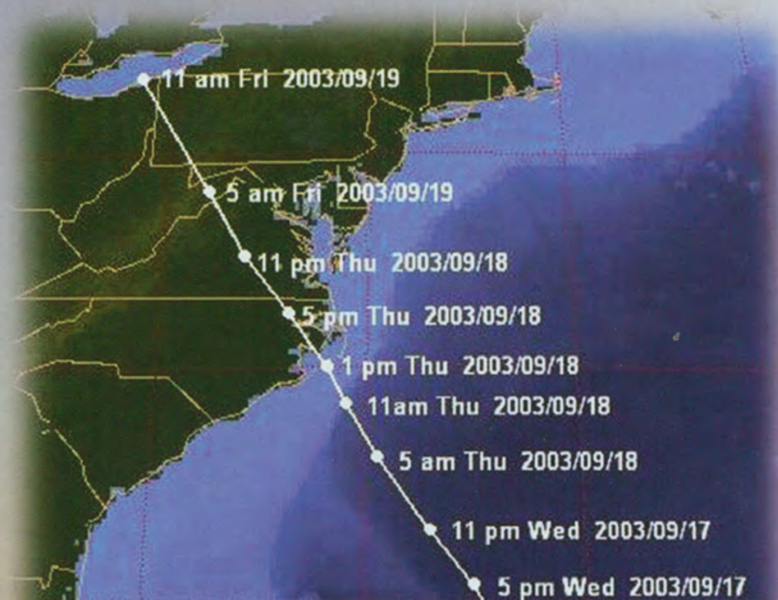
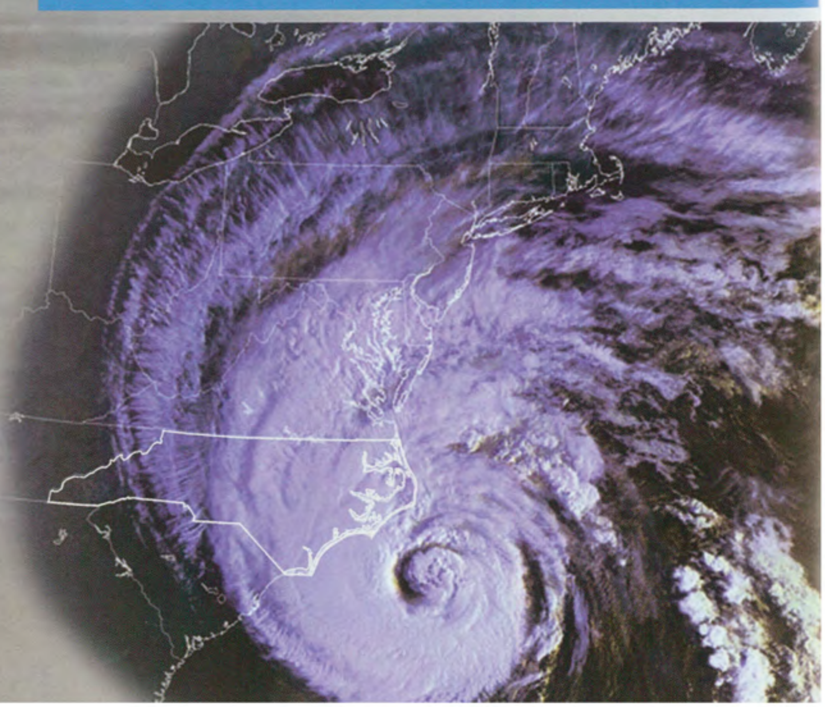


Figure 12 A & B

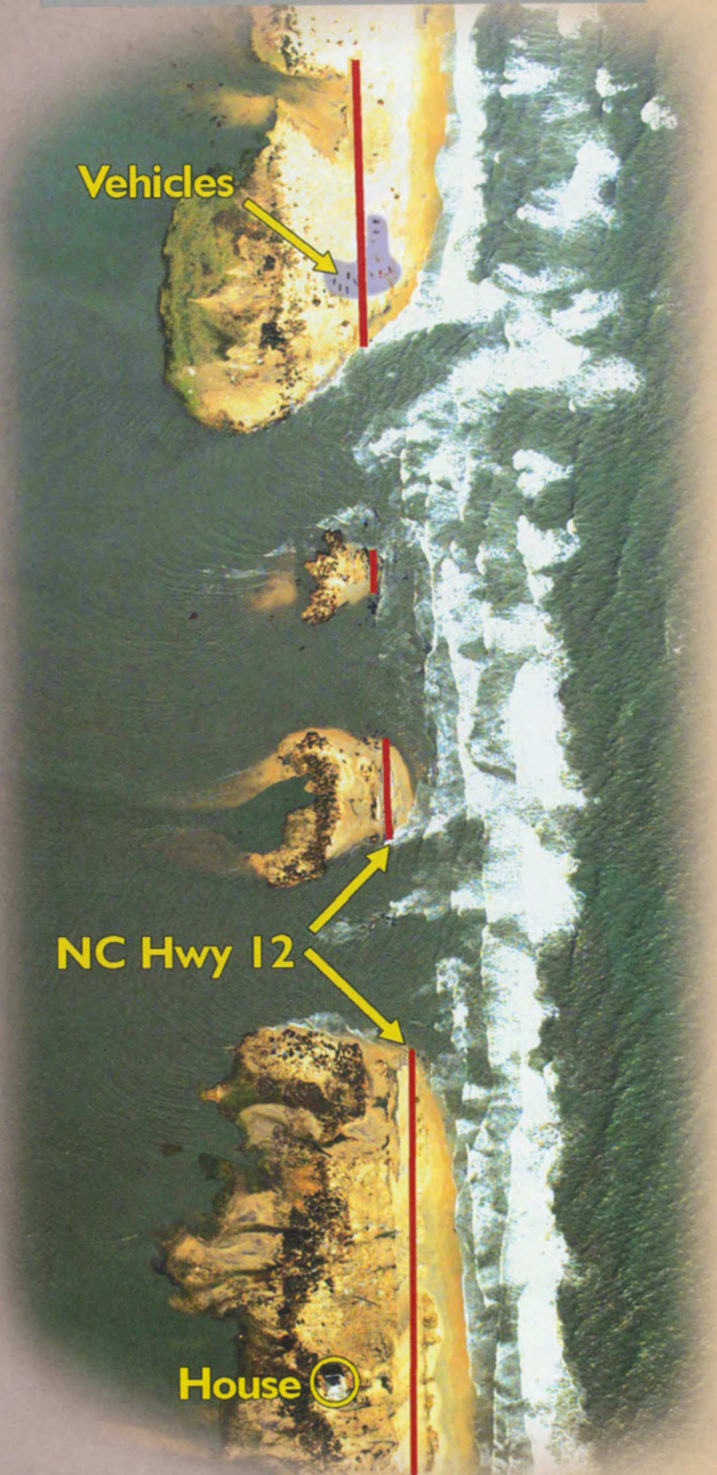
A. Track of Hurricane Isabel in September 2003. Image courtesy of the National Weather Service – Raleigh Office.
B. Satellite image of Hurricane Isabel. Courtesy of NOAA.



Proof of how quickly the barrier islands can change occurred on the morning of Sept. 18, 2003. Hurricane Isabel cut an inlet through Hatteras Island, severing NC Highway 12 and isolating Hatteras Village (fig. 14).

Figures 14

Overhead photo of Hatteras Island inlet after Hurricane Isabel in 2003. Photo courtesy of NOAA.



Inlet locations have changed throughout history. Currently, there are three inlets between Virginia and Portsmouth Island. Up to 16 inlet sites are known for this stretch of North Carolina's coastline in historical times. It takes financial resources and large amounts of sand to keep inlets open, beaches nourished and roads passable as these geologic features constantly change.

Figure 13

Top and middle photos of Kitty Hawk during Hurricane Isabel in 2003. Photo courtesy News24.com. Bottom photo of Topsail Island after Hurricane Fran in 1996. Photo courtesy of FEMA.

Sea Level Rise- The most significant long-term process causing change to our coastal zone is sea-level rise. At the peak of the last ice age about 18,000 years ago sea level was 425 feet lower than present and the North Carolina ocean shoreline was located 15 to 60 miles to the east. As the ice sheets melted, sea level began to rise. In general, the sea level has risen during this time but the rate of rise has varied and there have been periods of stability and falling sea level.

A significant amount of land that was once above sea level is now submerged. One line of evidence that sea level rise has affected humans comes from archaeological sites. Native American artifacts from on-land activities are being discovered under several feet of water. Also, maps from European settlers show entire islands that are now gone. Current estimates place the rate of rise in sea level at 1 to 1.5 feet per century. While that may seem insignificant, a vast amount of land along our coast and estuaries would be impacted (fig. 15).

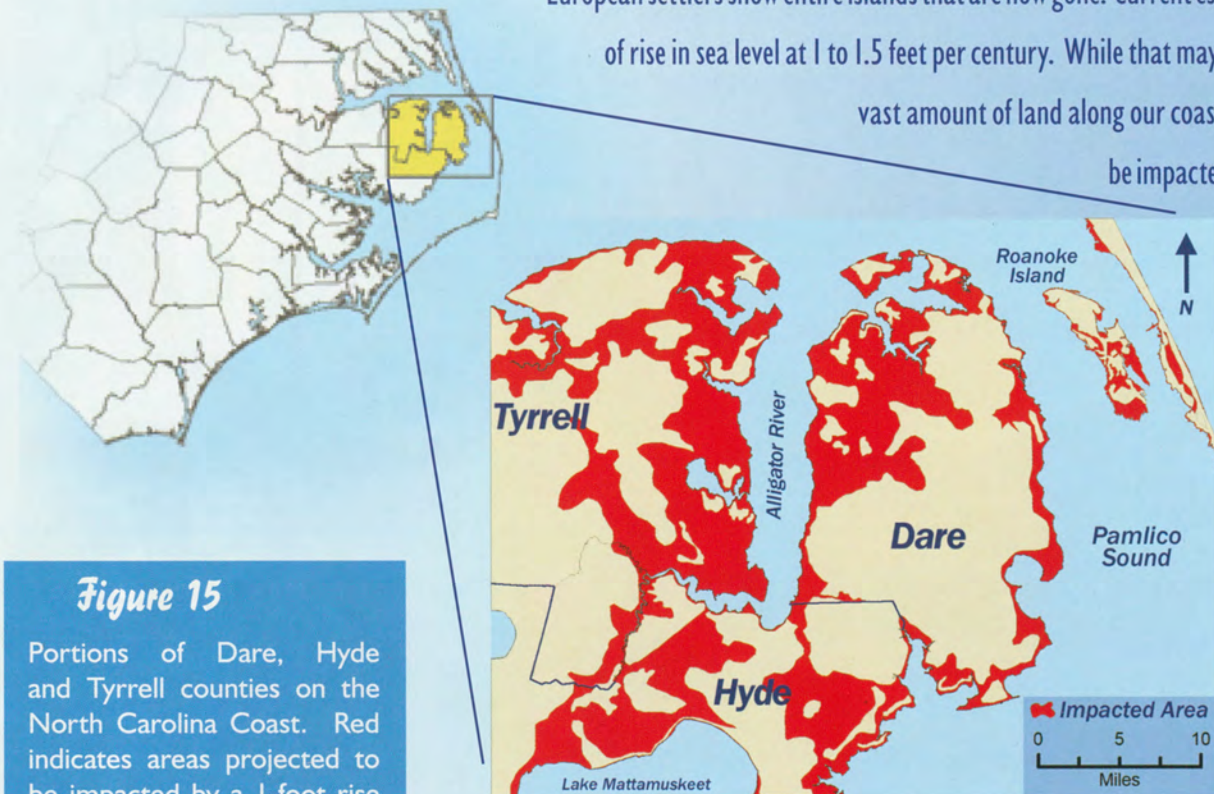


Figure 15

Portions of Dare, Hyde and Tyrrell counties on the North Carolina Coast. Red indicates areas projected to be impacted by a 1-foot rise in sea level.

Beach Erosion- Recent and ongoing studies by the North Carolina Geological Survey, East Carolina University and the United States Geological Survey have demonstrated that the local geology is an important factor in how the barrier island system changes in response to natural processes and events. In many areas our beaches are disappearing. Each location has a unique set of causes for the beach erosion. Along the Outer Banks, mud-filled, ancient river and stream channels run under the barrier islands and are exposed along the ocean floor. The soft muddy sediments offer less resistance to the erosive force of waves and currents, especially during storm events. In some areas of the southern coastal zone, the underlying geologic units are not "sandy" enough to supply the sand needed to keep the barrier islands "healthy." Areas such as these are more vulnerable to erosion than areas with more favorable geology.

Photo courtesy of news24.com

LiDAR Mapping is a valuable NEW tool - **Li**ght **D**etection **A**nd **R**anging works like radar but uses light waves instead of radio waves to measure the distance to objects. This modern laser technique surveys the topography of an area and the data generated is used to create highly accurate elevation maps. In the wake of the catastrophic flooding from Hurricane Floyd in 1999, the state-sponsored North Carolina Floodplain Mapping Program was instituted to remap the state's topography and floodplains. The elevation data from this program is being used by the NCGS to map landforms of the barrier islands and identify areas most vulnerable to flooding or inlet formation from storm surge (fig. 16). Using this new tool, we may be able to determine areas at risk to significant erosion and better plan development and responses to emergencies.

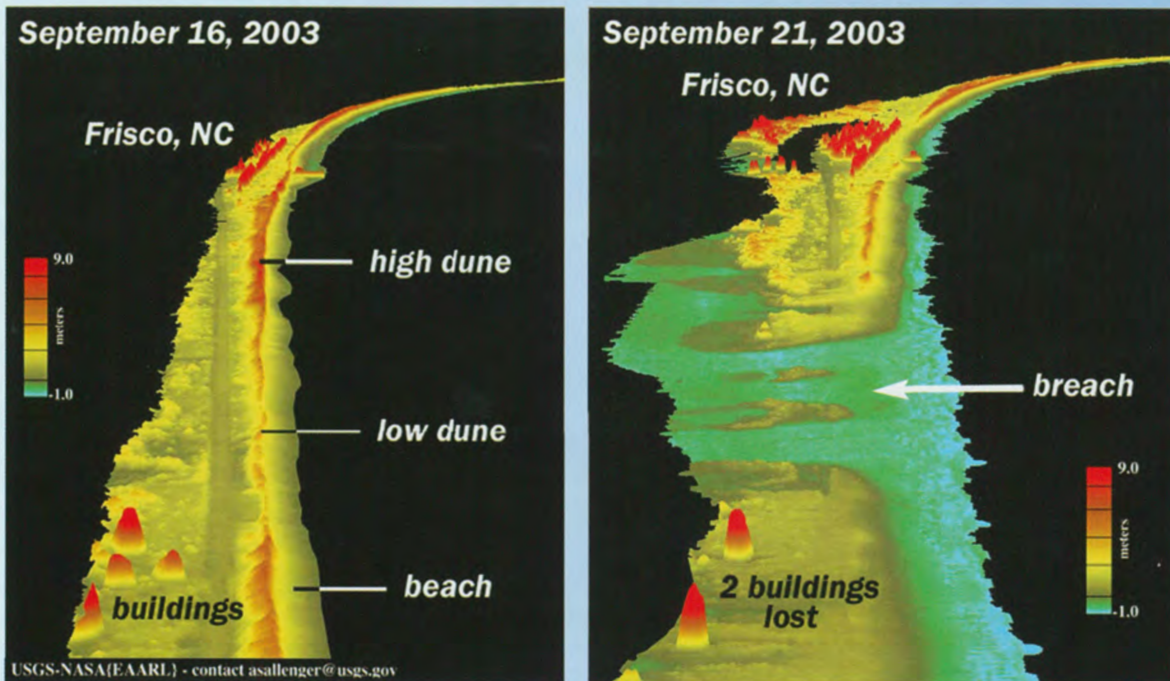


Figure 16

LiDAR image of Hatteras Island before and after Hurricane Isabel. In the before image, note the low dune area and four red "bumps" representing buildings. In the image after Hurricane Isabel, note that two buildings are gone and an inlet has been cut through Hatteras Island. Image provided by the United States Geological Survey.

Things to Consider:

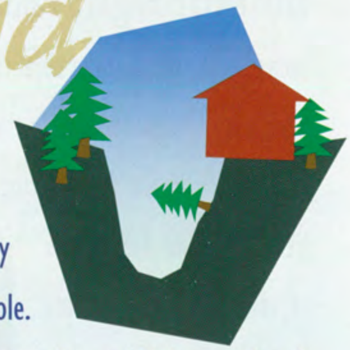
Atlantic basin hurricanes follow a cyclical pattern of activity wherein periods of relatively low or high storm activity span several decades. Many scientists believe that the mid-1990s were the beginning of a high-activity cycle that will last for 20-50 years. We cannot stop hurricanes, other storms like nor'easters or the rising sea from attacking our coast, but we can identify where we are most vulnerable and plan so that risks to life and property are minimized.

How this Affects You:

Even relatively minor hurricanes making landfall in developed areas can easily cause damage in the tens of millions of dollars. Significant storms like Bertha and Fran (1996), Bonnie (1998), Floyd (1999) and Isabel (2003) each caused coastal damage in the hundreds of millions of dollars. Although the owners of damaged property suffer the most, the financial burden of a storm is shared among taxpayers and insurance policy holders statewide.

Holes In The Ground

Sinkholes



Whether because of rock type or human activity, there are many reasons why the ground can sink into a hole.

These phenomena don't just happen in Florida. In North Carolina, sinkholes mainly occur in the southeastern Coastal Plain counties of Brunswick, New Hanover, Pender, Onslow, Jones, Lenoir, Craven and Beaufort (fig. 17). When sinkholes are common in an area, the area is said to have karst topography.

BELIEVE IT OR NOT
Sinkholes are actually collapsed caves or cavities.

Figure 17
Map of Coastal Plain counties where sinkholes mainly occur.

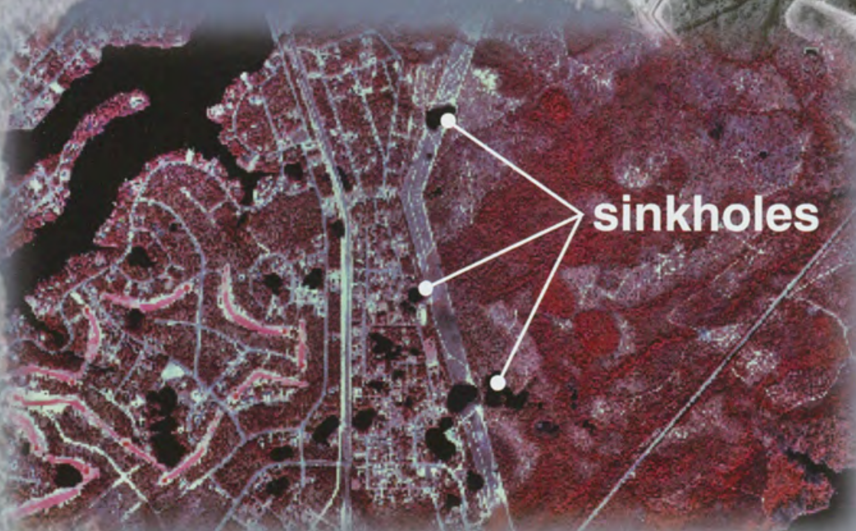
A sinkhole starts when water seeps down into limestone or other soluble rock like dolomite or marble, following cracks in the rock (fig. 18). Limestone lies under much of the southeastern Coastal Plain counties (fig. 17). The water dissolves the limestone, creating cavities. As the limestone is dissolved, a water-filled cavity forms. As more of the limestone is dissolved, the cavity grows in size. If the water is removed or if the ceiling of the cavity gets too thin, it can sag or collapse, forming a sinkhole, and anything on top falls into the depression or hole.

Figure 18
Sinkhole formation

Things to consider:

The coastal population is growing, as is the region's need for water. As more water gets pumped out of the ground for public and private use, the water level in the limestone cavities will drop. When the water is no longer in the cavity to help support the ceiling, the cavity will be more likely to collapse, forming a sinkhole.

Sinkholes come in many shapes and sizes. In North Carolina, some of these sinkholes fill with water, forming ponds or lakes, like around the town of Boiling Springs Lake and Sunny Point Military Ocean Terminal in Brunswick County (figs. 19A and B). Many of these areas are being developed for suburban living with lakefront property.



Figures 19 A & B

A. Above. Aerial photo of sinkholes at Sunny Point Military Ocean Terminal, 1956.
B. Left. Color-infrared photo of sinkholes near Boiling Springs Lake, 1998.

Not a Sinkhole - Another pond or lake-forming feature in North Carolina is a Carolina Bay. Although scientists are still trying to figure out how these features were made, they are very different from a sinkhole. They can be much larger than a sinkhole, but much shallower and do not overlie underground cavities. Most have an oval shape pointing in a northwest to southeast direction. Bay Tree Lake and White Lake are large Carolina Bays (fig. 20). Not all Carolina Bays form lakes; some have been drained for agriculture and some are swamps (fig. 20).

Figure 20

Color-infrared photo of water-filled and land-filled Carolina Bays. Several of the land-filled Carolina Bays are outlined. Bay Tree Lake and White Lake are large water-filled Carolina Bays.

How this affects you:

Our state's population growth and development, with its increasing housing and transportation needs, may be significantly affected by sinkholes. A sinkhole formed under I-40, a major transportation route near Wilmington, in the summer of 2001. Knowing the geology beneath the ground can assist in determining where surface geologic hazards may occur.

Even More Holes in the Ground
Abandoned Mines

North Carolina has a rich history of mining. Most underground mining in our state ended more than 100 years ago. There are literally hundreds of abandoned historic mines in North Carolina. We know where a lot of these abandoned historic mines are, but not all, and that can be a problem. The North Carolina Mining Act of 1971 requires mining operations (below and above ground) to acquire permits so there is now a record of where modern mining operations occur.

BELIEVE IT OR NOT

The first gold rush in the United States was here in North Carolina, not California. In 1799, a 12-year-old boy, Conrad Reed, discovered a 17-pound "yellow stone" near Charlotte. This was the beginning of our gold rush. A state historic site, the Reed Gold Mine, is now open to the public on the site of the old mine. Our gold rush ended when the gold started running out and the California Gold Rush began in 1849.

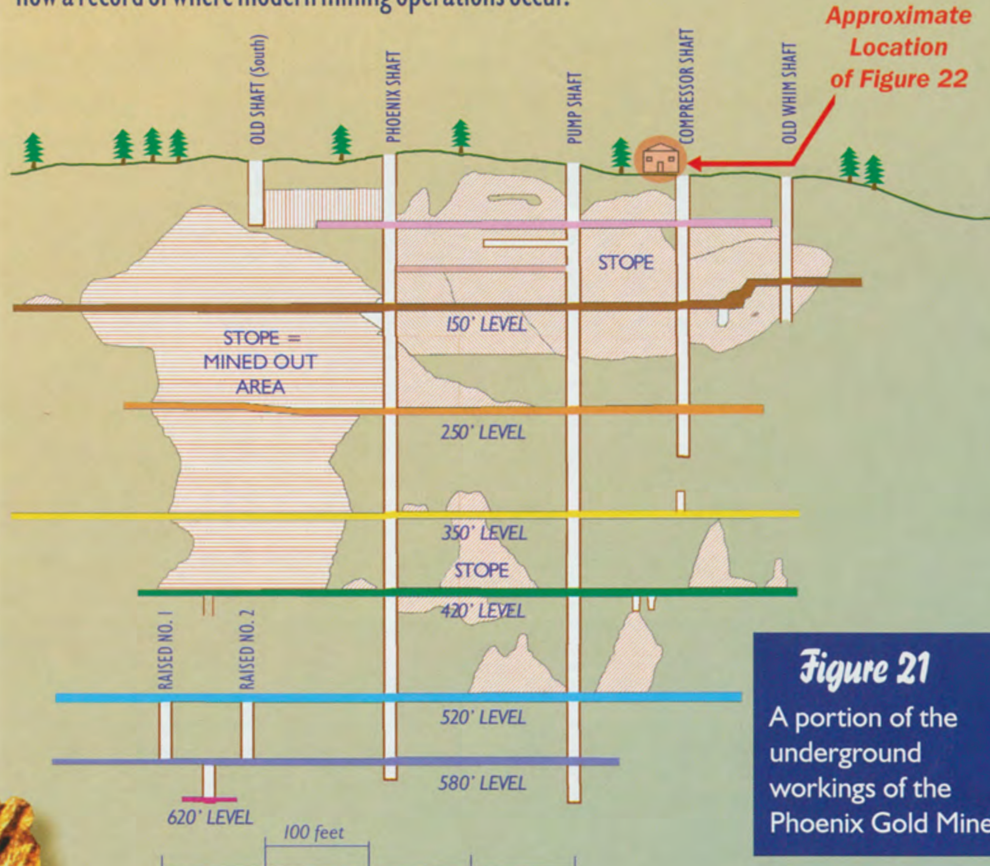


Figure 21
A portion of the underground workings of the Phoenix Gold Mine.

Another problem is that when you look at the surface of the ground, it is almost impossible to tell exactly in what direction and how deep mine workings go. Tunnels and shafts can extend hundreds of feet underground (fig. 21). Even if we know where an old mine starts, we do not always know where it goes underground. Old maps may be inaccurate and old mines may be inaccessible or too dangerous to enter. Modern technology, such as ground-penetrating radar, may be able to detect the extent of the mine workings. If these workings collapse underground, the land surface could sink, cracking building foundations, or the land could fall into the caved-in area forming a "sinkhole" or collapse hole.

Figure 22

Collapse hole above the old Phoenix Gold Mine (fig. 21) that formed in front of a Cabarrus County house on Feb. 8, 2000.

Abandoned mine collapses are relatively rare, but with urban development spreading quickly across our state, it is important to know the locations of old mines. Building above an abandoned mine can be dangerous if the mine is weak or near the ground surface. On Feb. 18, 2000, a collapse hole developed in the front yard of a house in Cabarrus County (fig. 22). The hole was above the old Phoenix Gold Mine, which closed in 1906. In the 1980s a suburban golf course community was built over the mine. Fortunately, the house was not built directly over the part of the mine that collapsed. The hole was only about 12 feet deep but the mine, according to historic records, went down much further (fig. 21).

In 1991, construction activities opened the entrance to a graphite mine on private property in Raleigh. The owner of the property pumped out groundwater from a portion of the mine (fig. 23). The structural timbers in the mine were dated to the late 1800s, indicating when the adit, a horizontal tunnel, was built. The owner was not aware of any underground mine workings on his property. Mining has been an important part of our state's economic development. As we have seen with the Phoenix Mine and graphite mine, we need to pay attention to where the past meets the present. If you suspect or find an entrance to an underground mine, DO NOT ENTER! Contact the North Carolina Geological Survey or local emergency management officials.

Figure 23

Homeowner is standing in a graphite mine discovered in 1991 on his property in Raleigh, NC.

Things to consider:

Before development of an area, for any purpose, a check of abandoned mine locations would be helpful for responsible development. This check would aid in avoiding future building damage and human injury because of sinking or collapse of the land above these mines. Most underground mines occur in the central Piedmont of North Carolina in a broad zone stretching between Charlotte and Greensboro.

How this affects you:

Just as with sinkholes, abandoned mines may become more of an issue with increasing population and development. Since most underground mining in North Carolina ended more than 100 years ago, there may be little or no surface evidence of underground mines.

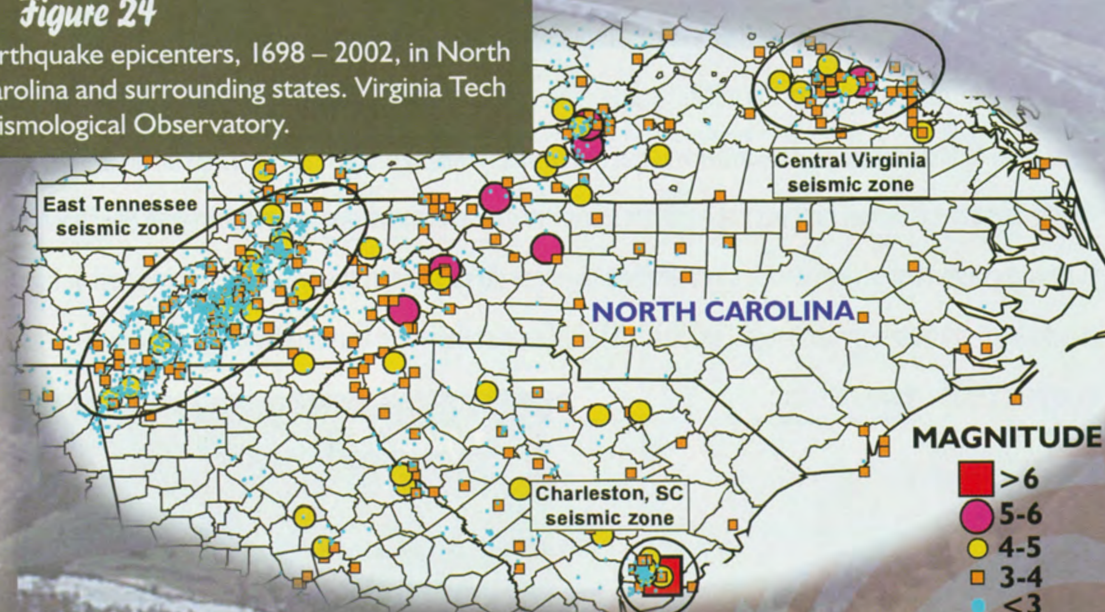
There's a Whole Lotta Shaking Going On!

Earthquakes

North Carolina has its share of earthquakes, but large, damaging seismic events are infrequent in our state. As you can see from the earthquake map, these seismic events originate in our state and surrounding states (fig. 24). Circles and squares represent earthquake epicenters and bigger symbols represent larger magnitude earthquakes. The effects of an earthquake cover a much larger area than the location of the dot or epicenter.

The long cluster of circles stretching from Tennessee through the edge of western North Carolina into northern Georgia is known as the East Tennessee seismic zone, or earthquake zone. Scientists are

Figure 24
Earthquake epicenters, 1698 – 2002, in North Carolina and surrounding states. Virginia Tech Seismological Observatory.



BELIEVE IT OR NOT

Damaging earthquakes have occurred in North Carolina. Below is a list some of the larger earthquakes that have originated in our state (table 1).

Table 1. Damaging Earthquakes in North Carolina from 1598 - 1989. *United States Geological Survey Professional Paper 1527.*

Year	Epicenter	Magnitude	Mercalli Intensity
1861	Near Wilkesboro, Wilkes County	5.0	VI
1916	Near Skyland, Buncombe County	5.2	VII
1926	Southern Mitchell County	5-6	VII
1957	Near Woodlawn, McDowell County	4.0	VI
1957	Buncombe County	3.7	VI
1957	Northwest Jackson County	3.9	VI
1981	Near Hendersonville, Henderson County	3.5	VI

studying this area to determine why so many earthquakes happen here. There are also small clusters of earthquakes in other areas of the southeast. On Dec. 9, 2003, a 4.5 magnitude earthquake near Richmond, Va. was felt in areas of Raleigh. This earthquake occurred in the Central Virginia seismic zone. The 1886 Charleston earthquake occurred in the Charleston, SC seismic zone.

It is very important to realize that 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 and the West Coast. In California there are many active faults where large, damaging earthquakes occur frequently. In contrast, there are no active fault zones in North Carolina. Earthquakes are more frequent in the western part of our state, but statewide they are relatively small, random and scattered events.

Figure 25

A general comparison of two scales for measuring earthquakes. The Magnitude Scale is an attempt to measure how much energy the earthquake releases. The Modified Mercalli Intensity Scale is a measure of how an earthquake "feels". Modified from www.fcs-net.com/biddled/scalesof.htm

MODIFIED MERCALLI SCALE		MAGNITUDE SCALE	
I. II.	Felt by almost no one. Felt by very few people.	2.5	Generally not felt, but recorded on seismometers.
III. IV. V.	Tremor noticed by many, but they often do not realize it is an earthquake. Felt indoors by many. Feels like a truck has struck the building. Felt by nearly everyone; many people awakened. Swaying trees and poles may be observed.	3.5	Felt by many people.
VI. VII.	Felt by all; many people run outdoors. Furniture moved, slight damage occurs. Everyone runs outdoors. Poorly built structures considerably damaged; slight damage elsewhere. Small landslides.	4.5	Some local damage may occur.
VIII. IX.	Specially designed structures damaged slightly, others collapse. All buildings considerably damaged, many shift off foundations. Noticeable cracks in ground.	6.0	A destructive earthquake.
X.	Many structures destroyed. Ground is badly cracked. Large landslides.	7.0	A major earthquake.
XI. XII.	Almost all structures fall. Very wide cracks in ground. Total destruction. Waves seen on ground surfaces, objects are tumbled and tossed.	8.0 and up	Great earthquakes.

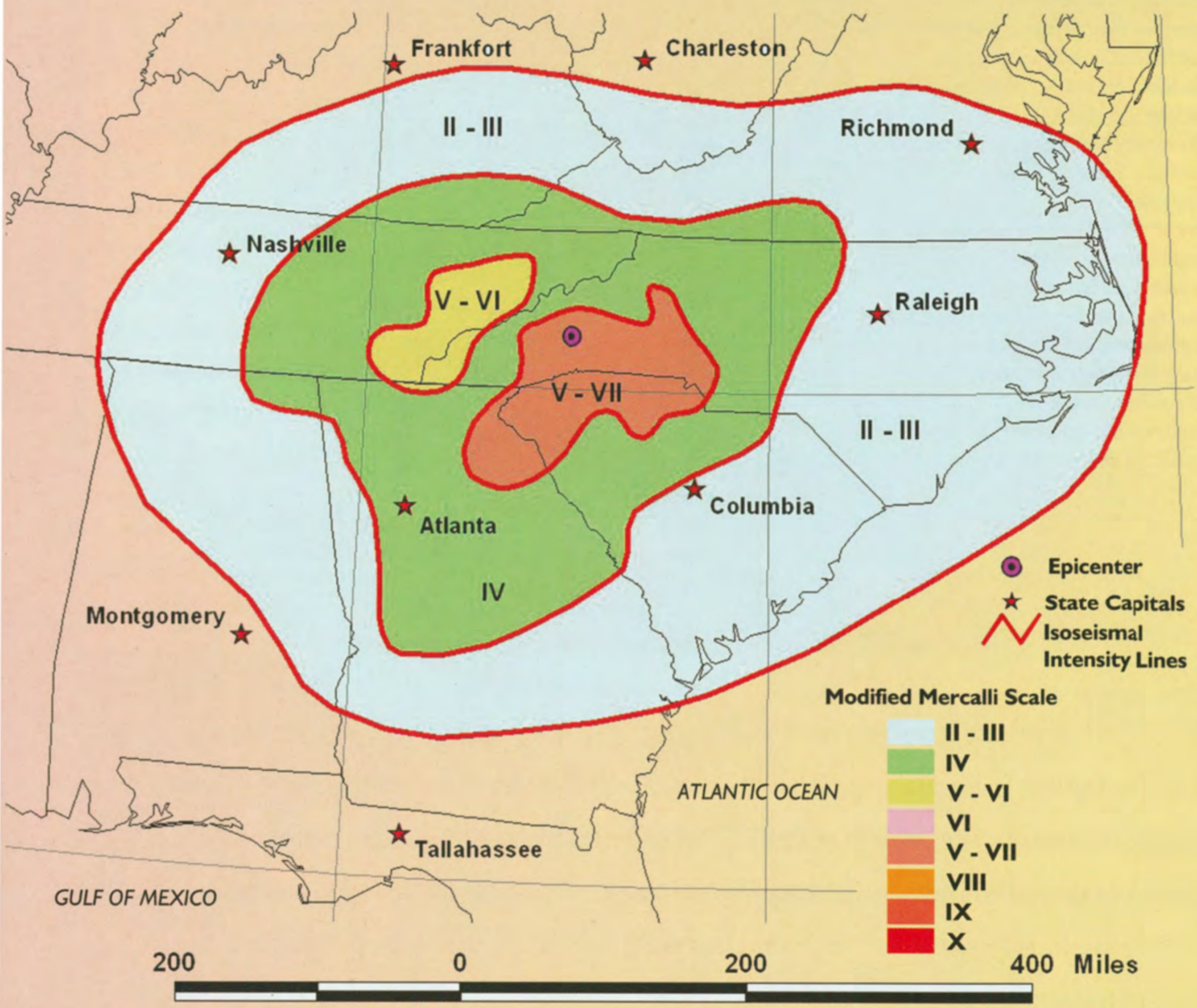
Scientists use various scales to determine the strength of an earthquake (fig. 25). Two of those scales are the Magnitude Scale and the Modified Mercalli Intensity Scale. The Magnitude Scale is an attempt to measure how much energy was released by the earthquake and is the number that most people associate with an earthquake, for example "magnitude 3." The Modified Mercalli Intensity Scale describes how earthquakes "feel" and how much destruction the earthquake causes. This scale has twelve levels designated by Roman numerals I – XII (one through twelve), to symbolize the amount of damage felt by the earthquake. Many factors determine the intensity of an earthquake at the surface of the earth, such as the depth where the earthquake originates and what kinds of rock and soil are at the surface.

There have been a few strong earthquakes in our mountain region in the last 100 years. As referenced in the United States Geological Survey Professional Paper 1527, in 1916 there was a magnitude 5.2 earthquake, with an intensity of VII (7) on the Modified Mercalli Intensity Scale, near Skyland in Buncombe County (fig. 26). Damage descriptions from the earthquake include "Chimneys were thrown to the ground, windowpanes cracked and people rushed into the streets." The Modified Mercalli map of intensity shows how far the effects of the 1916 earthquake were felt (fig. 26).

In 1886 there was a large earthquake centered in Charleston, S.C. It was estimated to be a magnitude 6.7, with an intensity of X (10) on the Modified Mercalli Intensity Scale (fig. 27). This earthquake was felt up and down the East Coast and throughout the Midwest. It was the most damaging earthquake in the Southeast and one of the largest earthquakes in the eastern United States in historical times. Compare the area

Figure 26

The Modified Mercalli map of the 1916 earthquake centered in Skyland, North Carolina. An isoseismal map indicates areas of equal (iso) shaking (seismicity). Modified from USGS Professional Paper 1527.



affected by the Charleston earthquake to the area covered by the 1916 North Carolina earthquake. Here in North Carolina the effects of the Charleston 1886 earthquake ranged from a V (5) to VII (7) on the Modified Mercalli Intensity Scale. Earthquakes happen every day around the world. We do not hear about most of them in the news because they are small or they shake isolated areas where few people live.

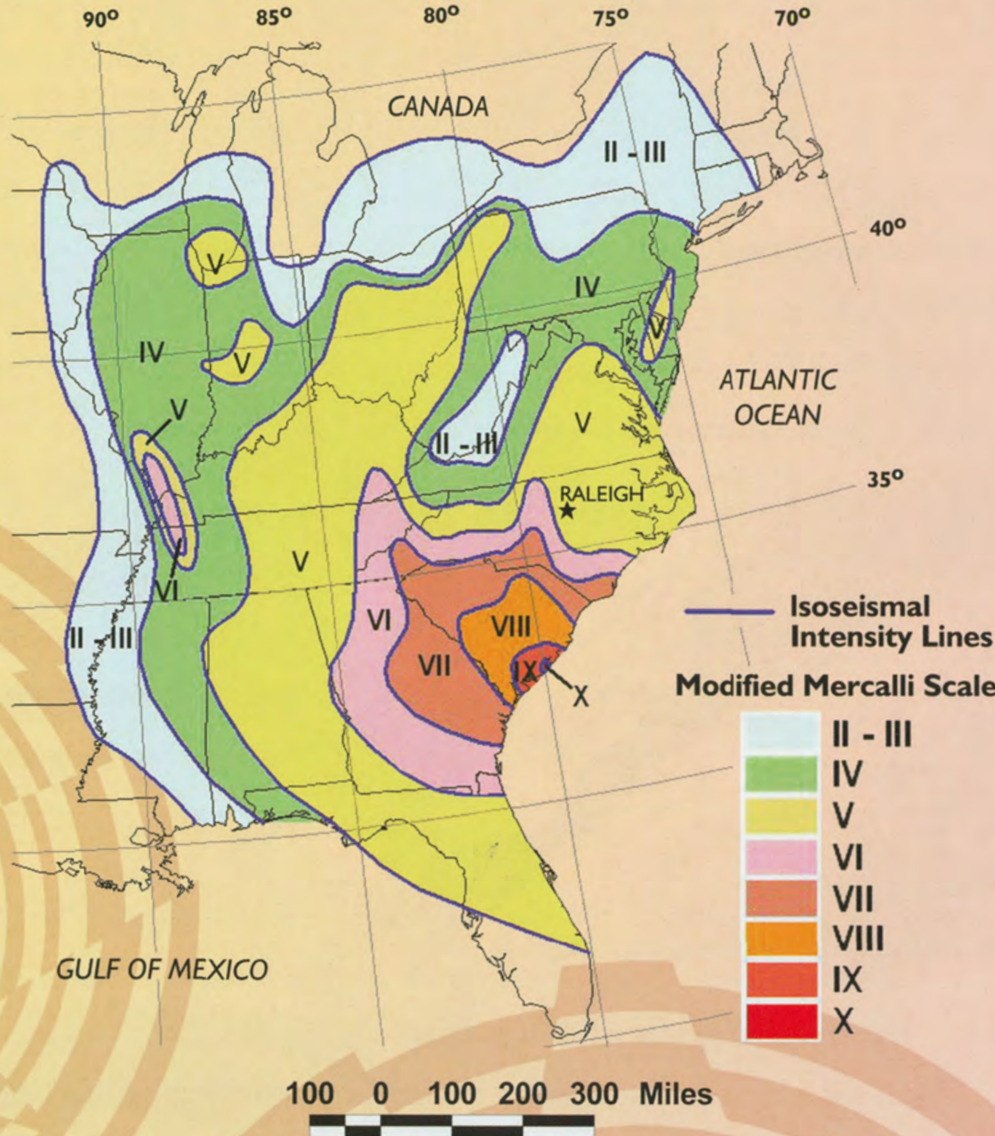


Figure 27

The Modified Mercalli map of the 1886 earthquake centered in Charleston, S.C. This earthquake was "felt" in a much larger area than the 1916 earthquake (fig. 26). An isoseismal map indicates areas of equal (iso) shaking (seismicity). Modified from USGS Professional Paper 1527.

Things to consider:

Although strong earthquakes here in North Carolina are infrequent, proper construction techniques need to be followed. An earthquake of magnitude 5 or greater could block major transportation routes in the mountains and cause structural damage elsewhere.

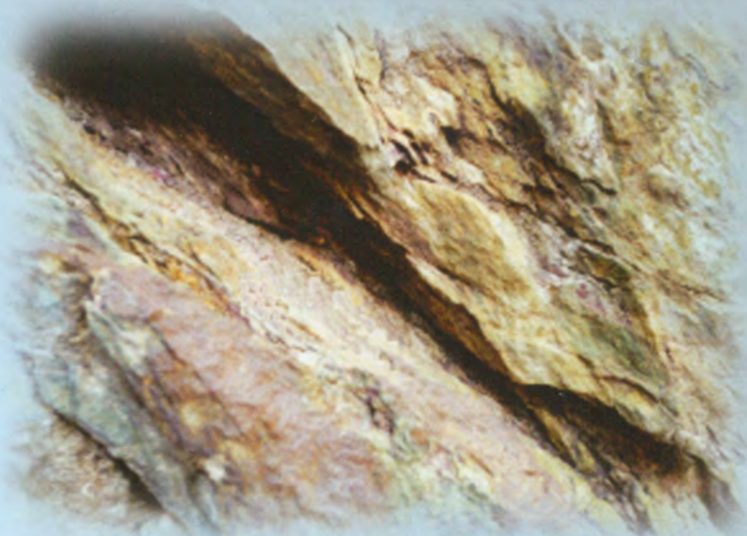
How this affects you:

Many of the larger earthquakes in North Carolina occurred when the state was more rural. Recent development includes buildings and infrastructure such as road and power networks. Modern building codes take into account the possibility of an earthquake but many older buildings were not constructed to withstand violent shaking.

Other Geological Hazards Affecting North Carolina:

Acid-Producing Rock

North Carolina has several different types of rock and soil that can produce acid when exposed to air and water. While releases of acid are easily controlled, acidic water can be harmful to plants and animals if left unchecked. Also, these rock types may be more susceptible to landslides. The North Carolina Department of Transportation pays close attention to road construction in areas of acid-producing rock. Acid-producing rocks occur in scattered areas throughout North Carolina.



Shrink/Swell Clays

As the name suggests, shrink/swell clays expand when wet and contract when dry. The constant expanding and contracting of clays can damage roads, building foundations and other structures if not properly engineered. Shrink/swell clays occur in limited areas of North Carolina.

Groundwater Contamination

Most rocks in North Carolina contain trace amounts of naturally occurring metals or radioactive minerals such as arsenic and uranium. Many of these rocks may contain amounts harmful to humans over extended time periods. Geologists and health experts are just beginning to understand the complex relationships that rocks, soil and groundwater play in human health.

Conclusion

There are a wide variety of geologic hazards here in North Carolina because of the many types of rocks and natural settings from the mountains to the sea. Each area of our state has a unique combination of human activities and geologic settings that do not always provide for the safest environment. With proper research, education and planning, many of these geohazards can be dealt with in a safe manner. There will always be acts of nature that are unforeseen, but with knowledge, preparation and continuing public education the loss of life and property can be minimized. To that end, the North Carolina Geological Survey, in association with other federal, state and local agencies, is investigating many of these geologic hazards to provide information for public planning and the development of our growing state.

Web Sources:

Earthquake 101

www.fcs-net.com/biddled/scalesof.htm

Earth Science Week

www.earthsciweek.org

National Aeronautics and Space Administration

www.nasa.gov/lb/missions/earth/f_lidar.html

National Climate Data Center

http://lwf.ncdc.noaa.gov/oa/ncdc.html

National Weather Service Raleigh

www.erh.noaa.gov/rah

North Carolina Division of Emergency Management

www.ncem.org

North Carolina Floodplain Mapping Program

www.ncfloodmaps.com

North Carolina Geological Survey

www.geology.enr.state.nc.us

North Carolina State Climate Office

www.nc-climate.ncsu.edu/climate

United States Geological Survey

www.usgs.gov

Virginia Tech Seismological Observatory

www.geol.vt.edu/outreach/vtso

Reference:

Stover, C.W. and Coffman, J.L., 1993, Seismicity of the United States, 1568-1989 (Revised), United States Geological Survey Professional Paper 1527, 418p.

Curriculum Correlation to the North Carolina Science Standard Course of Study, 2004 Revision

EARTH / ENVIRONMENTAL SCIENCE Grades 9 - 12

The Earth/Environmental science curriculum focuses on the function of Earth's systems. Emphasis is placed on matter, energy, plate tectonics, environmental awareness, materials availability and the cycles that circulate energy and material through the earth system. Learners will study natural and technological systems. The program strands and unifying concepts provide a context for teaching content and process skill goals. All goals should focus on the unifying concepts:

- Systems, Order and Organization
- Evidence, Models and Explanation
- Constancy, Change and Measurement
- Evolution and Equilibrium
- Form and Function

Strands: The strands are: Nature of Science, Science as Inquiry, Science and Technology and Science in Personal and Social Perspectives. Theses strands provide the context for teaching of the content goals and objectives.

COMPETENCY GOAL 1: The learner will develop abilities necessary to do and understand scientific inquiry in the earth and environmental sciences.

Objectives

1.03 Evaluate the uses of satellite images and imaging techniques in the earth and environmental sciences.

1.05 Analyze reports of scientific investigations and environmental issues from an informed scientifically literate viewpoint including considerations of:

- Appropriate sample.
- Adequacy of experimental controls.
- Replication of findings.
- Alternative interpretations of the data.

1.06 Identify and evaluate a range of possible solutions to earth and environmental issues at the local, national and global level including considerations of:

- Interdependent human and natural systems.
- Diverse perspectives.
- Short and long-range impacts.
- Economic development, environmental quality and sustainability.
- Opportunities for and consequences of personal decisions.
- Risks and benefits of technological advances.

COMPETENCY GOAL 2: The learner will build an understanding of lithospheric materials, tectonic processes and the human and environmental impacts of natural and human-induced changes in the lithosphere.

Objectives

2.01 Analyze the dependence of the physical properties of minerals on the arrangement and bonding of their atoms.

2.03 Investigate and analyze the processes responsible for the rock cycle:

- Analyze the origin, texture and mineral composition of rocks.
- Trace the path of elements through the rock cycle.
- Relate rock formation to plate tectonics.

- Identify forms of energy that drive the rock cycle.
- Analyze the relationship between the rock cycle and processes in the atmosphere and hydrosphere.

2.05 Create and interpret topographic, soil and geologic maps using scale and legends.

2.06 Investigate and analyze the importance and impact of the economic development of earth's finite rock, mineral, soil, fossil fuel and other natural resources to society and our daily lives:

- Availability.
- Geographic distribution.
- Conservation/Stewardship.
- Recycling.
- Environmental impact.
- Challenge of rehabilitation of disturbed lands.

2.07 Analyze the sources and impacts of society's use of energy.

- Renewable and non-renewable sources.
- The impact of human choices on Earth and its systems (e.g., global warming, smog, thermal pollution).

COMPETENCY GOAL 3: The learner will build an understanding of the origin and evolution of the earth system.

Objectives

3.01 Assess evidence to interpret the order and impact of events in the geologic past:

- Relative and absolute dating techniques.
- Statistical models of radioactive decay.
- Fossil evidence of past life.
  - Uniformitarianism.
  - Stratigraphic principles.
  - Divisions of geologic time.
  - Origin of the earth system.
  - Origin of life.

3.02 Evaluate the geologic history of North Carolina.

COMPETENCY GOAL 4: The learner will build an understanding of the hydrosphere and its interactions and influences on the lithosphere, the atmosphere and environmental quality.

Objectives

4.03 Analyze the mechanisms that produce the various types of shorelines and their resultant landforms:

- Nature of underlying geology.
- Long and short-term sea-level history.
- Formation and breaking of waves on adjacent topography.
- Human impact.

4.05 Investigate and analyze environmental issues and solutions for North Carolina's river basins, wetlands and tidal environments:

- Water quality.
- Shoreline changes.
- Habitat preservation.

COMPETENCY GOAL 5: The learner will build an understanding of the dynamics and composition of the atmosphere and its local and global processes influencing climate and air quality.

Objectives

5.03 Analyze global atmospheric changes including changes in CO_2, CH_4 and stratospheric O_3 and the consequences of these changes:

- Climate change.
- Changes in weather patterns.
- Increasing ultraviolet radiation.
- Sea level changes.

PHYSICAL SCIENCE - Grades 9-12

The Physical Science curriculum is designed to continue the investigation of the physical sciences begun in earlier grades. The Physical Science course will build a rich knowledge base to provide a foundation for the continued study of science. The investigations should be approached in both a qualitative and quantitative manner in keeping with the developing mathematical skills of the students. The unifying concepts and program strands provide a context for teaching content and process skill goals. All goals should focus on the unifying concepts:

- Systems, Order and Organization
- Evidence, Models and Explanation
- Constancy, Change and Measurement
- Evolution and Equilibrium
- Form and Function.

Strands: The strands are: Nature of Science, Science as Inquiry, Science and Technology and Science in Personal and Social Perspectives. They provide the context for teaching of the content goals and objectives.

COMPETENCY GOAL 2: The learner will construct an understanding of forces and motion.

Objectives

2.01 Measure and mathematically/graphically analyze motion:

- Frame of reference (all motion is relative - there is no motionless frame).
- Uniform motion.
- Acceleration.

2.02 Investigate and analyze forces as interactions that can change motion:

- In the absence of a force, an object in motion will remain in motion or an object at rest will remain at rest until acted on by an unbalanced force.
- Change in motion of an object (acceleration) is directly proportional to the unbalanced outside force and inversely proportional to the mass.
- Whenever one object exerts a force on another, an equal and opposite force is exerted by the second on the first.

COMPETENCY GOAL 3: The learner will analyze energy and its conservation.

Objectives

3.01 Investigate and analyze storage of energy:

- Kinetic energy.
- Potential energies: gravitational, chemical, electrical, elastic, nuclear.
- Thermal energy.

3.02 Investigate and analyze transfer of energy by work:

- Force.
- Distance.

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