ASSOCIATION OF ENVIRONMENTAL
& ENGINEERING GEOLOGISTS
-Carolinas Chapter

# Field Trip Guide
# Geological Hike along the Haw River, Chatham County, NC

## Spring Field Trip
## Saturday, April 22, 2017

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**Introduction**

This field trip involves hikes along two separate stretches of the Haw River within the Lower Haw River State Natural Area in the vicinity of the HWY 64 bridge crossing. The Lower Haw River State Natural Area is administered by the NC State Parks and includes 1,100 acres of land along both sides of the Haw River in Chatham County extending from the Town of Bynum to Jordan Lake.

The hike presents results of detailed geologic mapping by the NC Geological Survey in Chatham County and interpretations of various outcrops and landforms along the river. This portion of the Haw River is located within the Hyco Formation of the Carolina terrane. Generally, the Hyco Formation includes metamorphosed volcanic, volcaniclastic-sedimentary and intrusive rocks associated with a volcanic island arc active ca. 630 – 612 Ma.

The text for the guide is written for non-geologists and is intended to be part of a to-be-completed laypersons guide to the geology of the Haw River from its headwaters in Guilford County to Jordan Lake.

A simple fracture trace study of the outcrops south of the HWY 64 bridge was also conducted and is presented at the end of the guide.

**Geologic Trail Guide**

**West Bank of the Haw River, North of HWY 64 Bridge - Lower Haw River State Natural Area**

Parking: Park in the Lower Haw River State Natural Area gravel parking lot on the west side of the Haw. The lot is accessed from the eastbound lane of HWY 64 off of Foxfire Trace. River Access Road, which leads to the parking lot, is a left turn immediately off of Foxfire Trace.

Distance and difficulty of hike: From the Lower Haw River State Natural Area gravel parking lot, the round-trip is a little less than 1.5 miles. The trail is accessed by walking north from the parking lot under HWY 64. The trail includes areas of roots, loose and slippery rocks and may require the crossing of small streams. Hiking boots are recommended. Downed trees may require stooping or climbing at times. The trail is not regularly maintained.

What you will see:

- Outcrops of metamorphosed dacites, andesites and basalts of the Hyco Formation
- Possible historic quarry area
- Example of steeply incised Piedmont valley
- Interpreted evidence of brittle faulting

A generalized geologic map of the Lower Haw River State Natural Area is provided as Figure 1.

The geologic field trip of the northwest bank of the Haw River, begins by walking north, under the HWY 64 bridge. A topographic map with stop locations is provided as Figure 2. It is recommended that you acquire a map of the Lower Haw River State Natural Area indicating the extent of State-owned land before starting your trip. To avoid becoming lost or disoriented, it is recommended that the companion map (Figure 2) and the park map be referenced frequently during the hike. Please respect private property and remain within State-owned lands.

Unlike a guide to trees and plants, geologic features are often "hiding" in plain sight. The rocks may be covered in leaves, vines, and/or moss. Natural weathering hides the internal textures of the rock making most of the rock on the trail look the same. To get the most out of this trail guide, the user needs to be a "rock" detective and notice subtle differences in the shape of the rock outcrop and look into the surface of the rock. Take time to look closely at the rock from many angles and up close (within 1 foot of your eyes).

**Trail Guide and Points of Interest**

Begin the tour by hiking toward HWY 64, walk under the bridge and continue along the trail toward the northwest.

The parking lot and the first part of the trail traverses over metamorphosed andesitic to dacitic lavas and tuffs of the Hyco Formation of the Carolina terrane (unit Zhadlt on Figure 2). Generally, the Hyco Formation includes metamorphosed volcanic, volcaniclastic-sedimentary and intrusive rocks associated with a volcanic island arc that was active ca. 630 – 612 million years ago.

**Stop W1 – Large outcrop area of metamorphosed dacites**

This area has a large outcrop of metamorphosed dacite with prominent joint faces parallel to the river. It is suspected that this location may have been used as a small-scale quarry as a stone source for the foundations of former bridges over the Haw.

Dacite is a type of lava that is felsic (rich in silica and aluminum) in chemical composition. Dacite has a little more silica and aluminum (and less iron, magnesium and calcium) compared to the andesitic and basaltic lavas we will see later on this trail. Because dacite has more silica, the rocks are generally more resistant to erosion than other rock types in the area and form some of the taller hills and peaks in the area. A fresh surface of the rock shows a greenish-gray, fine-grained (aphanitic) groundmass with whitish-colored plagioclase crystals (phenocrysts)(Figure 3). Edges of freshly broken pieces, can be very sharp and draw blood if not careful. The sharp edges are a testament to the chemical composition and of how the rock formed over 630 to 612 million years ago.

Lavas are formed when molten rock (magma) extrudes onto the surface of the Earth. The magma cools very quickly, sometimes forming volcanic glass. This volcanic glass (obsidian) will devitrify (change from glass to microscopic minerals of quartz and feldspar over time). The abundance of microscopic quartz in the dacite makes the rock very hard and causes it to break into sharp-edged fragments. Because of these naturally sharp edges, Native Americans have utilized felsic lavas and tuffs for making projectile points all over the Carolina terrane. If you explore around the outcrop, you may observe areas with abundant lines in the rock. These lines are called flow banding. Flow banding forms as the lava was flowing out of the volcanic vent. Before leaving this location, take a moment to notice the shape of the outcrops. Hopefully you will notice that there are many angular (blocky-like) sides – kind of like a bunch of boxes of varying shapes and sizes stacked on top of one another. Keep this in mind when we discuss the next stop on the trail.

**Stop W2 – Outcrops of metamorphosed felsic tuffs**

This point of geologic interest consists of two locations, stops W2a and W2b. Stop W2a is a small outcrop area just off the trail at the toe of the slope. Stop W2b is a large outcrop area extending across the river.

The rock type exposed on this part of the trail are metamorphosed tuffs (part of the andesitic to dacitic lavas and tuffs unit – Zhadlt on Figure 2). Tuff is the rock name for volcanic ash that has hardened into rock.

As you walk from stop W1, the trail will turn toward the river and descend into a lower portion of the floodplain. At this location, pause, and If you want to observe a good example of a tuff up close you can visit stop W2a.

Stop W2a: From the location where the trail turns toward the river, turn around and retrace your steps a few feet. An outcrop area of lichen-covered and fin-shaped metamorphosed tuffs (Figure 4) are visible a short walk to the southwest away from the river. To find this outcrop, you will need a keen eye and "rock detective" skills. You will have to scan the slope and be willing to walk off the trail into the woods.

Notice that the overall shape of this outcrop is fin-shaped (like a fin of a shark) sticking out of the ground and the slope. Compared to the blocky nature of the outcrops at stop W1, the outcrops of tuffs are thin and fin-shaped. This shape is directly related to the geologic history of the rock (see discussion after stop W2b text).

Stop W2b:
Continue along the trail and stop at the first area of large outcrop that extends across the river. To the keen observer, looking in the river, you will notice rounded fin-shapes of rock (Figure 5a and 5b). These are more fin-shaped compared to the dacites at stop W1. These are tuffs like stop W2a.

***So why are these outcrops fin-shaped?***

Tuff, the volcanic rock formed from the consolidation of volcanic ash, was originally deposited in nearly flat-lying layers around 630 to 612 million years ago. Around 600 million years ago, the volcanic arc that carried these piles of tuffs and lavas collided with another island that caused the rocks to be folded and undergo low-grade metamorphism (changed through heat and pressure). Known as the Virgilina deformation (Glover and Sinha, 1973), the rocks in the Haw River area were folded into a set of large anticlines and synclines (Figure 6a and 6b) and developed an almost vertical foliation (Hibbard et al., 2002). The foliation that formed during the Virgilina deformation is visible in many of the volcanic rocks in the Haw River area. During the folding, the layers of tuffs and lavas were essentially turned on their side. Many of the finned-shaped rock outcrops along the Haw River are actually the layers of tuff or lava standing on end.

**Stop W3 - Outcrops of andesite and basalt in river**

Continue walking northwest along the trail. You will hopefully notice that outcrop is not easily observed in the river soon after leaving stop W2. Stop W3 is evident when you begin to see abundant rock in the river again. Somewhere along the way from stop W2 to stop W3, you crossed a geologic contact into another rock unit – andesitic to basaltic lavas (figure 2). The andesite to basalt rock types tend to have outcrops that are more blocky in shape compared to the fin shape of tuffs. We will look at the andesites and basalt more closely a little further up river. As you walk toward stop W4, take note of the rock debris lying around the trail. You may notice that some of the rock is greenish in color.

**Stop W4 – Stream incision and an example of steep river valley walls on the west-side (east facing slope) of the Haw River in contrast to the gently sloped east-side of the river**

The Haw River is an incised river, meaning that the river, over tens-of-thousands to millions of years, has cut down (incised) into the land. This occurred because the Piedmont has been slowly uplifting (rising) and subsequently eroding for the past 66 million years. The Piedmont experienced periods of slow uplift and erosion punctuated by periods of relatively rapid uplift and erosion. The uplift of the Piedmont is due in part to isostatic forces in the Earth's crust. Isostatic forces are similar to the buoyancy of a boat in water. The heavier the cargo, the lower the boat sits in the water. Conversely, the lighter the cargo the higher the boat sits in the water. The continental plates essentially float on top of the mantle. As rock is removed by erosion, the Earth's crust will react by uplifting a proportional amount - similar to a boat that will "sit high in the water" when its cargo is removed.

During times of relatively slow and gradual uplift, streams and rivers meander through their floodplain and erode the land surface into broad valleys. During times of relatively rapid uplift, streams and rivers become entrenched in their floodplains. This entrenchment of the rivers causes them to down-cut and incise their channels as the land surface is uplifted. The Haw River is an incised river with steep banks in many places.

The timing of the uplift and erosion of the Piedmont is not well understood by geomorphologists (scientists who study landforms). Generally, it is believed that the Piedmont was uplifted differentially (some parts uplifted faster than others) and entered a period of relatively rapid uplift and subsequent erosion about 5 million years ago. Recent research along the Potomac River in northern Virginia indicates that the deep incision of some Piedmont rivers may be geologically recent and have incised 30- to 60-foot (10- to 20-meter) gorges beginning as recently as 35,000 years ago (Reusser et al., 2004). The Earth was in the last Ice Age 12,000 to 35,000 years ago and during this time the northern portion of the North American continent was covered in ice. Global sea level was much lower. North Carolina had a climate wetter than today with abundant rainfall and snow. A wetter climate, coupled with lower global sea level, may have caused the gradients of Piedmont rivers and streams to greatly increase. The increased gradients subsequently increased the erosive power allowing the rivers to carve deep stream valleys in a geologically short period.

**Why is the west side of the river so steep compared to the east side?**

As with many things in geology, the cause of a steeper river valley walls on the west-side (east facing slope) of the Haw River in contrast to the gently sloped east-side of the river could be interpreted in different ways. Here we present one possible explanation.

One possible theory of why this side of the Haw is steeper than the east side of the River involves freeze-thaw action. Freeze-thaw action is the process in which water trapped in cracks in rock expands on freezing and splits the rock. Over hundreds and thousands of years, freeze-thaw action can literally break down a mountain.

Eastern- and northeastern-facing slopes of the Piedmont generally stay in the shade during the day and do not heat-up as much compared to the western- and southwestern-facing slopes. These shady slopes provide a cooler local climate slightly different than the other side of the river. This is one of the reasons why plants typical of the mountains can sometimes naturally occur on the eastern- and northeastern-facing slopes of the Piedmont (e.g. Mountain Laurel). The shady slope provides a local climate similar to the mountains.

During the last Ice Age, North Carolina's climate was much colder. Near-freezing temperatures were likely the norm even during the day time for a large portion of the year. The eastern and northeastern side of the river received enough sun light to heat up just enough to melt ice formed in the cracks of the rock. At night the water in the cracks re-froze splitting the rock a little more. This freeze-thaw cycle over hundreds and thousands of years could have broken-up the rock on the eastern and northeastern side of the river allowing the rock fragment to more quickly erode and be washed down the river compared to the rock on the western and southwestern side of the river. (Scientists describe this process as asymmetric slope-wasting arising from microclimatic differences on opposing valley side slopes.)

**Mountain Laurel's link to the recent geologic history of North Carolina**

This area is part of the Haw River Levees and Slopes Natural Area designated by the NC Natural Heritage Program. It is known for its scenic value, abundant plants, birds and other wildlife. One of the interesting plant types is Mountain Laurel. Mountain Laurel is common in the mountains but occurs less commonly in the Piedmont. When present, Mountain Laurel is usually found on slopes that receive relatively less direct sunlight, typically on steep north or northeast facing slopes with abundant shade. Because Mountain Laurel likes the cooler microclimate (slightly different climate compared to nearby areas), it thrives in the shady areas provided by the steep slope. The steep slope likely formed due to the continuous freeze-thaw cycle during the Pleistocene Period (1.8 million years ago to 11,000 years ago) discussed above. Most likely, Mountain Laurel was present over much of the Piedmont during the Pleistocene Period. The Mountain Laurel shrubs you see here on the steep slopes of the Haw are the ancestors of those plants from 11,000 years ago. As North Carolina's climate changed from a cooler climate after the end of the last ice age, only the Mountain Laurel in these shady steep slopes persisted.

**Stop W5 - Jointed outcrops of andesite and basalt**

This area has abundant outcrop of andesitic to basaltic lavas with a variety of textures and features including joints, hyaloclastic texture and amygdules.

Many of the outcrops display a geologic feature called jointing or joints. Joints are planar fractures in rock in which no appreciable movement has occurred. As you walk, try to find rock outcrops that have flat sides. The flat sides are the joint surfaces.

The lava here was originally formed as lava flows on the surface of the Earth or underwater. The lava flows were later buried by other rock types deep in the earth. When deep in the earth, the rock was under great pressure from the weight of the overlying rock. Over many millions of years, as the land surface uplifted and the rock above was eroded away, the pressure on the rock mass was greatly reduced allowing the rock to expand and crack. These expansion cracks are what geologists call joints. Some joints may also form from the faulting of rock. Joints often occur in sets perpendicular to one another. Streams and rivers often flow along zones of weakness caused by joints (or faults) in rocks.

Some of the outcrop faces have very rough and bumpy surfaces (Figure 7). The outcrop surfaces are rough because of differential weathering of a relict volcanic texture called hyaloclastic texture. Hyaloclastic texture forms when lava erupts into water or flows into water and quickly chills. The rapid chilling causes the lava to fragment into multiple pieces ranging from a few millimeters to meters in size. Sometimes the fragments appear to "fit" together like a jigsaw puzzle piece (Figure 8). In between the coherent fragments of lava, the lava chills so quickly that it is pulverized to clay-sized material consisting of mainly glass fragments. The glassy matrix devitrifies over time (changes from glass to microscopic minerals). When exposed to the weathering, the once glassy matrix weathers faster than the more resistant lava fragments. This differential weathering causes the lava clasts to stand out in positive relief while the fine-grained matrix weathers in negative relief – thus causing the very rough and bumpy surface.

The heavily-jointed outcrops in the river can be explored with care and display abundant amygdules on some surfaces. Amygdules are mineral-filled (often quartz) air pockets in the rock. Look for areas of the rock that have small 2 to 5 mm white-colored areas that are slightly raised (feel bumpy when rubbed with your finger) (Figure 9). An andesite or basalt with amygdules is called an amygdaloidal andesite or amygdaloidal basalt.

The trail continues to stop W6, but becomes more challenging. The trail is very rocky with many obstacles of tree roots and some downed trees.

**Stop W6 – Area of faulting in the andesites and basalts**

This area is on a steep slope of the river with abundant Mountain Laurel bushes. Abundant outcrop of andesites and basalts are present. Several boulders with flat surfaces are present lying near the trail. Look closely at the flat surfaces and you will notice a white-colored coating on the rocks (Figures 10 and 11). This coating is the mineral quartz. The quartz likely precipitated along an ancient fault zone active during the split-up of the supercontinent Pangea. So, you are standing in the center of an ancient geologic fault that was active in the Mesozoic era (245 to 66 million years ago).

The faulting that occurred during the breakup of Pangea formed many large and small faults. Faults are zones of broken-up rock and are often preferred pathways for migration of hydrothermal fluids and/or diabase. Hydrothermal fluids may contain abundant dissolved silica. With time, the silica in the fault zones precipitated out and formed quartz-lined fault zones or fractures. This faulting (commonly referred to as Mesozoic faulting by geologists) is also speculated to be responsible for the multitude of lineaments visible on Figure 12. (A lineament is a linear (relatively straight) topographic feature. A lineament can be interpreted to reflect characteristics of the underlying rocks.) Figure 12A is a hillshade elevation map created using LiDAR elevation data. It shows the Haw River and Jordan Lake prominently. If you look closely, you will also notice multiple thin linear features cutting across the county in a northwest to southeast trend. Geologic field mapping indicates that many of these linear features are ancient faults and/or diabase dikes (Figure 12B). Diabase is an igneous intrusive rock of Jurassic age and mafic composition that intruded the east coast during the rifting of Pangea. The flow directions of many of the streams and tributaries of the Haw (and parts of the Haw itself) may be controlled by the presence of faults originally formed during the breakup of Pangea.

The Haw River is following the “grain” of the rock which is probably controlled by joints and/or faults. See if you can pick out the sets of nearly vertical and perpendicular joints in the outcrop. Are some of the joint sets similar to the flow direction of the Haw River?

References:

Glover. L., and Sinha, A., 1973, The Virgilina deformation, a late Precambrian to Early Cambrian (?) orogenic event in the central Piedmont of Virginia and North Carolina, American Journal of Science, Cooper v. 273-A, pp. 234-251.

Hibbard, J., Stoddard, E.F., Secor, D., Jr., and Dennis, A., 2002, The Carolina Zone: Overview of Neoproterozoic to early Paleozoic peri-Gondwanan terranes along the eastern flank of the southern Appalachians: Earth Science Reviews, v. 57, n. 3/4, pp. 299-339.

Reusser, L.J., Bierman, P.R., Pavich, M.J., Zen, E., Larsen, J., and Finkel, R., 2004, Rapid late Pleistocene incision of Atlantic passive-margin river gorges. Science, v. 305, no. 5683, pp. 499-502.

**Geologic Trail Guide**

**East Bank of the Haw River, South of HWY 64 Bridge - Lower Haw River State Natural Area**

Parking: Park in the small Lower Haw River State Natural Area gravel parking lot on the east side of the Haw. The lot is accessed from the eastbound lane of HWY 64 and is a sharp right-hand turn immediately after passing over the Haw River. Traffic may be heavy at times. Extreme caution is necessary during entry and exit of the parking area.

Distance and difficulty of hike: From gravel parking lot, the round-trip is a little less than 2 miles. The trail is accessed by walking south from the parking area into the flood plain of the Haw River. The trail includes areas of roots, loose and slippery rocks and may require the crossing of small streams. Hiking boots are recommended. Downed trees may require stooping or climbing at times. The trail is not regularly maintained.

What you will see:

- Outcrops of metamorphosed dacites and andesites of the Hyco Formation
- Outcrops of metamorphosed conglomerates of the Hyco Formation
- Alluvium (floodplain) deposits from the Haw River and tributaries

A generalized geologic map of the Lower Haw River State Natural Area is provided as Figure 1. A topographic map with stop locations is provided as Figure 2. An aerial photograph with geologic points of interest for this section of the river is provided as Figure 13. It is recommended that you acquire a map of the Lower Haw River State Natural Area indicating the extent of State-owned land before starting your trip. To avoid becoming lost or disoriented, it is recommended that the companion map (Figure 2 and Figure 13) and the park map be referenced frequently during the hike. It may be helpful to use your smart phone maps to aid in navigation. Please respect private property and remain within State-owned lands.

Unlike a guide to trees and plants, geologic features are often “hiding” in plain sight. The rocks may be covered in leaves, vines, and/or moss. Natural weathering hides the internal textures of the rock making most of the rock on the trail look the same. To get the most out of this trail guide, the user needs to be a “rock” detective and notice subtle differences in the shape of the rock outcrop and look into the surface of the rock. Take time to look closely at the rock from many angles and up close (within 1 foot of your eyes).

**Trail Guide and Points of Interest**

The geologic trail guide of the east bank of the Haw River begins by walking toward the south down the embankment for the highway. At the base of the embankment, turn toward the river and walk to the edge of the Haw just downstream of the bridge supports.

The bedrock in this area of the trail traverses over metamorphosed andesitic to dacitic lavas and tuffs of the Hyco Formation of the Carolina terrane (unit Zhadlt on Figure 2). Generally, the Hyco Formation includes metamorphosed volcanic, volcaniclastic-sedimentary and intrusive rocks associated with a volcanic island arc that was active ca. 630 – 612 million years ago.

**Stop E1 – Boulders and other sediment in the alluvium (river deposits) of the Haw**

At this location, various boulders (some over 3 feet in diameter) along with clay- to cobble-sized sediment are present. This is alluvium (river deposits). Some of the boulders and cobbles are smooth and indicate that they were tumbled by the river. The once angular edges were worn smooth from the tumbling action of the river - like in a giant rock tumbler - resulting in cobble and boulders with rounded edges. Small-sized sediment (clay-and silt-sized) can be transported by the Haw river during normal flow periods. Larger-sized sediment, like sand- and gravel-sized sediment, get transported during higher flow periods (typical rainfall events). Cobble- and boulder-sized sediment only get transported by the river during peak flow events (like hurricanes and large rainfall events). So the loose large boulders present in the river represent different rock types from upriver that have been transported by the Haw and deposited at this location. Recognizable rock types of some of the boulders include andesite to basalt, conglomerate, and granodiorite.

Geologic mapping of the areas upriver indicate the presence of various rock types – some of which are represented here among the boulders. One boulder in this area stands out with a distinct texture. The boulder has abundant angular-shaped black-colored clasts in a light orangey-brown-colored matrix (Figure 14). This boulder is interpreted as the rock type called *intrusion breccia*. Intrusion breccia is formed when magma of an intrusive igneous rock (like granite or granodiorite) intrudes (squeezes into) older existing rock. Sometimes the magma forcefully intrudes and breaks up the older rock leaving angular fragments floating in a matrix of the solidified magma.

Upriver – a little more than 3 miles away at Bynum – a body of rock called the Farrington Pluton outcrops along the Haw River (Figure 1). The Farrington Pluton ranges from granite, granodiorite and diorite. The Farrington Pluton intrudes black-colored andesites that looks similar to the black angular clasts in this interesting boulder. So, it is probable that this boulder of *intrusion breccia* broke off of an outcrop along the Haw River just north of Bynum and has travelled over 3 miles to this location. The boulder's journey likely took hundreds of thousands of years to a few million years to move (a few inches at a time) during the periodic peak flow events during hurricanes and major rainfall events.

***How long did it take to travel here?***

We can speculate on how long it took for the boulder of intrusion breccia to travel from the Bynum area up river to this spot. Assuming the boulder is from three miles upriver: 3 miles = approximately 200,000 inches. If the boulder traveled 1 inch/year, it would take about 200,000 years for the journey. If the boulder only moved 1/10$^{th}$ inch/year, it would have taken approximately 2 million years for the boulder to travel to this location.

**Stop E2 – Small tributary with rounded to sub-rounded boulders**

Return to the main trail near the base of the embankment leading from the parking area. Follow the trail toward the south. You will go over a small tributary with multiple boulders that are rounded to subrounded of various rock types. This is stop E2. These boulders are alluvium like in stop E1. Notice how the boulders have somewhat rounded edges to sub-rounded (in between rounded and angular) edges. These boulders are present buried under the clay- to sand-sized sediment in the flood plain. This small tributary has washed away the small-sized sediment leaving only the large boulders. Before continuing on the trail, take mental note of the edges of the boulders (rounded and smooth) for comparison to the rocks at stop E3 in the next tributary encountered on the trail.

**Stop E3 – Small tributary with jointed outcrop of dacite**

At this location, the trail crosses another small tributary to the Haw. Take great care in descending and walking across the rocks – they can be very slippery. The tributary exposes outcrop of dacite (Figure 15) (see stop W1 description for additional information on dacite). The outcrop is jointed and blocky in appearance (composed of many intersecting flat surfaces). The exposed rock is connected to the larger mass of rock buried beneath the floodplain deposits and soil. Compare this location to stop E2. Stop E2 has multiple boulders with rounding that were transported to the location and deposited. Stop E3 (this stop) is the outcrop. It is bedrock in its original location with angular edges.

Continue to the south along the trail. Pay close attention to the trail watching for a smaller path leading to stop E4 – it is easy to overlook (especially in the spring and summer with heavy vegetation). This small path will lead you to extensive outcrops within the Haw River. It may be helpful to use your smart phone maps to aid in navigation by comparing your location to the point of geologic interest on Figure 13.

**Stop E4 – Extensive outcrops of dacites to andesites in the Haw River**

This location provides some of the most extensive rock outcrops in this part of the Piedmont (Figure 16). At low water, the outcrops can be explored with great care. There are many slippery surfaces and potential hazards. During high river flow, these outcrops are often under water.

These outcrops are primarily metamorphosed andesitic lavas. Some dacitic lavas may also be present. The outcrop surfaces are periodically "polished" by rapid water flow during high flow events and provide many excellent fresh surfaces to investigate. Splashing or pouring water on the outcrop surfaces can help made the rock textures more easily visible. Many different textures typical of fine-grained volcanic rocks and flowing lavas can be found on the outcrops. Textures include:

*Aphanitic (fine-grained) texture:* Aphanitic texture refers to an igneous rock in which the crystals are so small (so fine-grained) they cannot be seen with the naked eye. Aphanitic texture generally indicates the magma cooled quickly at or near the surface of the Earth. An example of a rock with an aphanitic texture is provided in Figure 17.

*Porphyritic texture:* Porphyritic texture refers to a volcanic rock that has distinct crystals visible in an aphanitic groundmass. Porphyritic texture is a typical texture of a volcanic rock formed from cooling magma. An example of a rock with an aphanitic texture is provided in Figure 3.

*Hyaloclastic texture:* Hyaloclastic texture is formed when lava is erupted into water or flows into water and is quickly chilled. The rapid chilling caused the lava to fragment into multiple pieces ranging from a few millimeters to meters in size. Sometimes the fragments will appear to "fit" together like a jigsaw puzzle piece (Figures 8 and 18).

*Peperite:* Peperite is a rock type that is forms when magma comes into contact with wet sediments. The magma rapidly cools, identical to the hyaloclastic texture formation process, but is mixed with fine-grained sediments. Peperite and hyaloclastic texture can look identical and are hard to tell apart.

*Amygdaloidal texture:* Amygdaloidal textures refer to a rock with amygdules. Amygdules are mineral-filled (often quartz) air pockets in the rock (fossil gas bubbles). Magma often contains gas that will concentrate in small cavities called vesicles. When minerals infill the vesicles, they are called amygdules (Figure 9). Amygdules get their name from the Greek work for almond. Sometimes amygdules look like little almonds.

**Stop E5 – More outcrops of dacites to andesites in the Haw River**

Continue to explore this area of extensive outcrop while looking for the textures mentioned above. Take a moment to look at Figure 13. You are directly northwest and in-line with a mapped geologic fault (the thicker red line on Figure 13). The line that marks the fault was drawn where the rock types changed from the dacites and andesites (unit Zhadlt) to the mainly sedimentary unit (unit Zhe/pl). Faulting usually occurs in zones (a fault zone). These outcrops in the area of stop E5 are heavily jointed (broken up in many straight segments). This jointing is likely due to the same forces that formed the fault. So, you are likely standing in the fault zone. Many faults have been mapped in Chatham County and several have been mapped along the Haw River. See the information provided for stop W6 for additional information how this ancient faulting may control the flow path of many streams and tributaries in Chatham County.

Retrace your path back to stop E4 and the main trail. Once re-connected with the main trail, follow the path toward the southeast. The path follows the boundary-line between the Corp of Engineers administered land and the State-owned land. As you walk toward stop E6, you will pass outcrops of metamorphosed dacites, andesites and tuffs of unit Zhadlt. It may be helpful to use your smart phone maps to aid in navigation by comparing your location to the point of geologic interest on Figure 13.

**Stop E6 – Conglomerate outcrops and abundant rounded boulders in the floodplain**

You will know you have reached stop E6, when the trail passes close to the river again and you see abundant round-shaped boulders of all sizes. This area has abundant boulders of alluvium. Similar to stop E1, the boulders are of multiple rock types from locations upstream. Explore the boulders for the multitude of different rock types and textures. Looking around closely you will hopefully see many of the boulders are the rock type conglomerate (Figure 19). Conglomerate is a sedimentary rock composed of fragments of rock that are typically rounded by tumbling in water. The rock fragments in the conglomerate are fragments of volcanic rock that washed off nearby volcanic highlands and were deposited with other sediments approximately 615 million years ago. Take time to look closely at the outcrop or boulders of conglomerate from many angles and up close (within 1 foot of your eyes).

To return back to the parking area, retrace your path along the trail. The parking area is a little less than a mile from stop E6.

## Fracture trace study of Haw River outcrops south of HWY 64 bridge.

The outcrops in the Haw River on the south side of the US HWY 64 bridge offer one of the best exposed areas of continuous outcrop in Chatham County. The primary rock type is metamorphosed andesite and basalt of the Hyco Formation of the Carolina terrane.

The outcrops display pronounced jointing and fracturing. A simple fracture trace study was performed by georeferencing high-resolution aerial photographs of the area and tracing the fractures in ESRI ArcMap (Figure 20A). Following the digitization of the fractures, the Data Management Toolbox-Features Toolset-Add Geometry Attributes-Line_Bearing tool was utilized to calculate the bearing of the fracture.

A rose diagram was constructed from the bearing data of the fracture traces (Figure 20B). The rose plot shows a dominant "rose petal" oriented to the south and south-southeast (corresponding to fracture sets trending north-northwest and south-southeast). A less dominant "rose petal" is oriented to the east (corresponding to fracture sets trending east-west). The east-west fracture set is generally parallel to local primary layering and metamorphic foliation.

The north-northwest/south-southeast fractures are the dominant fractures observed in the aerial photograph and in outcrop; they can be traced for hundreds's of feet in the photographs. East-west fractures are generally parallel to layering and foliation/cleavage. The east-west fracture set appear to be cut by the north-northwest/south-southeast set of through-going fractures and are likely older.

A rose plot of lineaments, faults and diabase dikes identified in Chatham County through detailed geologic mapping and Hillshade LiDAR data is provided as Figure 20C. Orientations are consistent with orientations of the north-northwest/south-southeast fractures in the Haw River.

A rose plot of joints from the Merry Oaks Quadrangle collected during detailed geologic mapping is provided as Figure 20D. Joint orientations are consistent with orientations of the north-northwest/south-southeast fractures and the east-west fractures in the Haw River.

### Implications on fracture systems in other lineaments in Chatham County.

In Chatham and nearby counties, abundant lineaments are present on the hillshade elevation map constructed from LiDAR elevation data. Many of the lineaments have been identified as brittle faults and/or contain diabase dikes. The Haw River is interpreted to occupy one of these lineaments. If fracture density as observed on the outcrops of the Haw River south of the Hwy 64 bridge are typical of such lineaments, then the lineaments may be good locations for water supply well installation. Conversely, the lineaments could provide preferential pathways for contaminant migration.

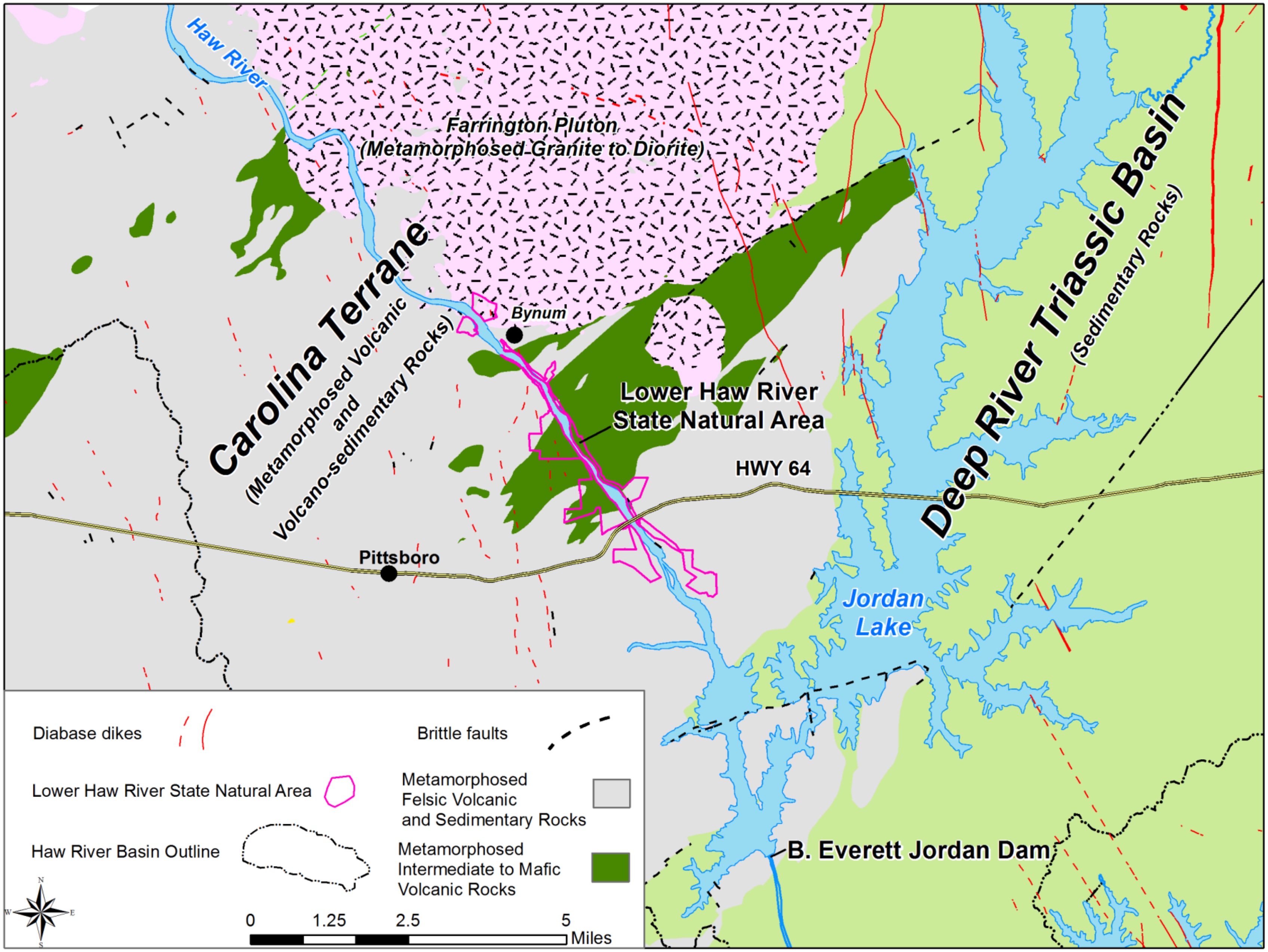



Figure 1: Generalized geologic map of the Lower Haw River State Natural Area.

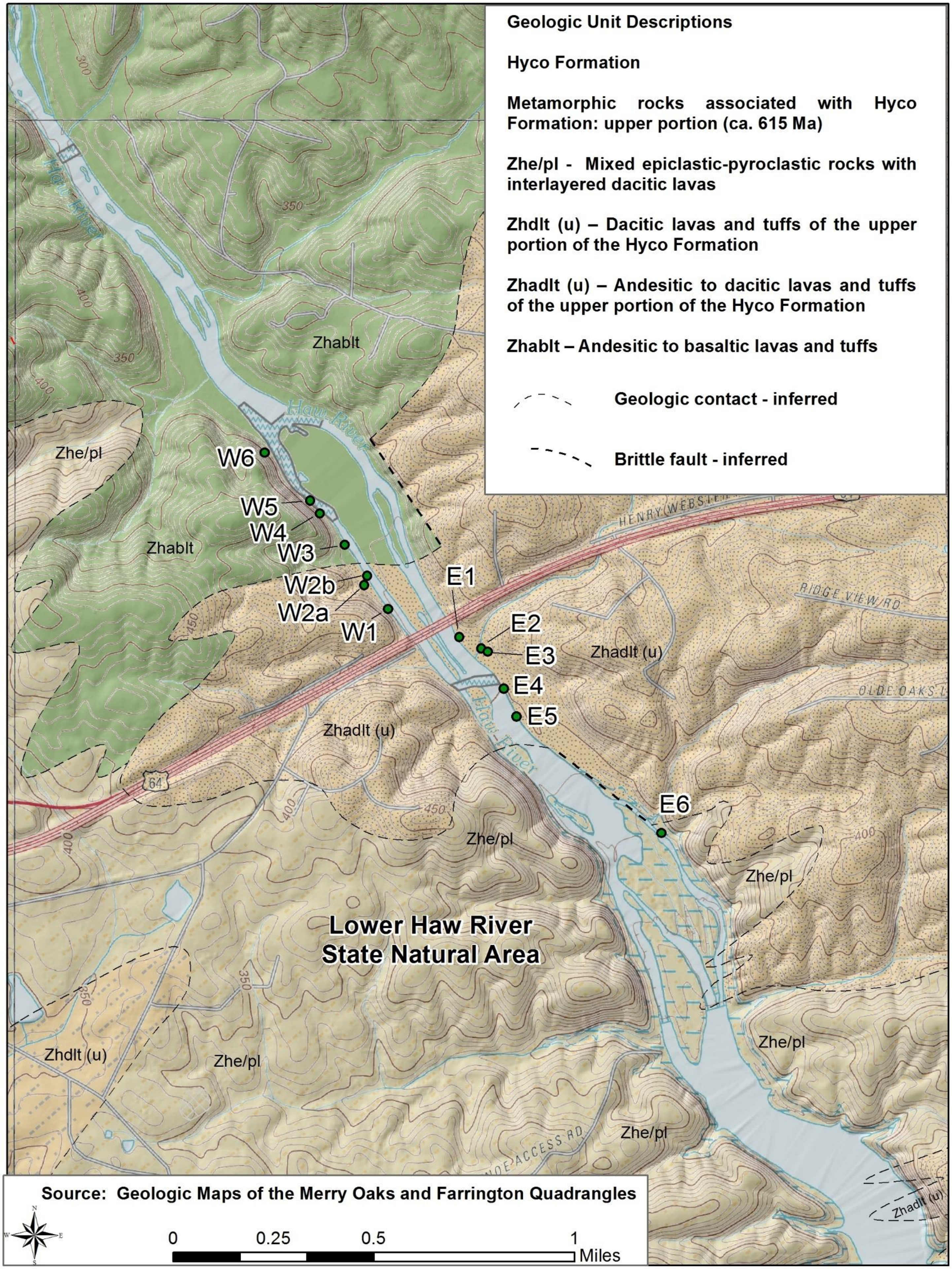


Figure 2: Compiled geologic map of the Lower Haw River State Natural Area with points of geologic interest indicated.

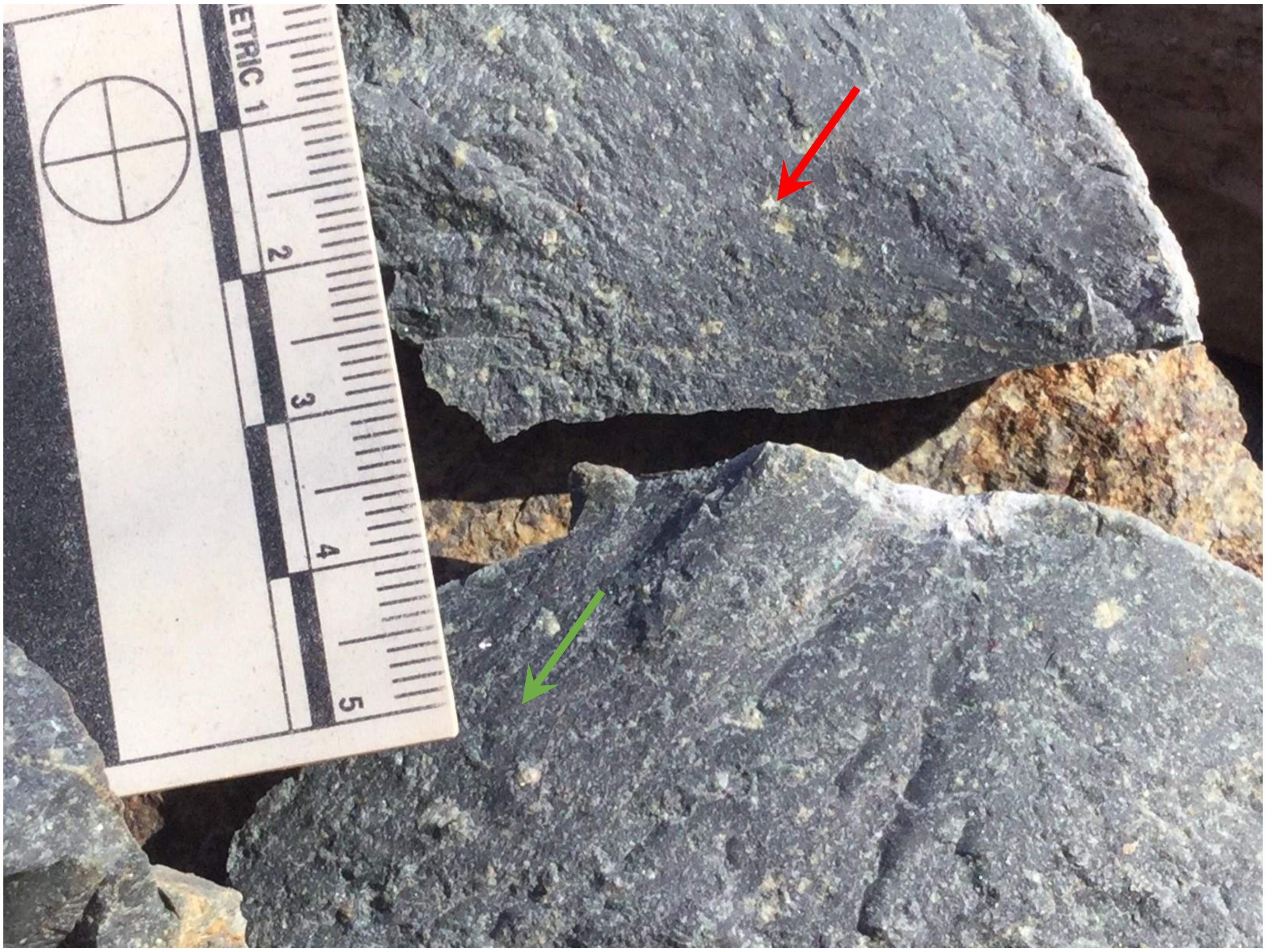



Figure 3: Close-up of fresh surface of metamorphosed dacitic lavas at Stop W1. The rock is greenish-gray with a fine-grained (aphanitic) groundmass (green arrow) and whitish-colored plagioclase crystals (phenocrysts) (red arrow) giving the rock a porphyritic texture.

Figure 4a: Outcrop of fin-shaped metamorphosed tuff at Stop W2A.

Figure 4b: Annotated photograph indicating persons legs for scale (red arrow) and general trend of fin-shaped outcrop (yellow and black overlay).

Figure 5a: Outcrops of fin-shaped metamorphosed tuff with in the Haw River at Stop W2B. Photograph looking northeast across the Haw River.

Figure 5b: Annotated photograph indicating person for scale (red arrow) and general trend of fin-shaped outcrop (yellow and black overlay).

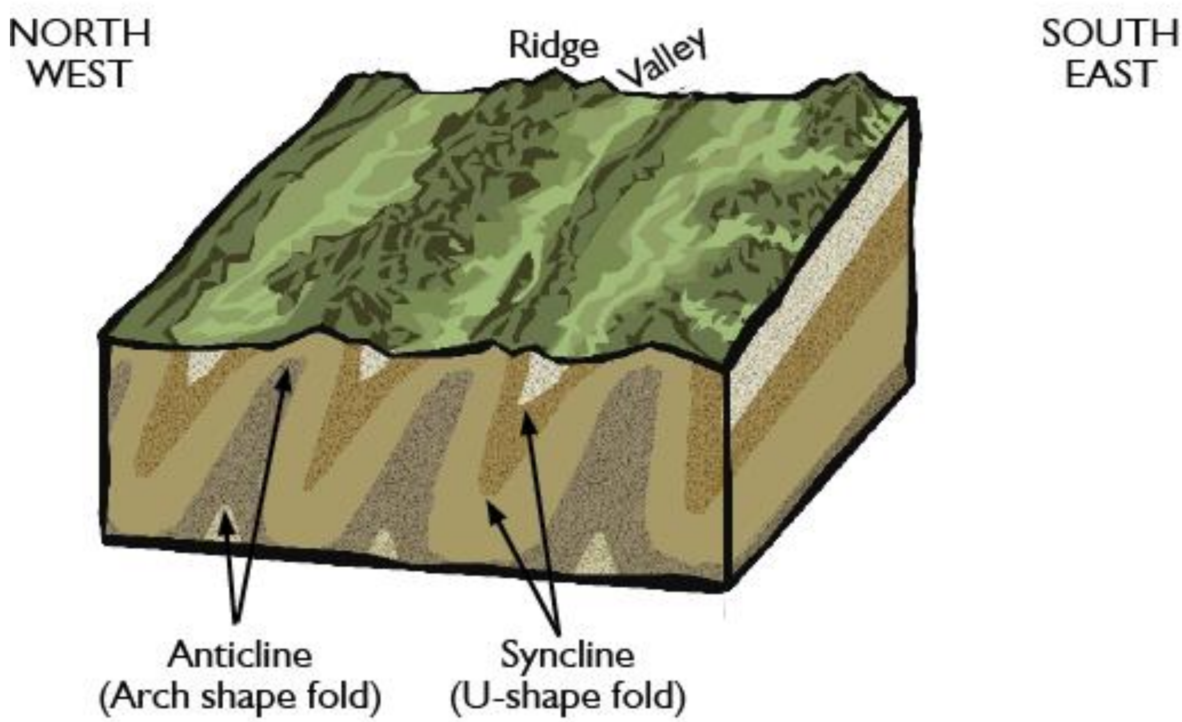



Figure 6: Schematic block diagram showing the folded rock layers in the Carolina terrane. Folding produced anticlines and synclines that essentially tilted the rock layers on end.

Figure 7: View of outcrop of andesitic to basaltic lavas at stop W5 with uneven weathering. Uneven weathering interpreted from differential weathered of relict hyaloclastic texture of rock. Rock hammer for scale – indicated by red arrow.

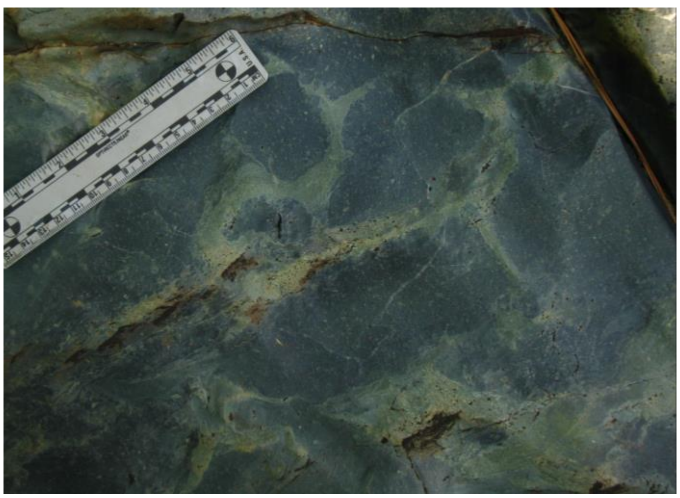


Figure 8: Close-up of fresh surface of metamorphosed andesitic lava with hyaloclastic texture. NCGS location MO-56 from the Haw River on south side of Hwy 64 bridge.

Figure 9: View of amygdules on weathered surface of andesites and basalts in river at stop W5 area. Individual amygdule indicated with red arrow.

Figure 10: Stop W6 - Large boulder of andesite to basalt with a quartz-coated fracture surface. Rock hammer for scale – indicated by red arrow.

Figure 11: Close-up of quartz-coated boulder at stop W6. Mechanical pencil for scale – indicated by red arrow.

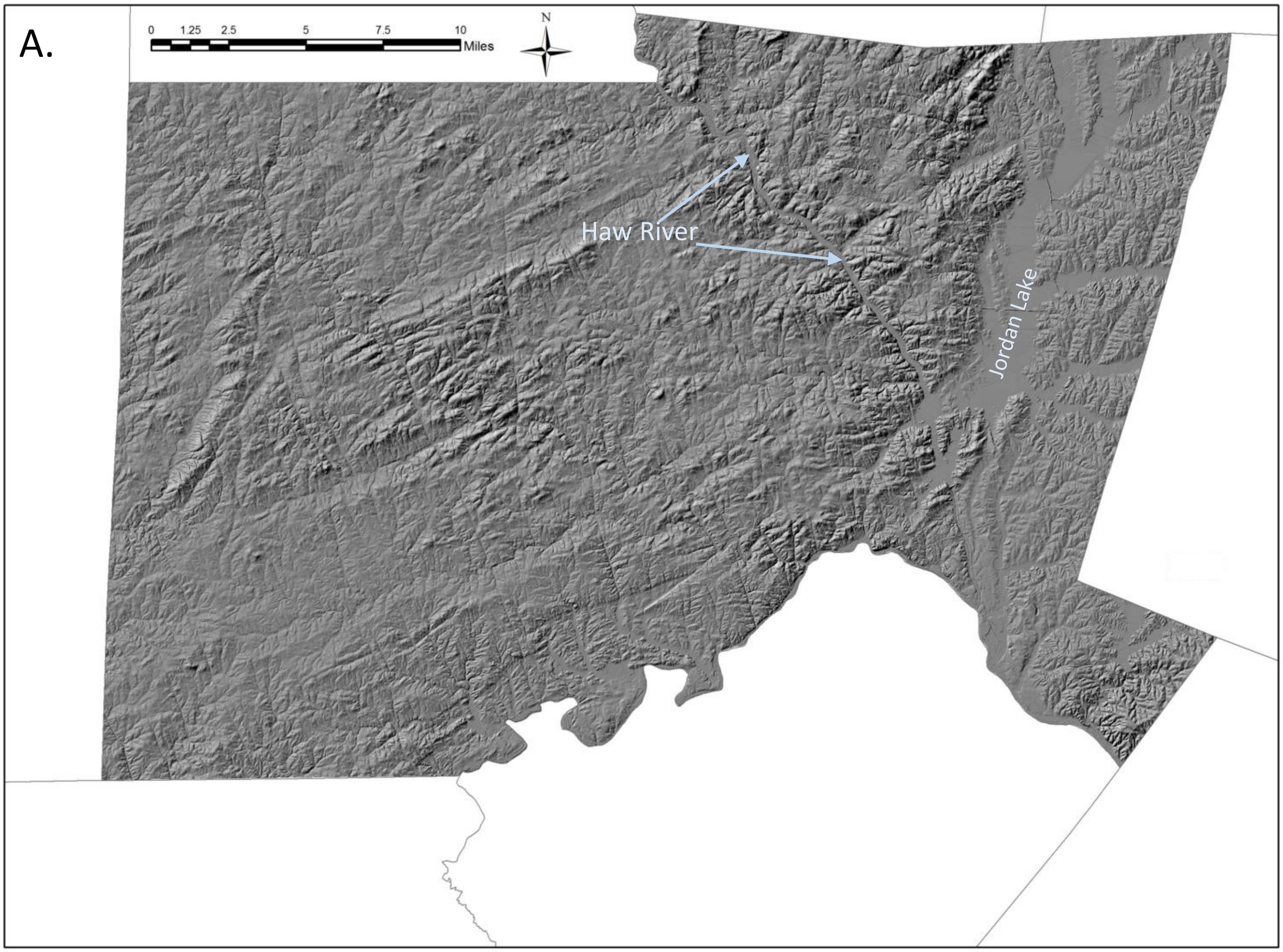
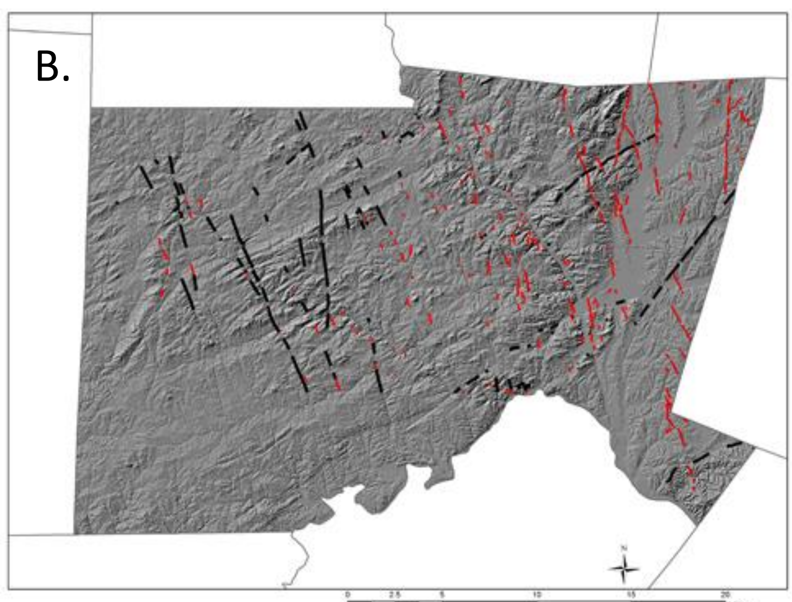



Figure 12: A) Hillshade elevation map created using LiDAR elevation data showing prominent topographic features and lineaments in Chatham County. B) Inset map with interpreted location of major topographic lineaments, faults and diabase dikes for part of Chatham County. Black lines represent lineaments and faults; red lines represent diabase dikes



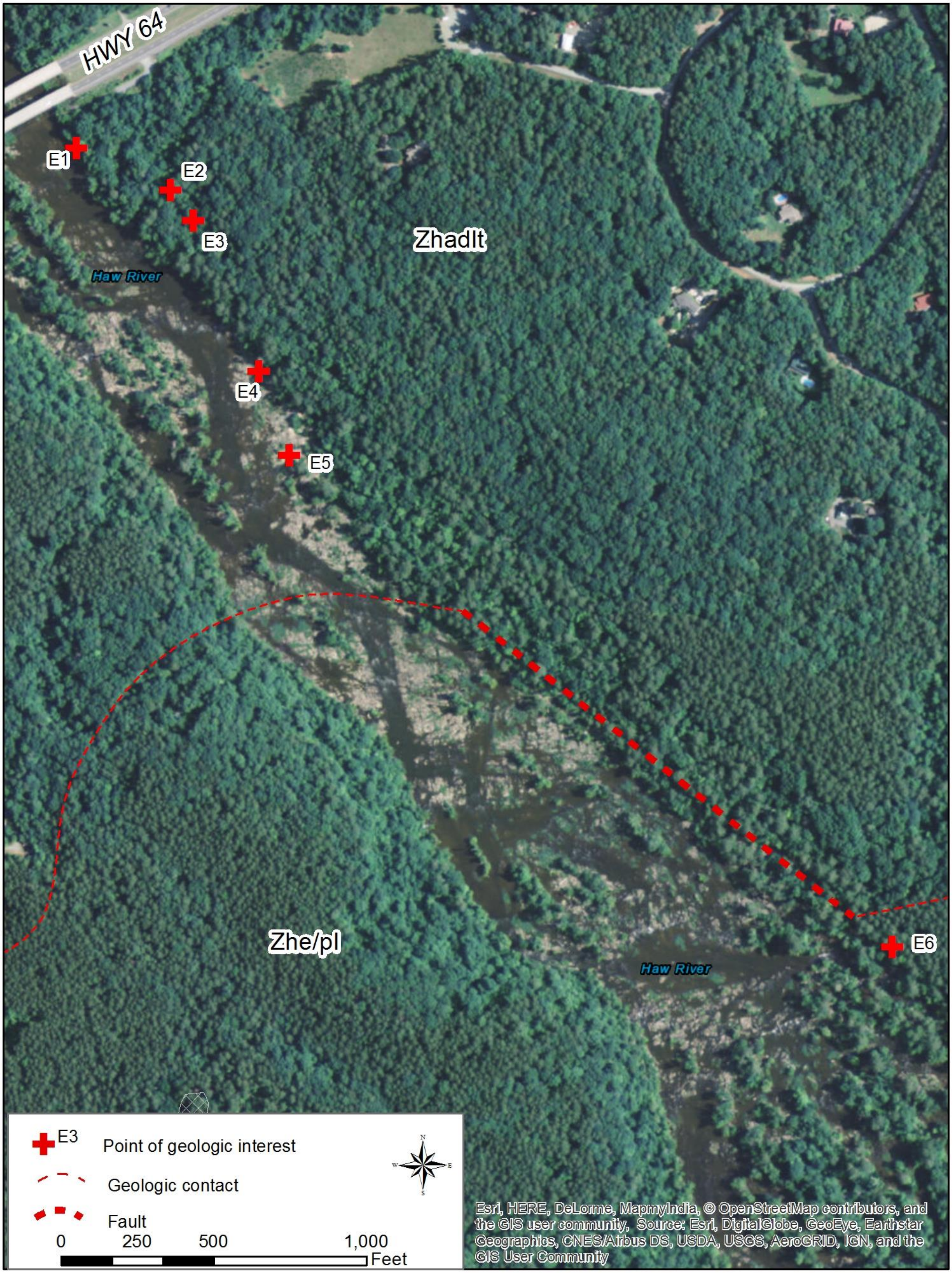



Figure 13: Aerial photograph with geologic points of interest on the east side of the river in the Lower Haw River State Natural Area. At low water, extensive outcrop is accessible.

Figure 14: Boulder in the flood plain deposits of the Haw River at stop E1 of intrusion breccia.  The Haw transported this boulder over 3 miles to this location.

Figure 15:  View of jointed and blocky outcrop of dacite in tributary at stop E3.

Figure 16: Outcrop area in stop E4-E5 area showing extensive outcrops in the Haw River.

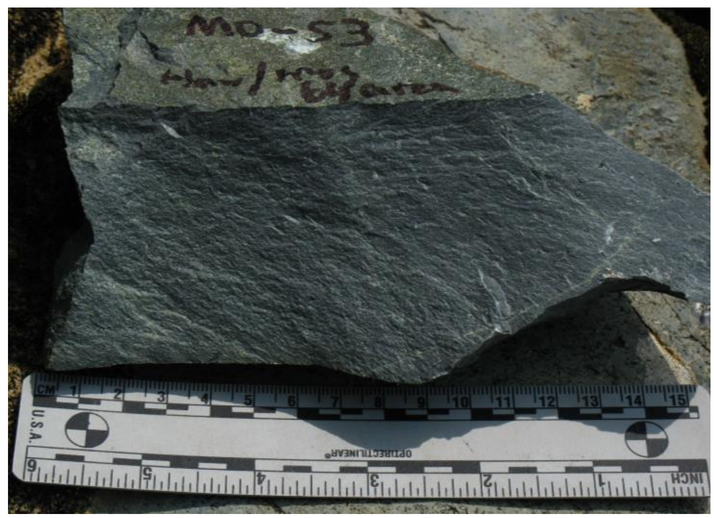



Figure 17: Close up of freshly broken surface in stop E4-E5 area showing an aphanitic texture in a metamorphosed andesitic lava.

Figure 18: Close up wet surface in the stop E4-E5 area showing hyaloclastic texture.

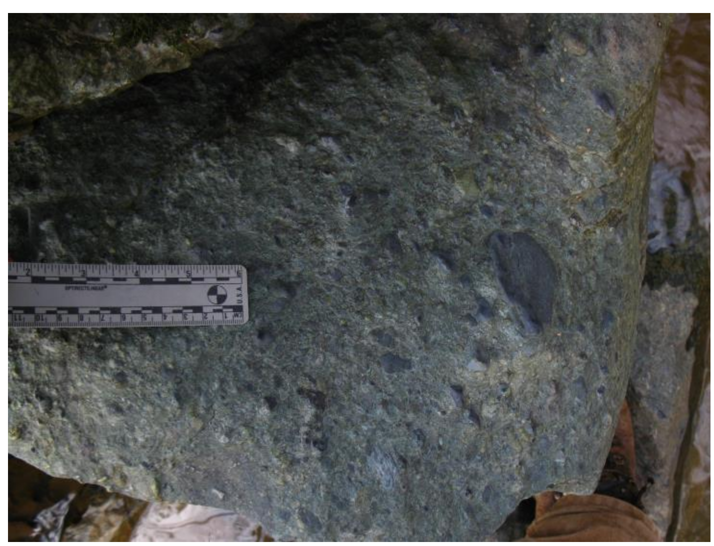
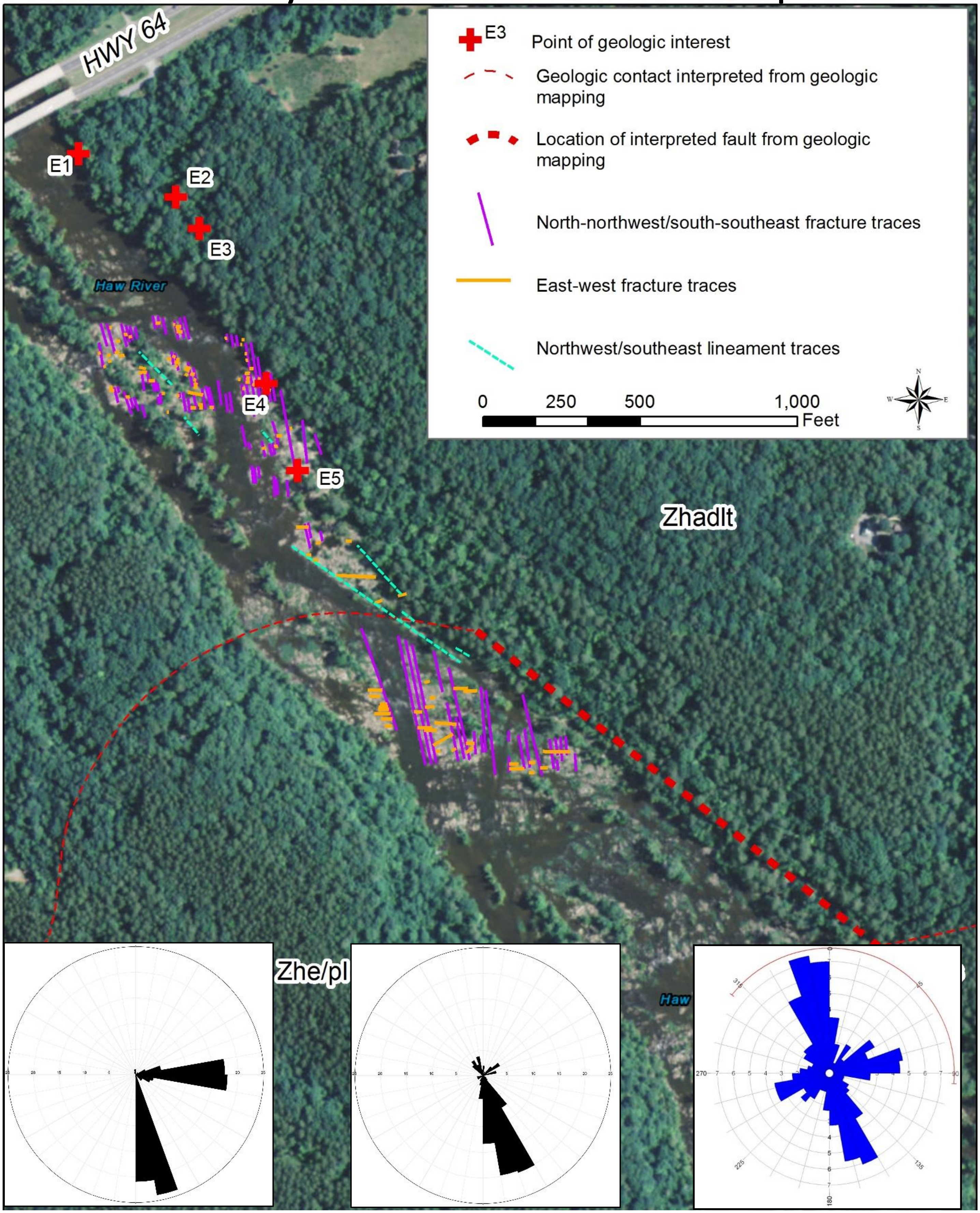


Figure 19: Close-up of weathered surface of metamorphosed conglomerate in the stop E6 area.

# Fracture Analysis – Haw River and HWY 64 Outcrops

A.




B. **Rose Diagram of Fracture Traces - Haw River and HWY 64 Outcrops.**
**N = 201**
**Outer Circle = 25%**

C. **Rose Diagram of LiDAR Lineaments, faults and Diabase Trends Mapped in Crystalline Portions of Chatham County.**
**N = 452**
**Outer Circle = 25%**

D. **Rose Diagram of Joints in Merry Oaks Quadrangle.**
**N = 429**
**Outer Circle = 7.5%**

Figure 20