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North Carolina Geological Survey
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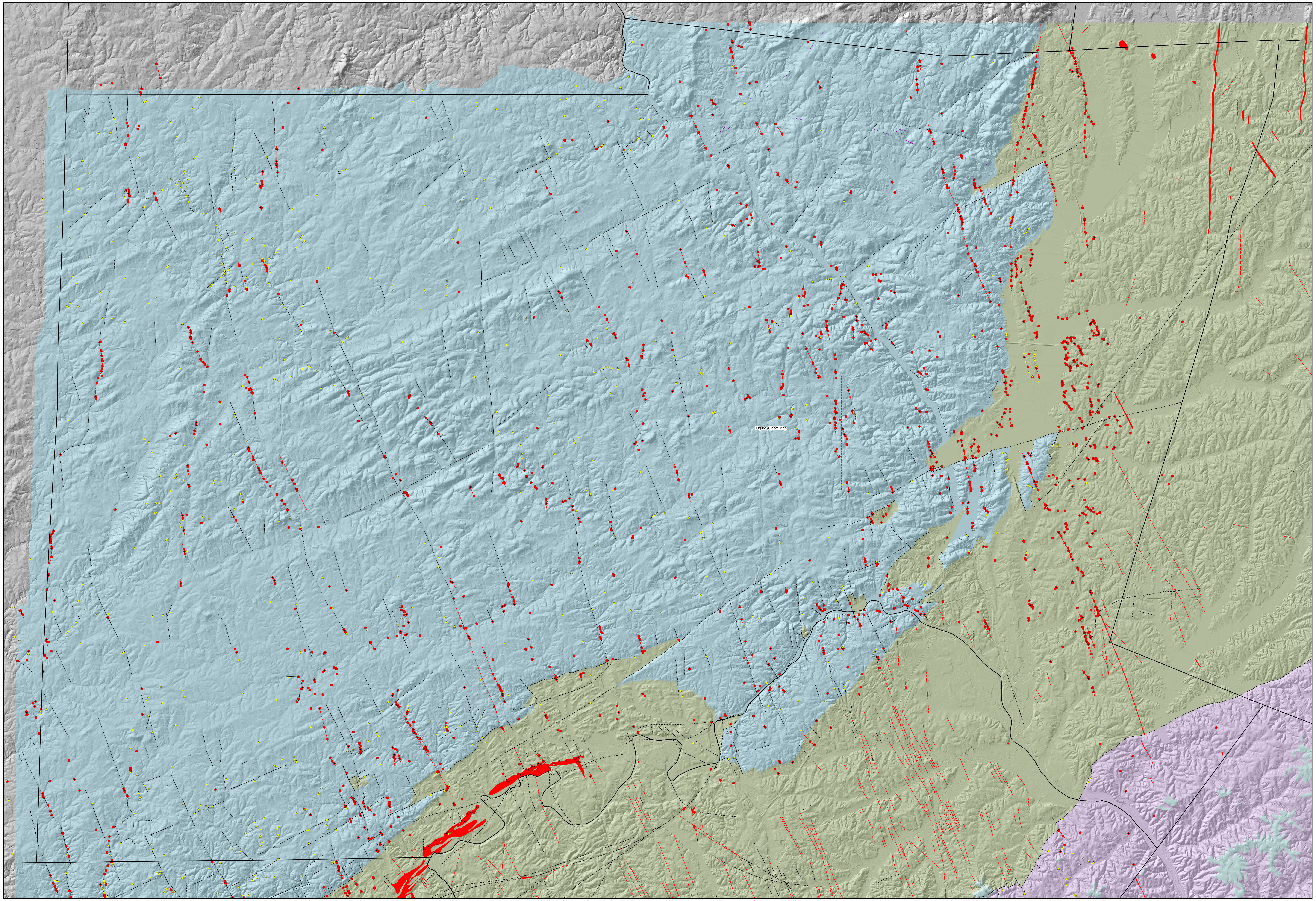

Hillshade image from elevation data from LiDAR collected by NC Floodplain Mapping Program. LiDAR data processing and Hillshade image by NC DOT - GIS Unit, 2007.

EXPLANATION OF MAP SYMBOLS
GROUNDWATER FEATURES

- indicates location of diabase boulder(s)
- indicates location of vuggy and/or massive quartz boulders
- inferred diabase dike
- inferred diabase dike intrusion along fault
- inferred fault location
- other geologic dikes distinct from diabase
- linear geomorphic feature interpreted from hillshade LiDAR - origin uncertain
- county boundaries
- diabase present as wide dike or sill

What is a Groundwater Features Map?
This Groundwater Features Map presents the approximate locations of geologic features that were identified during geologic mapping activities in Chatham County by the North Carolina Geological Survey (Bradley et al., 2022). The geologic mapping identified multiple geologic structures in the map area that are collectively interpreted as Groundwater Features.

Chatham County has abundant bedrock fractures. Groundwater is present in these fractures and groundwater is one of the main sources of potable water county wide. A Groundwater Feature, as designated on this map, may be a zone of increased bedrock fractures and may therefore be zones of increased groundwater flow. The Groundwater Feature may have important ramifications to groundwater availability and pollutant transport. This map is a tool for groundwater professionals, county staff, landowners, well drillers and other stakeholders to assist in their various decision-making processes as it pertains to groundwater issues.

When a groundwater professional is tasked with siting groundwater supply wells, waste disposal fields, investigating the extent of groundwater contamination or other tasks that involve groundwater quality and its flow in the subsurface, one of the first tasks is to develop a site-specific groundwater conceptual model. Using topographic maps along with their education and experience, a groundwater professional can make inferences that can approximate the groundwater conditions at a site. As other parameters (like the geology, precipitation amount, depth to groundwater, etc.) become available, the site conceptual model can be refined. This Groundwater Features Map will be very helpful in the initial stages of developing a site conceptual model. This process is usually done by groundwater professionals, however some of the basic concepts can be understood by the non-professional. An excellent resource for the groundwater professional and non-professionals interested in the techniques of developing a groundwater conceptual model for locations within the Piedmont and Mountains of NC is LeGrand (2004). The LeGrand (2004) guidance manual is written primarily for the groundwater professional, however key concepts will be understood by the non-professional.

Bedrock Fracture System
The geology of Chatham County is complex with many different rock types. The majority of the county is underlain by ancient metamorphosed volcanic rock known as the Carolina terrane (Slate belt). Smaller portions of the eastern and southern parts of the county are underlain by sedimentary rocks of the Triassic basin (Figure 1). Generally, the rocks of the Carolina terrane have more water-bearing fractures than the rocks of the Triassic basin.

Bedrock fractures can be very efficient conductors of groundwater and they may be interconnected in complex ways. The amount of water that fractures transmit can be highly variable and can result in drastically different well yields in a single neighborhood or street. Under natural (non-pumping) conditions, groundwater within fractures follows the local hydraulic gradient. In cases of strongly oriented fracture systems, the groundwater may follow the fractures and flow in directions inconsistent with the expected hydraulic gradient. When water is removed from a well by pumping, the natural groundwater flow directions are disturbed and groundwater from interconnected network of fractures is transported to the well. Undesirable contaminants (e.g. fecal coliform, nitrates, petroleum hydrocarbons, chlorinated hydrocarbons, metals, etc.) may also flow in the preferred pathways created by the fracture network. These contaminants can travel a great distance within the bedrock fracture systems.

Groundwater is recharged to the fracture system by the slow infiltration of rainwater through the soil and into the fractured rock. Often there are just a few highly fractured zones that transmit the infiltrating water to the deeper fracture network. Because of Chatham County's geologic history, the bedrock in parts of the county is more fractured and theses fractures can occur in a preferred orientation. Figures 2 and 3 present a rose diagram that displays directional data and the frequency of fracture data from outcrops in the Carolina terrane and Deep River Triassic Basin, respectively. The diagrams show a strong preferred orientation of fractures in a northwest – southeast direction that are consistent with the orientation of diabase dikes, brittle faults and lineaments. A northeast – southwest fracture pattern is also present.

What features are identified on the map?
The map includes point and line elements that are approximations of the occurrence of a relevant geologic feature, either observed in the field or interpreted from LiDAR hillshade elevation data.

Points
Diabase - The red circle points identify a location where a boulder(s) or cobble(s) of the rock type diabase was observed. Diabase is a mafic igneous rock with a composition similar to ocean floor basalts which intruded the Piedmont approximately 200 million years ago. Diabase occurs in narrow, nearly vertical sheets called dikes. The red circle locations mark the surface trace of a diabase dike. Diabase dikes are known by groundwater professionals to be good places to install productive groundwater wells in comparison to the surrounding rocks.

Quartz – Quartz is a common rock forming mineral and can be present as gravel- to boulder-sized debris throughout Chatham County. Zones of quartz can form associated with faulting and other geologic environments. In the map area, quartz cobbles and boulders are common. The quartz may be an indication of an area that was faulted in the geologic past and likely has abundant bedrock fractures.

Quartz can also occur associated with locations that have undergone hydrothermal alteration. Rocks that show signs of hydrothermal alteration are common in parts of Chatham and adjacent counties. The hydrothermal alteration is the reason there are historic copper mines in the southwest portion of Chatham County. Hydrothermal alteration occurs when water, heated by magma, permeates through rocks or deposits and changes their composition by adding, removing or redistributing chemical elements. Hydrothermal alteration often creates zones of the mineral quartz. Quartz formed during faulting and hydrothermal alteration can look identical. Site specific investigations may be needed if a site has abundant quartz debris to determine if it may be an indication of presence of abundant fractures or another reason.

Lines
Inferred diabase dike – A line representing the interpreted location of a diabase dike is provided when the distribution of diabase points and/or topography implies the presence of a mappable dike. Diabase dikes are present as thin (up to 200 feet wide – but more typically are a few feet to 40 feet wide) bodies. Diabase can also occur as sills within the sedimentary rocks of the Triassic basin. Sills are tabular bodies that are oriented generally parallel to the bedding of the Triassic sediments. The location of the line is an approximation and should be confirmed by a site-specific field investigation.

The orientation of diabase dikes can vary. Most are near-vertical, but some have dips as low as 45 degrees have been observed. As such, the surface trace does not necessarily match the subsurface location. When attempting to intersect a diabase dike to improve potential well yield, knowledge of the subsurface orientation of the diabase dike is needed. Diabase dikes can dip in any direction.

Inferred brittle fault - A line representing the interpreted location of a brittle fault is provided when geologic units abruptly end (truncated) and/or topography implies the presence of a mappable fault. The location of the line is an approximation and should be confirmed by a site-specific field investigation. On the map, a fault is designated as a line; however, a fault will have a zone of fractured rock on either side of the fault line – called a fault zone or damage zone. Faults can vary widely in length and width. Major brittle faults can extend for miles and have fault zones that are 100's to 1000's of feet wide. Smaller faults can extend for inches to 100's of feet. The general rule-of-thumb is an area that has a brittle fault is likely to have more fractures in the bedrock than a location away from the fault. Also, there is typically a decrease in the intensity of bedrock fractures as one moves farther away from the fault.

Linear geomorphic feature interpreted from hillshade LiDAR - A lineament is a linear (relatively straight) topographic feature. A naturally occurring lineament usually reflects characteristics of the underlying rocks. LiDAR elevation data for Chatham County became available in ca. 2007. LiDAR (Light Detection And Ranging) elevation data is acquired using an airplane-mounted laser transmitter that measures very accurate elevation data. This data set has revealed an extraordinary network of lineaments that are parallel to diabase dikes and known orientations of brittle faults. Some of these lineaments can be traced for multiple miles across Chatham County. The lineaments are interpreted to be likely fracture zones; however, field observations could not confirm the presence of each potential brittle fault.

The map area has hundreds of lineaments when viewed at varying scales. Only the major lineaments that are easily visible at 50,000- to 100,000-scale are identified on the Groundwater Features Map. Like brittle faults, lineaments can widely vary in length and width. Major lineaments extend for miles and have linear topographic expressions that are 100's to greater than 500 feet wide in some locations.

What features are not identified on the map?
Multiple unmarked geomorphic lineaments are visible when viewed at 24,000- to 50,000-scale on the data from LiDAR. These minor lineaments extend for short distances (100's to 1000's of feet). Minor lineaments are not indicated on the map but can be identified by a close inspection of the map. These minor lineaments may have important implications for site-specific investigations. Figure 4 shows an example of the identification of minor lineaments at a more detailed scale.

How to use the map
This Groundwater Features Map can be utilized for a variety of applications including: 1) locations to site groundwater wells to improve yield, 2) identify vulnerable locations and/or flow paths for groundwater impact, 3) identify groundwater recharge areas (useful to designate areas of protection), and 4) identify groundwater discharge areas.

When using this map, it is important to note that the size of data points and line widths are exaggerated compared to the size of data stations in the field. For example, all diabase stations are represented by red dots with a diameter of 0.05 inches on the map, equivalent to approximately 210 feet across in real-life. In Chatham County, diabase stations can range in size from several boulders that measure more than 3 feet in diameter to a few cobbles measuring less than one foot. Despite obvious differences in size, all diabase station locations are represented by the same symbol. The same is true for the features represented by lines on this map. While the lines that represent diabase dikes are approximately 0.02 inches wide on the map (about 80 feet in real-life), the real width of dikes covers a wide range. Therefore, the size of symbols on this map is not necessarily representative of the true size of groundwater features.

Example Potential Use of the Data
Siting of groundwater wells: This dataset can help land owners, environmental professionals, well drillers, and other stakeholders site productive groundwater wells. Wells installed within zones of increased fractures (a Groundwater Feature) will have a higher likelihood of being a productive well.

Mitigating the impact of well interference: Pumping a well removes groundwater and lowers the water level in the well and nearby rock as water is diverted toward the well. If multiple wells are installed in the same fractured network, they may compete for water and cause an enhanced lowering of the water table. In locations in the vicinity of Groundwater Features, the lowering of the water table may be more pronounced and may extend in a preferred direction due to the linear nature of the Groundwater Feature. Understanding the relationship of the location of water wells and the bedrock fracture network is important to avoid and/or help mitigate well interference issues.

Groundwater vulnerability: Groundwater Features are potential locations of local groundwater recharge and/or areas in which the groundwater may be more vulnerable to an impact from anthropogenic contamination due to the increased fractures in the underlying bedrock. Groundwater vulnerability is a measure of how easy or difficult potential contaminants can migrate from the surface or near surface to groundwater. The rate of infiltration is highly dependent on the soil and contaminant properties, which can vary greatly from location to location. This dataset of Groundwater Features can be used as part of a groundwater vulnerability study. The presence of a Groundwater Feature does not necessarily indicate vulnerable groundwater. The dataset can be used in the decision-making process to determine the extent of site-specific investigations into the vulnerability of the groundwater when siting of waste disposal facilities, chemical storage, or other facilities that have the potential to impact groundwater if not properly managed.

References
Bradley, P.J. (with contributions in alphabetical order from: Bechtel, R.; Blocher, W.B.; Butler, R.J.; Clark, T.W.; Gay, N.K.; Grimley, D.A.; Hanna, H.D.; Malaska, M.J.; Peach, B.T.; Rice, A.K.; Stoddard, E.F.; and Watson, M.E.), 2022, Compiled geologic map of Chatham County and surrounding areas, North Carolina: North Carolina Geological Survey Open-file Report 2022-03, scale 1:50,000, in color.

LeGrand, Harry, Sr, 2004, A Master Conceptual Model for Hydrogeological Site Characterization in the Piedmont and Mountain Region of North Carolina, North Carolina Department of Environment and Natural Resources- Division of Water Quality-Groundwater Section, 38 pages. http://digital.ncdcr.gov/cdm/ref/collection/p249901coll22/id/1360

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Groundwater Features Map of Chatham County and Surrounding Areas, North Carolina.

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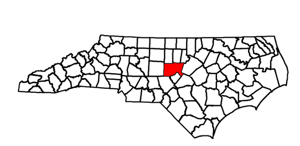
Map preparation and editing by Emily K. Michael

SCALE 1:50,000
2 1 0 2 4 6 Kilometers
1 0.5 0 1 2 3 Miles



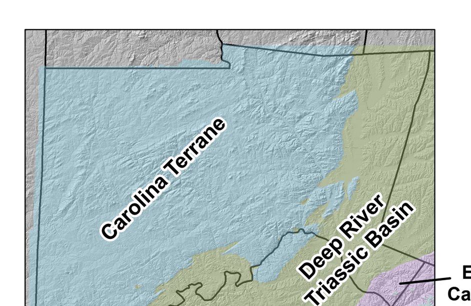


Figure 1: Generalized Geologic Map of Chatham County and Surrounding Areas

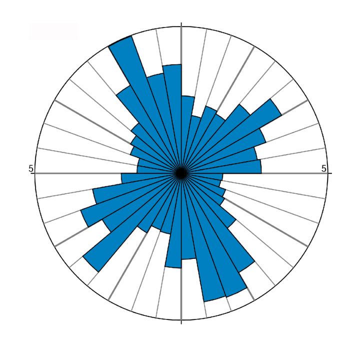


Figure 2: Unidirectional Rose Diagram of Fracture Orientations in Carolina Terrane Rocks
N = 2,048
Outer Circle = 5%

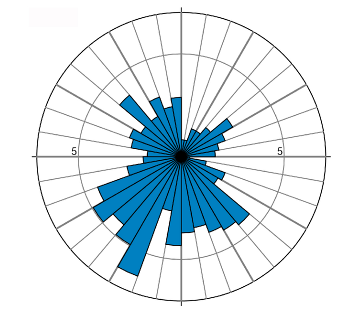


Figure 3: Unidirectional Rose Diagram of Fracture Orientations in the Deep River Triassic Basin
N = 488
Outer Circle = 7%

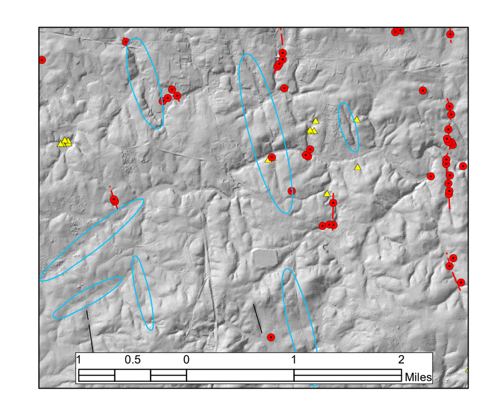


Figure 4: Example of identification of minor lineaments. Minor lineaments are indicated by blue ellipses. Other unmarked minor lineaments are present in area.

This is a derivative map with data collected during geologic mapping that was funded in part by the USGS National Cooperative Geologic Mapping Program under STATEMAP award numbers 01HQAG0061, 2001; 06HQAG0033, 2006; 07HQAG0140, 2007; G10AC00425, 2010; G11AC20296, 2011;G12AC20308, 2012; G13AC00204, 2013; G14AC00230, 2014; G15AC00237, 2015; G16AC00288, 2016; G17AC00264, 2017; G18AC00205, 2018; G19AC00235, 2019 and G20AC00249, 2020.

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