Geochemical lineaments and trends in NURE groundwater domestic well data, and their geologic relationships, North Carolina Coastal Plain

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Abstract

This study identifies several anomalous lineaments and trends in geochemical data from the National Uranium Resource Evaluation (NURE) database for the North Carolina Coastal Plain. Two of the lineaments (F, Groundwater pH, and Mg x MG/Cl) are closely associated with the Carolina Fault (CF) and Graingers Wrench Zone (GWZ) delineated in previous work. The GWZ is characterized by block faulting over a width of 10-20 miles. The widths of the anomalous geochemical belts are comparable. Another anomalous lineament (Mg, Mg x Mg/Cl, and alkalinity), here termed the **Beaufort Lineament**, extends N 10 W from near Beaufort, N.C. to the Virginia state line. The southern portion of the **Beaufort Lineament** is located along the southern segment of the Suffolk Scarp, but there is no identified geochemical association with the northern segment of the Suffolk Scarp that extends N 22 E from Pinetown, N.C.. Another geochemical lineament (Na, Cl, Mg, conductivity, alkalinity), here termed the **Bayview-Scranton Lineament** trends ENE-WSW and extends across Beaufort and Hyde counties. Infiltration of sea water has occurred along this lineament due to pumping from the Castle Hayne aquifer creating a large cone of depression. The chemical composition of water in the upper Cretaceous aquifers contrasts significantly with that of groundwater in the Castle Hayne aquifers. The Castle Hayne aquifer typicallyhas a more alkaline pH, higher electrical conductivity, alkalinity, Mg, Na, and Cl. The boundary lies just east of the GWZ.

Comparison of the azimuths of geochemical lineaments with those of the CF-GWZ, the Surry, Suffolk, and Orangeburg Scarps, and faults delineated in the eastern Piedmont show a distinct pattern. North of the **Bayview-Scranton Lineament**, the trends are N 10 W and N 22 E. South of this lineament the trends are N 10 W and N 45 E. Questions remain about the occurrence of faults in the North Carolina Coastal Plain, and whether or not all the geochemical lineaments identified here are faults. However, the identified patterns form a basis for future evaluations which will likely require drilling, trenching, and seismic work.

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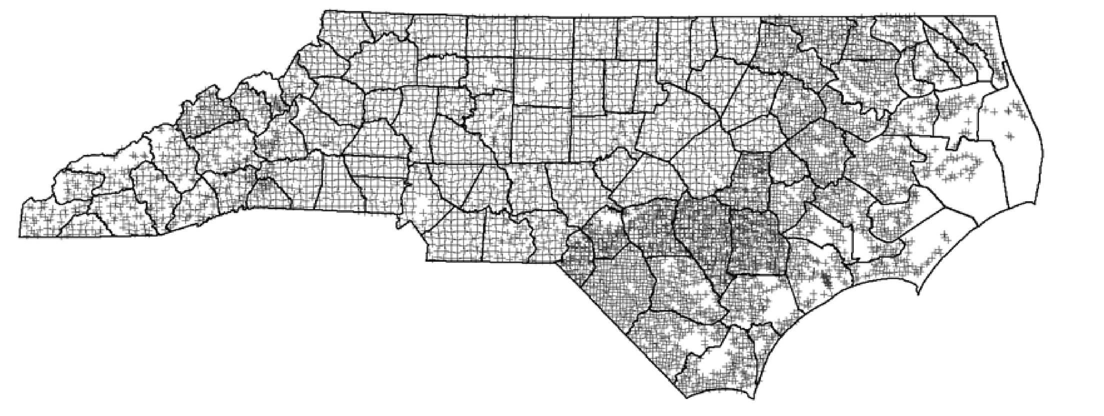

NURE Groundwater Sites. There are 6,705 sites (wells and springs) in North Carolina (black crosses). Variables analyzed for sites in North Carolina include aluminum, bromine, chlorine, dysprosium, fluorine, magnesium, manganese, uranium,vanadium, water pH, water conductivity (electrical), and alkalinity.

The National Uranium Resource Evaluation (NURE) program was initiated by the Atomic Energy Commission (AEC) in 1973 with a primary goal of identifying uranium resources in the United States. The Hydrogeochemical and Stream Sediment Reconnaissance (HSSR) program (initiated in 1975) was one of nine components of NURE. The NURE program effectively ended about 1983-84 when funding disappeared (condensed from Smith, 1997).

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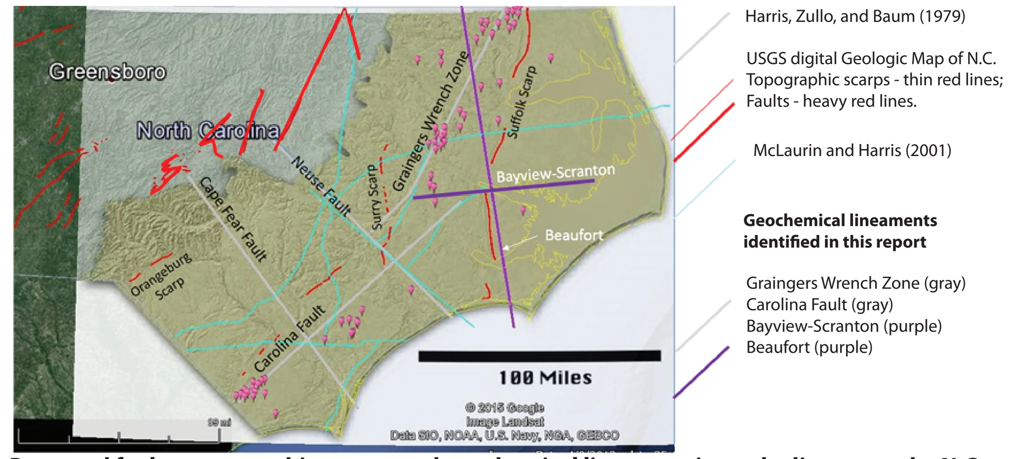

Proposed faults, topographic scarps, and geochemical lineament in, and adjacent to, the N.C. Coastal Plain. Fluorine (red-pink symbols) > 1,000 ppb shows alignment along, or parallel to, the **Graingers Wrench Zone (GWZ)** and the **Carolina Fault** as defined by Harris, Zullo, and Baum (1979). Other chemical variables also show trends related to these faults, as well as geochemical lineaments identified here (purple lines) that may, or may not, be faults. Subsequent figures will be restricted to these specific faults/lineaments.

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Graingers Wrench Zone (GWZ). Prior to 1977 several authors suggested possible faults in the Coastal Plain (Harris, Zullo, and Baum, 1979). The first documented fault was identified by Brown *et. al.* (1977) in Lenoir and Craven counties. They named this fault the Graingers Wrench Zone and documented the existence of horsts, grabens, and half grabens that are interpreted to be formed mainly by strike-slip movement along the zone. Cataclastic textures and offset marker beds (the Cretaceous-Tertiary boundary) are documented in cross sections across the structure. They conclude that the width of zone is approximately 15 miles.

In the 1979 Carolina Geological Society (CGS) guidebook, Harris, Zullo, and Baum (1979) presented the trace of this fault from near Kinston, N.C. to the Virginia State line. They also show maps of 3 other faults; the NW-SE-trending **Cape Fear** and **Neuse** faults, and the NE-SW trending **Carolina Fault** that is parallel to the **GWZ** and extends to the South Carolina border. In subsequent figures, these 4 faults will be shown for reference purposes, but only the **GWZ** and the **Carolina Fault** control hydrochemistry of groundwater in the Inner Coastal Plain.

McLaurin and Harris (2001) re-evaluated the **GWZ** and presented a map showing a revised compilation of faults and their traces throughout the North Carolina Coastal Plain. Regarding the **GWZ**, they interpreted east-west normal faulting in the Paleocene which is overprinted by more recent NE-SW movement that has obscured earlier movement. Unlike Brown *et. al.* (1977) who proposed that the zone primarily developed in a strike-slip regime, McLaurin and Harris (2001) consider the stresses to be mainly compressional resulting in normal faulting. Their map shows basement faults that were identified from gravity and magnetic surveys. A portion of the **GWZ** and the **Neuse** faults are shown, but neither the **Carolina Fault**, or **Cape Fear Fault** are shown in their compilation.

Our data best fits the compilation by Harris, Zullo, and Baum (1979). Consequently, these faults will be presented for reference in subsequent figures.

Carolina Fault. This fault was originally considered a regional fault about 300 km in length that extends north from South Carolina into Virginia (LeGrand, 1955; Ferenczi, 1959). Evidence consists of a sharp northeast turn in the Neuse River, and salt water incursion near the confluence of the Cape Fear and Black Rivers. Harris, Zullo, and Baum (1979) recognize this fault, but show that it is separate from the **GWZ**. Our data tends to support the existence of this fault, and its portrayal by Harris, Zullo, and Baum (1979).

Geochemical lineaments. Two geochemical lineaments are identified here that may, or may not, be faults. These are as follows:

Beaufort NW-SE Lineament. This lineament extends from the town of Beaufort on the coast to the Virginia State line, near the community of Como in Hertford County, and is aligned along the southern portion of the Suffolk Scarp.

Bayview-Scranton ENE-WSW Lineament. This lineament extends across Beaufort and Hyde counties, North Carolina.

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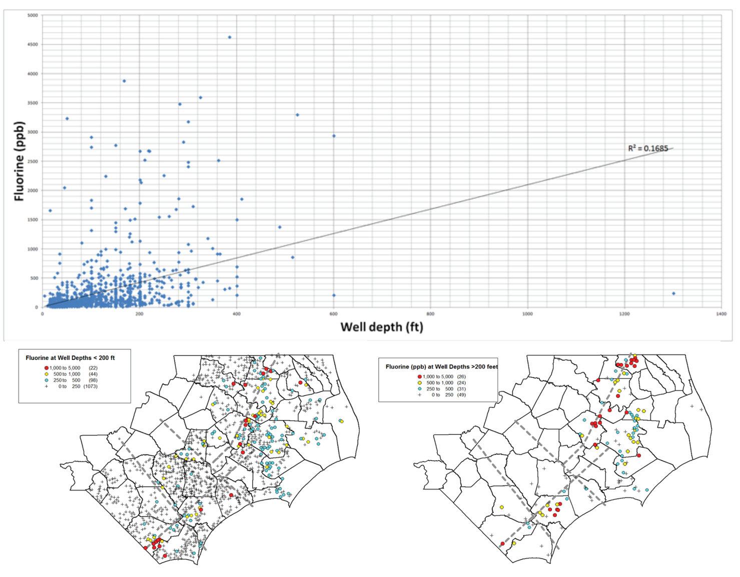

Fluorine. In an attempt to evaluate the influence of well depth on the variables, a plot of F (ppb) *vs.* well depth is shown. Correlation is poor; high fluorine is as likely to occur in anomalous concentrations in shallow wells as in deep wells.

Maps showing the distribution of F (ppb) in wells <200 ft. in depth are shown (lower left); results for wells >200 ft in depth are shown (lower right).

Clearly well depths are, on average, deeper along the **Carolina** and **GWZ**. This may be because the principal aquifer in this area (the Pee Dee aquifer)may have been down dropped within the fault zones.

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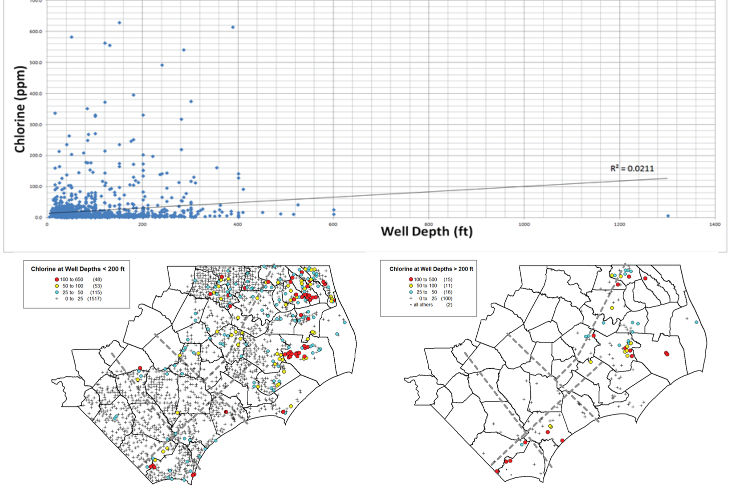

Chlorine. This relationship holds for chlorine as well as fluorine.

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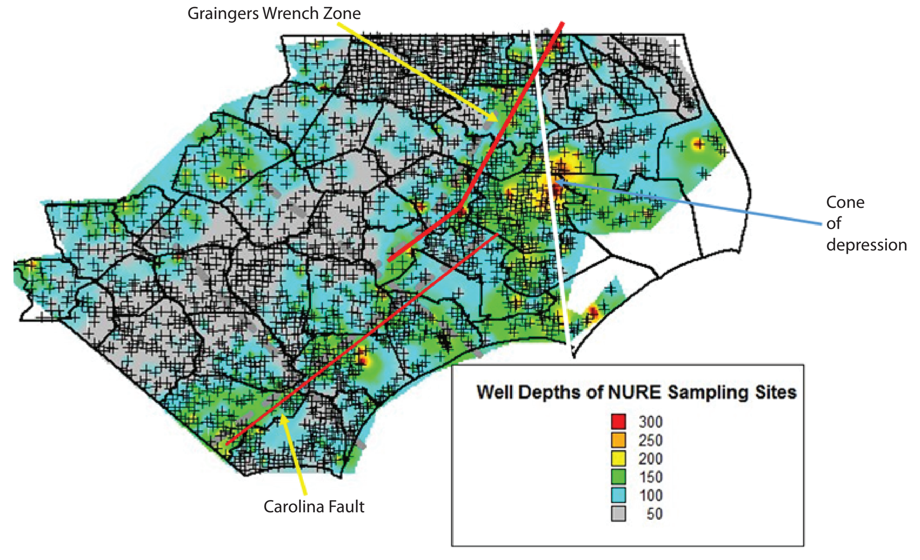

Well depths (ft) of NURE sampling sites. Grid cell thematic map of well depths (ft) sampled in the Coastal Plain. Depths tend to be higher along the Carolina and GWZ (red) and the **Beaufort lineament** (white line) identified in this study.

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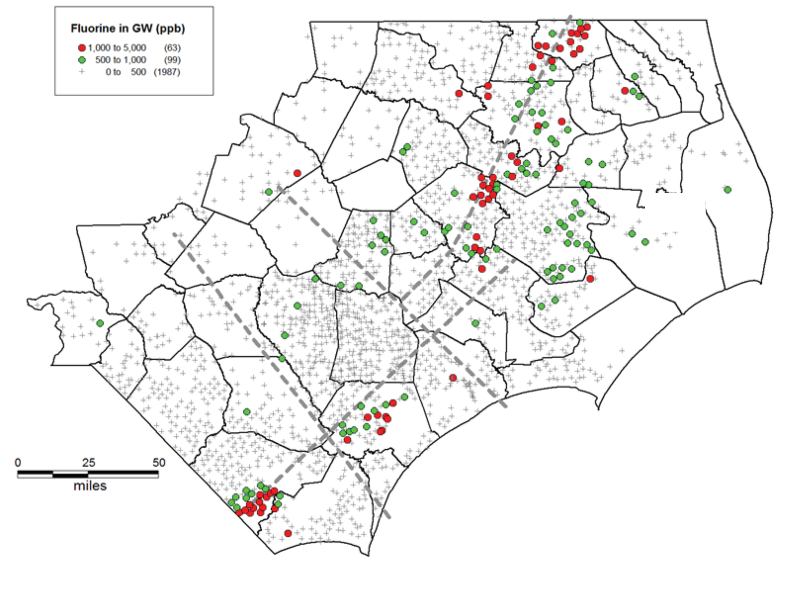

Fluorine in groundwater (ppb). Fluorine has the closest relationship to the NE-SW faults (**Carolina Fault** and **GWZ**) than any other variable. There is no close association of fluorine to the NW-SE faults (Cape Fear and Neuse faults).

Brown *et al.* (1977) consider the zone of deformation associated with the **GWZ** to be 15 miles in width. If a similar zone of deformation is associated with the **Carolina Fault**, most of the sites with F>1,000 ppb are located in these zones.

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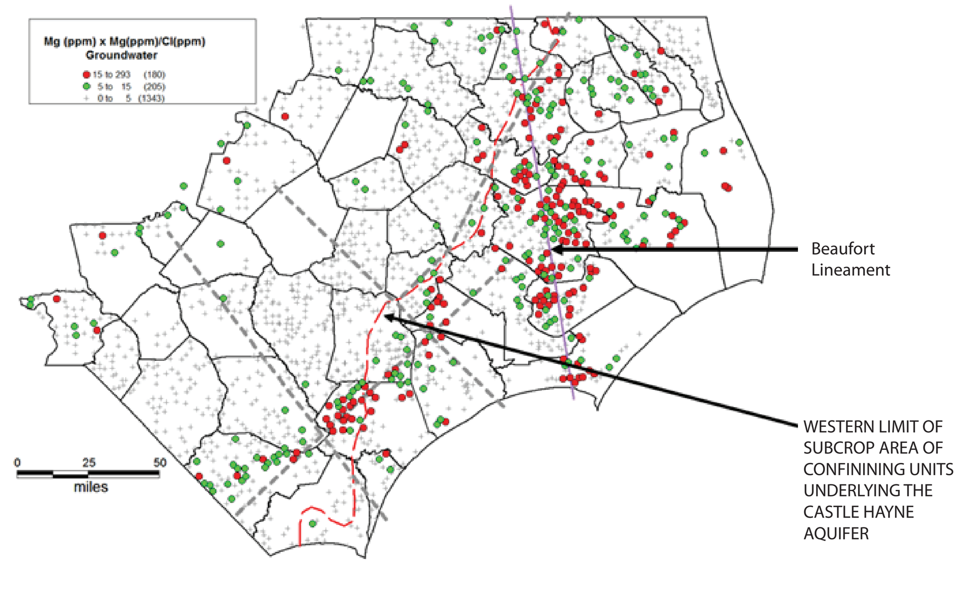

Mg (ppm) x Mg(ppm)/Cl(ppm) - groundwater. Mg x Mg/Cl emphasizes Mg that is related to dolomite dissolution rather than residual sea water. The **Carolina Fault** shows up well, and evidence for the **Beaufort Lineament** (purple) in the eastern Coastal Plain is also evident.

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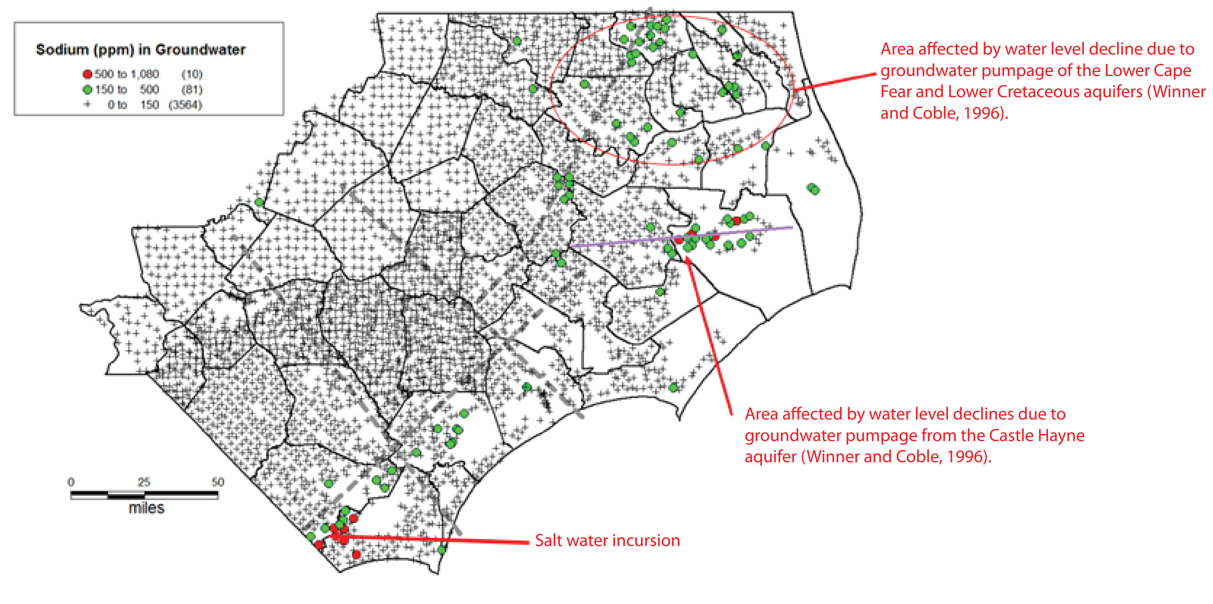

Sodium (ppm) in groundwater. High concentrations of sodium also follow rather precisely the NW-SE faults, but the east of the **Graingers Wrench Zone** there are some areas with high concentrations of sodium that form a belt trending ENE in Beaufort and Hyde counties; here termed the **Bayview-Scranton Lineament.** It is possible that the lineament is a structural feature along which sea water incursion has occurred.

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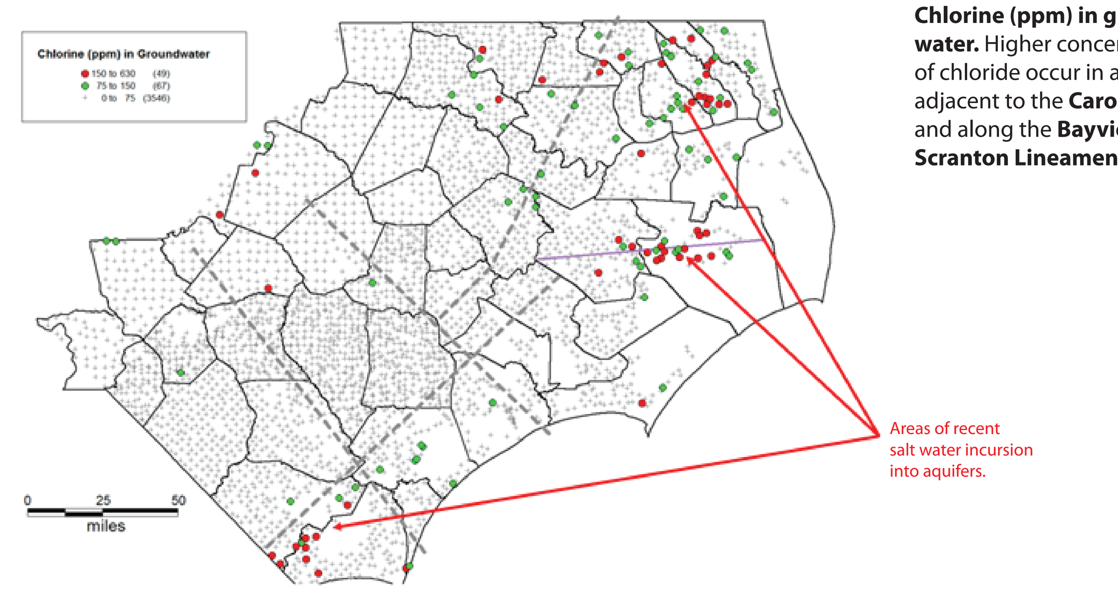

Chlorine (ppm) in groundwater. Higher concentrations of chloride occur in a belt adjacent to the **Carolina Fault** and along the **Bayview-Scranton Lineament**.

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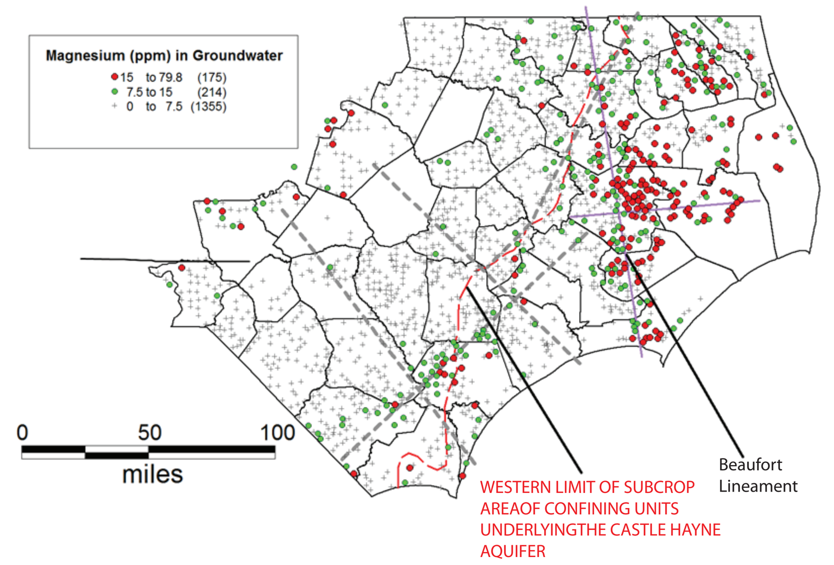

Magnesium (ppm) in groundwater. High concentrations of magnesium occur locally along the trace of the **Carolina Fault** zone, and to a lesser extent the **GWZ**, and along the **Beaufort** and **Bayfield-Scranton** lineaments (purple lines). The **Carolina Fault** and **GWZ** form a western boundary to high magnesium groundwater in the Coastal Plain. This also corresponds fairly closely to the western limit of the Castle Hayne aquifer (red line). Most of the high concentrations of Mg in groundwater in the Outer Coastal Plain can be attributed to dissolution of dolomite in the Castle Hayne aquifer, and the recent influx of seawater in the Outer Coastal Plain.

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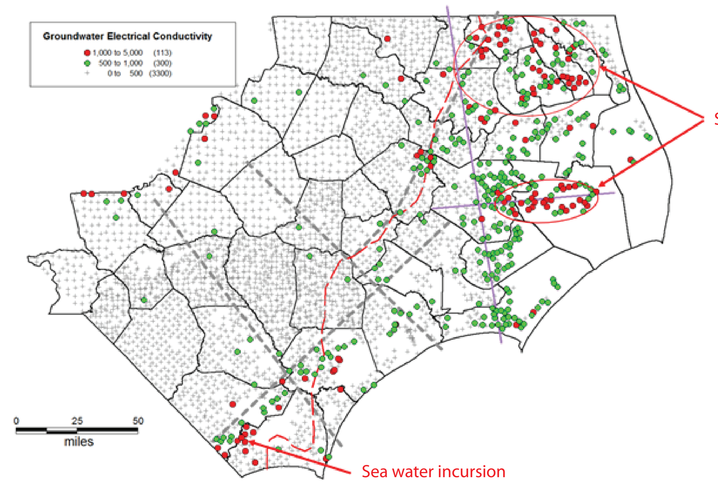

Groundwater electrical conductivity. Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge).

The western limit for high conductivity corresponds to both the NE-SW faults, and the western limit of the Castle Hayne aquifer (red line). A zone of high conductivity is also aligned along the **Beaufort** and **Bayview-Scranton** lineaments identified here.

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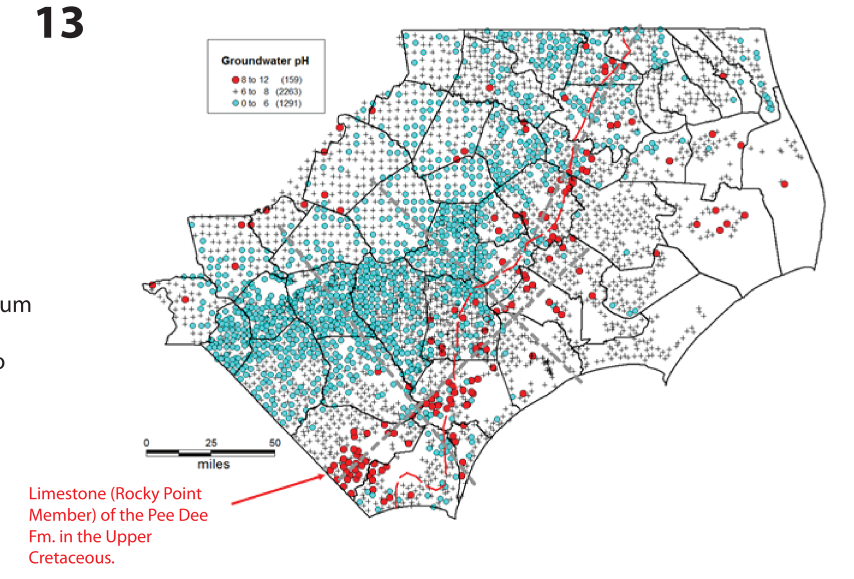

Groundwater pH. In chemistry pH is the negative log of the activity of the hydrogen ion in aqueous solution. Solutions with a pH less than 7 are said to be acidic and solutions with a pH greater than 7 are basic, or alkaline. Pure water has a pH of 7.

The **Carolina Fault** and the **GWZ** lie very close to the boundary between alkaline groundwater (pH>8, east - red circles) and acid (pH<6, west - blue diamond) and intermediate (pH>6 and <8 - black crosses) groundwater to the west. In some cases, alkaline water (east) is immediately adjacent to acid water (west) at a number of points. The Cretaceous aquifers consist mainly of unreactive sands and gravels so that acid surface water percolating into the aquifer remains acid. Alkaline groundwater occurs along the boundary between acid groundwater an the Castle Hayne aquifer, or in areas where the Cretaceous contains limestone beds.

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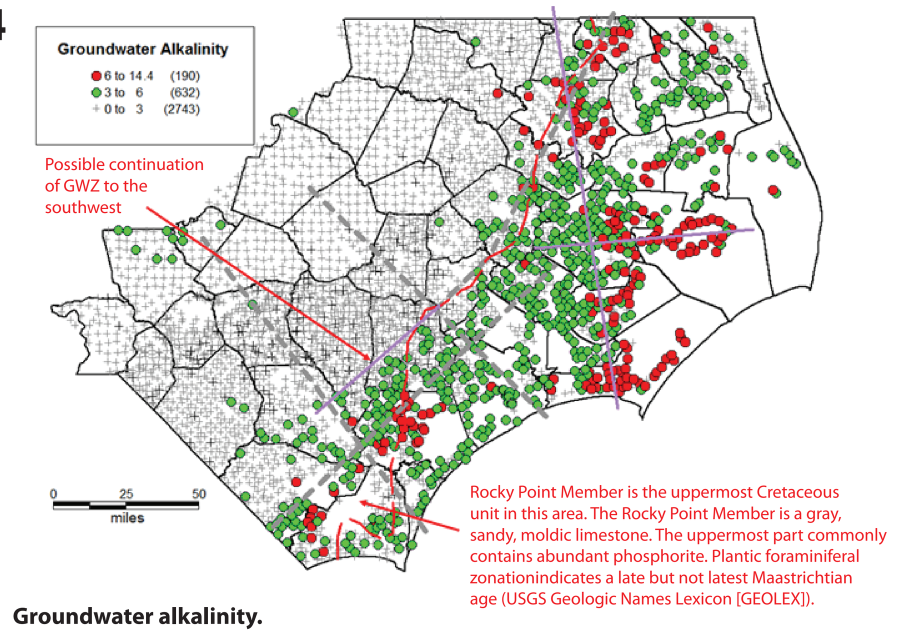

Groundwater alkalinity.

Alkalinity. This is the name given to the quantitative capacity of an aqueous solution to neutralize an acid. High alkalinity is mainly confined to the lower Coastal Plain east of the **Carolina Fault** and **Grainger Wrench Zone (GWZ)** with the boundary corresponding to the western edge of the Castle Haynes aquifer. An exception is the area just west of the **Carolina Fault** in the south-eastern most counties of North Carolina. In this area limestone of the Rocky Point Member occurs at the top of the Cretaceous aquifers. If the **GWZ** extended to the southwest, the space between the **GWZ** and Carolina Fault would contain a zone of high alkalinity in groundwater. The references fault distribution system does not account for this relationship unless the **GWZ** continues to the southeast.

Groundwater with high alkalinity also occurs alon the **Beaufort** and **Bayview-Scranton** lineaments.

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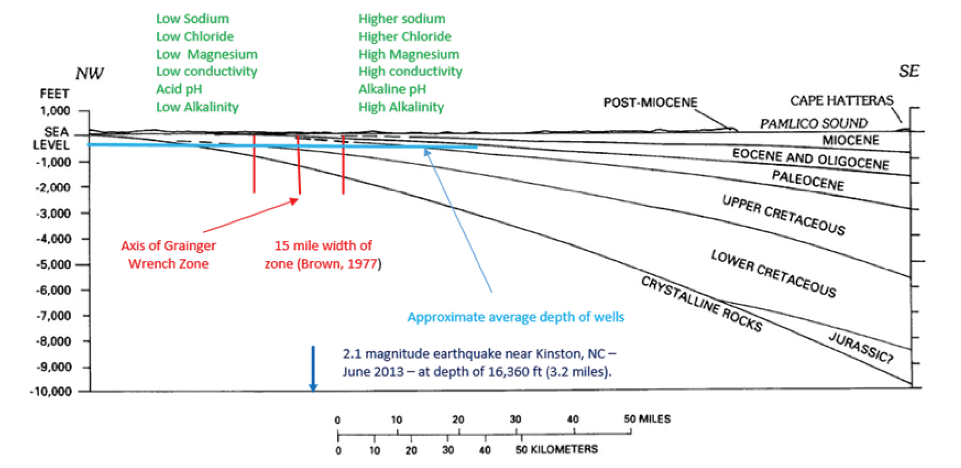

Generalized cross section of the North Carolina Coastal Plain from Wilson, N.C. to Cape Hatteras, N.C. (Winner and Coble, 1996) showing generalized age of sediments, location of the **Grainger Wrench Zone**, estimated well depths in the region, and relationship of groundwater variable along this zone.

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Faults and Triassic basins. Triassic basins that are buried or inferred in the Coastal Plain are based mainly on limited drilling and geophysical evidence. Faults that relate to hydrochemistry of Coastal Plain groundwater are the **Carolina Fault** (**CF**), the **GWZ**, and possibly the lineament identified in this study (green line). The **CF** may have been a bounding fault for either the Columbus basin or the Columbus South basin. The northern extension of the **CF**, and the southern extension of the **GWZ** bound the basin referred to as either the Graingers or Craven-Jones basin. However, McLaurin and Harris (2001) noted that a sample from this basin is actually Paleozoic argillite, not Triassic sediment. The Bertie basin is offset by the **GWZ**, and is parallel to the **Beaufort Lineament** (green line) identified in this study. It is possible that earlier movement associated with the **Beaufort Lineament** was an eastern bounding fault to the Bertie "basin". In the area referred to as the 'Cumberland-Marlboro basin', Reid *et al.* (2015) drilled three holes to basement and recovered metamorphic rock indicating a buried Triassic rift is not the cause of a large aeromagnetic anomaly where the holes where drilled.

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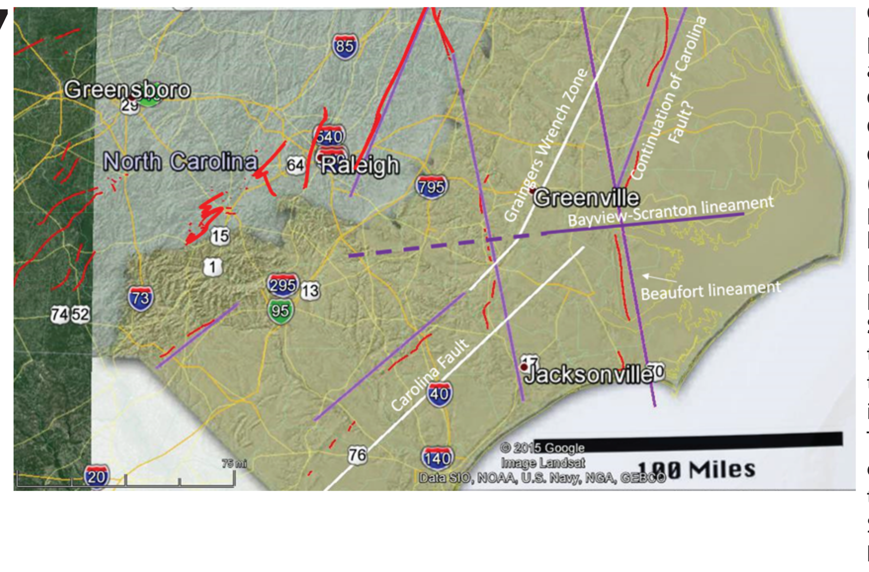

Comparison of geochemical lineaments presented here with scarps (thin red line) and faults (thick red lines) shown on the Geologic Map of North Carolina (North Carolina Geological Survey, 1985), and the **Graingers Wrench Zone** and Carolina faults (after Harris, Zullo, and Baum, 1979). Other possible trends (purple) are drawn along lineaments identified in this study, or parallel trends in the fault patterns, and the physiographic scarps. The **Bayview-Scranton Lineament** marks a change in trend of NE-SW faults or scarps. North of the **Bayfield-Scranton Lineament**, indicated trends are N 10 W, and N 22 E. Thus, the **Carolina Fault** may actually extend to the northeast along the same trend as the **Graingers Wrench Zone**. South of the **Bayview-Scranton Lineament** trends are N 45 E and N 10 W.

Conclusions

Controls on the hydrochemistry of groundwater variables included in the NURE database for the North Carolina Coastal Plain are as follows:

1) The **Graingers Wrench Zone** and the **Carolina Fault**, as presented by Harris, Zullo, and Baum (1979).
2) **Beaufort Lineament.** Geochemical lineament that trends N 10 E and extends NW from Beaufort, N.C.
3) Incursion of sea water in coastal area, and along the **Bayfield-Scranton Lineament** in the Pamlico Embayment area.
4) The lithologies of principal aquifers in the Coastal Plain (lower values of pH, electrical conductivity, alkalinity, and magnesium in sandy and conglomeritic units; higher values in units containing limestone and dolomite).

The fact that a segment of the Suffolk scarp is coincident with a geochemical lineament, and that segments of other scarps are parallel with faults or geochemical lineaments described here, reopens the question of whether faulting played a role in the origin of the Suffolk, Surry, or Orangeburg scarps.

Comparison of the azimuths of geochemical lineaments with those of the **Carolina Fault/Graingers Wrench Zone**, the Surry, Suffolk, and Orangeburg Scarps, and faults delineated in the eastern Piedmont show a distinct pattern. North of the **Bayview-Scranton Lineament**, the trends are N 10 W and N 22 E. South of this lineament the trends are N 10 W and N 45 E.

References Cited

Brown, P.M., Brown, D.L., Shufflebarger, T.E., Jr., and Sampair, J.L., 1977, Wrench-style deformation in rocks of Cretaceous and Paleocene age, North Carolina Coastal Plain: North Carolina Department of Natural and Economic Resources, Division of Earth Sciences, Special Publication 5, 47 p.

Ferenczi, I., 1959, Structural control of the North Carolina Coastal Plain: Southeastern Geology, v. 1, p. 105–116.

Harris, W.B., Zullo, V.A., and Baum, G.R., 1979, Tectonic effects on Cretaceous, Paleogene, and early Neogene sedimentation, North Carolina, *in* Baum, G.R., *et al.*, eds., Structural and stratigraphic framework for the coastal plain of North Carolina: Carolina Geological Society and the Atlantic Coastal Plain Association, Field Trip Guidebook, p. 17–29.

LeGrand, H. E., 1955, Brackish water and its structural implications in Great Carolina ridge, North Carolina: Am. Assoc. Petroleum Geologists Bull., v. 39, p. 2020-2037.

North Carolina Geological Survey, 1985, Geologic Map of North Carolina, scale 1:500,000, color.

McLaurin, B.T., and Harris, B.W., 2001, Paleocene faulting within the Beaufort Group, Atlantic Coastal Plain, North Carolina, GSA Bulletin; May 2001, v. 113, no. 5, p. 591–603.

Reid, Jeffrey C., Coleman, James L., Taylor, Kenneth, B., Marciniak, Katherine J., Haven, Walter T., Channell, Ryan A., and Warner, Chandler I., 2015, North Carolina Geological Survey Open-File Report 2015-XX: Cumberland-Marlboro basement drilling results – 2015: Cumberland, Hoke and Scotland counties, North Carolina, in preparation.

Smith, S.M., 1997, National Geochemical Database: Reformatted data from the National Uranium Resource Evaluation (NURE) Hydrogeochemical and Stream Sediment Reconnaissance (HSSR) Program, Version 1.40 (2006): U.S. Geological Survey Open-File Report 97-492, WWW release only, URL: http://pubs.usgs.gov/of/1997/ofr-97-0492/index.html, last accessed Feb. 1, 2006.

Winner, M.D. Jr., and R.W. Coble, R.W., 1996, Hydrogeologic Framework of the North Carolina Coastal Plain, U.S. Geological Survey Professional Paper 1404-1, 106 p.

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