

# **Previous work**

AREA, NORTH CAROLINA

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### ABSTRACT

The National Uranium Resource Evaluation (NURE) program was initiated by the Atomic Energy Commission (AEC) in 1973 with a primary goal of identifyin uranium resources in the United States. The program ended in 1983. Two major phases of the program included sampling and analysis of stream sediment and groundwater in many areas of the United States. This study utilizes stream sediment data. There were 397,609 stream sediment samples collected and analyzed for the United States (Smith, 1997).

Elements of interest in minus 100-mesh stream sediment include Th, REE, K, Fe, and Ti. The Durham sub-basin and the Rolesville batholith are enriched in Th, REE, and K, and depleted in Fe and Ti compared to the rocks of the Carolina, Falls Lake, Raleigh and Crabtree terranes that lies between these units. Monazite has been identified in the Rolesville batholith, and the La/Th ratios are consistent with that of monazite in both the Rolesville batholith and the Durham sub-basin. The La/Th ratio in rocks surrounding the basin are much higher, and out of the normal range of monazite. Consequently, La and Th likel reside in different minerals in these rock units.

A geologic model which explains these relationships involves uplift of the Rolesville batholith resulting in erosion and formation of a clastic wedge on a pediment surface that extended to the west. During the early history of the Durham sub-basin, the clastic wedge probably extended over the entire basin, and was captured by the basin during periods of subsidence along the Jonesboro fault. So long as the clastic wedge extended over the entire basin, rock units surrounding the basin were covered and did not contribute sediment. The northern portion of the Durham sub-basin is interpreted as a principal depo-ce From here, sediment was re-transported to more southerly portions of the sub-basin along basin axial flow.

Implications of these findings on the depositional, erosional, and tectonic history of the area complements recent studies on the natural gas resource potential of the Deep River basin (Reid and Milici, 2008; Reid and others 2011)





Fe and Ti concentrations in stream sediment. Fe and Ti concentrations in stream sediment minerals are much higher in streams draining the geologic terranes located between the Durham sub-basin (yellow shade, left) and the Rolesville batholith (tan shade, right).



Th and K concentrations in stream sediment. Th and K concentrations in stream sediment minerals are much higher in the Rolesville batholith and the Durham sub-basin than in the intervening geologic terranes.



Hypothetical model showing relationships during the Triassic compared to the present day erosional surface. The Rolesville batholith is uplifted by folding (Wake-Warren anticlinorium) and/or faulting to form a highland area.

PERMIAN, TRIASSIC, AND JURASSIC HISTORY OF THE RALEIGH – DURHAM AREA, NORTH CAROLINA

Biotite age of 255 Ma suggests that depth of crystallization had risen to 7.5 – 10 km below the existing surface. The uplift probably occurred on faults along the margin of the granite batholith.

Uplift continued throughout most of the Triassic, and when downdrop occurred along the eastern edge of the Durham sub-basin (this includes the Jonesboro and other faults near the eastern margin) at 235 Ma, basal sediment in the alluvial fan was captured and preserved within the basin. Later, as sedimentation occurred within the basin, downdrop along the eastern margin influenced facies relationships, and lacustrine deposits formed during periods of rapid downdrop of faults along the eastern margin of the basin.

. When diabase dikes were intruded at 200 Ma, they cross cut the Jonesboro fault with no offset suggesting that downdrop had ceased along the eastern margin of the Durham sub-basin by that time. However, vitrinite reflectance data and heulandite-harmatome relationship in dike amygdules indicate that 1-3 km of additional sediment covered the basin, but has subsequently been eroded away.

# Tracking the 12 km uplift history of the Rolesville Batholith through the period of development of the Durham sub-basin to the present.









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# Permian, Triassic, and Jurassic history of the Raleigh-Durham area, North Carolina

by Robert H. Carpenter\* and Jeffrey C. Reid\*\*

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# **Current study**

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Previously, Carpenter and Reid (2014) provided evidence that the Rolesville batholith was the principal source of sediment to the Durham sub-basin of the Deep River basin. They proposed that uplift of the batholith formed a highland area from which an alluvial fan extended at least to the western edge of the Durham sub-basin.

The present study extends this hypothesis using published geochronological and geobarometric data, and examines the uplift history of the Rolesville batholith during the Permian and Triassic periods. Key events are as follows:

Intrusion of Rolesville granite at 300 Ma. Rocks now exposed at the surface crystallized at an estimated depth of 12 km.

In early Jurassic time the highland area persisted without further uplift and was subsequently eroded to the present surface configuration.

- Geologic terrane map of the Raleigh-Durham area modified from Horton et. al., 1994.

2 - The section line corresponds to A-A' in the Grid cell thematic of Thorium in stream sediment.Note the parallelism of the Jonesboro fault with the western boundary of the Rolesville granite. This is a puzzle that needs to be dealt with. We suggest that this may



ions are constructed with no vertical exaggeration. I block is 4 km on a side. Relative locations of o Fault and Rolesville batholith are shown.

3 - Intrusion of the Rolesville Batholith about 300 Ma. Assumed depth of crystalization was ~12 km.



ALEXANDER SPEER

e Rolesville batholith is interpreted to be a late Paleozoic intrusion (Farrar, 1985 a,b). There have been many attempts to date the granites, but success appears to have been hampered by the composite nature of the pluton. The northern peraluminous border granitoid of the Castalia pluton has a Rb-Sr whole rock age of 313±13 Ma (Fullagarand Butler, 1979). Horton and Stern (1994) reported 207Pb/206Pb ages of bulk zircon splits for several granitoids within the Rolesville pluton: 312 Ma for the Lassiter granitoid, 298 Ma for the Mitchell granitoid, and 286 Ma for what may be the Rolesville main granitoid at the northernmost tip of the batholith An 40Ar/39Ar biotite cooling age of 255 Ma from the Rolesville main granitoid in the southwestern corner of the batholith was determined by J. Sutter (unpublished data) From: http://www.carolinageologicalsociety.org/CGS/1990s files/gb%201994.pdf

The granitic pluton east of the Jonesboro fault that is referred to in the text is the Rolesville Batholith, a granitic pluton formed in the late Paleozoic (Heller et al., 1998; Reference RAI 02.05.01-18 02). The batholith is interpreted to have been formed during a single pulse of magmatism at around 298 Ma (Schneider and Sampson, 2001 in Raleigh 100k quadrangle [NCGS, Reference 2.5.1-275]).

Depths of emplacement of Carboniferous-Permian granitoids range from 8-19 km. (McSween, Speer, and Fullagar – Carolinas Volume

4-255 Ma Section - Biotite closure age.



Assuming a geothermal gradient between 30° C/km and 40° C/km the 12 km depth of crystallization will have been raised to 7.5 to 10 km by 255 ma. We suggest that this uplift occurred along faults at, or near, the margin of the granite, and was largely due to isostatic adjustment of the lighter granite, but continued to rise as tensional forces developed in the

40Ar/39Ar biotite cooling age of 255 Ma. Biotite closure temperature is reported to be 300 degrees C by Wikipedia. If the geothermal gradient were 25 degrees C/km, (average for crust) the depth would still be 12 km – and there would be no uplift between 300 Ma and 255 Ma. If the geothermal gradient were 30 degrees C/km the depth would be 10 km, an uplift of 2 km during this period. This is more reasonable, and I will use this number. Should I change this? If the geothermal gradient were 40 degrees centigrade per kilometer, the depth of biotite closure would be 7.5 kilometers, and granite would be exposed at the surface.



approximate timescale of ke

Permian events.

Axis scale: millions of years ago.

Permian events. Axis scale: millions of years ago.



5 - Here is the geothermal gradient as it exists today. Higher values occur in areas where magma is near the surface (e.g., Yellowstone) or where heat flow from radioactive sources is higher than normal. Red arrows on scale shows our assumption of geothermal gradient at 255 ma (30° C – 40° C/km). This is not significantly different than the present-day geothermal gradient.

6 - Cross Section 235 Ma immediately before movement along the Jonesboro Fault





The Rolesville batholith, as shown, has been uplifted 6 km from original depth of emplacement. Approximately 1/2 of total uplift of the granite has occurred by 235 Ma. A prominent highland area has developed over the Rolesville batholith. An alluvial fan extends over the area now occupied by the Durham sub-basin. Assuming the alluvial fan derived from the granite has a slope of 4 degrees (on average) the height of the granite highland should be 3 to 4 km higher than the western edge of what will become the Durham sub-basin. This would constitute a significant mountainous terrane.

pre-date initial movement along the Jonesboro Fault.

7 - Deposition in Triassic basin - 235 to 225 Ma

The continents began to break apart at 235 million years, and it has been proposed that this is about the time that movement on the Jonesboro fault began. However faulting associated with the uplift of the Rolesville granite began earlier. If down droppir along the Jonesboro fault began at 235 ma, the basal sediment that was captured fro the alluvial fan would be older. About 5,000 feet of sediment accumulated in the deepes part of the Durham sub basin over the next ten million years (see red arrow in section In the diagram below, lacustrine and coal forming swamp environments are sandwiched by fluviatile sediments. We suggest here that lacustrine sediments and coal forming swamps formed during periods of more rapid down-dropping along the border faults.

It is possible that most of the sediment in the Pekin formation was "captured", and that sluggish drainages forming lacustrine and swamp sediment of the Cumnock formation represents the commencement of rapid down-drop along the eastern border faults.

	DEE	EP RIVER	BASIN		
Durham sub-basin		Sanford sub-basin	ı ı	Vadesbo sub-basi	ro n
	12	Sanford			
		Cumnock Pekin	▲#c] ▲]+	Pekin	
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Fig. 9-5. Co 1989) Bruce Co (oral communi	orrelation o ornet (oral ication, 198	f sub-basins communicati 89) for late Ca	within the I ion, 1989), F arnian-earl	Deep River b Robbins and V Norian (Da	asin w Trave anville
North America Social	Europe		The All o into Note Late	Superc f the ma a single that so Triassio	ontii ajor e lar outhe c eq
		11	Pale	eozo	ic

Since movement along the Jonesboro fault has not occurred, the character of sediment in the alluvial fan is not influenced by the half-graben structure. Therefore, when down-drop begins along the Jonesboro fault, sediments at the base of the alluvial fan are simply "captured" by the basin, and were not deposited in the basin. Traditional thinking is that all the sediment located within the basin was deposited there – but that is not necessarily the case. In fact, fossils near the base of the Triassic section may

Arbogast (1976) stated "...Facies relationships and petrographic interpretations suggest a fluvial origin for these sediments, which were derived from an igneous and high rank metamorphic source area that lay east of the Jonesboro border fault...."



with the Dan River basin. Based on data in Olsen and others (1977, 1982, erse (1980) for middle-late Carnian (Dan River basin, N.C.), and Litwin

tinent Pangea during Late Triassic time. continents of a today were assembled dmass surrounded by a large ocean. ern North America was located at the quator. Modified from Olsen (1997).

c granites (Right).

2005 - PALEOGEOGRAPHIC AND TECTONIC IMPLICATIONS OF THE LATE PALEOZOIC ALLEGHANIAN OROGEN DEVELOPED FROM ISOTOPIC SEDIMENTARY PROVENANCE PROXIES FROM THE APPALACHIAN FORELAND BASIN Thomas Patrick Becker, University of Kentucky, tpbeck2@uky.edu

Full recovery of woody trees<sup>[7]</sup>

-Mass extinction

An approximate timescale of key

Triassic events.

Axis scale: millions of years ago.

By Late Triassic time (~235 Ma)

and possibly earlier, this landmass

continents began to drift toward th

present-day positions over the last

Roy W. Schlische, Department of

Geological Sciences, Rutgers

began to break apart, and the

200 million years (m.y.).

University

The map on the left shows late Paleozoic granites in various age categories. The map on the right shows that many Triassic basins are covered by Coastal Plain sediments. It is quite likely that a number of late Paleozoic granites also occur beneath the Coastal Plain. Sediment eroded off of these granites and basins may have contributed extensively to the continental shelf.



ave been necessary for this much overburden to have been removed since middl Mesozoic time. The Jurassic burial-metamorphic event, more than 150 Ma, is the only such event recorded in the dike rocks (as paleomagnetic chemical remanent magnetizatior

From: http://pbadupws.nrc.gov/docs/ML0900/ML090070289.pdf



**Above:** Erosion depth estimates from multiple wells. Estimated maximum erosion shown based on the %Ro data using Dow's (1977) method to determine the amou of eroded strata (linear plots of the  $\log_{10}$  of vitrinite vs. depth). The regression line is extrapolated back to 0.2% Ro, the reflectance of early diagenetic woody plant matte to find the amount of missing section. It is assumed that there was no change in ther onductivity or geothermal gradient in the eroded section. Offset data points from the regression line reflect local block faulting (e.g., Bobby Hall #1 well). The Dummitt Palmer #1 (CBM) points that lie off the regression line were 'over-cooked' by diabase dikes resulting in anomalous %Ro (modfied from Reid and others, 2011, Fig. 19).

### 9 - 200 Ma section at time of diabase dike intrusion.



Section (left) shows age of emplacement of diabase dikes (200 ma). Geologic section (above) shows 5,000 ft. thickness of sediment now present in deepest parts of Durham sub-basin, and >3,000 feet of additional sediment that has been eroded away. The dotted line approximates the present erosional surface. Basically, uplift of the granite ceased at 200 ma, and all material above the dotted line has been eroded away since the beginning of the Jurassic.

New evidence for geologically instantaneous emplacement of earliest Jurassic Central Atlantic magmatic province basalts on the North American margin W.E. Hames\*1, P.R. Renne\*2 and C. Ruppel\*3

Dikes in the southeastern United States represent a major component of the Central Atlantic magmatic province and record kinematics of Pangean breakup near the critical, predrift junction of three major continental masses. Until now, the age of these dikes had not been determined with the same precision as those of Central Atlantic magmatic province basalts on other parts of the circum-Atlantic margin. Our new results for three dike samples from the South Carolina Piedmont yield plateau ages of 198.8 ± 2.2, 199.5 ± 1.8, and 199.7 ± 1.5 Ma. For comparison, we present new age determinations of the benchmark Watchung flows I and III of the Newark basin: 201.0 ± 2.1 and 198.8 ± 2.0 Ma, respectively. Collectively, these data suggest that basaltic volcanism responsible for the dikes, flows, and sills of eastern North America occurred within 1 m.y. of 200 Ma. The timing, brief duration, and extent of the Central Atlantic magmatism imply that it may have been causally related to Triassic-Jurassic mass extinctions. The distribution and timing of this magmatism and the absence However, the geochemical signature of NURE stream sediment within the basin is much more closely related to the of regional uplift or an identifiable hotspot track lead us to favor strong lithospheric control on the origin of the Central Atlantic magmatic province, consistent Petersburg granite. Consequently, the Petersburg granite is a very good candidate as a source rock for the Triassic. with the modern generation of plume incubation or edge-driven convection models.



10 - Tectonic terrane map of the Raleigh metamorphic belt in the eastern slate belt.

The major plutons are the Rolesville, Castalia, Wise, Sims, Buggs Island, Wilton, and Butterwood Creek. The major folds are the Wake-Warren anticlinorium, the Raleigh, Lake Royal, and Thelma antiforms. The major fault zones are the Jonesboro, Leesville, Falls Lake, Nutbush Creek, Lake Gordon, Macon, Middle Creek and Hollister. Jonesboro fault and proposed new faults along the border of the Rolesville granite are shown in red. Modified from Stoddard and others (1991) and Sacks (1999).

The axis of the Wake-Warren anticlinorium is shown to be coaxial with the Rolesville granite. It plunges to the southeast. Cover rocks wrap around the southern end of the batholith. This "anticlinorium" is assumed to represent the broad anticline formed upon intrusion of the granite







12 - Fe% in stream sediment - NURE data - Dan River basin, Virginia and North Carolina



own in red. It is a half graben like the Durham sub-basin, but in this case the fault is on th ere is another fault to the west of the border fault known as the Stony Ridge fault. It is also consider Mesozoic in age. Relationships are shown for iron in modern stream sediment. The blue hachure lines show the approx poundary of low iron sediment

The low-iron area is wide on the east side of the basin; but very narrow on the west side. If the geographical relationship of t ocks today are similar to what they were when Triassic sediments were deposited, the high iron rocks to the west did not provid sediment to the basin. It is possible that a zone only a few miles wide, perhaps the area between the Stony Ridge fault a western border fault, provided much of the clastic sediment in the basin. There are clastic wedges with coarse conglome hat are derived from rocks to thewest of the border fault. Since there may not be a wide source area for the low iron rocks, it would mean that a lot of uplift occurred in a rather small area. Further west, high iron rocks must have drained off to the west due to westward tilting of this area. In the Durham sub-basin, down drop along the Jonesboro fault was complemented by uplift of the Rolesville, quite a distance to the east. Here, down drop to the east of the border fault was complemented by uplift mmediately west of this fault. So, each basin has it own unique structural style. Also, granite plays an important role in the of the Durham sub-basin, but is of little or no importance for the Dan River basin.

3 - Stream sediment data (vanadium) for the Richmond basin area.



The Richmond basin is shown in vellow, the Petersburg granite in blue, fault lines are red. The source of geological data is the digital geologic map of Virginia. High concentrations of vanadium to the west of the basin are ot reflected in stream sediment from the basin. Therefore, rocks to the west are not a likely source of Triassic sedimer In fact, the alluvial fan model adapted for the Durham sub-basin might well apply here. Major down-drop occurred alor the Hylas fault along the western margin of the basin. The uplift component appears to be along the western border of the Petersburg granite, and the area immediately east of the Richmond basin.

14 - Comparison of the inferred structural architecture of the three



more easily identified in the field as the contrast between the Triassic sediment and crystalline rocks is easy to recognize. Assignment of uplift components may require faults that have not been previously recognized.

### Conclusions

- Sediment contained in Triassic basins has been the subject of detailed paleontological, stratigraphic, and sedimentological investigations. However, less attention has been given to the provenance of these sediments.

- This study suggests that establishing provenance can provide important information on the structural architecture of the basins that could be of importance in exploration for oil and gas. This study also indicates that considerable uplift of Late Paleozoic granites occurred at the time the Triassic basins were forming.

- These granite highlands, that may have been horst-block segments, and may have exceeded elevations of >10,000 feet above adjacent basins, have been eroded away in Jurassic and post-Jurassic time

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