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Abstract

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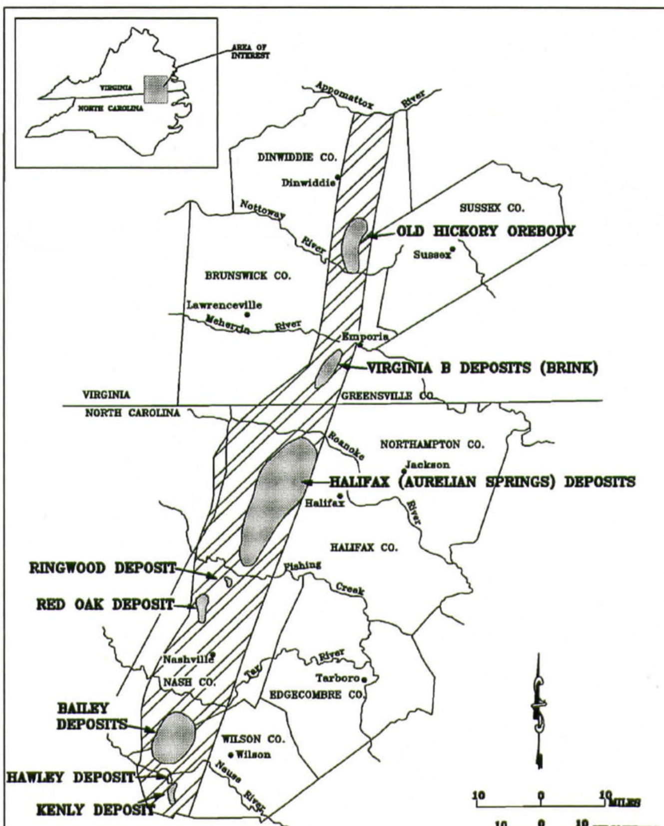

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DEPOSITIONAL ENVIRONMENT OF THE HEAVY-MINERAL DEPOSITS OF BAILEY, NORTH CAROLINA, U.S.A.

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ABSTRACT

The Bailey, North Carolina, heavy-mineral deposits cover 12.9 square kilometers and contain 5.72 million metric tons of heavy minerals. The sediments comprising this deposit average 6.2 meters thick and contain an average of 4.72 weight percent heavy minerals. Valuable heavy minerals comprise 65 to 70 percent of the heavy-mineral suite and are comprised of ilmenite, leucoxene, rutile, and zircon.

Most of the Bailey heavy-mineral concentrations lie south, southeast, east, and northeast of the town of Bailey, North Carolina. In this area, unconsolidated Cenozoic sediments of the inner Coastal Plain unconformably overlie the roughly circular Upper Paleozoic Sims pluton which intrudes the older slate belt rocks of the region. The Kenly and Hawley heavy-mineral deposits, south of the Bailey deposits, are probably a continuation of the Bailey deposits. The separation of the two areas of heavy-mineral concentrations most likely is the result of post-depositional stream erosion. It is hypothesized that tides and fluvial processes served as the main agents for concentrating the heavy minerals. It is also hypothesized that the presence of delta and salt water marsh environments resulted in the accumulation of the majority of the kaolin clay that is present. Heavy minerals of the Bailey deposits were probably carried by the Neuse River and deposited in a delta at the edge of a salt marsh. A combination of the crossbedding and *Ophiomorpha* strongly suggest that the ancient sediments were deposited in subtidal high-energy shoals associated with a tidally-dominated channel of moderate size, such as an inlet or sound associated with barrier islands. Thus, the clay and heavy-mineral concentrations seem to have been partially the result of tidal and fluvial processes operating in a shallow marine to brackish (salt marsh) depositional environment. The Sims pluton appears to have played a role in influencing the path of the Neuse River and, hence, the formation of the Bailey deposits. Based on the pollen present, the Bailey heavy-mineral deposits are probably of Late Pliocene or Early Pleistocene age.

INTRODUCTION

Fall Zone of North Carolina and Virginia

The Fall Zone is a 16- to 32- km (10- to 20-mile)-wide area where the wedge of sediments of the Coastal Plain Province overlaps and pinches out on the crystalline rocks of the Piedmont Province (Gallagher and Hoffman, 1990). Heavy-mineral concentrations in the high-level gravels of the Fall Zone in southeastern Virginia were recognized by Berquist (1987). Pirkle *et al.* (1991) published the locations of the deposits in April 1991 (Figure 1) and Carpenter and Carpenter (1991) published the first descriptions of the deposits later that year. The Old Hickory, Halifax, and Bailey deposits are the largest heavy-mineral concentrations located to

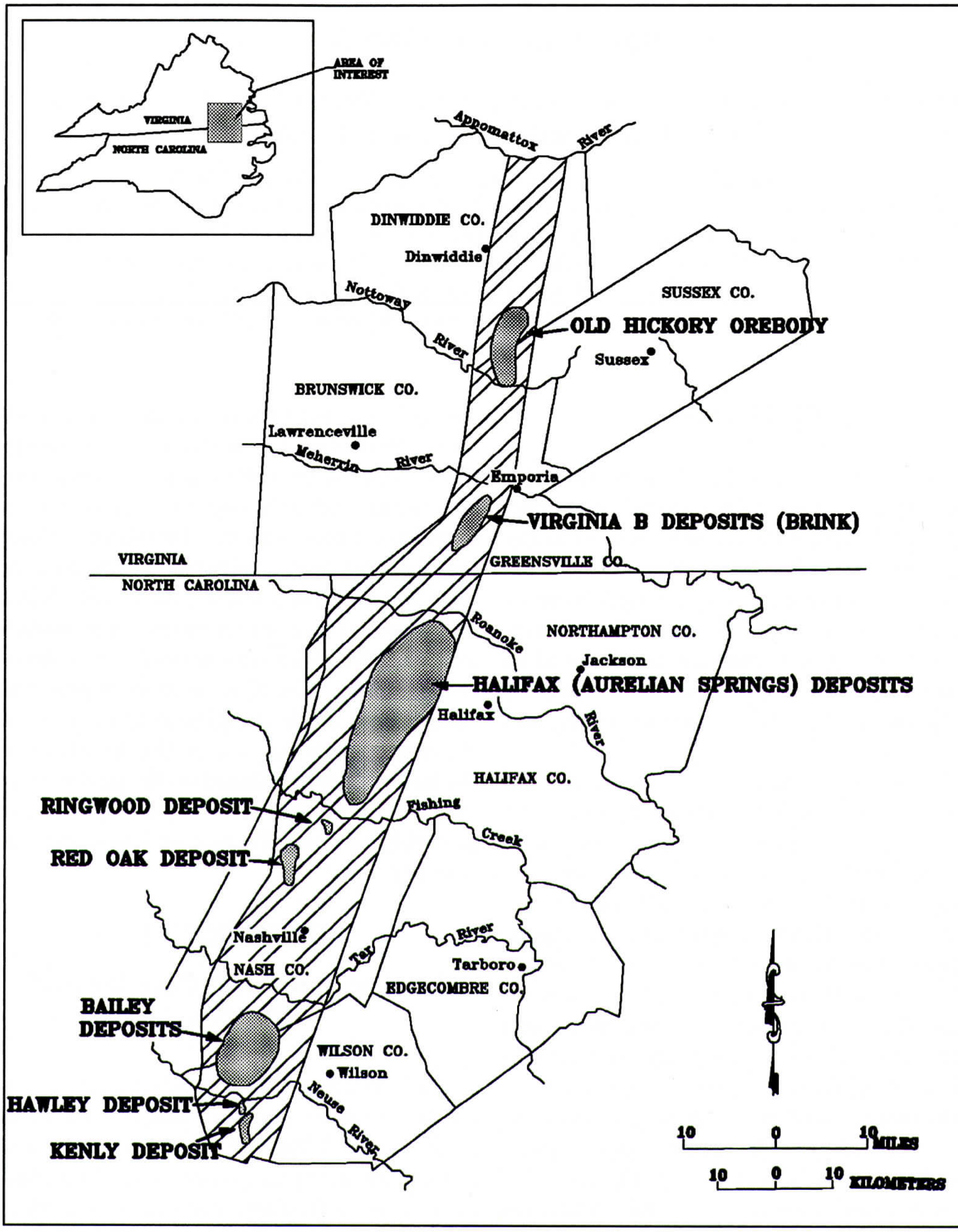

Figure 1. Areas along the Fall Zone in Virginia and North Carolina in which heavy-mineral concentrations are present. The various areas shown in the figure by parallel lines are not underlain throughout by heavy-mineral concentrations. However, there are heavy-mineral deposits within the lined areas. The Virginia B deposits of Pirkle *et al.*, 1991, were renamed the Brink deposits by Carpenter and Carpenter, 1991. The Halifax deposits of Pirkle *et al.*, 1991, contain the Aurelian Springs deposits of Carpenter and Carpenter, 1991. This figure is modified from Pirkle *et al.*, 1991, Carpenter and Carpenter, 1991, and Pirkle *et al.*, 2007a.

Series		Carpenter and Carpenter (1991)	Powars and Bruce (1999)		Cederstrom (1957)	Mixon *et al.* *(1989)*
Pliocene	U		Yorktown Formation	MooreHouse Member	Yorktown Formation (Miocene)	Yorktown Formation
		Upper Unit		Mogarts Beach Member		
		Lower Unit		Rushmere Member		
	L			Sunken Meadow Member		

Figure 2. Correlation of stratigraphic units (modified from Powars and Bruce, 1999).

date within the Fall Zone of Virginia and North Carolina. The Halifax deposit was renamed Aurelian Springs by Carpenter and Carpenter (1991). Hawley, Kenly, Ringwood, Red Oak and Virginia B [renamed Brink by Carpenter and Carpenter (1991)] are smaller deposits within this heavy-mineral province. Presently the Old Hickory and Virginia B (Brink) heavy-mineral deposits are being exploited.

Carpenter and Carpenter (1991) report that the heavy-mineral deposits in the North Carolina-Virginia Fall Zone contain a collective total of 22.7 million metric tons of heavy minerals at an average grade of 6 weight percent of the total 377.8 million metric tons of sand. They describe the sediments containing the heavy-mineral deposits as up-dip equivalents of the Yorktown Formation (Pliocene), and they relate the depositional history to episodes of transgression and regression as described by Bailey (1987 and Figure 2). Carpenter and Carpenter (1991) discuss two sedimentary units that are present throughout the upper Coastal Plain, identifying them as the lower unit and the upper unit, and report that the heavy-mineral deposits occur within the upper unit. They postulate that the heavy-mineral deposits formed during a worldwide, Pliocene, transgressive-regressive event that occurred between 3.5 and 3.0 Ma. They contend the deposits formed in beach or dune sands during the regressive phase of the event over an elevation range of 96 meters (315 feet) to 53 meters (175 feet). They believe the clay found in the sediments of the deposits was introduced into the sands after deposition and not from the weathering of sand-size feldspar grains deposited with the quartz sand and heavy minerals. Also, they relate the origin of the Trail Ridge heavy-mineral deposits in Florida and Georgia to this transgressive-regressive event.

Other workers have characterized the deposits as the result of "typical" nearshore or beach processes. Mallard (1992) postulates the Bailey concentrations were formed during stillstands or slight transgressions during a general regression. Shafer (2000) attributes storm energy as a major concentrating factor for the Old Hickory deposits.

Berquist and Bailey (1999) believe that economic concentrations of heavy minerals at Old Hickory were the result of nearshore processes interacting with promontories and embayments along a rocky coastline. According to their depositional model the youngest sediments exposed and mined at Old Hickory are shore-face and nearshore deposits. They also correlate these sediments to the Rushmere and Mogarts Beach members of the Yorktown Formation (Figure 2). Furthermore, Berquist and Bailey believe that faulting, active during the deposition of the sediments at Old Hickory, may have influenced hydrodynamic conditions responsible for the deposition of the heavy minerals. These workers did not address the origin of the clay in the deposits.

Newton and Romeo (2006) contend that the deposits at Old Hickory were formed by marine processes operating at the intersection of shore-

Figure 3. The Terrace deposits and upland sediments unit is typically reddish-brown. The 1-foot channel sample collected from this outcrop (located next to the shovel) contained 4.16 weight percent heavy mineral and 2.29 percent TiO_2. The sample contained 0.05 weight percent +12-mesh material, 5.19 weight percent 12 x 30-mesh material, 60.85 weight percent 30 x 325-mesh material, and 33.91 weight percent –325-mesh material. This outcrop is located within the Bailey heavy-mineral deposits at an elevation of 88 meters (290 feet) above mean sea level.

lines and major paleorivers during multiple transgressive-regressive sequences that may have started in the Cretaceous and continued through Tertiary time. They believe marine reworking of delta deposits played a major role forming the Old Hickory deposits in southeastern Virginia. They conclude that zones of faulting may have occurred along the edge of the Coastal Plain in Virginia and North Carolina and that uplift along reverse faults may have generated topographic ridges and troughs that acted as barriers and traps to help localize and concentrate heavy-mineral deposits. They consider the clay disseminated throughout the sand "to be secondary and post-depositionally introduced as supergene enrichment from weathering of feldspar and infiltration of clay-laden meteoric waters." (Newton and Romeo, 2006, p. 467).

Pirkle *et al.* (2007a; 2007b), however, suggest that these Fall Zone heavy-mineral concentrations formed in Fall Zone deltas with the concentrating mechanism being a combination of fluvial processes allied with basement highs and lows. These investigators believe that longshore current and wave action played only minor roles in concentrating the heavy minerals, although this does not exclude local tombolo effects. They also believe the clays are primary and were deposited as clay along with the quartz sand and heavy minerals.

Geologic Setting of the Heavy-Mineral Deposits in the North Carolina-Virginia Fall Zone

Gallagher and Hoffman (1990) provide general background information on the geology, physiography, and potential heavy-mineral resources of the North Carolina Fall Zone. They also provide a summary of previous studies including those related to the scarps and terraces within the area. In their study, Gallagher and Hoffman report that two sedimentary units are mappable within the area: (1) the Yorktown Formation; and (2) undifferentiated surficial

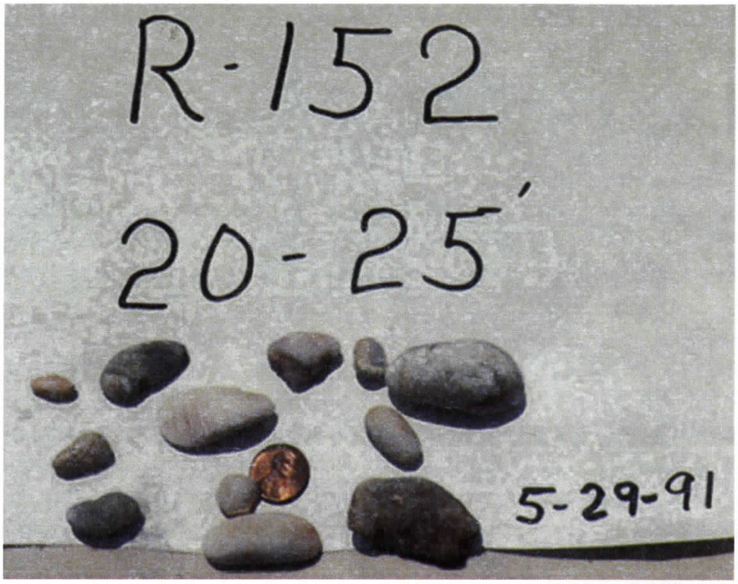

Figure 4. Pebbles recovered from 6.1–7.6 meters (20 –25 feet) below the land surface on the Red Oak heavy-mineral deposit. See Figure 1 for deposit location.

Figure 5. Cobbles collected from the fields within the Red Oak heavy-mineral deposit. See Figure 1 for deposit location.

sediments of the "terrace deposits and upland sediments" unit. The latter unit is the one of interest for heavy-mineral exploration within the Fall Zone region of North Carolina and Virginia. Gallagher and Hoffman (1990) describe the "terrace deposits and upland sediments unit" as consisting of gravel, clayey sand, clay, and sand with minor amounts of iron-cemented sandstone. The unit typically is reddish-brown (Figure 3). The size of the gravel ranges from granule to cobble-size and clasts are generally rounded (Figures 4 and 5). The gravel may exhibit crude cross-bedding, and the sand consists of coarse to very fine quartz sand with common to abundant feldspar. Some of the cobbles are found beneath the heavy-mineral bearing sedi-

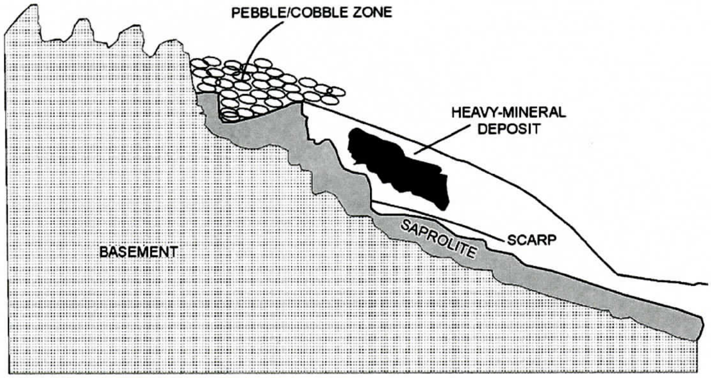

Figure 6. A generalized facies relationship of the pebble/cobble zone with the Fall Zone heavy-mineral deposits.

Table 1. General heavy-mineral suites found in heavy-mineral deposits of the Fall Zone and the Bailey deposits.

MINERAL SPECIES	PERCENT OF HEAVY-MINERAL FRACTION IN FALL ZONE DEPOSITS[1]	PERCENT OF HEAVY-MINERAL FRACTION IN BAILEY DEPOSITS[2]	PERCENT OF HEAVY-MINERAL FRACTION IN HAWLEY DEPOSITS[3]	PERCENT OF HEAVY-MINERAL FRACTION IN OLD HICKORY DEPOSIT[4]
Ilmenite/leucoxene	60	59.7	59.6	63[5]
Rutile	2.5	2.7	4.9	2.5[5]
Zircon	12.5	6.8	9.3	19
Staurolite	8.5	19.1	16.7	10
Tourmaline	0.7	1.1	1.5	
Kyanite and Sillimanite	4.3	9.5	7.1	6
Others	11.5	1.1	0.9	

1 From Carpenter and Carpenter, 1991
2 Data from drill holes 2 and 5 (Table 4). See Figures 7 & 8 for drill hole locations.
3 From Carpenter and Carpenter, 1989.
4 From Newton and Romeo, 2006.
5 Leucoxene is included with rutile.

ments while others are found in lateral facies relationships (Figure 6).

Carpenter and Carpenter (1991) and Hoffman and Carpenter (1992, p.54) also describe two sedimentary units that occur consistently throughout the heavy-mineral belt of North Carolina and Virginia. They describe the dispersed clay in their lower unit as often comprising more than 25 weight percent of the sediment.

Hoffman and Carpenter (1992) equate this lower unit to the Macks Formation of Daniels *et al.* (1966). Carpenter and Carpenter (1991) agree with Blackwelder and Ward (1979) that the Macks Formation is a nearshore equivalent of the Yorktown Formation. Citing work performed by Bailey (1987), Carpenter and Carpenter (1991) propose that the lower unit is equivalent to the Rushmere Member of the Yorktown Formation (Figure 2).

Hoffman and Carpenter (1992) state that their upper unit is much finer and is better sorted than the lower unit. Near the Bailey deposits the thickness of the upper unit ranges from 0 to

17 meters (55 feet). They describe the upper unit as mainly fine-grained, well-sorted and rounded, clayey, quartz sand that contains abundant heavy minerals, and they note that dispersed clay, mostly submicron kaolinite, generally comprises greater than 25 weight percent of the upper unit. The upper unit usually overlies the lower unit, but in a few areas it rests on the crystalline basement. According to Hoffman and Carpenter (1992) the upper unit hosts the heavy-mineral deposits of the Fall Zone and is equivalent to the surficial sands that Daniels *et al.* (1966) term the Pinehurst and Brandywine formations. Carpenter and Carpenter (1991) have interpreted this upper unit to be an updip member of Bailey's (1987) Mogarts Beach Member of the Yorktown Formation (Figure 2).

Table 1 provides petrographic information for the heavy-mineral suite of the North Carolina–Virginia heavy-mineral deposits that contain more than three weight percent heavy minerals. The TiO_2 content of the ilmenite in these deposits averages 57.6 percent. Hoffman and Carpenter (1992) state that the suite of heavy minerals in the Bailey area is slightly more enriched in kyanite, sillimanite, staurolite, and rutile and carries less zircon than the averages shown in Table 1.

BAILEY DEPOSITS

General Description

Most of the Bailey heavy-mineral deposits are located in Nash and Wilson counties, North Carolina, south, southeast, east, and northeast of the town of Bailey (Figure 7), and cover portions of the Lucama, Bailey, Stancils Chapel, and Middlesex 7.5-minute USGS quadrangles. Pirkle *et al.* (2007a) state that the mineralized area covers 12.9 square kilometers (3,182 acres), mineralized sand averages 6.2 meters (20.3 feet) thick, and the deposit contains 5.72 million metric tons of heavy minerals. The sediments comprising the Bailey deposits average 4.72 weight percent heavy minerals using a 2 weight percent heavy-mineral cutoff and a minimum thickness of 3 meters (10 feet) (McMahill, written communication, 2004).

Mallard (1992) reports an indicated resource of 50 million metric tons of sand with an average heavy-mineral content of 6.1 weight percent and with local concentrations exceeding 20 weight percent. Hoffman and Carpenter (1992) report that concentrations in the Bailey area average 4 to 6 weight percent heavy minerals with local concentrations of up to 50 weight percent of some beds. Table 2 shows heavy-mineral concentrations up to 27 weight percent. Mallard (1992) reports that the thickness of the Bailey deposits ranges between 6.1 and 7.6 meters (20 and 25 feet). Valuable heavy minerals contained in the deposit are ilmenite, leucoxene, rutile, and zircon, which comprise 65 to 70 percent of the heavy-mineral suite (Mallard, 1992).

The Bailey deposits are found within the upper unit of Carpenter and Carpenter (1991). According to Hoffman and Carpenter (1992) the upper unit ranges over a wide range of elevations. At elevations below 53.3 meters (175 feet) they describe the upper unit as being less sorted with grains that are less rounded, a higher silt content, and heavy minerals that are finer grained and less abundant than in the upper unit above 53.3 meters (175 feet). They report that within the North Carolina-Virginia Fall Zone, all known deposits containing greater than 3 weight percent heavy minerals occur above elevations of 53.3 meters (175 feet).

Two distinct terraces and one subtle terrace occur in the Bailey area and are described by Hoffman and Carpenter (1992). The distinct terraces occur at 54.9 to 61 meters (180 to 200 feet) and at 76.2 to 85.3 meters (250 to 280 feet), and the subtler terrace occurs at 70.1 to 73.1 meters (230 to 240 feet). The most pronounced scarp in the area has been correlated by a number of workers (Alt, 1974; Daniels et al., 1972, 1978; Hoffman and Carpenter, 1992) with the Orangeburg scarp of Colquhoun (1965). According to Hoffman and Carpenter (1992, p. 55) "Heavy minerals are most concentrated and form economic deposits within the upper unit where it overlies the two best-developed terraced surfaces of the lower unit."

Mallard (1992, p. 60) describes the heavy-mineral-bearing unit as being

"...generally a fine to medium, well-sorted,

Table 2. Percent by weight of heavy minerals from sediments penetrated by holes drilled through the Bailey heavy-mineral deposits

	Percent by weight of heavy minerals[1]						
	Hole 1	Hole 2	Hole 3	Hole 4	Hole 5	Hole 6	Hole 7
Depth in meters	(92)	(85)	(83)	(88.4)	(98.2)	(76.8)	(62.6)
0-0.8	3.83	2.81	4.01	4.43	3.54	7.48	4.82
0.8-1.5	2.20	3.52	3.49	3.46	3.58	7.33	4.67
1.5-2.3	2.32	9.35	3.53	4.25	2.40	7.63	4.40
2.3-3.0	2.63	7.52	3.96	4.25	4.59	10.12	3.67
3.0-3.8	3.37	1.54	5.05	4.52	4.68	6.11	2.96
3.8-4.6	4.18	2.38	4.04	3.76	4.60	1.04	2.62
4.6-5.3	4.79	2.85	2.59	5.81	4.89	0.91	1.64
5.3-6.1	5.33	1.47	1.87	6.43	7.24	1.26	1.76
6.1-6.9	5.47	1.35	1.06	4.59	27.41	1.04	0.23
6.9-7.6	3.76	0.82	0.47	5.11	19.15	0.75	
7.6-8.4	3.38	0.55	0.42	1.27	2.80		
8.4-9.1	3.48	0.58	0.51	0.95	7.69		
9.1-9.9	0.52	1.18	0.27		2.53		
9.9-10.7			0.39		1.86		

[1] Locations of these holes are shown on Figures 7 & 8; surface elevations (in meters above mean sea level) are given in parentheses below the hole numbers.

feldspathic clayey sand that contains clay which is primarily kaolinite…"

Relationship of the Bailey Deposits to the Sims Pluton

Within the area of the Bailey deposits unconsolidated Cenozoic sediments of the inner Coastal Plain unconformably overlie Upper Paleozoic coarse-grained biotite granite of the Sims pluton and metamorphosed Precambrian-Cambrian sedimentary and volcanic rocks of the eastern slate belt (Hoffman and Carpenter, 1992). The heavy-mineral concentrations are in the unconsolidated sediments that overlie the Sims pluton and the slate belt rocks (Figure 8). The Hawley and Kenly deposits, south of the Bailey deposits (Figure 1), probably are a continuation of the Bailey deposits. The separation of the two areas of heavy-mineral concentrations most likely is the result of post-depositional stream erosion, to be discussed later.

The Upper Paleozoic Sims pluton that intrudes the older slate belt rocks of the region is roughly circular and lies south and east of Bailey (Figure 8). Speer (1997) has discussed the lithologies of this pluton, and Farrar (1985) described the slate belt rocks of the region.

The richest part of the Bailey heavy-mineral deposits, that part containing more than 5 percent heavy minerals by weight, is confined almost entirely to the unconsolidated sediments overlying the Sims pluton (Figure 8). Most of the mineralized sediment north and south of the pluton contains from 2 to 3 percent by weight of heavy minerals. The sediments containing the

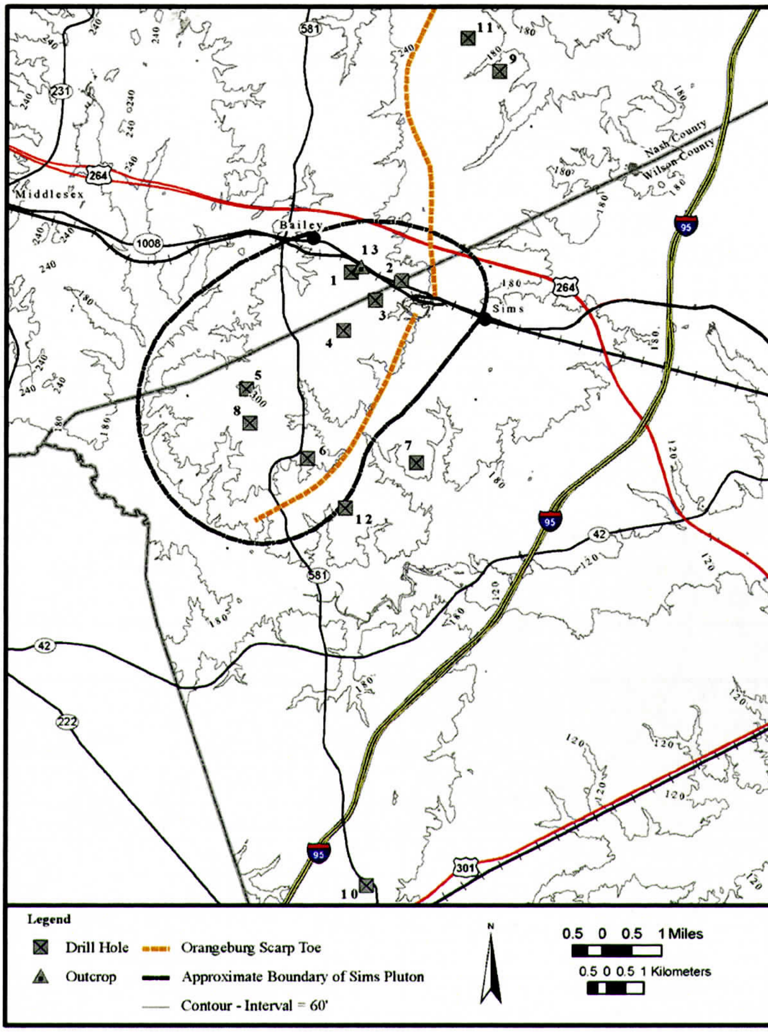

Figure 7. Overview of the Bailey area. Locations of holes 1- 12 and outcrop 13 are shown along with the Sims pluton and the Orangeburg Scarp. A few contour lines (in feet) are drawn in the area of the heavy-mineral deposits. The outline of the Sims pluton was taken from Speer (1997).

higher heavy-mineral grades overlying the Sims pluton are higher in elevation than the surrounding metamorphic slate belt rocks.

The lower unit of Carpenter and Carpenter (1991) lies above the Sims pluton. The lower unit's total thickness ranges from 0 –12.2 meters (0 – 40 feet). Figure 9 shows a pebble zone immediately above the granite saprolite. The pebbles are 7.6 – 10.2 cm (3 – 4 inches) thick and 15.2 cm (6 inches long). A few of the pebbles are discoidal in shape. None of the pebbles or cobbles within the pebble zone were derived from the crystalline basement, and the cobbles are well rounded (Figure 10). The material surrounding the pebbles in Figure 9 is 28.6 percent +10 mesh, 13.76 percent fine sand, 28.74 percent silt, and 28.90 percent clay. The clay minerals present are kaolinite with a trace of vermiculite.

In some areas saprolite is found on top of the pebble zones (Figure 11) and in other places mineralized sands are found below overhangs

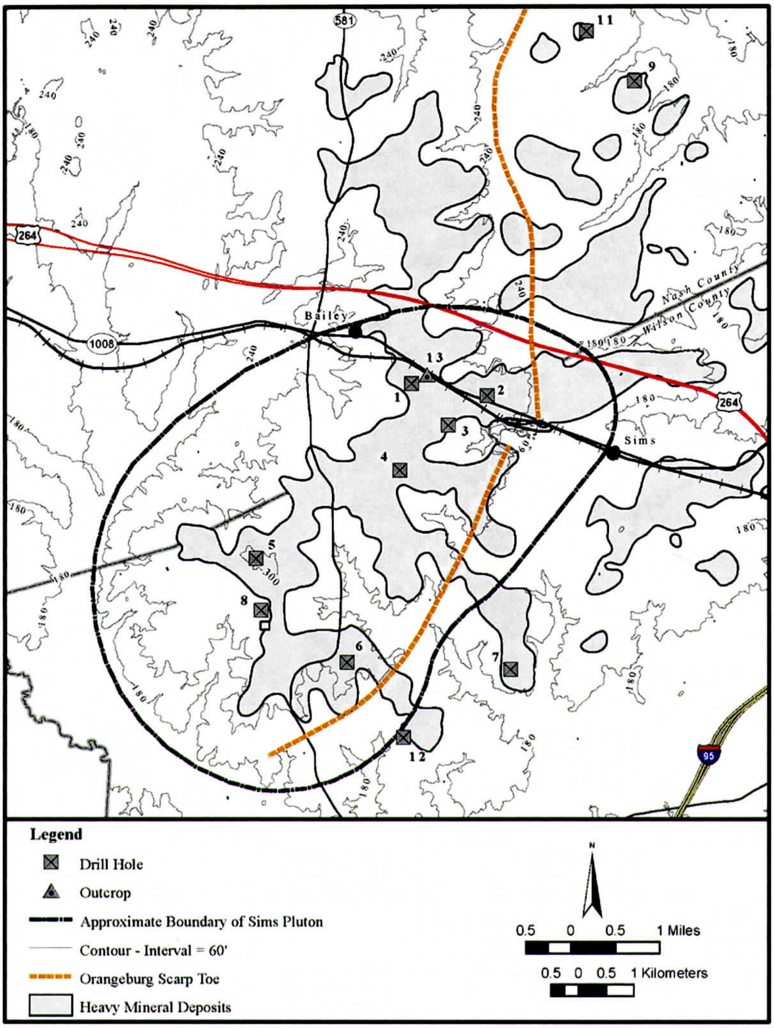

Figure 8. Main deposits of the Bailey heavy-mineral concentrations tend to occur over the Sims pluton. A few contour lines (in feet) are drawn in the area of the heavy-mineral deposits. Sieve analyses of sediments from drill holes 1 through 7 are given in Tables 5 and 6. The outline of the Sims pluton was taken from Speer (1997).

of saprolite (Romeo, 2005). The saprolite surface is uneven so it is possible that sediments from saprolite highs might have been eroded into lows over pebble lenses, providing the saprolite above the transported pebble layer. Faulting also may be responsible for the saprolite being on top of pebble layers. Berquist and Bailey (1999) and Newton and Romeo (2006) discuss faulting (including thrust faulting) in these deposits. Newton and Romeo (2006, p.469) note that in the Old Hickory deposits, "... NW-trending faults displacing saprolitic basement over top of heavy mineral sand in the older deposit were identified."

Sediments

The sediments containing the Bailey heavy-mineral concentrations are comprised on average of 66 weight percent sand, 29 weight percent silt and clay, and 5 weight percent heavy minerals (Table 3). The clay is primarily kaolinite and in general the sand fraction is coarse to

Table 3. Percent by weight of sediments penetrated by holes drilled through the Bailey heavy-mineral deposits.[1] Hole locations are given in Figures 7 & 8. Surface elevations (in meters above sea level) are given in parentheses beside the hole number.

	Hole 1 (92)			Hole 2 (85)			Hole 3 (83)			Hole 4 (88.4)		
Depth in meters	SAND	SILT / CLAY	HEAVY MIN	SAND	SILT / CLAY	HEAVY MIN	SAND	SILT / CLAY	HEAVY MIN	SAND	SILT / CLAY	HEAVY MIN
0-0.8	68.00	28.17	3.83	50.32	46.87	2.81	68.82	27.17	4.01	60.97	34.60	4.43
0.8-1.5	47.83	49.97	2.20	39.42	57.06	3.52	77.77	18.74	3.49	67.18	29.36	3.46
1.5-2.3	49.67	48.01	2.32	51.61	39.04	9.35	80.90	15.57	3.53	75.17	20.58	4.25
2.3-3.0	62.66	34.71	2.63	62.56	29.92	7.52	81.58	14.96	3.46	74.68	21.07	4.25
3.0-3.8	44.87	51.76	3.37	71.42	27.04	1.54	79.85	15.10	5.05	74.22	21.26	4.52
3.8-4.6	64.59	31.23	4.18	73.20	24.42	2.38	78.87	17.09	4.04	78.04	18.20	3.76
4.6-5.3	67.23	27.98	4.79	73.14	24.01	2.85	69.87	27.54	2.59	76.58	17.61	5.81
5.3-6.1	76.25	18.42	5.33	79.84	18.69	1.47				71.76	21.81	6.43
6.1-6.9	73.18	21.35	5.47	79.93	18.72	1.35				71.85	23.56	4.59
6.9-7.6	72.00	24.24	3.76	77.37	21.81	0.82				73.58	21.31	5.11
7.6-8.4	73.31	23.31	3.38	78.05	21.40	0.55				79.61	19.12	1.27
8.4-9.1	70.35	26.17	3.48	73.00	26.39	0.61				80.56	18.49	0.95
9.1-9.9	78.54	20.94	0.52	71.30	27.46	1.24				77.49	21.46	1.05

	Hole 5 (98.2)			Hole 6 (76.8)			Hole 7 (61.6)		
Depth in meters.	SAND	SILT / CLAY	HEAVY MIN	SAND	SILT / CLAY	HEAVY MIN	SAND	SILT / CLAY	HEAVY MIN
0-0.8	35.97	60.49	3.54	66.72	25.80	7.48	70.72	24.46	4.82
0.8-1.5	35.94	60.48	3.58	63.13	29.54	7.33	73.12	22.21	4.67
1.5-2.3	49.68	47.92	2.40	64.50	27.87	7.63	82.49	13.11	4.40
2.3-3.0	57.60	37.81	4.59	59.88	30.00	10.12	70.79	25.54	3.67
3.0-3.8	57.74	37.58	4.68	70.58	23.31	6.11	67.72	29.32	2.96
3.8-4.6	61.08	34.32	4.60	74.72	24.24	1.04	72.34	25.04	2.62
4.6-5.3	63.41	31.70	4.89	75.20	23.89	0.91	78.34	20.02	1.64
5.3-6.1	64.17	28.59	7.24	74.08	24.66	1.26	82.33	15.91	1.76
6.1-6.9	46.20	26.39	27.41	67.89	31.07	1.04	22.08	77.69	0.23
6.9-7.6	52.73	28.12	19.15	57.04	42.21	0.75	22.43	77.52	0.03
7.6-8.4	72.09	25.11	2.80						
8.4-9.1	70.86	21.45	7.69						
9.1-9.9	75.60	21.87	2.53						

[1]Most of the sand fraction consists of sand-size quartz particles (-1.0 to 4.0Φ). In some samples a slight amount of granule-size quartz particles are present. The silt and clay fraction consists of materials smaller then 4.0Φ. Before determining the heavy-mineral values, impurities such as iron oxide particles were eliminated.

fine in grain size though in some areas the sands are mainly medium to very fine in grain size (Tables 5 and 6).

Sand Analyses

The sand within the mineralized sediments in drill holes 1, 2, 3, and 4 (Figure 7) primarily is coarse to fine in grain size while the sands within the mineralized sediments encountered in drill holes 5, 6, and 7 (Figure 7) are mostly me-

Figure 9. Pebble zone immediately above granite saprolite. The sediment contains much clay, fine sand, and rounded quartzite pebbles. Some of the quartz pebbles are as much as 7.6-10.2 cm (3 or 4 inches) thick and 15.2 cm (6 inches) long. A few pebbles are discoidal in shape, and the pebble zones can be traced over some distance.

Figure 10. The cobbles in the pebble zones are well rounded.

dium to very fine in grain size (Table 5). In the sands encountered in drill holes 1,2, 3, and 4 the medium-size fraction generally constitutes 40 to 50 weight percent of the total sand, the fine-size fraction normally makes up from 20 to 30 percent of the sand, and the very fine-size fraction less than 10 percent of the sand. In drill holes 5, 6, and 7 the medium-size fraction generally constitutes between 15 and 30 percent of the sand while the fine-size fraction constitutes between 40 and 60 percent of the sand while the very fine-size fraction makes up 10 to 20 percent of the sands (Table 5).

Clay Analyses

James L. Eades, while at the University of

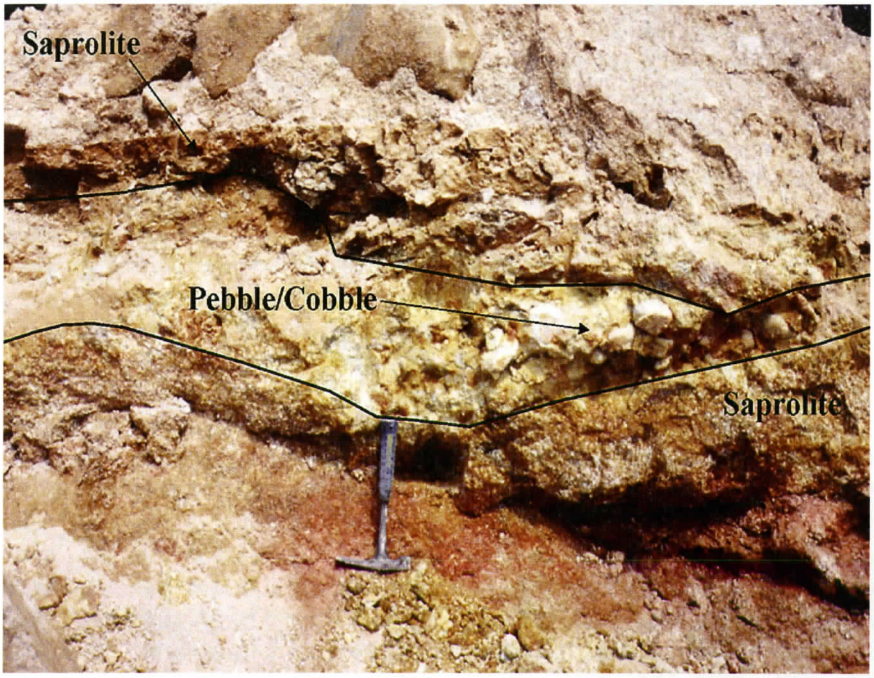

Figure 11. Saprolite on top of a pebble/cobble lens.

Florida, performed gradation and clay analyses on sediments recovered from several drill holes within the Bailey deposits and other deposits along the Fall Zone in North Carolina. From the Bailey deposits, samples were analyzed from a dozen drill holes scattered throughout the deposit. Three samples from one drill hole in the Ringwood deposit (Figure 1) and nine samples from a single drill hole in the Red Oak deposit (Figure 1) were also analyzed by Eades. Minerals identified are kaolinite, montmorillonite, illite, quartz, vermiculite, and goethite. Eades' analyses indicate that kaolinite is the dominant clay mineral in all of the samples. This is consistent with the findings of Carpenter and Carpenter (1991).

Drill hole 2 (Figure 7) was collared at an elevation of 85 meters (279 feet) above mean sea level and was drilled to a depth of 15.2 meters (50 feet). Kaolinite was the dominant clay throughout the total depth of the hole. In the upper 2.3 meters (7.5 feet) montmorillonite was present in minor amounts and was present in trace amounts throughout the remainder of the hole.

Drill hole 5 (Figure 7) was collared at an elevation of 98 meters (322 feet) and drilled to a total depth of 16.8 meters (55 feet). In the sediments of this hole, again, kaolinite was the dominant clay mineral. In the sediments from the upper 2.3 meters (7.5 feet) of drill hole 5, montmorillonite was present in minor amounts. Below a depth of 3 meters (10 feet) montmorillonite and illite were present in only trace amounts. Illite was not detected in the sediments from the upper 3 meters (10 feet) of the boring. Saprolite was encountered at a depth of 13.7 meters (45 feet). The clay content in the sediments recovered from this hole ranged from 12.7 to 47.2 percent. Sediments encountered between 6.1 and 6.9 meters (20 – 25 feet) below land surface contained 23.3 percent by weight heavy minerals, 49.4 percent non-heavy-mineral sand, and 27.3 percent silt and clay. Table 3 illustrates the relationship between the sediments encountered throughout the Bailey heavy-mineral deposits and the amount of sand and silt/clay these sediments contain.

Tables 1 and 4 give representative heavy-

Table 4. Heavy-mineral analyses from sediments penetrated in selected holes drilled through the Bailey heavy-mineral deposits. Hole locations are given in Figures 7 & 8. Surface elevations (in meters above sea level) are given in parentheses below the hole numbers.

Hole	Depth in Meters	Zircon	Staurolite	Kyanite & Sillimanite	Corundum	Ilmenite	Leucoxene	Rutile	Spinel	Tourmaline	Monazite	Garnet	Epidote	Ferro. Mag.	Others	Weight Percent Heavy Minerals
	0-0.8	10.06	26.10	10.02	0.94	37.02	11.24	2.60	0.00	1.65	0.15	0.00	0.10	0.00	0.00	2.81
2	0.8-1.5	6.30	22.72	10.93	0.49	53.38	2.99	1.81	0.08	1.14	0.11	0.00	0.00	0.00	0.00	3.52
(85)	1.5-2.3	7.90	22.18	8.39	0.62	57.61	0.23	1.99	0.07	0.75	0.10	0.00	0.00	0.00	0.10	9.35
	2.3-3.0	6.46	21.05	8.49	0.69	59.36	0.20	2.39	0.00	1.26	0.00	0.00	0.00	0.00	0.10	7.52
	3.0-3.8	4.98	29.11	14.07	0.90	45.93	0.48	2.12	0.09	2.19	0.10	0.00	0.00	0.00	0.00	1.54
	3.8-4.6	3.97	35.82	18.04	1.01	35.43	0.58	2.23	0.00	2.79	0.08	0.00	0.00	0.00	0.10	2.38
	4.6-5.3	5.02	23.18	16.73	1.03	48.33	0.79	2.72	0.00	2.14	0.00	0.00	0.00	0.00	0.00	2.85
	5.3-6.1	6.52	23.24	13.85	0.52	47.26	0.39	3.48	0.00	2.11	0.00	0.00	0.00	0.00	2.64	1.47
	6.1-6.9	3.80	21.75	14.66	0.97	49.96	0.61	3.44	0.00	2.31	0.00	0.00	0.00	0.00	2.53	1.35
	6.9-7.6	5.64	19.48	15.11	0.91	46.54	1.42	3.97	0.00	1.95	0.00	0.00	0.00	0.00	5.02	0.82
	7.6-8.4	4.73	19.81	13.57	0.46	51.04	0.68	2.60	0.00	0.93	0.19	0.00	0.00	0.00	5.82	0.55
	0-0.8	6.60	16.82	12.44	0.45	51.66	6.51	4.40	0.00	0.93	0.17	0.00	0.00	0.00	0.00	3.54
	0.8-1.5	8.71	15.53	7.26	0.48	59.17	2.76	4.06	0.00	1.25	0.19	0.00	0.00	0.00	0.57	3.58
	1.5-2.3	8.10	21.04	8.18	0.00	56.36	0.67	3.57	0.00	1.56	0.45	0.00	0.00	0.00	0.00	2.40
	2.3-3.0	6.25	20.32	10.59	0.67	58.37	0.12	2.26	0.00	1.20	0.00	0.00	0.00	0.00	0.23	4.59
5	3.0-3.8	5.81	18.92	10.89	1.00	58.11	0.53	3.37	0.00	0.91	0.17	0.00	0.00	0.00	0.26	4.68
(98.2)	3.8-4.6	7.57	17.03	8.75	0.72	60.40	0.68	3.91	0.00	0.58	0.17	0.00	0.00	0.00	0.21	4.60
	4.6-5.3	6.13	18.05	8.74	0.66	61.44	0.83	2.76	0.00	0.97	0.10	0.00	0.00	0.00	0.31	4.89
	5.3-6.1	4.70	21.48	9.37	0.89	59.47	0.53	2.39	0.00	1.07	0.09	0.00	0.00	0.00	0.00	7.24
	6.1-6.9	6.39	10.40	4.62	0.77	74.67	0.12	2.30	0.00	0.40	0.24	0.00	0.00	0.00	0.10	27.41
	6.9-7.6	7.07	9.41	4.85	0.47	74.91	0.21	2.50	0.00	0.29	0.09	0.00	0.00	0.00	0.21	19.15
	7.6-8.4	7.02	9.79	6.39	0.53	72.15	0.51	2.71	0.12	0.34	0.15	0.10	0.00	0.00	0.21	2.80
	8.4-9.1	10.14	9.68	3.93	0.79	72.08	0.19	2.58	0.00	0.61	0.00	0.00	0.00	0.00	0.00	7.69
	9.1-9.9	7.67	13.74	6.44	0.62	68.55	0.19	2.18	0.09	0.34	0.16	0.00	0.00	0.00	0.00	2.53
	9.9-10.7	7.43	12.12	5.85	0.56	69.10	0.32	2.19	0.00	0.76	0.16	0.00	0.00	0.00	1.53	1.86
	10.7-11.4	18.99	15.87	11.21	0.82	40.70	0.68	6.77	0.00	0.11	0.49	0.00	0.00	0.00	4.32	1.27
	11.4-12.2	6.32	11.21	3.23	0.29	73.75	0.13	2.51	0.00	0.18	0.11	0.00	0.00	0.00	2.26	1.39
	12.2-13.7[1]	1.78	2.87	1.01	0.06	28.78	0.03	0.44	0.00	0.00	0.05	0.00	0.00	63.73	1.17	1.18
	13.7-15.2	0.19	1.23	0.62	0.07	20.81	0.00	0.06	0.00	0.00	0.00	0.00	0.00	76.19	0.82	1.11
	15.2-16.8	0.21	0.16	0.15	0.04	14.71	0.00	0.05	0.00	0.03	0.00	0.00	0.00	83.92	0.72	0.79
7	0-0.8	10.69	19.25	10.00	1.27	28.32	25.61	2.77	0.00	1.79	0.14	0.00	0.00	0.00	0.16	4.82
	0.8-1.5	10.82	21.24	10.08	0.95	23.88	26.93	4.02	0.06	1.89	0.00	0.00	0.00	0.00	0.18	4.67
	1.5-2.3	12.22	23.20	12.27	0.93	19.71	25.24	4.27	0.00	1.88	0.13	0.00	0.00	0.00	0.15	4.40
	2.3-3.0	11.23	21.03	11.72	0.52	25.62	21.50	5.69	0.00	1.44	0.18	0.00	0.00	0.00	1.04	3.67
(62.6)	3.0-3.8	16.88	24.71	12.68	0.97	18.55	19.35	4.64	.0.14	2.03	0.00	0.00	0.00	0.00	0.05	2.96
	3.8-4.6	13.12	23.44	13.02	0.88	22.45	17.53	4.57	0.0	2.80	0.13	0.00	0.00	0.00	0.03	2.62
	4.6-5.3	7.87	26.72	15.41	0.61	41.69	2.96	2.12	0.08	2.07	0.12	0.00	0.00	0.00	0.28	1.64
	5.3-6.1	7.88	23.75	13.86	1.27	46.21	2.32	2.03	0.00	2.45	0.11	0.00	0.00	0.00	0.12	1.76

[1]At a depth of approximately 12.2 meters hit saprolite of Sims pluton.

Table 5. Sieve analyses and heavy-mineral content of sand from holes drilled in the Bailey heavy-mineral concentrations. Hole locations are given in Figures 7 & 8. Surface elevations (in meters above sea level) are given in parentheses below the hole number.

Hole	Depth of Sample in Meters	Weight Percent of Sand Retained on Mesh									Weight Percent of Heavy Minerals
		14 <0φ	20 0-1/2φ	35 1/2-1φ	45 1-1/2φ	60 11/2-2φ	80 2-21/2φ	120 21/2-3φ	170 3-31/2φ	230 31/2-4φ	
	0-0.8	0.19	2.95	11.64	18.88	22.03	18.81	12.94	8.88	2.70	3.83
1	0.8-1.5	0.23	5.56	16.44	21.75	22.24	13.75	10.40	5.25	2.94	2.20
(92)	1.5-2.3	0.32	5.60	17.82	23.08	23.21	13.84	9.91	4.27	1.53	2.32
	2.3-3.0	0.18	6.16	22.59	26.18	21.35	12.86	6.03	3.24	1.02	2.63
	3.0-3.8	0.07	4.01	17.42	22.63	23.15	14.17	10.39	5.32	2.26	3.37
	3.8-4.6	0.06	2.47	10.73	23.22	26.96	19.43	9.31	5.58	1.78	4.18
	4.6-5.3	0.10	2.77	11.84	21.80	27.99	17.57	10.59	5.04	1.88	4.79
	5.3-6.1	0.08	2.23	13.21	24.17	24.88	16.75	8.36	6.41	2.66	5.33
	6.1-6.9	0.08	4.05	14.84	21.71	24.44	15.75	10.55	5.65	2.17	5.47
	6.9-7.6	0.37	4.02	13.00	22.54	25.06	17.57	7.99	5.42	2.59	3.76
	7.6-8.4	1.02	10.88	22.41	24.11	21.00	10.27	6.17	2.58	1.25	3.38
	8.4-9.1	1.88	17.27	27.59	25.89	15.11	5.78	3.23	1.96	0.83	3.48
	9.1-9.9	1.89	16.56	22.72	19.35	20.03	11.57	4.55	1.66	1.13	0.52
2	0-0.8	0.18	2.40	10.56	22.07	25.47	15.79	12.02	6.36	3.80	2.81
(85)	0.8-1.5	0.18	2.19	11.24	25.73	26.14	16.26	8.74	5.92	2.47	3.52
	1.5-2.3	0.04	1.53	12.12	24.13	24.97	14.65	13.07	6.20	2.57	9.35
	2.3-3.0	0.05	1.71	10.50	23.63	25.41	16.89	9.94	7.26	3.26	7.52
	3.0-3.8	0.06	0.73	7.88	23.70	34.61	17.92	8.33	3.39	2.40	1.54
	3.8-4.6	0.12	3.24	15.18	25.12	26.39	17.07	6.94	3.50	1.67	2.38
	4.6-5.3	0.60	5.14	12.29	20.01	27.10	17.76	11.29	3.48	1.71	2.85
	5.3-6.1	0.50	4.04	8.46	13.15	20.39	26.54	18.62	5.47	1.95	1.47
	6.1-6.9	0.74	8.63	13.71	14.36	20.03	18.57	18.24	3.64	1.54	1.35
	6.9-7.6	8.51	8.59	11.11	17.26	18.67	5.41	1.34	0.63	0.00	0.82
3	0-0.8	0.28	4.97	23.25	24.78	12.54	14.84	10.91	6.16	2.17	4.01
(83)	0.8-1.5	0.20	3.26	16.15	19.84	22.71	17.69	11.80	5.26	2.15	3.49
	1.5-2.3	0.27	4.16	23.77	25.15	12.57	14.93	10.89	5.85	2.28	3.53
	2.3-3.0	0.21	4.04	14.94	19.04	23.06	18.02	11.19	5.27	2.67	3.96
	3.0-3.8	0.09	1.54	13.16	24.05	18.87	22.72	11.94	5.68	1.88	5.05
	3.8-4.6	0.05	0.73	5.51	15.81	31.32	28.12	12.73	3.73	1.42	4.04
	4.6-5.3	0.10	1.31	14.26	28.73	19.05	21.96	10.01	3.42	1.11	2.59
	5.3-6.1	0.04	0.26	4.21	18.91	34.40	26.47	10.22	3.16	1.40	1.87
	6.1-6.9	0.04	0.76	14.40	29.51	20.29	21.38	8.99	3.04	1.50	1.06
	6.9-7.6	0.20	1.83	10.91	18.44	27.18	25.05	10.50	2.95	1.52	0.47
	7.6-8.4	0.10	1.31	14.39	24.94	18.07	23.51	11.83	3.84	1.81	0.42
	8.4-9.1	0.12	1.19	7.20	15.85	24.12	26.14	16.72	4.70	2.04	0.51
4	0-0.8	1.37	3.33	12.50	21.18	23.86	15.15	12.07	6.67	2.99	4.43
(88.4)	0.8-1.5	0.13	4.60	18.42	26.48	21.61	12.62	6.80	5.74	2.59	3.46
	1.5-2.3	0.15	6.14	21.19	25.32	21.28	10.47	7.53	4.58	2.40	4.25
	2.3-3.0	0.28	7.61	21.06	26.31	23.26	10.43	6.17	2.93	1.39	4.25
	3.0-3.8	0.20	7.06	20.07	23.78	20.84	13.30	6.62	5.03	2.11	4.52
	3.8-4.6	0.40	9.52	23.69	22.77	19.84	11.23	6.84	3.24	1.73	3.76
	4.6-5.3	0.26	5.24	18.99	23.52	19.92	14.33	8.89	5.74	2.12	5.81
	5.3-6.1	0.13	3.08	14.91	19.52	19.11	17.34	17.62	5.59	2.07	6.43
	6.1-6.9	0.02	1.29	9.71	19.35	18.03	21.59	19.76	7.51	2.05	4.59
	6.9-7.6	9.70	14.88	14.96	13.87	12.89	3.48	1.20	0.38	0.00	5.11
	7.6-8.4	8.85	9.42	10.61	14.39	13.26	6.13	1.44	0.65	0.00	1.27

5 (98.2)	0-0.8	0.41	1.82	3.90	7.13	8.89	24.79	32.18	16.03	4.84	3.54
	0.8-1.5	0.46	1.24	2.37	4.25	12.35	27.16	33.23	14.07	4.87	3.58
	1.5-2.3	1.36	5.05	7.11	7.80	8.59	21.51	26.80	16.12	5.65	2.40
	2.3-3.0	0.21	1.08	3.37	6.97	10.31	26.96	31.52	15.76	3.81	4.59
	3.0-3.8	0.16	0.69	2.09	4.47	14.31	31.25	32.59	11.32	3.12	4.68
	3.8-4.6	0.04	0.79	4.59	10.28	12.11	29.70	29.61	10.55	2.32	4.60
	4.6-5.3	0.16	1.36	4.70	9.01	19.13	30.31	25.44	7.52	2.37	4.89
	5.3-6.1	0.12	2.67	11.74	15.38	13.41	24.74	21.62	8.37	1.95	7.24
	6.1-6.9	0.05	1.41	5.84	7.36	11.44	20.59	30.80	17.55	4.96	27.41
	6.9-7.6	0.02	0.53	4.25	9.37	10.10	24.91	33.10	15.08	2.63	19.15
	7.6-8.4	0.60	4.07	7.20	8.69	11.96	22.81	31.93	10.14	2.55	2.80
	8.4-9.1	0.43	3.89	17.26	16.12	8.80	17.59	23.18	10.68	2.05	7.69
	9.1-9.9	3.24	11.00	14.70	10.78	9.69	13.55	22.24	12.00	2.78	2.53
	9.9-10.7	3.27	13.84	17.48	8.52	5.00	11.45	18.79	17.93	3.71	1.86
6 (76.8)	0-0.8	0.13	1.32	3.02	6.24	17.78	25.46	30.20	11.21	3.46	7.48
	0.8-1.5	0.05	0.99	2.47	5.96	16.47	29.27	27.58	13.06	3.14	7.33
	1.5-2.3	0.10	0.90	2.42	5.84	18.31	27.26	30.47	10.65	3.14	7.63
	2.3-3.0	0.02	0.34	1.14	5.48	19.47	32.17	26.69	11.69	2.34	10.12
	3.0-3.8	0.06	0.83	2.07	8.66	27.09	27.82	24.10	6.96	1.77	6.11
	3.8-4.6	0.13	1.05	7.23	8.83	9.15	11.60	27.21	29.95	3.77	1.04
7 (61.6)	0-0.8	0.02	0.50	2.87	7.12	15.27	27.05	27.58	13.37	4.60	4.82
	0.8-1.5	0.09	0.81	3.74	8.57	18.04	25.02	28.80	9.85	3.96	4.67
	1.5-2.3	0.10	0.76	3.73	8.74	17.11	28.57	24.88	10.98	3.59	4.40
	2.3-3.0	0.08	0.75	3.87	7.98	15.43	20.38	25.67	12.33	8.25	3.67
	3.0-3.8	0.09	1.15	4.61	9.18	14.93	21.75	20.65	13.35	6.91	2.96
	3.8-4.6	0.11	1.26	5.80	12.84	20.74	21.80	20.45	8.63	4.94	2.62
	4.6-5.3	0.16	1.30	6.51	16.10	26.24	22.75	14.84	5.99	3.39	1.64
	5.3-6.1	0.15	1.42	7.05	17.04	26.52	24.61	12.82	6.46	2.41	1.76

mineral analyses for the Bailey deposits. The heavy-minerals of economic interest include the titanium-bearing minerals ilmenite, leucoxene, and rutile; monazite; zircon; staurolite; and kyanite and sillimanite. Note that in the upper 1.52 m (5 feet) of both drill hole 2 and drill hole 5 (Table 4) the quantity of ilmenite is slightly diminished as leucoxene is augmented.

The weight percent heavy minerals in drill hole 8 (Figure 7) reaches a high of almost 10 percent at a depth of 2.3 –3 meters (7.5 – 10 feet), but the –270 mesh (-52 microns) fraction at this interval remains above 30 percent. From 9 – 9.9 meters (30 – 32.5 feet) the gradation analyses performed by Eades resulted in 55.2 percent sand, 34.0 percent silt, and 10.8 percent clay. Kaolinite is the dominant clay with minor amounts of illite. From 9 – 10.6 meters (30 – 35 feet) montmorillonite is present as a trace. Kaolinite is the dominant clay within the Bailey heavy-mineral deposits.

Paleontology

Ichnology: Fossil burrows are present in an outcrop of the mineralized unit (upper unit of Carpenter and Carpenter, 1991) located along the railroad at the intersection of US Alt 264 and County Road 1945 about 1.61 kilometers (1 mile) southeast of the town of Bailey (location 13 on Figure 7). The outcrop consists of interbedded, crossbedded sands and lithified sandstones exposed in approximately 1 meter of section. The non-lithified sands have weathered into recessed ledges and have exposed small-diameter (ca. 1.0 – 1.6 cm), vertical burrows that penetrate both lithologies, but are better exhibited by erosion of the non-lithified sands. These burrows have a knobby exterior. Gale A. Bishop, Professor Emeritus, Georgia Southern University states they would be classified as the trace fossil *Ophiomorpha* (Frey et al., 1978).

Bishop states that these *Ophiomorpha* appear to be burrows of a thalassinoid shrimp such as *Callichirus major* Say, 1818 (the Carolinian Ghost Shrimp), or *Callianassa atlantica* Rathbun, 1926. He further notes that the *Ophiomorpha* approximate the size of burrows of *Callichirus major* previously measured on St.

Table 6. Analyses of selected samples of sediments of the Bailey deposit. Hole locations are given in Figures 7 & 8. Surface elevations (in meters above sea level) are given in parentheses below the hole number.

Hole	Depth of Sample in Meters	Very Coarse 14 <Ø	Coarse 35 0 - 1Ø	Medium 60 1 - 2Ø	Fine 120 2 - 3Ø	Very Fine 230 3 - 4Ø	Weight Percent of Heavy Minerals
1	0-0.8	0.19	14.59	40.91	31.75	11.58	3.83
(92)	0.8-1.5	0.23	22.00	43.99	24.15	8.19	2.20
	1.5-2.3	0.32	23.42	46.29	23.75	5.80	2.32
	2.3-3.0	0.18	28.75	47.53	18.89	4.26	2.63
	3.0-3.8	0.07	21.43	45.78	24.56	7.58	3.37
	3.8-4.6	0.06	13.20	50.18	28.74	7.36	4.18
	4.6-5.3	0.10	14.61	49.79	28.16	6.92	4.79
	5.3-6.1	0.08	15.44	49.05	25.11	9.07	5.33
	6.2-6.9	0.08	18.89	46.15	26.30	7.82	5.47
	6.9-7.6	0.37	17.02	47.60	25.56	8.01	3.76
	7.6-8.4	1.02	33.29	45.11	16.44	3.83	3.38
	8.4-9.1	1.88	44.86	41.00	9.01	2.79	3.48
	9.1-9.9	1.89	39.28	39.38	16.12	2.79	0.52
2	0-0.8	0.18	12.96	47.54	27.81	10.16	2.81
(85)	0.8-1.5	0.18	13.43	51.87	25.00	8.39	3.52
	1.5-2.3	0.04	13.65	49.10	27.72	8.77	9.35
	2.3-3.0	0.05	12.21	49.04	26.83	10.52	7.52
	3.0-3.8	0.06	8.61	58.31	26.25	5.79	1.54
	3.8-4.6	0.12	18.42	51.51	24.01	5.17	2.38
	4.6-5.3	0.60	17.43	47.11	29.05	5.19	2.85
	5.3-6.1	0.50	12.50	33.54	45.16	7.42	1.47
	6.1-6.9	0.74	22.34	34.39	36.81	5.18	1.35
	6.9-7.6	8.51	19.70	35.93	6.75	0.63	0.82
3	0-0.8	0.28	28.22	37.32	25.75	8.33	4.01
(83)	0.8-1.5	0.20	19.41	42.55	29.49	7.41	3.49
	1.5-2.3	0.27	27.93	37.72	25.82	8.13	3.53
	2.3-3.0	0.21	18.98	42.10	29.21	7.94	3.96
	3.0-3.8	0.09	14.70	42.92	34.66	7.56	5.05
	3.8-4.6	0.05	6.24	47.13	40.85	5.15	4.04
	4.6-5.3	0.10	15.57	47.78	31.97	4.53	2.59
	5.3-6.1	0.04	4.47	53.31	36.69	4.56	1.87
	6.2-6.9	0.04	15.16	49.80	30.37	4.54	1.06
	6.9-7.6	0.20	12.74	45.62	35.55	4.47	0.47
	7.6-8.4	0.10	15.70	43.01	35.34	5.65	0.42
	8.4-9.1	0.12	8.39	39.97	42.86	6.74	0.51

4 (88.4)	0-0.8	1.37	15.83	45.04	27.22	9.66	4.43
	0.8-1.5	0.13	23.02	48.09	19.42	8.33	3.46
	1.5-2.3	0.15	27.33	46.60	18.00	6.98	4.25
	2.3-3.0	0.28	28.67	49.57	16.60	4.32	4.25
	3.0-3.8	0.20	27.13	44.62	19.92	7.14	4.52
	3.8-4.6	0.40	33.21	42.61	18.07	4.97	3.76
	4.6-5.3	0.26	24.23	43.44	23.22	7.86	5.81
	5.3-6.1	0.13	17.99	38.63	34.96	7.66	6.43
	6.1-6.9	0.02	11.00	37.38	41.35	9.56	4.59
	6.9-7.6	9.70	29.84	26.76	4.68	0.38	5.11
	7.6-8.4	8.85	20.03	27.65	7.57	0.65	1.27
5 (98.2)	0-0.8	0.41	5.72	16.02	56.97	20.87	3.54
	0.8-1.5	0.46	3.61	16.60	60.39	18.94	3.58
	1.5-2.3	1.36	12.16	16.39	48.31	21.77	2.40
	2.3-3.0	0.21	4.45	17.28	58.48	19.57	4.59
	3.0-3.8	0.16	2.78	18.78	63.84	14.44	4.68
	3.8-4.6	0.04	5.38	22.39	59.31	12.87	4.60
	4.6-5.3	0.16	6.06	28.14	55.75	9.89	4.89
	5.3-6.1	0.12	14.41	28.79	46.36	10.32	7.24
	6.2-6.9	0.05	7.25	18.80	51.39	22.51	27.41
	6.9-7.6	0.02	4.78	19.47	58.01	17.71	19.15
	7.6-8.4	0.60	11.27	20.65	54.74	12.69	2.80
	8.4-9.1	0.43	21.15	24.92	40.77	12.73	7.69
	9.1-9.9	3.24	25.70	20.47	35.79	14.78	2.53
	9.9-10.7	3.27	31.32	13.52	30.24	21.64	1.86
6 (76.8)	0-0.8	0.13	4.34	24.02	55.66	14.67	7.48
	0.8-1.5	0.05	3.46	22.43	56.85	16.20	7.33
	1.5-2.3	0.10	3.32	24.15	57.73	13.79	7.63
	2.3-3.0	0.02	1.48	24.95	58.86	14.03	10.12
	3.0-3.8	0.06	2.90	35.75	51.92	8.73	6.11
	3.8-4.6	0.13	8.28	17.98	38.81	33.72	1.04
7 (61.6)	0-0.8	0.02	3.37	22.39	54.63	17.97	4.82
	0.8-1.5	0.09	4.55	26.61	53.82	13.81	4.67
	1.5-2.3	0.10	4.49	25.85	53.45	14.57	4.40
	2.3-3.0	0.08	4.62	23.41	46.05	20.58	3.67
	3.0-3.8	0.09	5.76	24.11	42.40	20.26	2.96
	3.8-4.6	0.11	7.06	33.58	42.25	13.57	2.62
	4.6-5.3	0.16	7.81	42.34	37.59	9.38	1.64
	5.3-6.1	0.15	8.47	43.56	37.43	8.87	1.76

Catherines Island, Georgia.

The crossbedding style (scour and fill structures bracketing climbing ripples) closely resembles the crossbedding style of high-energy tidally-dominated shoals seen on channel margins on St. Catherines Sound on the southeast Georgia coast and, on a smaller scale, in channels on ebb deltas at McQueens Inlet and Seaside Inlet on St. Catherines Island, Georgia. The combination of the crossbedding and *Ophio-*

morpha strongly suggests these sediments were deposited in subtidal high-energy shoals associated with a tidally-dominated channel of moderate size, such as an inlet or sound associated with barrier islands. This will be discussed in more detail later in this paper.

Newton and Romeo (2006, p. 467) report, "*Ophiomorpha*, thought to be fossilized burrows of the ghost shrimp *Callianassa*, have been found just below some of the high-grade heavy mineral zones." They take this evidence, along with the presence of locally preserved planar laminations and thin bedding to postulate the presence of a foreshore to upper shoreface depositional environment with rare high energy events. They also recognize a predominantly back-barrier dune environment deposited on top of the beach environment on the far eastern side of the northern half of the deposit.

Diatoms: Two samples from drill hole 10 and one sample from drill hole 11 (Figure 7) were sent to Lloyd C. Burckle of Lamont-Dougherty Earth Observatory for diatom analysis. Drill hole 10 was collared at an elevation of approximately 65.8 meters (216 feet) above sea level while drill hole 11 was collard at an elevation of approximately 63.4 meters (208 feet).

The two samples from sediments recovered from drill hole 10 were collected from depths of 4.6 meters (15 feet) below land surface and 5.8 – 6.4 meters (19 – 21 feet). Diatoms as well as other biotic remains were absent in the sediments of the first sample while five diatom fragments of *Thalassionema nitzschioides* as well as one fragment each of *Actinocyclus* sp. and an unidentified fragment of what appeared to be a marine diatom were observed in the second sample. The presence of these forms, coupled with the absence of nonmarine diatoms and pollen grains or opal phytoliths suggest that this sample had a marine origin. Both of these samples were collected below the mineralized zone, which extended from the land surface to a depth of 3.8 meters (12.5 feet) below land surface.

The sample from drill hole 11 analyzed by Burckle was collected from a depth of 11.0 – 12.2 meters (36-40 feet) below the land surface and came from below the mineralized zone. This sample contained no diatoms but did contain pollen grains, rare to common fungal spores, and rare opal phytoliths. The presence of pollen grains, fungal spores, and opal phytoliths suggests to Burckle that this sample is continental in origin.

Macrofossils: A sample collected from a depth of 9.5-9.8 meters (31-32 feet) below land surface was taken from this same boring (drill hole 11) and sent to Douglas S. Jones at the University of Florida for paleontological analysis. The sample contained mollusk shell fragments with marine affinities [e.g., oysters, pectinids (scallops)]. In addition, a tiny fish tooth was identified which probably belongs to *Pogonias cromis*, the black drumfish. The black drumfish can adapt to a wide range of habitats. Black drumfish are found in water in excess of 30 meters (100 feet) depth, but they can live in waters so shallow their backs are exposed, and can be found over sand or mud bottoms in bays and marshes and on beaches. Though they can survive in waters that are twice as salty as the present Gulf of Mexico, they are also attracted to freshwater runoff of creeks and rivers. One of the most consistently productive fisheries for big Drum is found in the St. Marys River in northeast Florida (www.beaufortonline.com). The presence of oysters and pectens, and the black drumfish tooth are consistent with the microfossil interpretations, which suggest a nearshore, intertidal origin for the sediments in question.

Palynology: Palynological data have been obtained from several localities within the geographic boundaries of the Bailey and Old Hickory heavy-mineral deposits. Peter P. McLaughlin, Jr. of the Delaware Geological Survey conducted an analysis on a sample recovered from below the ore zone and above the weathered bedrock at the Old Hickory heavy mineral mine. Carl R. Berquist of the Virginia Division of Mineral Resources collected this sample and Andrew Romeo, formerly Senior Mine Geologist and Acting U.S. Exploration Manager for Iluka Resources, Inc., provided McLaughlin's pollen analysis to the authors. Though McLaughlin reported that many of the grains were degraded, probably due to mechanical weathering, the suite was clearly dominated by pine, hickory/pecan, oak and composites of the *Ambrosia* (ragweed) type. Other identifiable types included grasses and chenopods, with minor sweet gum. The presence of two extinct or extirpated types, *Engelhardtia* and *Pterocarya* is significant. Winged Hickory is the common name for *Pterocarya*; this plant lived in upland forests during the Pliocene, and is a characteristic plant for that time in North America (Traverse, 1988). The occurrence of both *Engelhardtia* and *Pterocarya* indicates a Pliocene age for the sediments.

Strata from drill holes 2, 8, 9, 10, 11, and 12 (Figure 7) also were analyzed for pollen, spores and similar fossils. The analyzed sediments came from beneath the mineralized zone, which extends from the surface to a depth of 3 meters (10 feet) in these drill holes. A summary of these data is given in Table 7. The sediments analyzed from drill holes 10 did not yield any pollen.

Drill hole 2 was collared at an elevation of 85 meters (279 feet). The sediments from 4.5 – 5.3 meters (15 – 17.5 feet) below the land surface were barren of pollen as were the sediments collected from 5.3 – 6.1 meters (17.5 – 20 feet) below land surface, though fungal spores were present. The sediments from a depth 6.1 – 6.9 meters (20 – 22.5 feet) contained some pollen, but not enough to be statistically significant. Pine and ragweed were present and birch, sweet gum, oak, and elm were represented. Sediments from the remainder of the core contained minute fungal spores, and small particles of charcoal, but no palynomorphs. While one cannot deduce much from this, the composition of the organic remains, particularly the palynomorphs from 6.1-6.9 m (20 – 22.5 feet) is suggestive of derivation from a terrestrial source. Note that these pollen types are similar to those found in the Old Hickory sample described above.

Drill hole 8 (Figure 7) was collared at an elevation of 81.7 meters (268 feet). Sediments recovered from depth intervals of 9.1 – 9.9 meters (30 – 32.5 feet) and 9.9 – 10.6 meters (32.5-35 feet) were analyzed for pollen. Sediments from the 9.1 – 9.9 meters (30 – 32.5 feet) interval contained two *Pterocarya* grains. The pollen assemblage in these sediments looks like Late Pliocene samples that have been studied from South Carolina and Florida (Emslie *et al.* 1996; Rich and Pirkle, 1998). This is a marine-influenced sample as deduced from the presence of both spiny dinoflagellate cysts and microforams which are the chitinous inner linings of foraminifer tests, e.g. Rich and Pirkle (1994). The samples from 9.9 to 10.6 meters (32.5 – 35 feet) depth had too few pollen or spores to produce a statistically meaningful count, but it did contain microforams, dinoflagellate cysts, and abundant pyrite, as well as pollen of pine, oak and hickory. Based on the pollen contents of both samples, we believe the plant community that occupied the area near drill hole 8 was a near-shore hardwood/conifer assemblage typical of a southern evergreen forest, with species mixing having taken place at the shoreline.

The sample collected from drill hole 9 (Figure 7) also revealed some interesting palynological information. This drill hole was collared at an elevation of approximately 61.6 meters (202 feet) above mean sea level. The sample analyzed came from a depth of 6.0-6.2 meters (20 - 20.5 feet) below the land surface. A total of 201 identifiable pollen/spores was seen in the residue. Insoluble components consisted largely of finely divided humic debris and clays. Though pollen/spores were scarce, the condition of their preservation is instructive. Many indeterminate grains (not included in the pollen/spore sum) were folded and battered, and their condition was similar to what was described from the Old Hickory sample referred to above. Additionally, some pollen bore pyrite, with both framboids and euhedra being common. These conditions are normally interpreted to suggest that the grains suffered significant transportation (battering and folding or mechanical abrasion), and deposition in a marine environment (presence of pyrite).

Additional to the palynological data is the fact that bundles of wood cells (tracheids) possessing uniseriate circular bordered pits were present in the residue. These are interpreted to have been derived from conifers, and would have constituted part of the organic detritus de-

Table 7. Summary of findings. Hole locations are given in Figures 7 & 8

Hole Number	Collar Elevation (Meters/ Feet)	Elevation Base of Mineralization (Meters/Feet)	Sample Elevation (Meters/ Feet)	Sample Description	Findings	Comments
2	85 / 279	82 / 269	80.5-79.7 / 264-261.5	Light brown (5YR5/6) clayey sand	No Pollen	
			79.7-78.9 / 261.5-259	Slightly laminated light brown (5YR5/6) and very pale orange (10YR8/2) clayey sand	No pollen; fungal spores	
			78.9-78.1 / 259-256.5	Slightly laminated light brown (5YR5/6) and very pale orange (10YR8/2) clayey sand	Pine, ragweed, birch,sweet gum, oak, elm	Suggestive of terrestrial source
8	81.7 / 268	78.7 / 258	72.6-71.8 / 238-235.5	Heavily mottled dark yellowish orange (10YR6/6), dark yellowish brown (10YR4/2), and dusky yellowish brown (10YR2/2) silty/sandy clay; some mica	*Pterocarya*, spiney dinoflagellate cysts, microforams	Marine-influenced sample; Pliocene
			71.8-71.1 / 235.5-233	Light olive grey (5Y5/2) silty clay with some dark yellowish orange and dusky yellowish brown (19YR2/2) mottling; mica and some sand are present	Pine, oak, hickory; microforams; dinoflagellate cysts; abundant pyrite	Both samples from Hole 8 represent a near-shore hardwood conifer assemblage
9	61.6 / 202	58.7 / 192	55.6-55.4 / 182-181.5	Dry, light grey, apparently sandy clay with what looks like charcoal fragments; some sand is very coarse	Chenopod pollen, composite pollen, grasses; dinoflagellate cysts; wood fibers; pyrite	Sediments accumulated in salt marsh environment
10	65.8 / 216	62.0 / 203.5	61.2 / 201	Yellowish orange, sandy clay with minor amount of coarse and very fine sand. The clay is soft and sticky.	No diatoms or other biotic remains	
			60.0-59.4 / 197-195	Medium gray to medium bluish gray clay with minor amount of fine to very fine sand. From elevation 59.8-59.7 meters (196.25-196 feet) a sandy zone containing more fine to very fine sand occurs.	*Thalassionema nitzschioides, Actinocyclus* sp., unidentified marine diatom	Marine origin
11	63.4 / 208	59.6 / 195.5	54.0-53.6 / 177-176	Light olive gray clayey, silty, very fine sand, micaceous.	Mollusk shell fragments (oyster, pectinids = scallops); *Pogonias cromis*	Marine origin
			52.4-51.21 / 172-168	Dark gray, clayey, silty, very fine sand, micaceous.	No diatoms; contains pollen, fungal spores, opal phytoliths; unidentifiable shell fragments	Continental Origin
12	62.5 / 205	56.4 / 185	55.8 – 55.0 / 183-180.5	Dark yellowish grey (5GY4/1) clayey sand with well-rounded quartz pebbles [1-2 mm (0.04-0.08 in.)] diameter	*Pterocarya*, pine pollen, grass pollen, oak, composites, hickory/pecan, beach, sweet gum; abundant dinoflagellate cysts; microforams; abundant pyrite	Southern maritime forest, nearshore deposition; Pliocene

rived from a terrestrial source.

Chenopod pollen constituted 9.3 percent of the pollen/spore count, composite pollen was at 18.6 percent, and grasses were at 41.9 percent in this sample. All these numbers are very high as compared to other samples from the southeastern U.S. (Rich, 1985; Rich and Pirkle, 1994; Rich, 1998; and Booth and Rich, 1998). This information, in addition to the two dinoflagellate cysts present and the abundant pyrite suggests that the sediments probably accumulated in a salt marsh. The wood fibers could easily have been derived from conifers, and both pine and cypress were present in the pollen count. These would have been upland contributions to the microflora which, otherwise, looks like a coastal marsh.

Finally, a sample from Hole 12, 6.7-7.4 m (22-24.5 feet) produced an interesting, though numerically small palynoflora. The most numerous pollen types included pine, grasses, oak, and composites, in that order. Hickory/pecan, beech, and sweet gum were also present, suggesting a normal maritime forest assemblage. However, dinoflagellate cysts were abundant, microforams were present, and there was abundant pyrite in the residue. These latter characteristics suggest nearshore marine deposition and are compatible with a salt marsh depositional environment. It is also worth noting that one grain of *Pterocarya* appeared in this sample.

All the palynological data are suggestive of the same paleoenvironmental reconstruction. While more thorough sampling would certainly be helpful, the body of information we now have suggests that the heavy-mineral deposits described here probably accumulated during the Pliocene or later along a coast dominated by southern maritime forest and marshlands where there was significant marine influence, but not such vigorous sediment sorting that all the small fossil materials were winnowed out of the sediments. Because the Bailey heavy-mineral concentrations overlie the pollen bearing sediments in drill holes 8 and 12, and because of the presence of a reliable Pliocene marker within the sample taken from 9.1-9.9 m (30 – 32.5 feet) in drill hole 8 and 6.7-7.4 m (22 – 24.5 feet) in drill hole 12, the deposits must have a maximum age of Pliocene, with a probable maximum age of Late Pliocene because of the absence of additional Pliocene biostratigraphic markers.

Principal Components Analysis

In order to determine statistical patterns of the Bailey deposits for comparison with patterns of other heavy-mineral deposits and more modern sediments, several principal component analyses were performed on sediments collected from the Bailey heavy-mineral deposits. In a principal components analysis, the minimum number of uncorrelated factors (components) needed to account for most of the variation in a set of data is determined. The analysis helps to locate redundant information in the variables that were measured. In interpreting the analysis it is assumed that variables loading heavily on the same component are affected by the same process or processes.

To help in the interpretation of a principal component analysis, the factor loadings can be constructed so that a variable affected by only one factor will have a loading on that factor of one, and a variable not affected by a factor will have a loading of zero on the factor. Generally the pattern is complex with a variable being affected by a number of factors. However, one factor often will dominate a variable. If needed, rotations can be carried out to give a more easily interpreted pattern. If orthogonal rotations are used, the components remain uncorrelated. In this study an orthogonal Varimax rotation was performed.

Variables Analyzed

Variables from 99 samples collected from 14 drill holes located throughout the mineralized zone of the Bailey deposit were included in the principal components analyses. Weight percent of the grain sizes of the sediments (from 1ϕ to 4ϕ in 0.5 ϕ intervals) is included in the analysis because grain size may reflect sorting, availability of material (source), or a type of transport and could indirectly indicate an environment of deposition (Friedman, 1979). The weight percent total heavy minerals in each

Table 8. Bailey heavy-mineral deposit diagonalized simplified components factor loadings – Varimax Rotation

Component Property	Principal Components Component 1	Component 2	Component 3	Component 4	Component 5	Communality
14 mesh	+ + +					0.8790
20 mesh	+ + +					0.9329
35 mesh	+ + +					0.9436
80 mesh	- -					0.8989
120 mesh	- -		- -			0.9428
230 mesh		+ + +				0.9580
Pan		+ + +				0.8897
45 mesh			+ +			0.8901
60 mesh			+ + +			0.8650
170 mesh			- -			0.9134
Slime				- -		0.7756
H.M.					+ + +	0.9987

Explanation

	Positive	Negative
>0.80	+ + +	- - -
0.63 - 0.80	+ +	- -
≥0.63		

sediment sample is included because heavy minerals may reflect source materials and sorting. The percent slimes (-270 mesh) in each sample is included since the relationship of the slimes to the heavy minerals and grain size may reflect the deposition of the slimes. The slimes were removed from the sample through wet sieving prior to sieving the sand fraction.

Interpretation

Principal components analyses have been performed on the Trail Ridge heavy-mineral deposit, the Yulee heavy-mineral deposits, the Cabin Bluff heavy-mineral deposits, and the Altama heavy-mineral deposits in northern Florida and southeastern Georgia (Pirkle, 1977; Pirkle *et al.*, 1984; Pirkle *et al.*, 1989; and Pirkle, *et al.,* 1991). In addition Eichenholtz *et al.* (1989) studied two areas of beach ridges along present-day barrier islands of the northeastern Florida coast. The weight percent of heavy minerals in the Trail Ridge, Yulee, and Altama heavy-mineral deposits are related to various grain sizes. This relationship also is apparent in the modern beach ridges studied by Eichenholtz *et al.* (1989). In the Cabin Bluff deposit, however, the total heavy-mineral variable loads on a component by itself; it loads on Component 4 of that analysis. The same is observed for the heavy minerals of the Bailey deposits where they load on Component 5 (Table 8). The justification for the format used in Table 8 may be found in Pirkle *et al.* (1989).

It is very difficult to assign a process to a component containing only one variable. A possible explanation for the independent heavy-mineral loading might be found in a process or activity where heavy minerals are concentrated episodically, such as occurs during stormline deposition or as a result of seasonal sediment supply or seasonal vegetative cover variations. This type of activity might not have a major effect on the overall depositional history of the sedimentary body, but might be very important in the deposition of certain materials such as heavy minerals.

The mixing of environments of deposition also might explain the loading of heavy minerals on only one component. Two different sets of processes could be responsible for the deposition and concentration of heavy minerals, with neither set of processes being clearly dominant. At Cabin Bluff the independent loading of the heavy minerals is the result of mixing a dune (wind-dominated) environment with a backshore (water-dominated) environment (Pirkle *et al.*, 1991). The principal components analyses of the Bailey heavy-mineral deposits suggests that they are the result either of two or more different environments with different processes, or the result of a single environment that has variable processes of varying intensity acting on the sediments for varying lengths of time.

The slime variable also loads by itself on a single component (Table 8). If the slimes are derived from the weathering of feldspar one might expect the slimes to load in a positive manner with the size fraction containing most of the feldspars. If the feldspars occur in several grain sizes then the slimes might correlate to various degrees with each size fraction. If the clay is the result of primary deposition then one might expect the clay content to increase as the grain size decreases or the clay content might decrease as the grain size increases. None of these relationships are observed in the principal components analyses performed. As with the variable total heavy minerals, the variable slimes may be reflecting multiple origins of the clay.

DISCUSSION

Any discussion concerning the depositional environment of the Bailey heavy-mineral deposits must address the presence of the clay in the sediments along with the concentrations of heavy minerals observed, the gravel observed with the heavy minerals, and the results of the principal components analyses.

The fact that the sediments containing the highest heavy-mineral grades of the Bailey heavy-mineral deposits overlie the Sims pluton presents an interesting problem. The pluton is an irregular surface that is generally higher than the surrounding metamorphic rocks. If shoaling water overlying the topographic high of the pluton allowed wave action to wash away the lighter materials and concentrate the heavy minerals, then one needs an explanation as to why the clays were not removed with the lighter sands. The clays and clay contents of the sediments overlying the Sims pluton seem to be the same as those found in the sediments overlying the rocks of the slate belt. If these clays are primary i.e. deposited as sediment with the sands and heavy minerals, why were they not removed with the lighter materials? If these clays are secondary, i.e. formed by the decomposition of feldspars, one might expect the clays to have remained in place. If the latter (secondary clay) option is correct then why were the feldspars from which the clays formed not winnowed out like the rest of the lighter material in the higher grade portion of the deposits?

The principal components analyses suggest that the clay and heavy minerals were not deposited simply as a result of hydraulic equivalence. The analyses may be interpreted as indicating that both the clay and the heavy minerals were deposited either by more than one mechanism or in more than one depositional environment. The principal components analysis may be a reflection of the difference in seasonal sediment supply. These variations may be related to changes in increased river flow and sediment transport during the rainy season, a seasonal increase in storms (winter storms or summer hurricanes), or differences in temperature between winter and summer (Frey and Basan, 1985). Ranwell (1972) reports that warm weather during spring and summer may result in an increase in both the biological agglomeration of clay particles and the "flocculation" of particles because of increased salinity. Frey and Basan (1985) report seasonal effects in general are more pronounced in fluviomarine systems than in bay or lagoonal environments. Thus, the Bailey deposits do not seem to fit either the beach ridge model for heavy-mineral deposits or any of the "simple" beach models for heavy-mineral deposition and concentration.

The authors believe that fluvial processes, influenced by basement highs and lows, concentrated the mineralized sediments within the Fall Zone delta deposits. Longshore current and wave action are believed to have been relatively inconsequential, although this would not exclude local tombolo effects. As sea level regressed, existing rivers were forced to change

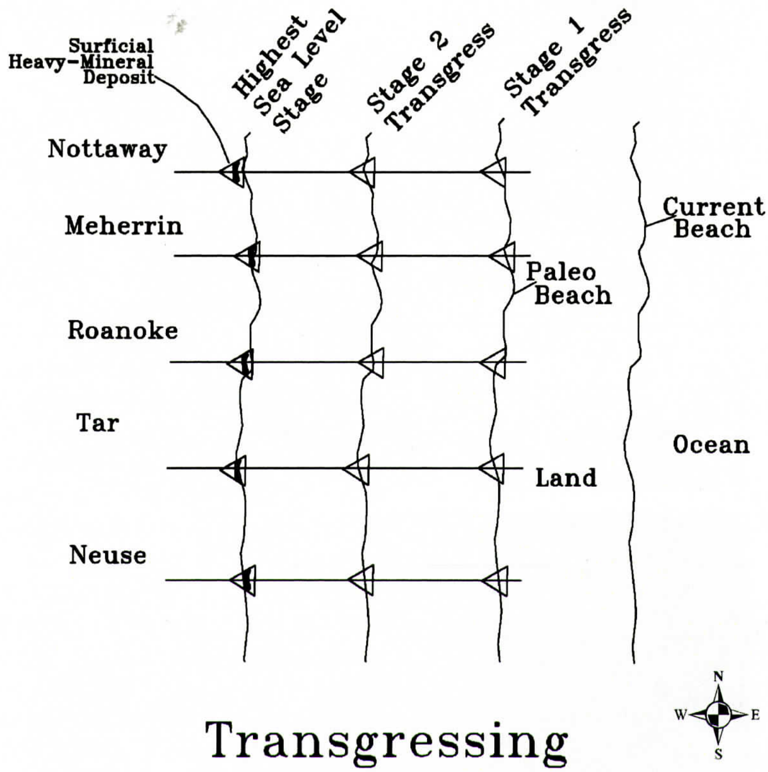

Figure 12. A conceptual model for the formation of the heavy-mineral deposits of the North Carolina-Virginia Fall Zone. Triangles represent hypothetical deltas.

their channels and pursue new courses in order to avoid erosion-resistant areas such as plutons and resistant beds with high clay content. Figure 1 shows that the major rivers near the heavy-mineral deposits (the Nottoway River at the Old Hickory ore body, the Meherrin River at the Virginia B deposits, the Roanoke River at the Halifax deposits, Fishing Creek near the Ringwood and Red Oak deposits, and the Neuse River near the Bailey deposits) are all deflected either north or south of the heavy-mineral deposits with which they are associated. Carpenter *et al.* (1995) believe the Sims pluton influences the courses of Turkey Creek and Moccasin Creek in the vicinity of Buckhorn Reservoir; thus, it might have influenced the course of the Neuse River.

Figure 12 is a conceptual model of how the heavy-mineral deposits may have formed. In this model a transgressing sea of probable Pliocene age had a stillstand at Stage 1 and a delta was built. The sea then transgressed to Stage 2, reworking the sediments into a second delta. From Stage 2 the sea transgressed to its highest sea level stage, again reworking sediments from the second delta and possibly incorporating some of the reworked sediments into the new delta being built. This new delta was near the Cretaceous source, and since there has not been a higher sea level since this sea was present, the heavy-mineral concentrations formed within the deltas have not been destroyed.

If the 1:24,000 United States Geological Survey topographic maps are studied for each deposit, a delta containing each of the deposits can be constructed. The generalized morphology of the deltas for three of the deposits is shown in Figure 13. Some coalescence of Fall Zone deltas may have taken place in closely spaced river systems prior to regression.

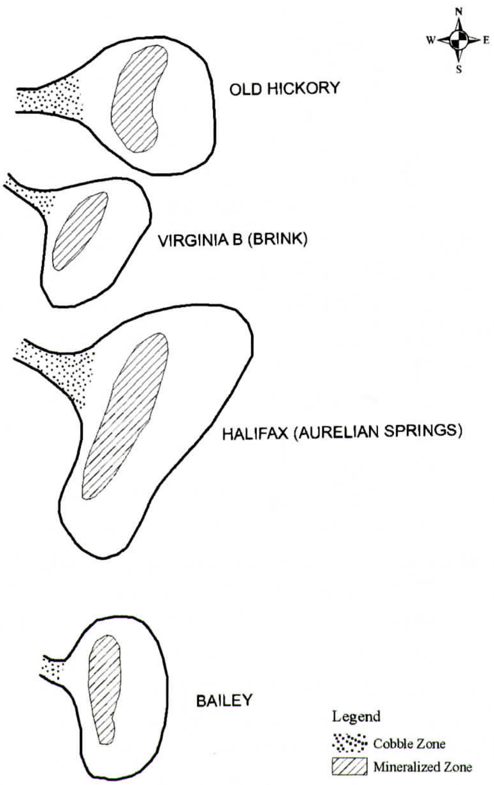

Figure 13. Diagrammatic, generalized deltaic morphology of selected North Carolina-Virginia Fall Zone heavy-mineral deposits. The dark lines are outlining current surface expressions of inferred deltas taken from U.S.G.S. 7.5 minute topographic maps. See Figure 1 for deposit locations. Diagram not to scale.

For a heavy-mineral deposit to form there must be a source of heavy minerals, a means of transportation, and an environment into which the heavy minerals are deposited and concentrated. Thus far the model presented for the origin of the Bailey heavy-mineral deposits has the source for the heavy minerals (the Cretaceous materials) and the means of transportation (the Neuse River). There must be an environment into which the heavy minerals are deposited. The *Ophiomorpha* burrows, the pollen present, and the diatoms observed all suggest a very shallow marine to salt marsh type of depositional environment. The *Ophiomorpha* suggests the sediments were deposited in subtidal high-energy shoals. *Ophiomorpha* form below the high tide line and only rarely are found at the high tide level. Ghost shrimp live in many places along a suitable shoreline as long as they get flooded by the tides or are never subaerially exposed for long periods. The common ghost shrimp of the southeastern United States, *Callichirus major*, ranges from the shallow subtidal up to the mid-tidal beach level; probably the mean tidal level of most people. The presence of the *Ophiomorpha* suggests a subtidal environment. The primary depositional site could have been a beach but the pollen present and the diatoms observed in the sediments suggest that the primary depositional environment was a very shallow marine to salt marsh associated with a tidally-dominated channel of moderate size, such as an inlet or sound associated with barrier islands.

If the Neuse River was carrying sand, silt, clay, and heavy minerals to a delta that was associated with a salt marsh, as is suggested by some of the pollen present, it is possible that tides could have served as the concentrating mechanism along with various fluvial processes allied with basement highs and lows. Thus all three requirements for the formation of a heavy-mineral deposit exist, and the heavy-mineral loadings seen in the principal components analyses are consistent with this multiple concentrating mechanism that involves both fluvial and marine depositional environments.

The notion that fluvial systems might have been prominent in the development of heavy-mineral deposits is not new, and heavy-mineral ore bodies of fluvial origin have been reported from around the world. The rutile deposits of Sierra Leone, for example, are considered to be alluvial in origin though some workers believe they should be called proluvial to diluvial placers (Raufuss, 1973). Verne Stocklemeyer of BHP Minerals delivered a paper entitled *The South West Region A New Heavy Mineral Province* to an Australian audience in 1995. This province is located in the Perth Basin and is referred to as the South West Region. He recognized eight heavy-mineral deposits of significance in the South West region. Of these, the five largest deposits are considered fluvial in origin; two are strand line deposits, and the

Figure 14. A and B. Kaolinite fecal pellets at the Old Hickory heavy-mineral deposit in Virginia. Photographs courtesy of Iluka Resources, Inc.

smallest is estuarine. One of the large fluvial deposits is named Beenup. Stanaway (written communication, 2012) states that the Beenup deposit contains high minus 45 micron "slimes." The slimes average 22 percent in the mineralized sediments at Beenup and vary from 18 percent to 30 percent. He believes the fines came from both interbedded clay beds and the decomposition of feldspar. Anonymous (2004) reports the clay content in the Beenup deposit to be 30 percent. Gültekín and Yavuz (1996) report the results of a study of an alluvial placer deposit in the valley of the Rahmanlar stream where it joins the Küçük Menderes River in Turkey. Finally, in New Jersey, both the Lakehurst ore body and the Manchester ore body occur in the Cohansey Formation which Markewicz (1969) believes to be fluvial in origin. Though Puffer and Cousminer (1982) believe the ore-bearing sands of the Cohansey Formation represent backshore and dune facies rather than being part of a fluvial system, Stanaway (1992), who studied drill core samples collected from these heavy-mineral deposits, concurs with Markewicz and believes there is clear evidence that the deposits are fluvial.

The clay content of our samples still must be addressed. Based on the pollen and other microfossils observed, much of the lower unit is probably derived from a salt marsh with deltaic material from the upper unit entering the salt marsh. Individual clay particles are so small and have such low densities they would not be expected to settle out of suspension. However, electrolytic flocculation of freshwater clays when exposed to salt water is known to result in larger-size clay aggregates of greater density and settling velocity; these have been documented by many investigators (Whitehouse *et al.*, 1958; Frey and Basan, 1985). In addition, stem density in coastal marshes is oftentimes such that the plants act as an effective sediment baffle, slowing the speed of currents so that fine sediments fall out and accumulate around the stems (Frey and Basan, 1985). Also, salt marsh grasses form tough root mats that create a shallow erosion-resistant base that causes storm waves to break before reaching higher land areas (Rogers, 1994). The waves are dissipated as they move through the marsh grass stems (Rogers, 1994; Knutson *et al.*, 1982; Gleason *et al.*, 1979). According to Rogers (1994) under most storm conditions about 6.1 to 9.1 meters (20 to 30 feet) of marsh grass is sufficient to prevent erosion. The cumulative evidence indicating the presence of salt marsh also suggests that sediment feeders, including worms and arthropods could have been (must have been) present. The ability of these organisms to consume clay-sized particles and bind them into fecal pellets at least the size of sand grains is well known (Farrell *et al.*, 1993); fecal pellets from the Old Hickory deposit are illustrated in Figure 14.

Our contention is that the electrolytic settling of clay particles, the baffling effect of the densely-spaced plant stems, and the likely presence of pelleted sediments would have made it quite possible for the clays to have accumulated in a coastal setting regardless of tidal range or wave energy. The only protection that was necessary was a barrier of some kind that would have allowed the plants to grow initially. The mixing of sands and clays, along with bioturbation of the sediments could account for the dissemination of the clay throughout the section while allowing clay to have remained as a primary depositional component.

Salt marshes are found in the intertidal area and contain fine sediments that have been transported by water and stabilized by vegetation (Boorman *et al.*, 1998). Back barrier lagoons and bays, river mouths, estuaries, deltas, and other areas where wave energy is dissipated over wide shallow near shore environments are places where salt marsh development is likely to occur (Davidson-Arnott *et al.*, 2002). Located between the land and the sea, salt marshes are affected by both salt and fresh water. Tidal effects are greatest on marsh areas below mean low water, while upland freshwater sources influence areas above mean high tide. Tides flush saline waters over the intertidal zone and rivers carry freshwater in from upland areas. The rivers contribute sediments to the marsh by continually transporting and redepositing sediment (U.S. Fish and Wildlife Service, 1999).

Deltas form in many different environments. They all, however, have one thing in common – a river supplies clastic sediment to the coast and inner shelf more rapidly than it can be removed by marine processes. Delta-plain landforms occur in nearly every type of coastal environment including distributary channels, river-mouth bars, open and closed interdistributary bays, tidal flats, tidal ridges, beaches, beach ridges, dunes and dune fields, and swamps and marshes (Wright, 1985). In our interpretation, the Bailey heavy-mineral deposits are found in the deltaic sediments that lie over the salt marsh.

A question that still must be addressed is whether the fluvial system (delta) was prograding over the salt marsh or whether the salt marsh was transgressing upon the fluvial system, thus helping to form the heavy-mineral deposits. If the mineralization occurred as the result of a stillstand or general regression or aggradation of a delta with respect to the shoreline, then the fluvial system is advancing over the salt marsh. If the sea were advancing over the salt marsh, the heavy-mineral concentrations would be typ-

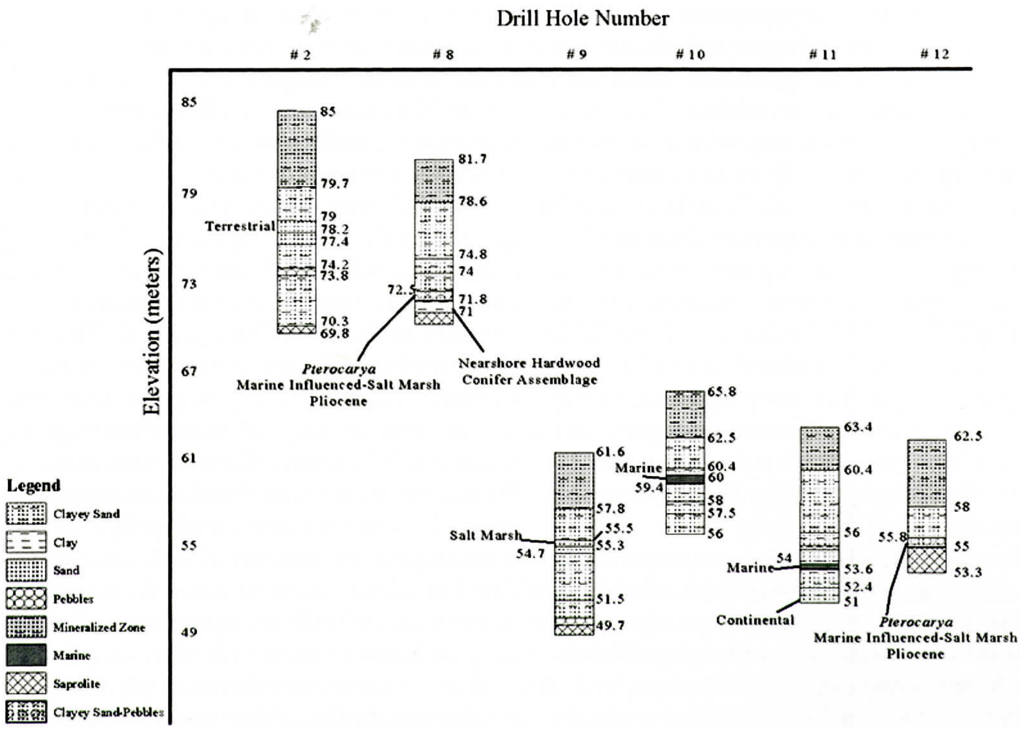

Figure 15. Sediment sequences west of the Orangeburg scarp and overlying the Sims pluton (holes #2 and #8) compared to sediment sequences east of the Orangeburg scarp and east of the Sims pluton (holes #9, 10, 11, 12). See Figures 7 and 8 for hole locations.

ical beach/dune placers.

To survive a sea level rise, the salt marsh must experience an elevation increase at a rate equal to or greater than the rate of sea level rise. This rise in elevation could be the result of the accumulation of organic matter produced by marsh vegetation and of sediment transported to the marsh platform; i.e., the interaction between tidal imports, vegetation, and depositional processes (Reed, 1994). If the salt marsh elevation increase is equal to the rate of sea level rise then a shoreline stillstand may result. Ancient deposits that illustrate the sedimentary sequence one might find in a shoreline stillstand situation are perhaps best shown in Cretaceous strata described by Beaumont *et al.* (1976). Cretaceous shoreline deposits are exposed in Chaco Canyon National Monument, New Mexico. According to Beaumont *et al.*(1976), "The overall Menefee-Cliff House- Lewis [Shale] sequence is a transgressive one; however, the main body of the Cliff House Sandstone in Chaco Canyon represents deposition during a near standstill of the strandline. Rapid accumulation of marginal marine sediments was keeping pace with basin subsidence." Paludal deposits, now represented by the coals, are vertically stacked southward of similarly stacked sands of the La Ventana Tongue of the Cliff House Sandstone. The sands interfinger with a stacked set of shale beds associated with the Lewis Shale formation. The entire shoreline was subsiding at about the same rate as the sediments accumulated.

If the marsh's elevation rise does not keep pace with the rate of sea level rise then marsh inundation may occur (Reed, 1994; Cavatorta *et al.*, 2003). According to Bartholdy (2000) many marsh environments are able to keep pace with sea level changes due to the rate of sedimentation. If the sediment supply is high, as Haslett *et al.* (2003) report concerning the estuaries along the Cotentin Peninsula (Normandy, France), the marsh will be infilled. This results, or would result, in a marine influence in the sedimentation within the salt marsh.

Study of the stratigraphy within the Bailey area suggests that the fluvial sediments prograded over the salt marsh. Thus these deposits seem to be the result of fluvial processes.

Heavy-mineral concentrations found on top of the Sims pluton (Figure 7) occur at elevations of about 17 meters to 26 meters (55 feet to 85 feet) higher than those found east and north of the pluton (Figure 15). The differences in elevations also follow the Orangeburg scarp (Figure 7) as it has been correlated to this area (Alt, 1974; Daniels *et al.*, 1972, 1978; Hoffman and Carpenter, 1992). Drill holes on and off of the pluton reveal similar sedimentary sequences including a stratum of probable salt marsh deposition containing Pliocene *Pterocarya* pollen (Figure 15). The *Pterocarya* bearing sediments are found at elevations of 72.6 meters to 71.8 meters (238 feet to 235.5 feet) over the pluton and at elevations of 55.8 meters to 55.0 meters (183 feet to 180.5 feet) east of the pluton (refer to holes 8 and 12 in Figure 15 and Table 7).

It is not known whether the differences in elevation represent faulting similar to that described from the Old Hickory deposits in southeastern Virginia (Berquist and Bailey, 1999; Newton and Romeo, 2006) or whether the elevation differences reflect two sea level stands during the Pliocene (?). The presence of *Pterocarya* pollen at two different elevations and the similar thickness of the mineralized zone at two different elevations suggest the possibility of faulting. During field investigations the authors saw no additional evidence of faulting other than the elevation differences in the sedimentary sequence. However, a detailed examination of faulting was outside the scope of the investigation.

Although the evidence for faulting is persuasive to account for the elevation differences in the sedimentary sequence, the possibility of two sea level stands cannot be ruled out. If the elevation differences represent two Pliocene (?) sea level stands, the higher stand likely would represent the maximum transgression in this area. The lower stand would represent a major sea level stand characterized by coastal environments similar to those of the higher sea level stand (delta prograding over salt marshes). This lower stand could be responsible for cutting the Orangeburg scarp in this area.

The Fall Zone deltas and their attendant heavy-mineral deposits have suffered considerable erosion since their deposition. One may speculate that this erosion began immediately upon the beginning of the regression from the Pliocene (?) transgression. The major rivers responsible for the Cretaceous deltas probably were located in similar Piedmont thalwags as the rivers that formed Miocene, Pliocene and Pleistocene deltas. The shoreline of the maximum Pliocene (?) transgression may lie eastward and at a lower elevation than some of the Fall Zone heavy-mineral deposits. However, where heavy-mineral concentrations formed in an aggrading delta environment (e.g. deltaic tidal flats), the maximum Pliocene (?) shoreline may have extended to the west of the deposits and be located between those deltas that contain the deposits. Upon recession, and possibly during still stands, a new and coalescing Delta Plain could have formed to the east, due to lower gradients resulting in a diminished flow velocity, thus forming the modern Coastal Plain. Several transgressions and regressions have taken place since the Fall Zone deltas formed. These later sea level fluctuations formed younger deposits that are dispersed (i.e., are less concentrated) due to their larger aerial extent and greater volume of material. Mineral sources for these younger, more eastward deposits are, (1) reworked Fall Zone delta material; (2) new material from the old source area piedmont sources; and/or (3) reworked previous still-stand material. No new material was added from local basement high sources due to their dip and extensive cover, and no penecontemporaneous cobbles exist in the post-Fall Zone deltas.

CONCLUSIONS

A transgressive sea [Pliocene (?)] reworked Cretaceous deltas and basement material in the upper Coastal Plain – lower Piedmont Fall Zone. Transgressive seas have not again approached these Fall Zone deposits since regression began in the Pliocene (?). Reworked, highly mature sediments from local source areas along with sediments brought in by fluvial systems from more distant source areas were deposited as mineralized zones within a delta complex as the Pliocene (?) sea began to recede. As sea level fell, existing rivers were forced to change their channels and pursue new courses in order to avoid erosion resistant areas such as plutons and resistant beds with high clay content. Some coalescence of Fall Zone deltas may have taken place in closely spaced river systems prior to regression. Paleorivers; fluvial processes, influenced by basement highs and lows; and tides rising and falling within existing deltas and salt marshes served, respectively, as the transportation mechanisms, depositional environments, and concentrating mechanisms that formed the heavy-mineral concentrations within the Bailey deposits and the other heavy-mineral deposits of the North Carolina and Virginia Fall Zone. Longshore current and wave action are believed to have been relatively inconsequential, although this does not exclude local tombolo effects.

Heavy minerals of the Bailey deposits were probably carried by the Neuse River and deposited in a delta at the edge of a salt marsh. The crossbedding style (scour and fill structures bracketing climbing ripples) closely resembles the crossbedding style seen on high-energy, tidally-dominated shoals along channel margins of St. Catherines Sound, Georgia, and, on a smaller scale, in channels on ebb deltas at McQueens Inlet and Seaside Inlet on St. Catherines Island, Georgia. The combination of the crossbedding and *Ophiomorpha* strongly suggest that the ancient sediments were deposited in subtidal high-energy shoals associated with a tidally-dominated channel of moderate size, such as an inlet or sound associated with barrier islands. Thus, the clay and heavy-mineral concentrations seem to have been partially the result of tidal and fluvial processes operating in a shallow marine to brackish (salt marsh) depositional environment. The Sims pluton appears to have played a role in influencing the path of the Neuse River and, hence, the formation of the Bailey deposits. Based on the pollen present, the Bailey heavy-mineral deposits are probably of Late Pliocene or Early Pleistocene in age.

The nature of the Cretaceous deltas, the Fall Zone deltas, and the Coastal Plain deltas are different because of (1) differences in the height of the source areas, and transport (gradient) distances with time (differences in geologic character of the paleo watersheds), (2) recycling of sediment, (3) paleoclimates, (4) nature of the depositional environment, and (5) changes in concentrating mechanisms.

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REFERENCES

Alt, D., 1974, Arid climate control of Miocene sedimentation and origin of Modern drainage, southeastern United States: *in* Oaks, R.Q. and DuBar, J.R., eds., *Post-Miocene Stratigraphy Central and Southern Atlantic coastal Plain*: Logan, Utah, Utah State University Press, pp. 21-52.

Anonymous, 2004, Moma mineral sands possibly Mozambique's next big project: Mining Review Africa, issue 2, February, accessed online at *www.miningreview.com* on October 14, 2008.

Bailey, R.H., 1987, Stratigraphy and depositional history of the Yorktown Formation in northeastern North Carolina: Southeastern Geology, v. 28, pp. 1-19.

Bartholdy, J., 2000, Process controlling import of fine-grained sediment to tidal areas: a simulation model *in* Oye, K. and Allen, J.R.L. (eds.), *Coastal and Estuarine Sedimentology, Geomorphology, and Geoarchaeology,* Geological Society, London, Special Publications, v. 175, pp. 13-30.

Beaumont, E.C., J.W. Shomaker, and W.J. Stone, 1976, Guidebook to Coal Geology of Northwest New Mexico: Circular 154, New Mexico Bureau of Mines & Mineral Resources, Socorro, NM, 58 p.

Berquist, C.R., Jr., 1987, Minerals in high-level gravel deposits along the Fall Zone of Virginia: Virginia Minerals, v. 33, pp. 37-40

Berquist, C.R. and Bailey, C.M., 1999, Late Cenozoic Reverse Faulting in the Fall Zone, southeastern Virginia: The Journal of Geology, v. 107, pp. 727 – 732.

Blackwelder, B.W. and Ward, L.W., 1979, Stratigraphic revision of Pliocene deposits of North and South Carolina: South Carolina Geological Survey Geologic Notes, v. 79, pp. 33-49.

Boorman, L.A., Garbutt, A., Barratt, D., 1998, The role of vegetation in determining patterns of the accretion of salt marsh sediment *in* Black, K.S., Paterson, D.M. and Cramp, A. (eds.), *Sedimentary Process in Intertidal Zone*, Geological Society, London, Special Publications v. 139, pp 389-399.

Booth, R.K. and Rich, F.J., 1998, Quaternary Evolution of the Georgia Coastal Plain as Indicated by Palynology, Stratigraphy, and Age of Selected Coastal, Inland, and Marine Deposits: *in* Rich, F.J. and Bishop, G.A., eds., *Geology and Natural History of the Okefenokee Swamp and Trail Ridge, Southeastern Georgia-Northern Florida*: Carrolton, Georgia, Georgia Geological Society field guide, v. 18, no. 1, p. 78-89.

Carpenter, P.A., III, Carpenter, R.H., Speer, J.A., and Stoddard, E.F., 1995, Geology of the Stancils Chapel 7.5-minute quadrangle, Johnston, Nash, and Wilson counties, North Carolina: North Carolina Geological Survey Open-File Report 94-3, 15p. and 3 maps.

Carpenter, R.H. and Carpenter, S.F., 1989, Preliminary evaluation of reserves, Hawley deposit, Wilson County, North Carolina, Becker Minerals Company Report.

Carpenter, R.H. and Carpenter, S.F., 1991, Heavy mineral deposits in the upper coastal plain of North Carolina and Virginia: Economic Geology, v. 86, pp. 1657-1671.

Cavatorta, J.R., Johnston, M., Hopkinson, C., and Valentine, V., 2003, Patterns of sedimentation in a salt marsh-dominated estuary: The Biological Bulletin, v. 205, pp. 239-241.

Cederstrom, D.J., 1957, Geology and ground-water resources of the York-James Peninsula: U.S. Geological Survey Water-Supply Paper 1361, 237 p.

Colquhoun, D.J., 1965, Terrace sediment complexes in central South Carolina: Field Trip Guidebook, Atlantic Coastal Plain Geological Association Field Conference, 62p.

Daniels, R.B., Gamble, E.E., Wheeler, W.H., and Holzhey, C.S., 1972, Untitled: Field Trip Guidebook, Carolina Geological Society and Atlantic Coastal Plain Geological Association, Raleigh, N.C., 36p.

Daniels, R.B., Gamble, E.E., and Wheeler, W.H., 1978, Upper Coastal Plain surficial sediments between the Tar and Cape Fear Rivers, North Carolina: Southeastern Geology, v. 19, 99. 69-81.

Daniels, R.B., Gamble, E.E., Wheeler, W.H., and Nettleton, W.D., 1966, Coastal Plain stratigraphy and geomorphology, near Benson, North Carolina: Southeastern Geology, v.4, pp. 159-182.

Davidson-Arnott, R.G.D., Van Proosdij, D., Ollerhead, J., and Schostak, L.E., 2002, Hydrodynamics and sedimentation in salt marshes: examples from a macrotidal marsh, Bay of Fundy: Geomorphology, v. 48, pp. 209-231.

Eichenholtz, M.E., Pirkle, E. C., and Pirkle, F. L., 1989, Sediment characteristics of selected beach ridges along Florida's northeastern coast: Southeastern Geology, v. 29, no. 3, pp. 155-167.

Emslie, S.D., Allmon, W.D., Rich, F.J., Wrenn, J.H., and de France, S.D., 1996, Integrated Taphonomy of an Avian Death Assemblage in Marine Sediments from the Late Pliocene of Florida: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 124, pp. 107-136.

Farrar, S.S., 1985, Tectonic evolution of the easternmost Piedmont, North Carolina: Geological Society of America Bulletin, v. 96, pp. 362 – 380.

Farrell, K.M., Henry, V.J., Jr., Cofer-Shabica, S.V., 1993, Geomorphology, facies sequences and processes in backbarrier salt marshes, Cumberland Island, Georgia: *in* Farrell, K.M., Hoffman, C.W., and Henry, V.J., Jr. (eds.), *Geomorphology and Facies Relationships of Quaternary Near St. Marys, Georgia,* Georgia Geological Society Guidebooks, v. 13, pp. 42 – 62.

Frey, R.W. and Basan, 1985, Coastal Salt Marshes *in* Davis, R.A. (ed.), *Coastal Sedimentary Environments,* Springer-Verlag, pp. 225 – 301.

Frey, R.W., Howard, J.D., and Pryor, W.A., 1978, *Ophiomorpha*: its morphologic, taxonomic and environmental significance: Palaeogeography, Palaeoclimatology, Palaeoecology, v.23, pp. 199-229.

Friedman, G. M., 1979, Address of the retiring president of the International Association of Sedimentologists: Differences in size distributions of populations of particles among sands of various origins: Sedimentology, v. 26, pp. 3 – 32.

Gallagher, P.E. and Hoffman, C.W., 1990, Geology and heavy-mineral exploration of sedimentary deposits along the Fall Zone of Northampton, Halifax, Nash, and Wilson counties, North Carolina: North Carolina Geological Survey Division of Land Resources Open-File Rept. 90-4, 17 pp.

Gleason, M.L., Elmer, D.A., Pien, N.C., and Fisher, J.S., 1979, Effects of stem density upon sediment retention by salt marsh cord grass, *Spartina alterniflora* Loisel: Estuaries, Journal of the Coastal Estuarine Research Federation, v.2, pp. 271-273.

Gültekin, A.H. and Yavuz, F., 1996, Heavy minerals in the fluvial sediments of Rahmanlar area, Ősemiş, western Turkey: Bulletin Technical University of Istanbul, v. 48, pp. 551-568.

Haslett, S.K., Cundy, A.B., Davies, C.F.C., Powell, E.S., and Croudace, I.W., 2003, Salt marsh sedimentation over the past c. 120 years along the west Cotentin coast of Normandy (France): relationship to sea-level rise and sediment supply: Journal of Coastal Research, v. 19, pp. 609-620

Hoffman, C.W. and Carpenter, R.H., 1992, Heavy-mineral deposits in the Bailey area, Nash and Wilson counties, North Carolina, *in* Dennison, J.M, and Stewart, K.G. (eds.), *Geologic Field Guides to North Carolina and Vicinity*, Chapel Hill, Univ. of North Carolina, Geologic Guidebook No. 1, Southeastern Section, Geological Society of America Annual Meeting Field Trip Number 5, pp.49-63.

Knutson, P. L., Brochu, R.A., Seelig, W.N., and Inskeep, M., 1982, Wave damping in *Spartina* alterniflora marshes: Wetlands, Journal of the Society of Wetland Scientists, v. II, pp. 87–104.

Mallard, E.A., 1992, An overview of RGC (USA) Minerals Bailey deposit, *in* Dennison, J.M, and Stewart, K.G. (eds.), *Geologic Field Guides to North Carolina and Vicinity*, Chapel Hill, Univ. of North Carolina, Geologic Guidebook No. 1, Southeastern Section, Geological Society of America Annual Meeting Field Trip Number 5, pp. 60-61.

Markewicz, F.J., 1969, Ilmenite deposits of the New Jersey Coastal Plain *in* S. Subitzky (ed.), *Geology of Selected Areas in New Jersey and Eastern Pennsylvania*, Rutgers University Press, New Brunswick, pp. 363-382.

Mixon, R.B., Berquist, C.R., Newell, W.L., Johnson, G.H., Powars, D.S., Schindler, J.S., and Rader, E.K., 1989, Geological map and generalized cross sections of the Coastal Plain and adjacent parts of the Piedmont, Virginia: U.S. Geological Survey Miscellaneous Investigations Series Map I-2033, 2 sheets, scale 1:250,000.

Newton, M. C., III and Romeo, A. J., 2006, Geology of the Old Hickory heavy mineral sand deposit, Dinwiddie and Sussex counties, Virginia, *in* Jeffrey C. Reid (ed.), *Proceedings of the 42nd Forum on the Geology of Industrial Minerals*, Information Circular 34, North Carolina Geological Survey, pp 464-481.

Pirkle, E. C., Pirkle, F. L., Pirkle, W. A., and Stayert, P. R., 1984, The Yulee mineral
sand deposits of northeastern Florida: Economic Geology, v. 79, no. 4, pp. 725 - 737.

Pirkle, F. L., 1977, Characterization of variation in grain size and heavy mineral content of Trail Ridge sediments, Ph.D. Dissertation, Pennsylvania State University, University Park, 231 p.

Pirkle, F. L., Pirkle, E. C., Pirkle, W. A., Dicks, S. E., Jones, D. S., and Mallard, E. A., 1989, Altama heavy mineral deposits in southeastern Georgia: Economic Geology, v. 54, no. 2, pp. 425 – 433.

Pirkle, F. L., Pirkle, E. C., Reynolds, J.G., Pirkle, W. A., Jones, D.S., Spangler, D. P., and Goodman, T. A., 1991, Cabin Bluff heavy mineral deposits of southeastern Georgia: Economic Geology, v. 86, no. 2, pp. 436-443.

Pirkle, Fredric L., Pirkle, W.A., and Pirkle, E.C., 2007a, Heavy Mineral Sand Deposits of the Atlantic and Gulf Coastal Plains *in* Maria A. Mange and David T. Wright (eds.), *Heavy Minerals in Use: Developments in Sedimentology*, Elsevier, Amsterdam, pp. 1145-1232.

Pirkle, F.L., Pirkle, W.A., Pirkle, E.C., Pirkle, D.L., and Spangler, D.P., 2007b, Heavy-mineral deposits of Bailey, North Carolina: 56th Annual Meeting of the Southeastern Section of the Geological Society of America, *Abstracts with Programs,* p. 77, 2007.

Powars, D.S., and Bruce, T.S., 1999, The effects of the Chesapeake Bay impact crater on the geological framework and correlation of hydrogeologic units of the lower York- James Peninsula, Virginia: U.S. Geological Survey Professional Paper 1612, 82 p., 7 pl.

Puffer, J.H. and Cousminer, 1982, Factors controlling the accumulation of titanium-iron oxide-rich sands in the Cohansey Formation, Lakehurst area, New Jersey: Economic Geology, v. 77, pp. 379-391.

Ranwell, D.S., 1972, *Ecology of Salt Marshes and Sand Dunes*, Chapman and Hall, London, 258 pp.

Raufuss, W., 1973, Structure, heavy mineral content, genesis and exploitation of the sedimentary rutile deposits in Sierra Leone: Geologisches Jahrbuch, Reihe D –Heft 5, Hannover, Translated from German by H. Michel.

Reed, D.J., 1994, The response of coastal marshes to sea-level rise: survival or submergence?: Earth Surface Processes and Landforms, v. 20, pp. 39-48.

Rich, F.J., 1985, Palynology and Paleoecology of a Lignitic Peat from Trail Ridge, Florida: Information Circular No. 100, Florida Geological Survey, Tallahassee, Florida, 15 pp.

Rich, F.J., 1998, A Review of the Origins of Tree Islands ("Houses") in the Okefenokee Swamp: *in* Rich, F.J. and Bishop, G.A., eds., *Geology and Natural History of the Okefenokee Swamp and Trail Ridge, Southeastern Georgia-Northern Florida*: Carrolton, Georgia, Georgia Geological Society field guide, v. 18, no. 1, p. 57-77.

Rich, F.J. and Pirkle, F.L., 1994, Paleoecological Interpretation of the Trail Ridge Sequence, and Related Deposits in Georgia and Florida. Based on Pollen Sedimentation and Clastic Sedimentology: *in* Traverse, A., ed., *Sedimentation of Organic Particles,* Cambridge University Press, pp. 287-310.

Rich, F.J. and Pirkle, F.L., 1998, Steinkerns as Pollen Traps: *in* Bryant, V.M. and Wrenn, J.H., eds., *New Developments in Palynomorph Sampling, Extraction, and Anal-*

ysis, American Association of Stratigraphic Palynologists Foundation, Contribution Series Number 33, pp. 87-94.

Rogers, S. M., Jr., 1994, Marsh grass protection with low-cost breakwaters shoreline erosion control demonstration: Albemarle-Pamlico Estuarine Study, Report No. 94-03, 61pp.

Romeo, A.J., 2005, Grade control in mineral sands – the unique conditions at Old

Hickory Virginia *in* Akser, M. and Elder, J. (eds.), *2005 Heavy Minerals Conference Proceedings,* Society for Mining, Metallurgy, and Exploration, Inc., pp. 235-239.

Shafer, P.L., 2000, Mineralogical and geochemical variations in the Old Hickory heavy mineral sand deposit, Sussex and Dinwiddie counties, VA: MS Thesis, Blacksburg, Virginia Polytechnic Institute and State University.

Speer, J. A., 1997, The Sims pluton, Nash and Wilson counties, North Carolina: North Carolina Geological Survey Bulletin 97, 56 p.

Stanaway, K.J., 1992, Heavy mineral placers: Mining Engineering, v. 44, no. 4, pp. 352-358.

Traverse, A., 1988, *Paleopalynology*: Unwin Hyman, London, 600 pp.

U.S. Fish and Wildlife Service, 1999, Coastal Salt Marsh *in* South Florida Multi-Species Recovery Plan, Atlanta, pp. 3-553 – 3-595.

Whitehouse, U.G., Jeffrey, L.M., and Debbrecht, J.D., 1958, Differential settling tendencies of clay minerals in saline waters: Clay and Clay Minerals, v 7 pp. 1-79.

Wright, L.D., 1985, River delta *in* Davis, R.A. (ed.), *Coastal Sedimentary Environments,* Springer-Verlag, pp. 1 – 76.

www.beaufortonline.com/fishing access on October 18, 2008.

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A PETROLOGIC STUDY OF PORPHYROBLASTIC GARNET CHLORITE SCHIST IN THE DAHLONEGA GOLD BELT FROM GARNET HILL, PAULDING COUNTY, GEORGIA

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ABSTRACT

Detailed petrographic, microstructural, and chemical analysis of specimens collected at Garnet Hill, central Paulding County, Georgia, provide insights on the conditions that led to growth of large (> 1 cm) garnet porphyroblasts during Appalachian metamorphism. Relationships between fabrics of minerals included in garnet porphyroblasts and matrix minerals indicate that lower amphibolite facies metamorphism overlaps deformation and continued after deformation ceased. Garnet cores overprint an early foliation fabric that curves into parallelism, potentially due to porphyroblast rotation, with the matrix fabric; garnet cores are wrapped by fabrics of minerals included in the garnet mantle. Shielded by the garnet, inclusion assemblages also show key differences from the matrix mineralogy. Chloritoid and K-rich white mica are preserved in the garnet mantle; chlorite and Na-rich white mica are found exclusively in the matrix. Preliminary exchange thermometry for garnet core, mantle, and rim give the following approximate temperatures for the growth of garnet along a prograde path: nucleation at 400 °C, growth of mantle at 460 °C and growth of skeletal rim at 510 – 550 °C. Continuing work will determine whether the sharp transition in garnet chemistry and inclusion fabrics found at the core-mantle boundary in the porphyroblasts represents a brief hiatus or a profound time break in garnet growth representing two distinct orogenic pulses.

INTRODUCTION

The focus of this study is on the porphyroblastic garnet-chlorite-quartz schist unit exposed along the margin of the Little Bob alteration zone (McConnell & Abrams, 1984; Higgins et al., 1984), which was developed for sulfide mining during the 19th and 20th centuries (Shearer & Hull, 1918). The centimeter-scale garnet crystals are of particular interest due to several factors: (1) garnet is a refractory mineral; intracrystalline diffusion rates are slow for most elements, which means that any chemical zoning produced during garnet growth is likely to be preserved; (2) the mineral assemblage present during early stages of garnet growth may be preserved within the garnet, so long as the phases are not completely consumed by the garnet-forming reaction; therefore (3) garnet compositions together with the fabrics and assemblages of the included minerals can be used to estimate pressure-temperature conditions at different stages of the metamorphic evolution. Mineral assemblages, microstructural analysis, mineral chemistries, and thermobarometric conditions will be evaluated to provide constraints on the timing of and conditions associated with regional metamorphism at Garnet Hill.

This study serves as a preliminary "piercing point" to correlate microstructural fabric development and chemical gradients observed on the thin-section scale with the orogen-scale interpretations and models for the evolution of the Southern Appalachian orogen during the Taconic orogeny. Competing models, based on observed field relationships, inferred paleogeographic reconstructions, and available geochronologic data have led to interpretation of the Ordovician deformation and orogenesis as either an episode of terrane accretion due to Laurentian subduction and arc collision (e.g., Hatcher et al., 2007; Moecher et al., 2004) or as an episode of back-arc extension and volcanism with no emplacement of exotic materials or accretionary prism development (e.g. Holm-Denoma & Das, 2010; Tull et al., 2007). By examining the evolution of deformational fabrics and metamorphic mineral growth on the micron-scale, these distinct models for the Paleozoic evolution of the Laurentian active margin can be further assessed.

REGIONAL GEOLOGY

Garnet Hill lies within the Ropes Creek Metabasalt unit of the Dahlonega Gold Belt (Fig. 1), which is mapped as part of the Eastern Blue Ridge province in the Southern Appalachians (Holm-Denoma & Das, 2010; Hatcher et al., 2007; Higgins et al., 1988; Higgins et al., 1984). The Ropes Creek Metabasalt unit has alternatively been assigned to the New Georgia Group (German, 1988; McConnell & Abrams, 1984) based on differing structural models and stratigraphic interpretations. In either case, Ropes Creek volcanic rocks have a generally MORB-like or oceanic arc-related geochemistry (Higgins et al., 1988). In Paulding County, units locally contain evidence of deformed pillow structures and stretched lapilli (McConnell & Abrams, 1984; McConnell & Abrams, 1983). At Garnet Hill, located in central Paulding County, basaltic rocks contain abundant sulfide-rich zones and belts of banded iron formation; these are interpreted as hydrothermally-altered and metamorphosed volcaniclastics (Higgins et al., 1988; McConnell & Abrams, 1983). Previous interpretations have left unclear whether the main pulse of hydrothermal alteration resulted from a seawater-dominated hydrothermal system (e.g. Riverin & Hodgson, 1980) or overprinted the effects of regional metamorphism (Hurst & Crawford, 1970). The age of the Ropes Creek volcanics are poorly-constrained, but stratigraphic and tectonic relationships place their development between the Late Proterozoic and the onset of the Ordovician Taconian orogeny that represents closure of the ocean basin (Crawford et al., 1999). U-Pb ages of felsic volcanics within the Dahlonega Gold Belt cluster in the Ordovician (460-470 Ma) (McClellan et al., 2007).

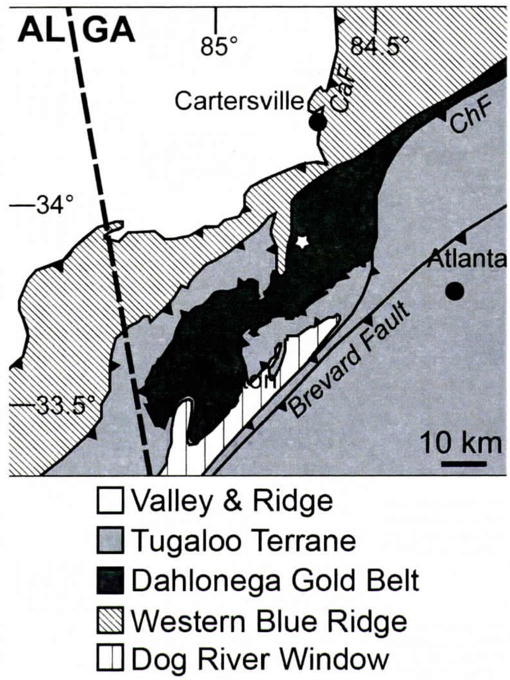

Figure 1. Simplified geologic map showing the location of the study area with respect to major tectonic provinces in western Georgia, modified after Hatcher et al. (2007). Star marks location of Garnet Hill.

Please note that this locality is now part of a residential area; future researchers are advised to obtain permission from landowners before visiting this site.

METHODS

Oriented specimens were collected at an exposure along Garnet Ridge Road (33.881657° N,84.804364° W), approximately 1 km south of the Little Bob Mine site (Shearer & Hull, 1918). Thin-sections and polished thick sections for petrographic and chemical analyses were prepared by careful slabbing normal to the chlorite-defined foliation, and parallel to the mineral stretching lineation. When possible, sections through the morphologic centers of garnet porphyroblasts were prepared by visual inspection and measurement of idiomorphic crystals, followed by progressive grinding of thick-sections to the desired position within the identified garnet.

Imaging, phase identification, and semi-quantitative point, line, and map analyses were performed using the FEI Quanta 200 SEM housed in the West Georgia Microscopy Center at the University of West Georgia. A suite of reference standards from the Smithsonian Institution (USNM 85276 – Fayalite; USNM 117733 – Diopside; NMNH 114887 – Magnetite; USNM 87375 – Garnet; USNM 143968 – Pyrope) were used to calibrate measurements and assess analytical precision. Image mosaics were manually assembled offline and annotated using the Adobe Creative Suite. Fully quantitative map and spot analyses were performed using the JEOL 8600 electron microprobe at the University of Alabama. Quantitative garnet maps were performed using a user-defined grid of point analyses; operating conditions of 15 kV and 200 nA sample current, and five second on-peak measurements of Si, Fe, Ca, Mg, and Mn. As part of this quantitative map analysis, Al content is estimated by difference. Additional quantitative analyses for garnet were collected using a 20 nA sample current at 15 kV, with peak and offpeak counting times: Si (10 s, 5 s); Al (10 s, 5 s); Fe (20 s, 7 s); Mn (20 s, 7 s); Mg (10 s, 5 s); Ca (10 s, 5 s); and Ti (20 s, 7 s). Chloritoid and mica were analyzed using a defocused electron beam at 15 kV and 20 nA sample current; measurements for all elements (Si, Al, Fe, Mn, Mg, Ca, Na, K, Ti, Cr) utilize 20 s on-peak and 7 s off-peak counting times. An appropriate suite of standards maintained by the Central Analytical Facility at the University of Alabama was used for calibration.

RESULTS

Structural Analysis

The orientation of the anastomosing foliation fabrics present in outcrop at Garnet Hill, defined by alignment of chlorite, is highly variable due to the abundance of porphyroblastic garnets within the rock unit: strike varies between N20°E – N55°E, averaging N41°E; average dips are 48° SE (Skinner et al., 2010). The poikiloblastic cores of the large garnet porphyroblasts contain numerous ilmenite and quartz inclusions that define an internal fabric that is not concordant with the matrix fabric (Fig. 2). At the margin of the core, there is an abrupt transition, in which orientation of the quartz and ilmenite inclusion trails changes by approximately 90 degrees (Hunt & Berg, 2010; Hunt & Berg, 2011). Beyond this transition, the orientation of the inclusion trails is concordant with the matrix fabric and wraps the garnet core (Spratt & Berg, 2009). Quartz-rich matrix domains are overgrown by skeletal garnet; chlorite-rich domains are overgrown by massive, less inclusion-rich garnet. Minor crenulations and low-angle shear band cleavage fabrics developed within the matrix are also present within the internal foliation fabrics of the garnet rims, but are less well-developed than in the external fabric (Berg, 2009).

Mineralogy and Mineral Chemistry

Detailed petrographic and chemical analyses of multiple Garnet Hill samples have identified several key changes in the stable mineral assemblage during and after garnet growth. The non-uniform distribution of phases within the garnet is roughly correlative with the microstructural domains described in the previous section, suggesting that these transitions may be geologically significant. The spatial distribution of several mineral phases as inclusions and within the matrix is summarized visually in Figure 3. Of particular note are the following observations: (1) the progressive change in orientation of abundant quartz inclusions in garnet cores on approach to the mantle of the porphyroblast (Fig. 3a); (2) ilmenite inclusions in the garnet mantle wrap idiomorphic garnet cores (Fig. 3b); (3) magnetite becomes much coarser grained and more abundant in garnet rims and matrix, although small amounts of

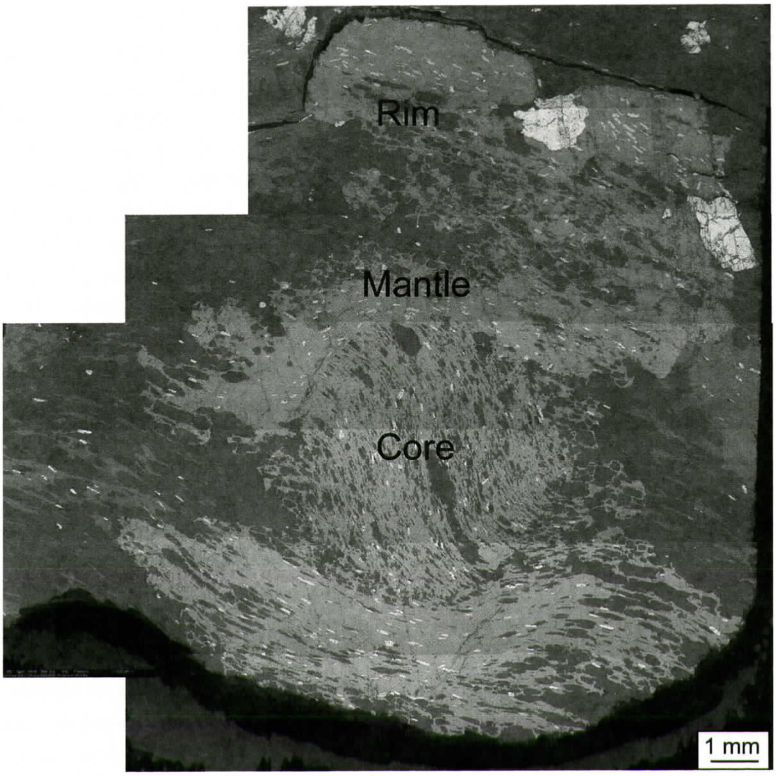

Figure 2. Backscattered electron (BSE) image mosaic of garnet porphyroblast GH-2. Lighter shades indicate higher mean atomic number in this grayscale image. Dark inclusions of quartz and bright inclusions of ilmenite define internal foliation. Alternating bands of chlorite and quartz define matrix foliation.

Table 1. Summary of Microstructural Relationships and Inclusion Assemblages

Location	Fabric	Inclusion Assemblage
Garnet Core	S_1 foliation	Quartz + Ilmenite + Zircon + Apatite
Garnet Mantle	S_2 (wraps Garnet Core)	Quartz + Ilmenite + Chloritoid + Monazite ±White mica ± Zircon
Garnet Rim	Skeletal garnet; $S_i = S_e = S_2$	Magnetite + Ilmenite + Monazite ± Chlorite ± White mica ± Zircon
Matrix	S_3 crenulation of S_2 fabric	Quartz + Chlorite + Ilmenite + Magnetite + White mica

magnetite are found in garnet cores (Fig. 3b); (4) small amounts of chloritoid are present only in the mantle and rim of the garnet and are completely absent from the matrix (Fig. 3c); (5) chlorite is present only in the matrix and as inclusions only in the outermost skeletal rims of the garnet (Fig. 3c); and (6) garnet cores contain abundant zircon (Fig. 3d) and apatite, while garnet mantles, rims, and the matrix contain significantly less of these accessory phases but instead monazite becomes more common (Fig. 3d). Inclusions of white mica are rare in garnet rims; radiating platelets of white mica are distributed throughout the matrix. The variations in inclusion assemblages and styles of internal fabric and garnet growth patterns are summa-

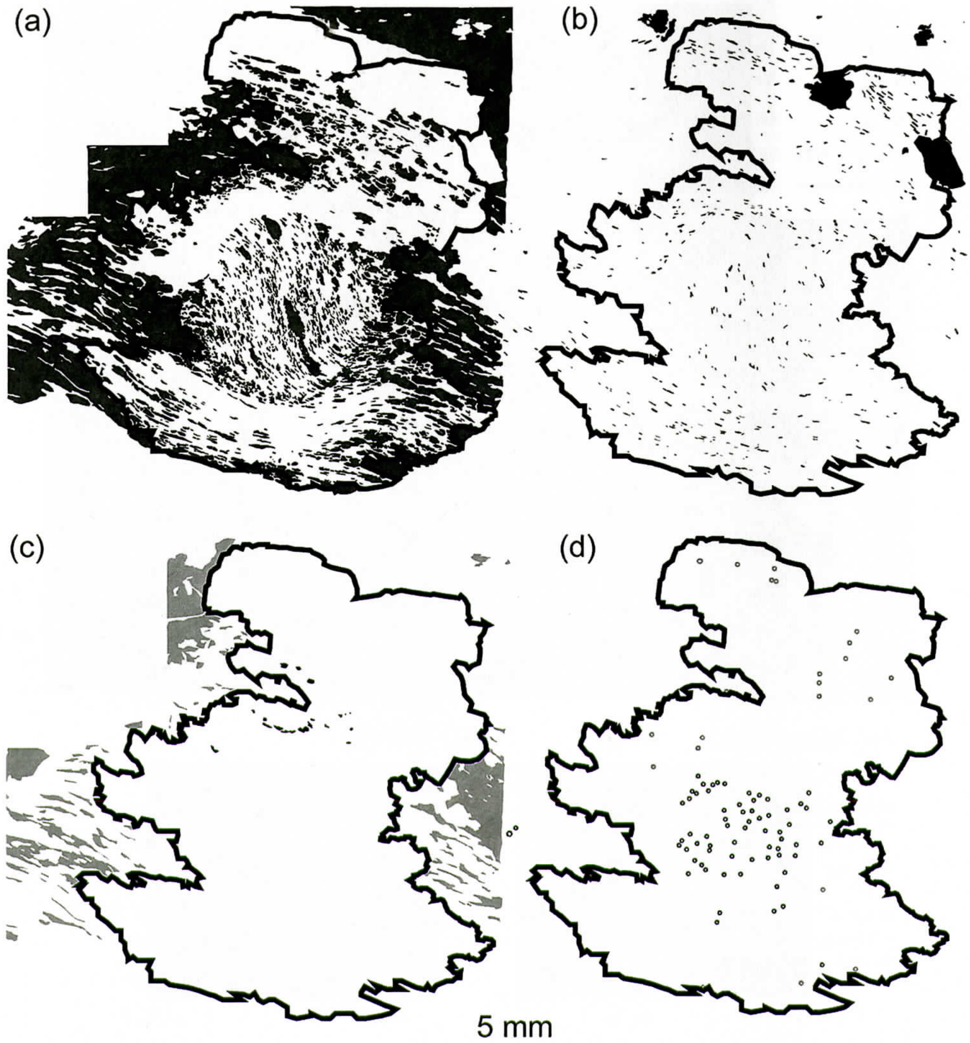

Figure 3. Distribution of minerals present as inclusions and within matrix of garnet GH-2 (after Hunt and Berg (2010): (a) quartz; (b) magnetite (dark shading) and ilmenite (light shading); (c) chlorite (light-gray) and chloritoid (dark-gray); (d) zircon (dark circles) and monazite (light circles). Black outline traces the rim of garnet porphyroblast.

rized in Table 1.

Garnet Hill porphyroblasts are compositionally zoned (Fig. 4): garnet compositions vary from $Alm_{69}Prp_{05}Sps_{19}Grs_{07}$ in the core to $Alm_{83}Prp_{08}Sps_{02}Grs_{07}$ at the rim. The mole fraction of almandine in garnet generally increases rimward (Fig. 4b); pyrope in garnet is low but also increases slightly from the core to the rim of the porphyroblast (Fig. 4c). Compositional breaks correspond to changes in microstructural fabrics and inclusion assemblages: the boundary between the core and mantle marked by the idiomorphic outline and wrapping ilmenite inclusions corresponds with a significant jump in grossular and spessartine component (Fig. 4d, 4e) (Hunt & Berg, 2011). Representative analyses of the garnet core, transition, mantle, and rim are presented in Table 2.

The results of microprobe analyses of chlorite, chloritoid, and white mica are displayed in Table 3. Chlorite analyses vary little within the scale of a thin-section. The chlorite in the Gar-

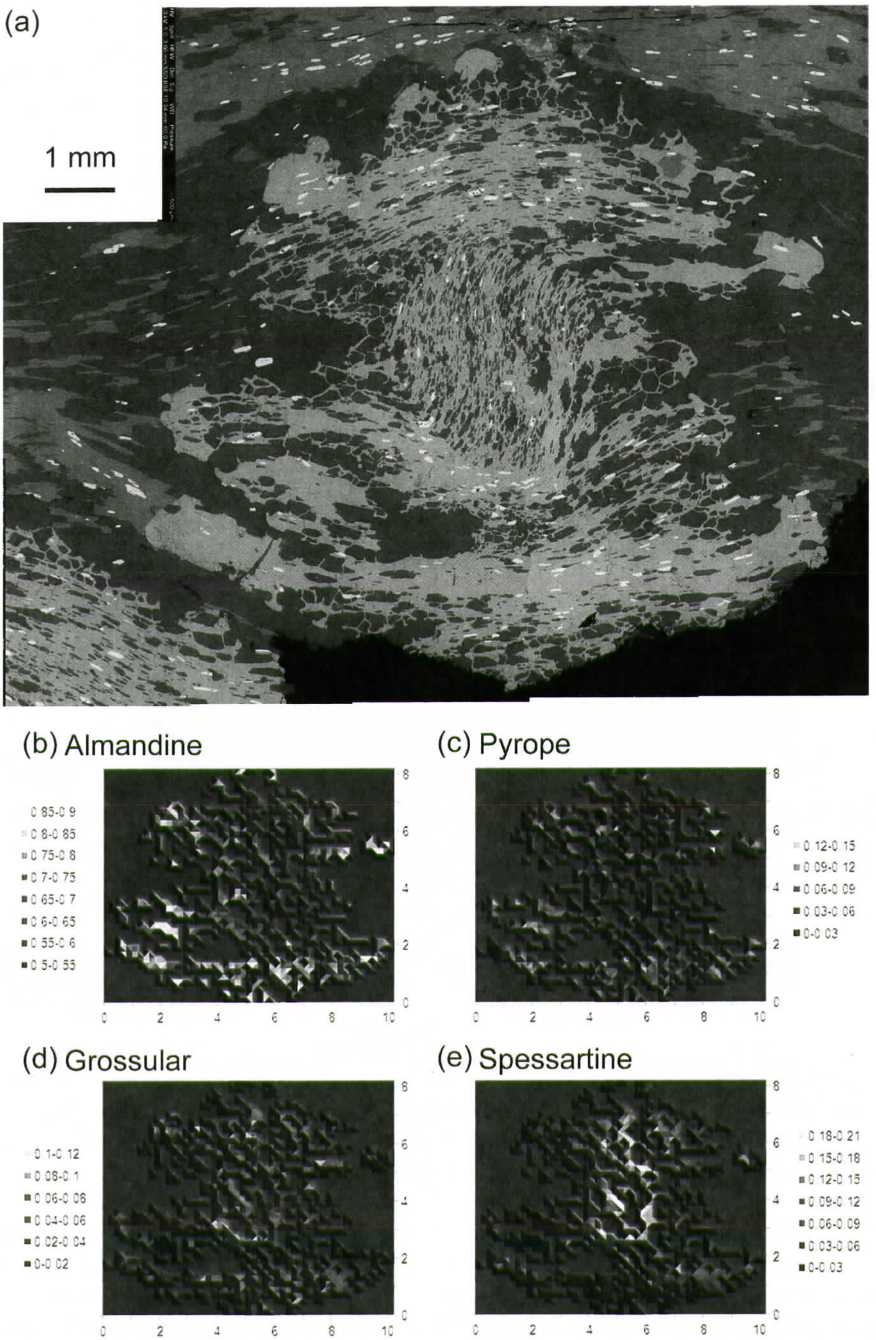

Figure 4. Results of quantitative map analysis of garnet GH-4; the level of grayscale shading in maps indicates compositional contours in garnet (lighter shading indicates increased concentration). (a) BSE mosaic of GH-4, for reference in cation maps. (b) Almandine; note gradual increase from core to rim (~Alm_{85} at rim). (c) Pyrope; Prp content steadily increases rimward to ~Prp_{12}. (d) Grossular; Grs content generally < Grs_{10}, with decreasing trend from core to rim, slight spike at core/mantle transition. (e) Spessartine; Sps content decreases rimward, with slight spike at core/mantle transition. X-Y scaling in millimeters in all charts.

Table 2. Representative garnet compositions for sample GH-4

	Core	Transition	Mantle	Rim	Rim
SiO_2	38.71	39.21	36.43	37.47	36.70
Al_2O_3	21.06	21.16	20.91	21.20	21.03
FeO*	29.75	28.83	33.85	34.62	35.57
MgO	1.23	1.17	1.51	2.50	1.95
CaO	2.40	3.46	2.14	1.23	2.47
MnO	8.09	7.66	3.88	1.48	0.88
Total	101.23	101.48	98.72	98.50	98.60
Oxygens	12	12	12	12	12
Si	3.08	3.10	2.99	3.04	3.00
Al	1.98	1.97	2.03	2.03	2.03
Fe	1.98	1.91	2.33	2.35	2.43
Mg	0.15	0.14	0.19	0.30	0.24
Ca	0.20	0.29	0.19	0.11	0.22
Mn	0.55	0.51	0.27	0.10	0.06
Fe/(Fe+Mg)	0.93	0.93	0.89	0.89	0.91

NOTE: All Fe is given as FeO.

Table 3. Representative analyses of Chloritoid and Chlorite, sample GH-4

	Chloritoid		Chlorite
Location	Garnet Mantle		Matrix
SiO_2	24.45	SiO_2	24.14
Al_2O_3	44.25	TiO_2	0.08
FeO*	24.82	Al_2O_3	24.71
MnO	0.23	FeO*	27.67
MgO	3.15	MnO	0.03
CaO	0.02	MgO	12.72
Na_2O	0.00	CaO	0.01
K_2O	0.00	Na_2O	0.00
TOTAL	96.94	K_2O	0.00
		TOTAL	89.41
Total Oxygens	12		
Si	1.91	Total Oxygens	28
Al	4.08	Si	5.03
Fe^{2+}	1.62	Al^{IV}	2.97
Fe^{3+}	0.00	Al^{VI}	3.10
Mn	0.02	Ti	0.01
Mg	0.37	Fe	4.82
SUM	8.00	Mn	0.01
Fe/(Fe+Mg)	0.82	Mg	3.95
		SUM	19.89
		Fe/(Fe+Mg)	0.55

NOTE: All Fe is given as FeO.

Table 4. Results of garnet-mineral exchange thermometry

Location	Method	Reference	T °C (*error*)
Garnet Core	Garnet-Ilmenite	Pownceby et al. (1991)	402 (±*50*)
Garnet Mantle	Garnet-Chloritoid	Perchuk (1991)	463 (±*39*)
Garnet Rim	Garnet-Ilmenite	Pownceby et al. (1991)	525 (±*50*)
	Garnet-Chlorite	Perchuk (1991)	550 (±*22*)
	Garnet-Chlorite	Grambling (1990)	512 (±*29*)

net Hill samples is a chamosite with Fe/(Fe+Mg) = 0.55. Chloritoid inclusions within garnet have Fe/(Fe+Mg) = 0.82. Analysis of white mica crystals in the matrix reveals that these crystals are paragonite, with Na/(Na+K) values of ~0.86. Preliminary analyses of small mica inclusions in the mantle of garnet GH-2 suggest that these micas are dominantly muscovite, and only ~25% paragonitic component.

Thermometry

Compositions of coexisting garnet core and ilmenite, garnet mantle and chloritoid, and garnet rim and chlorite were used to calculate metamorphic temperatures from several exchange thermometers, the results of which are summarized in Table 4. Due to the changes in stable mineral assemblages and compositions during garnet growth (Table 1), it is not possible to apply the same garnet-exchange thermometers across the total range of porphyroblast nucleation and growth (Hunt & Berg, 2011). For growth of the garnet core, the garnet-ilmenite Fe-Mn exchange thermometer developed by Pownceby et al. (1991) was applied. Ilmenite compositions for this thermometer were determined by SEM-EDS spot analysis, which is significantly less precise than electron microprobe analyses; X_{Mn} values used for these calculations are 0.023 for ilmenite included in garnet cores and 0.004 for ilmenite in the matrix. Temperature conditions during growth of the garnet mantle were estimated using the Perchuk (1991) garnet-chloritoid Fe-Mg exchange thermometer. Conditions during growth of the garnet rims were calculated using the Pownceby et al. (1991) exchange thermometer between garnet rim compositions and matrix ilmenite, and two formulations of the garnet-chlorite Fe-Mg exchange thermometer (Perchuk, 1991; Grambling, 1990).

Standard analytical errors propagate through the calculations and result in computational uncertainties of ± 7 °C and 8 °C for the Perchuk (1991) and Grambling (1990) garnet-chlorite thermometers, respectively; ± 14 °C for the Perchuk (1991) garnet-chloritoid thermometer; and ± 50 °C for the Pownceby et al. (1991) garnet-ilmenite thermometer. 1-σ errors based on analytical precision and reproducibility through multiple mineral pairs are reported in Table 4. Comparison of the exchange thermometer results indicates that, despite the garnet composition being outside the preferred range for application of the garnet-ilmenite thermometer (Feenstra and Engi, 1998), good agreement exists between temperatures calculated for the Mn-poor garnet rim using this thermometer and both garnet-chlorite Fe-Mg exchange thermometers.

DISCUSSION

Based on the results of analysis of textures, mineral assemblages, mineral compositions, and equilibrium exchange thermometers presented here, a detailed evaluation of the evolution of conditions during metamorphism at Garnet Hill is possible. Fabrics of minerals included in the garnet porphyroblasts can be used to relate garnet growth to deformational events (e.g., Berg et al., in press; Johnson, 1999; Christensen et al., 1989). Prior to attainment of garnet-grade conditions, an early (S1) foliation fabric developed; this early fabric generation is preserved as the planar quartz and ilmenite inclusion fabric within garnet cores (Figures 2 & 3). The latter stages of growth of the garnet core were pre- to early syn-kinematic with the development of the S2 fabric; inclusion trails curve from the cores into the mantle, reflecting possible rotation of garnet crystals during syndeformational growth (e.g., Passchier et al, 1992) or overgrowth by garnet over a recrystallized matrix (e.g., Fay et al., 2008). The growth of the garnet rim occurred during essentially static conditions—there was little to no deformation beyond incipient development of the minor S3 crenulations at a low angle to the S2 foliation. However, there were significant changes in metamorphic grade during the period of garnet growth, as shown by the evolution of the inclusion assemblages and exchange thermometry results. Chloritoid is present within garnet mantles, but is absent from both garnet cores and the matrix of the sample. Chlorite has not been found included in garnet, most likely, because chlorite was consumed during garnet growth. There are chlorite-rich layers overprinted by inclusion-free garnet, whereas quartz-rich layers are overgrown by poikiloblastic or skeletal garnet. The abundance of iron oxide minerals also varies spatially within the samples: ilmenite appears to be concentrated as inclusions within the garnet, whereas magnetite is more abundant within garnet rims and in the sample matrix. There are also distinct shifts in accessory phase abundance during garnet growth: zircon is abundant within the garnet core, but extremely rare in the matrix; monazite is more numerous in garnet rims and the matrix of the samples.

Based on the results of mineral exchange thermometry reported here, metamorphic conditions during garnet growth at Garnet Hill evolved from greenschist facies conditions during growth of the garnet cores to lower amphibolite facies conditions during growth of the garnet rims. This pattern is consistent with field reconnaissance mapping and observed assemblages in nearby pelitic rocks: McConnell & Abrams (1984) mapped the locality in the kyanite zone, although staurolite and sillimanite were also reported nearby (McConnell & Abrams, 1983). However, detailed examination of these samples reveals that the tectonometamorphic history of the area is more complex than previous interpretations suggested. Although there has been significant chemical alteration and open-system change in bulk composition of the protolith, much of which was likely due to premetamorphic metasomatism (McConnell & Abrams, 1983), the progression of inclusion assemblages, especially iron oxide, phosphate, and mica phases within the garnet show that some of the changes in bulk chemistry (presumably through metasomatism and fluid-rock interaction) may have continued throughout metamorphism. The distinct textural and compositional break at the core-mantle boundary within the garnet represents a hiatus in garnet growth; detailed garnet geochronology (Pollington & Baxter, 2011) can determine whether this break in garnet growth represents a change in garnet-forming reaction or reaction rate producing a minor gap in time, or a profound temporal break associated with distinct orogenic pulses (Taconian versus Neo-Acadian, for example). Continuing work that focuses on the production of equilibrium thermodynamic modeling and the timing of phases of garnet growth will shed light on the precise pressure-temperature-time (PTt) path traversed by these samples, and will permit testing and further refinement of large-scale models for the tectonic development of the Southern Appalachians (e.g. Hatcher et al., 2007; Tull et al., 2007).

SUMMARY AND CONCLUSIONS

Detailed examination of the microstructural fabrics, inclusion assemblages, and mineral compositions at Garnet Hill provides details of the changing conditions during metamorphism. Exchange thermometry shows that garnets nucleated and grew over a ~130 °C range of temperatures, up to lower amphibolite facies (510-550 °C). However, the spatial distribution of inclusion assemblages and inclusion fabrics preserve evidence for a complex, multi-stage history of garnet nucleation and growth that is at odds with a simple, single-stage alteration and metamorphism interpretation. Analysis of these microfabrics and the conditions of metamorphic mineral growth can be used to constrain the conditions extant during tectonic assembly; continuing work to evaluate the timing and precise thermobarometric conditions that accompanied garnet growth will better refine models for the tectonic evolution of this portion of the Southern Appalachians.

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REFERENCES

Berg, C. A., 2009, Assessment of equilibrium assemblages, mineral chemistries, and deformational fabrics associated with the growth of centimeter-scale garnet porphyroblasts at Garnet Hill, Paulding County, west-central Georgia: Geological Society of America Abstracts with Programs, v. 41, p. 635.

Berg, C. A., Carlson, W. D., and Connelly, J. N., in press, Strain rates at high temporal resolution from curved inclusion trails in garnet, Passo del Sole, Central Swiss Alps, Journal of Metamorphic Geology, doi:10.1111/jmg.12017.

Christensen, J. N., Rosenfeld, J. L., and DePaolo, D. J., 1989, Rates of tectonometamorphic processes from rubidium and strontium isotopes in garnet, Science, v. 244, p. 1465-1469.

Crawford, T. J., Higgins, M. W., Crawford, R. F., Atkins, R. L., Medlin, J. H., and Stern, T. W., 1999, Revision of stratigraphic nomenclature in the Atlanta, Athens, and Cartersville 30- x 60-minute quadrangles, Georgia: Georgia Geological Survey Bulletin 130, 45 pp.

Fay, C., Bell, T. H., and Hobbs, B. E., 2008, Porphyroblast rotation versus nonrotation: conflict resolution!: Geology, v. 36, p. 307-310.

Feenstra, A., and Engi, M., 1998, An experimental study of the Fe-Mn exchange between garnet and ilmenite: Contributions to Mineralogy and Petrology, v. 131, p. 379-392.

German, J. M., 1988, The geology of gold occurrences in the west-central Georgia Piedmont: Georgia Geological Survey Bulletin 107, 48 pp.

Grambling, J., 1990, Internally-consistent geothermometry and H_2O barometry in metamorphic rocks: the example garnet-chlorite-quartz: Contributions to Mineralogy and Petrology, v. 105, p. 617-628.

Hatcher, R., Bream, B., and Merschat, A., 2007, Tectonic map of the southern and central Appalachians: a tale of three orogens and a complete Wilson cycle, in Hatcher, R., Carlson, M., McBride, J., and Martinez Catalan, J., eds., 4-D framework of continental crust: Geological Society of America Memoir, v. 200, p. 595-632.

Higgins, M. W., Atkins, R. L., Crawford, T. J., Crawford, R. F., and Cook, R. B., 1984, A brief excursion through two thrust stacks that comprise most of the crystalline terrane of Georgia and Alabama: Georgia Geological Society annual field trip guide, 67 pp.

Higgins, M., Atkins, R., Crawford, T., Crawford, R., Brooks, R., and Cook, R., 1988, The structure, stratigraphy, tectonostratigraphy, and evolution of the southernmost part of the Appalachian orogen: USGS Professional Paper 1475, 173 pp.

Holm-Denoma, C. S., and Das, R., 2010, Bimodal volcanism as evidence for Paleozoic extensional accretionary tectonism in the southern Appalachians: Geological Society of America Bulletin, v. 122, p. 1220-1234.

Hunt, L. E., and Berg, C. A., 2010, Extracting changes in metamorphic conditions from compositional zoning, inclusion distribution patterns, and textural clues in garnet porphyroblasts from Garnet Hill, northwestern Georgia: Geological Society of America Abstracts with Programs, v. 42, p. 628.

Hunt, L. E., Berg, C. A., and Skinner, T. M., 2011, Variations in garnet chemistry, inclusion assemblage, and microstructural development at Garnet Hill, west-central Georgia: Geological Society of America Abstracts with Programs, v. 43, p. 22.

Hurst, V. J., and Crawford, T. J., 1970, Sulfide deposits in the Coosa Valley area, Georgia: U.S. Department of Commerce, Technical Assistance project, 190 pp.

Johnson, S. E., 1999, Porphyroblast microstructures: a review of current and future trends: American Mineralogist, v. 84, p. 1711-1726.

McClellan, E. A., Steltenpohl, M. G., Thomas, C., and Miller, C. F., 2007, Isotopic age constraints and metamorphic history of the Talladega belt: new evidence for timing of arc magmatism and terrance emplacement along the southern Laurentian margin: The Journal of Geology, v. 115, p. 541-561.

McConnell, K., and Abrams, C., 1983, Geology of the New Georgia Group and associated gold deposits, west central Georgia: Society of Economic Geologists fieldtrip guidebook, 27pp.

McConnell, K., and Abrams, C., 1984, Geology of the greater Atlanta region: Georgia Geological Survey Bulletin, v. 96, 127 pp.

Moecher, D. P., Samson, S., and Miller, C. F., 2004, Precise time and conditions of peak Taconian granulite facies metamorphism in the southern Appalachian orogen, U.S.A., with implications for zircon behavior during

crustal melting events: The Journal of Geology, v. 112, p. 289-304.
Passchier, C. W., Trouw, R. A. J., Zwart, H. J., and Vissers, R. L. M., 1992, Porphyroblast rotation: eppur si muove?: Journal of Metamorphic Geology, v. 10, p. 283-294.
Perchuk, L,. 1991, Derivation of a thermodynamically consistent set of geothermometers and geobarometers for metamorphic and magmatic rocks, in Perchuk, L., ed., Progress in metamorphic and magmatic petrology: a memorial volume in honor of D.S. Korzhinskiy, p. 93-111.
Pollington, A. D., and Baxter, E. F., 2011, High resolution Sm-Nd garnet geochronology reveals the uneven pace of tectonometamorphic processes: Earth and Planetary Science Letters, v. 293, p. 63-71.
Pownceby, M. I., Wall, V. J., and O'Neill, H. C., 1991, An experimental study of the effect of Ca upon garnet-ilmenite Fe-Mn exchange equilibria: American Mineralogist, v. 76, p. 1580-1588.
Riverin, G., and Hodgson, J., 1980, Wall-rock alteration at the Millenbach Cu-Zn mine, Noranda, Quebec: Economic Geology, v. 75, p. 424-444.
Shearer, H., and Hull, J., 1918, A preliminary report on a part of the pyrite deposits of Georgia: Georgia Geological Survey Bulletin, v. 33, 283pp.
Skinner, T., Berg, C., and Hunt, L., 2010, Correlation of microstructural fabrics and regional metamorphism: an example from Garnet Hill, northwestern Georgia: Geological Society of America Abstracts with Programs, v. 42, p. 290.
Spratt, N., IV, and Berg, C., 2009, Investigation of metamorphic conditions associated with the growth of centimeter-scale garnet porphyroblasts at the Garnet Hill locality, west-central Georgia: Georgia Journal of Science, v. 67, p. 47.
Tull, J. F., Barineau, C. I., Mueller, P. A., and Wooden, J. L., 2007, Vocanic arc emplacement onto the southernmost Appalachian shelf: characteristics and constraints: Geological Society of America Bulletin, v. 119, p. 261-274.

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"I WILL TEACH YOU TO PIERCE THE BOWELS OF THE EARTH" — *THE MINERS' & FARMERS' JOURNAL*, CHARLOTTE, NORTH CAROLINA: 1830 – 1835

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ABSTRACT

The southeastern United States gold rush (1799-1849) is a period when gold mining progressed from primitive methods developed in the 15th to 16th century to more practical, rapid, and profitable technologies adapted to the geology of the American South. The rapid exploitation of the California gold fields (1849-1855) depended greatly upon the modified techniques and expertise developed in North Carolina and Georgia. But how did these farmers-turned-miners gain the necessary knowledge, skills, and equipment to produce these changes?

While Benjamin Silliman's *American Journal of Science and Arts*, Robert Blakewell's Introduction to Geology (1829) or William Maclure's Observations on the Geology of the United States of America (1809) were important to academic geologic thought and practice at the time, the part-time miners and "boomers" more often read extracted articles from these and other American or European journals and books from a less lofty source - the newspaper. The *Miners' & Farmers' Journal* represents the first weekly North Carolina newspaper that specifically addressed mining and geology in addition to agricultural topics and techniques. The newspaper was available at public houses, reading rooms, and by subscription. In addition to reports on the mining practices and techniques found in Chile, Mexico, Russia and elsewhere, notices of new mines or the sale of potential gold deposits were advertised, as were proposals or investment opportunities for the development or group ownership of an established gold mine. As gold mining moved from placer to underground mining, paid advertisements of equipment and mining materials as well as patent notices for new and improved mining devices became prevalent. The *Miners' & Farmers' Journal* provided the farmers-turned-miners a valuable knowledge resource and allowed for the dissemination of the necessary knowledge and background to utilize these new techniques and equipment. Other newspapers followed their lead and the interchange of news articles and announcements of gold discoveries throughout the southeastern United States helped foment the gold fever that changed the South's economic and social landscape.

INTRODUCTION

On Monday morning, September 27th, 1830, a new weekly newspaper was found on the streets of the city of Charlotte, North Carolina. The *Miners' & Farmers' Journal*, printed and published by H. S. Noble and T. J. Holton, was focused on the two major aspects of life in Mecklenburg County – farming and gold mining. Although there had been some articles and reprinted periodicals dealing specifically with agricultural practices, farming techniques, and philosophy throughout the northern and southern states in the early 1800's, the *Miners' & Farmers' Journal* represents the first weekly North Carolina newspaper that specifically addressed mining and geology in addition to agricultural topics and techniques. In part, this was a result of the development of strong agricultural basis of the region and the blossoming gold mining industry that had sprung up in the Charlotte region. This newspaper emphasized the

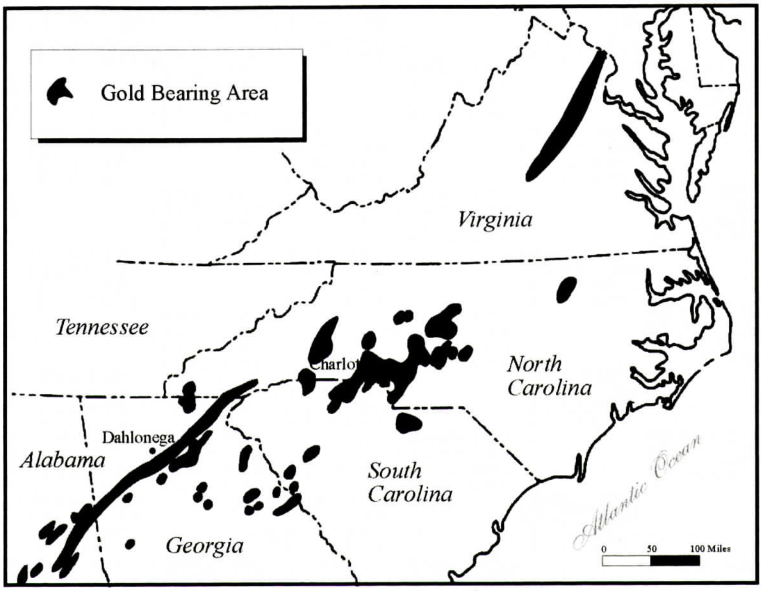

Figure 1. The village of Charlotte and its location relative to the gold-bearing areas of the southeastern United States in the 1830's. Modified after Pardee and Park, 1948.

logic of conjoining the two pursuits and offered practical advice, reprinted extracted scientific reports, and equipment advertisements for both occupations for only five years (Miners' and Farmers' Journal, 27 September 1830, *hereafter* MFJ; MFJ, 01 November 1830; MFJ, 27 December 1830).

So, why did this happen here in the Piedmont of North Carolina and what events or ideas set the stage for this new direction of newspaper? This paper will examine the setting for this development as well as address the factors that led to its initial success and eventual decline.

THE MINERS' AND FARMERS' JOURNAL: INCEPTION AND PURVIEW

In 1830, the village of Charlotte was a thriving, yet small town. Incorporated in 1768 as the village of "Charlotte Town," it was named after Charlotte of Mecklenburg-Strelitz, who became the queen consort of King George III in 1767 (Blythe and Brockman, 1961). Charlotte was the center of Mecklenburg County since its establishment as the county seat in 1774. The town provided general merchandise stores for necessary items, a blacksmith shop, a sawmill, flour mills (and later cotton gins), and a number of taverns. Primarily a crossroads for agricultural produce and livestock, it also was a way station on the main routes to western North Carolina, northern and western South Carolina, and Georgia. Although the railroad did not reach Charlotte until 1852, biweekly passenger (and cargo) stagecoaches provided access and communication with the developing nation. By 1830, mail reached the Charlotte post office, which had been established in 1795, by stagecoach every other day (Blythe and Brockman, 1961).

By 1830, several factors came together to allow the development of *The Miners' and Farmers' Journal*. The first dealt with agriculture and the growing of cotton. Until the invention of the cotton gin (1793), very little cotton had been grown in Mecklenburg County for anything other than home manufacture of textile goods (Cathey, 1956; Green, 1965). In general, agriculture from the earliest settlement of North Carolina was directed at producing subsistence crops rather than commercial crops (Cathey, 1956). In part this was a matter of geography. North Carolina, with respect to agricultural conditions and farming techniques of the time period, was along the southern fringe of the tobacco belt and along the northern fringe of the region in which cotton, rice, and indigo were commonly produced (Cathey, 1956).

However, with the invention and implementation of the cotton gin, the tenor of Charlotte changed so that the crossroads now became a major receiving and processing center for cotton. Cotton gins and cotton mills started to spring up throughout the city. The trend of cotton production was variable but appears to have steadily increased up to about 1825, followed by a decline in production until 1840, after which production steadily increased once more[1] (Cathey, 1956). As large acreage cotton plantations began supplanting once small farms, soil fertility decreased and the need for more labor increased. Consequently, an interest in better agricultural practices (often termed "scientific" farming) as well as the need for more labor-saving devices in the processing of cotton developed.

The interest in agricultural reform resulted in several North Carolina newspapers, such as the Raleigh *Star*, the Salisbury *Western Carolinian* and *Carolina Watchman*, the Tarboro *Southerner*, and the Hillsboro *Recorder* to include sections on "Agriculture," "Rural Economy," and "Rural Affairs." These sections discussed a variety of farm topics either from the viewpoint of local correspondents or by reprinting articles from other out-of-state newspapers, scientific journals, or agricultural societies (Cathey, 1956). However, for the majority of farmers, the *Farmers' Almanac*, that compendium of astronomical data, anecdotes, essays, cures, recipes, and articles on agriculture, was more widely circulated and read than the newspapers (Young, 1934; Cathey, 1956).

The second factor was that for more than 20 years following the 1799 discovery of gold by John Reed in Little Meadow Creek, local farmers in the Piedmont region (Figure 1) of Cabarrus and Mecklenburg Counties searched the alluvium of the streams using laborious and primitive placering methods to supplement their income (Knapp and Glass, 1999; Hines and Smith, 2002). In these early alluvial (or "branch") mines, farmers-turned-miners rarely excavated deeper than 8 or 10 feet and piled the gangue materials (waste rock material left over after the removal of the gold) haphazardly around the diggings as they excavated the more easily found gold nuggets, grains and dust (Hazen and Hazen, 1985).

The news of the initial discovery of gold in North Carolina was published on December 5, 1803 in the *Raleigh Register* newspaper. This story was widely reprinted in other national newspapers, such as *The Mail* (Philadelphia, PA; December 15, 1803), the *Maryland Gazette* (Annapolis, MD; December 22, 1803) and the Charleston (South Carolina) scientific journal *The Medical Repository* (1804, 1805). Other publications, such as the New York periodical *The Medical Repository of Original Essays and Intelligence, Relative to Physic, Surgery, Chemistry, and Natural History* (1804), also published notices attesting to the large size and fineness of the gold recovered.

However, by 1825, the Reed Mine partners (and numerous other small-scale work-a-day seasonal gold seekers) were no longer finding abundant surface placer deposits in eastern Cabarrus County (Knapp, 1999). In 1825, Samuel McComb successfully followed a vein of gold on his farm, which was then about a mile from the center of the town of Charlotte (now the intersection of South Graham and West Morehead Streets) (Blythe and Brockman, 1961). These diggings would develop into the Charlotte Mine (later renamed the St. Catherine Mine), one of the two most productive and profitable hard rock gold mines in Charlotte. His

1. The decline in cotton production probably corresponded to heavy emigration from North Carolina to the 'west' from the 1820's to the late 1840's. For example, the population of Mecklenburg County decreased 31% from 1830 to 1850 (Blythe and Brockman, 1961, 271). In part this migration was related to the fall in the price of cotton after 1819, decreased soil fertility from cotton production, increasing farm indebtedness, well as the scarcity of "new ground" for younger farmers (Cathey, 1956, 107).

diggers made large "winding, worm-like tunnels in the ground under many Mecklenburg County farms, trying to follow the veins" (Blythe and Brockman, 1961). At the same time they continued to dredge creeks and rivers and pan the sands for nuggets (Wilkinson, 1973; Birdsall, 1988).

These discoveries continued to fuel newspaper articles outside the gold regions. For example, the 14 January 1826 edition of the *National Gazette and Literary Register* (Philadelphia, PA) had an article on the discoveries of gold in 1823 to 1825, as well as a notice of the organization of the North Carolina Gold Company. This mining company organization notice was also an advertisement for skilled workers.[2]

When the Reed placer operation and surface "diggings" shifted to underground lode mining in 1830, inspired in part by the Matthias Barringer's hard rock mining shaft to the east, most other gold miners followed suit (Hines and Smith, 2006). Farmers could no longer afford to be part-time miners and were not equipped for deep mine drilling and maintenance or for milling gold ores in which gold existed but could not be seen. They had to become businessmen or find investors to pay for the labor, machinery and processing technology that this new type of mining demanded. They also, somehow, had to obtain the necessary knowledge and background to utilize this new equipment.

DISSEMINATION OF GEOLOGICAL AND AGRICULTURAL KNOWLEDGE TO THE MASSES: BOOKS, JOURNALS, AND NEWSPAPERS

During the first half of the 19th century, the American scientific community was concentrated in three cities: Philadelphia, Boston and New York (Baatz, 1991). In the southern states there were some smaller scientific societies with small subscription journals, usually promoted by the medical community, notably in Charleston and New Orleans (Ayres, 1807).

Private correspondence, public and private lectures, and publications and letters in the scientific journals of professional societies achieved communication among the members of these scientific communities. The young science of geology was often relegated to articles in less readily available European journals, especially those from England and Scotland. Although these journals were available in the United States, they could be purchased only by subscription. In addition, there was often a long wait for their arrival from overseas and the non-English titles presented the problem of translation.

In 1818, Benjamin Silliman, a professor at Yale in New Haven, began a scientific journal that rivaled those of Europe. It also created a vital link between the nascent scientific communities of the young nation and fostered a national view of domestic scientific endeavor. His journal not only published scientific articles but also announced developments in science within the scientific communities at home and abroad (Baatz, 1991).

For academic and practical geology in North Carolina and the rest of the nation, Silliman's *American Journal of Science and Arts* became a primary source for mining knowledge and techniques. The scientific reports and publications in this journal provided geologic information about known gold deposits as well as maps that could be used to locate existing and potential gold deposits. The dissemination of geologic information, and the practical skills and techniques to find and extract gold became more readily available in the American South. But, this is not to say that the farmer-turned-miner was limited to only this avenue of knowledge.

For example, in 1825, Robert W. Hodson, a Quaker farmer and miner in Guilford County, deferred his initial search for gold until after his crops had been harvested. Following the harvest, he and his brother sank a pit fifteen feet deep in a hillside above a creek where a few nuggets had been found, but to no avail. A few years later, after he had "*applied [his] mind closely to gain a knowledge of Geology, Mineralogy and Metallurgy from the best books*,"

2. *National Gazette, 1826, 1, "Those of who would work the mines, must specify the same before the 20th of February next, as this agency will close at this period."*

Hodson and his brother operated a profitable mining business in the agricultural off-seasons, with pits of up to fifty feet deep and a crew to dig and process the ores (Stockard, 1902; Glass, 1980, 14).

Many of the gold miners, farmers, and landowners followed this type of geologic self-education. To do this, they would have needed either access to individuals who had geologic knowledge or they would have had to obtain it for themselves. Robert Blakewell's Introduction to Geology (1829), as well as the English translation (1827) of Alexander von Humboldt's travels relating to the mines of Mexico, is an English language example of practical information concerning mining practices, geologic ideas and concepts.[3] In addition, William Maclure's 1809 book, Observations on the Geology of the United States of America contained the first geological map for the eastern states (Maclure, 1809, 1817; Fulton and Thomson, 1947).

However, obtaining the knowledge from the "best books" required a degree of literacy, occasionally fluency in other languages, and the availability of the volumes in the region. Few farmers (or landowners) in the North Carolina Piedmont enjoyed such a combination of circumstances. However, there is evidence that this type of self-learning was found in the gold regions of the Piedmont.

In 1837, Sarah F. Davidson of Charlotte, daughter of [Senator] William Davidson, wrote in her journal

> "16th Rain'd nearly all day – Engaged in reading Blakewell's *Geology* –
> 17th ......Finished reading Blakewell's *Geology* – how much more pleasing and profitable the perusal of this work would have been in conjunction with some friends equally interested ...."(McConnell et al., 2005).[4]

Despite the availability of journals (and books) to the importance in the development of academic geologic thought and practice in the United States, farmers-turned-miners more often received mining information from less lofty sources – the newspaper.

The dissemination of information by a newspaper was not a new direction. The newspaper arrived in North Carolina in 1751. Generally, newspapers in the late 18th and early 19th century were weekly, four page crown sheets produced by a press conductor (Elliott, 1965). Press conductors of the early 1800's newspapers were editors with influence in the community and/or publishers or printers with technical expertise or entrepreneurial talent (Nerone, 1989). They carried mostly foreign news (called "*foreign intelligence*") and stories copied from other papers or magazines. (McFarland, 1953; Nerone, 1989). What little local news there was consisted mainly of lottery advertisements, transcribed speeches and minutes of legislatures, court orders, current commodity prices, notices of sales, occasional letters from subscribers, editorial remarks, and advertisements.

About thirty papers were published in North

3. *There were other English language mining volumes ranging from William Hardy's practical The Miners Guide (1748) to the more elaborate folio Mineralogia Cornubienis by William Pryce (1778). The more detailed German mining works, which related the mining technology to the geological observations, were seldom translated to English primarily because they sold badly (Porter, 1973). However, the greatest of all mining "how-to-do" books, Agricola's De Re Metallica, was not available until the Herbert C. Hoover and Lou H. Hoover English language translation in The Mining Magazine (1912) and the later Dover Publications volume (1950).*

4. *William Davidson's plantation (The Grove) was 3 miles north of the Charlotte. He had found gold on the property and was actively engaged in surface mining in 1837 along with his son (William) and James H. Blake (his son-in-law married to his other daughter Margaret). Interestingly, Samuel McComb, whose first subsurface mine started hard-rock mining in the Piedmont, was Senator William Davidson's step-brother as well as being the Commissioner who supervised the building of the United States Mint in Charlotte in 1837.*

Carolina between 1815 and 1835, most of which were sold by subscription (McFarland, 1953; Stem, 1973). More than 70 newspapers and periodicals were published in North Carolina by the late 1850s. Although these publications were often regional in nature, it appears that these weeklies (or semi-weeklies) were subscribed to, passed around and read by a great number of people (Watson, 1983). The number of newspapers circulated was probably much smaller than the number of readers. For example, the May 12, 1832 issue of the Fayetteville *Carolina Observer* estimated 75,000 copies of newspapers were published in North Carolina each week (from Stem, 1973).

Papers were available at public houses and at reading rooms, and subscribers frequently complained that their non-subscribing neighbors enjoyed fuller use of their papers (Nerone, 1989). Newspaper sharing or borrowing was probably common, especially with respect to a weekly paper. Although there is no hard evidence, there are good reasons why a single copy of a weekly paper might reach as many as twenty readers. These weekly newspapers were printed on (generally) durable paper and were expensive and not easily seen as disposable as modern newspapers. In addition, as the only media for news communication outside of personal sources, these papers would remain useful past their date of publication.

AGRICULTURAL REFORM AND THE NEWSPAPER

New ideas about agriculture reached eastern North America in the 1780's. Originally instigated by practical agriculturalists in England, the ideas of agricultural reform revolved around efficiency of farming operations and the quality of agricultural products. In North Carolina, the need for agricultural reform arose due to the use of a primitive system of agriculture. The emphasis of agriculture in the state was on the production of a great variety of subsistence crops, rather than large-scale with an emphasis on producing a "cash" crop such as tobacco (Cathey, 1966). This meant that a surplus produced low prices at the local market and, since transportation costs were high and transportation of the surplus would be costly, the surpluses of crops often were disposed of by barter. This resulted in low cash flow and no incentive for increasing crop production or better agricultural methods (Cathey, 1966).

By 1821, farming, as described by Charles Fisher to the Rowan County Agricultural Society, was "*... a course of agriculture that takes all from the earth, and returns nothing to it: We go on, year after year, tilling our field, without any pains to return to the earth the strength that each crops takes from it. We completely exhaust our soil by an unvaried succession of crops, and, when it can produce no longer, we turn it out into the fields, let it wash into gullies, and grow up with pines and broom sedge, that never failing symptom of exhaustion. This is the common fate of our fields; the system that is defacing our country, and ruing our lands.*" (Quoted in *American Farmer*, III (August 1821), 169 and extracted from Cathey, 1956, 44, original spelling unchanged).

However, the agricultural reform movement in North Carolina, as well as the rest of the young nation, floundered in the 1820's and did not revive until the late 1830's (Cathey, 1956). This revival was facilitated in North Carolina by improved transportation, communication, and marketing facilities, as well as the prominence of certain individuals such as Edmund Ruffin, a planter and agricultural reformer (Cathey, 1956).

The growing interest in the nation for the improvement of farming practices also resulted in the development and publication of journals (magazines) that were devoted almost exclusively to agricultural topics. These agricultural journals drew attention to improvements in farming implements and encouraged their general use. Diagrams of new plows, carts, reapers, cultivators, horse-powered machines, and marl diggers accompanied enthusiastic endorsements of the editors (Demaree, 1941).

However, the editors also caused a disservice in their hasty endorsements for new and untested implements, as well as new farming practices or techniques[5] (Cathey, 1956).

Unfortunately, many of these journals had insufficient backing, since they were supported primarily through subscriptions, and were short-lived. One of the causes may have been that magazines had to pay a higher rate than newspapers and received no free postage considerations (Smith, 1977). From 1838 to 1860, of the seven journals specifically devoted to agricultural issues and reform, none lasted longer than four and one-half years, and by 1860 only two were in publication (Wallace, 1959; Cathey, 1966).

GETTING OUT THE WORD: THE *MINERS' & FARMERS' JOURNAL*

By 1830, the population in Mecklenburg County was 20,073 people and the town of Charlotte had more than 700 inhabitants (Tompkins, 1904).[6] However, despite the influx of people associated with the Piedmont gold rush, the population of Mecklenburg County (and many of the surrounding counties) decreased by 30% (or more) from 1830 to the 1850's (Tompkins, 1904). In part this was related to the migration of people westward toward the hope and promise of the 'over mountain' lands west of the Appalachian Mountains. Nevertheless, those who stayed in the region were closely associated with the three major industries of the area: agriculture, mining, or support activities for the first two industries. This set the stage for a new publication that would address an area that was lacking – more information and knowledge concerning agricultural practices and gold mining techniques.

The first newspaper in Charlotte was the weekly *Catawba Journal* that was started in October of 1824 (Blythe and Brockman, 1966). But within a few years, it had left Charlotte and moved to Salisbury, North Carolina (Blythe and Brockman, 1966). Other newspapers were available in the city due to the reasonable rates offered by the post office, but no other local paper was started until 1830. On September 27th, 1830, the *Miners' & Farmers' Journal*, printed and published by H. S. Noble and T. J. (Thomas Jefferson) Holton, provided a new weekly newspaper for the city of Charlotte.

The *Miners' & Farmers' Journal* represents the first weekly North Carolina newspaper that specifically addressed mining and geology in addition to agricultural topics and techniques. This is not to say it was the first newspaper to approach these topics in this manner. The *Western Carolinian*, established in Salisbury (NC) in 1820, had published articles and stories on the early gold mining in the Piedmont, as well as a number of agricultural notices and stories. Another weekly, *The North Carolina Spectator and Western Advertiser* (Burke County), in addition to occasional agricultural topics, reported on newly patented panning and mining devices as well as to advertise them for sale (North Carolina Spectator and Western Advertiser, 19 April 1830). However, neither of these newspapers identified themselves strictly with either profession.

Outside of North Carolina, other examples were available. The 1828 (to 1832*) Miners' Journal* from Galena (Fever River), Illinois developed from the mining activity in the Mississippi Lead District while the 1825 (to 1953) *Miners' Journal* from Pottsville (Schuylkill County), Pennsylvania concentrated on the coal mining industry (Miller, 1982; Hobbs, 1989). While there were agricultural articles published occasionally in these newspapers, these newspapers focused primarily on the mining aspects of the regions.

5. These agricultural "crazes" or "manias" ranged from mulberry trees and silk production culture to enormous pigs or unusual vegetables. The "crazes" followed the usual path of wild speculative build-up, extravagant claims and intense excitement followed by disillusionment and final collapse (Demaree, 1941, 165-167).

6. Population data prior to 1850 was only reported for Mecklenburg County. In addition, the city of Charlotte was growing from its original 360 acres and designation of city versus county was not very precise. Lastly, these values often did not include the slave population or the transient gold "boomers" that flocked to this region in the late 1820's through the 1830's.

THE NEWS (AND ONLY THE NEWS)

The first article of the *Miners' & Farmers' Journal* was "*Observations on the gold region and gold miners of North Carolina*" and set the stage for the five-year span of this publication (MFJ, 27 September 1830, 1). The editors "*saw it a few months past, as an original communication in the Greensboro (NC) Patriot, and it containing something new on an engrossing subject in this section, we were induced to present it to our readers*" (MFJ, 27 September 1830, 1).

In their editorial debut, Noble and Holton requested their subscribers and readers to "*consider it a favor to receive any original communications on the subject of mining, or facts connected with the gold region, in whatever form; and no doubt such writings would be acceptable to the public*" (MFJ, 27 September 1830, 1).

Lastly, they set out some idea of how they planned to disseminate this information: "*To present a detailed account of our mining operations, cannot be expected, no farther than a summary view of the works, which we shall publish hereafter. If not soliciting too much, we should wish to be favored with regular statements of the products of each mine, or principal ones, where the operations are extensive, for publication*" (MFJ, 27 September 1830, 3).

Throughout the first edition, stories and notes related to mining ventures are scattered (Figure 2). For example, a note (from the *Southern Recorder*) entitled "*Georgia and her Gold Regions*" summarized the movement of three additional companies of U.S. troops to render protection to the Georgian mines (MFJ, 27 September 1830). Local mining news was not slighted and included a note reprinted from the Hillsborough Recorder concerning

> "*a gold mine has been discovered.... which promises to be very productive. We have seen a bar worth about one hundred dollars, which had been procured in a few days with very imperfect machinery*" (MFJ, 27 September 1830, 5).

Agricultural news included an extract from "*The American Farmer,*" as well as the market prices for cotton and other agricultural products, including mercantile items, from the Charleston (SC), Camden (NJ), and Fayetteville (NC) markets provided for the subscribers. (MFJ, 27 September 1830, 4).

The paper let no one forget it major mission. On 22 November 1830, the masthead of the *Miners' & Farmers' Journal* proclaimed:

> "*I Will Teach You To Pierce The Bowels Of The Earth And Bring Out From The Caverns Of The Mountains Metals That Will Give Strength To Our Nation And Subject All Nature To Our Use And Pleasure.*"

This quotation from Samuel Johnson (1750) was retained on every paper until 26 March 1835, about three months before the change of the paper to the *Charlotte Journal* (3 July 1835).

In the following weeks and years, the *Miners' & Farmers' Journal* headlined either agricultural or mining reports on the front page. Often placed under column headings of "Agricultural Selection," "Agricultural," "The Gold Region," "Assaying," and "Mineralogy," these selections ranged from articles reprinted from other newspapers or from journals such as the *American Journal of Science and Arts*. Local or regional information, often headlined as "communications" or "domestic intelligence" was scattered throughout the newspaper (Russo, 1980; Shaw, 1981). The sources of most of this regional and national news for the *Miners' & Farmers' Journal* were the exchange newspapers (Bretz, 1909).[7] Because of favorable federal government support, primarily free or reduced postage, the newspaper had an edge over magazines and pamphlets that had to pay a higher rate than newspapers and received no free postage considerations (Kielbowicz, 1985). The editors of the *Miners' & Farmers' Journal* understood this issue and asked for

7. *The Federal Government in the Postal Act of 1792, which provided for free postage on papers exchanged between press conductors (i.e., editors), further favored the newspapers and their development. These exchange papers were the primary source of news for all but the large and elite eastern newspapers.*

MINERS' & FARMERS' JOURNAL.

PRINTED AND PUBLISHED EVERY MONDAY, BY *NOBLE & BOLTON*—CHARLOTTE, MECKLENBURG COUNTY, NORTH-CAROLINA.

VOL. I. MONDAY, SEPTEMBER 27, 1830. NO. 1.

ASSAYING.

From the American Artist's Manual.

ASSAY or ESSAY.

The term ASSAY, in chemistry, in a general sense, implies the analysis or examination of a sample of any substance, whose chemical composition is to be ascertained; but this term is also technically restricted to the analysis of gold and silver mixtures, with the express and sole purpose of determining the proportion of noble metal to that with which it is alloyed, in any individual mass. It is only in this sense that we here

From the Rutherfordton Spectator.

SKETCHES OF A TRAVELLER.

Mr. Editor:—Having recently made an excursion through the "gold region" in the upper part of Georgia, I am induced to make a few remarks on the very flattering prospect of mineral wealth in that part of the country. The country generally presents a broken unthrifty and uninviting appearance. The land, except that lying on the small rivulets, is very poor and of course infertile. Owing to the excessive severity of the winter, the mining operations were in a good degree suspended. Still I was shewn a number of mines which were spoken of as being immensely rich. As an evidence of the richness of one of the mines I visited, I will state a fact which transpired under my immediate observation. A gentleman with whom I was in company, purchased from one of the hands, a small piece of rock weighing about 2 ounces, for which he gave one dollar. It was immediately pulverized, when by means of quick-silver there was collected 5 dwts. and 17 grs. of pure gold, which afterwards sold in Augusta for nearly five dollars. Since this extraordinary product, another piece of rock has been found on the same lot, and sold at auction for $24, which on being pulver-

MINERALOGY.

ORES OF GOLD.—CONTINUED.

Stamping, Grinding and Sifting.

By these operations the picked ores, black copper, and mixtures of metals and semi-metals are reduced into fine powder; and their surfaces being thus increased, they mix and calcine better with the common or rock salt, which is added to them; otherwise, the calcining fire and the air could not act sufficiently on the grosser particles, nor could the sulphuric and muriatic acids properly penetrate them, or a perfect desulphuration and decomposition of such substances be brought on, in which the gold and silver particles are disguised.

The Journal.

CHARLOTTE:

WEDNESDAY, NOVEMBER 16, 1831.

The Raleigh Register says a very rich deposit of gold has been discovered in the vicinity of Ransom's Bridge Post Office, and near the place where the Counties of Nash, Franklin, Warren and Halifax join each other. One piece weighing several pennyweights has been found, and smaller pieces in great number. It is said to be quite common to make $5 to the hand a day, and there are nearly twenty different places where the precious metal can be obtained in sufficient quantity to reward the search for it.

Figure 2. Collage of articles, letters and notes from *The Miners' and Farmers' Journal* displaying the variety of coverage related to the gold mining industry.

> "*The courtesy of editors of papers to whom we may send, is respectfully solicited in exchanging with us*" (MFJ, 27 September 1830, 3).

Within a year, the *Miners' & Farmers' Journal* had published variously on "Farmers' Arithmetic" extracted from the Oxford (NC) *Examiner* (11 Oct 1830), "The Gold Mines" and "Gold Region of Carroll" concerning the Cherokee (Georgia) gold mines and Indian unrest (25 Oct 1830), "The Mecklenburg Gold Mines" (01 Nov 1830), the processing of "Ores of Gold" (10 March and 17 March, 1831), the machinery of the "St. Catherine Mills" (24 March 1831), and "The Country Farmer" reports extracted from the *New York Farmer (*04 January 1832).

Although the acquisition of news and other materials is what makes the exchange of newspapers important, the other important aspect is advertisement. In the November 22, 1830 edition was the following notice:

> "*Among our exchange papers, we lately received the Williamstown (Mass.) Advocate, in which we notice the following article: A new and very good weekly newspaper, entitled the "Miners' Journal," has recently been established in Charlotte, (in the gold region,) N.C. ...... we recommend to the editors of the Journal the publication of a particular account of the mining processes, together with the natural and geological features of the surrounding country. The geological part would be extremely interesting to individuals in this part of the country*" (MFJ, 22 November 1830, 3).

This interchange of news articles and announcements of gold discoveries in North Carolina and throughout the southeastern United States helped foment the gold fever that changed the Southeast's economic and social landscape. In addition, it brought more people and investors to the Charlotte (and Mecklenburg County) area as well as increasing the number of people with necessary skills and background in mining practices. A good example was Jonathon Humphrey Bissell from Connecticut who became the engineer (and later part owner) of the Charlotte Mine (St. Catherine Mine) (Knapp and Glass, 1999; McConnell et al., 2005).

HOW TIMELY WAS THE NEWS: DISSEMINATION AND RELEVANCE

Although the exchange papers allowed the editors of the *Miner's and Farmers' Journal* to post reasonably timely notices of local and regional activities or events, what was the timeliness of the journal or book extracts? An examination of *American Journal of Arts and Sciences*, as well as other agricultural or scientific farming journals, finds that interval between the initial article publication and it's reprinting in the *Miner's and Farmers' Journal* ranged around 3 months. For example, the 31 March 1831 newspaper reported on the appearance of articles published in Silliman's *American Journal of Science and Arts* from the January 1831 edition (MFJ, 31 March 1831, 3). This practice continued throughout the life of the newspaper, with the editors always attempting to connect the local industries of mining or agriculture to the article or report. Often these reports were broken up and published in sections over several months. The 14 May 1831 edition reprinted the article on "*The Gold of Mexico in a rock, equivalent to that which contains the Gold of the Carolinas*" which was extracted from the *American Journal of Science and Arts* from March 1831 (MFJ, 14 May 1831, 3; Eaton, 1831). Following weeks saw the reprinting of other articles from this journal.

Another aspect related to the timeliness of the information exchange relates to the day of publication. Starting with the 10 April 1832 edition, the *Miners' and Farmers' Journal* moved the publication date from Wednesday to a Tuesday edition so as to coincide with arrival of the Northern and Southern mail and the exchange papers and journals and magazines that they brought.

For material from foreign journals or books (generally from England and Europe) the dissemination timeliness was up to a year (or longer). For example, the April 23, 1831 newspaper reported on an "*Extract from the Re-*

ports of the Essex Agricultural Society for 1830," while the 25 January 1832 newspaper reported "*on Several Modes of Amalgamation as Practiced in the Hungarian and Tyrolese Mining Districts and in South America*" reprinted from the *London Mining Review* of April 1831.

These reports and extracts covered a range of topics and provided background information, techniques, and equipment designs as well as practical advice on mining and agriculture. The *London Mining Review* extracts, such as the "*Several Modes of Amalgamation*" discussed the Tyrolean mills and use of mercury for gold extraction (MFJ, 25 January 1832, 3). The 29 February 1832 article on "*Importance of the Separation or Classification of the Ores,*" extracted also from the April 1831 *London Mining Review,* discussed the processes of reduction in the smelting of ores and gave practical advice on evaluating the quality of the ore (MFJ, 29 February 1832, 4).

IN ADDITION TO THE NEWS: ADVERTISEMENTS, NOTICES, AND LETTERS TO THE EDITOR

For every industry there are numerous support industries. For agriculture this would include the seed suppliers, machinery manufacturers, fertilizer, tools, and repair facilities. For the mining industry this would include timber and saw mills, grinding stones and mercury, picks and shovels, candles, lanterns, and rope. So, what better place to market your services or materials than the local newspaper?

From the beginning, the *Miners' & Farmers' Journal* carried notices for "*Plantation for Rent*" and "*Apprentices Wanted*" (MFJ, 27 September 1830, 4. MFJ, 15 November 1830, 4). By late 1830 these notices and advertisements started to reflect the dual emphasis of the newspaper. Notices for "*Miners. Can be supplied with ropes of all size and warranted quality, at St. Catherine's Mills*" (MFJ, 22 November 1830, 4), "*Wanted Immediately, A boy of good character and steady habits for the Goldsmith's Business exclusively*" (MFJ, 10 February 1831, 4) and "*Notice. The subscriber ... offers for sale the valuable PLANTATION .... containing 300 acres.... immediately in the Gold Region. On the premises are, an excellent Mill Seat, good Saw-mill, and Cotton Gin. Gold has been discovered in different places on this Plantation, - no particular search has been made to ascertain the extent, but from all appearances there can be no doubt that it is rich with the precious metal*" became numerous and filled the paper (MFJ, 10 February 1831, 4).

The "*Markets*" section provided prices for goods (mercantile and agricultural) sold in several ports or distribution centers. However, this information was often a week to two weeks late as a result of its extraction from the exchange papers received by the *Miners' and Farmers' Journal.* For instance, the 25 October 1830 issue had market news for 11 October 1830 for the markets in Charleston (SC), Fayetteville (NC), and Camden (NJ) as well as information on the prices for United States bank notes, South Carolina, Virginia, and Georgia notes, and bank checks on New York (MFJ, 25 October 1830, 4).

The notices also carried proposals for new mining companies, books and journals, and other, somewhat speculative, endeavors. A good example of one of the speculative endeavors was:

> "*Money! Money! Money! In abundance in Market. To Owners of gold mines, plantations, and other property. The subscriber begs leave to inform his friends and the public that he is daily visited by capitalists, whose funds are great, and who are desirous of and anxious of purchasing wholes or shares of properties – improved or unimproved – who wish to become proprieters or partners of Gold-mining companies, or would loand or invest money at reasonable interest satisfactorily secured* ....[original spelling unchanged]" (MFJ, 17 February 1831, 4).

Because of gold mining, Charlotte evolved from little more than a village during the antebellum era (1820-1860) into a regional financial center. The lure of gold started to draw in investors from the northern states as well as from overseas who had read of gold discoveries in

Mecklenburg County. Many immigrated to the Carolina Piedmont to start or work in the mines. Although gold prospecting and mining occurred as far west as present-day Cherokee County and as far east as present-day Nash and Halifax Counties, most gold was found in the ten Piedmont counties of Guilford, Randolph, Davidson, Rowan, Montgomery, Stanly, Cabarrus, Mecklenburg, Gaston, and Union (Pardee and Park, 1948).

Thus, as numerous companies formed in the region, many of the newspaper notices dealt with the incorporation of mining companies such as the Mecklenburg Gold Mining Company (04 January 1832; incorporation), the Charlotte gold mining company (25 January 1832; incorporation), and Cabarrus Gold Mining Company (28 March 1832; incorporation).

However, as gold mining moved to subsurface extraction, more specialized advertisements and notices were printed.

> "*To the Gold Miners. Stone Cutting. The subscriber would respectfully inform Gold-miners, Owners of Mills, and the public generally, that he carries on the Stone Cutting Business in all its various branches …… his stones shall be made of the best grit in the State.... also has on hand, a few Arrastras beds, made of good grit and in a superior style of workmanship....*" (MFJ, 29 June 1831, 4).

At the same time, the agricultural industry in the region was expanding with the construction of cotton gins and cotton mills. Advertisements for "*The Lincoln Cotton Manufacturing Company*" indicate that not only were they announcing their cloth goods for sale, but also their ability to supply machinery such as spindle and saw mill cranks as well as tools for their installation (MFJ, 13 July 1831, 2).

THE END OF *THE MINERS' AND FARMERS' JOURNAL*

By 1828 the focus of gold mining was shifting from North Carolina, even before the first newspaper was published by *The Miners' and Farmers' Journal*. Prospectors working southwest from the Charlotte district reported placer gold strikes in the "Cherokee Country" of northeastern Georgia near Dahlonega (Fluker, 1902; Williams, 1993). This "gold belt" ranged from two to six miles wide and paralleled the Blue Ridge Mountains along a NE - SW strike for about 150 miles. The richest deposits were found in Georgia's Lumpkin and White Counties. By 1830, over 30,000 men were reported to be working in the industry, many originally from the North Carolina gold fields (Green, 1935; Bryan, 1955; Williams, 1993). Never-the-less, in these endeavors, *The Miners' and Farmers' Journal* provided them with news, mining information, and avenues for the acquisition of equipment and the sale of their gold.

The extension of the gold rush that started in North Carolina continued as prospectors, now mainly full time gold hunters called "boomers," scoured the potential placer deposits to the south and west. The associated social and political turmoil with the Cherokee Indians and the federal and state governments that occurred during this rush presaged later rushes in the Dakota and Montana territories in the 1870s (Hines and Smith, 2002). Miners searching ever further for the elusive "mother lode" discovered the westward limit of Southern placer deposits in 1831 on Hog Mountain in Alabama's Chilton County (MFJ, 25 May 1831; Adams, 1930; Russell, 1957; Big Ten, Inc., 1963; Thorndale and Dollarhide, 1987; Dean, 1991). The northern limit was reached in 1849 at Samuel Ellicott's farm near Brookville, Montgomery County, Maryland (Campbell, 1882; Green, 1937; Kuff, 1983).[8]

The 19 June 1835 issue of the *Miners' and Farmers' Journal* is the last known edition. On 03 July 1835 the *Charlotte Journal* took its place with a new managing editor (R. H.

8. *Although the Montgomery County gold placers and mines north of Washington D.C. are the most commonly recognized in the search for the northern limit of gold related to the Carolina terrane, a number of placer deposits (and gold finds) have been reported near the Maryland-Pennsylvania state border (i.e., Hayes mine and the Macon gold placer northeast of Baltimore).*

Madra), although it still appears to have been owned by T. J. Holton as publisher proprietor (FUMC, 2012). But, more importantly, the direction of the newspaper had changed. In his first editorial, R. H. Madra spent two-thirds of it espousing the Whig Party political stance of the newspaper, primarily as the agent for Hugh I. White and against Martin Van Buren (Charlotte Journal, 03 July 1835, 3). From the early 1830's to 1856, the Whig Party was formed to oppose the policies of President Andrew Jackson and the Democratic Party he had founded. The Whig Party in North Carolina established dozens of newspapers across the state to spread their message of order and economic progress, following the lead of the most prominent Whig newspaper editor, Horace Greeley of the *New York Tribune*. Most of these editors were from northern states and had moved to North Carolina where their influence allowed North Carolina Whigs to advocate policies similar to the national party's.

However, with respect to the *Miners' and Farmers' Journal* newspaper's emphasis on agriculture and mining activity in the region, the new managing editors' closing paragraphs dealt the death knell to this direction.

> "*As to State and Neighborhood concerns, the Charlotte Journal will continue to advocate all measures calculated to advance the prosperity and honor of North Carolina, and especially this portion of it. A due proportion of the paper will, as usual, be devoted to Religious, Commercial, Moral, Literary, other useful subjects, together with the passing News of the Day, both domestic and foreign*" (Charlotte Journal, 03 July 1835, 3).

CONCLUSIONS

The *Miners' and Farmers' Journal* was an important venue in the development and expansion of the North Carolina gold rush and provided important mineralogical and geological background information as well as mining procedures and techniques used in similar mining regions. It was also an important communication venue for the advertisement and sale of materials necessary for the mining industry. Although it could not provide the practical experience or engineering expertise a successful gold mine needed, it did inform the potential investor, the entrepreneur, and the farmer-turned-miner the necessity of securing men with these skills in order to maximize their profits. The *Miners' and Farmers' Journal* showed how a diversified weekly newspaper could have an important influence on the development of the economy of the region both in agriculture and mining. However, by 1834, the shift in active gold mining to the Dahlonega region in Georgia, together with increasing political fervor of Whig Party politics had started to change the focus of the newspaper from promoting local industries to the impending regional and presidential elections.

REFERENCES CITED

Adams, G. I. Gold Deposits in Alabama (Montgomery: Alabama Geological Survey, 1930), Bulletin 40, 91 p.

Ayres, Stephen, A Description of the Region in North Carolina Where Gold Has Been Found, Medical Repository, 1807, 10:150.

Baatz, Simon, "Squinting at Silliman": Scientific Periodicals in the Early Scientific Republic, 1810-1833, Isis, 1991, 82:223-244.

Big Ten, Inc., Big Ten's Map of Alabama Gold, 1963.

Birdsall, Clair M., The United States Branch Mint at Charlotte, North Carolina: Its History and Coinage, (Easley: Southern Historical Press, Inc., 1988).

Blakewell, Robert, Introduction to Geology (American edition, 1829)

Blythe, LeGette and Brockman, Charles Raven, Hornet's Nest: The Story of Charlotte and Mecklenburg County (Charlotte: Heritage Printers, Inc., 1961).

Bretz, J. P., Some aspects of postal expansion into the West. Annual Report of the American Historical Association, 1909 (Washington: 1911), 141-149.

Bryan, T. Conn, The Gold Rush in Georgia, The Georgia Review, 1955, IX: 398-404.

Campbell, J.L., The Virginia Gold Belt Near the Virginia and Allegheny Railroad, Engineering and Mining Journal, 1882, XXXIV: 135

Cathey, Cornelius Oliver, Agricultural Developments in North Carolina, 1783-1860, (Chapel Hill: University of North Carolina Press, 1956).

Cathey, Cornelius O., Agriculture in North Carolina Before the Civil War, (Raleigh: State Department of Archives and History, 1966). The Charlotte Journal, 03 July 1835, vol. 5 (no. 248), 3.

Dean, Lewis S., Golden Harvest of the Piedmont, Alabama Heritage, 1991 (Summer) 21:21-29

Demaree, Albert Lowther, The American Agricultural Press 1819-1860 (New York: Columbia University Press, 1941)

Eaton, Amos, The God of Mexico in a rock, equivalent to that which contains the Gold of the Carolinas, American Journal of Science and Arts, vol. 19 (no.2), March 1831

Elliott, Robert N. Jr., James Davis and the Beginning of the Newspaper in North Carolina, North Carolina Historical Review, 1965, 42(1): 1-20.

First United Methodist Church (Charlotte, NC) archives (FUMC) last accessed 2012. [www.archive.org/stream/firstunitedmetho00mcew/firstmetho00mcew_djvu.txt]

Fluker, W. H., Gold Mining in McDuffie County, Georgia, Engineering and Mining Journal, 1902, LXXIII (May 24): 725-26

Fulton, John F. and Thomson, Elizabeth H., Benjamin Silliman (1779-1864): Pathfinder in American Science (New York: Henry Schuman, 1947)

Glass, Brent David, King Midas and Old Rip: The Gold Hill Mining District of North Carolina, Ph.D. Diss., University of North Carolina at Chapel Hill, 1980

Green, Constance M., Eli Whitney and the Birth of American Technology. Reading, MA: Addison Wesley Educational Publishers, 1965.

Green, Fletcher Melvin, Gold Mining: A Forgotten Industry in Antebellum North Carolina, North Carolina Historical Review, 1935, 14:11

Green, Fletcher M., Gold Mining in Antebellum Virginia, Virginia Magazine of History and Biography, 1937, XLV(3): 227-35, 357-66

Hardy, William, The Miners Guide: Or, Compleat Miner (Sheffield, 1748; later Birmingham, 1762).

Hazen, Margaret H. and Hazen, Robert M., Wealth Inexhaustible: A History of America's Mineral Industries to 1850, Van Nostrand Reinhold Company, Inc., New York, 1985

Hines, Elizabeth and Smith, Michael S., (2002) Gold Is Where You Find It: Placer Mining in North Carolina, 1799-1849. Journal of Earth Sciences History, 21 (2), 119-149.

Hines, Elizabeth and Smith, Michael S., (2006) The Rush Started Here II: Hard Rock Gold Mining in North Carolina, 1825-1864. Journal of Earth Sciences History, 25 (1), 37-74.

Hobbs, Herwood E., (1989). 125 Years of Journalism: The Story of the Miner's Journal. Publications of the Historical Society of Schuylkill County, v. 9, no. 1, 24-37.

Hoover, Herbert C. and Hoover, Lou, H. (translators), Agricola's De Re Metallica (Dover Publications, 1950)

Johnson, Samuel, Essay, The Rambler, no. 33, 10 July 1750 (Tuesday)

Kielbowicz, R., Speeding the news by postal express, 1825-1861: The public policy of privileges for the press. Social Science Journal, 1985, 22, 49-63

Knapp, Richard F., Gold Promise in the Piedmont: The Story of John Reed's Mine (Raleigh: Division of Archives and History, 1999, revised ed.)

Knapp, Richard F. and Glass, Brent D., Gold Mining in North Carolina: A Bicentennial History (Raleigh: Division of Archives and History, 1999)

Kuff, K. R., Gold in Maryland (Baltimore: Maryland Geological Survey, pamphlet, 1983).

Maclure, William, Observations on the Geology of the United States of America, explanatory of a Geological Map. (In) Transactions of the American Philosophical Society, Held at Philadelphia, for promoting Useful Knowledge. Volume VI. (Philadelphia: C. and A. Conrad and Co., Jane Aitken, Printer. 1809). [http://www.davidrumsey.com/maps2126.html]

Maclure, William, Observations on the Geology of the United States of America (Munchen: Werner Fritsch, 1966; reprint of the 1817 edition).

McConnell, Karen M., Dyer, Janet S., and Williams, Ann (eds.), A Life in Antebellum Charlotte: The Private Journal of Sarah F. Davidson, 1837 (Charleston: History Press, 2005).

McFarland, Daniel Miles, North Carolina Newspapers, Editors and Journalistic Politics, 1815-1835, North Carolina Historical Review, 1953, 30(3): 376-414.

The Mail (Philadelphia, PA; December 15, 1803)

Maryland Gazette (Annapolis, MD; December 22, 1803)

The Medical Repository (Charleston, SC), 1804, 7:307, "Native Gold Discovered in North Carolina."

The Medical Repository (Charleston, SC), 1805, 8:439-440, "More Gold Picked Up In North Carolina."

The Medical Repository of Original Essays and Intelligence, Relative to Physic, Surgery, Chemistry, and Natural History (New York City, NY; Nov 1803-Jan 1804. Vol. 1, pp. 23 [unnumbered]).

Miller, Terry J., Galena's Century Milestone (Galena: Florence Bales Publisher, 1982).

Miners' and Farmers' Journal, 27 September 1830, vol. I (no.1), 1 "Observations on the gold region and gold mines of North Carolina."

Miners' and Farmers' Journal, 11 October 1830, vol. 1 (no. 3), 4.

Miners' and Farmers' Journal, 25 October 1830, vol. 1 (no. 5), 4.

Miner's and Farmers' Journal, 01 November 1830, vol. 1 (no. 6), 4, "Mecklenburg Gold Mines."

Miners' and Farmers' Journal, 15 November 1830, vol. 1 (no. 8), 4.

Miners' and Farmers' Journal, 22 November 1830, vol. 1 (no. 9), 1, 3.

Miner's and Farmers' Journal, 27 December 1830, vol. 1 (no. 14), 4.

Miners' and Farmers' Journal, 10 February 1831, vol. 1 (no. 21), 4.

Miners' and Farmers' Journal, 17 February 1831, vol. 1 (no. 22), 4.

Miners' and Farmers' Journal, 24 March 1831, vol. 1 (no. 26), 4.

Miners' and Farmers' Journal, 31 March 1831, vol. 1 (no. 27), 3.

Miners' and Farmers' Journal, 23 April 1831, vol. 1 (no. 30), 3, "Extract from the Reports of the Essex Agricultural Society for 1830."

Miners' and Farmers' Journal, 14 May 1831, vol. 1 (no. 33), 3, "Prof. Amos Eaton, The Gold of Mexico in a rock, equivalent to that which contains the Gold of the Carolinas."

Miners' and Farmers' Journal, 25 May 1831, vol. 1 (no. 33), 3, "Alabama Gold."

Miners' and Farmers' Journal, 13 July 1831, vol. 1 (no. 42), 2.

Miners' and Farmers' Journal, 04 January 1832, vol. 2 (no. 67), 2.

Miners' and Farmers' Journal, 25 January 1832, vol. 2 (no. 70), 3, "On Several Modes of Amalgamation."

Miners' and Farmers' Journal, 29 February 1832, vol. 2 (no. 75), 4, "Importance of the Separation or Classification of the Ores, and its influence on their subsequent treatment by either smelting or amalgamation."

Miners' and Farmers' Journal, 10 April 1832, vol. 2 (no. 81), 1.

Miners' and Farmers' Journal, 26 March 1835, vol. 5 (no. 234), 1.

The National Gazette and Literary Register (Philadelphia, PA), Saturday, January 14, 1826, 1.

Nerone, J. The Culture of the Press in the Early Republic: Cincinnati, 1793-1848. (New York: Garland Publishing, Inc., 1989).

The North Carolina Spectator and Western Advertiser, 19 April 1830, 32, "NOTICE TO MINERS. The subscriber claims the right of invention to the CAST IRON PLATES or SIVES (sic) used for the purpose of separating Alluvial Gold from the auriferous earth or pebbles."

Pardee, J.T. and Park, C.F. Jr., Gold Deposits of the Southeastern Piedmont, (Washington, D. C.: General Printing Office, USGS Professional Paper No. 213, 1948).

Porter, Ray, The Industrial Revolution and the Rise of the Science of Geology, (In) M. Teich and R. Young (eds.), Changing Perspectives in the History of Science: Essays in Honour of Joseph Hamilton (Holland: D. Reidel Publishing Company, 1973), 336-337.

Pryce, William, Mineralogia Cornubienis (London, 1778)

Raleigh Register (Raleigh, NC), 05 December 1803

Russell, R. A., Gold Mining In Alabama Before 1860, Alabama Review, 1957, 10, 5-14

Russo, Donald J., (1980) The origin of local news in the U. S. country press, 1840s-1870s. Journalism Monographs, 65, 1-43.

Shaw, Donald L., (1981) At the crossroads: Change and continuity in American press news 1820-1860. Journalism History, 8, 38-50.

Smith, C., The Press, Politics, and Patronage: The American Government's Use of Newspapers, 1789-1875. (Athens: University of Georgia Press, 1977).

Stem, Thad Jr., The Tar Heel Press, (Southport: North Carolina Press Association, Inc., 1973).

Stockard, Sallie Walker, The History of Guilford County, North Carolina (Knoxville, TN: Grant-Ogden Co., 1902)

Thorndale, William and Dollarhide, William, Map Guide to the U.S. Federal Censuses, 1790-1920 (Baltimore: Genealogical Publishing Co., Inc., 1987), 14-15

Tompkins, Daniel A., History of Mecklenburg County and the City of Charlotte: From 1740 to 1903. (Charlotte: Observer Printing House, 1904).

von Humboldt, Alexander, Selections, (London, 1827).

Wallace, Wesley H. (1959) North Carolina's agricultural journals, 1838-1861: A crusading press. North Carolina Historical Review, 36 (3), 275-306.

Watson, Helen R., (1963) A journalistic medley: Newspapers and periodicals in a small North Carolina community, 1859-1860. North Carolina Historical Review, 50 (4), 457-485.

Wilkinson, Henrietta H., The Mint Museum at Charlotte, A Brief History, (Charlotte: self published, 1973).

Williams, David, The Georgia Gold Rush: Twenty-niners, Cherokees, and Gold Fever (Columbia: University of South Carolina Press, 1993),

Young, W. P., A History of Agricultural Education in North Carolina, unpublished PhD dissertation, University of North Carolina, 1934.