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Abstract

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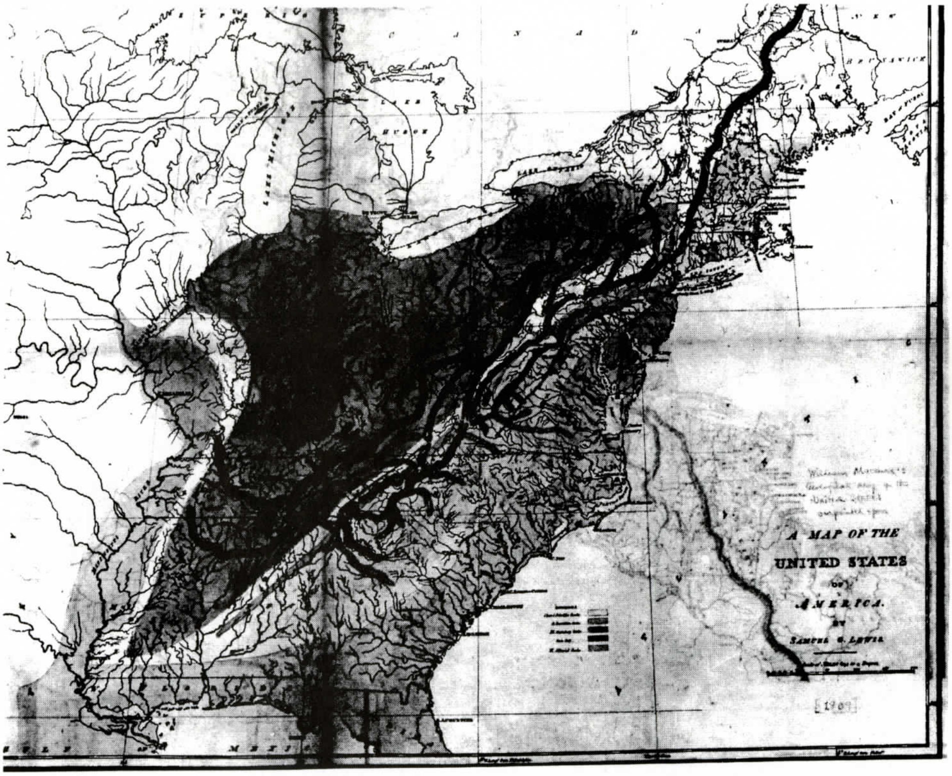
SOUTHEASTERN GEOLOGY



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EDITOR'S PAGE

Number Five

This issue of Southeastern Geology is a theme issue edited by Peter Lessing and Gregory A. Good. Below is their preface.

The eleven papers in this volume of **Southeastern Geology** were originally presented as a symposium at the southeastern section meeting of the Geological Society of America in Charleston, West Virginia, on March 30, 1998. The symposium, *"Historical Investigations of Appalachian Geology,"* represented the ideas and expertise of twelve geologists and historians. The papers included here are the expanded versions of all the original abstracts that together indicate only some of the interesting historical aspects of the Appalachians.

The early Spanish explorers of the 1500s named the mountains after the Apalachees Indians who lived in northern Florida and southern Georgia. Over the next several hundred years the name was used further north and many geologists now also include Newfoundland as part of this large mountain chain. The maximum height reaches 6,684 feet (Mt. Mitchell in North Carolina), but except for a few other peaks, nothing exceeds 5,000 feet.

The Appalachian mountains are one of the great training terrains for geologists where many new ideas have been born and many hypotheses have also died. We can still read the reports and papers of the 1700s and early 1800s authored by such individuals as Johann David Schöpf, Lewis Evans, Thomas Hutchins, Comte de Volney, William Maclure, Amos Eaton, William and Henry Rogers, and James Hall. Geological concepts related to mountain building have originated in the Appalachians such as waves of lava causing folds (the Rogers brother in 1842), geosynclines (James Hall in 1859 and James D. Dana in 1873), tangential forces illustrated by modeling (Bailey Willis in 1893), and thick- versus thin-skinned tectonics (John Rich in 1934). Several of these early geological pioneers (the Rogers brothers, Lardner Vanuxem, and James Hall) also helped formulate the stratigraphical and paleontological criteria presently used. Further, these early studies made significant contributions to the economic potential of this mountain range including coal, oil, gas, industrial minerals, and precious metals.

The eleven articles presented here cover a wide range of concepts such as early state surveys, geological mapping, the economics of coal, conflicts of personalities, and a little bit of politics. Their order of presentation in this volume is approximately chronological just as they were presented at the symposium. We hope that readers will enjoy these papers and that perhaps they will stimulate further research and historical studies of the Appalachians. The conveners would like to thank all of the authors for their contributions and we also extend our sincere thanks to Duncan Heron, Editor of **Southeastern Geology**, for making this publication possible.

Symposium Conveners
Peter Lessing
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Gregory A. Good
Department of History, West Virginia University

SOUTHEASTERN GEOLOGY
V. 38, No. 3, April 1999, p. 117-134

WILLIAM MACLURE'S WERNERIAN APPALACHIANS

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ABSTRACT

William Maclure (1763-1840), a geologist of Scottish ancestry, was also a man of many other talents and interests including educator, philanthropist, world traveler, prolific writer, patron of science, businessman, bibliophile, and social reformer. He produced the first American printing of a geological map of the United States in 1809 and followed this with four other editions identified as 1811, 1817A, 1817B, and 1817C. All were well received and reproduced by others at least 15 times, as recently as 1989. Maclure has been called "Father of American Geology," a title he rightly deserves, primarily for these maps, but also for the first cross sections through the Appalachians, many other geological articles, and substantial donations of specimens, books, and funds to many learned institutions, including the Academy of Natural Sciences of Philadelphia.

Maclure's delineation of Appalachian geology followed Werner's geognostic classification of strata using Primary, Transition, Secondary, and Alluvial, but with modifications and considerable doubt concerning their Neptunian origin. He added "Rock Salt" on his 1809 map as a line on the western edge of the Appalachians and "Old Red Sand Stone" on the 1811 map for the basins later identified as Triassic. In his later articles, Maclure noted several times that "trap" or basalt was an igneous rock and not an aqueous precipitate. He further stated that the Secondary and Transition strata are aggregates from the disintegration of the older Primitive rocks. He came to the conclusion near the end of his life that organic remains indicate "...that nature began with the most simple, and gradually proceeded to the more complicated and perfect."

INTRODUCTION

"Necessity dictates the adoption of some system, so far as respects the classification and arrangement of names the Wernerian appears to be the most suitable, First, Because it is the most perfect and extensive in its general outlines, and secondly, The nature and relative situation of the minerals in the United States, whilst they are certainly the most extensive of any field yet examined, may perhaps be found to be the most correct elucidation of the general exactitude of that theory, as respects the relative position of the different series of rocks. Without entering into any investigation of the origin or first formation of the various substances, the following nomenclature will be used. Class 1st. Primitive Rocks. Class 2d. Transition Rocks. Class 3d. Floetz or Secondary Rocks. Class 4th. Alluvial Rocks."

With these remarks, William Maclure (Figure 1) began his paper (1809a, p. 411; 1809b; see also Hazen, 1979) explaining his geological map of the United States. This hand-colored map from copperplate engravings, the first published in the United States by an American, covers an area stretching from the Atlantic Ocean to the Mississippi River at a scale of 1:4,725,500+/- (one inch equals 75 miles) and included Werner's four classes of rocks with an additional color for rock salt.

Little is known of Maclure's life, particularly prior to 1796 when he became a citizen of the United States. Much of the following information is from Doskey (1988) and Morton (identical publications of 1841, 1844a, and 1844b); Keyes (1925) and Moore (1947) contributed

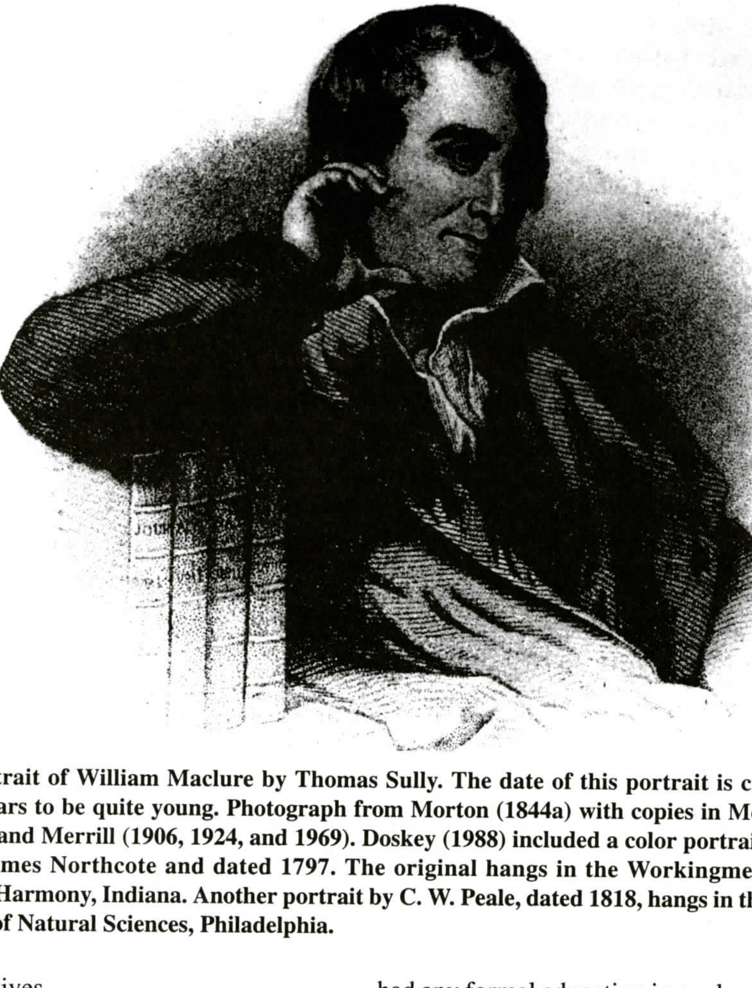

Figure 1. Portrait of William Maclure by Thomas Sully. The date of this portrait is circa 1795, as Maclure appears to be quite young. Photograph from Morton (1844a) with copies in Morton (1841), Keyes (1925), and Merrill (1906, 1924, and 1969). Doskey (1988) included a color portrait of Maclure painted by James Northcote and dated 1797. The original hangs in the Workingmen's Institute Library, New Harmony, Indiana. Another portrait by C. W. Peale, dated 1818, hangs in the Library of the Academy of Natural Sciences, Philadelphia.

other perspectives.

William Maclure was born in Ayr, Scotland, on October 27, 1763. The son of David and Ann (Kennedy) McClure, he had two brothers, Alexander and John, and three sisters, Anna, Helen, and Margaret. He was baptized James, but later always used William as his first name, even changing the spelling of his surname. He never married. His early education was under the tutorage of a Mr. Douglass who stressed classics and mathematics, thus providing Maclure with a liberal education. Morton (1844a, p. 2) has noted that Maclure often remarked that he tended to reject the teachings he had received from private tutors and schools and favored "...the simpler and more attractive truths of natural history." Biographers do not believe Maclure had any formal education in geology or even attended any institution of higher learning. In 1782, at the age of 19, he visited the United States and soon after returned to London as a partner of Miller, Hart, and Company, London. During his 14 years of employment, he amassed a small fortune which was to sustain him very comfortably. His employment with Miller, Hart, and Company involved extensive travel in Europe and America exporting textiles, hardware, and domestic utensils. He again visited the United States in 1796 to clarify some unsettled business of the parent firm and successfully earned citizenship with an established residence in Philadelphia.

Maclure essentially retired in the late 1790s and began what might be considered an extended European holiday. "I adopted rock-hunting in place of deer or partridge hunting considering mineralogy and geology as the sciences most applicable to useful practical purposes" (Doskey, 1988, p. xix). He visited most of the countries of Europe over the next 25 years. To some, such as England, France, and Spain, he traveled many times and returned occasionally to the United States. He even took the time to visit and study the geology of the Caribbean (Maclure, 1817b, 1832b).

During his European travels, Maclure examined the geology and shipped hundreds of cases of specimens to friends in other countries including the United States (Owen, 1840). He visited Freiberg in 1805, but whether or not he met with Abraham Gottob Werner is unknown. Maclure also toured various establishments concerned with new educational systems and industrial complexes such as printing houses, coal and oil manufacturers, steam-driven presses, and cotton and calico producers. Many of his nongeological writings discuss these topics, particularly educational systems. He became friends with some famous individuals during these trips in Europe and America including Thomas Jefferson, James Monroe, Napoleon Bonaparte, Tsar Alexander I, and scientists Benjamin Silliman, René Haüy, Robert Jameson, Richard Owen, Compte de Volney, and Pierre Cordier. In fact, it was Thomas Jefferson who sent Maclure to France in 1803 as a commissioner to settle claims of American sea captains and ship owners against the government of France for spoliation during the French Revolution. He became engrossed with geology and returned to America in 1808 to initiate his great work -a geological survey of the United States. Prior to 1808, Maclure had traveled extensively in the U.S., primarily during 1796 to 1799, collecting geological information. This material, combined with his 1808-1809 field work, formed the basis of his first map (Maclure, 1809a).

Although Maclure's time in the United States was limited, he did spend part of 1816 and 1817 in the field and in Philadelphia preparing his revised map. During this time, he became more involved with members of the Academy of Natural Sciences of Philadelphia (he had become a member when it was founded in 1812). He encouraged the Academy to issue publications, which it began in 1817, the year Maclure was elected the Academy's President. He held that post until his death in 1840. During his tenure, he gave the Academy thousands of specimens and about $1,000 each year. Maclure was also President of the American Geological Society from 1819 until 1828 when it ceased to exist, he was elected a Foreign Member of the Geological Society of London in 1823, and in 1799 was elected a member of the American Philosophical Society.

Maclure's interest in progressive education stemmed from visits to various schools in Europe (Maclure, 1824d), principally the Pestalozzi system taught by Mr. Phiquepal d'Arusemont and Madame Marie D. Fretageot in Paris (see Elliott, 1994), and Robert Owen's progressive school in Edinburgh. Eventually, Phiquepal and Fretageot set up schools in the United States with financial support from Maclure (1826a). Maclure was also happy to hear that Robert Owen would purchase land at New Harmony, Indiana, from the Rappites to promote his socialist experiment in communal living called the Owenites (Maclure, 1825a, 1825c, 1826b, 1826c). Maclure was persuaded to join the community in 1825 and in December of that year, a party of 40 boarded the 85-foot-long keelboat "Philanthropist" at Pittsburgh for the trip down the Ohio River to New Harmony. The so-called "boatload of knowledge" (Pitzer, 1989) was soon stuck in the ice and many members abandoned ship and continued overland; eventually all reached New Harmony in January 1826. Maclure had previously visited New Harmony in 1816 as part of a geological traverse (original notebook by Maclure, volume 21). While in New Harmony, Maclure became querulous and somewhat confused and forgetful, even arguing bitterly with Owen, as most people did. Robert Owen's experiment failed because of unpaid mortgages and several lawsuits. Maclure left in 1827 and moved to Mexico in 1828, primarily because of his deteriorating health. During the next 10 years, he wrote over 300 short essays covering a variety of subjects; these were published in three volumes at New Harmony (Maclure, 1838b). While trying to visit New Harmony in 1840, he died in the little town of San Angel, Mexico, on March 23 and is buried in the English cemetery in Mexico City. After Maclure's death, Benjamin Silliman of Yale College bestowed upon him the title "Father of American Geology."

WERNER'S GEOGNOSY AND MACLURE'S NOMENCLATURE

Abraham Gottlob Werner (1749-1817) returned to teach at the Academy of Mines at Freiberg in Saxony (Germany) when he was only 25 years old after attending the Academy as an undergraduate. He was a popular teacher and attracted many students from all over Europe. He did not like to write, however, avoiding the task very successfully, so most of what we know about his geological work and ideas comes from his students, mainly Jameson (1805, 1808, 1811).

Essentially, Werner set up a two-part system that he called "geognosy." The first part was a classification of rocks, designated from oldest to youngest as Primitive (Urgebirge), Transition (Übergangsgebirge), Secondary (Flötzgebirge), and Alluvial (Aüfgeschwemmte Gebirge). He believed this system was applicable worldwide. He later was forced to add a fifth class, Volcanic (Vulkanische Gebirge), composed of "true volcanic" and "pseudo-volcanic," the former believed to be caused by the combustion of coal but both were considered unimportant in his worldwide system. Each of the five classes actually contained many formations of various rock types (see Greene, 1984; Branagan, 1998).

The second part, Werner's Neptunian school of thought, concerned the origin of these "universal formations" that enveloped the entire globe as precipitates and clastic depositions from a primordial ocean. Werner's scheme, although certainly not original, considered that the formations of the Primitive were precipitated first because they occupied the highest elevations. Later, as the primordial ocean was lowered, the Transition formations were precipitated with some minor clastic deposition. The Transition rocks rested on the Primitive, were inclined, and occupied a lower elevation. The ocean continued to shrink and the Secondary was precipitated as essentially flat-lying strata, but with more clastic deposition. Finally the Alluvial was deposited, primarily as clastic material. His world history of rocks was almost entirely in his mind and few of his ideas could be justified in the field, even around Saxony.

Werner's geognosy was somewhat usable and predictive for many years until other geologists, including his own students, began to look at field evidence in many areas of the world and found that it did not fit the classification or the origin vigorously defended by the Neptunists. Many of the problems, conflicts, and total contradictions have been elaborated by Adams (1954) and Geike (1962), such as what happened to all the water in the primordial ocean as it shrank, and how did all the minerals, primarily from the Primitive, get into solution in the first place? However, as Jameson noted in 1808 (Geike, 1962, p. 219), "When you meet with an insuperable difficulty, look it steadfastly in the face - and pass on." We now know that the structure of the Transition is controlled by tectonics, not the time of deposition. We also know that the crystalline rocks of the Primitive are not necessarily the oldest rocks, but can also be quite young intrusives and metamorphics, even younger than some of the Secondary. But Werner's geognosy was developed over 200 years ago when the science of geology was in its infancy and it should be judged in the context of its own time.

Maclure proposed a two-part classification of rocks in 1805 (Doskey, 1988, p. 755) and again in 1818 (Maclure, 1818b, 1832a, 1838a), but actually adopted the Wernerian classification from Jameson (1808), except for the volcanic rocks from active volcanoes which he failed to find in the eastern United States (Table 1). On all of Maclure's maps and in his papers the strata are labeled Primitive, Transition, Secondary, and Alluvial. However, he also included Rock Salt and Old Red Sandstone on several editions. His Primitive was composed of granite, gneiss, slate, granular limestone, and other crystalline rocks; it contained no fossils. On his maps, this is the present Precambrian of the Piedmont, Blue Ridge, and Adirondacks; he also included most of New England. The Transition comprised strata resting on the Primitive, had a significant dip, contained numerous fossils, and included limestone, trap, graywacke, flinty slate, anthracite coal, and gypsum. Maclure's maps show this as essentially equivalent to the folded Valley and Ridge Province. There are also several "fingers" of Transition within the Primitive. Secondary strata were flat-lying rocks consisting of sandstone, limestone, gypsum, salt, trap, bituminous coal, and abundant fossils. The Secondary is colored on all his maps as everything west of the folded Valley and Ridge Province. The Triassic basins are labeled Secondary on Maclure's 1809 map, but as Old Red Sandstone on later editions. The Alluvial was the youngest class, formed from preexisting rocks and occurring both in mountain valleys and low-lying lands. It contained peat, sand and gravel, loam, bog iron ore, calc tuff, and calc sinter. Maclure locates Alluvial along the eastern seaboard, across Florida, and up the Mississippi Valley, equivalent to the present-day Coastal Plain. He later added Alluvium to all of Long Island, based on additional data from Mitchill (1811).

Maclure believed in the rock classification of Werner (as shown in the quote used in the introduction) and noted in letters to Benjamin Silliman from Paris, "In some of the memoirs of geology there is a little inaccuracy in the names of the rocks which should be as strictly scientific as possible; the Wernerian nomenclature is still the best understood" (1821, p. 363). And again, "Perhaps the most useful classification, in the present state of the science, would be to retain Werner's five classes as being well defined...and to make some subdivisions in each class, without deranging the system already best known, or the ideas of those who follow it" (1825b, p. 254).

Werner's classification of rocks was further elaborated by Maclure in three different situations and illustrated that fossils and composition had little to offer, but that the dip and structure were critical to differentiate the Transition from the Secondary.

"They have, in common with all the transition rocks, a regular and uniform dip from the horizon, from 10 to 40 degrees; and sometimes more. This is perhaps the strongest mark of distinction which separates them from the secondary, which are horizontal, or follow the inequalities of the surface on which they were deposited" (1819, p. 212).

In Pennsylvania, Zachariah Cist discussed the anthracite coal at Wilks-Barre and Maclure commented on this report.

"In describing the accompanying rocks, he gives a very correct mineralogical description, but that is not sufficient to be comprehended by the European geologist; for all the aggregates, secondary or transition, have pretty much the same mineralogical structure; but the position and relative situation decides the class and fixes the nature of the rock. The whole region about Wilkesbarre belongs to the Transition class, and all the slate he describes with spots of mica, must be gray wacke slate" (1824b, p. 260).

Maclure further commented on the work of François Sulpice Beudant, a French geologist working in Hungary.

"M. Beudant takes no notice of the regular dip of the transition rocks which I have always been led to consider as the most evident and distinguishing line of separation between them, and the secondary or horizontal class of rocks" (1824a, p. 259).

Thus, it is evident from these and other writings by Maclure that the structural configuration was of primary importance in separating the Secondary from the Transition. He followed Werner's ideas that the steeply-dipping Transition was the result of deposition upon the very irregular contours of the Primitive or they may even have slipped down steep slopes (Adams, 1954, p. 223).

MACLURE'S TRAVELS AND MAPS OF THE UNITED STATES

Morton (1844a, p. 3) rather dramatically eulogized Maclure's field work, but one gets the feeling that this paragraph is somewhat excessive, considering that Maclure was a wealthy individual who could well afford a few amenities.

"He went forth with his hammer in his hand

Table 1. Wernerian strata used by Maclure (1809a) for his geology of the United States.

Class 1st. Primitive Rocks	
1. Granite	8. Porphyry
2. Gneiss	9. Sienite
3. Mica slate	10. Topaz-Rock
4. Clay slate	11. Quartz-Rock
5. Primitive Limestone	12. Primitive Flinty-Slate
6. Primitive Trap	13. Primitive Gypsum
7. Serpentine	14. White-Stone
Class 2d. Transition Rocks	
1. Transition Limestone	4. Transition Flinty-Slate
2. Transition Trap	5. Transition Gypsum
3. Grey Wacke	
Class 3d. Floetz or Secondary Rocks	
1. Old Red Sandstone or 1st Sandstone Formation	7. Third Floetz-Sandstone
2. First or Oldest Floetz-Limestone	8. Rock-Salt Formation
3. First or Oldest Floetz-Gypsum	9. Chalk Formation
4. 2d or Variegated Sandstone	10. Floetz-Trap Formation
5. 2d Floetz-Gypsum	11. Independent Coal Formation
6. 2d Floetz-Limestone	12. Newest Floetz-Trap Formation
Class 4th. Alluvial Rocks	
1. Peat	5. Nagel fluh (conglomerate)
2. Sand and gravel	6. Calc-tuff
3. Loam	7. Calc-sinter
4. Bog iron ore	

and his wallet on his shoulder, pursuing his researches in every direction, often amid pathless tracts and dreary solitudes, until he had crossed and recrossed the Alleghany mountains no less than fifty times. He encountered all the privations of hunger, thirst, fatigue and exposure, month after month, year after year, until his indomitable spirit had conquered every difficulty, and crowned his enterprise with success."

Actually, very little is known about Maclure's field work in the United States and even when and where he actually "...crossed and recrossed the Alleghany mountains no less than fifty times." There are only three known field notebooks concerning his travels, rock descriptions, expenses, and general itinerary in the United States, unlike his European journals edited by Doskey (1988). The original notebooks examined by the writer represent brief descriptions of his travels in New York, New England, New Jersey, and Pennsylvania. He was in the field for at least part of 1796 to 1799, 1808 to 1809, 1816 and 1817, and 1825. His delineation of the various rock units using Werner's classification should have made his field examinations relatively easy. The Primitive was crystalline, the Transition was inclined, the Secondary was relatively flat-lying, and the Alluvial was unconsolidated. Although he certainly looked at the compositions and characteristics of the numerous strata he encountered, his four mapping units probably did not present any significant problems. His more serious concerns were probably logistics as he negotiated the terrain via boat, carriage, horseback, and considerable walking.

On some of his travels, Maclure noted other phenomena such as "The large masses of granite...scattered over the secondary between Lake Erie and the Ohio [River]" and also correctly observed the complete lack of granite outcrops in the area. He goes on to speculate "...that the large pieces of floating ice from the north side might carry those blocks attached to them..." (1823, p.

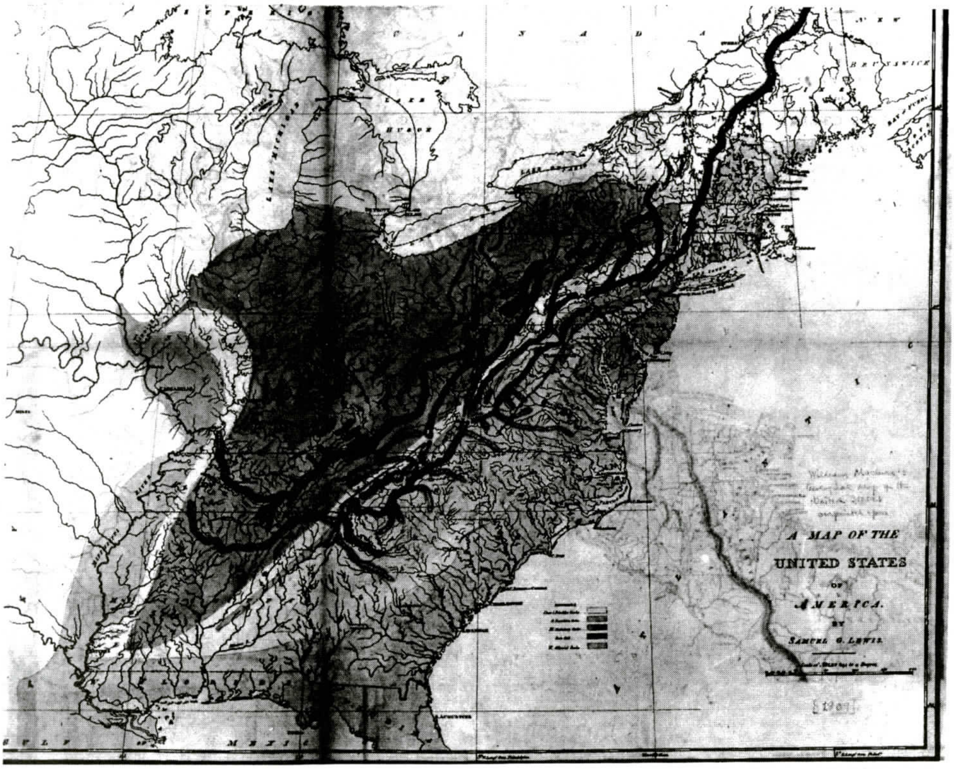

Figure 2. William Maclure's 1809 geological map of the United States. The name Samuel G. Lewis appears in the lower right and he is occasionally, and erroneously, credited as the author. Photograph from the Library of Congress.

102). Although Maclure is describing glacial erratics and a possible origin, he is not envisioning continental glaciation, but rather smaller lakes completely frozen. In the Kanawha Valley (near present Charleston, West Virginia) he observed soft, black earth that can be penetrated by a pole upwards of 15 feet deep. From this hole, "hydrogene gas" escapes and will burn for weeks when lighted (1809a, p. 246).

Much of his work was certainly his own, but he also borrowed heavily from and without acknowledgment to Evans, Mitchill, Schöpf, and especially Volney (1803). In his 1809a paper, Maclure acknowledges this help, but without specific names:

"The foregoing observations are the result of many former excursions in the United States, and a knowledge lately acquired by crossing the dividing line of the principal formations, in 15 or 20 different places, from the Hudson to Flint river [Georgia]; as well as from the information of intelligent men, whose situation and experience, make the nature of the place near which they live familiar to them; nor has the information that could be acquired from specimens, when the locality was accurately marked, been neglected, nor the remarks of judicious travellers."

Maclure is the author of five versions of his geological map, which have been well documented by White (1977) and also discussed by Wells (1959), King and Beikman (1974), Lessing (1989, 1996), and Nelson (in press). They are identified by White as 1809, 1811, 1817A, 1817B, and 1817C and are relatively easy to distinguish by the different base maps or geognostic coloring schemes that Maclure used. In most cases, he followed the convention of yellow for Alluvial, light blue for Secondary, pink for Transition, brown for Primitive, green for his salt and gypsum line, and dark blue for Old Red Sandstone. All scales are noted with a +/-

Figure 3. Maclure's 1811 geological map used Volney's 1803 French base map with its strange caterpillar-like lines in Canada indicated as Primary. Photograph from the University of Illinois Library.

because his base maps are not completely accurate and thus, scales vary across different parts of each map. The titles, with capital and lowercase letters, are shown exactly as they appear on the original maps.

1809 Map

A MAP OF THE UNITED STATES OF AMERICA. BY SAMUEL G. LEWIS.

The 1809 version (Figure 2) lacks a map border on the top and left, and southern Florida is cut off. Maclure's name is not on the map, but Samuel G. Lewis' name appears in the lower right as draftsman of the base. The map was printed in Philadelphia by Tanner So. (and son?) and the size is 21.5 inches wide by 17.25 inches high. The scale is 1:4,725,500+/- and it has a five-degree longitude and latitude grid with the prime meridian passing through Philadelphia. There is a five-color legend in the lower right center, called "references," but no colors were used west of the Mississippi River, in the Adirondacks, or in northern New England. Four of the colors used represent Primitive, Transition, Secondary, and Alluvial; the fifth is a greenish line just west of the Transition referred to as "Rock Salt." A wide band with no color also appears between the Transition and Secondary. The original base map was cut and this is the reason there are no borders on the top and left. Copies were published in Moxon (1843), Merrill (1906 and 1924), and Lessing (1989).

1811 Map

CARTE DES ETATS-UNIS DE L'AMÉRIQUE-NORD Pour servir aux observations géologiqueir [sic], Par W. Maclure.

Maclure used Volney's 1803 French base map for this French version (Figure 3) that was engraved by E. Collin. The size is 21.75 inches

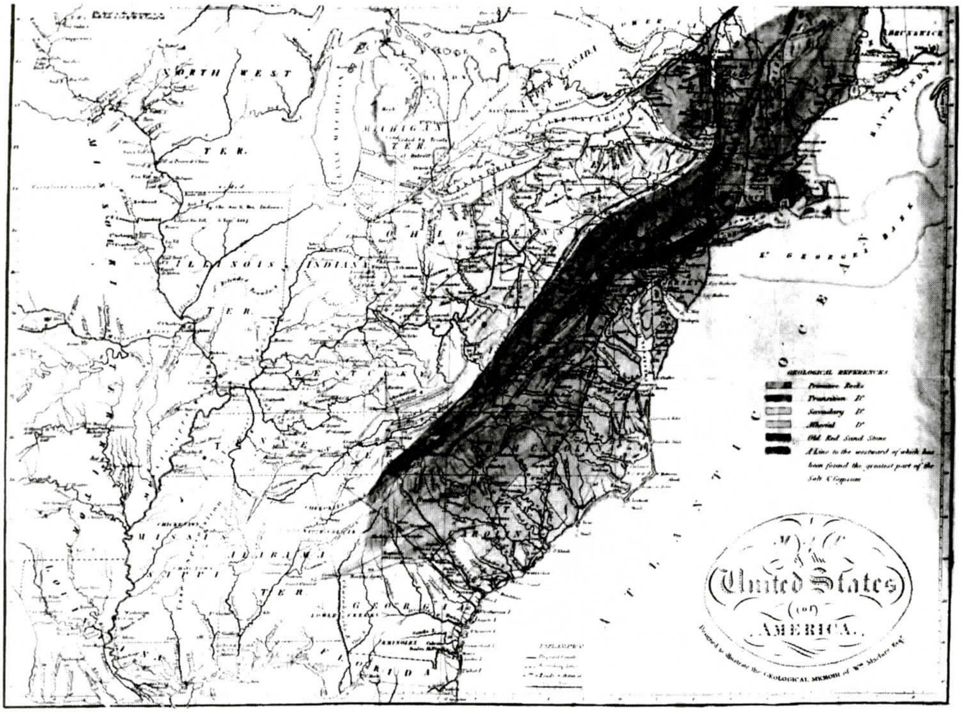

Figure 4. Maclure's 1817A geological map used in both his 1817a and 1818a publications. Photograph from the University of Illinois Library.

wide by 17.0 inches high, identical to the 1817C map below, and it has a complete map border while southern Florida is cut off. Maclure's name appears with the title at the lower right, but there are no dates in the title box as shown on Hubbard's map (1972). The scale is calculated as 1:6,206,400+/- and it has a five-degree longitude and latitude grid with the prime meridian through Paris. There is no legend, but six hand-colored units were used that are explained in the text (1811). There are no colors west of the Mississippi River. However, there are strange caterpillar-like lines in Canada colored for the Primitive. The Adirondacks, northern New England, and the area between the Transition and Secondary are uncolored except for the green salt line restricted to the southern Appalachians. The Triassic basins are labeled for the Old Red Sandstone that is shown in dark blue and only one large area is colored in Connecticut, unlike the two Triassic areas on the 1817C map. Copies were published in de Beaujour (1814), Walton (1814), Marcou (1858), and Hubbard Scientific Company (1972).

1817A Map

MAP of the United States of AMERICA. Designed to illustrate the GEOLOGICAL MEMOIR of Wm. Maclure Esqr.

The 1817A map (Figure 4) has a complete border and southern Florida is cut off. Maclure's name appears with the title in the lower right and the map was published by John Melish of Philadelphia. The map is 16.75 inches wide and 12.75 inches high. The scale is calculated as 1:6,140,000+/- and there is a five-degree longitude and latitude grid only over land. The prime meridian is Washington, D.C., along the bottom and London along the top. There is a six-color legend on the right. The Secondary is colored west of the Mississippi River for 400 miles to the edge of the map in the Missouri Territory. The Adirondacks and northern New England are now colored as Primitive and the Triassic

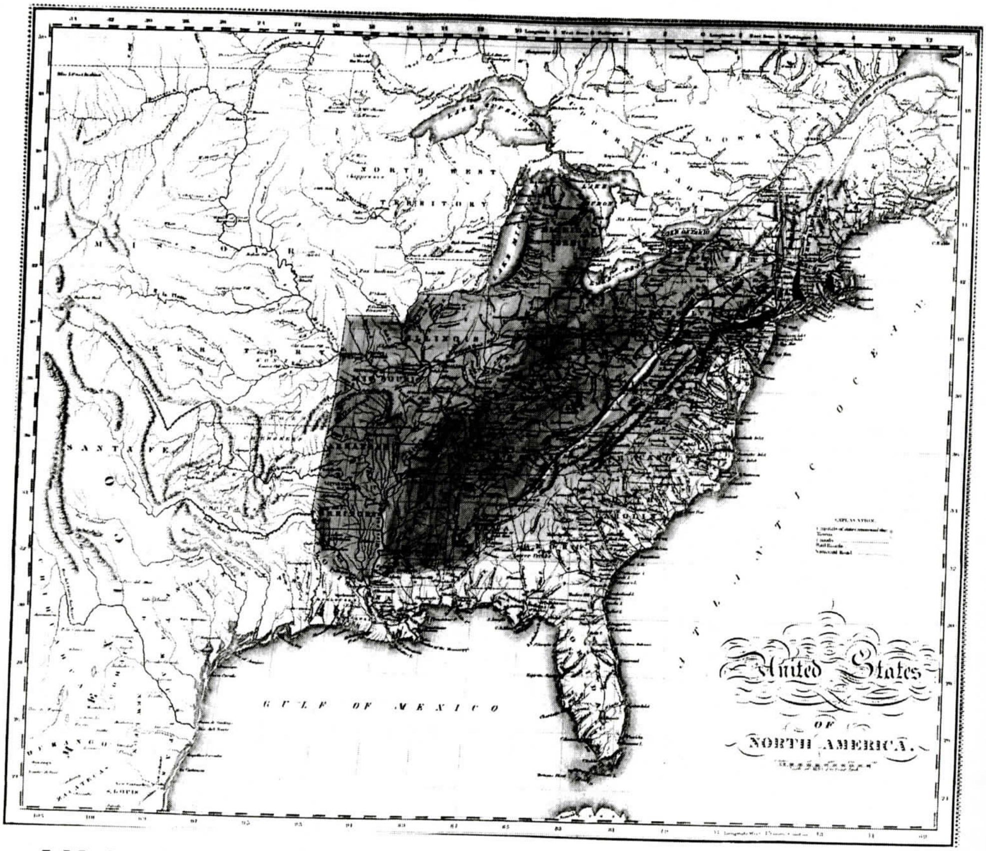

Figure 5. Maclure's 1817B geological map is the only version that includes all of Florida. Photograph from the University of Illinois Library.

basins are labeled "Old Red Sand Stone." This edition of his map is the first to show all of Long Island as Alluvial, based on Mitchill's information (1811). Also appearing on the map is the green line at the border of the Transition and Secondary now noted as "A Line to the westward of which has been found the greatest part of the Salt & Gypsum." This map was again published by Maclure a year later (1818a) at a scale of 1:5,959,100+/- with dimensions of 17.375 inches wide by 13.0 inches high, and included the five accompanying cross sections that appeared in Maclure's earlier publication of 1817a (Figure 7). Copies of the map were published in Cleaveland (1816 and 1822), Academic Reprints (1954), and Schneer (1981).

1817B Map

United States OF NORTH AMERICA.

This map, noted as 1817B (Figure 5), has a complete border and covers a much larger area west to the Rocky Mountains with all of Florida included. Maclure's name does not appear on the map, nor does the printer's. The scale is 1:7,603,200+/- and the map measures 18.75 inches wide by 16.25 inches high. It has a two-degree longitude and latitude grid with the prime meridian through London along the bottom and Washington, D.C., along the top; just the reverse of the 1817A version. There is no legend on the map, but six colors are shown on an attached paper tab and the Secondary is colored west of the Mississippi River for 400 miles. West of Lake Michigan, labeled the "North West Territory," is uncolored, unlike the

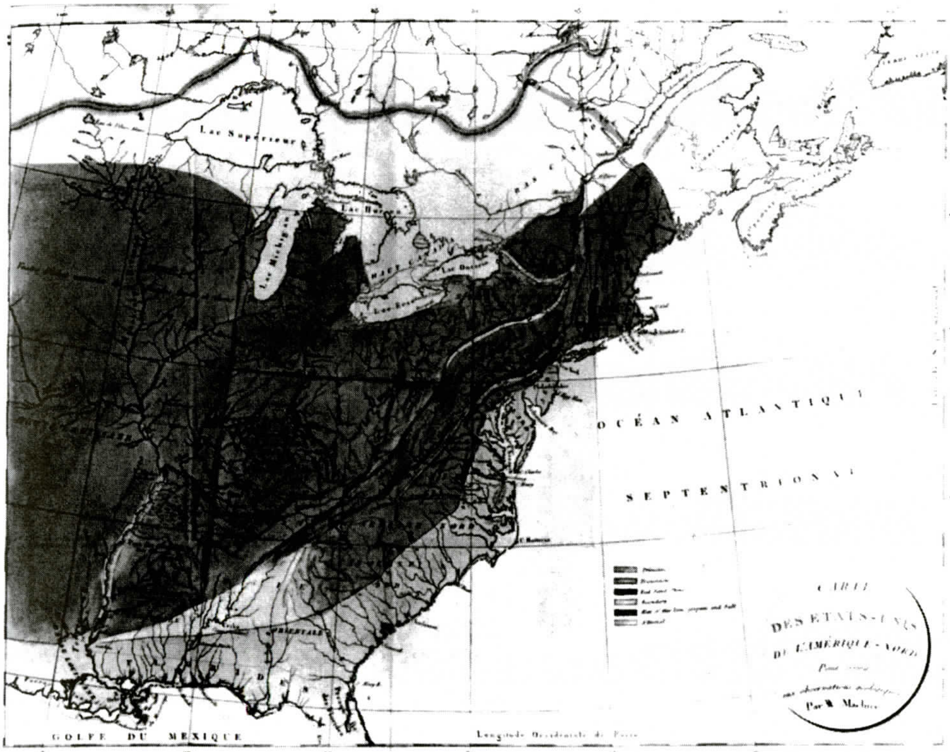

Figure 6. Maclure's 1817C geological map employs Volney's base map previously used in 1811 (Figure 3). Photograph from the University of Illinois Library.

1817A map. The Adirondacks and northern New England remain colored as Primitive and the same green salt and gypsum line that occurs on 1817A is also on this edition. Copies were published in Woodbridge (1824), Fritsch (1962 and 1966), Merrill (1969), and King and Beikman (1974).

1817C Map

CARTE DES ETATS-UNIS DE L'AMÉRIQUE-NORD, Pour servir aux observations géologiqueir [sic], Par W. Maclure.

White (1977) noted that he had seen only two copies of the 1817C version (Figure 6) published in Maclure (1817a). The author has also seen only two original copies and the base map is definitely Volney's 1803 map, measuring 21.75 inches wide by 17.0 inches high, previously used for the 1811 map and printed by E. Collin. This version has a complete border and southern Florida is cut off. There is no scale on the map, but it has been calculated by the writer as 1:6,206,400+/-. The map has a five-degree longitude and latitude grid with the prime meridian in Paris. There is now a legend in the lower right with six colors and the Secondary is colored west of the Mississippi River to the western edge of the map. The caterpillar-like lines are again colored for the Primitive, but two segments are not colored as on the 1811 map. Other differences from the 1811 map include Long Island colored as entirely Alluvial; the Adirondacks are colored for Primitive; the green salt line starts at Albany, New York; and there are six extra towns added to the base map in dark black type. No known copies have been previously reproduced.

The author is unable to determine why Maclure printed his 127-page book (1817a) using these three different geological maps noted above as 1817A, B, and C. Particularly puzzling is the introduction of the rare 1817C map, but it

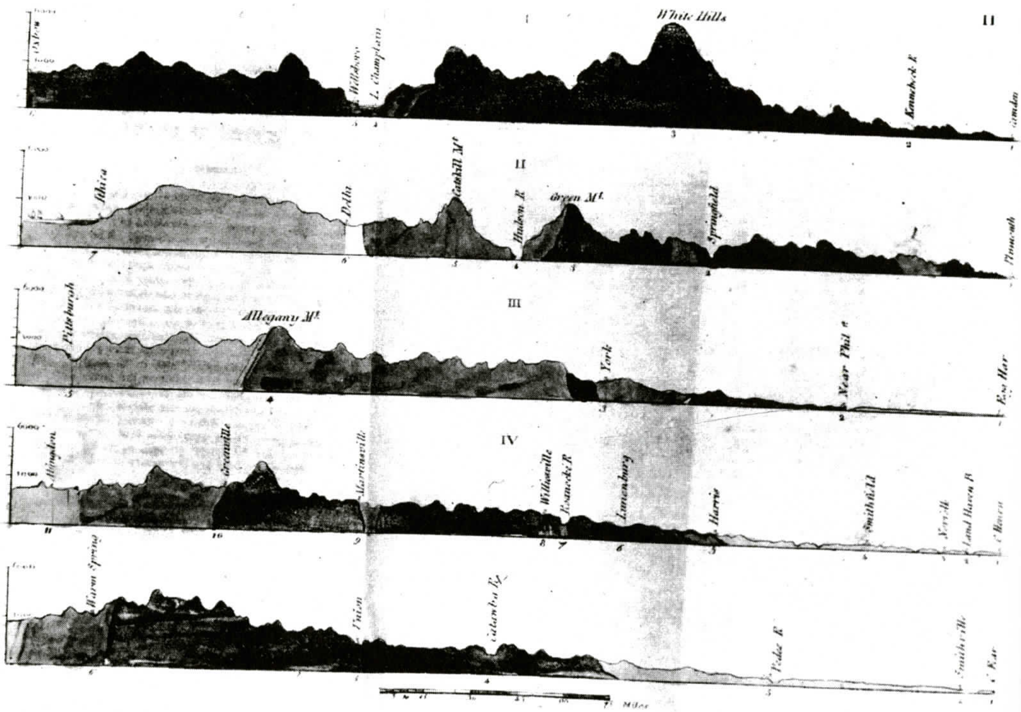

Figure 7. William Maclure's five geological cross sections were the first through the Appalachians and included in his 1817a and 1818a publications. Photograph from the University of Illinois Library.

is also intriguing that he used two other maps for this publication as well. In his 1818a publication, Maclure only used the 1817A map, so it does not appear that a depleted supply of maps was a problem. Although all editions of Maclure's 127-page book bear the date 1817, it has been suggested that the version containing the 1817B map may have been published later. This is based on the various states and territories that changed from the 1817A map to the 1817B map as suggested by White (1977). Removed for 1817B are the Illinois and Alabama territories and added to 1817B are Illinois, Alabama, Missouri, and the Arkansas Territory. This would suggest, but does not prove, the date of publication for Maclure's 1817a text containing the 1817B map was after 1821.

None of Maclure's maps follow the suggestions of Werner concerning the coloring and the use of structural symbols (Jameson, 1811). Werner's coloring scheme included using tints that came close to the actual color of the rock in question and at the base of each unit, the color would be darker. This coloring method was used by William Smith on his 1815 map of England, but why Maclure did not follow his mentor is unknown. Werner even went so far as to delineate the actual colors to be used for his Neptunian rock units. Werner also developed many symbols to illustrate the structural attitude of the various rock units. The dip of the strata was to be shown by black arrows; the shorter the length of the arrow, the steeper the dip. The length of the arrows were suggested as 1/8 inch for 80° to 60°, 1/4 inch for 60° to 40°, and 1/2 inch for 40° to 10°, but lengths could vary depending on the scale of the map. Vertical and near vertical strata were to be marked by an X, while horizontal beds were to be depicted as an X with arrowheads at each of the four ends. Maclure probably chose not to use any structural symbols because of the small scale of his maps.

Maclure has also commented on another rather famous geological map and classification. "In the year 1815...Mr. Smith...published a geological map of England, the nomenclature of which is to a great extent composed of the local or vulgar names given to rocks by the miners or quarry-men that wrought in them. He likewise endeavored...to specify each individual rock, in colors on the map - a thing very difficult, perhaps impossible to be done, with any degree of accuracy" (1824a, p. 257).

Maclure's Cross Sections

The five geological cross sections (Figure 7) appear in all known editions of Maclure's publications of 1817a and 1818a, and are discussed on two pages of text as "Explanation of Plate II." To the writer's knowledge, these are the first cross sections to be published through the Appalachians. The original is 11.50 inches wide and 8.50 inches high with a horizontal scale of 25.40 miles to the inch. The vertical scale is actually two different scales; the top half in thousands of feet for a total of 5,000 feet and the bottom half in hundreds of feet for a total of 1,000 feet. Maclure writes in the explanation, "The colours correspond with those on the map...", but this is not true for all of the editions examined by the author. The sections illustrated in Figure 7, from east to west and top to bottom, are noted by Maclure as follows:

"1. Camden in Penobscot bay, district of Maine to Oxbow, fifty miles east of Kingston on Lake Ontario.

2. Plymouth in Boston bay, Massachusetts to Cayuga lake at Ithica [sic].

3. Egg Harbour in New Jersey to Pittsburg in Pennsylvania.

4. Cape Henry, Chesapeak bay, Virginia to Abingdon, Virginia.

5. Cape Fear in North Carolina to Warm Springs, near the frontiers of Tennessee."

MACLURE'S NON-NEPTUNIAN THOUGHTS

Werner's Neptunian origin for all the rocks in the world was another matter entirely and Maclure avoided the issue in the beginning. The major concern centered on volcanic lavas and basalt, which Werner believed were all of aqueous origin. The results of volcanic activity could be seen in central France and Italy. Basalt was nearly identical in composition to recent lava and occurred parallel and crosscutting the Secondary, Transition, and Primitive. Werner did admit to "true volcanic" lava, but many of his contemporaries began to think that basalt was also of igneous origin and heat played an important role in the formation of the Earth's crust. This was a particularly important aspect that concerned two of Werner's most famous students, Leopold von Buch and Alexander von Humboldt, both of whom became Vulcanists based on their own extensive field work (see Adams, 1954, p. 209-238).

Maclure also had his doubts concerning the universal ocean that precipitated all the world's rocks. As early as 1805 while visiting the volcanic region of Auvergne, France, his traveling companion, Joseph Cabell, wrote "In some of...these [lava flows] the compact basalt was united to porous lava and this was calculated to disprove the theory of Werner as to the Neptunian origin of basalt" (Doskey, 1988, p. 15). Maclure discussed the basalt of central France in 1812 and said "Nothing is more astonishing or shows the force of system more than the attempting to prove that the basalt or lava all around this place could have any other origin than the same rocks around Vesuvius or Etna" (Doskey, p. 574).

Maclure wrote on numerous occasions of his belief in the non-Neptunian origin of basalt, such as "...this species of trap, like the currents of lava, covers indiscriminately all classes of rocks, and is one reason why I consider it as the remains of ancient lava" (1819, p. 212), and "...this hornblendish rock is the nearest to a volcanic formation, of any I have ever seen in the United States..." (1822, p. 197-198). When discussing Werner's newest Floetz Trap, he notes "...these rocks alternate with the Alluvial, Secondary, and most probably even with the Transition, and are mostly ancient Vulcanic rocks" (1825b, p. 254).

Maclure also directed his attention to the origin of Werner's other classes of Neptunian rocks, which he based on his own studies both in the United States and Europe. He was never able to observe the formation of the Primitive and, consequently, wrote very little concerning "...our entire ignorance with regard to the origin or formation of the Primitive class of rocks" (1818b, p. 264). However, based on his observations of composition and structure and by direct analogy and general "situations," he deduced (1823) that the Transition, Secondary, and Alluvial were chemical precipitates and clastic depositions. He considered the Alluvial and Secondary as "...the aggregation of the detritus or particles of more ancient rocks..." (1824c, p. 261) and that they differed primarily by age, or length of time since each had been deposited. He believed that the three major classes of rock above the Primitive were aggregates of clastic material derived from the Primitive in addition to chemical precipitates. The chemical precipitates, in the true sense of Werner, were based on Maclure's observations of fossils that he referred to as "Neptunian marks of organic remains" (1829, p. 385). Today, we would consider these rocks of marine origin.

The early 1800s were times of major changes and differing hypotheses concerning the origin of rocks as well as the origin of the entire Earth. Maclure was a part of this debate, along with Smith, Cuvier, von Buch, and many others. In 1824 Maclure also realized that "fire and water" had both shaped the Earth and he warned against adopting extreme theories: "The pendulum by the impulsion of Werner has been long kept in the extreme exaggeration of the Neptunian theory; now that Werner is dead, it is likely to swing as far in the opposite direction, and scorch our globe with fire, as unmercifully, as the Neptunians inundated it with water" (1824c, p. 262).

White (1970) wrote a short paper that specifically points out Maclure's use of Werner's names, but attached four pages written by Maclure in 1836 indicating his Uniformitarian views and ideas concerning the origin of those rocks. But Maclure went even further, expressing his Larmarkian thoughts, which centered around the fossil remains that he and others had found in various strata.

"By the organic remains found in most parts of the earth's strata, except the primitive, we have the proof of a great difference in the forms, size and nature of animals which formerly inhabited the earth and sea...no bones or remains of the human species being found in any strata which, from its relative position, can be supposed to be of an ancient date, leads to the supposition, that man was one of the last formations, which agrees with the speculation of Lamark, that nature began with the most simple, and gradually proceeded to the more complicated and perfect" (1838b, v. 3, p. 177).

The concept of organic remains changing from the simple to the complex was a fairly common interpretation, even before Maclure's time, but not in Darwin's sense of non-progressive evolution by natural selection.

CONCLUSIONS

William Maclure deserves the title "Father of American Geology," applied by Benjamin Silliman, regardless of his Wernerian terminology and his geological interpretations that resulted in errors concerning the proper delineation of the stratigraphy of the eastern United States. However, his "errors" are recognized only with the sage knowledge of retrospection. Considering that Werner's classification assumed an age relationship later to be found erroneous, Maclure correctly mapped the Primitive, Transition, Secondary, and Alluvial rocks nearly 190 years ago. He was using a rock classification that was well known at the time and, in fact, there were no other stratigraphic columns for the United States. To accomplish the geological mapping of approximately one million square miles for the first time, mostly alone and in relatively hostile territories of the new western frontier, was in itself a major achievement. True, he did not acknowledge his predecessors, but then he was not alone in that regard.

Maclure also deserves the title for his non-Neptunian ideas concerning the origin of many rocks in the eastern United States. By taking advantage of his geological observations in various European settings and applying them to the United States, he found that he could not strictly follow Werner's Neptunian doctrine. Maclure had witnessed active volcanoes in Italy, extinct volcanoes at Auvergne, France, the Giant's Causeway in Ireland, and the Salisbury Crags in Scotland. So, basalt or "trap" and its origin in this country was not a surprise, even though there were no volcanoes. Likewise, he interpreted the clastic nature of the Alluvial, Secondary, and Transition being formed from pre-existing formations, mainly the Primitive. Those rock units above the Primitive that contained fossils, or "Neptunian marks," are for the most part marine and placed severe limits on the extent that the Vulcanists could "scorch our globe with fire."

Cuvier, Brongniart, and Smith were setting the stage for stratigraphy based on fossil correlations, regardless of rock type or structure. This major historical event in stratigraphy was followed closely by the non-Wernerian nomenclature in the United States proposed by Henry Darwin Rogers and William Barton Rogers (Lessing, 1995), and finally Lardner Vanuxum's New York system that was eventually adopted. Maclure concluded his 1809a paper stating prophetically, "Should this hasty and imperfect sketch, call forth the attention of those possessed of more talents and industry for the accurate investigation of this interesting subject, the views of the writer will be fully accomplished." At the time of his death in 1840, considerably more detailed geological investigations were well underway.

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REFERENCES CITED

Academic Reprints, 1954, Observations on the geology of the United States of North America: Stanford, California, nos. 5 and 6, 91 p.(Reprint of Maclure, 1818a.)

Adams, F.D., 1954, The birth and development of the geological sciences: Dover Publications, Inc., New York, 506 p. (Reprint of 1938 volume.)

Branagan, D.F., 1998, Geological periodization, *in* Good, G.A., editor, Sciences of the Earth - An Encyclopedia: Garland Publishing, Inc., New York, p. 306-314.

Cleaveland, Parker, 1816, An elementary treatise on mineralogy and geology being an introduction to the study of those sciences, and designed for the use of pupils, for persons attending lectures on these subjects, and as a companion for travellers in the United States of America: Cummings and Hilliard, Boston, 668 p. (Includes copy of Maclure's 1817A map on a different base at 1:9,705,500+/- scale. Reprinted in 1978 by Arno Press without map.)

Cleaveland, Parker, 1822, An elementary treatise on mineralogy and geology...: second edition, Cummings and Hilliard, Boston, v. 1, 480 p., v. 2, 418 p. (Includes copy of Maclure's 1817A map on a different base at 1:8,260,700+/- scale.)

de Beaujour, L.A.F., 1814, Apercu des Etats-Unis, au commencement du XIX siècle, dupuis 1800 jusqu'au 1810 avec des tables statistiques: Paris, 274 p. (Includes copy of Maclure's 1811 map at 1:6,000,000+/- scale.)

Doskey, J.S., editor, 1988, The European journals of William Maclure: Memoirs of the American Philosophical Society, Philadelphia, Volume 171, 815 p.

Elliott, J.M., 1994, Partnership for posterity; the correspondence of William Maclure and Marie Duclos Fretageot, 1820-1833: Indiana Historical Society, Indianapolis, 1151 p.

Fritsch, Werner, 1962, Observations on the geology of the United States of America: Werner Fritsch, Müchen, Stechert-Hafner Service Agency, New York, Printed by Anton Kölher, Ulm-Donau, 127 p. (Reprint of Maclure, 1817a. Also reprinted 1966. Both reprints include copy of Maclure's 1817B map and his cross sections.)

Geike, Archibald, 1962, The founders of geology: 2nd edition, Dover Publications, Inc., New York, 486 p. (Reprint of 1905 volume.)

Greene, M.T., 1984, Geology in the nineteenth century. Changing views of a changing world: Cornell University Press, Ithaca, 324 p.

Hazen, R.M., editor, 1979, North American geology, early writings: Dowden, Hutchinson and Ross, Stroudsburg, Pennsylvania, 356 p.

Hubbard Scientific Company, 1972, Carte des Etats-Unis de l'Amérique-Nord, pour servir aux observations géologiques par W. Maclure: Northbrook, Illinois, 1:6,100,000+/- scale.

Jameson, Robert, 1805, Treatise on the external characters of minerals: University Press, Edinburgh, 32 p.

Jameson, Robert, 1808, Elements of Geognosy: Edinburgh. (Reprinted 1976 with the title, The Wernerian Theory of the Neptunian Origin of Rocks: Hafner Press, New York, 387 p.)

Jameson, Robert, 1811, On colouring geognostical maps: Memoirs of the Wernerian Natural History Society, v. 1, p. 149-161.

Keyes, C.R., 1925, William Maclure; Father of modern geology: Pan-American Geologist, v. 43, p. 81-94.

King, P.B. and Beikman, H.M., 1974, Explanatory text to accompany the geologic map of the United States: U.S. Geological Survey, Professional Paper 901, 40 p. (Includes modified copy of Maclure's 1817B map in black and white at 1:15,840,000 scale.)

Lessing, Peter, 1989, Early geological maps of West Virginia: Earth Sciences History, v. 8, p. 14-35. (Includes reduced copy of Maclure's 1809 map.)

Lessing, Peter, 1995, The Rogers-Hotchkiss geological maps of Virginia and West Virginia: Earth Sciences History, v. 14, p. 84-97.

Lessing, Peter, 1996, A catalog of West Virginia geological maps, 1752-1992: second edition, West Virginia Geological and Economic Survey, Publication C-45, 95 p.

Maclure, William, 1809a, Observations on the geology of the United States, explanatory of a geological map: American Philosophical Society Transactions, v. 6, part 2, p. 411-428. (Includes Maclure's 1809 map. Also reprinted in Hazen, 1979 without map. Copies of map in Moxon, 1843; Merrill, 1906 and 1924; Lessing, 1989; see also Maclure, 1809b.)

Maclure, William, 1809b, Observations sur la géologie des Etats-Unis, servant à expliquer une carte géologique: Journal of Physique, Chimie, et Histoire Naturelle and des Arts, v. 69, p. 204-213. (Translation of Maclure, 1809a without map)

Maclure, William, 1811, Suite des observations sur la géologie des Etats-Unis servant à l'explication de la carte ci-jointe: Journal of Physique, Chimie, et Histoire Naturelle and des Arts, v. 72, p. 137-165. (Includes Maclure's 1811 map. Copies in de Beaujour, 1814; Walton, 1814; Marcou, 1858; reprinted by Hubbard Scientific Company, 1972.)

Maclure, William, 1817a, Observations on the geology of the United States of America; with some remarks on the effect produced on the nature and fertility of soils, by the decomposition of the different classes of rocks; and an application to the fertility of every state in the Union, in reference to the accompanying geological map: Abraham Small, Philadelphia, 127 p. (Includes Maclure's 1817A, B, or C map and five geological cross sections. Reprinted by Fritsch, 1962 and 1966 with 1817B map. Copies of map in Cleaveland, 1816 and 1822; Woodbridge, 1824; Merrill, 1969; and Schneer, 1981.)

Maclure, William, 1817b, Observations on the geology of the West India Islands, from Barbados to Santa Cruz, inclusive: Philadelphia Academy of Natural Sciences Journal, v. 1, no. 1, no. 6, p. 134-149. (See also Maclure 1832b.)

Maclure, William, 1818a, Observations on the geology of the United States of North America; with remarks on the probable effects that may be produced by the decomposition of the different classes of rocks on the nature and fertility of soils; applied to the different states of the union, agreeably to the accompanying geological map: Transactions of the American Philosophical Society, New Series, v. 1, p. 1-91. (Includes Maclure's 1817A map at 1:5,959,100+/- scale and five geological cross sections. Reprinted by Academic Reprints, 1954, with black and white copy of map and cross sections.)

Maclure, William, 1818b, Essay on the formation of rocks, or an inquiry into the probable origin of their present form and structure: Philadelphia Academy of Natural Sciences Journal, v. 1, no. 2, p. 261-276; 285-310; 327-345. (Also reprinted in Hazen, 1979. See also Maclure 1832a and 1838a.)

Maclure, William, 1819, Hints on some of the outlines of geological arrangement, with particular reference to the system of Werner, in a letter to the Editor, from William Maclure, Esq. dated Paris, 22d August, 1818: American Journal of Science and Arts, v. 1, no. 3, p. 209-213. (Also reprinted in Hazen, 1979.)

Maclure, William, 1821, Remarks on the study of geology: American Journal of Science and Arts, v. 3, no. 2, p. 363.

Maclure, William, 1822, Extracts of a letter from Wm. Maclure, Esq. to the editor, dated, Madrid, Dec. 4, 1821: American Journal of Science and Arts, v. 5, no. 1, p. 197-198.

Maclure, William, 1823, Some speculative conjectures on the probable changes that may have taken place in the geology of the continent of North-America east of the Stoney Mountains; by William Maclure, Esq. President of Academy of Natural Sciences, at Philadelphia, and of the American Geological Society; Madrid, July 9, 1822: American Journal of Science and Arts, v. 6, no. 1, p. 98-102.

Maclure, William, 1824a, Observations on Mr. Beudant's geological travels in Hungary, etc. with miscellaneous remarks on coal, etc., by William Maclure, Esq., President of the American Geological Society, in a letter to the Editor, dated Madrid, Aug. 20, 1822: American Journal of Science and Arts, v. 7 no. 2, p. 256-260.

Maclure, William, 1824b, Remarks on the rocks accompanying anthracite at Wilksbarre and elsewhere, by Pres. Maclure, in a letter to the Editor dated Madrid, Aug. 20, 1822: American Journal of Science and Arts, v. 7, no. 2, p. 260-261.

Maclure, William, 1824c, Miscellaneous remarks on the systematic arrangement of rocks, and on their probable origin, especially of the Secondary, by William Maclure, President of the Am. Geol. Soc'y, in a letter dated Alicante in Spain, April 29, 1823, addressed to the Editor: American Journal of Science and Arts, v. 7, no. 2, p. 261-264.

Maclure, William, 1824d, Memoranda, extracted from a Letter to the Editor, dated Alicante, (Spain) March 6, 1824, from William Maclure, Esq. President of the American Geological Society, etc. etc.: American Journal of Science and Arts, v. 8, no. 1, p. 187-191.

Maclure, William, 1825a, Extracts of letters, addressed to the Editor, by William Maclure, Esq. President of the American Geological Society: American Journal of Science and Arts, v. 9, no. 1, p. 157-164.

Maclure, William, 1825b, Geological systems. - Geological maps. - Chatoyant feldspar. Extracts of letters to the Editor, dated at Paris January 10, and March 14, from William Maclure, P. A. N. S. and P. A. G. S.: American Journal of Science and Arts, v. 9, no. 2, p. 253-256.

Maclure, William, 1825c, Mr. Owen and his plans of education: American Journal of Science and Arts: v. 9, no. 2, p. 383-384.

Maclure, William, 1826a, An epitome of the improved Pestalozzian system of education, as practiced by William Phiquepal and Madam Fretageot, formerly in Paris, and now in Philadelphia; communicated at the request of the editor: American Journal of Science and Arts, v. 10, no. 1, p. 145-151.

Maclure, William, 1826b, Extracts of a letter from William Maclure, Esq. to the Editor, dated Paris, May 2, 1825: American Journal of Science and Arts, v. 10, no. 1, p. 165-167.

Maclure, William, 1826c, Notice of Mr. Owen's establishment, in Indiana -in a letter from William Maclure, Esq. to the editor, dated New-Harmony, March 16, 1826: American Journal of Science and Arts, v. 11, no. 1, p. 189-192.

Maclure, William, 1829, Remarks on the theory of a central heat in the earth, and on other geological theories: American Journal of Science and Arts, v. 15, no. 2, p. 384-386.

Maclure, William, 1832a, Essay on the formation of rocks, or an inquiry into the probable origin of their present form and structure: New Harmony, Indiana, printed for the author, 53 p. (See also Maclure 1818b and 1838a.)

Maclure, William, 1832b, Observations on the geology of the West India Islands, from Barbados to Santa Cruz, inclusive: New Harmony, Indiana, printed for the author, 17 p. (See also Maclure 1817b.)

Maclure, William, 1838a, Essay on the formation of rocks, or an inquiry into the probable origin of their present form and structure: Philadelphia, printed by John Wilbank, for the author, 32 p. (See also Maclure 1818b and 1832a.)

Maclure, William, 1838b, Opinions on various subjects, dedicated to the industrious producers: New Harmony, Indiana, v. 1, 1831, 483 p., v. 2, 1837, 556 p., v. 3, 1838, 320 p. (Reprinted 1969 by Burt Franklin, New York.)

Marcou, Jules, 1858, Geology of North America; with two reports on the prairies of Arkansas and Texas, the Rocky Mountains of New Mexico, and the Sierra Nevada of California, originally made for the United States Government: Zürcher and Furrer, Zurich, 144 p. (Modified color copy of Maclure's 1811 map at 1:12,000,000+/- scale.)

Merrill, G.P., 1906, Contributions to the history of American geology: Report of the U.S. National Museum (Annual Report of Smithsonian Institute for 1904), Washington, D.C., p. 189-733. (Includes copy of Maclure's 1809 map at 1:10,137,600+/- scale and his five geological cross sections from Maclure 1818a.)

Merrill, G.P., 1924, The first one hundred years of American geology: Yale University Press, New Haven, 773 p. (Includes copy of Maclure's 1809 map at 1:10,264,320+/- scale.)

Merrill, G.P., 1969, The first one hundred years of American geology: Reprint of 1924 volume by Hafner Publishing Company, New York, 773 p. (Includes copy of Maclure's 1817B map at 1:7,603,200+/- scale.)

Mitchill, S.L., 1811, An amendment proposed to the geological chart of the United States, as respects the character of the north side of Long-Island, which is shown to be alluvial and not primitive, as therein stated: American Mineralogical Journal, v. 1, part 2, p. 129-133.

Moore, J.P., 1947, William Maclure - scientist and humanitarian: Proceedings of the American Philosophical Society, v. 91, p. 234-249.

Morton, S.G., 1841, A memoir of William Maclure, Esq., late President of the Academy of Natural Sciences of Philadelphia: T.K. & P.G. Collins, Philadelphia, 37 p. (Text identical to Morton, 1844a and 1844b.)

Morton, S.G., 1844a, A memoir of William Maclure, Esq., late President of the Academy of Natural Sciences of Philadelphia: American Journal of Science and Arts, v. 47, no. 1, p. 1-17.

Morton, S.G., 1844b, A memoir of William Maclure, Esq., late President of the Academy of Natural Sciences of Philadelphia: Merihew & Thompson, Philadelphia, 33 p.

Moxon, C., editor, 1843, The geologist, being a record of investigation in geology, mineralogy, etc., for the year 1843: H. Bailliere, London, v. 2, 248 p. (Includes copy of Maclure's 1809 map at 1:19,800,000+/- scale.)

Nelson, C.M., in press, Toward a reliable geologic map of the United States, 1803-1903, *in* Carter, E.C. II, editor, Surveying the record; North American scientific exploration to 1900: American Philosophical Society, Philadelphia.

Owen, D.D., 1840, Catalogue of mineralogical and geological specimens, at New-Harmony, Indiana. Collected in various parts of Europe and America by William Maclure: New Harmony, Indiana, 16 p. (Includes descriptions of approximately 300 rocks and minerals.)

Pitzer, D.E., 1989, The original boatload of knowledge down the Ohio River; William Maclure's and Robert Owen's transfer of science and education to the midwest, 1825-1826: The Ohio Journal of Science, v. 89, no. 5, p. 128-142.

Schneer, C.J., 1981, William Maclure's geological map of the United States: Journal of Geological Education, v. 29, p. 241-245. (Includes reprint of Maclure's 1817A map at 1:7,983,360+/- scale.)

Volney, C-F.C., 1803, Tableau du climat et du sol des États-

Unis d'Amérique: Courcier, Paris, 523 p. (1968 reprint of 1804 English translation by C. B. Brown, Hafner Publishing Company, New York, 446 p.; map scale is 1:6,800,000+/-.)

Walton, William, 1814, translator, Sketch of the United States of North America, at the commencement of the nineteenth century, from 1800 to 1810: (English version of de Beaujour's article and his 1814 copy of Maclure's 1811 map at 1:6,000,000+/- scale.)

Wells, J.W., 1959, Notes on the earliest geological maps of the United States, 1756-1832: Journal of the Washington Academy of Sciences, v. 49, no. 7, p. 198-204.

White, G.W., 1970, William Maclure was a Uniformitarian and not a real Wernerian: Journal of Geological Education, v. 18, p. 127-128.

White, G.W., 1977, William Maclure's maps of the geology of the United States: Journal of the Society for the Bibliography of Natural History, v. 8, p. 266-269.

Woodbridge, W.C., 1824, A system of universal geography, ancient and modern; on the principles of comparison and classification: Oliver D. Cook and Sons, Hartford, 336 p. (Includes copy of Maclure's 1817A map at 1:60,000,000+/- scale.)

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JACOB CIST (1782-1825) AND THE PENNSYLVANIA ANTHRACITE: LOCAL EXPERTISE, SCIENTIFIC AUTHORITY, AND GLOBAL CORRELATION

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ABSTRACT

Jacob Cist was a merchant, naturalist, inventor, and postmaster of Wilkes-Barré, Luzerne County, Pennsylvania, who pioneered the use of Pennsylvania anthracite. Cist explored the geology of Luzerne County, particularly in the Wyoming Valley of the Susquehanna, eventually coming to be regarded as a local expert. His dogged advocacy of anthracite as a clean, efficient, and abundant fuel encouraged experimentation among artisans and manufacturers. Cist cultivated exchanges of books, specimens, and correspondence with prominent scientists in the United States and abroad, and his fossil plant specimens helped correlate the Pennsylvania anthracite with similar deposits in Europe. His ventures into anthracite mining, though largely unprofitable, nonetheless laid the groundwork for improvements in the infrastructure of the Eastern Seaboard, culminating in a mining and transportation boom that began shortly after his death in 1825. Cist's dual status as merchant and naturalist is an interesting and complex one. On the one hand, it is unclear exactly how Cist's local reputation as a man of science played out for him commercially. On the other hand, his involvement in commerce both helped and hurt his scientific pursuits. His commercial interest compromised his objectivity in the eyes of disinterested observers, but also motivated production of an expert level of local detail and quantification exceeding that required to answer the geological questions of the day. In addition, his commercial contacts and entrepreneurial drive facilitated the cultivation of contacts, and the exchange of specimens, geological data, and ideas.

INTRODUCTION

In 1782, Jacob Cist was born into the family of a prominent Philadelphia printer.[1] Before immigrating from St. Petersburg, Russia, Charles Cist, Jacob's father, had studied medicine at the University of Halle. In addition to his publishing business, Cist's father was also a partner in the Lehigh Coal Mining Company (Harvey, 1909). Through his father, Cist was exposed to business and the natural sciences at a young age.

Jacob Cist helped his father with the family business and attended local schools until age 12, at which time he was sent to the Moravian academy at Nazareth, Pennsylvania to prepare for a career in commerce. At Nazareth, Cist acquired a facility with French, German, Greek, and Latin, and a strong interest in geography and manufacture. The curriculum included illustration and Cist became proficient in drawing and painting, landscapes and factories being among his favorite themes. This preparation would later prove invaluable not only for Cist's commercial enterprises but for his scientific pursuits as well.

In 1797, Cist finished his formal schooling and began work in the family printing and publishing business, first in Philadelphia and then in Washington, where he managed the print

1. Charles Cist's native language was German, and his business catered extensively to Pennsylvania's large German-speaking population, in addition to printing in English and other languages (Childress, 1991).

shop and spent his spare time painting, writing, and inventing. When the nation's capital moved to Washington, Cist was awarded a clerkship in the United States Post Office.

With his father's death in 1805, Cist inherited shares in the Lehigh Coal Mine Company, which he found to be such a poorly managed concern — "a many headed monster" — that he nearly sold the stock (Powell, 1978). That initial impulse was checked by a grand vision of anthracite-driven prosperity both for himself and for Pennsylvania. In 1807 he resigned his clerkship and returned to Pennsylvania, marrying Sarah Hollenback, daughter of Matthias Hollenback, a wealthy Wilkes-Barré merchant and land baron. His father-in-law offered Cist a partnership in the family business. He accepted the offer, moved to Wilkes-Barré, and in 1808 was appointed the borough's first postmaster, an office he would hold the rest of his life (Harvey, 1909).

COMMERCIAL ACTIVITIES

Under the tutelage of his self-taught father-in-law, Cist spent two years learning the mercantile trade — driving cattle, purchasing goods, managing the store, and transporting cargo by ark down the Susquehanna River.[2] He soon assumed responsibility for all facets of Hollenback & Cist, including the management of their extensive real estate holdings, which included 48,500 acres of anthracite coal land, as well as deposits of manganese and iron ore. Cist saw anthracite as an underutilized alternative to soft coal, charcoal, and wood. Artisans in the Wyoming Valley had used it for years, mining it themselves from local outcrops, but there was prejudice against its use in cities such as Philadelphia, Baltimore, and New York. Three factors which Cist spent a lifetime trying to change stood in the way of widespread anthracite use — difficulty lighting it, an entrenched practice of using other fuels, and the unimproved means and high cost of transporting it to market.

In the early 1800's, soft coal prices hovered around thirty cents per bushel as they had since the American Revolution, half the price of anthracite. With a decided market preference for soft coal, prospects for developing a market for anthracite were bleak (Powell, 1978). Those prospects improved greatly when the War of 1812 precipitated a fuel crisis in Philadelphia (Powell, 1978). A British blockade of the Chesapeake and Delaware bays in 1813 had shut off supplies of soft coal from Virginia, tripling the price of coal and making Pennsylvania anthracite competitive at one dollar per bushel. The inflated prices sparked interest in Philadelphia and Baltimore in obtaining anthracite from the Lehigh and Wyoming valleys.[3]

In 1813, Cist and partners obtained a lease on Lehigh Coal Mine Company land near Mauch Chunk, Pennsylvania, and began mining and shipping tons of anthracite coal by wagon and river ark to Philadelphia and Baltimore. Meanwhile Cist spared no effort in increasing the demand for anthracite. To solve the problem of igniting it, he invented and patented an anthracite heating stove in 1814 (Harvey, 1909). Cist met with valley blacksmiths who already used anthracite, and hired a Wilkes-Barré journeyman who accompanied Cist's business partner Isaac Chapman from forge to forge in Philadelphia, demonstrating the technical points of anthracite use (Powell, 1978, p. 46). Cist spoke to numerous manufacturers about the advantages of anthracite — it burned longer, hotter, and more cleanly and efficiently than soft coal. He drew sketches detailing potential modifications to existing forges, nail and glass furnaces, kilns, and stills that would permit the use of anthracite. Cist solicited testimonials from anyone whose opinion he thought might hold sway with potential customers. Still, artisan practices

2. The term "ark" denoted a wooden vessel built to transport goods downriver. A boatman would reside aboard the ark during passage, dismantling it at the point of delivery and selling the lumber (Silliman in Cist, 1822)

3. Brockelman to Jacob Cist, 21 April 1812-28 March 1914 (Academy of Natural Sciences of Pennsylvania: Manuscript collection 152, hereafter Cist Collection, envelope 12, items 11-19.

proved slow to change, and demand for anthracite primarily fluctuated according to the price of soft coal, which dropped again when Madison declarėd peace in 1815, at which time Cist and his partners ceased operations (Powell, 1978).

Cist's anthracite advocacy was undaunted. In 1815 he published the results of his marketing campaign as a pamphlet on the necessity of introducing anthracite coal into general use (Cist, 1822).[4] The pamphlet contained testimonials from Philadelphia area blacksmiths, brewers, distillers, gunsmiths, and even one banker. In addition to these "practical men", Cist appealed to University of Pennsylvania chemistry professor James Woodhouse to conduct chemical analyses of the "Lehigh coal" and to experiment with it as a fuel for air furnaces, eventually receiving a positive testimonial from him.[5] The pamphlet was distributed throughout Philadelphia and was reprinted in local newspapers.

JACOB CIST AND THE GEOLOGICAL COMMUNITY

As much for enjoyment as for commercial interest, Cist explored the geology of northeastern Pennsylvania with fellow geology enthusiasts such as judge John B. Gibson.[6] He also devoted much of his "leisure time" to improving his understanding of the science of the day through the study of books and journals. Apparently tireless, Cist worked at teaching himself mineralogy and chemistry, exchanging mineral specimens with Dickinson chemistry professor (and later president of South Carolina College) Thomas Cooper, whose chemical compendium he was sent in 1810.[7] Cist's correspondence with these gentlemen intimates both a scientific curiosity and an entrepreneurial bent.

From 1813 to 1816, Cist kept a sketchbook of coalmines throughout Luzerne County, noting the thickness, strike and dip of beds, probable quantity of coal, as well as their proximity to navigable rivers and roads, and plans for improving ways of getting coal to market.[8] He compiled these local observations into fairly detailed regional maps and cross-sections in which he attempted to correlate coal "veins" from various outcrops in the Wyoming Valley. Correlations were made primarily on the basis of thickness, order of succession of strata, and rock-type. Cist used a combination of terms from the works of European mineralogists (e.g., Werner's *Blende* and *Glantz Kohle*, Haüy's *Anthracite*) and various English terms (e.g., argillite, grit, sandstone, schist, slate), in his rock descriptions. These terms indicate an effort to apply what he had read to what he observed. One of Cist's methodological innovations was distinguishing between red-ash and white-ash anthracite, an experimental discovery of his (Cist, 1825; Powell, 1978). This property was a useful one for tracing coal seams between discontinuous outcrops.

Cist came to the attention of the wider scientific community in 1822 when a work of his was published in the *American Journal of Science* (popularly referred to as Silliman's *Journal*; Baatz, 1994).[9] Silliman's *Journal* served the role of a scientific bulletin board and was a weigh station for the trafficking of the objects

4. The pamphlet was excerpted in Cist (1822). For a reprint, see Hoffman (1968).
5. Woodhouse to Jacob Cist [date missing] (Cist Collection, env. 13, item 120). "Mineralogical Notice of Lehigh Coal" (Cist Collection, env. 12, item 36).
6. John B. Gibson was a member of the American Philosophical Society and a minor geological author (Gibson 1825).
7. Thomas Cooper to Jacob Cist, 10 October 1810 (Cist Collection, microfilm). The British-born Cooper (1759-1839) was also a Pennsylvania judge, commentator on geological problems, political radical and friend of Joseph Priestley.
8. Jacob Cist, Sketch Book: Coal Mines of Luzerne County with notes made on the spot (Cist Collection, env. 11, item 1).
9. Silliman was under the mistaken idea that Cist's first name was Zachariah. Consequently the author of two of Jacob Cist's papers (Cist 1822, 1825) is listed as Zachariah Cist. A plausible explanation is that Silliman misread Jacob Cist's signature — "Jacb Cist" — as "Zach Cist".

and ideas of natural history, science, and the practical and decorative arts. The expertise of practical men on matters of technology and natural history was particularly valuable in the young republic, and they were explicitly encouraged to submit their views (Silliman 1818a, 1818b). There was great interest on the part of geologists in England and on the continent in the mineralogy and geology of North America, and a small, curious, but largely untrained set of Americans like Cist who would collect the necessary observations and specimens.

In 1818, in the inaugural volume of his journal, Silliman had published French geologist Alexandre Brongniart's guidelines for the proper collection and labeling of organized fossil remains (Brongniart, 1818). The notice was intended not only to mobilize fossil-collecting but to standardize it as well.[10] The desiderata Brongniart listed indicate that he intended to use American fossils to determine the successional relations among formations in North America and Europe. His son Adolphe was particularly interested in applying his knowledge of botany to the study of fossil plant impressions.

In 1821, Cist responded to Brongniart's plea, sending via the Philadelphia chemist, Robert Hare, specimens of anthracite, manganese ore, and "schists" containing some thirty fossil plant impressions. Through Silliman, he also passed on a copy of his pamphlet on the advantages of "Lehigh Coal" (Cist, 1822), as well as a drawing of a coal mine and the first range map of the Pennsylvania Anthracite (Figure 1).[11] This map, the result of Cist's fieldwork, showed the geographic range of anthracite localities in northeastern Pennsylvania. The map, drawing, excerpts from the pamphlet—including a series of testimonials—and Cist's letters to Brongniart and Silliman were published in the *American Journal of Science* in 1822. Cist's letter to Silliman chiefly concerns the economics of the Pennsylvania anthracite trade. A postscript to this letter contains a series of descriptions of stratigraphic sections for several coal mines. The precision of these descriptions exceeds that typically seen in contemporary geological accounts published in Silliman's *Journal*. As in his sketchbook, Cist is careful to note dips, thicknesses and rock types, but the mineralogical descriptions are much more detailed than in the sketchbook.

Silliman's editor's note to the excerpt from Cist's pamphlet is noteworthy in drawing attention to the mercantile nature of Cist's remarks and the testimonials he collected (Cist, 1822). Presumably the note was necessary not only to alert readers of potential bias in the testimonials or their selection (all of them gave anthracite favorable reviews), but also because Cist had a financial interest in demonstrating the utility of anthracite, potentially compromising his objectivity, but not his expertise. Curiously enough, Silliman himself later published his own article on the Pennsylvania anthracite in which he cites the results not only of his laboratory experiments but also his favorable experiences using anthracite in his own home (Silliman 1826b). He even appends a series of testimonials from artisans and manufacturers (all of them favorable). In short, Silliman's conclusions on the benefits of using anthracite were in agreement with Cist's and based on rather similar evidence. However, from editorial remarks elsewhere, it is clear that although Silliman greatly valued the expertise of Cist and other practical men, he saw his own role as that of the financially disinterested (and in that sense more objective) observer (Silliman 1826a).[12]

10. The first few volumes of the *American Journal of Science* contain many pleas from correspondents in Britain and on the Continent for the use of standard descriptions, such as dip of beds and Wernerian formation names, in reports of geological observations. See for example the postscript to John Farey's 1819 letter to the *Journal* (Farey, 1820, p. 81).

11. Benjamin Silliman, Sr. to Alexandre Brongniart, 7 August 1821 (Silliman Family Papers, Stirling Memorial Library, Yale University, Microfilm HM 140, Reel 9). I would like to thank Bob Silliman for providing me a copy of this letter.

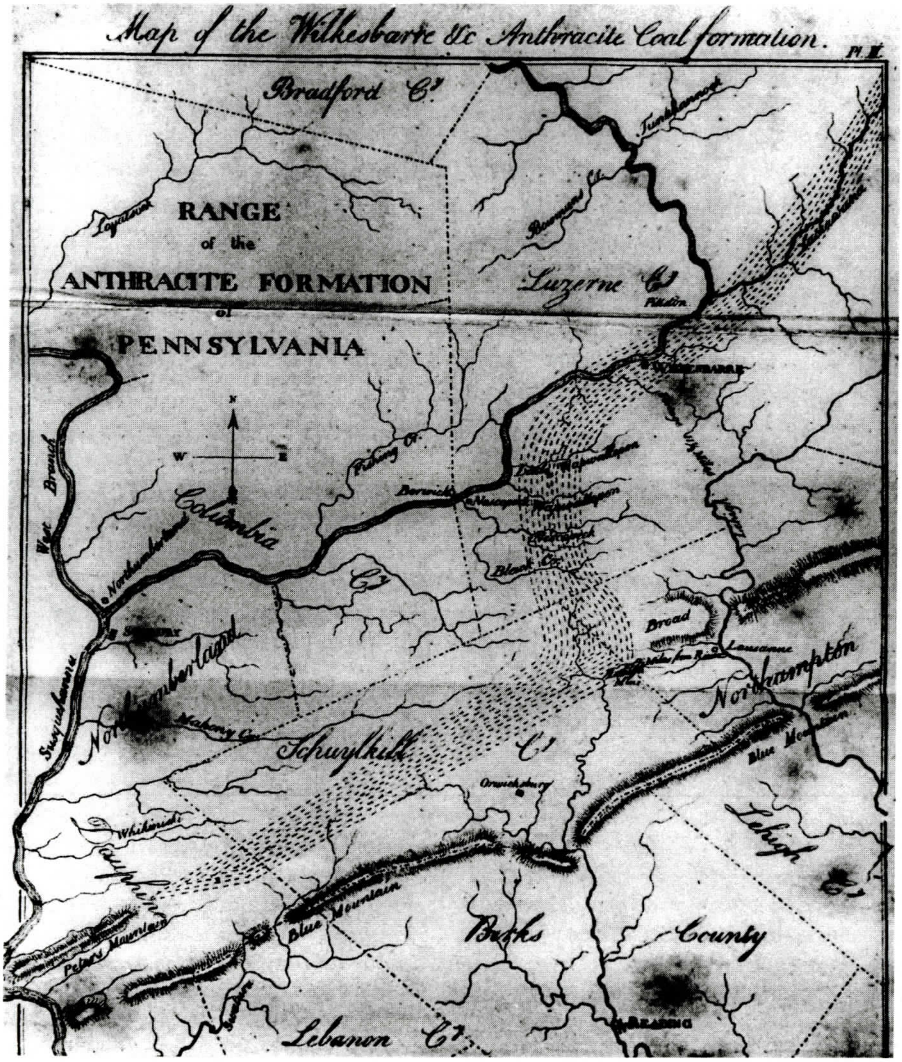

Figure 1. The first published map of the Pennsylvania anthracite (Cist, 1822). The northeast-southwest trending dashed sigmoidal pattern is Cist's determination of the distribution of anthracite in northeastern Pennsylvania.

Cist's letter to Brongniart in the same article gives a detailed description of the geography of the Wyoming Valley of the Susquehanna River, the local surficial and bedrock geology, and the mode of occurrence of the specimens he had sent (Cist, 1822). The remarks therein give some indication of what Cist took to be common knowledge and what he thought noteworthy. For example, he took for granted that anthracite forms from the compression of plant remains, a somewhat contentious point at the time. And while apparently eager to learn the scientific names of each of his plant specimens, he only briefly mentions the presence of "habitations of molluscous [sic] animals" without enclosing specimens or inquiring after their names. Instead he describes their use in the manufacture of lime. Cist did avail himself of what scant American sources on fossil plants there were (e.g. Steinhauer, 1818; Martin, 1809), but also recognized how rudimentary they were, following artificial rather than natural systems of classification. He was eager to learn from the European experts their true designation (Cist, 1822).

As for geology, Cist was clearly familiar with Werner's system, widely used in his day, but it is unclear why he did not consistently employ it. He did point out that even though no such rocks crop out for some 120 miles upriver, the bed gravels of the Susquehanna are composed almost entirely of Primitive rocks. At the same time he failed to assign the local bedrock to either the Transition or the Secondary class, an omission for which he was mildly upbraided in a letter to Silliman from William Maclure, then president of the American Geological Society. A former student of Werner, Maclure considered such classification the "most essential part of Geology" (Maclure 1824). The reason for Cist's omission is unclear, but Cist most likely read Maclure's remarks, for the map he submitted to the Geological Society of London in 1825 was clearly labeled "transition" (Geological Society of London, 1829).[13]

In short, Cist paid much attention to the min-

12. When Silliman published extracts from Cist's anthracite pamphlet in the *American Journal of Science* (1822), he prefaced them with the following editorial caveat:

"This pamphlet appears to have been published about six years ago, and although written evidently not with scientific, but with mercantile views, we have every reason to confide in the truth of the statement of the facts, having often heard them from other, and those disinterested persons, of probity and intelligence. As the subject is one of national importance, and appears not to be extensively understood, we subjoin some certificates of practical men as to the value of this coal in different arts, depending on fire—EDITOR."

Contrast this with an editorial note appended to Silliman's own article on the Anthracite Coal of Rhode Island published in *AJS* (1826a):

"I wish it to be understood, that my remarks and opinions, respecting the Rhode-Island [*sic*] coal, as a fuel valuable in domestic economy and the arts, are derived *entirely* from my experience with a quantity sent me from the mines. I am assured that it was a fair specimen of that which is now raised and offered to the public. I vouch for nothing more than a correct report of the facts which, *with views wholly disinterested*, I have observed, while using, and performing experiments on the materials, which were placed in my hands."

13. Cist enlisted the aid of family friend Thomas Horsfield in forwarding these materials to the Geological Society of London. Horsfield was an American-born naturalist who spent most of his life making sense of Indonesian natural history. Born in Bethlehem, Pennsylvania, he attended Moravian schools, took a medical degree at the University of Pennsylvania, and signed on as a physician aboard an American merchantman to Jakarta (then Batavia), where he spent 1800-1819 serving as paid naturalist to British and Dutch mercantile concerns. Horsfield was a family friend of the Cists, a friendship he maintained through correspondence while in Indonesia and London. Jacob Cist's father, Charles, and older brother Lewis exchanged letters with Horsfield over Indonesian trade prospects. In 1819, Horsfield returned to London, joined a host of scientific societies, and began work on his tome of Javan natural history titled *Zoological Researches in Java, and the Neighbouring Islands* (Horsfield, 1824).

Three months before his death, Cist sent Horsfield a complete geological suite of the Anthracite Formation, some specimens of fossil plants, a fully annotated stratigraphic column, and a range map similar to that published in 1822 (shown in Figure 1). (Jacob Cist to Thomas Horsfield, 16 September 1825, Cist Collection, env. 4, item 30). Cist and Horsfield held in common a passion for entomology. A year earlier, Cist had sent Horsfield a large collection of insects with accompanying figures. Unfortunately, Cist never completed a multi-volume work on the insects of eastern North America. Much of this work has been lost. Some of Cist's insect drawings are housed in the archives of the Wyoming Historical and Geological Society, Wilkes-Barré, Pennsylvania.

eralogy, structure, and especially the stratigraphy of Pennsylvania's northern anthracite field, displaying a detailed familiarity with its local geology, and incorporating what he learned through reading and correspondence. As for dynamical causes, if Cist harbored ideas on the geological processes responsible for the discontinuity and inclination of beds, he rarely mentions what they were. In one article, he attributes the synclinal form of the strata in Wyoming Valley to the valley having sunk (Cist, 1822), an hypothesis no more ad hoc than other early nineteenth century speculations on the dynamical causes for geological structures (see R. Silliman, this volume).

Soon after the publication of his 1822 article, Cist likewise sought to establish contact with other leading paleobotanists in Europe, including Kaspar Graf von Sternberg and Ernst Friedrich Schlotheim (Schlotheim, 1820).[14] To serve as intermediary, Cist called upon an old friend and commercial contact, William L. Brockelman, who had relocated from Baltimore to Bremen, Germany following the War of 1812.[15] Brockelman indicated a willingness to oblige but it is unclear whether any exchange was made before Cist's death.

CONCLUSIONS

The nascent state of science in America in the early decades of the nineteenth century produced a loosely knit, nonprofessionalized scientific community. Jacob Cist provides an example of someone with expert local knowledge, but his status as someone with a financial stake in the anthracite trade had some bearing on how his views were to be received by the scientific community. Cist's geological and mineralogical observations were made largely in the service of estimating quantities of mineral resources and finding ways to exploit and market them (Powell, 1978).[16] While his geological explorations did have a strong commercial aspect, his interests in entomology and paleobotany were almost entirely motivated by intellectual curiosity and a desire to contribute to natural science and cultivate relationships with those similarly interested (Cist, 1824). At the same time it does appear that Cist also saw these relationships as potentially useful commercially. Cist was nothing if not forward-looking in these respects.

Cist's most important achievement was laying the groundwork for the anthracite trade and internal improvements in Pennsylvania. His most lasting contribution to geology was probably his careful collection of fossil plant specimens, although he did not live to see the positive results of either of these labors.[17] Along with the contributions of other Americans, Cist's specimens and their localities were important contributions to Adolphe Brongniart's tabulation of the distribution of fossil plant taxa, the intercontinental correlation of "Coal Measures" (Carboniferous) strata, and one of the first attempts at reconstructing ancient climates from fossil plants (Brongniart 1828a, 1829).[18] Cist's contributions to science were modest but timely, coming at a time when geol-

14. Whether Cist had obtained or seen copies of their works is unclear, but he cited the German titles of a number of paleobotanical works in a letter to Brockelman. Jacob Cist to Brockelman, 21 December 1822 (Cist Collection, env. 12, item 34).

15. Cist's interest in natural science had both a commercial and a purely intellectual aspect, but his commercial relationships also proved useful in the latter. Shortly after Brockelman relocated to Bremen, he re-established a commercial correspondence with Cist, informing Cist of the German market for American goods and materials, and inquiring about the American market for German goods and materials. In a letter to Cist dated 12 May 1816, Brockelman writes that he has spoken with German mineralogists about arranging an exchange of duplicate specimens with Cist (Cist Collection, microfilm).

16. On the view that the science of geology had little to offer the practical miner in the early nineteenth century, see Gordon (1994).

ogists were engaged in correlating stratigraphic successions on different continents using fossils and establishing the extent of exploitable mineral resources.

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REFERENCES CITED

Baatz, Simon, 1991, "Squinting at Silliman": Scientific periodicals in the early American republic, 1810-1833: Isis, v. 82, p. 223-244.

Brongniart, Alexandre, 1818, Notice of M. Brongniart on organized remains: American Journal of Science, v. 1, p. 7174.

Brongniart, Adolphe, 1828a, Prodrome d'une histoire des végétaux fossiles: F.G. Levrault, Paris, 223 p.

Brongniart, Adolphe, 1828b, Observations sur les végétaux fossiles des terrains d'anthracite des Alpes: Annales des Sciences Naturelles, v. 14, p. 127-136.

Brongniart, Adolphe, 1829, General considerations on the nature of the vegetation which covered the surface of the earth, at the different epochs of the formation of its crust: Edinburgh New Philosophical Journal v. 6, p. 349-371.

Childress, Brian, 1991, Charles Cist, Philadelphia printer: Papers of the Bibliographical Society of America, 1991, v. 85, p. 72.

Cist, Jacob, 1824, Notice of the Melolontha, or May Bug: American Journal of Science, v. 8, p. 269-271.

Cist, Zachariah [sic], 1822, Account of the mines of anthracite, in the region about Wilkes-Barré, Pennsylvania:

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17. Alexandre Brongniart's son Adolphe, today recognized as one of the founders of modern paleobotany, described and figured Cist's fossil plant specimens, assigning them to genera. *Catalogue des Roches et petrifications* (Cist Collection, microfilm). The names of four novel species erected by the younger Brongniart — *Calamites cistii*, *Neuropteris cistii*, *Sigillaria cistii*, and *Lepidodendron cistii* — recall their collector (Brongniart, 1828a). Affinities between these species and those found in anthracites in the Savoy Alps figured heavily in a debate not just over the age of the latter but whether fossils could be guides to rock succession at all (Rudwick, 1985; Brongniart, 1828b).

18. Brongniart would have been familiar with the pioneering geographical botany of Alexander von Humboldt (1807) in which Humboldt viewed the distribution of vegetation in relation to altitude and latitude. Brongniart counted the number of known fossil plant species within six higher taxa for each of the four geological periods they spanned in order to characterize the vegetation of each period. In interpreting the distribution of plant taxa in time, Brongniart drew an analogy to the geographical and climatic distribution of modern plant taxa. The result was a general paleogeographic and paleoclimatic history of continental emergence and climatic cooling and drying over the course of geologic history.
Cist also exchanged fossil plant specimens with Brongniart's American contemporary, Columbia professor of experimental philosophy James Renwick (Renwick Family Papers, Butler Library, Columbia University, Box 3). A letter from Renwick to Cist dated 13 December 1824 shows the contrast between the approaches of Renwick and Brongniart and, presumably, America and the Continent at this time. In his letter, Renwick mentions Noah's flood, and the final conflagration, and reconciles the geological data and opinion of the day to revealed religion. In contrast, Brongniart makes no reference to revealed religion throughout his writings on past worlds (Cist Collection, env. 13, item 89).

American Journal of Science, v. 4, p. 1-16, map.
Cist, Zachariah [sic], 1825, Notice of impressions of plants accompanying the anthracite of Wilkes-Barré: American Journal of Science, v. 9, p. 165-166.
Farey, John, 1820, On different modes of expressing the magnitudes and relations of Musical Intervals, with some remarks, in commendation of Professor Fisher's proportionally tempered Douzeauve: American Journal of Science, v. 2, p. 65-80.
Geological Society of London, 1829, A list of donations to the library, to the collection of maps, plans, sections, and models; and to the cabinet of minerals, belonging to the Geological Society: Transactions of the Geological Society of London, 2nd series, v. 2, p. 423ff.
Gibson, John B., 1825, Observations of the trap rocks of the Connewago Hills near Middletown, Dauphin County, and of the Stony Ridge near Carlisle, Cumberland County, Pennsylvania: Transactions of the American Philosophical Society, v. 2, p. 156-166.
Gordon, Robert B., 1994, Custom and consequence: early nineteenth-century origins of the environmental and social costs of mining anthracite, In McGaw, Judith A., ed., Early American Technology: Making and Doing Things from the Colonial Era to 1850: University of North Carolina Press, Chapel Hill, p. 240-277.
Harvey, Oscar J., 1909-1930, A history of Wilkes-Barré, Luzerne County, Pennsylvania: Raeder Press, Wilkes-Barré, v. 4.
Hoffman, John N., 1968, Anthracite in the Lehigh Region of Pennsylvania, 1820-1845: Contributions from the Museum of Science and Technology, Washington, D.C., p. 132-141.
Horsfield, Thomas, 1824, Zoological researches in Java, and the neighbouring islands: Kingsbury, Parbury, & Allen, London, 328 p., 72 pl.
Humboldt, Alexander von, 1807, Essai sur la géographie des plantes: F. Schoell, Paris, 155 p., 1 pl.
Maclure, William, 1824, Remarks on the rocks accompanying anthracite at Wilkes-Barré and elsewhere: American Journal of Science, v. 7, p. 260-261.
Martin, William, 1809, Petrificata derbiensia; or, Figures and descriptions of petrifactions collected in Derbyshire: D. Lyon: Wigan, 28 p., 52 pl.
Powell, H. Benjamin, 1978, Philadelphia's first fuel crisis: Jacob Cist and the developing market for Pennsylvania anthracite: Pennsylvania State University Press, University Park, 167 p.
Rudwick, Martin J.S., 1985, The Great Devonian Controversy: University of Chicago Press, Chicago, 494 p.
Schlotheim, Ernst F., 1820, Die Petrefactenkunde auf ihrem jetzigen Standpunkte: Becker, Gotha, 432 p., 37 pl.
Silliman, Benjamin, 1818a, Plan of the work: American Journal of Science, v. 1, p. v-vi.
Silliman, Benjamin, 1818b, Introductory remarks: American Journal of Science, v. 1, p. 1-8.
Silliman, Benjamin, 1826a, Anthracite coal of Rhode Island: American Journal of Science, v. 9, p. 78-104.
Silliman, Benjamin, 1826b, Anthracite coal of Pennsylvania etc. [sic]: remarks upon its properties and economical uses: American Journal of Science, v. 10, p. 331-351.
Steinhauer, Henry, 1818, On Fossil Reliquia of unknown Vegetables in the Coal Strata: Transactions of the American Philosophical Society, v. 1, p. 265-297.

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THE CONFLICT BETWEEN "PRACTICAL UTILITY" AND GEOLOGY: DENISON OLMSTED, ELISHA MITCHELL AND THE 1823 TO 1828 GEOLOGIC SURVEYS OF NORTH CAROLINA

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ABSTRACT

Geological investigations in nineteenth-century America were conducted by either rudimentary surveys sponsored by the United States government, the states or through the actions of individuals who funded their own studies. The first instance of state-supported and funded geologic investigation was in North Carolina. In 1817, Denison Olmsted and Elisha Mitchell, Yale graduates and students of Benjamin Silliman, took positions in chemistry and mathematics at the University of North Carolina at Chapel Hill. At this time there was interest in improving the state's transportation routes by dredging and digging canals. In 1821, Olmsted approached the Board of Internal Improvements with a proposal to fund a geological survey of the state to aid in this endeavor. Continued efforts led, in 1823, to the State Board of Agriculture authorizing a state geological survey and appropriating funds. Under the Board, Olmsted was charged to "promote agriculture and family manufactures with this state" and given $250 for the next 5 years to accomplish this. Olmsted realized that he must "direct his attention chiefly to such objects as were of practical utility" and in the summer of 1824 began the first geological survey, concentrating on economic minerals and materials in the Piedmont and eastern Blue Ridge. This survey, and the second in 1825, produced, in his viewpoint, nothing more than a "sketch of the Geology of North Carolina." Olmsted returned to Yale in 1825 and Elisha Mitchell was appointed to conduct the geological survey. Mitchell proposed to change the direction of the survey from a random listing of industrial and agricultural resources to the construction of an overall geologic picture of the state. His 1828 and 1829 reports focused on sketching in the boundaries of major formations and providing constraints on their age and origin. This, however, did not supply what the state legislature felt was important and they withdrew their support from the survey. This viewpoint, especially in the agriculture-dominated economies of the South, continually affected the development and survival of state supported geological investigations

INTRODUCTION

Transportation and agriculture fueled the development of the North Carolina geological survey. By the early 1800's there was growing concern with the improvement of overland and river travel and the potential of canal construction for the transportation of goods and people throughout the Piedmont and Coastal Plain of North Carolina. This interest was, in part, a response to the economic boom caused by canal and river transportation improvements in New York and Pennsylvania (Jordan, 1979). In 1819 the North Carolina State Legislature, by an act of the general assembly, created a Board of Internal Improvements to make recommendations, as well as plans and surveys, for the improvement of internal navigation (Hendrickson, 1961). From 1821 to 1843, surveys were made of all rivers east of the Blue Ridge as well as numerous surveys for railroads, turnpikes and canals (Merrill, 1920). In addition, this organization also initiated investigations and surveys of the potential for draining and utilizing the lowland swamps and marshes of the Coastal

Plain for agricultural development. Thus, the stage was set for individuals who, in addition to describing the rocks and minerals and their history, could locate and evaluate the mineral and soil resources so that they might be exploited as a source of wealth and commerce. The route by which Denison Olmsted and Elisha Mitchell were involved in this proposal reveals a great deal about the early history of geological research and mapping in North Carolina, as well as much of the American South.

DENISON OLMSTED AND ELISHA MITCHELL AT YALE

Denison Olmsted and Elisha Mitchell both entered Yale University in the 1809 winter term. Olmsted's education at Yale was strong in the classics, with courses in the sciences in his junior and senior years (Schoepflin, 1977). In his studies of the sciences, he was under the instruction of the leading proponent of American science, Benjamin R. Silliman. However, due in part to his mother and other events in his life, Olmsted had a strong interest in religion and in his senior year at Yale was still undecided on any profession. In April of 1812, he left Yale to take charge of Union School, a select grammar school at New London, Connecticut. This leave of absence at the end of the senior year was a common practice for graduating seniors at the time. At Union School, where he replaced a cousin (Professor Kellogg), his teaching position allowed for his continued interest in religion as well as the ability to interact with a preferred segment of society (Schoepflin, 1977). In September, 1813, Olmsted returned to Yale to graduate with high honors in his class and began a careful investigation into pursuing the ministry. In 1814, even though he had planned to go to Andover Theological Seminary and commence a course of study in preparation for ministry, Olmsted was elected a tutor at Yale, where he still pursued the study of theology in his free time. In the fall of 1816 Olmsted was awarded his M.A. degree, which implied little more than a three-year interval of time since completing his undergraduate education (Schoepflin, 1977).

Elisha Mitchell was also a student of Benjamin Silliman, studied the same curriculum as Olmsted and was in the upper ranks of their graduating class in 1813. In the following years, Mitchell was employed as a teacher at the Union Hall Academy for boys in Jamaica, Long Island (1813 - 1815) and then as the master of a school for girls in New London, Connecticut (1815 - 1816) (Chamberlain, 1945). In January of 1816 Mitchell was employed as a tutor at Yale and awarded his M.A. degree in the fall of 1816. However, there is little evidence to suggest that either Olmsted or Mitchell had received any special training in the subjects they were to teach at the academies they were employed at or with their future positions at the University of North Carolina (Schoepflin, 1977, p. 79). Although both had been in charge of academies in New London, Connecticut, the level of teaching at the academies can be typified by the example of Union School. When Olmsted taught there, Union School had comprised a small group of students, no more that 30, whose families desired for their sons "a superior training for business or college" (Schoepflin, 1977, p. 79). The teaching experiences of Mitchell would have probably been very similar. Nevertheless, both Yale graduates had sufficient academic and teaching credentials to be considered viable candidates for any faculty position opening.

DENISON OLMSTED AND ELISHA MITCHELL AT THE UNIVERSITY OF NORTH CAROLINA

In 1817, Denison Olmsted and Elisha Mitchell were both singled out as candidates for new positions in science and mathematics at the University of North Carolina, Chapel Hill (UNCCH). They were recommended to the trustees of the university by Judge William Gaston, then a member of the United States House of Representatives. This recommendation was suggested to Judge Gaston by the Reverend Sereno E. Dwight, a Yale graduate and the Chaplain of the House of Representatives (Philliss, 1884).

Founded in 1795, the University of North Carolina at Chapel Hill was the school of the sciences in the southeastern United States. From 1805 to the 1840's the faculty at UNCCH fostered the development of scientific research in a variety of fields, including those of geology and mineralogy (Cherry, 1993). Yale, which was becoming a leading center in the nascent United States for training in chemistry, mineralogy and geology, was developing a growing number of professionals. The connection between Yale and UNCCH was part of the "ivy league pipeline" which generally provided qualified individuals for faculty and staff positions. This indicates the close ties among the early schools of science in the United States, as well as the strong Yale-UNCCH connection that continues to this day.

Olmsted was offered the Chair of Mathematics and Natural Philosophy and Mitchell the Chair of Chemistry, Mineralogy and Geology. However, Olmsted felt that he was deficient in mathematics and inveigled Judge Gaston to change his appointment recommendation to the Chair of Chemistry, Mineralogy and Geology and have Elisha Mitchell appointed to the Chair of Mathematics and Natural Philosophy (Schoepflin, 1977). Thus, Olmsted and Mitchell obtained academic employment at UNCCH late in 1817.

In order to rectify the gaps in his academic background, Olmsted, who discarded temporarily his plans for the ministry, requested and obtained a year's leave of absence so that he might study under Benjamin Silliman in preparation for his teaching duties (Schoepflin, 1977). In particular, the year leave was spent in intensive study of topics that he had ignored in his Yale curriculum - geology, mineralogy and chemistry. This is an important insight into the minds of the Committee of Appointment for the Board of Trustees at UNCCH. In their search for a candidate to the Chair of Chemistry, Mineralogy and Geology they proclaimed that a "mere theorist" in chemistry was not an acceptable choice (Schoepflin, 1977). They needed someone who had practical experience. Olmsted assured the faculty that he could become "skilled and expert" in performing chemical experiments and that he had been assigned "the most convenient room this college (Yale) affords" so that he might devote himself "wholly to Chemistry and Mineralogy" (Schoepflin, 1977, p. 80). The Committee agreed that Olmsted, while under study with Silliman at Yale, would be considered "a member of our Faculty; and shall be entitled to pay or salary as such" (Schoepflin, 1977, p. 80).

Elisha Mitchell, much like Olmsted, had been planning to prepare for the ministry. Upon his appointment to the Chair of Mathematics and Natural Philosophy, he attended Andover Theological Seminary to secure his licensure from what he called an "orthodox congregational association in Connecticut", the Western Association of New Haven County on December 30 (Philliss, 1884; Dexter, 1912; Chamberlain, 1945, p. 7). Elisha Mitchell arrived at Chapel Hill on New Year's Day 1818 and began teaching in February, increasing the number of faculty at UNCCH to three.

During his year leave of absence at Yale, Olmsted corresponded with Elisha Mitchell. This way he was able to keep up with the developments on the campus, especially with respect to the laboratory facilities. "Hope they will not build the laboratory before I come on," he wrote to Mitchell (Olmsted, 1817). "As to apparatus, 700 dollars worth would enable us to make a respectable beginning." Although money was forthcoming from the university, it also appears that Olmsted (and Mitchell) contributed their own personal funds for equipment and material, a precedent that continues today. Olmsted wrote about sending "2 or 3 hundred dollars at my own risk," with a Mr. Griscom of New York who was leaving for England in order to purchase equipment that "I shall never have such a chance again" (Olmsted, 1817).

When Olmsted reported to UNCCH to teach in 1819, his instruction was confined to seniors, whose curricular requirements included Chemistry, Mineralogy and Geology (Schoepflin, 1977). Although he taught mineralogy and geology principally in conjunction with his course on chemistry, it is apparent that he embraced his geological interests in the state of North Carolina. In April, 1822 he donated to the American Geological Society a collection of rock and mineral samples, mainly from North Carolina

(Olmsted, 1822). In this development of a 'cabinet' of samples, he was following the example of Silliman at Yale and reflects the start of his practical portrayal of the state's geological framework.

THE FIRST SURVEY: PART I

On 1 December 1821, Olmsted, now a resident member of the faculty at the UNCCH, submitted a letter of intent before the Board of Internal Improvements (Holmes, 1889). In this letter, he proposed to devote his vacations to the development of a mineralogical and geological survey of the state and asked for an appropriation of $100 per year to defer his expenses. Probably an underlying reason for Olmsted's proposal to the Board of Internal Improvement was an earlier proposal (in November 1817) by Benjamin Silliman to the Connecticut Academy of Arts and Sciences (CAAS) for an examination of the geology of Connecticut and the formation of a geological map (Schoepflin, 1977).

Because this proposal was to the group that was investigating the improvement of riverine travel, Olmsted proposed that a geological survey was "very intimately connected with the improvement of internal navigation" such that "by free navigation their value as articles of exports is, like that of the productions of agriculture, greatly enhanced" (reproduced by Merrill, 1920. p. 365). However, the main emphasis of the letter was that a geological survey "would furnish to the board and the public an account of the various useful productions of the mineral kingdom, which either have been discovered already, or which may, from certain well-known indications, be reasonably expected to be found hereafter" (Merrill, 1920, p. 363-364).

In addition to listing the potential materials that this investigation might find, as well as their economic potential, Olmsted specifically addresses the results of other publicly-funded geological surveys. "In the State of New York where public enterprise is directed to the objects as those which this honorable boards have in view, the geological examinations of the country, through which their operations are carried on, has been attended with highly important and beneficial results, as will be seen by reference to the later speeches of his excellency the governor of New York, to the legislature of that state" (Merrill, 1920, p. 364).

But Olmsted also made sure in this proposal that this investigation required a specially trained individual and could not be properly administered by anyone. He suggests that "an actual examination of the country, conducted with the requisite knowledge of the geological principles, will have a tendency to multiply the discoveries, and extend the uses of these valuable substances" (Merrill, 1920, p. 364).

Lastly, he proposes that "The acquisition of knowledge, by which I might be better able to fulfill the duties of my profession and the opportunity of furnishing a geological description of this hitherto undescribed country to the American Geological Society, of which I have the honor to be a member, would afford all the recompense I require; and the collection of specimens to illustrate my lectures, as well as an increased ability to impart information to my pupils respecting their native State; would be the means of securing some advantages to the university" (Merrill, 1920, p. 365). These statements show academic political acumen, as well as the importance, even at this time, of a need to present results of research before their peers in a prestigious journal. This should not be surprising since both Olmsted and Mitchell were active members in the Connecticut Academy of Arts and Sciences along with their mentor, Benjamin Silliman. This organization, which was to "promote, diffuse and preserve the knowledge of these Arts and Sciences, which are the support of Agriculture, Manufactures and Commerce, and to advance the dignity, virtue and happiness of a people", provided a medium for interaction and stimulus on a wide range of topics (CAAS, 1810). In 1818, Benjamin Silliman was preparing the first publication of his "Scientific Journal". Olmsted, while on his year leave at Yale, wrote to Mitchell in Chapel Hill to solicit a manuscript for the first issue, which was called the "American Journal of Science, more especially of mineralogy, and the other branches of natural history, including also agriculture and the ornamental as well as the useful rounded by a few acres of corn and cotton, marks the little improvement which has been made by man, in a region singularly endowed by nature" (Olmsted, 1825b, p. 6).

In this investigation, Olmsted was probably assisted by Charles E. Rothe, "a miner and mineralogist recently from Saxony" (Holmes, 1889). Although there are no salary expenditure records for Rothe, it is recorded that he was engaged for a short time in 1825 to make an examination of portions of the "great slaty formation" which crosses the state (Holmes, 1889). Rothe's major contribution is in connection with the gold mining boom that was occurring at this time (Green, 1969; Hines and Smith, 1996). Olmsted acknowledged three principal placer and hard-rock gold mines in his survey - the Anson, Reed and Parker (Olmsted 1825a, 1827). Rothe made his visits to these mines "under the patronage of the North Carolina Board of Agriculture to which duty I was assigned by my scientific friend, Professor Olmsted" (Rothe, 1828, p. 201). "During that excursion, my investigations were directed to ascertain the geological formations of the whole region, rather than to make a particular examination of the mines themselves. Having performed this duty, as well as circumstances would permit me, and made my report to Professor Olmsted, accompanied by a geological map of the country, I immediately returned to the Yadkin (another name for the Pedee River above the junction with the Uwharre River), with a view of examining more minutely the mines themselves" (Rothe, 1828, p. 201). Olmsted's report on the gold mines of North Carolina (and in his official survey report) does not mention Rothe or provide any form of geological map (Olmsted 1825a, 1825b, 1827, 1828). Rothe's report however was appended by Mitchell in 1828 with his formal report on his portion of the geological survey (Mitchell, 1828a). Nevertheless, the publication of the location, techniques, and potential of gold mining (placer and hard-rock) in the Piedmont of North Carolina fueled the rush of gold seekers to this region and the development of a sporadic gold mining industry that continued until the discovery of gold in California in 1849 (Hines and Smith, 1996).

During his winter vacation of 1825, Olmsted conducted the field investigations that led to the second report on the geology of North Carolina. This investigation took him to the coastal plain, where he studied shell and stone marl, limestone, fine sand and its possible uses in window glass, as well as the location of iron beds (Olmsted, 1827). However, the "extreme shortness of the time at command" and the weather conditions hampered his study (Cherry, 1993). His report to the legislature included a proposal for the opening of a new canal between Clubfoot and Harlow creeks so as to allow a route between New Berne and the ocean by way of Beuford, as well as pointing out the location of deposits of economic importance, but did not specify their specific uses as he had in his first report (Olmsted, 1827; Cherry, 1993).

THE FIRST SURVEY: PART II

In 1825, Denison Olmsted was offered the position as Professor of Mathematics and Natural Philosophy at Yale (Schoepflin, 1977). Although Olmsted felt that he was not qualified to fill this position, it appears that his lack of specific training for this position was not an important consideration. Of more importance was his prior association at Yale as a student and tutor and his obvious religious interests (Schoepflin, 1977). In addition, there were several other considerations that allowed him to make this decision. Among these was that his family (and particularly his mother) were still in the New England area as well as some conflict among members of the faculty at the UNCCH (Schoepflin, 1977). Although there are no specifics as to the conflict, Olmsted resolved, in his personal journals, to shun certain vices; especially back-biting and telling all he knew about the University at Chapel Hill (Schoepflin, 1977, p. 101-102). Nevertheless, he submitted his resignation to the Trustees and left for Yale in the winter of 1825 (Dexter, 1912).

Elisha Mitchell, who apparently preferred geology (and botany) to mathematics, applied for and was appointed to the Chair of Chemistry, Mineralogy and Geology at UNCCH. Olmany form of scientific investigation. Then, as today, this perception can only be overcome (or moderated) by forceful individuals (or agencies such as Silliman's American Journal of Science and Arts) who spent their own time (and resources) to educate the public so as to promote geological investigations.

REFERENCES CITED

Aldrich, Michele L.,1979, American State Geological Surveys, 1820-1845, *in* Schneer, Cecil J. (editor) Two Hundred Years of Geology in America, University Press of New England, Hanover, p. 133-144.

anonymous, 1828, Notice of the Report on the Geology of North Carolina: American Journal of Science and Arts, XIV, no. 1, p. 230-251.

Battle, Kemp P, 1905, Diary of a Geological Tour by Dr. Elisha Mitchell in 1827 and 1828: James Sprunt Historical Monograph, no. 6, University of North Carolina, Chapel Hill, 73 p.

Battle, Kemp P, 1907, The History of the University of North Carolina, From its Beginning to the Death of President Swain, 1798-1868: v. 1. Edwards and Broughton Printing Co., Raleigh.

CAAS, 1810, "An Act to incorporate the Connecticut Academy of Arts and Sciences", *in* Memoirs of the Connecticut Academy of Arts and Sciences, v. 1, part 1, Oliver Steele and Co., New Haven, p. v.

Chamberlain, Hope S., 1945, Life Story of Elisha Mitchell, D.D., 1793-1857, unpublished manuscript, University of North Carolina, Chapel Hill, Southern Historical Collection and Manuscript Department.

Cherry, Thomas K., 1993, Science at the University of North Carolina, 1795-1853, unpublished M.A. thesis, University of North Carolina at Chapel Hill, 185 p.

Dexter, Franklin B, 1912, Biographical Sketches of the Graduates of Yale College with Annals of the College History, v. VI, September 1805 - September 1815, Yale University Press, New Haven, p. 586-589.

Green, Fletcher M., 1969, Gold Mining: A Forgotten Industry of Antebellum North Carolina, *in* Copeland, J. Issac (editor) Democracy in the Old South, Vanderbilt University Press, p. 3-49.

Hendrickson, Walter B., 1961, Nineteenth-Century State Geological Surveys; Early Government Support of Science: Isis, v. 52, part 3, no. 169, p. 357-371.

Hines, Elizabeth and Smith, Michael S., 1996, Gold Mining in North Carolina. *in* Bennett, D. Gordon (editor) Snapshots of the Carolinas: Landscapes and Cultures, Special Publication, Association of American Geographers, p. 43-48.

Holmes, J. A., 1887, Biography of Dr. W. C. Kerr: Journal Elisha Mitchell Scientific Society, v. IV, part II, p. 1-24.

Holmes, J. A., 1889, Historical notes concerning the North Carolina Geological Surveys: Journal Elisha Mitchell Scientific Society, v. l. VI, part I, p. 5-18.

Jordan, William M., 1979, Geology and the Industrial-Transportation Revolution in Early to Mid Nineteenth Century Pennsylvania, *in* Schneer, Cecil J. (editor) Two Hundred Years of Geology in America, University Press of New England, Hanover, p. 91-103.

Merrill, George P., 1920, Contributions to a History of American State Geological and Natural History Surveys, Smithsonian Institution, Bulletin 109, p. 363-387.

Merrill, George P., 1964, The First Hundred Years of American Geology, Hafner Publishing Company, New York. 773 p.

Mitchell, Elisha, 1828a, Professor Mitchell's Report on the Geology of North Carolina with C.E. Rothe's Remarks on the Gold Country and Report on the Subject of Manufacturing Establishments and Raising of Sheep Conducted under the Direction of the Board of Agriculture, Article IX, Part III, J. Gales and Son, Raleigh.

Mitchell, Elisha, 1828b, On the Character and Origin of the Low Country of North Carolina: American Journal of Science and Arts, v. XIII, no. 2, p. 336-347.

Mitchell, Elisha, 1829a, On the Geology of the Gold Region of North Carolina: American Journal of Science and Arts, v. XVI, no. 1, p. 1-19.

Mitchell, Elisha, 1829b, Papers on Agricultural Subjects; On the Silkworm and Making Silk; On the Vine and Making Wine; and Professor Mitchell's Report on the Geology of North Carolina Conducted under the Direction of the Board of Agriculture, J. Gales and Son, Raleigh.

Mitchell, Elisha, 1842, Elements of Geology, with an Outline of the Geology of North Carolina: for the use of the students of the University, University of North Carolina Press, 141 p, with a geological map of the state.

Olmsted, Denison, 1817, Correspondence to Elisha Mitchell, 11 March 1817, University of North Carolina, Chapel Hill, Southern Historical Collection and Manuscript Department. (As noted by Schoepflin, 1977 and the archivists at UNCCH this correspondence is probably misdated and should be 11 March 1818.)

Olmsted, Denison, 1822, Descriptive catalogue of rocks and minerals collected in North Carolina and forwarded to American Geological Society: American Journal of Science and Arts, v. 5, p. 257-264.

Olmsted, Denison, 1825a, Report on Agricultural Subjects and Professor Olmsted's Report on the Geology of Part of the Western Counties of North Carolina, conducted under the direction of the Board of Agriculture, Article IX, Part I, November 1824. J. Gales and Son, Raleigh.

Olmsted, Denison, 1825b, On the gold mines of North Carolina: American Journal of Science and Arts, v. 9, p. 5-15.

Olmsted, Denison, 1827, Papers on Agricultural Subjects and Professor Olmsted's Report on the Geology of North Carolina, conducted under the direction of the Board of Agriculture, Article IX, Part II, November 1825. J. Gales and Son, Raleigh.

Olmsted, Denison, 1828, Report on the geology of North Carolina: American Journal of Science and Arts, v. 14,

p. 230-251.
Philliss, C., 1884, A sketch of Elisha Mitchell: Journal Elisha Mitchell Scientific Society, v. I, p. 9-18.
Rothe, Charles E., 1828, Remarks on the Gold Mines of North Carolina: American Journal of Science and Arts, v. XIII, p. 201-217.
Schoepflin, Gary L., 1977, Denison Olmsted (1791-1859), Scientist, Teacher, Christian: A Biographical Study of the Connection of Science with Religion in Antebellum America, unpublished Ph.D thesis, Oregon State University, 432 p.
Silliman, Benjamin, 1818-1819, Plan of the Work: American Journal of Science and Arts, v. 1, p. v.
Silliman, Benjamin, 1822, Notice of a Geological Survey of North Carolina: American Journal of Science and Arts, v. 5, p. 202.
Sydnor, Charles S., 1940, State Geological Surveys in the Old South, *in* Jackson, David Kelley (editor) American Studies in Honor of William Kenneth Boyd, Duke University Press, Durham. p. 86-109.

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TROY, NEW YORK — HOME OF AMERICAN GEOLOGIC PIONEERS

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ABSTRACT

The Capital Region of New York, and Troy in particular, has the distinction of being the birthplace of the study of geological science in America during the early 19th century. The understanding of geology was in its infancy at that time and exceedingly little had been published on the subject up until 1818. It was largely through the work of Amos Eaton (1776-1842), founder and first professor of the Rensselaer School in 1824, now the Rensselaer Polytechnic Institute or simply Rensselaer, that the study of geological science in America took a giant leap forward. Indeed, Eaton was so influential during these early years that in American geology the period between 1818 and 1836 was called the "Eatonian Era" by Merrill (1924). Geology was central to the curriculum at Rensselaer and it focused on field trips as one of the fundamental teaching media.

The importance of Stephen Van Rensselaer (1764-1839) to the early study of geology cannot be over-emphasized. Before 1830, the science was in its infancy and was being actively pursued in only few places, among them Troy with a population under 11,000, and London, then the largest city in the world! This was due to Van Rensselaer's encouragement and generous sponsorship of the activities of Amos Eaton, and his founding of the Rensselaer School, the first in America dedicated to the study of science.

The advancement of American geology was stimulated in large measure by the strong science curriculum at the Rensselaer School. By 1860 seven state geological surveys were headed by graduates of Rensselaer, a number exceeding that of any other university in the United States. The graduates and faculty included James Hall, Ebenezer Emmons Sr., George H. Cook, Douglas Houghton, James C. Booth, Lewis C. Beck, and others. Hall later proposed the concept of the geosyncline which had been declared the most important single geological concept made in America. Its influence lasted more than one hundred years and vied with the early concepts of continental drift and plate tectonics.

INTRODUCTION: THE VAN RENSSELAERS AND AMOS EATON (1776-1842) — BIRTHPLACE OF GEOLOGICAL SCIENCE IN AMERICA

The Capital District, and Troy, New York, in particular, has the distinction of being considered the birthplace of the study of geological science in America during the early nineteenth century. The understanding of geology was in its infancy at that time and virtually nothing was published on the subject up until 1809 (Maclure 1809, 1818a,b,c). It was largely through the work of Amos Eaton (1776-1842) (Figure 1), founder and first professor of the Rensselaer School in 1824, now the Rensselaer Polytechnic Institute or simply Rensselaer, that the study of geological science in America took a giant leap forward. Eaton's "greatest contribution to American geology was probably his training of an entire generation of geologists who staffed the earliest state geological surveys" (Johnson 1977). Hence Troy became known as the hallowed ground of geological pioneers. Eaton's legacy is still felt today. When the 28th International Geological Congress met in the United

Figure 1. Amos Eaton, founder of American geology as well as founder and first senior Professor of the Rensselaer School, later to become known as Rensselaer Polytechnic Institute.

States in 1989, a field trip followed in Eaton's footsteps for several days. In fact part of the field trip's title was 'in the footsteps of Amos Eaton' (Rodgers and others 1989). Troy is located in Rensselaer County, New York, named after the distinguished Van Rensselaer family who established the only successful Dutch Patroonship, which thrived as a manorial estate from 1630 to the mid-1800s. One branch of the family produced Jeremias Van Rensselaer (1793-1871).

Though forgotten now, Jeremias Van Rensselaer (1793-1871) was in his day a well-known and respected geologist who lectured and wrote and was well known in both Europe and America. He inherited the old Rensselaer mansion and lands in the Greenbush area, east of Albany. Van Rensselaer's book (1825), was one of the first student textbooks on geology published anywhere, and it preceded that of the other two Rensselaer giants of geology, Ebenezer Emmons Sr. (1826) and Amos Eaton (1830). In it he notes, "it is my lot to treat of Geology -- and I propose to give a rapid sketch of the rise and progress of this Science" (1825, p. 18). This book attempted to popularize the science of geology and Van Rensselaer felt that no published work existed "that even hints at the many points properly treated under the head of geology" (Van Rensselaer, 1825, p. IX). An earlier notable publication by Van Rensselaer (1823) concerned the formation and economics of salt. This pioneering study was based on observations from modern sediments and rocks. He correctly noted "the most satisfactory hypothesis is the supposition of its [salt] being deposited from the sea; or by the desiccation of salt lakes formerly covering our present continents" (p. 51). This publication highlighted the potential of finding and exploiting rich deposits of salt in New York State, the results of which led to Syracuse becoming the "Salt City" and an important Erie Canal port. Tables in his publication indicate the value of salt shipments from various places at the time. The author named the Rensselaer Center of Applied Geology on 3rd Street in downtown Troy, New York in honor of Jeremias Van Rensselaer.

Jeremias Van Rensselaer's cousin was Stephen Van Rensselaer (1764-1839). The importance of Stephen Van Rensselaer to the early study of geology cannot be over-emphasized (Figure 2). Before 1830, the science was in its infancy and was being actively pursued in only few places, among them Troy with a population under 11,000, and London, then the largest city in the world! This was due to Van Rensselaer's encouragement and generous sponsorship of the activities of Amos Eaton, and his founding of the Rensselaer School, the first in America dedicated to the study of science.

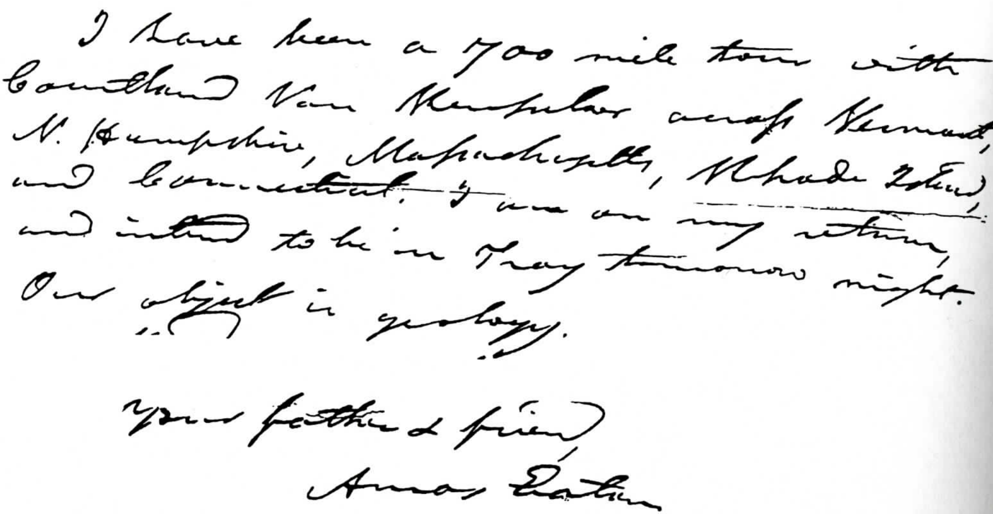
Stephen Van Rensselaer, born on November 4, 1764, was a twelfth-generation descendant of the original Dutch immigrant patroon. He graduated from Harvard University in 1782, served as New York State legislator from 1791 to 1796, as Lieutenant Governor of New York from 1795 to 1798, and as General of the New York State militia. His father, likewise Stephen Van Rensselaer, was the eighth Patroon and 6th Lord of the Manor of Rensselaerwyck; his mother was Catharine Livingston, daughter of Philip Livingston - one of the signers of the Declaration of

Figure 2. Stephen Van Rensselaer, New York statesman, engaged Amos Eaton to complete geological surveys of the areas now known as the northern Appalachian Basin and Appalachian Mountains.

Independence (Van Rensselaer, 1956, p. 24, 37).

In 1819, the legislature of the state of New York elected Stephen Van Rensselaer President of the Central Board of Agriculture. This board published two volumes on the geology of Albany and Rensselaer counties authored by Amos Eaton. "It was believed then, and it is believed now, that these were the first two attempts in this country to collect and arrange geological facts, with the direct view to the improvement of agriculture" (Barnard, 1839, p. 72) and he dwelt at length on Van Rensselaer's geological contributions. After republishing the studies on the geology of Albany and Rensselaer counties "at his own cost, in a separate and convenient form, for extensive and gratuitous distribution" (Barnard, 1839, p. 74), he next turned his attention to a more extended scientific survey, to be carried through the entire length of the State on the line of the Erie Canal. This was commenced and prosecuted, under his orders, in the fall of 1822, by Professor Amos Eaton aided by two competent assistants. Van Rensselaer considered the geological studies of these two counties and the Erie Canal route part of a grander scheme, a plan for a "large and generous contribution to the science of Geology" (Barnard, 1839, p. 75). This plan embraced a particular examination of the strata and formations of American rocks, by the survey of a transverse section, running across the Great Primitive Ranges of New England and the Transition and Secondary Ranges of eastern and western New York (Barnard, 1839, p. 75). He engaged Amos Eaton who completed this survey in 1823. His section extended from Boston to Lake Erie, a distance of about 550 miles, stretching across 9 degrees of longitude and embracing a belt of about 50 miles wide. In 1824, a publication was made with maps exhibiting a profile view of the rocks (Eaton, 1824). This work presents a survey of greater extent than had ever been offered to geology before.

However, according to Barnard (1839, p. 76) "the crowning glory of this good man's life" resulted on November 5, 1824 in the founding of the Rensselaer School to which he appointed two professors, Amos Eaton as senior professor and as junior professor, Lewis C. Beck, later to be the famous State Mineralogist of New York. Beck was followed by Ebenezer Emmons Sr., one of the giants of nineteenth century American geology. By 1839, Rensselaer "had furnished to the community more State Geologists than has been furnished, in the same time, by all the colleges of the Union" (Barnard, 1839, p. 83, in Friedman, 1979, 1981). Stephen Van Rensselaer was personally most interested in geology. In the early part of the last century the Transactions of the Geological Society of London published annually "a list of donations...to the museum" of the society. The 1829 Transactions note under donation "July 2, 1825: rocks from America. Donor the Hon. von Rensellare" (sic).[1]


I have been a 700 mile tour with Courtland Van Rensselaer across Vermont, N. Hampshire, Massachusetts, Rhode Island and Connecticut. I am on my return, and intend to be in Troy tomorrow night. Our object is geology.

Your father & friend
Amos Eaton

Figure 3. Excerpt of a letter which Amos Eaton wrote to his son Amos B. Eaton.

AMOS EATON'S EARLY GEOLOGY BEFORE AND AFTER THE FOUNDING OF THE RENSSELAER SCHOOL

An excerpt in one of Eaton's letters (Figure 3) addressed to his son, Lieutenant Amos B. Eaton from New York City, on June 12, 1829 states "I have been (on) a 700 mile tour with Courtland Van Rensselaer through Vermont, N. Hampshire, Massachusetts, Rhode Island, and Connecticut. I was on my return, and intend to be in Troy tomorrow night. Our object is geology..........Your father and friend, Amos Eaton" (the original letter is in the archives of the G.M. Friedman History of Geology Collection, formerly in possession of George F. Eaton, New Haven, Connecticut, see McAllister, 1941, p. 531). To Eaton geology was everything and everywhere. He developed the most successful training for field geology in the United States. He peddled geology, lecturing and holding classes. In an 1816 letter to Benjamin Silliman, Sr. (1779-1864), he wrote: "My class room is crowded with the first people of both sexes and all ages. I have in my class 55 ladies, four practicing lawyers, three law students, three practicing physicians, two students of physics, three other gentlemen from Yale College, one senator, one representative in Congress, and one Common plea judge" (Badgley, 1982, p. 148).

A self analysis of his lecture ability is summarized in a letter to John Torrey (1796-1873) in 1817: "I know not a person in the world who would become a (more) successful scientific pedler. I have learned to act in such a polymorphus character, that I am, to men of science a curiosity, to ladies a clever schoolmaster, to old women a wizzard (sic), to blackgards (sic) and boys, a showman and to sage legislators a very knowing man" (Badgley, 1982, p. 148).

Eaton's Background and Career

Amos Eaton was born in 1776 in New Concord, Columbia County, New York, the son of a farmer of English ancestry. While he was of high-school age he did surveying; in 1799 he graduated from Williams College. Three years later, after an apprenticeship in New York, he

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1. For my research I would like to know what kind of collection Van Rensselaer had donated: the kinds of minerals, rocks, and fossils, and their sites of sampling. I discussed this matter with the curator of the Geological Society of London, John Thackray, who thought that the collection is now housed at the Museum of Natural History in London, where Thackray, likewise holds the office of curator. He introduced me to someone who is more familiar with the dead-storage area of the museum who thought that all trace of the Geological Society collections may have been lost, "although there may be boxes in the sub-basement".

was admitted to the New York Bar (Fisher, 1978). He and his father later bought 5,000 acres from Nathaniel Pendleton, and they managed another quarter of a million acres. Pendleton later charged Eaton with forgery, and Eaton was convicted by a jury on August 26, 1811, and sentenced to life imprisonment at hard labor for forgery. After serving four years "time" he was granted a conditional pardon by Governor Tompkins. This document was later changed to a full pardon by Governor Dewitt Clinton (Badgley, 1982).

As shown on a circular of 1827, geology was allotted prominence early at Rensselaer. This document reads "it is now required that each student take two short mineralogical tours to collect minerals for his own use, for the purpose of improving himself in the science of mineralogy and geology." The advancement of American geology was stimulated in large measure by the strong science curriculum at the Rensselaer School founded in 1824. Eaton was so influential during these early years that in American geology the period 1818-1836 is known as the 'Eatonian era'. Merrill (1924) initially coined this term for the period 1820-1829, but Wells (1963) extended it to encompass the larger period. The term 'Eatonian era' pays tribute to the astonishingly effective public promotion of geology by Eaton. Johnson (1977) reviews geology at the Rensselaer School for the years 1825-1860.

The German mineralogist Abraham G. Werner (1749-1817) had great influence on the geological thinking of Eaton. Eaton accepted Werner's simple concepts of the origin of rocks from a primaeval ocean, hence Eaton was a "neptunist". "From his earliest works to his latest, he acknowledged his debt to Werner" (Ospovat manuscript).[2]

Before the Rensselaer School was founded, Eaton had conducted a survey of the Williamstown-Northampton, Massachusetts area (Eaton, 1818, 1820). This survey is the first recorded instance of the American use of the field-trip technique that would become such an important tool in university and public-school curricula a century later. In fact, the field trip became a regular feature of geology at Rensselaer, and by its novelty and the enthusiasm of the students involved, attracted educators from all over the country. Eaton completed geological surveys of Albany (with T. Romeyn Beck, 1820) and Rensselaer counties (1822) commissioned by the New York State Agricultural Society, but paid for by the philanthropic patroon Stephen Van Rensselaer. Van Rensselaer also supported Eaton's geological survey of the territory adjoining the Erie Canal route during 1823-1824 (Eaton, 1824). In 1818 Eaton published a textbook, where he not only incorporated a time and rock classification scheme, but introduced a local guidebook, and published a cross section extending from the Atlantic Ocean to the Catskill Mountains. In 1824 Eaton appealed to Van Rensselaer for $300 as part of the effort to establish the Rensselaer School in Troy. Van Rensselaer provided these funds immediately and continued his financial support until 1829. Despite a heavy load of teaching and administration Eaton authored a textbook (1830) as well as a geologic map of New York State (Figure 4).

Eaton guided his students on long excursions into New England, and most importantly along the new Erie Canal. One result of the "Rensselaer School Flotilla" (Figure 5) was a report entitled Van Rensselaer's Canal Survey which revolutionized geology and other new sciences through its introduction of new and precise nomenclature for the rocks of New York State (Eaton, 1823, 1824). More than a century would have to pass before geologists could view Eaton's achievement objectively enough to ful-

2. Some years ago I established a medal for distinction in the history of geology which the Geological Society (of London, England), the world's oldest geological society (founded in 1806, Royal Charter dated 1825) awards each year. This medal shows the Siccar-Point unconformity in Scotland by Sir James Hall (1761-1832) (not to be confused with James Hall of New York) and lists Sir Charles Lyell (1795-1875), James Hutton (1726-1797), and William Smith (1769-1839) as the fathers of geology. The council of the society requested from me the names of German and American founding fathers, but would not accept Abraham G. Werner nor Amos Eaton.

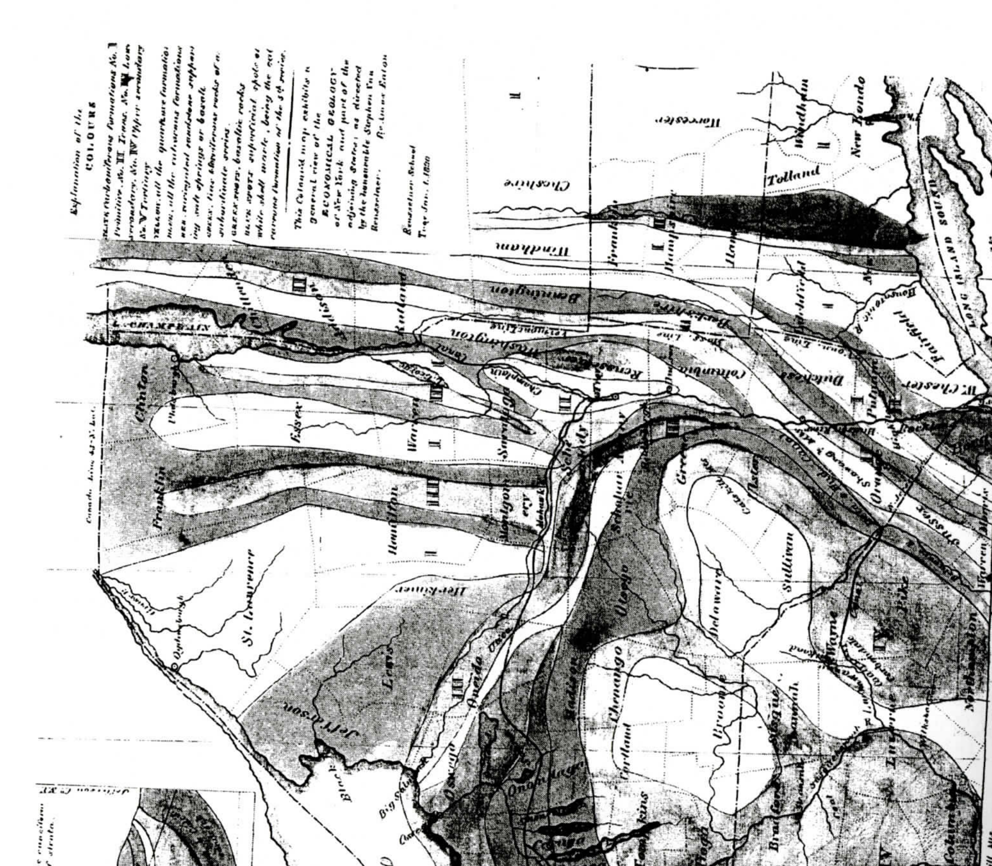

Figure 4. Black-and-white rendition of Amos Eaton's colored map of New York State "as directed by the hono(u)rable Stephen Van Rensselaer."

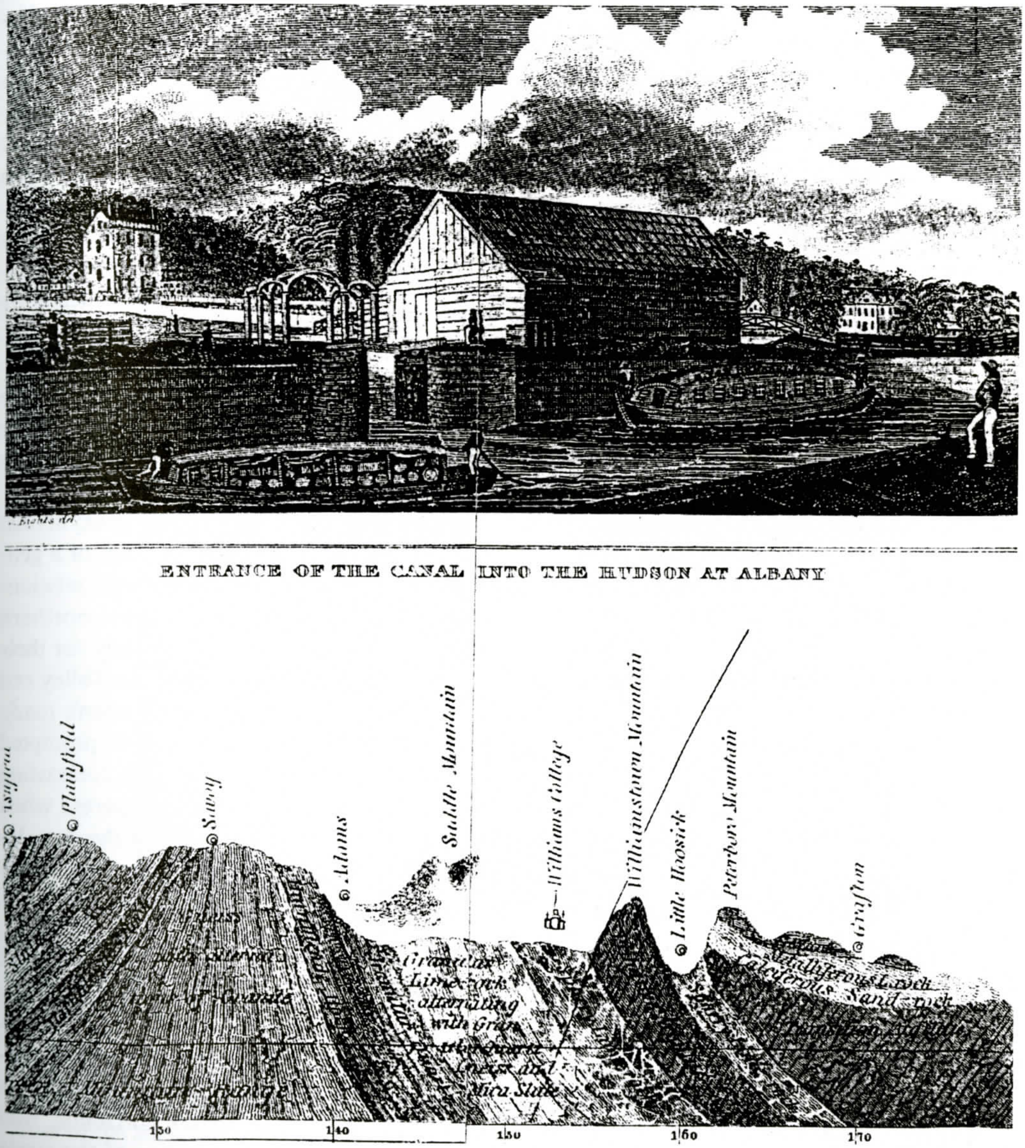

Figure 5. Part of a profile across the northern Appalachian Mountains and Basin along the Erie Canal route. Stephen Van Rensselaer commissioned this geologic survey. It was published in 1828 and was an extraordinary feat to have undertaken at that time on foot. Note the ships of the "Rensselaer School Flotilla" at the entrance of the Erie Canal into the Hudson River at Albany. The ship on the right has the inscription S. Van Rensselaer.

ly appreciate his accomplishment.

One student permanently influenced by his participation in the 1826 Rensselaer School Flotilla was Joseph Henry (1797-1878), later the founder of the Smithsonian Institution and the Library of Congress, and a leader of the American scientific community. On May 5th he noted in his journal, "Mr. E [Eaton] this morning gave us a lecture on the general principles on Geology in which he observed that the Europeans were obliged to come to America to study the regular arrangements of rocks on a large scale" (Reingold, 1972, p. 140). But Eaton would have to wait until 1841 to meet with his

English colleague, Sir Charles Lyell.

James D. Dana (1813-1895) was a "grand-student" of Amos Eaton. Dana was born in Utica, New York, and attended Utica Gymnasium. Dana was fortunate to have Fay Edgerton (1803-1832) as a science teacher at that school. Edgerton had received his training at the Rensselaer School under Amos Eaton. Fay Edgerton was the person who encouraged Dana's entry into geology.

After a visit to Niagara Falls with James Hall in September of 1841, Charles Lyell made it a point to visit the bedridden Eaton in Troy, after which he noted, "The mind of this pioneer in American geology was still in full activity and his zeal unabated. His Survey of the Erie Canal was the earliest account of the Niagara district, but nearly all of the rocks and groupings [he named] have been since adopted by the New York surveyors" (Lyell, 1845).

At the time of his death in 1842, Eaton had become the most influential American geologist. By 1860 in state geological surveys of the United States, the following Rensselaer alumni held positions of responsibility: George H. Cook (1818-1889), New Jersey; Charles Briggs, Jr. (1812-?), Virginia; Ebenezer Emmons Sr. (1800-1863), James Hall (1811-1898), Ezra S. Carr (1819-1894), Eben N. Horsford (1818-1893), and George W. Boyd (? -1840), New York; James C. Booth (1810-1888), Pennsylvania; Charles Briggs, Jr. (1812-?), Ohio; James C. Booth (1810-1888), Delaware; Douglas Houghton (1809-1845), Michigan; Ebenezer Emmons Sr. (1800-1863), South Carolina; Ezra S. Carr (1819-1894) and James Hall (1811-1898), Wisconsin; James Hall (1811-1898), Iowa.

THE CONCEPT OF THE GEOSYNCLINE DEFINING THE NORTHERN APPALACHIANS

Among the most influential alumni of Rensselaer was James Hall (1811-1898), the "Father" of the Geosyncline (Figure 6). Hall is alleged to have walked 220 miles from his home in Hingham, Massachusetts, to enroll and study under the great Eaton. Hall's first job at Rensselaer included white washing one of its buildings and tidying up the school; later he became librarian, and by 1835 he was listed as a full professor. Persuaded by Eaton, the New York State Legislature established a Geological and Natural History Survey in 1836 of which James Hall was appointed State (Chief) Geologist of the western district of the state, then at the age of 26. He was said to be a pompous, aggressive workaholic. He browbeat (backed by the threat of an ever-present shotgun) his employees and apprentices and cajoled and threatened (with his ever-present cane) the politicians. Hall remained on the Rensselaer faculty on a part-time basis for almost 70 years (Fenton and Fenton 1952).

Hall was the originator of the geosynclinal concept (Sharpe, 1998). The concept of a geosyncline was inspired by the geologic relationships that were worked out for the northern Appalachian Mountains, particularly for their western parts, a region known as the Valley and Ridge province. The generalizations made about this part of the Appalachians prompted similar studies in Europe, but with contrasting results. This contrast becomes apparent when one compares American views of the Appalachians with European views of the Alps (Friedman, Sanders, and Kopaska-Merkel, 1992).

Hall (1859) observed that, where the Paleozoic marine strata in the interior of North America are thin (thicknesses of only a few hundreds or a few thousands of meters), they are flat lying. By contrast, in the Appalachians, thicknesses of equivalent strata amount to thousands of meters and the strata are not horizontal. Hall hypothesized that the substance of the strata within a trough, where they would be extra thick, provided the mechanism for folding them (Figure 7).

Shortly afterward James Dwight Dana (1873) argued that subsidence alone would not fold the strata. Instead, Dana proposed that the strata had become thick by sinking unmolested in a great synclinal trough (which he named a geosynclinal, later renamed geosyncline). According to Dana, only afterward were these thick, trough-filling strata folded (Figure 8). Dana suggested that the deformation of the

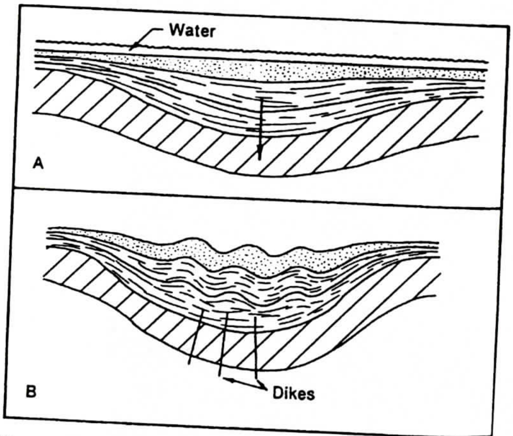

Figure 7. Sketch of origin of geosynclinal sediments and structures, according to the ideas of James Hall (1859, p. 69-70). (A) Trough subsides; strata in center become thicker than on sides. (B) With great subsidence, crust beneath the center of the trough fails, cracks open on stretched part along base of trough, and dikes are intruded. Strata above are folded by squeezing together of limbs of trough (Friedman, Sanders, and Kopaska-Merkel, 1992, p. 644).

most important single geological concept made in America. Its concept was inspired by the geologic relationships that were worked out for the northern Appalachian Mountains. Its influence lasted from its inception in 1859 to the 1970's. In the 1950's the concept of the geosyncline was still so entrenched that it challenged the early acceptance of continental drift and plate tectonics. In line with this discussion I want to relate an anecdote of the 1950's. In 1953 Lawrence H. Lattman (1923-) took his Ph.D. examination at the University of Cincinnati. I was one of his examiners. The others were a distinguished group of sedimentary geologists and paleontologists: John L. Rich (1884-1956), Gordon Rittenhouse (1910-1974), and Kenneth E. Caster (1908-1992). Two hours were spent discussing sedimentation patterns in geosynclines. I tried to steer questioning into other areas of stratigraphy. To my shock all three colleagues protested and contended almost at a high-pitched decibel level, that only geosynclines really mattered. Almost to the closing bell, the examination proceeded with elaboration on the geosyncline. This account emphasizes the importance of the concept of the geosyncline to the geological community of the time. Now, it is surprising in terms of historical analysis of ideas that the term geosyncline is not even listed in the subject index of current textbooks of stratigraphy and basin analysis, or of elementary texts on physical and historical geology! Yet what is amazing to me is that the geosynclinal concept, relating to the northern Appalachians which Hall initially developed seventeen years after the death of Amos Eaton, dominated stratigraphy for more than one hundred years.

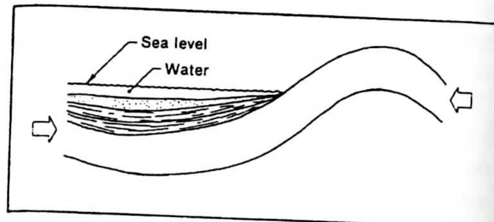

Figure 8. Sketch of origin of geosynclinal sediments and structures, according to ideas of J.D. Dana. Dana visualized five steps, as follows: (1) Trough subsides and sediment accumulates; (2) downbending of crust requires the complementary upward flexure of a geanticline (stages 1 and 2 sketched above); (3) heat rising from below weakens the bottom of the geosyncline; (4) the weakened trough yields as a result of lateral pressure; (5) "the stratified rocks become, in the partial collapse, upturned or folded, and pressed into a narrower space than they occupied before; a mountain range exists as a result" (J.D. Dana, 1880, p. 820). (Sketch based on J.D. Dana, 1873, p. 170 and 1880, p. 819-821.) (Friedman, Sanders, and Kopaska-Merkel, 1992, p. 645).

OTHER ALUMNI

Edgerton was born in Burlington, Vermont, and was 21 years old (1825), when he entered the Rensselaer School. In 1826 he became adjunct to Amos Eaton and remained in this position, till after graduation, until the fall of 1828 (Nason, 1887). After leaving Rensselaer he went to Utica as a professor at the Utica Gymnasium with the title of professor of natural science, where Dana became his student. Edgerton's title almost matched Dana's choice of a profession: he wanted to pursue his interest

Figure 9. Ebenezer Emmons Sr., alumnus and Junior Professor at Rensselaer, member of the New York State Geological Survey, founder of the North Carolina Geological Survey, and State Geologist of North Carolina; father of the Taconic System.

in natural history (Dana, 1835; Newell, 1997).

Another early alumnus who became a giant in the nineteenth century was Ebenezer Emmons Sr. (1799-1863) (Figure 9). A graduate of Rensselaer in the first class of 1826, Emmons had been inspired by Eaton. He became Junior Professor at Rensselaer in 1830, a position he held for ten years, and, while serving there, was appointed State (Chief) Geologist of the northern Geological District of the New York State Geological Survey in 1836. He named the Adirondack Mountains (1838) and Taconic Mountains (1844, 1846) and acquainted the public with these regions. Emmons had noted the presence of a group of rocks between the Potsdam Sandstone, the oldest of the then recognized sedimentary formations in New York, and what was called then the Primitive Rocks of Central Vermont. This interval he proposed to call the Taconic System. He later became state geologist for North Carolina, spreading the influence of Rensselaer, and promoted his ideas of the Taconic system. Emmons published several classic texts in 1826, 1842, 1854, and 1860.

In his study of the northern Appalachians, Emmons inferred that the deformed rocks in Washington County, New York, were older than any fossiliferous rocks then known. For these oldest fossil-bearing rocks he coined the name Taconic System. This discovery led to the infamous Taconic Controversy in which Hall, supported by Louis Agassiz (1807-1873), filed antagonistic newspaper reports, that led to court action with libel and counter libel suits (Fisher 1981; Schneer 1978). Emmons lost out; the court action was against him. "For days twelve Irishmen and Dutchmen of Albany County listened to the geologic fireworks (in court) and doubted sleepily that it made much difference whether there existed a group of rocks to be known as the Taconic System" (Fenton and Fenton 1952, p. 157). James D. Dana was particularly non-compromising. Fay Edgerton, Dana's teacher in Utica, was a student of Emmons. Edgerton had showed Emmon's textbook of mineralogy and geology to Dana, then still in high school, who recorded (Dana, 1886, p. 401) that this book kindled his interest and probably his career choice. Yet Dana succeeded in barring the official acceptance of Taconian as the name for the Early Cambrian (Fisher 1981). Fisher noted (1981, p. 37): "Emmons' ability and accomplishments deserve better treatment than has been accorded him. However, the antagonisms of Hall, Dana, Lyell (and others), avowed geological pundits of their day, overshadowed Emmons and his credible and thought-provoking work on the Adirondack and Taconic Regions." Rodgers (1997) reviews the Taconic controversy and notes (p. 356) "that Emmons had been shabbily treated and was the victim of a conspiracy against him on the part of James Hall and others, including Dana."Preceding Ebenezer Emmons Sr. as Junior Professor at the Rensselaer School was Lewis C. Beck. Born in Schenectady, New York, on October 4, 1798, Beck was appointed the first junior professor at Rensselaer. The Beck family was well represented in the early history of the school. His brother T. Romeyn Beck (1791-1855) was Vice President as well as Trustee. Nicholas F. Beck (1796-?), another brother, served likewise as Trustee, but their terms as Trustees did not overlap (Sebring and Sebring 1934). Lewis Beck published his classical Account of the Salt Springs at Salina, Onondaga County, State of New York in 1826 (Sebring and Sebring 1826). In 1829 Beck resigned from Rensselaer and in 1836 joined the New York State Geological Survey as mineralogist. The New York State legislature in that year appropriated $104,000 for a Geological Survey justified by Lewis's brother T. Romeyn Beck. Governor William L. Marcy, an eager proponent of conservation, especially in the Adirondack Mountains area, appointed Lewis Beck to conduct the mineralogical survey. In his first year of the survey, Beck traveled 2,412 miles in his capacity as State Mineralogist, the following year 3,180 miles, and the third year 2,433 miles. By 1841 his field work was completed. In 1842 he devoted his time to preparation of the final report which was published in late 1842; one of the great classics of the New York State Geological Survey. Beck possessed an M.D. degree from Albany Medical College and by 1842 was Professor of Chemistry and Natural History at Rutgers College, New Jersey (Donald W. Fisher, personal communications, September 23, 1998).

POSTSCRIPT

In 1933, a memorial plaque was unveiled on a vertical wall of Devonian limestones in the Helderberg Mountains in Thacher State Park, Albany County, New York. The inscription reads "In memory of those pioneer geologists whose researches in the Helderbergs from 1819-1850 made this region classic ground." Amos Eaton heads a list of seventeen names which includes James Hall, James D. Dana, Sir Charles Lyell, and Louis Agassiz. Conspicuous by its absence is Ebenezer Emmons' name. Emmons deserves to be included, but Hall, Agassiz, and Dana had smeared his name, so that even seventy years after his death, Emmons was not considered worthy of inclusion. Emmons spent his later years as state geologist of North Carolina. Interestingly, after his death, his body returned to Albany, New York, where he is buried in the Albany Rural Cemetary just a few feet away from James Hall.

ACKNOWLEDGMENTS

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REFERENCES CITED

Badgley, K.C., 1982, Amos Eaton (1776-1842), geologist overcame stigma, inspired Rensselaer: Northeastern Geology, v. 4, p. 147-150.

Barnard, D.D., 1839, A Discourse on the Life, Services, and Character of Stephen Van Rensselaer Delivered Before the Albany Institute April 15, 1839 with a Historical Sketch of the Colony and Manor of Rensselaerwyck *in* an Appendix. Hoffman & White, Albany, 144 p.

Beck, L.C., 1842, Mineralogy of New York: Natural History of New York. Thurlow Weed, Albany, NY, 536 p.

Dana, J.D., 1835, Letter to his father, July 27, in Gilman, D.C., 1899, The life of James Dwight Dana: scientific explorer, mineralogist, geologist, zoologist, professor in Yale University. Harper and Brothers, New York, 409 p.

Dana, J.D., 1873, On some results of the Earth's contraction from cooling, including a discussion of the origin of mountains and the nature of the Earth's interior: American Journal of Science, 3rd Series, v. 5, p. 423-443; v. 6, p. 6-14, 104-115, 161-172.

Dana, J.D., 1886, The history of Taconic investigation previous to the work of Professor Emmons: American Journal of Science, 3rd Series, v. 31, p. 399-401.

Eaton, Amos, 1818, An Index to the Geology of the Northern States, with a Transverse Section from the Catskill Mountains to the Atlantic, Hori Brown, Leicester, MA, 52 p.

Eaton, Amos, 1820, Index to the Geology of the Northern States, with a Transverse Section from the Catskill Mountains to the Atlantic; Prepared for the Geological Classes of Williams College, 2nd ed., Troy, NY 286 p.

Eaton, Amos, 1822, A Geological and Agricultural Survey of Rensselaer County in the State of New York [with a geological profile of the rocks from Onondaga Salt Springs, NY, to Williams College, MA], Albany, NY, 70 p., reprinted 1823, New York State Board Agriculture Memoir 2, p. 3-18, 41-43.

Eaton, Amos, 1823, Amos Eaton collection: Third Canal Tour, Journal C (DR10685), New York State Library.

Eaton, Amos, 1824, A Geological and Agricultural Survey of the District Adjoining the Erie Canal, in the State of New York...Together with a Geological Profile Extending from the Atlantic to Lake Erie. Packard and Van Benthuysen, Albany, NY, 163 p.

Eaton, Amos, 1830, Geological Text-book, Prepared for Popular Lectures on North American Geology; with Applications to Agriculture and the Arts. Websters and Skinners, Albany, NY, 63 p.

Eaton, S.A. and Beck, T.R., 1820, A geological survey of the county of Albany..... Albany, 56 p.

Emmons, Sr., Ebenezer, 1826, Manual of mineralogy and geology, Albany, 230 p., 2nd edition (1832), Albany, 299 p.

Emmons, Sr., Ebenezer, 1838, Report of E. Emmons, Geologist of the Second Geological District of the State of New York; NYS Assembly No. 200, p. 185-250 (February 15, 1838).

Emmons, Sr., Ebenezer, 1842, Geology of New York, Part 2, comprising the survey of the Second Geological District, 437 p.

Emmons, Sr., Ebenezer, 1844, The Taconic System; based on observations in New York, Massachusetts, Maine, Vermont, and Rhode Island. Albany, p. 65.

Emmons, Sr., Ebenezer, 1846, Remarks on the Taconic system: American Quarterly Journal of Agriculture, v. 4, p. 202-209.

Emmons, Sr., Ebenezer, 1854, American geology, containing a statement of the principles of the science with full illustrations of the characteristic American fossils. Part 1, 194 p., Albany; vol. 1, pt. 1, 194 p., pt. 2, 251 p., (1855), Albany; pt. VI(111), 152 p., (1857), Albany; another ed., 3 pts. (1875) Albany.

Emmons, Sr., Ebenezer, 1860, Manual of geology..., 290 p., Philadelphia; 2nd edition, 297 p., New York (1863).

Fenton, C.L. and Fenton, M.A., 1952, Giants of Geology. Doubleday & Co., Garden City, NY, 333 p.

Fisher, D.W., 1978, Amos Eaton — Passionate Peddler of Science: The Conservationist, v. 32, no. 4, p. 36-39.

Fisher, D.W., 1981, Emmons, Hall, Mather, and Vanuxem-the four "horsemen" of the New York State geological survey, *in* Jordan, W.M., ed., History of geology in the northeast: Northeastern Geology, v. 3, p. 29-46.

Friedman, G.M., 1979, Geology at Rensselaer: a historical perspective: Compass of Sigma Gamma Epsilon, v. 57, p. 1-15.

Friedman, G.M., 1981, Geology at Rensselaer Polytechnic Institute: an American epitome: Northeastern Geology, v. 3, p. 18-28.

Friedman, G.M. and Sanders, J.E., 1978, Principles of Sedimentology. John Wiley & Sons, New York, NY, 792 p.

Friedman, G.M., Sanders, J.E., and Kopaska-Merkel, D.C., 1992, Principles of Sedimentary Deposits: Stratigraphy and Sedimentology. Macmillan, New York, 717 p.

Hall, James, 1859, Paleontology: vol. III, containing descriptions and figures of the organic remains of the Lower Helderberg Group and the Oriskany Sandstone: New York Geological Survey, Natural History of New York, part 6, 532 p.

Johnson, M.E., 1977, Geology in American education: 1825-1860: Geological Society of America Bulletin, v. 88, p. 1192-1198.

Lyell, Charles, 1845, Travels in North America in the Years 1841-1842; with Geological Observations on the United States, Canada, and Nova Scotia. Wiley and Putnam, New York, v. I, 251 p., v. II, 221 p.

McAllister, E.M., 1941, Amos Eaton, Scientist and Educator 1776-1842. University of Pennsylvania Press, Philadelphia, 587 p.

Maclure, William, 1809, Observations on the geology of the United States, explanatory of a geological map: American Philosophical Society, v. 6, p. 411-428.

Maclure, William, 1818a, Observations on the geology of the United States of America..., Philadelphia, 127 p.

Maclure, William, 1818b, Observations on the geology of the United States of North America...: American Philosophical Society, Transactions, v. 1, p. 1-91.

Maclure, William, 1818c, Essay on the formation of rocks... Academy of Natural Sciences of Philadelphia, Journal, v. 1, p. 261-276, 285-310, 327-345.

Merrill, G.P., 1924, The First One Hundred Years of American Geology. Yale University Press, New Haven, 188 p.

Nason, H.B., 1887, ed., Biographical record of the officers and graduates of the Rensselaer Polytechnic Institute, 1824-1886. William H. Young, Troy, NY, 614 p.

Newell, J.R., 1997, James Dwight Dana and the emergence of professional geology in the United States: American Journal of Science, v. 297, p. 273-282.

Ospovat, A.M., The "Wernerian Era" of American Geology. Unpublished manuscript, 15 p.

Reingold, Nathan, ed., 1972, The papers of Joseph Henry, v. 1. Smithsonian Institution Press, Washington, DC, 496 p.

Rodgers, John, 1997, James Dwight Dana and the Taconic controversy: American Journal of Science, v. 297, p. 343-358.

Rodgers, John, Grasso, Thomas, and Jordan, W.M., 1989, Boston to Buffalo, in the Footsteps of Amos Eaton and Edward Hitchcock. 28th International Geological Congress, Field Trip Guidebook, T169, 99 p.

Schneer, C.J., 1978, The great Taconic controversy: Isis, v. 69, p. 173-191.

Sebring, L.B. and Sebring, L.B., Jr., 1934, Life of Lewis C. Beck, M.D., physician, traveler, geologist, author, educator: privately printed. Schenectady, NY, and New York City, 21 p.

Sharpe, Adrian P., 1998, Geosyncline, in Sciences of the Earth: An Encyclopedia of Events, People, and Phenomena, edited by Gregory A. Good, New York: Garland Publishing, p. 389-392.

Van Rensselaer, Florence, 1956, The Van Rensselaers in Holland and America. American Historical Co., Inc., New York, 103 p.

Van Rensselaer, Jeremias, 1823, An essay on salt, containing notices of its origin, formation, geological position and principal localities. O. Wilder and J.M. Campbell,

New York, 80 p.
Van Rensselaer, Jeremias, 1825, Lectures on geology; being outlines of the science delivered in the New York Atheneum in the year 1825. E. Bliss and E. White, New York, 358 p.
Wells, J.W., 1963, Early investigations of the Devonian System in New York, 1656-1836: Geological Society of America Special Paper 74, 74 p.

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COLLIDING PARADIGMS: LYELL AND THE ROGERS BROTHERS ON APPALACHIAN OROGENY

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ABSTRACT

As state geologists in the late 1830s and 1840s Henry D. Rogers (1808-1866) and William B. Rogers (1804-1882) made fundamental contributions to Appalachian geology, offering a comprehensive description of the structural features of the mountain range and proposing a causal theory to explain their origin. Exposed to the work of the Rogers brothers during his North American tours, the British geologist Charles Lyell (1797-1875) agreed with the common judgment of the time that while the descriptive component of their Appalachian studies was masterful, their theory left much to be desired. A consideration of the contrasting theoretical approaches of Lyell and the Rogers brothers, as well as the tension in their professional relations, sheds light on the transition from catastrophism to uniformitarianism in nineteenth-century geology.

INTRODUCTION

In their roles as state geologists of New Jersey, Pennsylvania, and Virginia in the late 1830s and 1840s the Rogers brothers, Henry Darwin Rogers (Figure 1) and William Barton Rogers (Figure 2), made pioneering, fundamental contributions to the understanding of Appalachian geology. Their work had two general features that they themselves, as well as their boosters and critics, sharply distinguished. In the first place, building upon wide-ranging field surveys, they mapped extensively and constructed an accurate empirical description of the structural features of the mountain range. Although their underestimation of the dimensions of horizontal overthrusting has been noted (Merrill, 1906),[1] the descriptive side of their work has been universally praised and admired (Greene, 1984). Secondly, venturing into geological dynamics, they proposed a theory explaining how the structural pattern they described originated and gave it broad scope by applying it to other mountain ranges and by employing an adaptation of its central hypothesis, crustal undulations, to explain coal and drift (glacial) deposits. By citing analogies with observable phenomena, as well as a wide range of application, they tried conscientiously to build a case for the soundness of their causal theory.

As "the first coherent view" (Faill, 1985, 24) of Appalachian mountain building the theory initially sparked wide interest, but ultimately it was not a success, winning no permanent converts and having no role in the debates on Appalachian orogeny that soon engaged James Hall (1811-1898), James Dwight Dana (1813-1895), Thomas Sterry Hunt (1826-1892), Joseph LeConte (1823-1891), and others. In retrospect it is tempting to ascribe the poor response to the theory simply to its grounding in excess speculation and a dubious mechanics of crustal deformation (Vose, 1866). Yet, in comparison with the widely credited orogenic views of Léonce Elie de Beaumont (1794-1874), who found the origin of mountains in sudden, proxysmal bucklings of the crust, it does not appear to have been markedly less "scientific." Other factors, evidently, were more weighty in conditioning how it was judged. Of course, the favor enjoyed by Elie de Beaumont's theory (Greene, 1984) had the effect of putting any newly proposed theory under a disadvantage, but the

1. John Peter Lesley to James Dwight Dana, 17 Sept. 1890, Dana Family Papers, Yale University Library, New Haven, CT.

Figure 1. Henry Darwin Rogers (E.S. Rogers, 1896).

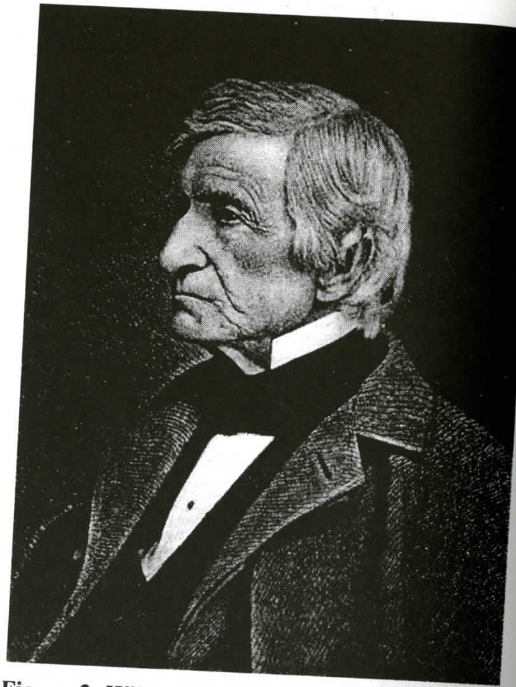

Figure 2. William Barton Rogers (E.S. Rogers, 1896).

more decisive factor in the indifferent success of the Rogers brothers' dynamic scheme was probably the shift away from catastrophism in geological thinking that was then in progress. "Wildly catastrophistic" (Greene, 1984, 124), the Rogers brothers' orogenic views were unlikely to find credit with geologists who were flocking to the uniformitarian banner. Not surprisingly, it had no standing with James Hall, who had his own, thoroughly gradualistic take on mountain elevation (Dott, 1979; Greene, 1984; Mayo, 1985). But the clash in fundamental geological paradigms emerges most clearly in the response to the Rogers brothers' theory made by Charles Lyell, the foremost of the uniformitarians, and, thanks to his geological expertise and personal engagements with the Rogers brothers, a colleague well situated to appraise their theory.

Lyell made his first visit to North America when the Rogers brothers were still actively engaged in their surveys. In the fall of 1841, not long after his arrival in America, the visitor was taken by Henry Rogers, whose acquaintance he had made in London nearly a decade earlier, on an eleven-day excursion through the anthracite district of Pennsylvania (Lyell, 1845; Brice, 1978). "We went," Rogers reported in a letter to his brother William, "by way of Reading to Pottsville, Mauch Chunk and Beaver Meadows, returning by Easton and the Delaware, through Trenton" (E.S. Rogers, 1896, I, 194). Pleased with the opportunity to explain his work and display the field evidence on which it rested, Rogers pressed his interpretive views on Lyell and believed--too optimistically, as time would prove--that he had won him over. Writing again to William, Rogers proudly remarked, "I did not state in my last [letter] how greatly I astonished Lyell at the breadth of some of our results and doctrines connected with *structure*. Though incredulous for the first day or two, even as to the thickness of our rock, I quite made a convert of him before we parted" (E.S. Rogers, 1896, I. 197). Seven months later at the meeting of the Association of American Geologists in Boston Lyell heard the Rogers brothers read a paper making public for the first time a summary of their Appalachian findings.

THE ROGERS BROTHERS' THEORY

The mountain-building theory they presented in 1842 had been in hand for some time, indeed, as early as 1837, soon after Henry completed his first year of fieldwork on the Pennsylvania survey (Gerstner, 1994). Though intended for presentation at the next meeting of the British Association for the Advancement of Science, the manuscript account of the theory drawn up by Henry at this time was never submitted and resides today, still unpublished, in the library of Brown University (Gerstner, 1994). Nevertheless, the Rogers brothers already had the gist of their theory by this early date, and the importance of subsequent fieldwork was largely to refine it. In their public presentation of the theory in 1842 William read the topographical or descriptive portion of the paper and Henry its dynamical or explanatory part (W.B. Rogers and H.D. Rogers, 1843). Essentially unchanged, the theory was again set out in full sixteen years later in Henry's final report on the geology of Pennsylvania (H. Rogers, 1858).

Before we examine Lyell's response, a brief summary of the theory will be useful. Consider first the descriptive part. With justifiable pride the Rogers brothers announced that they had discovered structural laws regulating the confusing complex of folded, broken, and partially denuded elements that make up the broad belt of the Appalachians extending 1300 miles from northern New England to Alabama. At the most fundamental level they drew attention to the fact that, unlike some other mountain chains, the Appalachians lack a prominent central ridge, having instead the structure of a giant washboard with numerous, lesser ridges running parallel to one another. Long, narrow, of nearly equal height, the ridges are sometimes almost perfectly straight and sometimes gently curved. Within this general structural framework the Rogers brothers distinguished nine subdivisions extending from north to south and, at right angles to the strike of the range, four major parallel zones extending southeast to northwest. The key observation was that toward the southeast, the crustal folds occupying these zones are tight and arch over so that their "axial planes," rather than being normal to the horizon, dip acutely to the southeast. As one proceeds to the northwest the folds gradually flatten out, displaying gentler slopes and a more symmetrical profile.

To visualize what the Rogers brothers were describing, refer to Figure 3. Since the sections the Rogers brothers appended to the published version of their 1842 paper have long horizontal extensions with minimal vertical exaggeration and are therefore difficult to reproduce, we avail ourselves of an idealized section published by Lyell in his *Travels in North America* to illustrate the Rogers brothers' findings (Lyell, 1845). Divided into two segments placed one above the other, Lyell's section represents a stretch of 850 miles extending from the Atlantic Ocean to the Mississippi Valley. Note the tight plications in the east and particularly the overturned fold. Note further that, as we proceed westward, the terrain flattens out and the last major fold, the doming around Cincinnati, is regular with a very low profile. While it fails to suggest the abundance of accurate detail that the Rogers' brothers incorporated into their picture of the Appalachians, Lyell's section gives an adequate idea of the main elements and overall pattern of their descriptive scheme.

In the dynamical theory the Rogers brothers proposed to explain these descriptive findings, the region now occupied by the Appalachian mountains was originally a submerged basin of crystalline rock that until late in the Paleozoic gradually filled with sediments. Beneath the crust supporting these deposits was a sea of liquid lava and the gaseous vapors it evolved. From time to time the pressure here would be released as the gases exploded upward through the crust making long, narrow fissures. Rising into these vents and then rebounding downward the molten matter would vibrate, sending a train of waves laterally beneath the crust. Lifted and dropped in succession, the overlying crust bore the impress of these undulations and retained its foldings, filled and supported from below with congealed magma, when the disturbance had passed. But the crustal foldings would have been symmetrical, if that were all there had been to the disturbance. To explain why they are

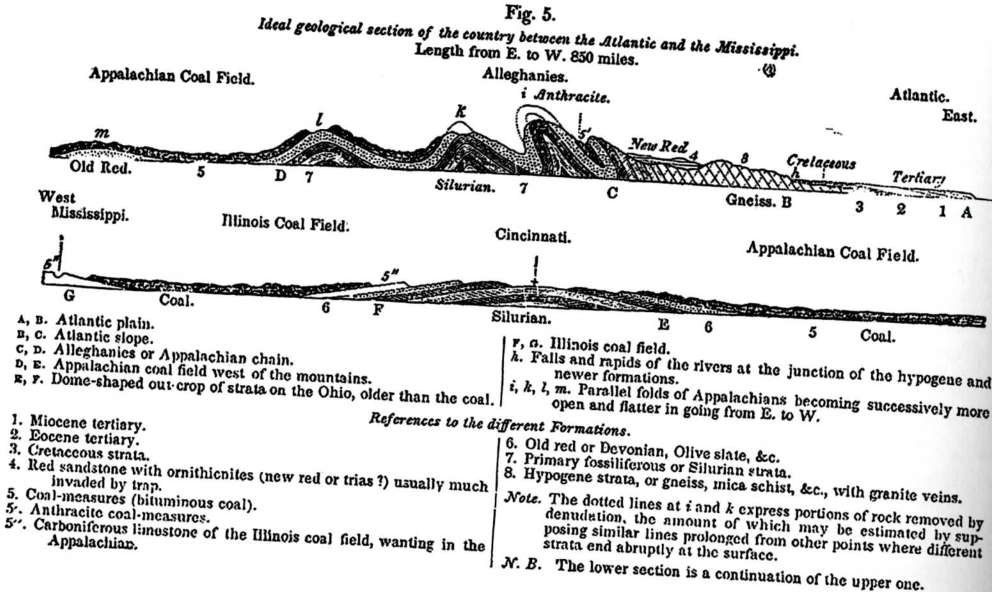

Figure 3. Idealized Vertical Section from the Atlantic Ocean to the Mississippi River (Lyell, 1845).

overturned the Rogers brothers postulated a tangential or horizontal force that acted at the same time as the oscillatory motion and shoved the crust to the northwest. Since the strata of which the folds consist are nearly all conformable, the major disturbance--there may have been feeble ones at other times--could be dated to the end of the Carboniferous.

LYELL'S RESPONSE TO THE THEORY

Sitting in the audience in Boston when the Rogers brothers gave their paper, Lyell warmed to "the ready eloquence" of the two Americans and "freely expressed his surprise at the ability and profound research which were exhibited" (Emerson, 1843). Nevertheless, it is not unreasonable to suppose that some negative thoughts also crossed the mind of the British visitor as he listened to the presentation. Nor was the scientific content of the paper all that would have piqued him. A month before the meeting an article had appeared in a Boston newspaper under the pseudonym "Hamlet"--the author was James Hall, assisted by George B. Emerson (1797-1891)--charging that Lyell was employing his American tour to misappropriate the hard-won and still-unpublished findings of American geologists (Silliman, 1995). Should he publish the material generously put at his disposal, he would be guilty of "piracy in its worst form."[1] Though smarting from the allegation, Lyell had the strength of character to show up at the meeting and act as if nothing were wrong. The Americans, for their part, were civil enough to the visitor, but his presence in their midst produced underlying tensions that surfaced in various ways. Henry Rogers, troubled that his hospitality and openness to Lyell in Pennsylvania might he repaid by the theft of his work, was hardly conciliatory. As if to build himself up at Lyell's expense, several times during the meeting he pointedly contested the geological views of the British visitor. In the Appalachian paper, for example, he rejected Lyell's suggestion that the wave-like ground movements associated with earthquakes might be referred to "vibratory jars" within solid rock rather than to continuous waves in a hypothetical subcrustal lava (W.B. Rogers and H.D. Rog-

1. James Hall to Benjamin Silliman, Sr., 28 Mar. 1842, Silliman Family Papers, Yale University Library, New Haven, CT.

ers, 1843). The disagreements between Lyell and the Rogers brothers on Appalachian geology were certainly not determined, but they were likely colored, by their personal-professional differences. Nurturing a sense of rivalry with Lyell, the Rogers brothers sharpened their opposition to Lyellian principles and persisted in it for years. Wanting to be conciliatory, Lyell actively supported the descriptive work of the Rogers brothers, but he could not bring himself to say anything good about their causal theory.

In fact, only once did Lyell make any public comment on the causal theory, even though successive editions of his *Manual* or *Elements of Geology* included a summary of the Rogers brothers' descriptive account of the Appalachians and credited them with the "important discovery of a clue to the general law of structure prevailing throughout this range of mountains" (Lyell, 1865, 495). This approach to the work of the Rogers brothers, praising their descriptive findings and ignoring their causal theory, was already evident in the paper Lyell sent back to the Geological Society of London, reporting on his Pennsylvania tour (Lyell, 1842). Here, citing an Appalachian map shown him by Henry Rogers, he gave a brief characterization of the overall pattern of parallel ridges and noted that the Pennsylvania coals are successively bituminized as one proceeds northwesterly away from the area of greatest disturbance on the southeast. On the cause of the disturbance he made no comment.

When Henry Rogers read this paper, he was not pleased, perceiving that it gave him insufficient credit for the novel facts it reported (E.S. Rogers, 1896), and from this point onward he aligned himself with those harboring suspicions that Lyell was, indeed, capable of intellectual piracy. Anxious to allay these suspicions and get back on good terms with the Americans, Lyell went out of his way to be helpful to Henry Rogers. When it seemed that another foreign visitor to Pennsylvania, William E. Logan, was making unacknowledged use of Rogers' work, Lyell came to the latter's defense, meeting with Logan and chastising him for his illicit borrowings (Silliman, 1995). To prevent any future misappropriations, Lyell urged Rogers to draw up an account of his Appalachian investigations for the Geological Society of London or the British Association. Rogers took the advice, sending off a paper for the British Association meeting in Manchester in 1842. While the paper stirred much discussion, it was generally agreed that for want of accompanying diagrams it was rather obscure. When the British Association met the following year in Cork, Lyell took to the podium and, displaying a transverse section of the Appalachians furnished him by the Rogers brothers, gave a more effective account of their "law of general structure," noting that he himself had verified it in the field (Silliman, 1995).

Lyell's only public reference to the Rogers brothers causal theory was made two years later in his *Travels in North America*. Here he explicitly dissented from the theory, saying, "I cannot imagine any real connection between the parallel undulations of the rocks and the real waves of a subadjacent ocean of liquid matter, on which the bent and broken crust may once have rested" (Lyell, 1845, I, 78). Though allowing that the existence of a hypothetical sea of liquid lava was probable, Lyell proposed a different explanation for the phenomena. The parallel ridges he ascribed to a gradual process that began with a heat-induced vertical uplift in narrow, contiguous zones. Uplift might have been simultaneous over a broad belt or successive in one narrow zone after the other. In the course of time the subterranean heat would diminish, bringing local collapse and crumbling. In other words, the plications, fractures, and lateral thrusts that made the mountain range what it was were produced during the subsidence phase of the process, when, because of cooling, the rock strata were squeezed into a contracted space. In judgment on his own hypothesis, as well as on that of the Rogers brothers, Lyell wrote of "the difficulty of restoring in imagination the successive changes which have occurred, and of accounting in a satisfactory manner for the origin of this mountain chain" (Lyell, 1845, I, 80).

This statement might have served as an epigram for Lyell's understanding of mountain building in general, a subject that was little developed in his geological thinking. In a debate on orogeny that heated up among British geologists in the 1830s his contribution was merely critical, consisting of an attack on the Elie de Beaumont's paroxysmal scheme of mountain elevation. Lyell assailed the theory, not because it contradicted a theory of his own, but because he saw in its popularity a threat to his campaign to promote uniformitarian principles. The mountain-building theory of Elie de Beaumont, he judged, lent unwelcome support to the catastrophists; so, too, did that of the Rogers brothers, though in its assumption of constant heat within the Earth it had at least one uniformitarian feature (Greene, 1984). Lyell's commitment to the formative role of slow, gradual, continuous processes in the history of the Earth made him critical of contemporary mountain-building schemes, virtually all of which were non-uniformitarian. At the same time, his uniformitarianism hampered him from conceiving an alternative theory. Routinely he invoked elevation and subsidence to explain varied geological phenomena, but a satisfactory explanation for folded mountains on uniformitarian principles eluded him.

CONCLUSION

Ironically, in light of Lyell's scant public treatment of it, the Rogers brothers' theory fell victim to the spread of uniformitarian thinking. Initially the theory received a few favorable notices, but it soon dropped from view (Gerstner, 1975). Those interested in Appalachian orogeny looked rather to the newer, more sophisticated conceptions of Hall and Dana (Vose, 1866). Lyell kept himself informed about these developments, confessing, however, that he felt "greatly in the dark," when speculating on the subject. Perhaps because of his uncertainties he continued for a long time to mull over the work of the Rogers brothers and corresponded about it with Henry Rogers' successor as state geologist of Pennsylvania, J. Peter Lesley (1819-1903). In an 1869 letter to Lesley, Lyell penned a tribute to the importance of Rogers' field observations. "Without adopting his theory of the cause," he wrote, "his description of the undulations is very clear. If it really be a general law in the Alleghanies, Alps & the Rhine that there is always a steepening of the flexure of the folds on the side toward which the movement has proceeded, it is a grand fact. No hypotheses which will not explain this ought for a moment to be entertained."[1] Lyell could go no further than that.

Nor is there evidence, at least over the short term, of any greater intellectual flexibility and movement on the part of the Rogers brothers. On October 28, 1852, Lyell and Henry Rogers had a conversation in Boston, where Lyell had come on his third American tour to lecture at the Lowell Institute. Talk turned to the subject of Lyell's forthcoming lecture on the Richmond (Massachusetts) boulder trains, a glacial phenomenon on which the two geologists disagreed, Lyell interpreting it in the uniformitarian mode of oceanic submergence and ice-rafting and Rogers invoking a diluvial catastrophe brought about by crustal undulations originating beneath the Arctic Ocean. Not letting their differences rest, Rogers, as Lyell reported the conversation, "threw down the gauntlet first, & especially appealed to the case [of the boulder trains] as disproving my mode of dealing with geology"[2]. Years later Rogers was sounding the same theme. On December 23, 1859, he wrote to his brother William, informing him of the appearance of the *Origin of Species* and remarking, "When you read it you will often say, I think, that in his geology Darwin outdoes Lyell himself in ignoring paroxysmal actions. This is its chief blemish with me" (E.S. Rogers, 1896, II, 18). But the passage of years finally brought a changed outlook. When in the late 1870s William Rogers was queried about the treatment he and his brother had accorded the Richmond boulder trains in their paper of 1845, he replied: "At that time (i.e., when this paper was written) paroxysmal dynamics had still many advocates, and the attempted ex-

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1. Charles Lyell to John Peter Lesley, 27 Mar. 1869, Lyell Papers, Edinburgh University Library, Edinburgh, Scotland.
2. Charles Lyell to James Hall, 25 Oct. 1852, Hall Papers, New York State Archives, Albany, NY.

planation may be interesting as a specimen of the bold type of speculation in which some of the early geologists ventured to indulge. But, for myself, I may say that long years of observation and study make me more distrustful of our knowldge of causes and more willing, in geology as in other things, to labor and wait" (Merrill, 1906, 405). Had he been asked about the 1842 paper on the Appalachians, he could only have said the same thing.

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REFERENCES CITED

Brice, W. R., 1978, Charles Lyell and Pennsylvania: Pennsylvania Geology, v. 9(2), p. 6-11.

Dott, R.H, Jr., 1979, The Geosyncline--first major geological concept "made in America": Two Hundred Years of Geology in America, C.J. Schneer, ed., University Press of New England, Hanover, p. 239-264.

Emerson, G.B., 1843, Professor Rogers Lectures: Boston Daily Advertiser, Nov. 29.

Faill, R.T., 1985, Evolving tectonic concepts of the central and southern Appalachians: Geologists and Ideas: A History of North America Geology, E.T. Drake and W. M. Jordan, eds., Geological Society of America, Centennial Special Volume 1, p. 19-46.

Gerstner, P.A., 1975, A dynamic theory of mountain building: Henry Darwin Rogers, 1842: Isis, v.66, p.26-37.

Gerstner, P.A., 1994, Henry Darwin Rogers, 1808-1866, American geologist: University of Alabama Press, Tuscaloosa & London, 311 p.

Greene, M.T., 1984, Geology in the nineteenth century. Changing views of a changing world: Cornell University Press, Ithaca & London, 324 p.

Lyell, C., 1842, A letter addressed to Mr. Fitton [on some of the phenomena connected with the coal measures and older strata of Pennsylvania]: Proceedings of the Geological Society of London, v. 3, p. 554-558.

Lyell, C., 1845, Travels in North America, in the years 1841-2; with geological observations on the United States, Canada, and Nova Scotia: Wiley and Putnam, New York, v. 1, 251 p., v. 2, 221 p.

Lyell, C., 1865, Elements of geology, or the ancient changes of the earth and its inhabitants as illustrated by geological monuments: John Murray, London, 794 p.

Mayo, D.E., 1985, Mountain-building theory: The nineteenth-century origins of isostasy and the geosyncline: Geologists and Ideas: A History of North American geology, E.T. Drake and W.M. Jordan, eds., Geological Society of America, Centennial Special Volume 1, p. 1-18

Merrill, G.P., 1906, Contributions to the History of American geology: Report of the United States National Museum for 1904, 135, Government Printing Office, Washington D.C., p.189-734.

Rogers, E.S., editor, 1896, Life and letters of William Barton Rogers: Houghton, Mifflin & Co, Boston & New York, v. 1, 427 p, v. 2, 451 p.

Rogers, H.D., 1858, The geology of Pennsylvania. A government survey with a general view of the geology of the United States, Vol. II: W. Blackwood & Sons, Edinburgh & London; J. B. Lippincott, Philadelphia, 1045 p.

Rogers, W.B. & Rogers, H.D., 1843, On the physical structure of the Appalachian chain, as exemplifying the laws which have regulated the elevation of great mountain chains, generally: Reports of the First, Second, and Third Meetings of the Association of American Geologists and Naturalists, Gould, Kendall, & Lincoln, Boston, p. 474-531.

Silliman, R.H., 1995, The Hamlet affair: Charles Lyell and the North Americans: Isis, v. 86, p. 541-561.

Vose, G.L., 1866, Orographic geology; or, the origin and structure of mountains. A review: Lee and Shepard, Boston, 135 p.

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ON 'CREEKS' AND 'RUNS' OR WHY THERE WERE TWO BATTLES OF BULL RUN AND NOT TWO BATTLES OF BULL CREEK

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ABSTRACT

For about the first 250 years of European settlement in northern Virginia, the terms 'creek' and 'run' were mutually exclusive categories, creeks being narrow tidal waterways and runs being relatively steep upland streams. A map prepared by George Washington about 1767 illustrates this understanding. Over the last century, 'creek' changed meaning so that 'creek' and 'run' have become synonyms, with 'run' having archaic and colloquial implications. These changes were the somewhat delayed realization in northern Virginia of a national trend that was noticed at the beginning of the 19th century in Noah Webster's dictionaries (1806, 1828). For most of the time since initial settlement, the tidal waterway now known as the 'Occoquan River' was known to local residents as 'Occoquan Creek', even though 18th- and 19th-century regional maps labeled the waterway 'Occoquan River'. Beginning at the end of the 19th century, the local name, 'Occoquan Creek', appeared on maps and persisted until around 1970, when the mapped name went back to 'Occoquan River'. In both these later changes, the U.S. Geological Survey probably responded to local usage and influenced other map makers. Northern Virginia streams now known as Pohick Creek, Accotink Creek, and Dogue Creek were known as Pohick Run, Accotink Run, and Dogue Run in the 18th and 19th centuries. These changes from 'creek' to 'river' and from 'run' to 'creek' reflect the Americanization of the English meaning of 'creek' as colonists from the tidewater moved inland and upstream. Bull Run has remained Bull Run because it was clearly tributary to the Occoquan, in the same way that South Run, the major tributary in the Pohick drainage, has remained South Run.

NORTHERN VIRGINIA STREAMS

Washington's Map

Bull Run and other streams named in this paper have their sources on the metamorphic and igneous rocks of the northern Virginia Piedmont. The streams flow off the Piedmont, through steep incised valleys across the Fall Line, and out onto the inner margin of the Coastal Plain to the tidal Potomac. The distance between upland Piedmont and tidewater is remarkably short. Names given to these streams reflect this geomorphology and English colonial history.

In 1742, the legislature of colonial Virginia formed the County of Fairfax from the northern part of the County of Prince William. The legislature set the boundary between the counties on "the south side of Occoquan and Bull Run." Bull Run is the major tributary of the Occoquan, and the Occoquan is a tributary to the Potomac River. Because the Potomac is a tidal, but fresh water, river at the shores of southeastern Fairfax County, the lower Occoquan is a large fresh-water tidal estuary of the Potomac.

The southeastern shores of Fairfax County were the earliest settled parts of the county (Stetson, 1935), and include Mount Vernon and Gunston Hall, the colonial homes of George Washington and George Mason. George Washington drew a map of that area (Truro Parish),

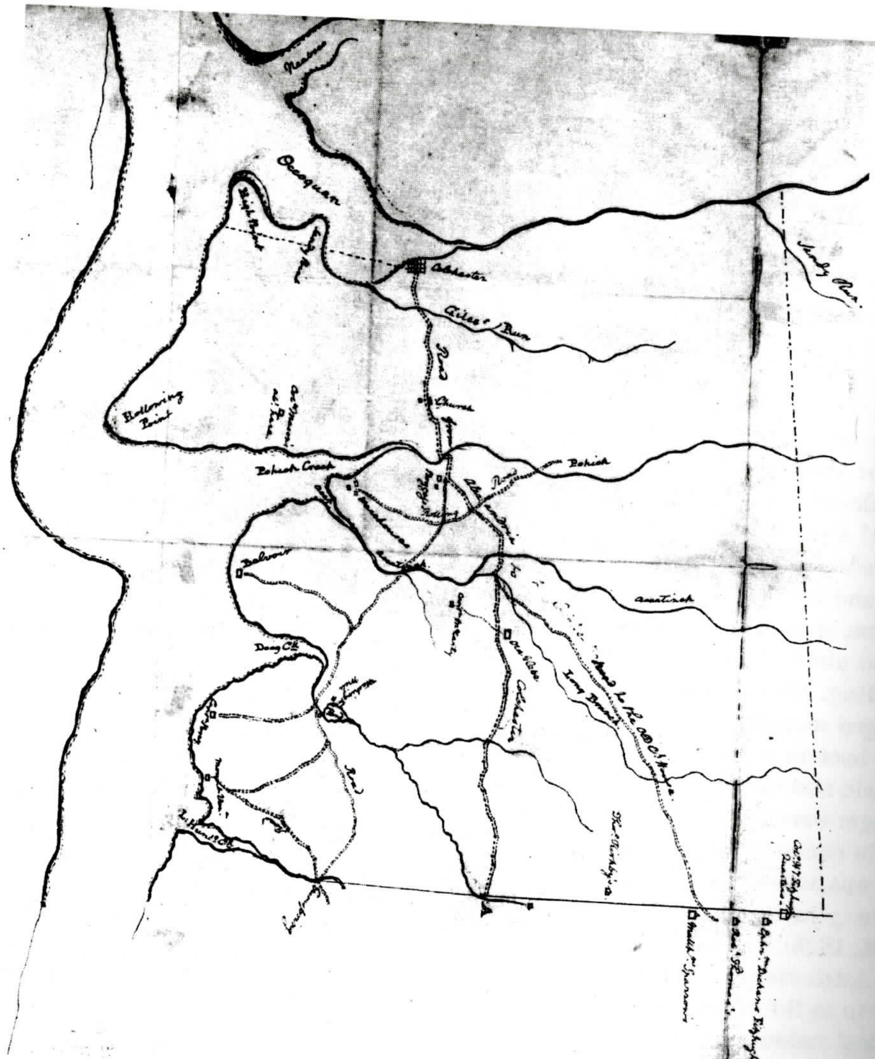

Figure 1. Part of George Washington's "Sketch of Roads and Country between Little Hunting Ck and Colchester", probably finished in November 1767 (Stephenson, 1983). Southwest is at the top. The tidal Potomac River is along the left side, with downstream towards the top. The letter A in bottom center marks "the Ford at Doeg Run". From A to Colchester on the Occoquan is about 9.5 miles (15.3 km). From the copy of a copy in the Collections of the Library of Congress. 1967 gift of Prof. Wills, Birmingham.

probably in November 1767, which he labeled "Sketch of the roads and country between Little Huntg Ck and Colchester" (Stephenson, 1983). Little Hunting Creek is a tidal stream that enters the Potomac River just upriver from Mount Vernon, and Colchester, which is now an archeological site, was a tobacco port on the Occoquan. According to Stephenson (1983): "Washington based his Truro Parish map on the survey of the parish boundaries completed by George West on June 15, 1765; he then added road surveys he made in November 1867... It is possible that Washington used this map at a meeting of the vestry of Truro Parish on November 20, 1767, when a new location for Pohick Church was being discussed." Figure 1 is part of that Truro Parish sketch showing the Potomac shore of southeastern Fairfax County.

The tidal waterways named on Washington's sketch include, from west to east, 'Occoquan', 'Pohick Creek', 'Doeg C^{k}', and 'L. Huntg C^{k}'. Upland tributaries of these waterways named on Washington's sketch include 'Sandy Run', 'Giles Run', 'Pohick', 'Accotinck', and 'Long Branch'. Washington wrote 'Run' and 'Branch' on streams that were clearly, from their location on his sketch, upland and non-tidal. Washington wrote 'Creek' or 'C^{k}' on waterways that were clearly, from their location on his sketch, tidal tributaries of the Potomac. Washington did not name the Potomac on his sketch, although he drew its banks.

The Occoquan

Since at least 1654, 'Bull Run' has been the name (in English) of the principal tributary entering the Occoquan (Mitchell, 1979), but the 'Occoquan' has alternated between 'River' and 'Creek' through the years. (The spelling of 'Occoquan' has varied widely, but that is not considered here. In this paper, I use late 20th-century spellings, except where stated otherwise.)

Neither the Washington sketch nor the 1742 law that divided Fairfax County from Prince William County go further than the word 'Occoquan'. Most early regional maps, and acts of the Virginia legislature dealing with ferries, identify the Occoquan as a 'river'. The Occoquan is a river on maps of Virginia by Joshua Fry and Peter Jefferson (1755, 'Occoquan R.'), Bishop James Madison (1807, 'Occoquan R.'), and Herman Böye (1826, 'Occoquan River'); on several Civil War maps from both sides including General Irvin McDowell (Aug. 1862, 'Occoquan River'), Engineer Department of the Union Army (1863, 'Occoquan River'), and a map among papers of General Jubal Early ('Occoquan River'); and on the influential G. M. Hopkins' map (1879, 'Occoquan River'). In the above list, Peter Jefferson was the father of President Jefferson, and Bishop Madison was the first cousin of President Madison. The map of Virginia by David H. Burr (1839) was the only widely distributed pre-Civil War map that departs from 'River', but the Burr map has 'Occoquan Cr' only for the area above the mouth of Bull Run and has no name below Bull Run. All the maps mentioned in this paragraph are included in the compilation by Stephenson (1983).

At Colchester, the Occoquan is about 200 meters wide and 4 meters deep, which satisfies the present (1999) conception of 'river'. However, until relatively recently, local people probably did not call the Occoquan a 'river'. Probably, they called it a 'creek'. The history of Colchester shows that the Occoquan was called a 'creek' in public documents of 1653, 1797, 1814, and 1872 (see pages 6, 94, 108, 121 of Sprouse, 1975), but a 'river' during the Civil War (p. 117 of Sprouse, 1975). A listing (Lossing, 1912) of many skirmishes during the Civil War includes one on 'Occoquan Creek', 12 November 1861, in which three Union soldiers were killed and one wounded, but none that say Occoquan 'River'. Because Lossing probably died in 1891, his book reflects 19th-century usage. On the other hand, Long (1971) lists four incidents on the 'Occoquan River', including this 12 November 1861 skirmish, but here, the later 20th-century 'river' is probably an anachronism.

More convincing that 'creek' was the preferred local term in the 19th century is the definition of election district boundaries in the Fairfax County Deedbook (1852, Q–3:489) which states that part of the boundary of Election District 2 runs "with the old Colchester road to Occoquan *Creek*, and with the *creek* to Wolf Run..." [emphasis added].

This preferred local usage eventually affected map makers, particularly the influential quadrangle mapping program of the US Geological Survey (USGS). The 1888 Mount Vernon 30-minute quadrangle is the earliest USGS map to include the Occoquan (Moffat, 1985), and this map says 'Occoquan Creek'. Towards the end of the 19th century and into the early 20th century, other maps began to name the Occoquan as a 'creek", the later maps probably relying on the authority of the USGS for the change. In the list that follows, the USGS published all maps identified as 'quad', i.e., quadrangle. Among other sources in the Virginia

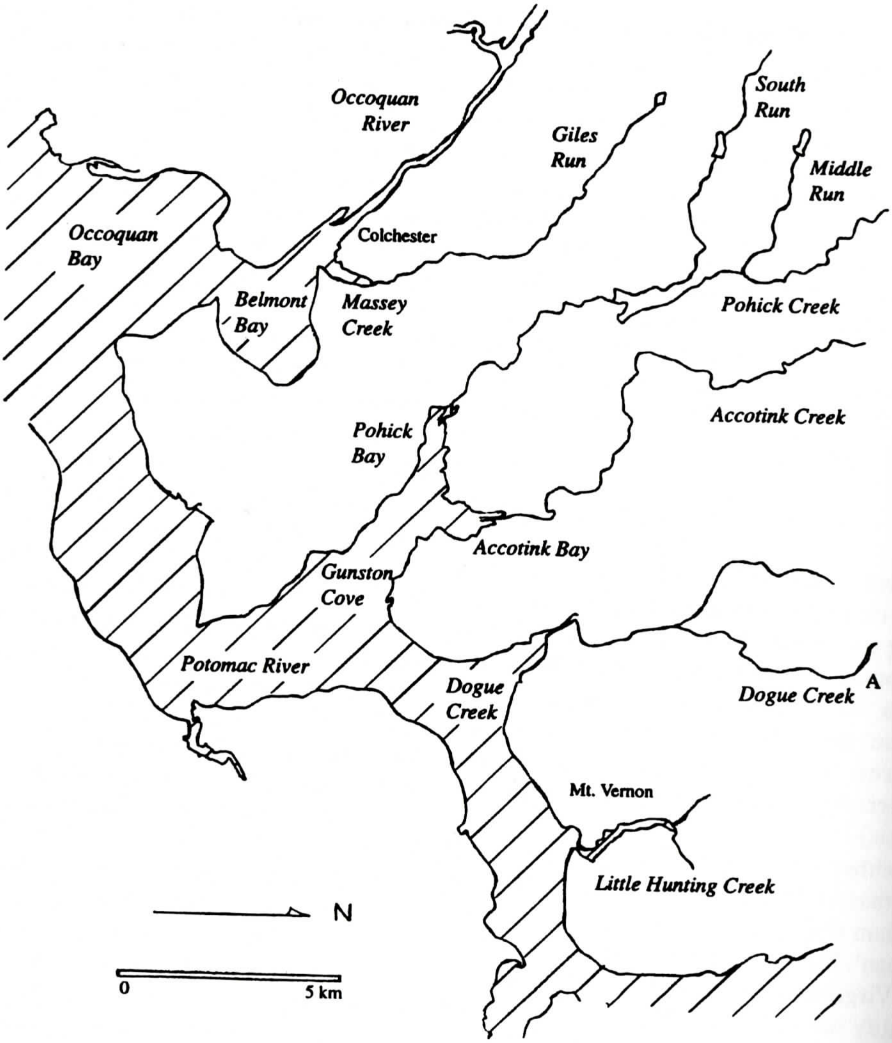

Figure 2. Names of waterways and streams in southeastern Fairfax County, Virginia, drawn from USGS Fairfax County map, 1991. Original scale is 1:50,000. West is at top. The "Ford at Doeg Run" shown on Figure 1 is at A on the right edge of this map.

Room, Fairfax Library, that show this change from 'river' to 'creek' are:

1894 Mount Vernon 30-minute quad (reprinted 1909)

1897 Mount Vernon 30-minute quad

1912 Rural Mail Delivery Routes, Post Office Department

1923 Fort Humphries map

1927 Quantico 15-minute quad

1927 Fairfax County Chamber of Commerce Map

1930 Map of Fairfax County, Office of County Engineer

1945 Virginia Geological Survey, Bulletin 64, p. 35

1951 Belvoir [sic] $7^1/_2$-minute quad

1956 Occoquan $7^1/_2$-minute quad

1957 Quantico 15-minute quad

This change from 'river' to 'creek' was reversed during the last half of the 20th century when the mapped identity of the Occoquan changed back from 'creek' to 'river'. The formal change by the Board on Geographic Names in the Department of Interior occurred on 8

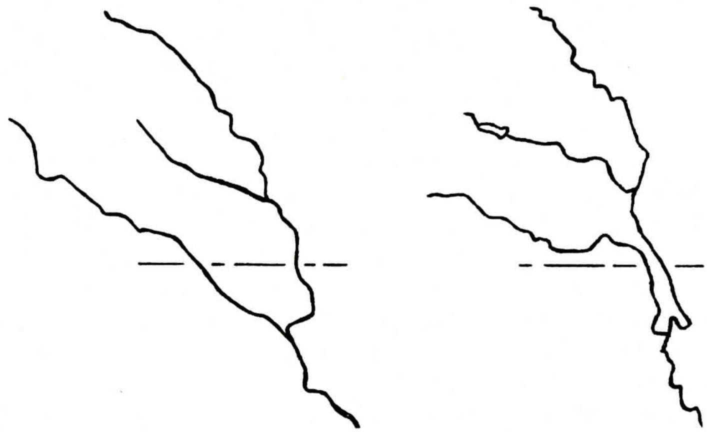

Figure 3. Contrast in mapped drainage of Pohick Creek circa 1900 (left) and today (right). Surveys of 1885 - 1887 were used from 1888 to 1920s. Horizontal dashed line at constant latitude. Along this line, stream thalwegs and divide between streams are at approximately same elevation on both maps, but distance between mapped streams was about 2.5 km circa 1900 and 0.2 km today. Earlier map assumes dendritic drainage which does not exist. Earlier map shows downstream-pointing stream junctions which neither Middle Run nor South Run have. Refer to Figure 2 for stream names.

April 1971, apparently due to the agitation of an 80-year old resident, Mrs. Rosemary Selecman (see the *Journal Messenger*, Manassas, Virginia, 6 May 1971). This reversal was shown immediately by the Occoquan quad (1956 edition, revised 1966, photorevised 1971) and the Fort Belvoir quad (1965 edition, photorevised 1971). These two quads and their subsequent revisions in 1984 and 1983, respectively, use 'Occoquan River' rather than 'Occoquan Creek'. Everywhere, the Occoquan is identified as a 'river', both below and above the Occoquan Dam.

Pohick and Accotink Waterways

In Fairfax County, the name Pohick is given to a stream, a tidal bay, a road, an Episcopal Church built in 1772, and a small settlement dating to earliest colonial times. The name may be related to an Indian word, *pawcohiccora*, for an oily food removed from kernels of the shagbark hickory nut (Little, 1995, p 353). Hickory trees are still abundant on some bottomlands along Pohick Creek.

On 20th-century maps and charts, the tidal water body that George Washington labeled 'Pohick Creek' (Figure 1) is now three named water bodies, none of them 'Pohick Creek' (Figure 2). Figure 2 is compiled from the 1991 US Geological Survey (USGS) map of Fairfax County. Washington's 'Pohick Creek' is now Pohick Bay, Accotink Bay, and Gunston Cove. The upland streams that Washington labeled simply 'Pohick' and 'Accotinck' are now Pohick Creek and Accotink Creek, respectively (Figure 2). (On other maps, 'Pohick' appears under many spellings including 'Pohic', 'Poheik', 'Poheick', Poehick', 'Pohica', and 'Polish'. On Figure 1, Washington used 'Accotinck' for 'Accotink'.)

The upland streams now called 'Pohick Creek' and 'Accotink Creek' were for most of their histories known as Pohick Run and Accotink Run. According to Beth Mitchell (1979), 'Accotink Run' was first used in a land patent in 1694, after which time the other stream assumed the name of the bay and became 'Pohick Run'. The chain of title to deeds for lands abutting Pohick Creek or Accotink Creek at the end of the 20th century often remembers the 18th- and 19th-century Pohick Run or Accotink Run.

Pohick Run was considered to have three branches: the main or north branch of the Pohick (present Pohick Creek); the middle branch (present Middle Run); and the south branch of the Pohick (present South Run). The maps show that the spatial relations of these three streams were comparatively unknown into the 20th century (Figure 3). Map makers and geomorphologists expect tributaries to join the main stream at an oblique angle that points downstream, so the mapped junctions of Middle Run with Pohick Creek and South Run with Pohick Creek were shown as oblique angles pointing downstream well into the 20th century. The 1897 USGS quad shows South Run meeting Pohick Creek at an exaggerated oblique angle pointing downstream (Figure 3, left). But in the field, the junctions are not as expected: Middle Run flows north to join the south-flowing Pohick Creek, and South Run joins Pohick Creek at a right angle (Figure 3, right). These unusual junctions are not the results of temporary meandering in alluvial channels because both actual junctions are more-or-less fixed by bedrock.

About 1.5 km upstream from where South Run empties into Pohick Creek, the two streams are actually less than 200 meters from each other. (See description of Stop 3 in the Field Guide by Galvin, and others (1998).) But maps such as Hopkins's (1879) map show the two streams at this point to be about 1.6 km apart. The USGS 1897 Mount Vernon quadrangle shows about 2.5 km, rather than under 200 meters, between the streams at this latitude! On the map, a fictitious hillslope occupies the actual South Run valley. The overgrown, steep terrain makes it understandable why such fundamental geography could remain unknown into the 20th century, although the area is within 30 km of the US Capitol Building in Washington. This territory contains the boundary between Piedmont and Coastal Plain, the Fall Line, and it is even today quite inaccessible on the ground. The August 1862 Civil War map of General McDowell contains only one warning for the troops in northeastern Virginia, and that is the phrase "Difficult Passage" added to the land between Middle Run and Pohick Creek (Davis, and others, 1891-1895).

The choice between 'creek' and 'run' might vary along the same stream: 'creek' might be applied upland to the 'run' if the person approached the stream from the downstream (tidal) side. For example, land purchased by George Riley in April 1843 lies just below what is now (1999) highway I95, and it extends about 430 meters along Pohick Creek in today's terminology (Mitchell, 1998). Boundaries of Riley's land were surveyed sometime between 5 November 1867 and 30 January 1869 to establish the estate left by a neighbor (see CFF#57e, Kincheloe v. Kincheloe, 1867 (1869) in Fairfax County Court Archives). The surveyor (Thomas Carter) of that land labeled the stream itself 'Pohick Creek' on his plat, and started his survey on the south (downstream) side of the Riley property. He went inland along the south boundary of the property, north along Pohick Road, and came back to the stream on the north boundary of the property. In the wording used by the surveyor for the deed, he says 'Pohick Creek' and 'said creek' at the starting point on the south property line. When he returns to the same stream on the north property line, the deed says 'Pohick Run' and 'said run'. The surveyor uses 'Creek' and 'Run' for the same stream at points only about 430 meters apart. Possibly, the surveyor changed terms because of rapids which extend about 30 meters along Pohick Creek between the north and south boundaries of the property. Below this rapids, the Pohick is a typical coastal plain stream, and above it, there are many rapids across the Fall Line more severe than those at the Riley property.

The Riley rapids itself has its own geologic interest. The bedrock of the rapids is clearly a metamorphosed sediment, probably the upper Ordovician Quantico Formation of Seiders and Mixon (1981), but it is mapped by them as Quaternary sediments. If it is the Quantico Formation, it would be the most northerly outcrop of that formation known to me.

The Alexandria and Fredericksburg Railroad, now the Richmond, Fredericksburg, and Potomac Railroad, laid tracks across the upstream boundary of George Riley's land about 1872. William Riley, probably George's son, died in 1876 from injuries received "by falling through the railroad bridge over Pohick Run" according to the Alexandria Gazette, 3 June

1876. The Gazette was the local paper, and as shown by this notice, it calls the Pohick at the railroad bridge a 'run'. The bridge is immediately upstream of the Riley rapids. (Again, beware of spelling: Thomas Carter's plat, circa 1868, identifies 'Geo Reily' as owner, but the clerk entering the original deed witnessed at court, 15 May 1843, began by spelling the name 'Ryley', crossed that out, and put 'Riley'. Archival records show several Ryleys but no Rileys in Fairfax County during the 18th century. The 1860 census suggests that George and William Riley were illiterate farmers (Sprouse, 1996).)

To summarize the evolution of names for water bodies called Pohick and Accotink: What is now Pohick Bay and Accotink Bay had been Pohick Creek in the 18th century. What is now Pohick Creek and Accotink Creek were, in the 18th and 19th centuries, Pohick Run (or north branch of Pohick Run) and Accotink Run.

ENGLISH AND AMERICAN DEFINITIONS

Creeks

It is clear from the above discussion of the Occoquan, Pohick, and Accotink, that the name 'creek' was used in a consistent way that does not accord with contemporary, late 20th-century, American usage. Certainly the Occoquan is too wide and deep to be called a 'creek' by contemporary American standards, and the Occoquan is tidal as well, which is often outside the American understanding of a 'creek' at the end of the 20th century. Probably most Americans now consider a 'creek' to be a flowing stream, certainly smaller than a river and probably larger than a brook. However, neither Englishmen living now, nor Americans living at George Washington's time would agree with such a definition of creek.

Noah Webster (1806) defines creek to be "a small bay, alley, nook, corner, turn" (the total 1806 entry under creek). Webster's first (1828) edition of *An American Dictionary of the English Language* gives an etymology that suggests the word 'creek' comes from an earlier term meaning a notch or groove. The word has four definitions in Webster (1828): (1) "A small inlet, bay or cove, a recess in the shore of a sea or of a river." (2) "Any turn or winding" (attributed to Shakespeare), (3) "a prominence or jut in a winding coast" (probably not legitimate, according to Webster), and (4) "In some American states, a small river."

Definition (1) of Webster (1828) is the one that the Fairfax County contemporaries of George Washington had inherited from their English ancestors and the one which they and their descendants continued to use into the 20th century. Definition (4) of Webster (1828) is an early recognition of the meaning that eventually superseded definition (1) everywhere in the United States. Webster has this to say about definition (4): "This sense is not justified by etymology, but as streams often enter into [definition (1)] creeks and small bays or form them, the name has been extended to small streams in general."

It seems probable that the early colonists, who settled first along creeks fitting the tidal definition, took the word 'creek' with them as they worked their way inland and upland following the streams entering those tidal creeks. Where the main stream met a tributary, 'creek' would be applied upland to the main stream, so South Run, which is clearly a tributary in the Pohick drainage, and Bull Run, which is clearly a tributary in the Occoquan drainage, would retain the term 'run'. (The name 'Bull Run' also has stability from being in the 1742 law that established Fairfax County.) The existence in the colonies of unsettled land upstream differed from the situation in England where the upland streams had long been settled and named.

The *Oxford English Dictionary* (OED), second edition, 1989, shows that Webster's definition (1) of 1828 remains the primary usage today in England. The principal OED definition for 'creek' is "A narrow recess or inlet in the coast-line of the sea or the tidal estuary of a river; an armlet of the sea which runs inland in a comparatively narrow channel and offers facilities for harboring and unloading smaller ships." This is an ideal description of the Occoquan and, also, for examples, of Massey Creek

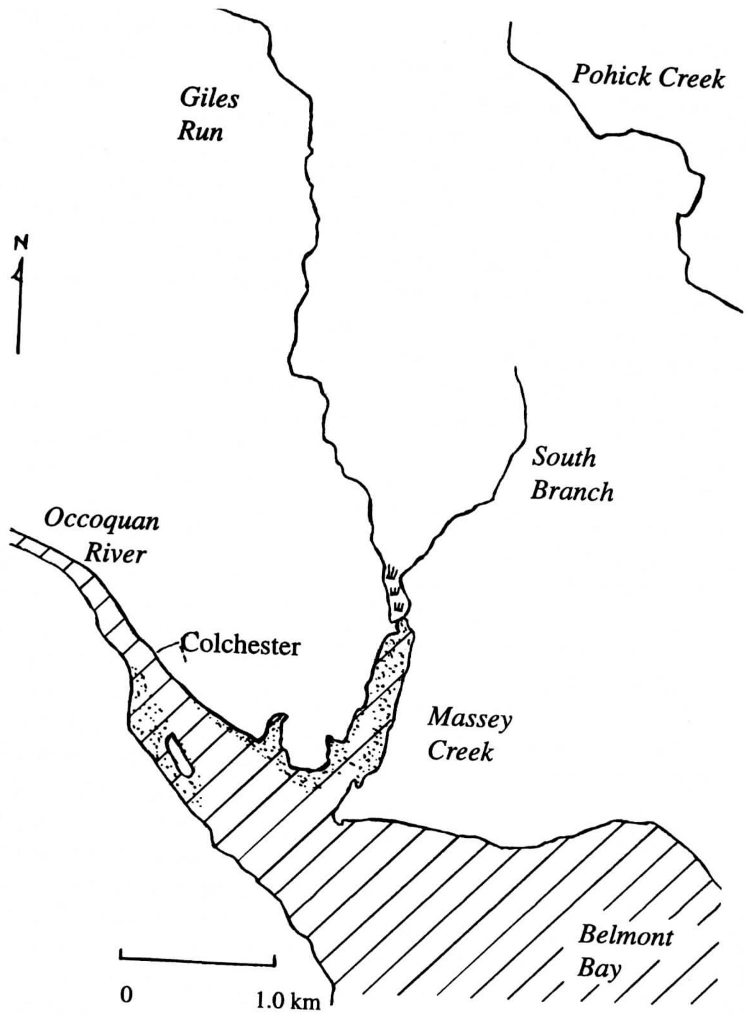

Figure 4. Massey Creek and Giles Run. The creek from the 1951 Belvoir quad shows conditions prior to development and dredging. Stippled patterns show tidal flats on the 1951 map. 'Occoquan River' was labeled 'Occoquan Creek' on 1951 map. Giles Tillet developed upland around 1700, prior to Lee Massey developing tide land around 1770.

and of parts of Dogue Creek before they shoaled up with sediment.

Massey Creek, which is entirely tidal, and its principal tributary, Giles Run, are exceptions that prove the rule about colonists carrying the name 'creek' with them as they moved upstream (Figure 4). Massey Creek appears to be named after Rev. Lee Massey, Rector of Pohick Church, 1767-1777, who took holy orders at the urging of Washington and owned an estate, Bradley, near Massey Creek (Netherton and Netherton, 1968). Giles Run, an upland stream, is the principal tributary of Massey Creek. It carries the first name of Giles Tillet, who owned land drained by Giles Run prior to 1706 (Netherton and Netherton, 1968; Mitchell, 1979). It appears that Giles Tillet gave his name to this upland tributary before Rev. Massey established himself downstream, precluding the normal sequence of extending tidal names upstream. Giles Run was well known to the colonists because they had to ford it on their way to the tobacco port of Colchester, but Massey Creek was out of their sight on that journey.

Doeg C^k is a tidal water body on Washington's map (Figure 1), and still today this tidal water body is named Dogue Creek on some (but not all) maps (Figure 2). The Doeg were a tribe of Indians that inhabited the land at the time of initial European settlement. Washington changed his spelling from 'Doeg' to 'Dogue' about the time of the Revolutionary War. In Fitzpatrick's (1925) edition of Washington's Diaries, George Washington wrote 'Doeg' at least through 1773, and he adopted 'Dogue' as his regular spelling about 7 January 1785. However, he used 'Dogue' in some entries during 1774, and had few opportunities to mention the site following 1774 until after the War.

In 1767, Washington knew the upland stream that feeds this tidal waterway as Doeg *Run*. A note on Washington's Truro Parish map (off the limits of Figure 1) identifies point A on Figure 1 as 'the Ford at Doeg *Run*', not at 'Doeg *Creek*'. His farm on that stream was Dogue *Run* Plantation (Fitzpatrick, 1925), not Dogue *Creek* Plantation. The Dogue Run of Washington is now Dogue Creek on USGS maps. The 1890 USGS Mount Vernon quad has 'Doag Cr.' in the tidewater where Washington wrote 'Doeg C^k' on Figure 1, but the same map has 'Dogue Cr.' for the upland stream that Washington knew as 'Doeg Run'. The spelling variants suggest that the USGS cartographer may have had access to Washington's manuscripts while working on the 1890 quadrangle.

The series of quotations given by the OED to illustrate the meaning of 'creek' range in age from 1250 to 1854, and clearly make 'creek' a tidal waterway. *Frenchman's Creek*, the novel by Daphne DuMaurier, is a tidal creek in this English sense. Poets rarely mention creeks, but these lines from Matthew Arnold's *The Forsaken Merman* (1849) communicate the essentially tidal nature of 'creek' in Great Britain (Tinker and Lowry, 1953):

> Up the still, glistening beaches,
> Up the creeks we will hie;
> Over banks of bright seaweed
> The ebb-tide leaves dry.

The OED (1989) has this to say about American contemporary use of the word 'creek': "an application entirely unknown in Great Britain".

Runs and Synonyms

So much for the definition of 'creek'. What about 'run'? 'Run' is a word with many meanings. Definition (14) of Webster (1828) is the relevant one: "In the middle and southern states of America, a small stream; a brook". The OED defines 'run' (II.9a) as "a small stream, brook, rivulet, or watercourse. A channel or overflow. Chiefly US and north dialect." The OED's illustrative quotations for this use of 'run' clearly imply a stream with falls or rapids, which is consistent with how most 19th-century runs, including Bull Run, Pohick Run, and Accotink Run, cross the Fall Line that separates the upland Piedmont from the Coastal Plain in Fairfax County.

In Maryland around Baltimore, the word 'falls' appears to be a synonym for 'run'. For examples, Jones Falls, Gwynns Falls, and Gunpowder Falls are not 'falls' in the singular sense of 'Niagara Falls', but streams across the Fall Line similar to Pohick Creek in the 20th-century sense. I have not found 'falls' as a type of stream in any dictionary, although Jefferson describes the Great Falls of the Potomac as being "15 miles in length, and of very great descent" (*Notes on the State of Virginia*). Perhaps 'falls' was a term used around Baltimore to attract British investment during colonial settlement at a time when waterpower was a valuable asset.

To a remarkable degree, poets avoid stream names like 'runs' or 'creeks'. When they do specify the type of stream, 'brook' is preferred, but 'brook' is not common in northern Virginia. Poets, who must pay special attention to the meaning of words, imply that brooks are smaller, less permanent streams than creeks or runs. In *Hyla Brook*, Robert Frost expects the brook to dry up during summer. In *With rue my heart is laden*, A. E. Houseman implies that brooks are ordinarily narrow enough for lads to leap them. In *The Brook*, Tennyson implies that the brook is a small, noisy, foamy stream, although probably permanent.

The preference of poets for 'brooks' over 'creeks' no doubt has something to do with the sound of the words, but it is also consistent with the environment of tidal creeks – muddy, weedy, unromantic locales. Matthew Arnold, whose poems often reflect a mood more suited to marshes than to mountains, produced the only poetic 'creek' that I have read, but he also wrote "And what sedg'd brooks are Thames's tributaries" (from *Thyris*, 1866, Tinker and Lowry, 1953).

SUMMARY

'Creek' and 'run' originally were mutually exclusive categories in America, and remain that way in Great Britain. In America, 'creek' changed meaning to become a synonym of 'run', with 'run' having an archaic flavor. 'Creek' implied a small, narrow, tidal water body to the English colonists who were George Washington's contemporaries, and there are good examples of creeks, so defined, along the Potomac shore in southeast Fairfax County. 'Creek' retained that English meaning in Fairfax County well into the 20th century, and still today, Massey Creek and the tidal portion of Dogue Creek retain that meaning. 'Creek' retains that tidal meaning today in Great Britain, to the total exclusion of the American idea.

Nineteenth-century maps containing Fairfax County failed to use 'creek' in the English sense to describe the Occoquan, even though there is archival evidence that 'creek' was the term used by local people. Eventually, beginning at the end of the 19th century, map makers recognized the local usage of 'creek' in the English sense for the Occoquan, and then, in 1971, they changed back again to call the Occoquan a 'river'. This reversal reflects a tardy adoption of the more national American sense of the word 'creek'. Undoubtedly, with the suburban development of metropolitan Washington, D. C., expanding into Fairfax County in the closing decades of the 20th century, it became incongruous for immigrants from elsewhere in the US to identify as 'creeks' what to them are tidal bays tens to two hundred meters wide.

'Run' is a regional term in both America and Great Britain. 'Run' implies the existence of rapids and small falls. The upland streams draining the Piedmont must cross the Fall Line to reach the tidal Potomac, and thus are good examples of 'runs'. The largest tributary to Pohick Creek retains the name South Run, which is consistent with the hypothesis that the settlers carried the term 'creek' upstream from tide water along the main stream. Likewise, Bull Run is the largest tributary to the Occoquan, but clearly a tributary, and it retains its original name.

In the great War Between The States, Fairfax County bordered on the two battles of Bull Run where Confederate Armies won significant victories within a short distance of the Union capital at Washington. The Fairfax County citizens of the day, whose sympathies lay largely with the Confederates, would have understood why Bull Run was not a 'creek', but most Americans living at the end of the 20th century will consider Bull Run to be a creek, and the name 'run' to be a quaint holdover from the past.

ACKNOWLEDGMENTS

For the past quarter of a century, I have lived on the divide between streams now known as Pohick Creek and Accotink Creek. Inquiries about this site gradually raised interest in the historical meanings of a creek and a run. At a meeting on tidal geology in May 1996 (the SEPM Tidalites Meeting in Savannah), I observed the surprised reaction of Dr. Graham Evans (an English geologist from the Isle of Jersey) when confronted with the ordinary American conception of a creek, and that set in motion this study. The work was made easier and more interesting through the help afforded by the staffs of the Virginia Room and Reference Room, Fairfax Public Library, and by Sandra K. Rathbun and Robin Walter, Archives Division, Circuit Court of Fairfax County. The Archives of the Circuit Court of Fairfax County contain valuable sources of information in the compilations of Beth Mitchell and Edith Moore Sprouse. The Mitchell works (1979, 1987, 1998) are essentially maps with explanatory text, showing Fairfax County conditions in 1760 and 1860. The Mitchell work (1998) puts the property boundaries of 1860 on a 1988 tax base, which greatly aids in locating earlier records. Sprouse (1996) identifies the people present in 1860, and in many cases their descendants, from all sources including census, court records, newspapers, and other reports. Edith Moore Sprouse, Howell Peregrine, and Judy Ehlen commented on earlier versions of this work. Edward Redmond of the Library of Congress provided access to and information on Figure 1. The staffs of the US Geological Survey Library and National Mapping Division Reference Library helped with this paper. Suzan Yow prepared this manuscript.

REFERENCES

Davis, George B. and others, 1891-1895, ATLAS to accompany the Official Records of the Union and Confederate Armies: US Government Printing Office, Washington.

Fitzpatrick, John C., 1925, The Diaries of George Washington, volume II, 1771-1785, and volume III, 1786-1788: Houghton Mifflin, Boston. 461 p. and 458 p.

Galvin, Cyril, Lisle, L. L., DeWall, A. E., Nord, J., 1998, From Piedmont Upland to Tidal Estuary: The Path of a Sedimentary Particle: Guide book for field trip held in Fairfax County on 4 Apr. 98 as part of the 24th Assateague Shelf and Shore Workshop. 33 p.

Hopkins, G. M., 1879, Atlas of Fifteen Miles around Washington, including the Counties of Fairfax and Alexandria, Virginia. Compiled, Drawn and Published from Actual Surveys: 320 Walnut Street, Philadelphia.

Little, E. L., 1995, National Audubon Society Field Guide to North American Trees, Eastern Region: Knopf, New York, 714 p.

Long, E. B., 1971, Civil War Day by Day; An Almanac, 1861-1865: Doubleday. Garden City, New York, 1135 p.

Lossing, Benson John, 1912, Matthew Brady's Illustrated History of Civil War: 1861-1865; reprinted by Fairfax Press, 1977, 512 p.

Mitchell, Beth, 1979 (2nd printing), "Beginning at a white oak..." Patents and Northern Neck Grants of Fairfax County, Virginia: Fairfax County Administrative Services, McGregor and Werner, 346 p.

Mitchell, Beth, 1987, Fairfax County, Virginia, in 1760: An interpretive historical map, Office of Comprehensive Planning, Fairfax County, Virginia, 101 p, plus map.

Mitchell, Beth, 1998, 1860 property Owners Map Book, Fairfax County, Virginia. (work in progress)

Moffat, Riley M., 1985, Map Index to Topographic Quadrangles of the United States: Western Association of Map Libraries, Occasional Paper No. 10.

Netherton, Nan, and Netherton, R. D., 1968, Pohick Church, Truro Parish, Fairfax County, Virginia: Fairfax Historical Landmarks Preservation Commission: Fairfax, 44 p.

Sieders, V. M. and Mixon, R. B., 1981, Geologic Map of the Occoquan Quadrangle and part of the Fort Belvoir Quadrangle, Prince William and Fairfax Counties, Virginia: US Geological Survey, Map I-1175.

Sprouse, Edith M., 1975, Colchester: Colonial Port on the Potomac: Fairfax County Office of Comprehensive Planning, Fairfax, Virginia, 196 p.

Sprouse, Edith M., 1996, Fairfax County in 1860: A Collective Biography, in two Volumes: (Volume I from Benjamin Abbot to John Michael Kuehling, p 1 to p 1170, and Volume II from Moses Lackey to Wilmer Zimmerman, p 1171 to p 2317.)

Stephenson, Richard W., 1983 (revised second printing), The Cartography of Northern Virginia, Facsimile Reproductions of Maps Dating from 1608 to 1915: Office of Comprehensive Planning, Fairfax County, Virginia.

Stetson, Charles W., 1935, Washington's Woods on Four Mile Run: Records of the Columbia Historical Society of Washington, D.C. v. 35-36, p. 154-192.

Tinker, C. B., and Lowry, H. F., editors, 1953 (reprint of 1950 ed.), Poetical Works of Matthew Arnold: Oxford University Press, London, 509 p.

Webster, Noah, 1806, A Compendious Dictionary of the English Language: A Facsimile of the first (1806) edition, Crown Publishers, Bounty Books, 1970, 408 p.

Webster, Noah, 1828, An American Dictionary of the English Language: Johnson Reprint Corp. New York, 1970. In two volumes, not paginated.

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MICHAEL TUOMEY'S 1848 GEOLOGICAL SURVEY OF SOUTH CAROLINA

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ABSTRACT

One hundred and fifty years ago, Michael Tuomey completed his "Report on the Geology of South Carolina," the result of four years of arduous labor. The report is the first detailed and comprehensive geological description of the entire state, and it includes a geological map that shows the distribution of Coastal Plain and Piedmont-Blue Ridge units. In the sesquicentennial of Tuomey's survey, it is fitting that we recognize his important early contribution to the geology of South Carolina and the southeast.

Tuomey's report is a 293-page volume with a 48-page appendix and an index. Although he gave a complete depiction of Coastal Plain geology and delineated Cretaceous, Lower Eocene, Eocene, Miocene, Post-Pliocene, and alluvial units on his map, the emphasis herein is on his mapping of the Piedmont and Blue Ridge. The metamorphic units he delineated are clay slate, mica slate, talcose slate, hornblende slate, gneiss, and lime rock. Gneiss is the most extensive unit on the map. His map shows many elements of the geologic framework we recognize today. The distribution of his clay slate unit corresponds closely with the Carolina slate and Bel Air belts as we know them now. The gneiss between the two clay slate areas matches the Kiokee belt. Areas of mica slate approximate the northern part of the Kings Mountain belt and the Chauga belt. He also recognized that his talcose slate unit was associated with gold deposits.

Granitic and basaltic intrusive rocks are also delineated on the map. It shows the Newberry, Columbia, and Liberty Hill granites we recognize today. Basaltic intrusives outlined include the Bush River of western Newberry County, Dutchmans Creek, Big Wateree Creek, and Ogden gabbros. He described the regional extent of diabase dikes as occurring from Virginia to Alabama, noted their preferred direction and diagrammed their near-vertical orientation. He also referred to the distinctive soil and topography that develops on the large gabbros.

Michael Tuomey's report is truly a benchmark publication, for sixty years passed before the next statewide survey was done. Upon completing the report, he left South Carolina to become director of the Alabama Geological Survey.[1]

Figure 1. Michael Tuomey (1805-1857). Photograph from G. P. Merrill, 1924, The First One Hundred Years of American Geology: Yale University Press, 773 p.

1. Reprinted with permission from Geological Society of America, Abstracts with Program, v. 30, no. 4, p. 53.

SOUTHEASTERN GEOLOGY
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JAMES BUCKMAN (1814-1884) ENGLISH CONSULTING GEOLOGIST AND HIS VISIT TO THE GUYANDOTTE COAL-FIELDS IN 1854

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ABSTRACT

This paper reveals the background behind the visits paid by the English consulting geologists James Buckman and David T. Ansted to coalfields along the Guyandotte River in Virginia (now West Virginia) in 1853 and 1854. These were operations hoping to raise English capital to advance the opening of mines here. It was thought vital that existing American geological reports by John Locke should be checked by English experts. Buckman visited the sites with Locke and was able to confirm most of Locke's expectations. These visits shed light on both how such operations were then being planned and funded and how international geological consultancy was then developing. Sadly the financial panic of 1857 and then the American Civil War put an end to these expectations.

INTRODUCTION

The conjunction of events which drew this English professor of geology to survey coal deposits in West Virginia in 1854 can be traced back to a letter written by the radical English politician Joseph Hume (1777-1855) in June 1845, seeking information on the quality of coals being used by the British Navy (De la Beche and Playfair, 1848, p. 539). Hume pointed out that the United States had already made such experiments, in 1842-43, and that there was now a public laboratory in Craig's Court, London perfectly qualified to direct and test such British coals for the British Admiralty without delay. Hume's letter caused the Lords of the Admiralty to ask the establishment that Hume had named, the Museum of Practical Geology - founded in 1835 - to undertake such an investigation.

JOHN WILSON AND COAL

The "superintendence of the economical part of the experiments" was immediately confided in 1845 to John Wilson (1812-1888), who had trained at University College, London and then in medicine, chemistry and general science in Paris, (Clarke, 1909). Wilson was still busy on this investigation in August 1846, having then just visited all South Wales coal mines, by when he had clearly come to be regarded as something of an expert on coal.

But, following financial crises at the recently founded Royal Agricultural College, at Cirencester in Gloucestershire, Wilson was instead appointed Professor of Agriculture there in the autumn of 1846, and in 1847 was made Principal of the College (Sayce, 1992). His letter sending the Director of the Museum of Practical Geology, Henry de la Beche (1796-1855), the first installment of his Coal Report, which was on the evaporative power of coals, was embossed with the Museum of Practical Geology's stamp, although written from the College on 18 May [1847] (Geology Dept., National Museum of Wales, De la Beche archive). His College's survival now depended on reaching student admission targets and when these failed to be met, more money still had to be saved, by 'remodelling' the professorships. Early in 1848, James

Buckman was appointed to an amalgamated chair of Geology, Natural History and Botany under Wilson (Torrens, 1988).

Buckman and Wilson were some of the first professional scientists trying to make livings from science in England, in Buckman's case from 1844. Buckman's career, as one of these early professional scientists, is thus of particular interest. He had previously been the paid Curator and Secretary of the Birmingham Philosophical Institution until financial problems there had forced his departure in September 1847. All these events should remind us of the precarious financial situations facing those who professed science without independent means in 1840's Britain.

At Cirencester, Buckman started his botanical experiments to solve the problem of the identity of species, which Charles Darwin applauded in the first edition of his *Origin of Species*, where he noted "Mr. Buckman's recent experiments on plants seem extremely valuable" (Darwin, 1859, p. 10). Buckman also here continued to publish widely, right across the fields of his professorship and proved an inspirational teacher. Wilson and Buckman worked happily together at Cirencester until 1851 when, following further financial crises at the College, Wilson resigned to be appointed Deputy Juror for raw materials to the "Great Exhibition of the Works of Industry of all Nations", which opened on 1 May 1851 at Hyde Park, London. The raw material then, both in America and Britain, was of course coal. The annotator of the raw materials entries in the Official Catalogue of this Exhibition (Anonymous, 1851a, volume 1, p. 88) was another English consulting geologist, D.T. Ansted, who also became an American coal prospector in Virginia in 1853 and who will re-emerge in this paper. Ansted wrote the "Account of the nature and extent of the various Deposits of Mineral Fuel in various parts of the World" for this Catalogue (Anonymous, 1851a, volume 1, p. 178-183).

THE GREAT EXHIBITIONS AND THE CRYSTAL PALACE COMPANY

The 1851 Exhibition caused a sensation in both Britain and America, partly on account of the quality of many American exhibits. The magazine *Punch* coined the name Crystal Palace, which was used by the new Company which later purchased the original structure and permanently re-erected it with some modifications at Sydenham, South London where it reopened in 1854. *Punch* also joked (Anonymous, 1851b) how

"Yankee Doodle sent to town
His goods for exhibition;
Every body ran him down,
And laughed at his position."
But soon we
"must now be viewed all
As having been completely licked
By glorious Yankee Doodle."

This sudden and unexpected revelation of the prowess of American manufacturing methods has been rightly called the "High Noon in Hyde Park" of British Victorian engineering (Rolt, 1970, p. 148). American reaction to the Exhibition was gratitude that its remarkable industrial exploits had been so publicly and quickly recognized and, in view of the great profitability of the 1851 Exhibition to its English organizers, a rival 1853 New York Industrial Exhibition, modelled on that held in London, was soon organized (Rosenberg, 1969).

The British, worried about the quality of American exhibits in 1851, now proved the extent of their concern in 1853 by sending a team of special Royal Commissioners to report on this American Exhibition, and the whole state of American industry under the leadership of Francis Egerton (1800-1857), first Lord Ellesmere (Anonymous, 1853a, p. 6), who was 1842 President of the British Association for the Advancement of Science - hereafter BAAS (Boase, 1908). Wilson was one of those chosen to report, on U.S. minerals, as far as their economic and metallurgical operations were concerned, among many other fields which also included agriculture and tanneries. The famous English geologist Charles Lyell (1797-1875) was anoth-

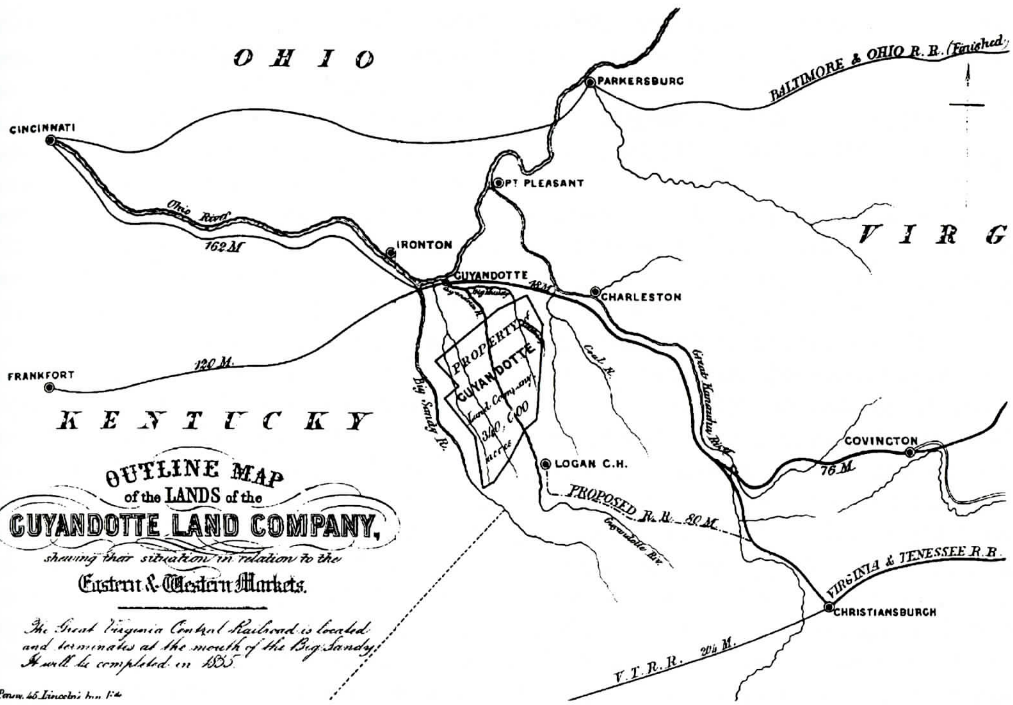

Figure 1. Map of the Guyandotte lands published in 1853 to show the location of the Company's property.

er, asked to report on U.S. mining, quarrying and mineral productions. Lyell and Wilson's reports were finally presented to the British Parliament on 6 February 1854 (Lyell, 1854; Wilson, 1854). There were great delays with the New York Exhibition which was not opened until 14 July 1853, with some of the Commissioners, like Lyell, having to return home early in August. So the American geologist James Hall (1811-1898) was asked to help write Lyell's report (Lucier, 1995, p. 262-3). Wilson was instead given the additional task of reporting on American raw materials outside those exhibited at New York and, during his extended stay, he was able to "visit various parts of the United States in which raw materials were likely to be most abundant" (Anonymous, 1854a, p. 390), and gave lectures to local American agricultural societies, before his departure for home on 19 October 1853.

Amidst much mutual goodwill, there was then considerable political animosity between the British and the Americans, largely on account of the vexed question of slavery. This had been abolished by the British who were now trying to encourage Americans to do the same. Both Buckman and Ansted (Ansted, 1854, p. 294-311) were to refer to this, from their own experiences in America. With such different and highly political attitudes current, it was vital that some Anglo-Americans came forward to 'build bridges'. Two of those who did are of particular importance in this story: the philanthropist George Peabody (1795-1869) and General James Watson Webb (1802-1884). Peabody, an American banker permanently based in England since 1837, had been the chief source of funds for the American Pavilion at the 1851 Great Exhibition, after "Congress failed to appropriate money for a display at the Crystal Palace exhibition, his gift of \$15,000 made it possible to show American products and inventions [there] beside those of other nations" (Albion, 1934). Webb, after army service between 1819 to 1827, instead became a highly successful American journalist and proprietor of the Whig newspaper, the *New York Courier and Enquirer* between 1827 and 1861 (Crouthamel, 1969), with a short spell as a rejected diplomat in Vienna.

GENERAL WEBB AND HIS GUYANDOTTE COMPANY

Webb sent a special giant edition of his newspaper to the Crystal Palace Exhibition in 1851 which was nearly twice the size of the London *Times* (Crouthamel, 1969, p. 94). Webb was to visit London three times during 1853-54, the first as soon as the 1853 New York Exhibition closed. He was now deeply involved in journalism on the "Eastern Question", which exercised people both in Britain and America and which was to lead to the Crimean War of 1854, when Webb became involved in a bitter controversy with the editor of the London *Times*. Earlier, in October 1853, Webb had recorded in that same English newspaper, his "thanks [for] our kindly feeling for the land of our fathers - our recollections of the past and our hopes for the future - to our common origin, language, literature and laws - and, above all and over all, to our natural love of liberty and constitutional freedom." He further commented on how "the pecuniary interests of England and America have become so interwoven and so inseparable, that this consideration alone, aside from their common origin, should bind them together as one people" (Webb, 1853, p. 9).

Webb was then particularly seeking English investment in his Guyandotte Company in West Virginia (Figure 1). This company had been established in 1849 as the Guyandotte Land Company (Anonymous, 1853b, p. 1), but its considerable mineral wealth was soon pointed out in 1850, by the geologists, Charles Upham Shepherd (1804-1886) and William Barton Rogers (1804-1882) and an American engineer, who had been much based in Britain, named Joseph Gill. Rogers had been the Virginia State Geologist from 1835 until 1848, despite funds not being renewed after 1841 (Aldrich and Leviton, 1982).

By 1852 the directors of the Guyandotte Company were five New York-based businessmen who now sought to raise a capital of $1 million, at $30 to $40 a share on their over 330,000 acres there. By mid 1853 Webb had obtained control of the entire stock of this Company and started to advertise this property in London. His first letter extolling the potential of the Company was written in London on 15 September 1853 at the request of one Gerard Ralston (Anonymous, 1853b, p. 16) a London agent who had been earlier involved (in 1835 and 1836) in the supply of British wrought iron rails for the Baltimore and Susquehanna railroad (Elsas, 1960, p. 190-1).

Webb had commissioned a "hasty" Geological Report in August 1853 on the Company's lands from John Locke (1792-1856) who had just resigned from the chair of chemistry and pharmacy at the Medical College of Ohio, having been appointed professor of chemistry there in 1835 (Winchell, 1894). This contained detailed coal sections and sketch plans showing their accurate locations on the Company's lands. Locke, between 1837 and 1848, had been involved in the State Geological Surveys of Ohio and Michigan and in the Surveys of the Mineral Lands of the United States (Merrill, 1906, p. 704). Rogers, who might instead have been involved in reporting, had resigned his position at the University of Virginia in 1853 (Aldrich and Leviton, 1982, p. 100). These are names to add to the significant number of consulting geologists then active in eastern America (Lucier, 1995).

Webb, in London in September 1853, now "felt the necessity of having this coal field examined - and the explorations of an American geologist verified - by an English geologist of high character" with Peabody paying for the survey (Anonymous, 1853b, p. 18-9), although this survey was to be much delayed. Webb wanted Locke's "Report" checked and validated by an English geologist to encourage English investment in his Company. On 10 February 1854 Webb was one of the four promoters (the other three were all based in Britain) who provisionally registered the newly renamed Guyandotte Land, Coal and Iron Company in London, with registered offices at 22 Moorgate. Registration was granted on 13 February 1854 (Public Record Office, London, BT 41/280/1610) and this was the origin of the new 1854

"Prospectus" which the Company published, again in London (Anonymous, 1854b). The only notices Webb's biographer takes of this company were a letter to Webb dated 14 March 1854 and a New York newspaper notice of the following month, but he did record how Webb enjoyed the hospitality of his titled English friends, and used them to combine business with pleasure in marketing stock in this Company to them (Crouthamel, 1969, p. 131-2). The only one of those friends named by Crouthamel known to have been involved with this Guyandotte Company was Lord Ellesmere, the leader of the British Commissioners sent to the New York Industrial Exhibition.

BUCKMAN IS APPOINTED

Webb and Peabody clearly became involved with Wilson through these Anglo-American Exhibitions of 1851 and 1853 (although no documentation of exactly how seems now to survive). It was certainly through Wilson that Buckman was invited by Webb's Guyandotte Company to be the English geologist who would go to the States to give this second opinion. Buckman had equally clearly been chosen because he had been actively involved before this in industrial consulting work on coal mining (he was also then active as industrial consultant in botany - both of which activities were to cause his career at Cirencester to come to a sudden, and sad, end in 1863 - Torrens, 1988).

In 1848 Buckman had read a paper to the BAAS meeting in the South Wales coal field at Swansea, on two earlier attempts made in the 1840's to find coal in England, both of which proved completely abortive, and on both of which Buckman was professionally consulted. The first was near Droitwich, in Worcestershire in Jurassic, Lower Liassic rocks, where workmen found a black mineral they took to be coal. This encouraged a local capitalist to purchase the estate to exploit this "coal." This unknown capitalist had first bored down through 300 feet of Triassic Keuper Marls without success, and only then sought Buckman's advice, who immediately urged this search be abandoned. The second attempt was near Malmesbury, Wiltshire where several trials had been previously made (from 1784 to 1789 and in 1816) before those of the mid 1840's, in lignite-bearing Upper Jurassic Oxford Clays, which were here, as so often in England, once more confused by the scientifically uninformed with true coal. Again Buckman urged the already 300 feet deep shaft here be immediately abandoned.

Buckman argued that both attempts were misguided and doomed to failure on correct stratigraphic grounds (Buckman, 1849, see also Buckman, 1855a and 1858a). The BAAS President for Geology, Henry De la Beche, noted after Buckman's paper was read, how it provided "another instance of persons fooling with large sums of money in boring for coal in places, as must be known by persons having the slightest geological information, coal could not have been in existence" (Anonymous, 1848, p. 3).

Wilson's first recorded contact with Buckman regarding his visit to America was in person in London on 27 May 1854 by which time Buckman already possessed a copy of the first Guyandotte Company Prospectus (Anonymous, 1853b). On 31 May Wilson sent Buckman his written instructions, on Museum of Practical Geology notepaper, in an envelope embossed with the Crystal Palace Company logo (to confirm Wilson's continuing involvement with both these organizations). The Museum of Practical Geology had opened its fine new premises in May 1851, which a later president of the Geological Society of London, Roderick Murchison (1792-1871), called "the first palace ever raised from the ground in Britain... entirely devoted to the advancement of Science!" (Geikie, 1895, p. 184). Wilson's instructions were that the Guyandotte Company wanted Buckman to re-examine Locke's Geological Survey Report, already submitted to them by the present proprietor Webb. The property was now of 360,000 acres and contained both coal and iron.

Wilson thought Locke's previous geological examination had been by "a Geologist of some standing." It had been published in 1853 (Anonymous, 1853b, p. 33-51) and was summarized again in 1854 (Anonymous, 1854b). "It had been produced to the projectors of the proposed

Guyandotte Company as evidence of the value of the estate" and Wilson and Webb wanted Buckman to check its accuracy, to examine the extent of the mineral deposits there, and collect and bring back carefully identified samples and finally to report on the availability of labour to work any future mines. From the great extent of the property, it would be also turned eventually to agricultural or township purposes, so Buckman was also asked to report on the general physical character of the surface and on its timber growth. Webb alone had to disprove its reported occupation by "squatters." Buckman was asked to return to England by the end of July, giving him a clear month in the United States (Wilson to Buckman letter, 31 May 1854, British Geological Survey - hereafter BGS - archives, 1/1565/1, Keyworth, UK).

BUCKMAN AND LOCKE IN AMERICA

The small brass-locked (6.5 by 4 inches) field notebook that Buckman took to, and used in, the United States has also survived (BGS archives, 1/1565/2). It records that he departed from Liverpool on the British and North American Royal Mail Steamship's (later Cunard) new paddleship *Arabia* on 3 June 1854 (Anonymous, 1854c, p. 1). It was the last wooden vessel to be built for the Cunard Co., launched in 1852. On his way across the Atlantic, Buckman noted icebergs and on 12 June a "fresh breeze said to be the air of freedom - at 400 miles [distance] not tainted by the smell of slavery." He arrived in New York late on 13 June and on the 15th met Webb at Tarrytown up the Hudson River. On 19 June Buckman set off again from New York by train, via Philadelphia and Pittsburgh. On 21 June he boarded the *Challenger* paddle steamer (of which a sketch survives in his notebook) to travel down the Ohio River. After being stuck on a sandbar the whole day of 23 June, Buckman arrived at the settlement of Guyandotte on the morning of the 25th. On 26 June he met Locke and from 27 to 30 June inclusive they went together on their "Coal Expedition", checking the several sections that Locke had illustrated (Anonymous, 1853b, plates 1 - 8), of which an original uncut version again survives in the Buckman papers (BGS archives, 1/1565/3). Locke had correctly reported that coal could be directly loaded here from the veins exposed along the local rivers into boats trading on the Guyandotte River (Anonymous, 1853b, p. 44).

Over 1 and 2 July, Buckman stayed at Guyandotte, whose "inhabitants betray a free country where everyone may say what he pleases if he dare." On 2 July he now sent Webb a short note saying that he had completed his Survey, accompanied by Locke, whose "Report" Buckman found was "in its main features substantially correct." That same day Buckman also sent Wilson a letter to the same effect, noting that the Coal Measures on the estate were "fully prepared for work, that there is a rich mine... of about 28 feet of coal... in such a position as to be easily worked." And that his journey from the mineral districts to the Guyandotte Township, "... had been accomplished in a Steam Boat worked with this Coal." Buckman was less convinced of the availability of iron here. Locke's "Report", Buckman thought, "had been prepared with great care and as you would expect from his reputation for skill and ability is generally accurate." Buckman would be sending Wilson his full Report later (copies of his two letters from Guyandotte survive only in this notebook), but his full Report now seems lost, and no details have survived of how much Buckman was paid.

Buckman started his long journey home via Cincinnati to Cleveland by train where, now clearly in more relaxed mood, he moved by boat on to Buffalo, then to Niagara to see the Falls, and via Saratoga Springs to Pokahoe. This was Webb's estate at Tarrytown which he had bought in 1838 and sold by 1862 (Crouthamel, 1969, p. 80 and 197). Today this is recorded only in the former Pokahoe Drive - recently renamed Sleepy Hollow - of North Tarrytown. Here Buckman again met Webb before moving to New York City, where he started his Atlantic return on the *Europa* (another Cunard liner launched in 1848) on 12 July 1854, arriving back at Liverpool on 24 July after an absence of over 7 weeks.

FALLOUT IN LONDON

On 14 July, soon after Buckman left, Webb wrote a long letter from Poke-a-hoe to James Edward Coleman (c1789-1868) of London about the future of the Guyandotte Company. Coleman was a major London accountant, then much involved in investigations of the solvency of suspect firms (Jones, 1986) and in trying to properly register the Company in Britain and in finding investors there. This copy letter is the last document to survive in the Buckman papers to relate to his work in America (BGS archives, 1/1565/4). In it Webb took a highly euphoric view of his company's prospects, "we have the most valuable coal Property in the World, with greater facilities for reaching a market than any other we can possess. He [Buckman] will report at least, 24 feet of coal, the seams of which are from 5 to 10 feet in width [*sic* - *i.e.* thickness] and all of which may be opened at hundreds of different places and the coal slided from the openings, into boats lying in from 7 to 18 feet water." Webb then discussed the costs of, and profits from, mining such coal, where "without a shadow of a doubt the demand very greatly exceeds the supply and will continue to increase much more rapidly than the supply." Webb also forwarded to Coleman a report from the Cumberland Coal and Iron Co., which had been incorporated in 1841 and which was then working 12,000 acres on the eastern slopes of the Allegheny mountains by railroad. Webb also cited the Kanawha Saline Company working similar coals much nearer to the Guyandotte property but which lay at twice the distance from markets. Despite this problem, Webb reported that the Kanawha Co. had divided in that year (1853-1854) $600,000 profit on a capital of $184,000!

Webb's letter names a number of others involved with the Guyandotte Company in England, of whom Sir Henry Bulwer (1801-1872) is the most significant. He had been British Ambassador in Washington from 1849 to 1852 and had there enjoyed an immense popularity (Kent, 1908). Bulwer's brother Edward (1803-1873) was also Webb's favorite author (Crouthamel, 1969, p. 80). It seems likely however that their collective attempts to raise sufficient investors in England failed, as the last date in the relevant British company file is dated 9 March 1854. The Company was never registered in Britain, under new legislation which came into force in 1856.

THE KANAWHA COMPANY AND D.T. ANSTED

The above Kanawha Saline Company was one of those primarily involved in that most important industry of the Kanawha valley. In 1854 salt made there had amounted to 3 million bushels and was valued at $1 million. There were by 1855 at least 20 coal companies doing business in Charleston (Dunaway, 1922, p. 180). The Great Kanawha Company must have been another of these, organized in 1855 according to their "Statement", apparently published in that same year (copy in University of Kentucky library, Lexington). Certainly in either 1859 or 1860 they too had also published separate English and American editions of their "Evidence of value and title" (Anonymous, 1860a and b). These contained an 1854 Geological Survey and Report on their property, again by John Locke and his son Joseph, as well as an 1857 Survey and Mining Report by Joseph Gill, exactly the same people as had been earlier involved with surveys for Webb's Guyandotte Company.

Perhaps most intriguing of all, these Kanawha coal fields had also been the subject of a survey by another English geologist early in 1853, in this case Professor David Thomas Ansted (1814-1880), a Fellow of the Royal Society (elected 1844). He was soon after this, in March 1853, forced to resign his chair at King's College, London from the "pressure of business engagements"(Hearnshaw, 1929, p. 246). Ansted had arrived in New York on 31 December 1852 to survey the Coal Basin of the Kanawha and published his Report in New York later in 1853 (Ansted, 1853). The township of Ansted, 30 miles ESE of Charleston is now named after him, in response to his work here.

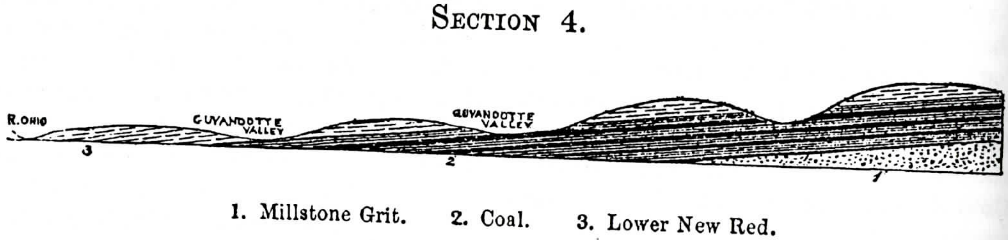

Figure 2. Buckman's section of the Coal Measures across the Guyandotte River Valley published in 1858.

BUCKMAN REPORTS BACK IN ENGLAND

Buckman soon sent a report on his America work to be read to the BAAS at its Liverpool meeting in September 1854, of which only an 8 line summary was published (Buckman, 1855b). He also published observations on the grass *Poa pratense* in America, which were again used by Darwin (Burkhardt and Smith, 1991, p. 242-3). In these Buckman noted "in the United States and Canada, hundreds of acres may be seen occupied with the cultivated form - timothy grass; and on the alluvial flats of the Ohio, and the broad alluvial lands left by the contraction of the American lakes, this grass yields enormous crops with spikes of flowers sometimes as much as six inches in length." These are comments clearly based on his personal observations here in 1854 (Buckman, 1856, p. 515 and Buckman, 1858b, p. 36).

Buckman published a more general paper on "The Practical Application of Geology in Coal-Seeking" in 1858 which gave fuller details of his activities in Virginia (Buckman, 1858a). In this Buckman again noted the English attempts, at Droitwich and Malmesbury, with which he had been earlier involved, and how they showed the importance of a basic knowledge of geology to the practical coal seeker. From which it was "often easier to decide where coal is not than where it is." Finally Buckman reported on his American experience, "which showed that correct stratigraphic principles are universally practical, being a sure guide in a coal investigation 3,000 miles distant." Buckman confirmed that it had been a group of English gentlemen which had asked him to ascertain whether the large estates at Guyandotte really did posses the coal they were claimed to have. At Guyandotte, Buckman noted that he had made a good start by discovering that a sandstone exposed there was the equivalent of the coal-grits in the roof of coal seams in English (Staffordshire) mines. From the dip of this bed, it became clear to Buckman that, as he ascended the Guyandotte river to its mountain source, he would meet with progressively older beds, so, having started from the roof beds of the coal, it was clear that he should soon expect to find Coal Measures below these.

Buckman traced the limits of these coal veins from north to south as one after another were exposed in creeks opening onto the Guyandotte river "until ultimately all sign of coal was lost and a hard rock presented itself, which I could readily identify as the floor of the coal. This peculiar rock was a rough, hard, gritty sandstone, with occasional impressions of such plants as mark our own coal measures - *Stigmaria*, *Sigillaria*, *Lepidodendron*, *Calamites*, Ferns and other relics of an ancient flora, which differed much less from our own of that period than the American and European floras do from each other at the present day." Buckman concluded that "no better preparation can be made for studying the[se] great western [American] coal deposits than by obtaining a knowledge of our own Welsh coal-field." He demonstrated the stratigraphic relationships here by a diagram - his section 4 - reproduced here in figure 2.

Later in that same year, we have news of Buckman's final involvement in American mining. In at least the English edition of the booklet promoting the Great Kanawha Estate (Anonymous, 1860b) is a short letter from Buckman, dated 5 August 1858 giving his testimonial for Professor John Locke. It reads "I know Dr Locke very well and have the highest respect for his character as a gentleman and his ability and judgement as a professional man" (Anonymous, 1860b, p. 23). This shows only that Buckman was quite unaware that Locke had died, on 10 July 1856 in Cincinnati, since their last meeting.

THE GUYANDOTTE COMPANY FAILS

Sadly we know little further of the Guyandotte Company's activities. The fact that their only other known surviving Prospectus is a 12 page American edition signed by the then President, Henry M'Farlan, and dated April 1857 (in the Library of Congress, Washington, DC) must indicate that their 1853-54 attempts to raise English capital had failed. The Company had by 1857 only opened three adits 100 to 250 yards long into a hill in the north of its estates and was now planning to lease collieries here, instead of working them itself. It also planned to move its offices to Philadelphia. The financial panic of 1857 must have made all these plans redundant.

The start of the horrendous American Civil War in 1861 prevented any further exploration of either the Guyandotte or Kanawha estates. In final irony the Great Kanawha Company was registered in London on 25 January 1861, less than three months before the start of the Civil War. It is little wonder that the surviving Company file here notes that "no returns were sent in 1862-1877." This Company was dissolved in March 1882 (Public Record Office, London, BT 31/530/2131).

When interest in these coal fields was again re-kindled after the Civil War, this was led by an English-trained mining engineer, called Matthew Fontaine Maury junior (died 1886), Fellow of the Geological Society of London (elected 1870), and son of the famous American hydrographer of the same name (1806-1873) (Schlee, 1975). The son had trained at the London Royal College of Chemistry and the nearby Royal School of Mines between 1866 and 1869 (Reeks, 1920, p. 130). In 1873 he issued his book "The Resources of the Coalfield of the Upper Kanawha... setting forth some of their markets and means of development" (Maury, 1873). But it is clear from a later book (Edwards, 1892) how little development of these Kanawha and Guyandotte fields had taken place even by that date. The wilderness condition of the country and the problems of transportation there (whether of coal or men) were cited as the main reasons for this. Edwards further noted that it had been the wild condition of the rivers and the frequent losses of whole boatloads of coal on them which had brought an end to the 1850's explorations which brought Buckman to the United States. The frontier spirit of America was not able to unlock these coal fields until the twentieth century.

GEOLOGICAL CONSULTING

One final comment concerns the too-often hidden careers of these geological consultants. Buckman was unusual in having published a little on his private coal-prospecting work, both in England and America. Although the printed reports on Ansted's consulting activity are excessively rare, at least he wrote a fascinating account of his career as a mining geologist. The publication of such a book is however highly unusual, while the standard account of his life gives the usual short shrift to his consulting work (Anonymous, 1908). The normal historical silence towards the mining and industrial activities of such academic geologists has been similarly accorded to the American John Locke, whose American biographers seem in equal ignorance of any such activity by him. One is forced to agree with Geoffrey Tweedale (1991) that applied geological work has so far proved of little interest to historians, in part because of the particular difficulty in locating source materials and also because of the long bias towards academic and theoretic geology by historians. Paul Lucier's recent work (1995) has started to give us a much needed corrective.

ACKNOWLEDGMENTS

Libraries from Cleveland, Ohio to Cambridge, England and many in between have been quarried to uncover this story. Our grateful thanks to all who keep our library and archive resources so available on both sides of the Atlantic and in particular to John Thackray (London), to whom we dedicate this paper in tribute. Bob Dott (Wisconsin), Tom Sharpe (Cardiff) and Earle Spamer (Philadelphia) gave vital specific assistance. Hugh Torrens owes grateful thanks to Bill and Heather Brice for library investigations and their wonderful hospitality and transportation on a rapid exploration of the area that Buckman had visited 145 years earlier.

REFERENCES CITED

Albion, R.G., 1934, George Peabody (1795-1869): Dictionary of American Biography, v. 14, p. 336-8, H. Milford, London.

Aldrich, M.L. and Leviton, A.E., 1982, William Barton Rogers and the Virginia Geological Survey, 1835-1842, in Corgan, J.X., editor, The Geological Sciences in the Antebellum South: University of Alabama Press, Birmingham, p. 83-104.

Anonymous, 1848, Comment by Henry De la Beche: The Cambrian, 11 August 1848, p. 3.

Anonymous, 1851a, Official Descriptive and Illustrated Catalogue of the Great Exhibition of the Works of Industry of all Nations: Spicer Bros, London, volume 1, cxcii + 478 p.

Anonymous, 1851b, The Last Appendix to Yankee Doodle: Punch, v. 21, 13 September 1851, p. 117.

Anonymous, 1853a, Exhibition in New York: The Times, 26 April 1853, p. 6.

Anonymous, 1853b, Reports and Letters relating to the Guyandotte Land Company 1853: William Penny, London, 53 p, (copy in Library of Congress).

Anonymous, 1854a, Report: Gentleman's Magazine, April 1854, p. 390.

Anonymous, 1854b, Guyandotte Land, Coal, & Iron Company. Synopsis of Reports, Geological Surveys, and other facts in relation to this property: William Penny, London, 32 p, (copy in Library of Western Reserve Historical Society, Cleveland, Ohio).

Anonymous, 1854c, Advertisements: The Times, 15 May and 22 May 1854, p. 1.

Anonymous, [1860a], Great Kanawha estate. Evidence of value and title: Philadelphia, H.G. Leisenring, 84 p. (copy in New York Public Library).

Anonymous, [1860b], Great Kanawha estate. Evidence of value and title: London, no publisher named, 75 p. (copy in the British Library, London).

Anonymous, 1908, David Thomas Ansted (1814-1880): Dictionary of National Biography, v. 1, p. 509.

Ansted, D.T., 1853, Report on the "Wilson Survey" near the Great Kanawha River, Virginia: Wm.C. Bryant, New York, 16 p. (copy at University of Wisconsin).

Ansted, D.T., 1854, Scenery, Science and Art; being Extracts from the Note-Book of a geologist and mining engineer: J. Van Voorst, London, 323 p.

Boase, G.C., 1908, Francis Egerton (1800-1857): Dictionary of National Biography, v. 6, p. 571-2.

Buckman, J., 1849, On some Experimental Borings in search of Coal: Report of the meeting of the British Association for the Advancement of Science, Swansea 1848, p. 67.

Buckman, J., 1855a, On some Coal mining Operations at Malmesbury: Wiltshire Archaeological Magazine, v. 2, p. 159-161.

Buckman, J., 1855b, An account of coal deposits in West Virginia: Report of the meeting of the British Association for the Advancement of Science, Liverpool 1854, p. 78.

Buckman, J., 1856, On the natural history of British meadow and pasture grasses: Journal of the Royal Agricultural Society of England, v. 17, p. 513-542.

Buckman, J., 1858a, The practical application of Geology in Coal-Seeking: Geologist, v. 1, p. 129-134 & 184-189.

Buckman, J., 1858b, The Natural History of British Meadow and Pasture Grasses: Hamilton, Adams & Co., London, 73 p.

Burkhardt, F. and Smith, S., 1991, The Correspondence of Charles Darwin, v. 7, 1858-9: University Press, Cambridge, 671 p.

Clarke, E., 1909, John Wilson (1812-1888): Dictionary of National Biography, v. 21, p. 586-7.

Crouthamel, J.L., 1969, James Watson Webb, A biography: Wesleyan Univ. Press, Middletown, Conn., 262 p.

Darwin, C., 1859, The Origin of Species: Murray, London, 502 p.

De la Beche, H. and Playfair, L., 1848, First Report on the Coals suited to the Steam navy: Memoirs of the Geological Survey of Great Britain, v. 2, part 2, p. 539-630.

Dunaway, W.F., 1922, History of the James River and Kanawha Company: Columbia University, New York, 251 p.

Edwards, W.S., 1892, Coals and Cokes in West Virginia: R. Clarke and Co., Cincinnati, 162 p.

Elsas, M., 1960, Iron in the making. Dowlais Iron Company Letters 1782-1860: Cardiff, Glamorgan County Council, 247 p.

Geikie, A., 1895, Memoir of Sir Andrew Crombie Ramsay: Macmillan and Co., London, 397 p.

Hearnshaw, F.J.C., 1929, The Centenary History of King's College London, 1828-1928: G. Harrap, London, 543 p.

Jones, E., 1986, William Turquand (1818/9-1894): Dictionary of Business Biography, v. 5, p. 582-4, Butterworths, London.

Kent, C., 1908, William Henry Lytton Earle Bulwer (1801-1872): Dictionary of National Biography, v. 3, p. 263-5.

Lucier, P., 1995, Commercial Interests and Scientific Disinterestedness: Consulting Geologists in Antebellum America: Isis, v. 86, p. 245-267.

Lyell, C., 1854, New York Industrial Exhibition. Special report of Sir Charles Lyell: Harrison and sons, London, 50 p.

Maury, M.F., 1873, The Resources of the Coalfield of the Upper Kanawha... setting forth some of their markets and means of development: Sherwood and Co., Baltimore, 44 p.

Merrill, G.P., 1906, Contributions to the History of American Geology: Report of the U.S. National Museum in Annual Report of the Smithsonian Institution, 1904, p. 189-733.

Reeks, M., 1920, Register... of the Royal School of Mines, London: School of Mines, London, 233 + 212 p.

Rolt, L.T.C., 1970, Victorian Engineering: Penguin Press, London, 300 p.

Rosenberg, N., editor, 1969, The American System of Manufactures: University Press, Edinburgh, 440 p.

Sayce, R., 1992, The History of the Royal Agricultural College, Cirencester: Alan Sutton, Stroud, 370 p.

Schlee, S., 1975, A History of Oceanography: Robert Hale, London, 398 p.

Torrens, H.S., 1988, What Price the Advancement of Science: unpublished paper presented to the 150th annual meeting of the British Association for the Advancement of Science, Oxford 1988 (copy in Royal Agricultural College library, Cirencester).

Tweedale, G., 1991, Geology and industrial consultancy: British Journal for the History of Science, v. 24, p. 435-51.

Webb, J.W., 1853, Letter: The Times, 3 October 1853, p. 9.

Wilson, J., 1854, New York Industrial Exhibition. Special report of Professor Wilson: Harrison and sons, London, 133 p.

Winchell, N., 1894, Sketch of Dr. John Locke: The American Geologist, v. 14, p. 341-356.

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JOHN FULTON, SURVEYOR, GEOLOGIST, AND FRIEND OF THE SECOND PENNSYLVANIA GEOLOGICAL SURVEY

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ABSTRACT

The Second Pennsylvania Geological Survey was created by an act of the State Legislature in May of 1874 and J. Peter Lesley (1819-1903) was selected as its director. Lesley had been a member of the First Survey in 1836 made under the guidance of Henry D. Rogers. The same year Lesley began the Second Survey, John Fulton (1826-1916) was hired by the Cambria Iron Company in Johnstown, Pennsylvania. Shortly thereafter Lesley enlisted Fulton for the geological mapping of Cambria and Somerset counties.

Fulton had been a surveyor in his native Ireland, and started his geological work in the Broadtop coal fields of Pennsylvania in the 1850s during which time he became acquainted with Lesley. In the fall of 1887, Lesley was having difficulty obtaining the funding necessary to continue publishing the individual county reports, and he called upon Fulton for help. Fulton was then General Superintendent of the Cambria Iron Company, which at that time was one of the largest such companies in the world. Given his important business position, Fulton was able to arrange a meeting with the Governor to present Lesley's case. Fulton's plea appears to have been heeded and the following year state funds were released and some county geological maps were published, including his own.

Thus, Fulton was not only a worker for the Second Survey, but he was able to assist Lesley by exerting political pressure on the governor to release funds for the publication of the geological material. After his retirement from the iron and steel business, Fulton turned to professional geological and mining consulting with commissions in Canada, throughout Europe, and in Puerto Rico.

INTRODUCTION AND EARLY LIFE

In many ways John Fulton (Figure 1) is a typical product of nineteenth century America: immigrant to the United States, high moral character, essentially self-taught in his fields of expertise, and successful in most of them. But his life was not without turmoil. He experienced early poverty as well as personal pain and anguish later in life. For example, in the span of a few months in 1884-85, Fulton and his wife lost both their young adult sons to unknown illnesses.

He carried the name of both his Irish great-

Figure 1. John Fulton in 1858.

grandfather and his grandfather and was the son of Thomas Fulton and Maria (McKeon) Fulton. John Fulton, the oldest of five boys and one girl, was born on October 16, 1826 in Tyrone County in what is known today as Northern Ireland. As a farm lad, he was raised with "...tales of witches, warlocks, fairies and other unhealthy beings."[1] But given the location of his birth, not all the violence he experienced was fiction. As a young boy he witnessed some of the sectarian clashes that were part of his world then, and, unfortunately, still exist in that part of the world today. He watched his own father participate in the destruction of a Catholic village by a group of Protestants that was prompted by a Catholic group's attack on a Protestant parade. He later noted, "I was awed at this carnival of retributive justice."[2]

His early education was at home, in the Irish language, but then after some tutoring in English, he attended "Ardtrea Classical School," the local English school. Here young Fulton discovered that he had a talent for numbers and figures, which was an advantage because the teacher was a literature expert and had little time for arithmetic and mathematics. As a result, young John was his own teacher in those quantitative subjects. His later career demonstrated that he was a good teacher as well as a good pupil, because he had to contend with poor instruction and he had to survive the usual hazing that occurred in the schools. Very early in his stay at Ardtrea School, he was put to the test, for he had to fight a Mr. Porter, a student much larger than he, whom he dispatched quickly. After that fight, he had no more trouble with the older boys. He also attended school at the Killyman Anglican Church, even though his family were "Primitive Wesleyan Methodists" and not Anglican.

When Fulton was in his teens, his farmer father became a land surveyor, in addition to his duties as an itinerant minister in the Wesleyan Methodist Church. Although not out of high school, John began assisting his father making maps of the local area. Not only was he good with numbers, but John possessed quite a talent for drawing and draftsmanship. Some of his maps looked as if they were copper engravings instead of drawn by hand. Unfortunately, even with preaching, farming, and surveying, the family could not survive financially if they stayed on the farm. Thus, they rented out the land and moved to the larger town of Dungannon in 1841. Many years later, Fulton still recalled the pain of closing the farm and moving. He noted in his diary that while on the farm, "...we felt the poverty of our present situation." He then offered a few nostalgic lines of poetry:

"Thus sighing, looking back through the waves of time/For the long-faded glories they cover."[3]

With their life on the farm over, the Fultons lived in Dungannon for about seven years. John attended the Erasmus Smith School for his high school training, where he showed quite a gift for painting and learned the art of making copper engravings. He even worked for a short time in Dublin in 1845-46. Through his acquaintance with Thomas S. Irwin, who was surveying some land near Omagh, young John Fulton found employment in 1847 as part of the land surveying crew developing the route for the Great Western Railway from Dublin to Galway. Having little money, he had to walk over 16 miles to start this job. As with almost any task he undertook, the survey work was done well. He was even given a pocket knife in appreciation for his "correct chaining." At that time surveyed distances were measured with an actual chain of known length. Despite his youth, Fulton's ability to lead men was recognized and he was assigned as "chairman to a corps of employees managed by Butler and Fortescue."[4] Fulton's good position and the move to Dungannon notwithstanding, the fami-

1. John Fulton Diary, Vol. I, p. 12. Most of the biographical information used in this paper is taken from a set of diaries prepared by John Fulton primarily between 1912-1914. Accompanying the diaries are a few personal papers that survived the 1889 flood. John Fulton Papers; Johnstown Area Heritage Association Archives, P. O. Box 1889, Johnstown, Pennsylvania 15907-0889. The collection is housed at the Flood Museum Library in Johnstown, Pennsylvania, and hereafter reference to this material is given as "John Fulton Diary."

2. John Fulton Diary, Vol. I, p. 19.

3. John Fulton Diary, Vol. I, p.20.

ly circumstances remained difficult as the financial panic of 1847-48 and the famine of 1848 descended on Ireland. On October 13, 1848, the Fultons sold their farm and emigrated to the United States.

LIFE IN THE NEW COUNTRY

After six weeks at sea on the *Sarah Siddons*, sleeping on pine boards, and eating meals cooked by the passengers themselves, the group spotted Sandy Hook and soon landed at New York. Fulton immediately left the family and traveled by river barge and stage coach to Wayne County, Pennsylvania. There a friend of his father's had promised him work building a canal near Cherry Ridge, "the North Branch Canal"[5], in which his surveying skills would pay great dividends. During the journey, Fulton had a casual conversation with a gentleman whose advice made quite an impression on the young 22 year-old immigrant. After hearing Fulton's tale of life in Ireland and leaving his homeland to seek a new beginning and seeing that he was a bright, strong young man, the stranger said words to him that Fulton remembered over 60 years later when he prepared his autobiographical diaries. The man said that: "...[with] sober earnest effort I [Fulton] could not fail to realize a competence."[6]

For his work on the canal, Fulton was paid $0.75/day ($1.00/day during the summer months) with no meals included, and his work "day" lasted from daybreak to sundown. Here Fulton began his direct involvement with rocks, albeit with a drill and blasting powder, not making geologic maps, as he was to do later. The winter months were the hardest, for he had no gloves or mittens and used his old socks as mittens to protect his hands from the cold. Once again, as with the previous position with the Great Western Railway in Ireland, he showed that he was a quick learner, and within a few months he was made "Boss" over 40-50 men. Not long after that he was promoted to "Walking Boss." Now he was the "Boss of Bosses," but to gain extra income during this time, in addition to his work at the canal site, he did clerical work and bookkeeping at the hotel where he was living. Within one year he had saved $100, and brought his family to Wayne County. Most of his family eventually settled in Virginia, where his father was a Methodist minister. His mother, Maria McKeon Fulton, died in 1864, and his father died in Campbell County, Virginia, on June 24, 1890.[7]

When the North Branch canal was completed, during 1853-54 Fulton moved on to work on the Junction Canal between Athens, Pennsylvania and Elmira, New York. He was almost 30 years old, and his life was a solitary one, but was soon destined to change. Another family, the MacKays, whom the Fultons had known in Dungannon, emigrated at the about same time, but they went to Canada. As Elmira is closer to Canada than where he was in Pennsylvania, Fulton could now travel to Arthur, Canada to visit them and socialize with Miss Anne MacKay, a daughter who had been born in Dungannon on November 20, 1830. Their courting went well and in February 1855, Anne and John Fulton were married. Anne died in Johnstown, Pennsylvania, on October 2, 1912, after 57 years of marriage. The union produced four children, Maria (1856), James (1857), Thomas (1860), and Nannie (birth date unknown).

THE BROADTOP YEARS

Fulton and his young bride had but a brief stay in Elmira where he worked on the Johnny Cake dam before moving on to Bedford County, Pennsylvania, in about 1856. There he was first employed as assistant engineer of the Barclay Railroad and then as resident engineer for the Huntington & Broadtop Mountain Railroad and

4. John Fulton Obituary: *The Daily Tribune*, Johnstown, Pennsylvania, Friday Evening, January 21, 1916, p. 10.
5. John Fulton Obituary: *The Daily Tribune*, Johnstown, Pennsylvania, Friday Evening, January 21, 1916, p. 10.
6. John Fulton Diary, Vol. II, p. 32.
7. John Fulton Obituary: *The Daily Tribune*, Johnstown, Pennsylvania, Friday Evening, January 21, 1916, p. 10. Also mentioned in John Fulton Diary Vol. II, p. 61 3/4.

Figure 2. J. Peter Lesley, Director, Second Geological Survey of Pennsylvania.

Coal Company, a line chartered in 1852 primarily to move coal from the Broadtop mines (Bennett, 1990). With his experience in surveying and rock blasting, Fulton was put in charge of "Maintenance & Ways and Mines." This was a time of great expansion, with just under 43,000 tons of coal being shipped in 1856, and almost 80,000 tons in 1857. His connection with the Broadtop Company lasted until 1874, even though he worked concurrently for another company during the last three or four years he was there.

Part of his responsibility at the company was to survey the mines and determine the stratigraphic layout in order to keep the mine diggings within the coal seams. It was this activity that brought him in contact with J. Peter Lesley (Figure 2) who had been one of the assistants on the Henry D. Rogers' Geological Survey of Pennsylvania, begun in 1836. Fulton ran into difficulty in trying to correlate some of the coal seams in the Broadtop field and called upon Lesley for help. But after looking at the section and inspecting the work Fulton had done, Lesley could make no major corrections. In his opinion, Fulton had the stratigraphy in the proper sequence, and one of the coal seams still bears the name "Fulton Seam," in recognition of this work. Although this was Fulton's first encounter with Lesley, it was not to be the last, and throughout his life, Fulton maintained the highest respect and affection for Lesley: "I never changed my love [for] and devotion to the really great and learned man."[8]

By 1860, just as the Civil War was beginning, Fulton had surveyed an extension of the Broadtop Railway into Bedford County. Fulton volunteered and raised a company of men to fight for the Union, but the military officials decided that his presence was essential to keep the much needed coal flowing from the Broadtop mines. Thus, Fulton did his wartime duty in his regular position at Broadtop while living in Saxton, Pennsylvania where he and Anne had moved their family.

In the late 1860s and early 1870s, Fulton began to have more professional contacts within the fields of geology and mining engineering. In 1868 he read a paper at the meeting of the American Mining Institute, and he was a long-time member of that organization. Through Lesley's influence, Fulton became a member of the American Philosophical Society of Philadelphia. He also developed contacts with Benjamin Silliman, Jr., professor of geology at Yale University, after Silliman examined the iron ore deposit at Tussy's Mountain in 1872 (Silliman, 1872). But his energies were mostly directed toward the coal production of Broadtop, which reached over 350,000 tons/year in 1873. His mining success and his skill in working with people had not gone unnoticed in the business world. In 1870, while still maintaining his connection with the Broadtop company, he became chief engineer for the Bedford and Bridgeport Railroad, from which he retired when it became part of the Pennsylvania Railroad system in 1872. Then, in 1874, Fulton's life changed yet again. Coincidentally, this was the same year that Lesley was asked to direct the Second Pennsylvania Geological Survey.

8. John Fulton Diary, Volume II, p. 61 3/4.

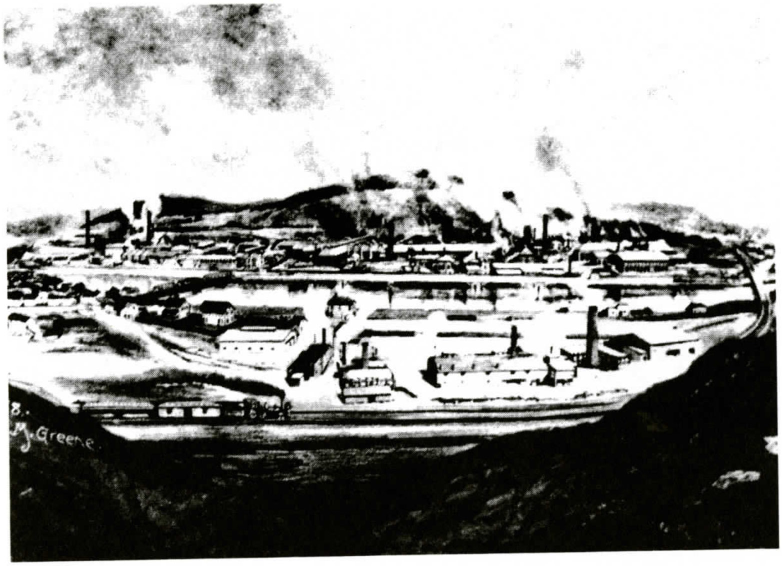

Figure 3. Cambria Iron Company, Johnstown, Pennsylvania, in the late 1880s when Fulton was the General Manager.

CAMBRIA IRON COMPANY

In 1874, Fulton became General Mining Engineer with the Cambria Iron Company in Johnstown, Pennsylvania (Figure 3), at a salary of $3000/year. All during the 1870s he organized and supervised working parties to survey Company coal and iron mining properties in Michigan, Virginia, and North Carolina, as well as the local mines in the Johnstown area. These experiences provided him an opportunity to study the local and regional geology (Fulton, 1874, 1875). Mr. Daniel Johnson Morrell, the General Superintendent of Cambria Iron, and E. Y. Townson, President of the Company, were quite pleased with the contribution Fulton was making to the Company. As an indication of that appreciation, Morrell rewarded Fulton with a $500 cash bonus in 1882. The Fulton family had a nice home on Central Park in Johnstown, and one son was enrolled at Columbia University studying mining engineering and the younger son appeared destined to do likewise. It seemed that life was indeed good for the Fulton family, but that did not last for long. The younger son, Thomas, became ill and died on September 20, 1884. The remaining elder son, James, who was attending Columbia University, became ill and had to return home. Despite the best attention of the physicians, his unknown illness continued to weaken him and he died on January 18, 1885. John and Anne (Figure 4) probably never fully recovered from this double blow which gravely challenged their deeply held religious beliefs.

The personal tragedies of his life, however, did not interfere with his professional work. He gave lectures on geology while in Michigan inspecting the mines there (Fulton, 1887). He was elected Vice President of the American Institute of Mining Engineers in February 1885, and that same year he published a paper concerning fire-gas in the coal mines around Johnstown (Fulton, 1885). In the local Johnstown Library Hall he taught courses in "Practical Mining," a subject close to his heart. With the death of Morrell in 1885, Fulton quickly moved up the corporate ladder, becoming General Superintendent of the steel works in 1887 at a salary of $4,000, and then General Manager of the Company in 1888.

THE SECOND PENNSYLVANIA GEOLOGICAL SURVEY

During the 1870s and 1880s Fulton renewed his connection with Lesley and the Second

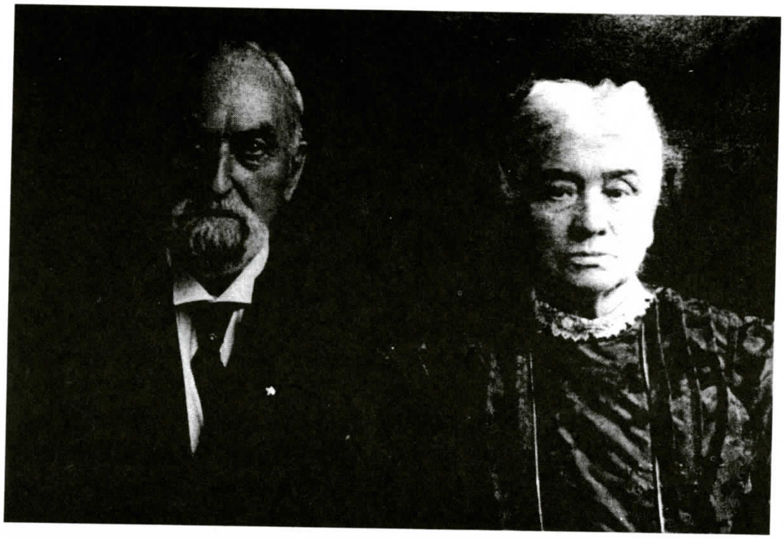

Figure 4. John and Anne Fulton in their later years.

Pennsylvania Survey which had been created by the Pennsylvania Legislature on May 14, 1874. J. Peter Lesley, a professor of geology and mining at the University of Pennsylvania was chosen to lead the new Survey (Anonymous, 1988). Lesley's approach to the Survey work differed from Rogers'. Where Rogers held all the individual reports for a massive final report, Lesley published each report as soon as the work was completed and assembled, thus producing over 100 atlases and volumes, totaling over 25,000 pages (Anonymous, 1988).

According to his obituary and the title given on his geological maps, Fulton held the title of "Assistant State Geologist."[9] Many of Fulton's scientific contributions were in coke manufacture (Fulton, 1876, 1878). Unfortunately, most of the original notes, letters, diaries, and maps from 1887-1888 were lost in the 1889 Johnstown Flood (see Figure 5). Perhaps the greatest irony of this situation arises from the fact that Fulton personally inspected the South Fork Dam during 1888 and, according to his diaries, stated in his report that he found the facility had been repaired with roots of trees and branches, and that there were many leaks in it. It was his opinion that, "...it is only a matter of time until the dam would break."[10] He sent the report to the dam owners, but, according to Fulton, received only, "...an impertinent reply..."[11] for his troubles. Less than a year later, his words proved prophetic.

The material that did survive the flood suggests that Fulton was heavily involved in preparing the geological maps of Cambria and Somerset Counties. Based upon the few surviving notes and letters among his papers, he was of service to Lesley on the political side as well. In the fall of 1887, Fulton received a note from Lesley stating, "I have not the money to go to market." Lesley commented that the State Legislature had promised, but had not, so far, delivered, over $6000 which had been appropriated for the Survey work. In addition, Lesley indicated to Fulton that even his own salary had not been paid. This was not the first time Lesley's Survey had political difficulty with appropriations. John C. Branner, later the second president of Stanford University, was a member of the Second Survey and worked in the Scranton area in the middle 1880s. In letters to a former

9. John Fulton Obituary: *The Daily Tribune*, Johnstown, Pennsylvania, Friday Evening, January 21, 1916, p. 10.

10. John Fulton Diary, "Retired Volume", p. 144.

11. John Fulton Diary, "Retired Volume", p. 144.

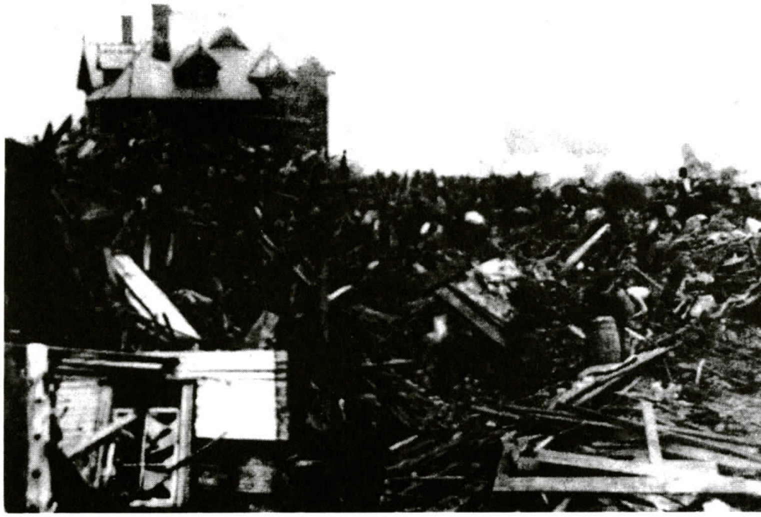

Figure 5. In the foreground is the site of the Fulton house after the 1889 Johnstown Flood.

classmate at Cornell University, Orville A. Derby, who was in Brazil and had his own difficulties keeping his State Geological Survey of São Paulo financially afloat, Branner said: "Every two years they [the Second Geological Survey officials] have the same old fight over in the legislature for the appropriation, and while it may generally be forthcoming, there is a feeling of uncertainty about it that is awe inspiring to a married man."[12] In another letter to Derby shortly after he wrote the one above, Branner indicated one reason for the lack of governmental support: "The Governor in his message questions the utility of such work [geological work by the Second Survey]..."[13]

After hearing from Lesley, and with the full authority of being head of what was then the largest iron/steel company in the world, Fulton immediately contacted the governor's office in Harrisburg, perhaps by telegram, requesting a face-to-face meeting. The governor's office granted his request and he caught the next train. In the company of the local senator, Senator Lemon, Fulton had a conference with Governor Harding, at which time Fulton showed the Governor Lesley's letter. Among the Fulton papers there is no record of the conversation, but no doubt Fulton's discussion did make an impression, for according to Fulton: "...immediate steps were taken to relieve his [Lesley's] impecunious condition."[14]

Nonetheless, except for Lesley's back salary, little money was forthcoming immediately, and shortly afterward Lesley contacted Fulton again: "I have only $1100 left for the geological survey and mapping of Cambria and Somerset Counties: as you know the general geology of these counties, won't you undertake the work?"[15] In his diary, Fulton recorded the following response: "I employed a small force at very limited salaries, and the maps of these two counties were completed."[16] And then added, in phrasing which seems to echo the earlier words of Branner: "The stupidity of the Legislature and its inability to grasp the value of this

12. John C. Branner to Orville A. Derby, February 18, 1884. Special Collections and Archives, Green Library, Stanford University; John C. Branner Papers 1882-1921; SC-34, Box 1, Book 2, p. 144-145.

13. John C. Branner to Orville A. Derby, March 1, 1885. Special Collections and Archives, Green Library, Stanford University; John C. Branner Papers 1882-1921; SC-34, Box 1, Book 2, p. 432-435.

14. John Fulton Diary, Volume III, p. 179.

15. John Fulton Diary, "Retired Volume", p. 137b.

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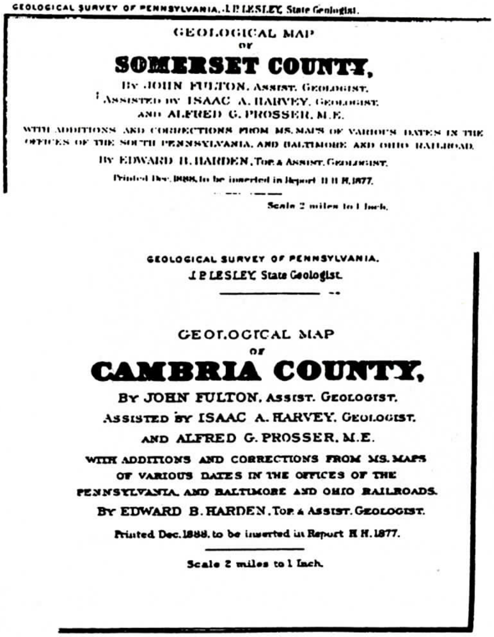

Figure 6. Title portions of the geologic maps of Cambria and Somerset Counties (Anonymous 1888).

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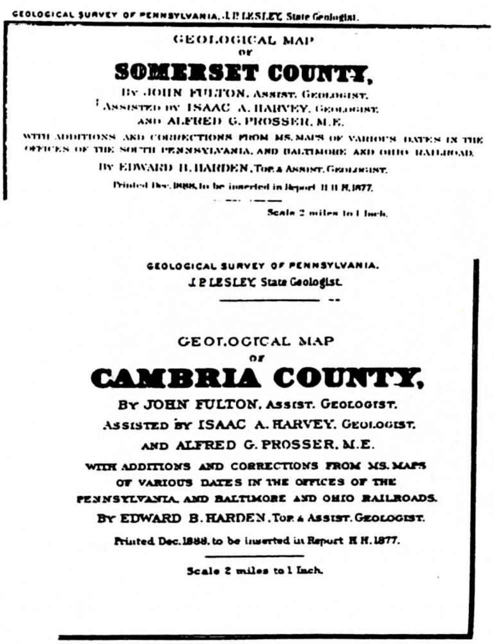

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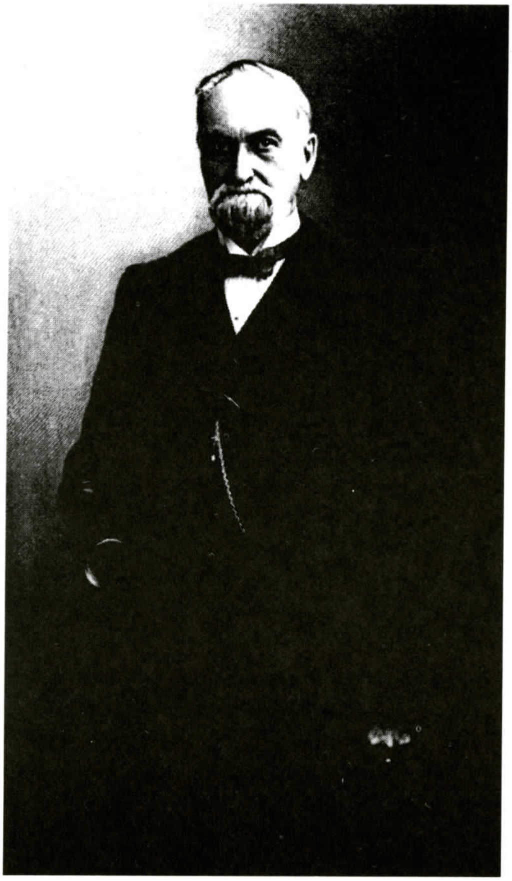

Figure 7. John Fulton, 1902, age 76.

had ever been, notwithstanding the fact that in October of 1900 he celebrated his 73rd birthday. He worked as a consultant in Newfoundland and Nova Scotia, France, Germany, England, and Puerto Rico. As a member of the United States Geological Survey Committee on Mines and Minerals, Fulton helped create an exhibit for the St. Louis Exposition of 1903. In 1906, in his 80th year, he was inspecting mines in Virginia, and the following year he prepared the geological section of Greenbriar Mountain in West Virginia, the site of an iron mine owned by Mr. A. J. Moxham. To give an illustration of his vigor, in 1908 he was an expert witness in a court trial before the Supreme Court of Maine, *C. W. Hotchkiss vs. Bon Air Coal and Iron Company.* At one point he was on the witness stand for an entire day and local newspaper articles remarked on how well he held up under all the pressure, "...for a man of 73"; he was really 82 at the time. He was still publishing professional papers in 1909 (Fulton, 1909).

FINALE

Never one to shirk his civic duty, Fulton served for many years on the Pennsylvania and Johnstown Boards of Health, and was president of both for over 10 years. In addition to his work with the Second Geological Survey, Fulton was also a member of the State Forestry Commission. Locally he was a founding member of Grandview Cemetery, where his remains were later buried, and he was a pillar of the First Presbyterian Church of Johnstown where he taught a Sunday School class for over 40 years. In his late 70s he undertook a trip through the Holy Land. Fulton seemed not to have any difficulty reconciling his deeply held religious views with his passion for geology. At his funeral service the officiating minister, Rev. Dr. C. C. Hays, made reference to this fact: "He [Fulton] was a geoligan[24] [*sic*] and a theologian, too, and if there was one thing that aroused his ire more than another it was any reflection on the Inspired Book by any of the so-called scholars of the day, or any intimation on the part of scientific men that that [*sic*] there is anything here that is not in accord with science. He knew the rocks as well as any man, was thoroughly conversant with the process of the earth's formation and he knew God too, and held that all true scientific investigation is in perfect accord with the first statement of the Bible,....we shall not soon see the like of him again."[25]

Maria, the Fulton's elder daughter, married John D. Ligon of Washington, D. C., and from this union came Fulton's two grandchildren; Mrs. Anna Ligon Howser, and John Fulton Ligon, all living in Washington in 1916. Nannie West Fulton did not marry and was living with her father at 136 Park Place in Johnstown at the

24. It is surmised that the original word used by Dr. Hays was "geologian" to parallel "theologian", but the quote is given as it was printed
25. *The Daily Tribune*, Johnstown, Pennsylvania, Monday Evening, January 21, 1916, p. 4.

time of his death, in his 90th year, on January 20, 1916.

Perhaps his life is best summarized in a letter from an old friend, written to him in 1914, a little over a year before Fulton's death. Joseph R. Richards, retired Chief Engineer of Maintenance for the Pennsylvania Railroad, had known and worked with Fulton since the middle 1870s. The letter was written on the occasion of Fulton's birthday (Richards thought it was his 89th, but it was only his 88th): "You have done so much prominent work all along of recent years and shown such strength and energy that your friends have rated you very much younger, i.e., you are younger than your years. The habit of mind has kept you young."[26] Would that we all maintain such a "habit of mind."

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REFERENCES CITED

Anonymous, 1888, Atlas to Reports HH and HHH, 1877: Second Geological Survey of Pennsylvania.

Anonymous, 1988, Pennsylvania: *in* Socolow, Arthur A., Editor, The state geological surveys - a history: Association of American State Geologists, p. 372-388.

Bell, Isaac Lowthian, 1875, Notes of a visit to coal- and iron-mines and ironworks in the United States: Newcastle-on-Tyne, M. and M. W. Lambert, 66 p.

Bell, Isaac Lowthian, 1877, Report on the iron manufacture of the United States of America, and a comparison of it with that of Great Britain: London, G. E. Eyre and W. Spottiswoode for H. M. Stationery Office, 40 p.

Bell, Isaac Lowthian, 1892, The Iron and Steel Institute in 1890. On the American iron trade and its progress during sixteen years: Edinburgh, Ballantyne, Hanson, 208 p.

Bennett, Lola M., 1990, The company towns of the Rockhill Iron and Coal Company: Robertsdale and Woodvale, Pennsylvania: Washington, D.C., National Park Service, Department of the Interior, 98 p.

Clarke, John, 1914, Tenth report of the Director of the State Museum and Science Department: New York State Museum Bulletin, Number 173.

Fulton, John, 1874, Note on the Somerset County coal beds in Pennsylvania: American Philosophical Society Transactions, v. 14, p. 157-158.

Fulton, John, 1875, Description of the coal estate of the Valley and Gulf Railroad and Coal Company, at Sparta, Illinois, U. S. America, with proposed method of development and channels to market: Bellefonte, Pennsylvania, Bellefonte Press Company, 10 p.

Fulton, John, 1876, A report on methods of coking coal for furnace use; its efficiency and economy, as compared with anthracite coal in the metallurgy of iron; Appendix *in* Platt, Franklin, Special report on the coke manufacture of the Youghiogheny River valley in Fayette and Westmoreland Counties. With geological notes of the coal and iron ore beds from surveys by Charles A. Young: Second Geological Survey Report L, p. L.117-L.145.

Fulton, John, 1878, On the coking of bituminous coal; Appendix *in* Lesley, Peter (Editor), Report of progress in Bradford and Tioga Counties: Second Geological Survey Report G, p. 235-252.

26. Joseph T. Richards to John Fulton, September 12, 1914. Johnstown Area Heritage Association Archives: Fulton Papers, File Box 2/1.

Fulton, John, 1885, The source and behavior of fire-gas in the Johnstown mines: Transactions of the American Institute of Mining Engineering, v. 13, p. 771-782.

Fulton, John, 1887, Mode of deposition of the iron ores of the Menominee Range, Michigan: Transactions of the American Institute of MiningEngineers, v. 16, p. 525-536.

Fulton, John, 1888, Notes on Cambria County; *in* Anonymous, 1888, Atlas to Reports HH and HHH, 1877: Second Geological Survey of Pennsylvania, p. 361H3-396H3.

Fulton, John, 1890, The Adams Improved Bee-Hive Coke-Oven: The Colliery Engineer, v. 11, p. 8-9.

Fulton, John, 1895, Coke: a treatise on the manufacture of coke and other prepared fuels and the saving of by-products, with special references to the methods and ovens best adapted to the production of good coke from the various American coals: Scranton, Pennsylvania, The Colliery Engineer Company, 342 p.

Fulton, John, 1905, Coke: a treatise on the manufacture of coke and other prepared fuels and the saving of by-products, with special references to the methods and ovens best adapted to the production of good coke from the various American coals, 2nd Edition: Scranton, PA., International Textbook Company, 476 p.

Fulton, John, 1909, The Mitchell Patent Coke Oven: a form of oven especially adapted for machine drawing of the coke: Mines and Minerals, November, p. 1-8.

Lesley, J. Peter, 1885, A geological hand atlas of the sixty-seven counties of Pennsylvania, embodying the results of the field work of the Survey from 1874 to 1884: Report of Progress X, Harrisburg, Pennsylvania, Second Geological Survey, cxii, 61 maps.

Merrill, George P., 1906, Contributions to the history of American geology; *in*: Annual report of the Board of Regents of the Smithsonian Institution showing the operations, expenditures, and condition of the Institution for the year ending June 30, 1904, p. 189-733.

Platt, F. and Platt, W. G., 1877, Report of Progress in the Cambria and Somerset District of the Bituminous Coal-fields of Western Pennsylvania; Part I. Cambria (HH); Part II. Somerset (HHH): Second Geological Survey of Pennsylvania, Part I, 194 p.; Part II, 348 p.

Silliman, Benjamin, Jr., 1872, On the fossil iron ore and its associates in southern Pennsylvania: Iron and Steel Institute Journal, v. 2, p. 334-341.

Taylor, Richard C., 1832, Section of the Allegany Mountain and Moshannon Valley, in Centre Co., Pennsylvania: Monthly American Journal of Geology, v. 1, p. 433-438.

Taylor, Richard C., 1835a, On the geological position of certain beds which contain numerous fossil marine plants of the family Fucoides, near Lewston, Mifflin Co., Pennsylvania: Geological Society of Pennsylvania, Transactions, v. 1, p. 5-15.

Taylor, Richard C., 1835b, On the relative position of the transition and secondary coal formations in Pennsylvania, and description of some transition coal or bituminous anthracite and iron ore beds near Broadtop Mountain in Bedford Co., and of a coal vein in Perry Co., Pennsylvania: Geological Society of Pennsylvania, Transactions, v. 1, p. 177-193.

Taylor, Richard C., 1835c, On the mineral basin or coal field of Blossburg on the Tioga River, Tioga, Co., Pennsylvania: Geological Society of Pennsylvania, Transactions, v. 1, p. 204-223.

Vanuxem, Lardner, 1842, Geology of New York, Part III, comprising the survey of the Third District: Albany, New York, 306 p.

Wells, John West, 1963, Early investigations of the Devonian System of New York, 1656-1836: Geological Society of American Special Papers, No. 74, 74 p.

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DR. COOPER CURTICE - UNKNOWN WORKER IN INTERPRETING THE CAMBRIAN OF ALABAMA

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ABSTRACT

Cooper Curtice was an assistant to C. D. Walcott from 1883-1886. In 1885, he spent four months, mostly in Alabama, measuring sections of Paleozoic rocks and searching for fossils, mainly in the Cambrian. In 1888, Walcott concurred with foreign authorities that the rocks called Middle Cambrian in North America were Early Cambrian in age and vice versa, requiring a new interpretation of Cambrian strata. Curtice returned to Alabama for geologic investigations in 1892, and again briefly with Walcott in 1895. Since that time Cambrian stratigraphy in the southeastern United States has remained virtually unchanged.

INTRODUCTION

Among stratigraphers and paleontologists, Charles Doolitte Walcott is best remembered for his contributions to the Cambrian (Yochelson, 1967; 1998). He was a prodigious worker with an impressive record of publication. One secret of Walcott's success was that he had assistance; he was also fortunate in that his help was competent. By all odds, the best assistant he ever had was Cooper Curtice, employed full time by the United States Geological Survey (USGS) from 1883-1886 and intermittently after those dates. Walcott is poorly known to the present generation of geologists; Curtice is unknown to geologists, though in the quite unrelated field of veterinary parasitology he is still remembered for his many contributions.

CURTICE IN BRIEF

Cooper Curtice (Figure 1) was born May 7, 1856, in Stamford, Connecticut; as an adult he never used his first name "Frederick" (Logue, 1995). The family moved to Wisconsin, where his mother died when he was two and then to Moravia, New York, and, after a short time, on to Hamden, Connecticut. At age eighteen, he obtained a job rather than attending college as his father desired, but at twenty-one he went to Cornell where he took courses in geology from H. S. Williams. After graduation in 1881, he attended medical school for one year in Michi-

Figure 1. Dr. (Frederick) Cooper Curtice. Courtesy of National Agricultural Library. This picture is the frontispiece of Logue (1995).

gan, but then transferred to Columbia Veterinary College in New York City and in 1883 received his Doctor of Veterinary Science degree. It was at that time he crossed paths with Walcott.

Walcott was six years older, but the two had similar backgrounds (Yochelson, 1998). His father had died when he was two, he had moved several times in central New York, and rather than going to college, Walcott had gone to work. Despite the lack of any formal training, Walcott became an assistant to New York paleontologist James Hall for two years, and then in July, 1879, he joined the brand new U.S. Geological Survey as employee number 20. In 1883, he was in the final stages of organizing data on the fossils of the Eureka, Nevada, mining district (Walcott, 1884). A bit of money was left in the project, and Williams suggested Curtice when Walcott asked about promising young men for temporary employment. Curtice said yes, and his efforts were so satisfactory to Walcott that Curtice soon was offered a permanent job in Washington.

CURTICE ON THE U.S. GEOLOGICAL SURVEY

Cooper Curtice was appointed a Paleontologic Assistant, at a salary of $600 per year. Walcott recognized his merit and at the start of 1884, his salary was $720; six months later he was promoted to Assistant Paleontologist at $900. Finally, in January, 1886, Curtice received a heady $1,200 annual salary, until his resignation July 31, 1886, to join the Bureau of Animal Industry, U.S. Department of Agriculture.

From mid-August, 1883, for two months, Walcott was involved with the Cambrian of the northeastern United States. "Mr. Cooper Curtice accompanied me as assistant, and on our return stopped at Troy, N. Y., to make a collection of Cambrian fossils from the hills east of that city" (Walcott, 1885, p. 54). During the winter and spring of 1884, Curtice both prepared fossils and started a card catalogue of Cambrian species by reviewing the literature.

Later that summer, Curtice went to the Upper Mississippi valley. November 1, 1884, Walcott reported to the Director: "Mr. Cooper Curtice has been engaged in collecting fossils from the Upper Cambrian (Potsdam) horizon in Wisconsin and Minnesota.... The amount of material collected is very large, consisting of thirty one (31) barrels and sixteen (16) boxes of specimens. The study of it will add materially to the knowledge both as to the composition of the faunas and its geographic distribution." [1]

CURTICE-1885

During the summer of 1885, Curtice was sent off to the Southeast. He spent nearly four months away from Washington, most of that time in Alabama. The field notes of Curtice consist mainly of information on strike and dip at a variety of localities. Fortunately, another source of information is available in the monthly reports which Walcott submitted to the Director. For October, 1885, Walcott wrote "Mr. Cooper Curtice collected Cambrian fossils in Northern Alabama and Georgia, and is, at present, in the vicinity of Knoxville, Tennessee." [2]

Walcott's monthly report for November, 1885, summarizes his efforts: "Mr. Cooper Curtice, paleontologic assistant, was instructed to proceed to Cedar Bluff, [Cherokee County] Alabama, for the purpose of collecting Cambrian fossils, and locating their geologic horizons by taking the best geologic section he could. After completing that, he was instructed to continue north and endeavor to trace the connection between the faunas of the Upper Cambrian of Alabama, northeastern Georgia and those of eastern Tennessee. Mr. Curtice obtained valuable collections of fossils in both [sic] Alabama, Georgia and Tennessee; and the stratigraphic data is of such a character that I will submit it as

1. C. D. Walcott, Monthly Report to the Director of the USGS, November 1, 1884. Record Group 57, National Archives and Record Service, Archives II, College Park, Maryland.

2. Walcott, Monthly report, November 9, 1885.

a special report, as soon as prepared, for the use of geologist in charge of the Appalachian Division of Geology; I? am? [unreadable] now giving an outline of the work accomplished by him as given in his report.

"A section taken from Cedar Bluff southward, shows that there is a remarkable development of Cambrian strata whose outcrop extends from the Chattanooga [Curtice or Walcott who was writing meant Coosa] river, on the north, to Craigs mountain on the south, a distance of at least fifteen miles. Their dip is a little east of south and, although complicated by faults, the thickness appears to be very great judging from the lithologic and paleontologic characters.

"That, those strata contain an excellent fauna and many of the genera and species are apparently identified with those in Wisconsin and Tennessee. This fauna ranges upward from the lowest point of the Upper Cambrian (perhaps from the Middle Cambrian). The uppermost fauna of the Wisconsin Cambrian (Dicellocephalus [sic] was not found." [3]

That Walcott would praise Curtice so highly and circulate his report is an indication of what the young man accomplished by way of both new interpretations of geology and collections of fossils.

INTERLUDE

The end of July, 1886, Curtice transferred to the Bureau of Animal Industry (BAI), organized about two years earlier under the U.S. Department of Agriculture. He first studied tapeworms of sheep and in 1887 pursued them in the field around Colorado Springs; he did find time that year to meet Mary Katherine Kolbe, have a whirlwind romance, and marry. That fall he fought hog cholera in New Jersey before returning to his work on sheep parasites. During his years on the U.S. Geological Survey, Curtice pursued an M.D. degree at night and soon finished; thereafter, Walcott referred to him as Dr. Curtice.

From about 1888 onward, Curtice became deeply interested in the diseases of cattle. He resolved the cause of warble, caused by a parasitic fly. He then began investigating Texas fever, and was soon convinced that the disease was transmitted by ticks, and devoted several years to intensive study of their life cycle. By 1890, Curtice had several noteworthy publications in parasitology to his name, though he was unable to convince his BAI colleagues as to the merits of considering the tick as a vector of the disease.

Meanwhile two important events occurred in the study of Lower Paleozoic geology. For one, in 1887, Walcott was finally able to resolve the "Taconic problem" and removed that presumed geologic system from the stratigraphic column. That simplified, to some extent, general interpretation of Lower Paleozoic stratigraphy.

The second event is more germane to this story. In Sweden, W. C. Brøgger pointed out that *Olenellus* occurred below *Paradoxides* and that American workers had reversed the sequence. In 1888, Walcott confirmed that he and others in North America were wrong. Middle Cambrian rocks were actually Lower Cambrian and Lower Cambrian was actually Middle. The immediate result of this work was Walcott's investigation of the *Olenellus* zone. However, this reinterpretation did not extend further south than Chilhowee Mountain in Tennessee (Walcott, 1890).

While that large work was in the final stages of preparation, Walcott produced several short works, including describing previously unknown Middle Cambrian fossils, that is of authentic Middle Cambrian age. *Olenoides curticei* "was collected by Dr. Cooper Curtice in the Cambrian shales of Coosa Valley, near Blaine Post Office, Cherokee County, Ala., where it occurs on the surface of dark flint nodules" (Walcott, 1889, p. 443-444). In this short paper, that trilobite is the only species which is illustrated. Immediately following it, Walcott described *Olenoides* sp. undet. "found by Dr. Curtice in an argillaceous shale on the Edward's farm, near Craig's Mountain, Cherokee County, Ala." (Walcott, 1889, p. 444).

Walcott was stretched to the limit in pursuing Paleozoic stratigraphy, so he asked the Department of Agriculture for a temporary loan of

3. Walcott, Monthly report, December 1, 1885.

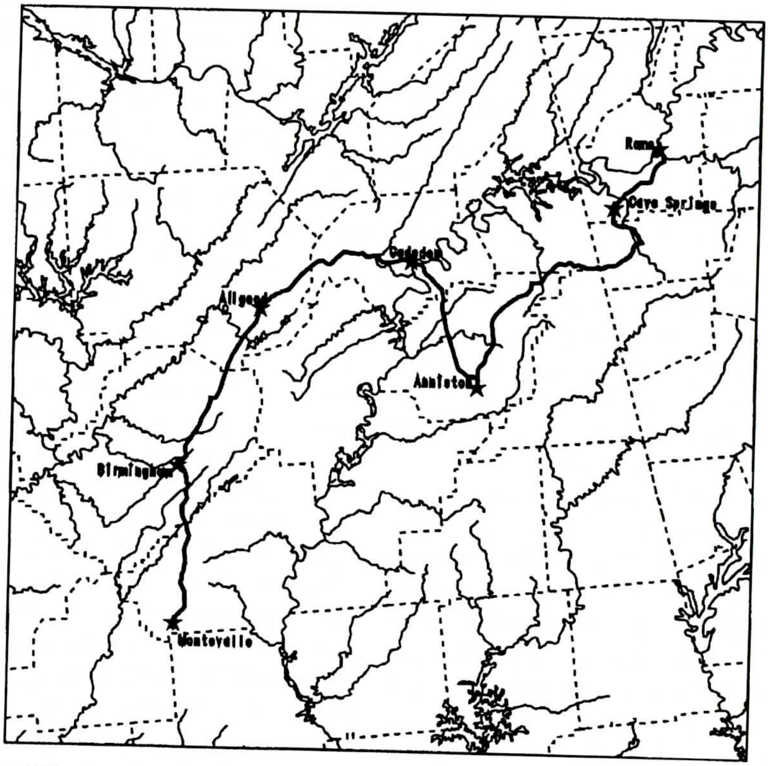

Figure 2. Route of Curtice during his 1892 season. He reported his first field work at Chepultepec(=Allgood), then went through Birmingham to Montevallo, and finally northeastward, ending the season at Rome, Georgia.

Curtice. There were major problems in the California gold belt, and fossils were exceedingly scarce. Rocks had been dated as Carboniferous on the basis of supposed plants; Curtice found that these were crushed belemnites and the rock was Jurassic. Curtice was away from his family for six months. Meanwhile, at Curtice's prime employment, the official action of the BAI was to use quarantine to control the spread of Texas fever, whereas Curtice strongly championed the eradication of the ticks.

Because of his outspoken views and a reorganization of the Bureau, in May, 1891, Curtice resigned and moved his growing family - with no visible means of support - to Moravia, New York. Curtice worked as a veterinarian when he was not out campaigning against ticks; he returned to Texas to stir the pot and wrote article after article urging tick eradication.

It was during the spring of 1892, shortly after Walcott (1890) published his major work documenting Early Cambrian fossils that Curtice was again hired by Walcott - despite serious budgetary difficulties. The Congress was waging war on the U.S. Geological Survey and Director Powell needed Walcott in Washington (Rabbitt, 1980).

Mapping was progressing in the southern Appalachians, but with uncertainties. The poor outcrops and the low-angle thrust faults, not well understood and difficult to recognize, made for difficulties in interpretation of structure. The difficulties were compounded when the ages of Lower and Middle Cambrian rocks were switched. More fossils, stratigraphically located, were needed, and Curtice was the man to provide them.

CURTICE-1892

In the official report for the year, Walcott simply mentions Curtice as temporary assistant.

Fortunately, Curtice sent a series of letters back to Walcott, reporting his activities. Through them we were able to trace the principal places that he investigated; his general route is shown in Figure 2. Travel from place to place was by train; local investigations were done by hired buggy or afoot. One letter is transcribed below to give the flavor of the work and document Curtice's powers of observation.

"Saturday I arrived here [Montevallo]. Yesterday and today have been <u>busy</u> & <u>lucky</u>. I ship tomorrow morning by mail a cigar box [of] fossils. This town <u>seems to be</u> in lower members of the chert series. The next rock below is the limestone and shale of which I send samples. It is the same as the limestones & shales of that part of the coosa valley south of Blaine or Jordans X roads limestones. Some of the fossils belong to the cobble series, but no Olenoides Curticei were found.

"Below these are the <u>variegated shales</u> & <u>limestones</u>. I suppose the Montevallo shales of Smith E./& although they lie West & northwest of here. Out of the upper part I have a few little brachiopods. Out of limestones in the lower part also a few pieces, possibly the Olenoides (Doropyge[?]) limestones near Rome. More likely not though.

Beneath these are sandy shales which carry Olenellus, specimens of which you will find in the box. I cannot connect the series yet as the Olenellus locality is about 4 1/2 miles north of here near the fault between the <u>Carb.</u> & <u>Camb.</u> So you see the Montevallo shales are included between the coosa valley limestones and the Olenellus fauna.

"This afternoon I found north of this place point where the limestones of the series widened out. The highest fauna I found was the D6 fauna. It contained Hyolithes and [included here is a drawing of a trilobite] the only fossil I could find to fix it. From the thickness of the limestone at that point, it appears that the <u>Chert</u> limestones have been pushed over onto the lower part of the Cambrian limestones at this place (Montevallo) so that all of the upper part of the limestones are covered by it. I believe too that the D7 fauna should have shown in this valley were it not covered by the Chert series.

"Unless I find something else against it later the succession here from such of the faunas as I can find in the limestones is D6, upper part of A and then shales, probably Bathyuriscus which I hope to find. I do not believe I will be able to do much with the shale fauna here as they are highly contorted, so I will not be able to locate the C4 fauna. Will try it again.

"This afternoon I found, at a point 1 1/2 miles north of here Olenellus in shales. They are quite pretty specimens and one slab promised to give embryonic forms. It was so late when I came upon it that I deferred working it until tomorrow. I have already a cigar box nearly full, but will not send it until I finish the place. For that point to the east side of the Cambrian will give a good section.

"So down goes the Montevallo shales as a distinct division lying above Coosa shales or the Sparry limestones of the Birmingham sections or Chepultepec [now Allgood, Alabama]. And up goes the upper part of <u>A</u> from below the colored shales to the lower part of the limestones which overlie them. Also there is stratigraphic work ahead at Rome [Georgia]. Hayes [C. W. Hayes, USGS geologist] overthrust is probably all right but he has got his overturned side of his anticlinal tangled up with his geologic column, and that is where we can help him out.

'I hope to write more definitely later as rain is brewing." [4]

A railroad cut 1 1/2 miles from Montevallo, which might well be the locality mentioned by Curtice, still yields *Olenellus* (Figure 3). It is the fauna from this one locality that is the linchpin for dating the Rome Formation as Early Cambrian. In the last 100 years, few additional Cambrian localities have been found to supplement those discovered by Curtice.

In a footnote, Hayes (1892, p. 34-35) wrote "Since the accompanying map was prepared and this report sent to press, however, addition-

4. Letter, Cooper Curtice to Walcott, March 14, 1892. Department of Paleobiology, National Museum of Natural History, Washington, DC [Copies in files of authors].

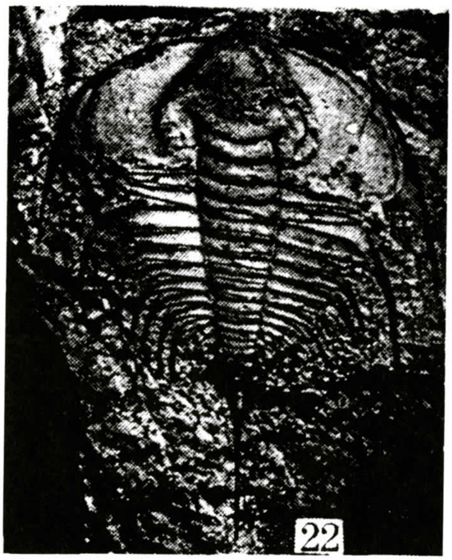

Figure 3. ***Olenellus thompsoni*** **(Hall) x2. The illustrated specimen was collected 1 1/2 miles from Montevallo. Although some of the other specimens illustrated by Butts are in the collections of the National Museum of Natural History, this individual has not been located. If it was not collected by Curtice, it was almost certainly obtained from the locality mentioned in his letter. Enlarged from Butts, Charles, The Paleozoic rocks, a part of The Geology of Alabama, Geological Survey of Alabama, special report, no. 14 (plate 22, figure 5).**

al field work has been done which throws light on the question and adds the weight of structural evidence to the conclusion suggested by Mr. Walcott after a study of the fossils that the Conasauga and Coosa shales occupy the same stratigraphic position." On the legend to the geological map of Alabama (Smith, 1894), the Cambrian above the Chilhowee Sandstone is divided into the Montevallo below, characterized by *Olenellus*, and the Coosa above, with a more diverse fauna. Both of these significant works indicating major changes in stratigraphy stem directly from the 1892 efforts of Curtice.

CURTICE-1895

Because of illness of his father, after little more than a month in Alabama, Curtice cut short his investigations in 1892. He returned to Moravia to continue his veterinary practice and to write tomes on Texas cattle fever. The next year his father Hosea died, and the fourth child in the family was born. Curtice received an appointment to the New York Board of Health and put his talents to stamping out bovine tuberculosis. Though this led to the slaughter of many cattle and many unhappy farmers, the disease disappeared. Meanwhile Curtice desired to return to the BAI. In 1894, Walcott became Director of the U.S. Geological Survey, and one of his first acts was to write to the Secretary of Agriculture on Curtice's behalf. Curtice was reappointed and in the fall Dr. Curtice returned to Washington, leaving his long suffering wife to run the household and manage five children in Moravia.

By 1895, Walcott was able to take the time to see the southern outcrops and do a little politicking with state geologists. He and Curtice left Washington April 27 for the Atlanta Exposition, and three days later were in northeastern Alabama with Henry McCall, Assistant State Geologist, and later, Eugene A. Smith, the State Geologist. In less than two weeks they went over some of the Curtice localities, found one new fossil occurrence, surveyed the metamorphic rocks around Talladega, and were back in Washington. Presumably both state and federal geologists were satisfied with the conclusions reached on this field trip.

MORE ON CURTICE

Curtice was away for long periods on BAI efforts. Though he was convinced that tick eradication was the key to Texas fever, he was placed in charge of a cattle inoculation program. For years, Dr. D. E. Salmon, Chief of the Bureau, was involved in political problem after problem, some, but not all, of his own making. Curtice was apolitical, yet it was characteristic of him that he ended a lengthy speech with "LET YOUR WAR CRY BE DEATH TO THE TICKS." That was too much for the authorities and November 28, 1896, Curtice was summarily fired. He continued to campaign against Texas fever and bovine tuberculosis, at considerable personal cost.

In 1897, there was a chance that Curtice might again work for Walcott, but before that happened he obtained a position at the University of North Carolina where he started an eradication program in his capacity as state veterinarian. Two years later he moved to the University of Rhode Island and helped the geese industry resolve the major disease problem of goose septicemia; later he was involved with fowl typhoid.

Curtice never received credit from his former BAI associates for his insight that ticks transmitted Texas fever. Nevertheless he also never stopped campaigning for tick eradication, and in a November 1905 speech, his audience included the U.S. Secretary of Agriculture. On July 15, 1906, Dr. Curtice was appointed an expert on tick eradication at BAI, at a salary of $200 a month. In twenty years of unremitting work and public service he had doubled his salary. Within one year of his appointment 40,000 square miles in North Carolina and Virginia were removed from quarantine restrictions.

Inside a few years, Curtice was asked to work on cattle disease in Central America. While there he collected fossils for Walcott, though the details have not been traced. There was more field work in Texas on eradication of cattle fever; he was away so long that his wife wrote the Bureau Chief inquiring when he might return. He started a project on sheep parasites but was again off to a variety of places during World War I. Before he could properly settle down, this research was moved to Mississippi, and he traveled between there and Virginia. By a quirk of fate, the sheep station was at Reston, Virginia, where the U. S. Geological Survey was to build a headquarters many years later.

In 1930, at 75, Curtice was retired by the BAI. He continued at the Bureau unpaid, until shortly before his death in 1939. In 1933, the American Veterinary Medical Association finally honored his accomplishments with a medal; for the U.S. Geological Survey, he was another of the early unsung workers.

EPILOGUE

In 1905, the brachiopod genus *Curticia* was added to the literature (Walcott, 1905, p. 319). A monographic study of Cambrian brachiopods explained that "The generic name is given in recognition of the excellent work of Dr. Cooper Curtice, of Moravia, New York, both as a field collector and laboratory assistant" (Walcott, 1912, p. 369). The type species happens to be from Minnesota and in that sense commemorates the collecting Curtice did for Walcott during 1884 in the Upper Mississippi Valley; (eighteen of the Cambrian species in this defintive work are from Alabama).

If Walcott appreciated Curtice, the feeling was more than mutual. On February 24, 1906, the seventh child and fourth son was born into the Curtice family. His name was Charles Walcott Curtice.

ACKNOWLEDGMENTS

Lewis Dean, Geological Survey of Alabama, helped interpret the handwriting of Curtice, among many other services. Ralph Lichtenfels, Beltsville Agricultural Service, contributed background information on Curtice; both read and improved the manuscript. The authorities of the National Agricultural Library granted permission for the use of the photograph of Curtice, which is reproduced from Logue (1955). Figure 2 was prepared by the Automatic Data Processing Laboratory of the National Museum of Natural History.

REFERENCES CITED

Hayes, C.W. 1892, Report of the geology of north-eastern Alabama and adjacent portions of Georgia and Tennessee. Geological Survey of Alabama, Bulletin No. 4.

Logue, J.M. 1995, Beyond the Germ Theory - The story of Dr. Cooper Curtice: Texas A & M University Press, College Station Texas, 149 p.

Rabbitt, M.C., 1980, Minerals, lands, and geology for the common defence and the general welfare: v. 2, 1879-1904. United States Government Printing Office, 407 p.

Smith, E.A., 1894. Geological map of Alabama with explanatory chart. Montgomery, Alabama.

Walcott, C.D., 1884, Paleontology of the Eureka District. U. S. Geological Survey, Monograph 8, 298 p.

Walcott, C.D., 1885, Report of Mr. Charles D. Walcott in

Administrative reports of chiefs of divisions: U. S. Geological Survey, 6th Annual Report for 1885-86, p. 74-78.
Walcott, C.D., 1889, Description of new genera and species of fossils from the Middle Cambrian: Proceedings of the United States National Museum for 1888, v. 11, p. 441-446.
Walcott, C.D., 1890, The fauna of the Lower Cambrian or *Olenellus* zone: U. S. Geological Survey, 10th Annual Report, part 1, p. 569-774.
Walcott, C.D., 1905, Cambrian Brachiopoda, with descriptions of new genera and species: Proceedings of the United States National Museum, v. 28, p. 227-337.
Walcott, C.D., 1912, Cambrian Brachiopoda: U. S. Geological Survey Monograph 51, part 1, 862 p.; part 2, plates and captions, 363 p.
Yochelson, E.L., 1967, Charles Doolittle Walcott (1850-1927): National Academy of Sciences, Biographical Memoirs, v. 39, p. 471-540.
Yochelson, E.L., 1998, Charles Doolitte Walcott, Paleontologist. Kent State University Press, Kent, Ohio, 510 p.

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THE HISTORY OF INVESTIGATION OF THE BREVARD FAULT ZONE AND EVOLVING CONCEPTS IN TECTONICS

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ABSTRACT

The Brevard fault zone has been a persistent subject of interest in the tectonics and structural geology of the southern Appalachian mountains. Since 1905, when Arthur Keith first defined the structure, its interpretive history has paralleled evolving concepts in global and regional tectonics. In this review, a few of the significant or interesting themes to emerge from the study of the Brevard fault zone are discussed.

The earliest interpretations of the Brevard fault zone reflect contractionist ideas modified to incorporate horizontal movement in thrust systems. Such concepts led to Keith's views of the fault zone as a deep, faulted "infold", called by P.B. King a "dejective zone" in which a highly deformed Cambrian cover sequence was preserved within a sea of Archean rocks. Eardley and later Burchfiel and Livingston invoked a model for the Brevard fault zone revising Keith's basic view to one of an alpine root zone.

Anna Jonas' reconnaissance investigation of rocks in the Brevard fault zone proved that part of this sequence was generated during retrogressive dynamic metamorphism in the shear zone; partly on this basis she proposed a great overthrust along the Brevard fault zone in 1932. White's 1950 hypothesis of the Brevard fault zone as a young normal fault is a unique and unresolved idea.

Interpretations of strike-slip movement in the fault zone appear in two intervals in the history. First proposed by Reed and Bryant in 1964, this interpretation ran counter to interpretations of northwest-directed thrust movement in the adjacent Blue Ridge. The strike-slip concept was revitalized in 1984 using new, powerful field tools for shear sense determination. Although it is now recognized that the Brevard fault zone is probably a composite structure, the preeminent hypothesis has been that most of the displacement can be accounted for by reverse or thrust movement in at least two stages. The latest deformation, that must post-date lateral movement late in the Alleghanian orogeny, is illustrated by reverse motion on the Rosman fault and related structures.

Each of these interpretations, as well as others not discussed in the present article, resulted from inherited concepts and traditions that have evolved even as has the interpretive history of the Brevard fault zone.

INTRODUCTION

"For a true understanding of nature both are indispensable, the broad distant outline and the minute detail filled in at the points nearest our vision. Seeing the one in the setting and perspective of the other, creates in the inquiring mind that feeling of intense satisfaction which transforms the work of the geologist from a task into a liberating experience" (Bucher, 1964, p. 489).

Bucher's remark reminds us that modern scientific inquiry is not purely the accumulation of data nor is it solely the construction of overarching hypotheses. These two modes of investigation, and all those between, converge in synthesis to keep the canonical body of tectonics in order.

Notable geologic structures, especially those that span a significant part of a mountain belt, are often studied repeatedly. That is, successive investigations attempt to describe the present

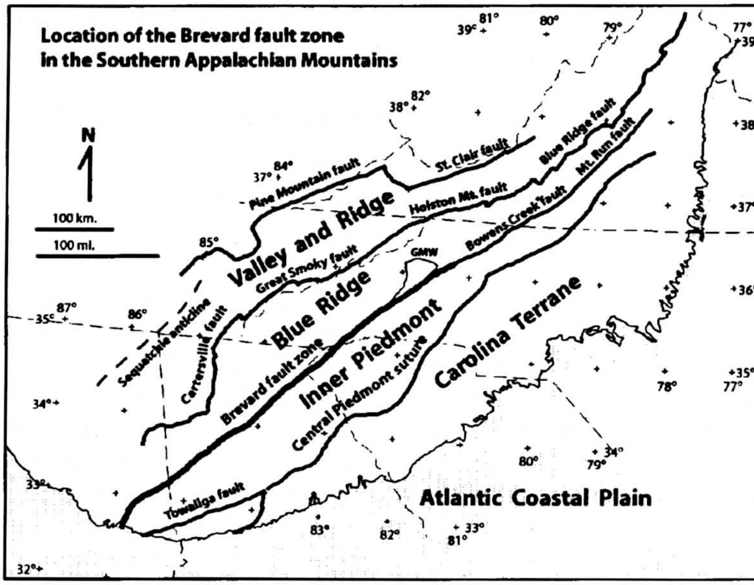

Figure 1. Location of the Brevard fault zone in the southern Appalachian Mountains (modified from Hatcher and others, 1989). GMW - Grandfather Mountain window.

architecture of the structure in order to understand its geologic history. These investigations occur at intervals, and each study is formulated in a context where a guiding hypothesis of tectonics may be emerging, dominating, or fading. Consequently, summary interpretations of regional structures change under the influence of new hypotheses as investigators embrace them.

The Brevard fault zone (also known as Brevard zone, Brevard schist, and others) is a regional geologic structure in the crystalline part of the southern Appalachian mountains (see Figure 1 and Hatcher and others, 1989). The history of investigation of this fault zone represents at least four generations of geologists and the remarkable array of interpretations that they have contributed. Furthermore, this history incorporates several schools of thought in tectonics, some pre-dating the beginning of specific research in the Brevard fault zone and others evolving simultaneously with research on the fault zone.

There are numerous summaries of interpretations of the Brevard fault zone. A good starting point for an introduction is the essay by Horton and McConnell (1991, pp. 53-55). The present article examines only a few parts of the interpretive history of the Brevard fault zone from 1905 until the present. Furthermore, I wish to emphasize in these selections only certain developments as they reflect the feedback loop between interpretive advances in global and regional tectonics. Mainly, I address some of the major themes that have persisted through time.

Some themes are omitted deliberately. For example, as the theory of plate tectonics grew during the late 1960s and early 1970s, many Brevard fault zone researchers presented various interpretations of the structure within the context of these new concepts (Dewey and Kidd, 1974; Rankin, 1975). Similarly, much could have been written about geochronology and the resolution of timing in the fault zone. I will not discuss that debate for lack of space. The full history of interpreting the Brevard fault zone is long and deserves a more spacious forum.

THE BREVARD FAULT ZONE

In The Beginning

In 1887 the U.S. Geological Survey began a program of detailed regional mapping in the southern Appalachian mountains (Rodgers, 1949, p. 1649-1651). Bailey Willis (1857-1949) managed a team that included Marius R. Campbell (1858-1940), C. Willard Hayes (1859-1916) and Arthur Keith (1864-1944). These investigators, with notable contemporaries including Charles Butts (1863-1946), provided the first database of regional geology in the southern Appalachians in their maps, geological folios and articles. Keith and Campbell initially mistook thrust faults for unconformities, but eventually Keith (1907b) accepted low-angle thrusts in the western Blue Ridge (Rodgers, 1949).

While the mechanics of fold and fault formation were being refined with surveys in the Valley and Ridge and western Blue Ridge provinces, these early workers struggled with the crystalline rocks of the Piedmont and eastern Blue Ridge. Keith (1903; 1905; 1907a) first differentiated rocks in the Brevard fault zone as "infolds" of Cambrian strata within what had otherwise been shown as a gigantic mass of Archean crystalline rocks in the Piedmont and Blue Ridge (see map in McGee, 1893 map date).

Developments in orogenic analysis prior to and during surveys by Keith and his contemporaries provide a framework through which his syntheses (Keith, 1923; 1928) can be understood. A Eurocentric account by Miyashiro and others (1982) hails Eduard Suess (1831-1914) as the champion of modern tectonics. Suess (1875) recognized the role of horizontal motion in formation of the Alps, noted the asymmetry of mountain belts, described structural heredity (the control of preexisting structures on superposed deformation), and emphasized the importance of both structural geology and stratigraphy in orogenic analysis. Seuss was a contractionist who initially supported some aspects of geosynclinal theory, but later rejected the concept (Suess, 1885-1909).

By 1910, the European theater had begun to split into two schools of tectonics: the "Kober-Stille school" (fixism in a contractionist frame) and the "Wegener-Argand school" (mobilism in a uniformitarian frame with support for continental drift) (Miyashiro and others, 1982, pp. 23-24). The Kober-Stille school assumed much of its contractionist foundation from geosynclinal theory that originated in North America (Miyashiro and others, 1982, p. 23). Evolution in the mapping and understanding of regional fold and thrust belts in the southern and central Appalachians by Hayes (1891), Willis (1893), and Butts (1927) surely influenced Keith's work.

Keith (1923) proposed that the "Appalachian system" involved Paleozoic sedimentary rocks of the Valley and Ridge and peripheral flexures as far west as the Mississippi River valley, and "Precambrian" crystalline rocks of the Blue Ridge and Piedmont eastward to and beneath the Atlantic Coastal Plain. He had done exceptionally detailed work in producing folio maps covering many parts of the western Piedmont in the Carolinas; some maps remained unpublished (see King, 1955, for comments on the Cowee, Morganton, and Lincolnton quadrangle maps). Keith recorded metamorphosed Cambrian strata in asymmetric, tightly folded and faulted synclines in the Brevard fault zone (which he called Brevard schist) and Kings Mountain belt. Some of these infolded rocks are more variably layered than surrounding gneiss and schist, and are composed of incomplete greenschist facies mineral assemblages that had been dynamically retrogressively metamorphosed from the amphibolite facies minerals more characteristic of the region. (The Brevard fault zone does include low grade or nonmetamorphosed sedimentary rocks along with the shear zone rocks (Hatcher, 1969; 1970) but it is now known that the nonmetamorphosed rocks are allochthonous bodies from beneath a crystalline Piedmont overthrust sheet.)

Keith's view of the Brevard fault zone as an infold is consistent with his contractionist interpretation of the mechanics of mountain building (Keith, 1923). Although Keith recognized that great horizontal stresses were necessary to drive thrust sheets, he ultimately relied on a modified contractionist model. His model invokes an early, Pennsylvanian, phase of west-directed thrusting driven by thermal doming in the western Atlantic Ocean ("outthrust of the domed sea-floor") followed by gravitational collapse in the Permian. Intrusive magmatism, metamor-

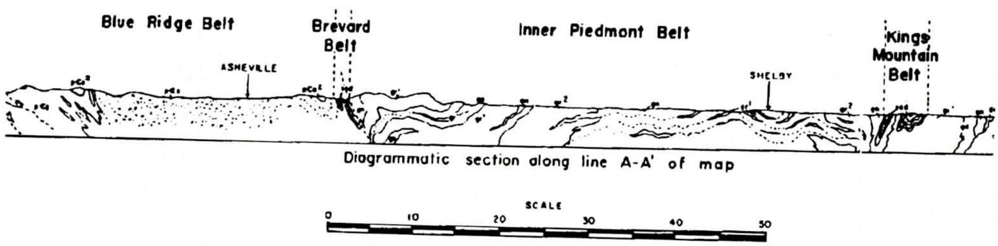

Figure 2. Interpretive cross section through the Piedmont and eastern Blue Ridge (King, 1955). The Brevard fault zone ("Brevard belt") is drawn as extremely tight faulted synclines.

phism, folding (of the early thrusts), and more faulting attended the peak of the "Appalachian revolution." Although contractionist in most aspects, Keith did write that his model is not gradualistic as required by whole-earth reduction but episodic, an interpretation in concert with the Kober-Stille school.

Keith reviewed (and largely dismissed) most extant hypotheses for mountain building including: contraction (shrinking of the earth by heat loss), "suboceanic spread" (deformation marginal to dense and downsinking oceanic crust), isostasy (differential elevation of the crust because of adjacent erosion and deposition centers), geosynclines, "continental creep" (continental drift), and other hypotheses that might be due to a "cosmic factor" (Keith, 1923, p. 361). He finally settled on the batholithic intrusion model. In his 1928 paper he persisted in uplift driven by batholithic intrusion into oceanic crust resulting in geanticlinal welts along both North American continental margins.

The Fancy of Folds

A synclinal (or synformal) fold in the Brevard fault zone persists in the literature through the 1970s (see King, 1955; Medlin and Crawford, 1973; Stose and Smith, 1939). For example, King's 1955 map with a cross-section through the Brevard fault zone near Asheville, NC, retains a syncline, albeit one that is faulted on at least one limb (Figure 2). Combining elements of faulting, folding, shearing, and localized shear-related metamorphism, King (1955, p. 351) thus called the Brevard fault zone a "dejective zone". He also believed that the dejective zone must extend to "great depth" because the structure is so linear and long at the surface (Figure 2). King's cross-section in the crystalline part of the southern Appalachians, consistent with the practice of the time, is "thick-skinned"; faults and major folds extend downward to the base of the section.

At issue is not the presence of folding (this is evident in virtually every study) but if the structure is fundamentally a remnant of the Cambrian cover sequence trapped in a syncline in the sense of Keith. Over time, the dominance of faulting of various kinds and ages appears to have subsumed the primacy of fold models.

Jonas and a Whale of an Observation

King (1955, pp. 340-343) compared Keith's summary interpretations of the crystalline southern Appalachians to those of Anna Jonas (later Anna Stose) (1881-1974). Jonas did only reconnaissance mapping south of Virginia. She did, however, enter the arena well prepared to do petrologic studies in fault zone rocks because of her training as a student with Florence Bascom (1862-1945) as mentor and Eleanor Bliss Knopf (1881-1974) as classmate at Bryn Mawr College (Schneiderman, 1997). In effect, Jonas injected the concepts of structural and metamorphic petrology into interpretations of the Brevard fault zone.

Examination of the lineage of structural and metamorphic petrology reveals a rich tradition within structural geology. Albert Heim (1849-1937) was an important contributor to this tradition that includes, among many others, Adam Sedgwick (1785-1873), Charles Lapworth (1842-1920), and Henry Clifton Sorby (1826-1908). Heim excelled at detailed structural

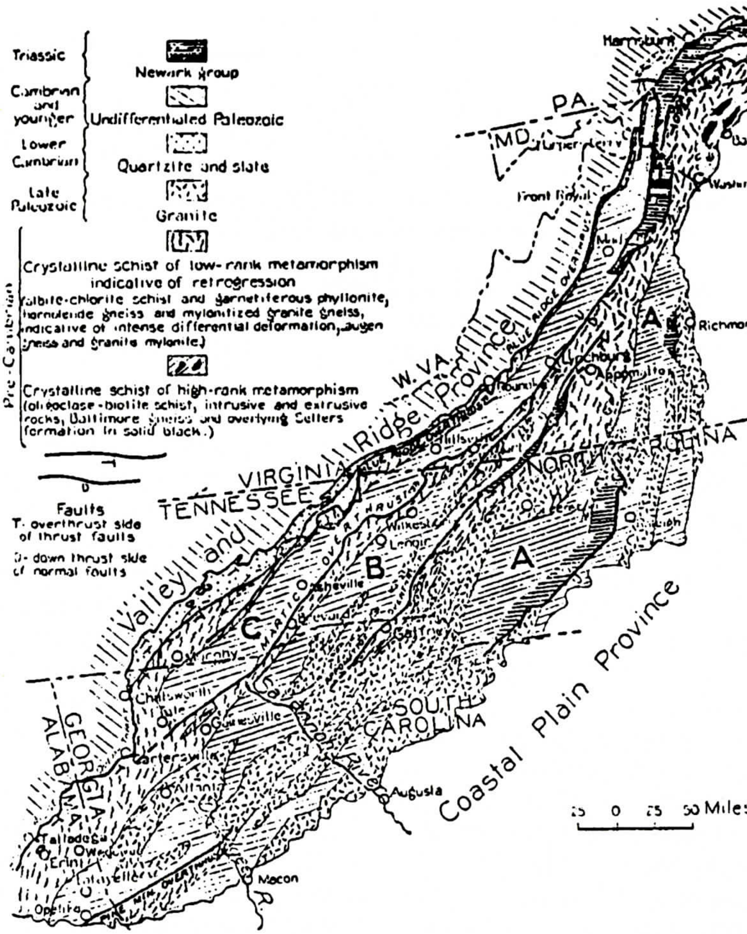

Figure 3. Generalized map of the central and southern crystalline Appalachians (Jonas, 1932, Figure 1). The Martic overthrust coincides with the Brevard fault zone in the southern part of the orogen. Her map is very generous in showing the width of the fault zone.

analysis (Milnes, 1979) and called on horizontal stresses to initiate the brittle–ductile transition in the evolution of thrust faults from folds. In further support of lateral forces in mountain building, Heim is well known for his interpretation of the doubly-vergent Glarus fold in the Swiss Alps. Marcel Bertrand (1847-1907) later showed that this structure is a thrust nappe (Bertrand, 1884).

In North America, Turner and Weiss (1963, p. 3) noted the significance of the "Wisconsin school" of structural analysis (see Leith, 1905; 1913; Van Hise, 1896) as well as the influence of the later work of Sander (1934; 1939). C.R. Van Hise trained Florence Bascom during her Ph.D. studies at the University of Wisconsin, where her father was president of the institution. (Van Hise became president of the same university in 1903). Bascom later assisted Van Hise, Roland Irving and G.H. Williams in special studies in the Lake Superior region (Rabbitt, 1980, p. 129, 264).

C.K. Leith, himself a graduate of the University of Wisconsin, traveled extensively in the Appalachian mountains in 1897-1900. He visited Florence Bascom in her field area near Philadelphia and Arthur Keith, who was mapping Ocoee series rocks in Virginia and Georgia (Rabbitt, 1980, p. 277)

Bruno Sander's comprehensive system of determining tectonic fabrics was brought to the English language literature by Knopf (1933)

Figure 4. Normal fault origin for the Brevard fault zone and Blue Ridge escarpment (White, 1950, Figure 5). The section crosses the fault zone northeast of Asheville, NC.

and Knopf and Ingerson (1938). Furthermore, Knopf and Ingerson introduced experimental studies of rock deformation, which promoted microstructural investigations and the consideration of mechanical principles in the interpretation of naturally deformed rocks.

Jonas (1932) inferred three great overthrusts in the crystalline Appalachians from Pennsylvania to Alabama: the Martic, Appomattox, and Blue Ridge overthrusts (Figure 3). She noted, long before the details and extent were known, the presence of retrograde metamorphism and mylonitization in the Martic and Appomattox zones. Her sketch map (Jonas, 1932, Figure 1) shows "crystalline schist and low-rank metamorphism indicative of retrogression" and "of intense differential deformation". Jonas in part debunked Keith's inclusion of (Cambrian) Erwin quartzite in the Brevard schist. She examined thin sections of these fine-grained rocks and found feldspar augen and dark banding containing "broken grains of epidote with mica and magnetite" that provided an apparent layering in the otherwise leucocratic matrix. She concluded that the "cataclastic character of the rock is evident". Later, Reed and Bryant (1964) and Conley and Drummond (1965) would reiterate the significance of mylonites in the Brevard fault zone.

Jonas made two important contributions to the study of the Brevard fault zone. First, she recognized that the metamorphic and stratigraphic arrangements of the rocks were caused by deformation. Second, she traced the fault zone for a significant length of the Appalachian orogen thereby putting it into a regional perspective. Her mobilist interpretation of the fault zone as an emergent thrust was speculative and derived from studies in the Taconic ranges (see Jonas, 1932, p. 242), but is in accord with much later studies that placed a detachment beneath the Piedmont.

A Reverse to Normal

White's (1950) paper on the geomorphology of the physiographic Blue Ridge front in North Carolina and Virginia provides a topographical interlude in the stream of tectonic ideas for the Brevard fault zone. In contrast with the purely erosional origin of the Blue Ridge scarp presented by Davis (1903), White suggested that the conspicuous feature, a series of en echelon lineaments, is a late Tertiary normal reactivation of a Triassic or older fault (Figure 4). White references a paper by Hayes and Campbell (1894), who suggested that the Blue Ridge scarp is on the flank of a monocline dipping toward the southeast (White, 1950, p. 1313).

White's argument was based on analysis of the present topography as well as measurements of minor faults (slickensides and slickenlines), that were rather uniform in a down-to-the-Piedmont sense. Many of these structures are "manganese-coated surfaces" in highly weathered rock and saprolite. White observed some of these to pass downward into less weathered bedrock. I have seen many of these surfaces in saprolite in the same areas that White studied in North Carolina. They too are remarkable in their consistent orientations and shear senses for southeast-dipping normal faulting. Once reverse movement was documented in the brittle Rosman fault (Hatcher, 1971; Horton, 1980; 1982), little attention has been placed on the possibility of late (post-Paleozoic) normal movement in the Brevard fault zone. Furthermore, K-Ar isotopic ages acquired in traverses across the Brevard fault zone showed no significant post-Mesozoic vertical displacement (Stonebraker, 1973).

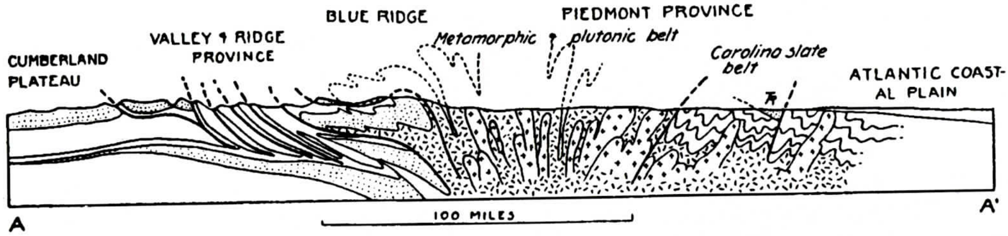

Figure 5. Generalized cross-section of the North Carolina Piedmont (Eardley, 1954, Figure 23). The Brevard fault zone is not indicated on the diagram, but it is the tight syncline beneath the second "E" in "BLUE RIDGE".

The Root of the Problem

Eardley (1954) followed King's (1950) description and nomenclature for geologic belts in the southern Appalachian mountains. In particular, Eardley noted the similarity between King's "infolded belts of metasedimentary rocks", that included the "Brevard schist belt", and Collet's (1933; 1935; 1974) Alpine root zones (Figure 5). In the second edition of his book, Léon William Collet (1880-1957) acknowledges M. Lugeon, Emile Argand, Albert Heim, and Rudolf Staub, among others for maps and sections. Collet (1935, p. 26-27) noted that his observations and those of his colleagues strongly supported Wegener's hypothesis for continental drift.

Collet (1974, p. 12) described root zones as follows: "The root of a recumbent anticline, or of a nappe, is the core of the anticline in the region where it is more or less vertical and gives the impression of rooting to the depths.

"The roots of a nappe or recumbent fold with several digitations are the anticline cores of the different digitations where they are more or less vertical and in connection with the depth. If a nappe, or a recumbent fold, is separated from its roots by erosion we then have, somewhere in the rear, a zone of roots."

Collet's root zone employed a generally steep or vertical dip of layering and tightly appressed synclines preserving remnants (the "roots") of mostly eroded fold nappes. The root zone is notable for the extent and intensity of deformation. Clearly, Eardley saw in King's and Keith's descriptions what appeared to be structures analogous to the southern Alps. Much later, Butler (1971) would cogently expand the comparison of structures in the crystalline southern Appalachian and Alpine orogenic belts.

This thread of infolds, dejective zones, and root zones continued within a specific model for the Brevard fault zone proposed by Burchfiel and Livingston (1967; 1968). They characterized the Urseren and Pusteria-Insubric zones as root zones for the Helvetic nappes of the Swiss and Austrian Alps. They then interpreted the Brevard fault zone to be comparable to an Alpino-type (linear) root zone with substantial northwest-directed thrusting ("downward movement of crustal material").

In discussions arising from the root zone thesis, Dunn and others (1968) pointed out that it is incorrect to characterize the Brevard fault zone as a steeply dipping structure (Burchfiel and Livingston, 1968). Dips of foliation within the fault zone vary from steep to shallow depending where along its entire length attitudes are measured (Dunn and others, 1968; Higgins, 1966; Higgins, 1968).

The root zone hypothesis as a sole explanation for the Brevard fault zone failed because it "cannot be characterized simply as a structural feature of one genetic type" (Dunn and others, 1968, p. 218). Today, parts of the Alpine root zones are known to have had multiple periods of movement as well.

Striking Back

In 1956 and 1957, Bruce Bryant and John C. Reed, Jr. of the U.S. Geological Survey began detailed mapping in the region of the Grandfather Mountain window (Figure 1), that is in the

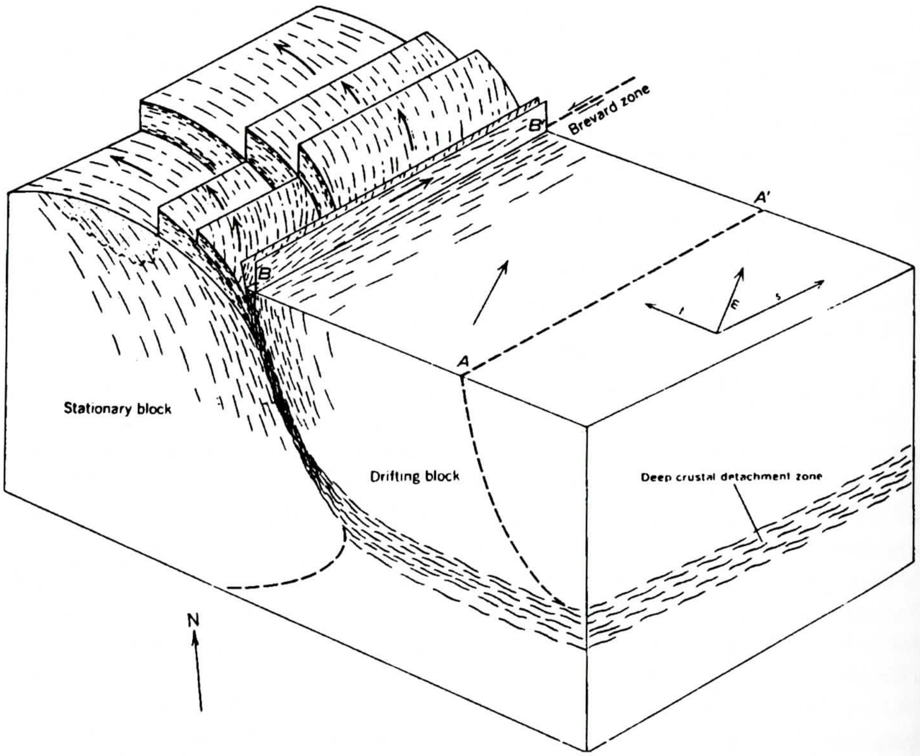

Figure 6. Kinematic model of Brevard fault zone (Bryant and Reed, 1970, Figure 106). This model places a sub-horizontal detachment beneath the Inner Piedmont, which obliquely converges on the Blue Ridge. The motion sets up sinistral displacement in the Brevard fault zone contemporaneous with thrusting in the Blue Ridge.

eastern Blue Ridge of North Carolina. Their map overlaps with the folio work of Arthur Keith in large part, but Bryant and Reed benefited from 50 years of geologic and economic exploration of the area. The summary work (Bryant and Reed, 1970) remains a substantial contribution to the geology of the southern Appalachian Blue Ridge and western Piedmont near the traditional northern terminus of the Brevard fault zone. Along the way, Bryant and Reed introduced an important thread in the interpretive history of the structure: the Brevard fault zone as a major strike-slip fault. Reed and Bryant referenced prior and concurrent work in the Brevard fault zone and also compared the geology of the fault zone to the Great Glen (Scotland) and San Andreas (California) faults.

Reed and Bryant (1964) presented a structural analysis of the Brevard fault zone that included kinematic indicators in the form of mineral (stretching) lineations and quartz C-axis diagrams. Their paper and the works of Reed and others (1961) and Hamilton (1957) represent perhaps the first extensively detailed structural petrographic analysis of the fault zone. Their conclusion, based on the apparent distortion of the Grandfather Mountain window, lineations in the eastern Blue Ridge, steepness of foliation, and linearity of the zone was that the Brevard fault zone is a late Paleozoic to Triassic (post Blue Ridge thrusting) dextral strike-slip fault. Lacking stratigraphic continuity across the fault zone, Reed and Bryant proposed lateral displacement greater than 135 miles.

Later, these investigators reevaluated the significance of curved lineation trends and proposed that the Brevard fault zone is a sinistral strike-slip fault that formed concurrently with thrusting in the eastern Blue Ridge (Bryant and Reed, 1970; Reed and others, 1970) (Figure 6).

The earlier study (dextral) viewed lineations mainly as passively rotated markers; the later study (sinistral) maintained these structures as kinematic or at least directional indicators. Bryant and Reed (1970) provided an additional element to the geology of the Piedmont. Their 1970 model for the Brevard fault zone incorporated a subhorizontal detachment in the deep crust of the Piedmont into which the Brevard fault zone rooted. It was nearly a decade later that the presence of such a structure was verified by seismic reflection.

The imprint of the work of Bryant and Reed in the interpretive history of the Brevard fault zone is strong. Their mapping in the Grandfather Mountain window area was actually completed in 1962, well before the publication of U.S. Geological Survey Bulletin 615 (Bryant and Reed, 1970). Their approach was clearly influenced by the traditions of structural petrology exemplified by Jonas and field mapping exemplified by Keith. Jonas established the significance of retrogressive metamorphism and orogen-scale shear zones in crystalline rocks. Bryant and Reed, in their various contributions, voiced a counterpoint to the thrust-dominated status quo in the southern Appalachians. While the strike-slip hypothesis did not replace the thrust hypothesis, it stimulated interest in the feasibility of this style of deformation within crystalline massifs of orogenic belts.

The strike-slip theme did not end after Bryant and Reed's syntheses. Michael Higgins recognized oblique slip in the Brevard fault zone in Georgia (Higgins, 1966; 1968), later restricted to about 20 miles (35 km) of dextral displacement in one section of that part of the structure (Higgins and others, 1988, pp. 94-96). Around 1980, detailed structural studies in shear zones outside of the Appalachian mountains provided a new, reliable form of shear sense indicator in the form of extensional crenulation cleavage (S-C mylonites and other names) (Berthé and others, 1979; Lister and Snoke, 1984; Platt and Vissers, 1980; White and others, 1980). Certain mylonites in the Brevard fault zone ("button schist" in the Brevard fault zone vocabulary) are archetypal S-C mylonites (see descriptions in Bobyarchick, 1982; 1983; Roper, 1972).

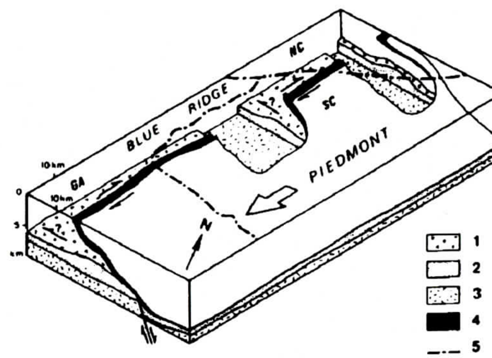

Figure 7. Kinematic model for dextral strike-slip on the Brevard fault zone (Vauchez, 1987, Figure 4). This model utilizes strike-slip motion on a subhorizontal detachment.

New field investigations of shear sense indicators, that included button schist and quartz fabrics, revived the strike-slip hypothesis because they consistently show dextral shear in the Brevard fault zone in the Acadian or Alleghanian orogenies (Bobyarchick, 1984; Edelman and others, 1987; Evans and Mosher, 1986; Vauchez, 1987). These observations led to models for orogen-parallel dextral shear in the Piedmont (Bobyarchick, 1988; Davis and others, 1991; 1993; Vauchez and Brunel, 1988) (Figure 7), although no conclusive value for the magnitude of displacement has been determined.

Shift to Reverse

Today, most investigators agree that the Brevard fault zone is the cumulative result of multiple deformations. A polyphase history was recognized and described in meso- and microstructural investigations in the Carolinas part of the fault zone by researchers at the University of North Carolina at Chapel Hill (Dunn and others, 1966; Roper and Dunn, 1973; Roper and Justus, 1973). Most detailed field studies have found conclusive evidence of superposed folding and metamorphic events recording multiple deformations. The historical body of Brevard fault zone hypotheses, however, is dominated by contractional tectonics asymmetrically vergent toward the foreland.

From Keith onward, even ardent fold proponents recognized the presence of reverse fault-

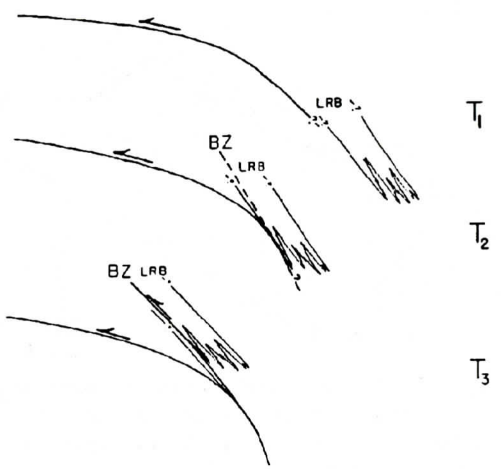

Figure 8. Hatcher's (1971) model for the Brevard fault zone as a backlimb thrust off the Blue Ridge thrust. The cross-section is roughly drawn with west to the left side of the diagram.

ing in the Brevard fault zone. The root zone and early strike-slip hypotheses attempted to link reverse faulting in the Blue Ridge to events in the Brevard fault zone by various mechanisms. It should be noted that there are at least two periods of contractional motion to be explained. Early ductile folding, shearing, and nappe formation (Butler and Dunn, 1968; Hatcher, 1972; 1978; Higgins and others, 1988; Medlin and Crawford, 1973) is the first. Evolutionary models depict this phase (or phases) in the Ordovician Taconic orogeny and/or Devonian Acadian orogeny.

The second contractional event is a brittle deformation that post-dates strike-slip structures. It is characterized by the Rosman fault (Horton, 1980; 1982; Horton and Butler, 1986), but is probably best described as a series of faults largely localized within the broader ductile range of the Brevard fault zone. The first ductile phase(s) (and superposed dextral shearing) is responsible for the distributed ductile fault zone fabrics. The ductile fabrics are overprinted by brittle fabrics of the Rosman fault family, however, that I wish to address.

Hatcher (1971) and Hatcher and others (1973) used the presence of weakly or nonmetamorphosed "exotic" sedimentary rocks similar to rocks of the lower Paleozoic shelf in the Valley and Ridge, repetitions of stratigraphy, and fault cutoffs in the Brevard fault zone to propose that the structure is a thrust fault. (These rocks, the Shady Formation, are found in thrust slices inside the Grandfather Mountain window in North Carolina.) He further suggested that the Brevard fault zone contains a backlimb thrust off the Blue Ridge thrust, which places Neoproterozoic to Lower Cambrian rocks of the Blue Ridge allochthon on lower Paleozoic autochthonous rocks of the Laurentian margin (Figure 8).

Hatcher's model was consistent with the regional tectonic style of the Blue Ridge and Valley and Ridge to the northwest of the Brevard fault zone. It carried the thin-skinned architecture of the foreland at least as far east as the Brevard fault zone and to nearby lithotectonic belts of the Inner Piedmont. Bryant and Reed (1970) had extended a detachment (presumably Alleghanian) beneath the Inner Piedmont in their speculative model. A remarkable series of events in the 1970s and early 1980s would provide confirming evidence of the thrust hypothesis.

Clark and others (1975; 1978) conducted a short seismic reflection profile across the Brevard fault zone at Rosman, North Carolina. A concave-upward listric reflector, presumably representing the distinctive stratigraphic sequence involved in the fault zone as portrayed by Hatcher, emerged from the survey. The position and geometry of the reflector matched what was expected from the Rosman fault. Subsequently, Hatcher (1978), Roeder and others (1978) and Boyer and Elliott (1982) constructed models incorporating an Alleghanian fault (and by implication part of the Brevard fault zone) into the Alleghanian fold and thrust belt.

Deep seismic reflection profiles across the southern Appalachian orogen (Cook and others, 1979; Harris and Bayer, 1979; Harris and others, 1982; Pratt and others, 1988) and high resolution profiles near the South Carolina-Georgia border (Hatcher and others, 1986) confirmed the seismic structure of the Brevard fault zone. The large-scale studies further suggested that the entire Inner Piedmont might be allochthonous. A remaining puzzle is how the full

Table 1. Interpretations of the Brevard fault zone 1905-1993.

1905–1971			1972–1993		
Author	**Year**	**Interpretation**	**Author**	**Year**	**Interpretation**
Keith	1905	syncline	Hatcher	1972	thrust fault (7.2 km)
Jonas	1932	thrust fault	Stirewalt and Dunn	1973	refolded isoclinal syncline
Stose and Smith	1939	syncline/slide	Odom and Fullagar	1973	Taconic suture and root zone
White	1950	normal fault	Medlin and Crawford	1973	fold zone overprinted by cataclasis
Eardley	1954	root zone	Roper and Justus	1973	reactivated Taconic detachment
King	1955	dejective zone	Carpenter and Dallmeyer	1974	reverse fault (unroofing)
Reed and others	1961	oblique fault	Clark and others	1975	listric thrust fault
Reed and Bryant	1964	dextral strike slip fault	Rankin	1975	transported suture
Higgins	1966	strike slip fault	Roeder and others	1978	Alleghanian reverse fault
Burchfiel and Livingston	1967	root zone	Hatcher	1978	reactivated Taconic root zone (thrust)
Butler and Dunn	1968	isoclinal syncline	Harris and Bayer	1979	Alleghanian splay thrust
Hatcher	1969	back limb thrust fault	Cooke and others	1979	Alleghanian splay thrust
Reed and others	1969	oblique sinistral strike slip fault	Harris and others	1981	Alleghanian thrust splay
Roper and Dunn	1970	sheared isoclinal syncline	Boyer and Elliott	1982	branch line merger
Reed and others	1970	sinistral strike slip and root zone	Bobyarchick	1984	Alleghanian dextral strike slip
Watkins and Huggett	1970	subduction zone	Evans and Mosher	1986	Alleghanian dextral strike slip
Hurst	1970	trough fault	Edelman and others	1986	transported Alleghanian dextral strike slip
Bentley and Neathery	1970	refolded thrust fault	Vauchez	1987	Low-angle dextral strike-slip
Rankin and others	1971	thrust fault	Bobyarchick	1988	Alleghanian dispersal fault
Butler	1971	fault or root zone	Davis and others	1991	Acadian to Alleghanian transpression
Griffin	1971	root zone	Vauchez and others	1993	Acadian to Alleghanian dextral strike-slip

spectrum of Alleghanian events, including contractional and lateral motion, may be integrated. It has been suggested by Boyer (1992) that there are early and later periods of thrusting in the Blue Ridge around the Grandfather Mountain window. Detailed mapping by Conley and Drummond (1981) clearly shows that the Linville Falls fault (or an early version of that structure) is folded and overturned toward the northwest in that region. All that is known of the strike-slip motion is that it persisted toward the latter stages of ductile deformation in the Brevard fault zone, but is older than the Rosman fault.

The reverse, or thrust, hypothesis of the Brevard fault zone in its several phases is consistent with the tectonic history of the western part of the southern Appalachian orogen. It is supported by observations at all scales. The evolution of this part of the interpretive history illustrates the remarkable convergence of numerous streams of methodologies and concepts over a period of more than 60 years.

SUMMARY

Table 1 updates the historical summary of interpretations from Roper and Justus (1973, p. 119-120). The interpretive history of the Brevard fault zone in many ways mirrors evolving concepts in tectonics and structural geology. While basic observations for the most part remain unchanged, the context within which those observations have been made has evolved.

The Brevard fault zone has attracted many researchers perhaps because it is the most extensive linear structure in the southern Appalachian mountains. On the other hand, the fault zone largely lies at a topographic break between the steep slopes of the eastern Blue Ridge and, with a few exceptions, the lower rolling hills of the Piedmont. It may be this scenic contrast that draws investigators inward.

The regional importance of the Brevard fault zone continues to be a source of debate. Some studies conclude that the Brevard fault zone is a major structure in the orogenic belt. Others propose that it is insignificant as a tectonic boundary.

Some important elements of the structure remain to be resolved. One element is the true lateral extent of the fault zone as a more or less singular lineament. The southern extent of the Brevard fault zone (and the Piedmont) is covered by the Gulf Coastal Plain (Horton and others, 1984). How far did the fault zone continue prior to opening of the Gulf of Mexico? Similarly, the Brevard fault zone must continue for some distance to the north beyond the Sauratown mountains anticlinorium. Perhaps the Mountain Run fault in the western Piedmont of central Virginia (Pavlides and others, 1983), which has a similar regional setting and kinematic history, is the northern continuation of at least the strike-slip component of the Brevard fault zone.

In places there appears to be little displacement of stratigraphy across the Brevard fault zone, yet elsewhere the fault sharply divides tectonostratigraphic sequences. The magnitude of lateral offset on the fault therefore ranges from apparently insignificant (a few km) to hundreds of kms. Are the notable gaps in stratigraphic continuity simply cutoffs due to the late brittle phase of reverse motion in the fault zone?

The Brevard fault zone has a polyphase deformation history. How do these phases relate to plate motions? Given the heterogeneous architecture of the former Laurentian margin, preexisting structures may have acted as stress guides so that displacement directions do not directly show plate motions.

The interpretive history of the Brevard fault zone shows inheritance of traditions and reoccurrence of concepts. It may be that what remains to be done is simply refinement of existing interpretations based on existing data. On the other hand, this history of investigation in the Brevard fault zone records the impact that new theories have on regional studies. In all likelihood, such new theories will require future reexaminations of the Brevard fault zone.

ACKNOWLEDGEMENTS

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REFERENCES CITED

Bentley, R. D., and Neathery, T. L., 1970, Geology of the Brevard fault zone and related rocks of the Inner Piedmont of Alabama: p. 119.

Berthé, D., Choukroune, P., and Jegouzo, P., 1979, Orthogneiss, mylonite and non-coaxial deformation of granites: The example of the South Armorican shear zone: Journal of Structural Geology, v. 1, p. 31-42.

Bertrand, M. A., 1884, Rapports de structure des Alpes de Glaris et du bassin houiller du Nord: Bull. Soc. Géol. Fr., 3eme Sér., v. 12, p. 318-330.

Bobyarchick, A. R., 1982, Microscopic textures of shear band cleavage in micaceous mylonites: Geological Society of America Abstracts with Programs, v. 14, p. 446.

Bobyarchick, A. R., 1983, Structure of the Brevard Zone and Blue Ridge near Lenoir, North Carolina, with observations on oblique crenulation cleavage and a preliminary theory for irrotational structures in shear zones: Ph.D. dissertation, Albany, NY, State University of New York At Albany, 360 p.

Bobyarchick, A. R., 1984, A component of late Paleozoic strike-slip displacement in the Brevard zone, Southern Appalachians: Geological Society of America Abstracts with Programs, v. 16, p. 126.

Bobyarchick, A. R., 1988, Location and geometry of Alleghanian dispersal-related strike-slip faults in the southern Appalachians: Geology, v. 16, p. 915-919.

Boyer, S. E., 1992, Sequential development of the southern Blue Ridge province of northwest North Carolina ascertained from the relationships between penetrative deformation and thrusting *in* Mitra, S., and Fisher, G. W., ed., Structural geology of fold and thrust belts: Baltimore, Johns Hopkins University Press, v. p. 161-188.

Boyer, S. E., and Elliott, D., 1982, Thrust systems: American Association of Petroleum Geologists Bulletin, v. 66, p. 1196-1230.

Bryant, B., and Reed, J. C., Jr., 1970, Geology of the Grandfather Mountain window and vicinity, North Carolina and Tennessee: U.S. Geological Survey Professional Paper 615, U.S. Geological Survey, 190 p.

Bucher, W. H., 1964, Deformation of the Earth's crust, An inductive approach to the problems of diastrophism: New York, Hafner Publishing Co., Inc., 518 p.

Burchfiel, B. C., and Livingston, J. L., 1967, Brevard zone compared to Alpine root zones: American Journal of Science, v. 265, p. 241-256.

Burchfiel, B. C., and Livingston, J. L., 1968, Reply [to discussion of 'Brevard zone compared to alpine root zones,' by D. E. Dunn, J. R. Butler, 1967, and P. S. Justus, 1968]: American Journal of Science, v. 266, p. 215-220.

Butler, J. R., 1971, Comparative tectonics of some Alpine and Southern Appalachian structures: Southeastern Geology, v. 12, p. 203-221.

Butler, J. R., and Dunn, D. E., 1968, Geology of the Sauratown Mountains anticlinorium and vicinity, North Carolina (Guidebook for field excursions, Geological Society of America Southeastern section, Durham, N.C): Southeastern Geology Special Publication 1, p. 19-47.

Butts, C., 1927, Fensters in the Cumberland overthrust block in southwestern Virginia: Virginia Geological Survey Bulletin 28, Charlottesville, VA, Virginia Geological Survey, 12 p.

Carpenter, R. H., and Dallmeyer, R. D., 1974, A new theory for the tectonic evolution of the Blue Ridge allochthon in Tennessee and the Carolinas: Geological Society of America Abstracts with Programs, v. 6, p. 682.

Clark, H. B., III, Costain, J. K., and Glover, L., III, 1975, Preliminary seismic reflection studies of the Brevard zone near Rosman, North Carolina: Geological Society of America Abstracts with Programs, v. 7, p. 478.

Clark, H. B., III, Costain, J. K., and Glover, L., III, 1978, Structural and seismic reflection studies of the Brevard ductile deformation zone near Rosman, North Carolina: American Journal of Science, v. 278, p. 419-441.

Collet, L. W., 1933, Les mylonites gneissiques du versant sud de la Tour Salliere (Pointes a Boillon): Compte Rendu des Seances de la Societe de Physique et d'Histoire Naturelle de Geneve, v. 50, p. 212-216.

Collet, L. W., 1935, The structure of the Alps (2nd edition): Edward Arnold & Co., 304 p.

Collet, L. W., Jones, O. T., and Carozzi, A. V., 1974, The structure of the Alps (English translation of 1935 edition): Huntington, NY, Robert E. Krieger Publishing Co., 304 p.

Conley, J. F., and Drummond, K. M., 1965, Ultramylonite zones in the western Carolinas: Southeastern Geology, v. 6, p. 201-211.

Conley, J. F., and Drummond, K. M., 1981, Geologic map of the NE1/4 Marion quadrangle, North Carolina: Raleigh, NC, State of North Carolina Department of Natural Resources and Community Development, GM 210-NE, Geologic Map, 1:24,000.

Cook, F. A., Albaugh, D. S., Brown, L. D., Kaufman, S., Oliver, J. E., and Hatcher, R. D., Jr., 1979, Thin-skinned tectonics in the crystalline southern Appalachians; COCORP seismic-reflection profiling of the Blue Ridge and Piedmont: Geology, v. 7, p. 563-567.

Davis, T. L., Hatcher, R. D., Jr., Liu, A., and Tabor, J. R., 1991, Southern Appalachian western Inner Piedmont: A progressive crustal-scale shear zone: Geological Society of America Abstracts with Programs, v. 23, p. A138.

Davis, W. M., 1903, The stream contest along the Blue Ridge: Geographical Society of Philadelphia Bulletin, v. 3, p. 213-244.

Dewey, J. F., and Kidd, W. S. F., 1974, Continental Collisions in the Appalachian-Caledonian Orogenic Belt: Variations Related to Complete and Incomplete Suturing: Geology, v. 2, p. 543-546.

Dunn, D. E., Butler, J. R., and Justus, P. S., 1968, Discussion--Brevard zone compared to Alpine root zones: American Journal of Science, v. 226, p. 215-219.

Dunn, D. E., Butler, J. R., and Stirewalt, G., 1966, Competence control of slip cleavage development, Pilot Mountain, North Carolina: Program Abstracts, Geological Society of America Annual Meeting, p. 58-59.

Eardley, A. J., 1954, Structural geology of North America: New York, Harper and Brothers, 624 p.

Edelman, S. H., Liu, A., and Hatcher, R. D., Jr., 1987, The Brevard zone in South Carolina and adjacent areas: An Alleghanian orogen-scale dextral shear zone reactivated as a thrust fault: Journal of Geology, v. 95, p. 793-806.

Evans, C., and Mosher, S., 1986, Microstructures and sense of shear in the Brevard fault zone, Southern Appalachians: Geological Society of America Abstracts with Programs, v. 18, p. 596.

Griffin, V. S., Jr., 1971, Stockwork tectonics in the Appalachian Piedmont of South Carolina and Georgia: Geologischen Rundschau, v. 60, p. 868-886.

Hamilton, W. B., 1957, Polymetamorphic rocks of Blue Ridge front near Old Fort, North Carolina: American Journal of Science, v. 255, p. 568-573.

Harris, L. D., and Bayer, K. C., 1979, Sequential development of the Appalachian orogen above a master decollement - A hypothesis: Geology, v. 9, p. 568-572.

Harris, L. D., DeWitt, W., Jr., and Bayer, K. C., 1982, Interpretive seismic profile along Interstate-64 from the Valley and Ridge to the Coastal Plain in central Virginia: Reston, VA, U.S. Geological Survey, U.S. Geological Survey Chart Oil and Gas Investigations Chart - 123.

Harris, L. D., Harris, A. G., DeWitt, W., Jr., and Bayer, K. C., 1981, Evaluation of Southern eastern overthrust belt beneath Blue Ridge-Piedmont thrust: American Association of Petroleum Geologists Bulletin, v. 65, p. 2497-2505.

Hatcher, R. D., Jr., 1969, Stratigraphy, petrology, and structure of the low rank belt and part of the Blue Ridge of northwesternmost South Carolina: South Carolina Division of Geology, Geologic Notes, v. 13, p. 105-141.

Hatcher, R. D., Jr., 1970, Stratigraphy of the Brevard zone and Poor Mountain area, northwestern South Carolina: Geological Society of America Bulletin, v. 81, p. 933-940.

Hatcher, R. D., Jr., 1971, Stratigraphic, petrologic, and structural evidence favoring a thrust solution to the Brevard problem: American Journal of Science, v. 270, p. 177-202.

Hatcher, R. D., Jr., 1972, Developmental model for the Southern Appalachians: Geological Society of America Bulletin, v. 83, p. 2735-2760.

Hatcher, R. D., Jr., 1978, Tectonics of the western Piedmont and Blue Ridge, southern Appalachians: Review and speculation: American Journal of Science, v. 278, p. 276-304.

Hatcher, R. D., Jr., Osberg, P. H., Drake, A. A., Jr., Robinson, P., and Thomas, W. A., 1989, Tectonic map of the U.S. Appalachians, Plate 1 *in* Hatcher, R. D., Jr., Thomas, W. A., and Viele, G. W., ed., The Appalachian-Ouachita orogen in the United States: Boulder, CO, Geological Society of America, v. F-2, p. 767.

Hatcher, R. D., Jr., Price, V., Jr., and Snipes, D. S., 1973, Analysis of chemical and paleotemperature data from selected carbonate rocks of the Southern Appalachians: Southeastern Geology, v. 15, p. 55-70.

Hatcher, R. D., Jr., Williams, R. T., Costain, J. K., Phinney, R. A., Hopson, J. L., Stieve, A. L., Roy- Chowdhury, K., and Anonymous, 1986, Regional tectonic implications of seismic reflection, gravity, structural, and stratigraphic data from new Appalachian Ultradeep Core Hole (ADCOH) site study: American Association of Petroleum Geologists Bulletin, v. 70, p. 599.

Hayes, C. W., 1891, The overthrust faults of the southern Appalachians: Geological Society of America Bulletin, v. 2, p. 141-152.

Hayes, C. W., and Campbell, M. R., 1894, Geomorphology of the southern Appalachians: National Geographic Magazine, v. 6, p. 63-126.

Higgins, M. W., 1966, The geology of the Brevard lineament near Atlanta, Georgia: Bulletin 77, Georgia Geological Survey, 49 p.

Higgins, M. W., 1968, Geologic map of the Brevard fault zone near Atlanta, Georgia: U.S. Geological Survey Map I-511, 1:48,000.

Higgins, M. W., Atkins, R. L., Crawford, T. J., Crawford, R. F., III, Brooks, R., and Cook, R. B., 1988, The structure, stratigraphy, tectonostratigraphy, and evolution of the southernmost part of the Appalachian orogen: U.S. Geological Survey Bulletin 1475, p. 173.

Horton, J. W., Jr., 1980, Post-mylonitic deformation in the Brevard fault zone, North Carolina (abstract) *in* Wones, D. R., ed., Proceedings, "The Caledonides in the U.S.A.", IGCP Project 27-Caledonide Orogen, 1979 meeting: Blacksburg, Virginia Polytechnic Institute and State University Memoir 2, v. p. A17.

Horton, J. W., Jr., 1982, Geologic map and mineral resources summary of the Rosman quadrangle, North Carolina: Raleigh, NC, North Carolina Department of Natural Resources and Community Development, Division of Land Resources, Geological Survey Section, Geologic Map 185-NE, MRS 185-NE, 1:24,000.

Horton, J. W., Jr., and Butler, J. R., 1986, The Brevard fault zone at Rosman, Transylvania County, North Carolina *in* Neathery, T. L., ed., Centennial Field Guide, Southeastern Section: Boulder, CO, Geological Society of America, v. 6, p. 251-256.

Horton, J. W., Jr., and McConnell, K. I., 1991, The western Piedmont *in* Horton, J. W., Jr., and Zullo, V. A., ed., The geology of the Carolinas: Knoxville, The University of Tennessee Press, v. p. 127-141.

Horton, J. W., Jr., Zietz, I., and Neathery, T. L., 1984, Truncation of the Appalachian Piedmont beneath the Coastal Plain of Alabama: Evidence from new magnetic data: Geology, v. 12, p. 51-55.

Hurst, V. J., 1970, The Piedmont in Georgia *in* Fisher, G. W., Pettijohn, F. J., Reed, J. C., Jr., and Weaver, K. N., ed., Studies of Appalachian geology: Central and Southern: New York, Interscience Publishers, v. p. 383-396.

Jonas, A. I., 1932, Structure of the metamorphic belt of the southern Appalachians: American Journal of Science, v. 24, p. 228-243.

Keith, A., 1903, Description of the Cranberry quadrangle, North Carolina-Tennessee: U.S. Geological Survey, U.S. Geological Survey Geologic Atlas, Folio 90, 9 p.

Keith, A., 1905, Description of the Mount Mitchell quadrangle North Carolina-Tennessee: U.S. Geological Survey, U.S. Geological Survey Geologic Atlas, Folio 124, 9 p.

Keith, A., 1907a, Description of the Pisgah quadrangle (NC-SC): U.S. Geological Survey, U.S. Geological Survey Geologic Atlas, Folio 147, 8 p.

Keith, A., 1907b, Description of the Roan Mountain quadrangle: U.S. Geological Survey, U.S. Geological Survey Geologic Atlas, Folio 151, 11 p.

Keith, A., 1923, Outlines of Appalachian structure: Geological Society of America Bulletin, v. 34, p. 309-380.

Keith, A., 1928, Structural symmetry in North America:

Geological Society of America Bulletin, v. 39, p. 321-385.

King, P. B., 1950, Tectonic framework of the southeastern states: American Association of Petroleum Geologists Bulletin, v. 34, p. 635-671.

King, P. B., 1955, A geologic section across the Southern Appalachians - an outline of the geology in the segment in Tennessee, North Carolina, and South Carolina *in* Russell, R. J., ed., Guides to southeastern geology: New York, Geological Society of America, v. p. 332-373.

Knopf, E. F. B., 1933, Petrotectonics: American Journal of Science, v. 225, p. 433-470.

Knopf, E. F. B., and Ingerson, F. E., 1938, Structural petrology: Boulder, CO, Geological Society of America Memoir 6, 270 p.

Leith, C. K., 1905, Rock cleavage *in* U.S. Geological Survey Bulletin 239: U.S. Geological Survey, v. p. 112-116.

Leith, C. K., 1913, Structural geology: New York, Henry Holt and Company, 169 p.

Lister, G. S., and Snoke, A. W., 1984, S-C mylonites: Journal of Structural Geology, v. 6, p. 617-638.

McGee, W. J., 1893 map date, Reconnaissance map of the United States showing the distribution of the geologic system so far as known, Plate II *in* Powell, J. W., ed., U.S. Geological Survey Fourteenth Annual Report 1892-'93, Part II–Accompanying Papers: Washington, DC, U. S. Geological Survey, v.

Medlin, J. H., and Crawford, T. J., 1973, Stratigraphy and structure along the Brevard fault zone in western Georgia and eastern Alabama: American Journal of Science, v. 273-A, p. 89-104.

Milnes, A. G., 1979, Albert Heim's general theory of natural rock deformation (1878): Geology, v. 7, p. 99-103.

Miyashiro, A., Aki, K., and Sengör, A. M. C., 1982, Orogeny: New York, John Wiley & Sons, 242 p.

Odom, A. L., and Fullager, P. D., 1973, Geochronological and tectonic relationships between the Inner Piedmont, Brevard zone, and Blue Ridge belts, North Carolina: American Journal of Science, v. 273-A, p. 133-149.

Pavlides, L., Bobyarchick, A. R., Newell, W. L., and Pavich, M. J., 1983, Late Cenozoic faulting along the Mountain Run fault zone, central Virginia Piedmont: Geological Society of America Abstracts with Programs, v. 15, p. 55.

Platt, J. P., and Vissers, R. L. M., 1980, Extensional structures in anisotropic rocks: Journal of Structural Geology, v. 2, p. 397-410.

Pratt, T. L., Coruh, C., Costain, J. K., and Glover, L., III, 1988, A geophysical study of the Earth's crust in central Virginia; implications for Appalachian crustal structure: Journal of Geophysical Research B Solid Earth and Planets, v. 93, p. 6649-6667.

Rabbitt, M. C., 1980, Minerals, lands, and geology for the common defence and general welfare, Vol. 2, 1879-1904: Reston, VA, U.S. Geological Survey, 407 p.

Rankin, D. W., 1971, Guide to the geology of the Blue Ridge in southwestern Virginia and adjacent North Carolina *in* Guidebook to Appalachian tectonics and sulfide mineralization of southwestern Virginia: Blacksburg, VA, Virginia Polytechnic Institute and State University Guidebook, v. 5, p. 39-86.

Rankin, D. W., 1975, The continental margin of eastern North America in the Southern Appalachians: The opening and closing of the proto-Atlantic Ocean: American Journal of Science, v. 275-A, p. 298-336.

Reed, J. C., Jr., and Bryant, B., 1964, Evidence for strike-slip faulting along the Brevard zone in North Carolina: Geological Society of America Bulletin, v. 75, p. 1177-1196.

Reed, J. C., Jr., Bryant, B., and Myers, W. B., 1970, The Brevard zone: a reinterpretation *in* Fisher, G. W., Pettijohn, F. J., Reed, J. C., Jr., and Weaver, K. N., ed., Studies of Appalachian geology - Central and Southern: New York, Interscience Publishers, v. p. 261-269.

Reed, J. C., Jr., Johnson, H. S., Jr., Bryant, B., Bell, H., III, and Overstreet, W. C., 1961, The Brevard fault in North and South Carolina: U.S. Geological Survey Professional Paper 424-C, p. C67-C70.

Rodgers, J., 1949, Evolution of thought on structure of middle and southern Appalachians: American Association of Petroleum Geologists Bulletin, v. 33, p. 1643-1654.

Roeder, D., Gilbert, O. E., Jr., and Witherspoon, W. D., 1978, Evolution and macroscopic structure of Valley and Ridge thrust belt, Tennessee and Virginia: Studies in Geology (Knoxville) n. 2, Department of Geological Sciences, Knoxville, TN, United States, University of Tennessee, 25 p.

Roper, P. J., 1972, Structural significance of the "button" or "fish-scale" texture in the phyllonitic schist of the Brevard zone: Geological Society of America Bulletin, v. 83, p. 853-860.

Roper, P. J., and Dunn, D. E., 1970, Geology of the Tamassee, Satolah, and Cashiers quadrangles, Oconee County: Columbia, SC, South Carolina Development Board, Division of Geology, MS-16.

Roper, P. J., and Dunn, D. E., 1973, Superposed deformation and polymetamorphism, Brevard zone, North Carolina: Geological Society of America Bulletin, v. 84, p. 3373-3386.

Roper, P. J., and Justus, P. S., 1973, Polytectonic evolution of the Brevard zone: American Journal of Science, v. 273-A, p. 105-132.

Sander, B., 1934, Petrofabrics (Gefuegekunde der Gesteine) and orogenesis: American Journal of Science, v. 163, p. 37-50.

Sander, B., 1939, Gefuegekunde und ihre Anwendungen: Zeitschrift fur Angewandte Mineralogie, v. 1, p. 285-312.

Schneiderman, J. S., 1997, A life of firsts: Florence Bascom: Geological Society of America Today, v. 7, p. 8-9.

Stirewalt, G. L., and Dunn, D. E., 1973, Mesoscopic fabric and structural history of Brevard zone and adjacent rocks, North Carolina: Geological Society of America Bulletin, v. 84, p. 1629-1650.

Stonebraker, J. D., 1973, Potassium-Argon Geochronology of the Brevard Fault Zone, Southern Appalachians:

Ph.D. dissertation, Tallahassee, FL, The Florida State University, 145 p.

Stose, G. W., and Smith, R. W., 1939, Geologic map of Georgia: Georgia Division of Mines, Mining, and Geology, 1:500,000.

Suess, E., 1875, Die Entstehung der Alpen: Vienna, W. Braumüller

Suess, E., 1885-1909, Das Antlitz der Erde: Wien, Freytag

Turner, F. J., and Weiss, L. E., 1963, Structural analysis of metamorphic tectonites: New York, McGraw-Hill, 545 p.

Van Hise, C. R., 1896, Principles of North American Precambrian geology *in* 16th Annual Report of the U.S. Geological Survey, Part I: U.SA. Geological Survey, v. p. 571-874.

Vauchez, A., 1987, Brevard fault zone, southern Appalachians: A medium-angle, dextral, Alleghanian shear zone: Geology, v. 15, p. 669-672.

Vauchez, A., Babaie, H. A., and Babaei, A., 1993, Orogen-parallel tangential motion in the Late Devonian - Early Carboniferous southern Appalachian mountains: Canadian Journal of Earth Sciences, v. 30, p. 1297-1305.

Vauchez, A., and Brunel, M., 1988, Polygenetic evolution and longitudinal transport within the Henderson mylonitic gneiss, North Carolina (southern Appalachian Piedmont): Geology, v. 16, p. 1011-1014.

Watkins, J. S., and Huggett, T., 1970, Evidence of middle Palezoic sea-floor spreading in the southern Appalachians: v. 51, p. 824.

White, S. H., Burrows, S. E., Carreras, J., Shaw, N. D., and Humphreys, F. J., 1980, On mylonites in ductile shear zones: Journal of Structural Geology, v. 2, p. 175-187.

White, W. A., 1950, Blue Ridge front--a fault scarp: Geological Society of America Bulletin, v. 71, p. 1309-1346.

Willis, B., 1893, The mechanics of Appalachian structure: U.S. Geological Survey 13th Annual Report, Part 2, p. 211-281.Bentley, R. D., and Neathery, T. L., 1970, Geology of the Brevard fault zone and related rocks of the Inner Piedmont of Alabama: p. 119.