A THEORY FOR THE VOLCANIC ORIGIN OF RADIOACTIVE SHALES AND CLAYS: EXAMPLES FROM THE SOUTHEASTERN UNITED STATES

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Abstract

An explanation is offered, within the young-earth Flood model, for the origin of radioactive shales and clays via the alteration of volcaniclastic material (ash deposits) which contain radioactive elements. This is based on the similarity of radioactive elements identified as leaching from altered volcanic ash deposits in the western United States. The Southeastern United States has many marine organic rich "black" shales, massive clays, and sandstone layers which contain radioactive elements at levels significantly higher than the surrounding strata. The radioactivity associated with those clastics is derived from several radioactive isotopes including uranium (^{234}U), thorium (^{232}Th), potassium (^{40}K), and radium (^{226}Ra). Two specific stratigraphic units, the Chattanooga Shale of Tennessee and various clay units within the massive clastic deposits of the Hawthorn Group of west central Florida, are proposed as examples where radioactive volcaniclastics have altered in-situ to yield radioactive shales, clays.

Introduction

The uniformitarian model proposes that clastic sediments have been generated through weathering processes which have operated over vast eons of time. Weathering of the continents, over the millions of years suggested, have resulted in the generation of sands, silts, and clays which were transported to former seas and oceans. It is in this marine setting where only certain silts and clays became radioactive. Suggested mechanisms include the direct precipitation of uranium salts, bioaccumulation by organisms, adsorption by clay or organic matter, or derivation from "hypothetical" radioactive heavy minerals derived in turn from igneous intrusives of the adjacent highlands, which were deposited within the fine-grained clastics. We will examine these many theories, along with one which fits within the young-earth Flood model, in an attempt to determine how these layers became radioactive.

It has been estimated that shales comprise 82 percent of all sedimentary rocks on Earth and that they contain the largest concentrations of radioactive substances (Beers, 1945, p. 2). Many studies have investigated various radioactive clays and shales found in the Southeastern United States (Bell, Goodman, and Whitehead, 1940; Sheppard, 1944; Beers and Goodman, 1944; Beers, 1945; Cathcart, 1950; Swanson, 1960). Most of these have been undertaken in an effort to locate valuable petroleum and mineral deposits. The origin, nature, and extent of the radioactivity of the shales and clays has remained, for the most part, unaddressed.

Uniformitarian weathering processes suggest that the earth has undergone billions of years of long-term uplift and erosion, with the eroded sediments slowly filling subsiding basins. Within this framework, exposed land surfaces eroded toward total peneplanation until diastrophic (i.e., tectonic) activity created new highlands. The sediments derived from this cycle then imply the millions of years required (using today's hydrologic cycle) to accommodate the uniformitarian time frames.

According to Uniformitarians, the vertical stratigraphic section of Southeastern United States reflects many millions of years of eustatic sea-level changes resulting in the deposition of certain sequences of sediments which can be further subdivided into lithologic facies, all of which can be understood in terms of the concepts of sequence stratigraphy (Froede, 1994a). These facies are then used to identify the original environment(s) in the vertical sequence, using concepts such as Walther's Law. This conceptual model of facies development (e.g., deltas, barrier complexes, estuarine settings, meandering river complexes, etc.) over the vast periods of time in which they are purported to have existed (i.e., millions of years), is used to support the uniformitarian model. Although the recognition of catastrophic processes is gaining support among many of the uniformitarian geoscientists, it is still used within their time frames of millions of years.

Figure 1. Chattanooga Shale as exposed along Interstate 40 approximately 15 miles west of Nashville, Tennessee.

The I believe that there is a major disconnect between the facies concept and the original source(s) of those sediments. Uniformitarians suggest that the sediments which compose the present day southeast were derived from a variety of sources, including mountain ranges (e.g., Appalachians, Ouachitas), localized areas of uplift (e.g., Cincinnati Arch, Nashville Dome, Ocala Arch, Hatchetigbee Anticline), biogenic rock sources (e.g., carbonate producers), and reworked "older" deposits. However, most of these original sediment source areas, which are suggested as supplying sediments over millions of years, remain ambiguous and vague. For example, the issues of when, what types of materials

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and how much sediment they contributed to the southeastern stratigraphic section have, in most cases, not been addressed.

The young-earth Flood model also requires that we identify the sources of the sediments identified in the Southeastern United States. This paper proposes that one commonly overlooked major source of sediments is from volcanic activity which was initiated during the Flood. These volcaniclastics compose significant amounts (i.e., both by volume and in areal extent) of sediments in the Southeastern United States vertical stratigraphic section. Additionally, the author recognizes that other sediments were added to the southeastern stratigraphic section from the sources previously mentioned (i.e., mountains, areas of uplift, biogenic activity, and reworked deposits). The major difference between the uniformitarian and young-earth Flood models is in the amount of time available to construct the southeastern vertical stratigraphic section (i.e., either within the course of millions of years or within a few thousand years).

Identification of Volcanically Derived Sediments

It is now well documented that past volcanic events have contributed significant amounts of pyroclastic sediments to the stratigraphic record (e.g., Huff, Bergstrom and Kolata, 1992; Lockley and Rice, 1990; Rice, 1990; Axelrod, 1981; Fisher and Smith, 1991; Rampino, 1991; Carey, 1991; Smith and Lowe, 1991; Donn and Ninkovich, 1980; Kennett and Thunell, 1975; Ross, 1928; Ross, 1955). The contribution of pyroclastic rock to the sedimentary record is probably greater than currently understood, because an unknown amount of fine grained tephra is largely unrecognized in rocks classified as shale (Fisher and Schmincke, 1984, p. 5; Ross, 1955, p. 427; Grim, 1958, p. 252; Weaver, 1963, p. 343; Pettijohn, 1957, p. 153). Volcanism is recognized as having occurred in the geologic past in the Southeastern United States (Byerly, 1991). However, the level of volcanic activity is generally viewed by Uniformitarians as being rather small in scale due to the limited lateral extent and volume of "recognized" volcaniclastic sediments.

Radioactivity In Shales, Petroleum, Coals, and Clays

As a result of petroleum exploration, many radioactive shale and clay layers have been identified in the Gulf Coastal Plain (Bell, Goodman, and Whitehead, 1940, pp. 1540-1542; Levorsen, 1967, pp. 527-529). Many scientists have investigated the possibility that radioactivity was responsible for the origin of petroleum deposits; their results, however, were inconclusive (Sheppard, 1944; Landes, 1976, pp. 165-167; Whitehead, 1954).

Russell (1945) examined the radioactivity of 510 samples of sedimentary rock from the subsurface of the Gulf Coastal Plain and found that marine shales are highly radioactive as compared with other sediments. Additionally, he found that Paleozoic shales display higher radioactivity levels than do the Cenozoic shales (Russell, 1945, p. 1486). Beers (1945, p. 2) found that pure limestones and quartzites exhibit practically no radioactivity, while black organic shales contain high concentrations of three principal radioactive elements (i.e., uranium, thorium, and potassium).

Figure 2. Closeup photograph of the Chattanooga Shale showing stratification. Scale along left side of photograph is in six inch units.

McKelvey and Nelson (1950, p. 38) have stated that nonmarine oil shales, coals, and associated black shales as a group have abnormally low uranium content.

In attempting to discuss the formation of black shales using uniformitarian processes. Arthur and Sageman (1994) revealed at least two inconsistencies in the model to explain its occurrence. First they stated that black shale; appear to be associated with marine transgressions or highstands (pp. 505, 536) and also with high rates of sedimentation (p. 514). Arthur and Sageman (1994, p. 522) relate the following when discussing the occurrence of a variety of trace elements commonly found in association with black shales:

> For many elements (Ag, As, Cd, Cr, Mo, Sb, U, V, and Zn) a sedimentary sequence more than 10 times as thick as the black shale layer has to be leached of its trace metal content with complete transfer to the black shale bed in order to account for enrichments; in general, this mechanism does not explain relatively thick sequences of trace-metal enriched black shale.
>
> Many trace metals undergo a dramatic solubility decrease at the O_2 / H_2S-boundary and are removed from the water column, usually by precipitation as sulfides, and finally buried in the sediments.

> Again, this trace element enrichment may be more noticeable when sedimentation rates and corresponding dilution by terrigenous detritus are low.

Thus the exact model for the formation of marine black shales and their varied elemental content remains an enigma for geologists. No single mechanism can be found to work in all cases to explain the occurrence of the marine black shales, and many of the present models remain unsatisfactory in explaining how these deposits have formed (Arthur and Sageman, 1994, p. 541; Wignall, 1994, p. 44).

Many petroleum and coal deposits are known to contain elevated levels of various metals and radioactive elements and their "contamination" has yet to be fully explained (e.g., Levorsen, 1967, p. 190; Coleman, Crawford, and Medlin, 1986, p. 5). For example, Gentry et al., (1976) identified uranium within coalified wood, which they suggested was deposited in the wood before it turned to coal. Additionally, Breger and Schopf (1955) postulated the occurrence of germanium, uranium, vanadium, and nickel within the less than one-inch thick coal seams of the Chattanooga Shale as reflecting deposition of these metals before the wood became coal. McKelvey and Nelson (1950, p. 39) suggest that the uranium is held by the organic content of the Chattanooga Shale rather than the shale itself. Swanson (1960, pp. 5-6) investigated the occurrence of oil yield and uranium content in black shales in the Southeastern United States and concluded that the uranium was deposited with the original clays. Most of the radioactive shale and clay layers identified in the subsurface of the Southeastern United States have not been reported or investigated because of the proprietary nature in which the petroleum companies operate and because these layers are located at great depth and do not lend themselves to easy examination or exploitation.

Source of Radioactivity

Currently, there are two basic theories which are proposed by Uniformitarians to explain the occurrence of radioactive shales and clays. The first holds that marine sediments containing radioactive elements (e.g., uranium, thorium, potassium and radium) are the result of prolonged periods of exposure to seawater, and/or were located in areas of coastal upwelling (McKelvey and Nelson, 1950; Cathcart, 1950; Swanson, 1960, p. 5; Church and Bernat, 1972; Veeh, Calvert, and Price, 1974; Yen and Tang, 1977; Miller and Sutcliffe, 1985; Sweeney and Windham, 1979; Arthur and Sageman, 1994, p. 523). Although this concept has been questioned (Breger and Schopf, 1955, p. 291), it is still widely supported. These conditions are suggested to account for the higher concentrations of radioactive elements in specific shale and clay layers relative to surrounding sediments. Based on the uniformitarian timescale, however, almost all marine sediment would be exposed to seawater for millions of years and it would follow that every marine sediment should be radioactive.

Three modifications to the long term seawater exposure theory have been suggested: (1) uranium precipitated as salts into the sediments; (2) uranium was adsorbed by clay, organic matter, or other finely divided material; or (3) organisms served to concentrate the uranium in layers as a result of their metabolic

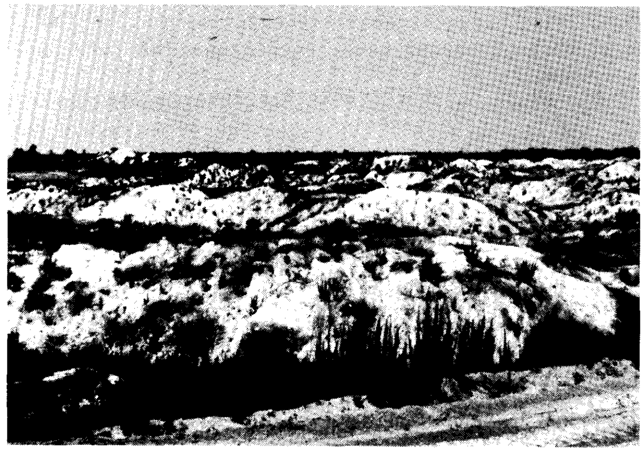

Figure 3. Phosphate mining spoil piles in mining district in Polk County, Florida.

processes (McKelvey and Nelson, 1950, pp. 44-46). All of these suggested modifications are recognized as requiring long periods of nondeposition to account for the concentrations found in the thin radioactive layers (McKelvey and Nelson, 1950, p. 41).

A second theory suggests that radioactive heavy minerals were the source for those elements found in the shales and clays. These heavy minerals were derived from igneous intrusives and metamorphic rocks from the adjacent highlands. Upon weathering the heavy minerals washed to the sea and mixed as fine particles with the marine clastics. Eventually the heavy minerals weathered away leaving high concentrations of radioactive elements (Beers and Goodman, 1944, pp. 1247-1248; Beers, 1945, p. 14; Russell, 1945, p. 1481; Sackett and Cook, 1969). With the weathering of radioactive heavy minerals, the shales and clays would then retain the radioactivity with no evidence of the original radioactive heavy minerals. However, these theories are not the only possible ways in which radioactive shale and clay sediments could have formed.

The Breakdown of Volcanic Ash

Many volcanic ash deposits have been identified as containing significant levels of radioactive elements. Daniels (1954, pp. 193-194) cites the collection of many volcanic ash deposits which were found to contain both uranium and thorium. Additionally, it was reported that acidic volcaniclastics usually contain higher concentrations of uranium (and other radioactive elements) than basic volcanic deposits (Adams, 1954, pp. 89-98). Studies performed by several scientists have shown that the alteration of a volcanic ash can yield radioactive elements (i.e., uranium [^{234}U], thorium [^{232}Th], potassium [^{40}K], and radium [^{226}Ra]). These radioactive elements can move within the groundwater until a change in the reduction/oxidation (redox) potential causes precipitation (e.g., Denson, Zeiler and Stephens, 1955; Eargle, Dickinson, and Davis, 1975; Galloway, 1978; Sherborne et al., 1979; Zielinski, Lindsey and Rosholt, 1980; and Zielinski, 1982). Bell (1954, pp. 98-114) reports the leaching and precipitation of uranium and thorium, from radioactive element containing sources, via the groundwater. Volcanic ash is now identified as the source for many uranium ore deposits in the western United States (Nations and Stump, 1981, pp. 202-203; Sharp and Kyle, 1988, p. 470; Wood and Fernandez, 1988, p. 363). According to Klein (1982, p. 42), by groundwater movement of uranium minerals:

> . . . are concentrated diagenetically at contacts where ground water flow is impeded. The ground waters responsible for such a diagenetic accumulation are highly oxidizing and alkaline. Presumably, the precipitation of uranium is accelerated by concentration of organic material along channel floors . . .

According to Fisher and Schmincke (1984, p. 329) an oxygenated and well-flushed volcanic ash (i.e., glass) layer can leach high concentrations of uranium into solution, which can travel for great distances before precipitation occurs. The leaching of the radioactive elements and/or their daughters would also affect the radiometric dating of the sediments or materials contained within those sediments (Kulp, 1955, pp. 617-621; Gentry et al., 1976). In addition to radioactive elements and minerals, volcanic ash has also been identified as a source of a wide variety of trace elements including Y, Zr, Rb, Cr, Ni, Ag, Au, Mo, Sb, V, Li, Be, B, F, Sn, Cu, and Zn, along with many other elements and associated minerals (Fisher and Schmincke, 1984, p. 339; Galloway, 1978, p. 1669; Hildreth, 1979, pp. 56-57; Zielinski, Lindsey, and Rosholt, 1980, p. 144; Zielinski, 1982, pp. 194-195). The variety of minerals and elements found in combination with radioactive containing shales and clays should provide sufficient evidences to link the sedimentary unit to its volcanic origin.

The author suggests that where leaching and/or flushing has not occurred to a great degree, the volcaniclastic would retain the majority of its original radioactive composition, and associated elements and minerals and would simply alter in-situ into radioactive element containing clays and shales. This is not a new idea. Russell (1945, pp. 1483-1484) alluded to the possibility of a volcanic origin for radioactive marine shales, but discounted it due to insufficient evidence. Klein (1982, p. 87) suggested that uranium containing sandstone is "derived from a granitic or volcanic source containing uranium, and interbedded with mudstone." Grim (1968, p. 553) has stated that altered volcanic ash comprises a large quantity of the clays found in the Gulf Coast.

Thus it would appear that the Southeastern United States contains altered volcaniclastic deposits which are the source for radioactive elements. I acknowledge that other secondary causes can account for small accumulations of radioactive elements within the marine shales and clays. These secondary processes, however, cannot account for the massive accumulation of the radioactive elements in what are recognized as ore grade deposits.

Radioactive Shales and Clays: Examples From the Southeastern U.S.

As previously stated, the Southeastern United States contains many lithostratigraphic units which the author suggests are of volcanic origin. In this work two specific stratigraphic units (i.e., the Chattanooga Shale of Tennessee and the Hawthorne Group in west central Florida) are discussed to highlight evidence in support of their volcanic origin. Currently, uniformitarian scientists do not view these two stratigraphic units as being of volcanic ash origin. While some of these stratigraphic units extend outside of the Southeastern United States, it is beyond the scope of this paper to examine and correlate these units outside of what is proposed here. The primary reason is the potential variability caused by the mixing of what were originally volcanic sediments with other sedimentary, environmental facies. This potential variability would lead to an undefinable original source sediment. Other investigations must be performed to determine the original source(s) for sediments outside of the Southeastern United States.

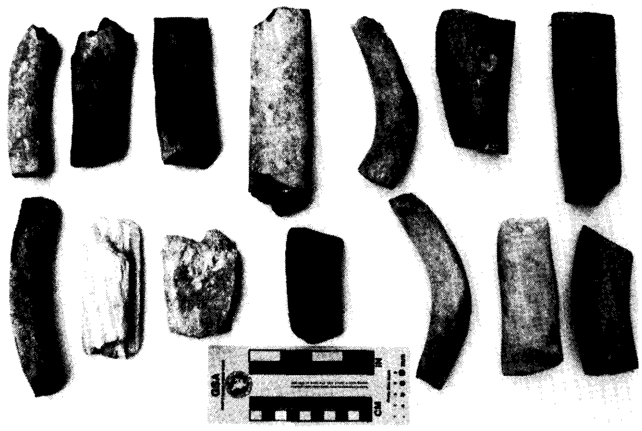

Figure 4. Radioactive fossilized "Sirenian rib bones" from the Bone Valley Member of the Hawthorn Group.

The stratigraphic units of specific interest for this article are the Devonian Chattanooga Shale found in Tennessee (Levorsen, 1967, p. 529; Press and Siever, 1974, p. 858; Upham, 1992, p. 47; Alexander 1953) and various clay units within the Miocene montmorillonitic Hawthorne Group (including the Bone Valley Member of the Peace Formation [Scott, 1988]) found in west central Florida (Cathcart, 1950; Calver, 1957; Miller and Sutcliffe, 1985; Campbell, 1986).

Volcanic Origin

I suggest that the Chattanooga Shale and various units within the Hawthorne Group clays represent two examples of what were originally radioactive volcanic ash deposits which have been altered and are no longer recognizable as such. Due to quick burial, both of these stratigraphic units still retain radioactive elements and have simply altered into the shales and clays we observe today.

Additional evidence for volcanic origin is suggested by the chert layers found immediately above the Chattanooga Shale (Fort Payne Chert) and in various layers throughout the Hawthorne Group. These chert layers are a logical consequence of the breakdown of silica rich material (i.e., volcanic ash) as it altered into various clay minerals. This alteration would release large quantities of silica into solution that would precipitate at lithologic contacts between strata and result in the formation of layers of silica-cemented sands or chert (Altschuler, Dwornik and Kramer, 1963, p. 151). If the original sediments were deposited as clays, then the release of large amounts of silica from those units would not be expected, and the chert layers should not exist. However, the existence of these silica-rich features suggests that there was an abundance of free silica derived from some source (e.g., volcanic ash) and that it precipitated from groundwater along a lithologic contact.

McKelvey and Nelson (1950, p. 43) describe the origin of uranium containing marine sediments as:

> . . . of syngenetic origin that is, it was deposited at the same time as the containing sediments. This is shown by the fact that thin uraniferous layers persist over areas of thousands of square miles with little if any change in lithology or uranium content and are interstratified with layers having markedly different composition, both as regards major and minor constituents. Moreover, the uranium-bearing rocks are as diverse in texture, permeability, and porosity as many of the non-uraniferous rocks with which they are interbedded.

A syngenetic origin would also fit for radioactive elements derived from a blanket of volcanic ash. The only difference would be one of time.

If sufficient flushing of these volcaniclastic units occurred, and geochemical conditions were such that the radioactive elements were liberated into solution, then the radioactive elements could move with the silica solution and/or groundwater. This is the suggested scenario for radioactivity found in the Florida Hawthorne Group. For example, the movement of ^{234}U with opal in solution has been suggested by Zielinski et al., (1980). However, if flushing of the original volcaniclastics did not occur in great measure, and this is what the author proposes for the Chattanooga Shale, then the radioactive elements would still largely remain within the altered clays and shales.

The Chattanooga Shale of Tennessee

I suggest that the Chattanooga Shale, as found in Tennessee, originated as a volcaniclastic deposit which mixed with organic debris. Work performed by Milici and Roen (1981, p. 2) has shown the Chattanooga Shale can be divided into four units based on color, which in turn is a function of organic content. However, their study did not report the levels of radioactivity found in each interval. Ettensohn, Fulton, and Kepferle (1979) documented the successful use of a scintillometer and gamma-ray logs in defining the radioactive profiles of organic-rich shales in Kentucky and Ohio, which are chronostratigraphic to the Tennessee Chattanooga Shale. Their work was performed in an attempt to correlate organic-rich shale sections across great distances. However, they did not suggest a possible source of the radioactive elements. Glover (1959) also used a scintillometer in his investigation of the variability in radioactivity and organic content of the Chattanooga Shale, as found in Alabama, Georgia, and Tennessee. Over time, and as a function of subsurface conditions, geochemical reactions between the original volcanic ash, organic material, and the connate groundwater would occur. The volcanic ash would alter to a clay and release silica and other soluble constituents. The addition of heat and pressure would subsequently alter the clay to a shale. If subsurface conditions did not provide a means of removing the radioactive elements from either the original ash or subsequent clay or shale via flushing and changes in the redox potential, then the radioactive elements would remain. This would result in the formation of a radioactive shale deposit, which this author suggests is representative of the Chattanooga Shale. The organic composition of the Chattanooga Shale is also believed to have adsorbed some of the leached radioactive elements (McKelvey and Nelson, 1950, p. 39; Swanson, 1960, p. 4).

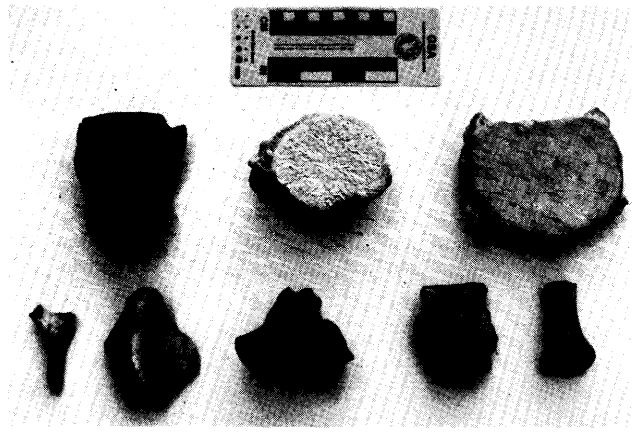

Figure 5. Radioactive fossilized miscellaneous vertebra (i.e., dolphin and whale) from the Bone Valley Member of the Hawthorn Group.

Today, the Chattanooga Shale is recognized as a lithified organic rich marine shale containing high concentrations of radioactive elements (Russell, 1945; McKelvey and Nelson, 1950; Beers and Goodman, 1944; Beers, 1945; Russell, 1945; Glover, 1959) (Figure 1). Levels of uranium found within the shale are sufficiently high to qualify the shale as a uranium ore (Upham, 1992, p. 47; Alexander, 1953). However, some variation in radioactivity is noted based on organic content. Studies have suggested that the richest organic layers (the "blackest" intervals) contain the highest concentrations of radioactivity (e.g., uranium, thorium and potassium).

Work performed by several investigators has also noted the unusually high concentrations of uranium and daughters, along with other metallic species, contained within thin seams of coal found within the Chattanooga Shale. These workers suggest that the uranium was added to the woody plant tissue following its deposition, but before it underwent coalification (Gentry et al., 1976, p. 316; Breger and Schopf, 1955, p. 292). This can best be explained by the alteration of a volcanic ash which leached radioactive elements into the formation pore water. As the pore water moved through these woody deposits, metals (radioactive and non-radioactive) precipitated due to the differences in geochemistry existing within these organic rich deposits. The deposits were later subjected to heat and pressure and formed into today's radioactive shale and coal deposits.

The Hawthorn Group of West Central Florida

The clay units comprising the Hawthorn Group of west central Florida are also suggested as being clay units derived from volcaniclastic materials. In this case the original volcanic deposits did not mix with organic material (as did the Chattanooga Shale), but rather they mixed with the surrounding marine sediments. While the source of the volcanic ash remains unidentified, it is widely recognized that volcaniclastics can be transported via water currents over vast distances (e.g., Cas and Wright, 1987, p. 288; 1991, p. 372-374; Fisher and Schmincke, 1984, pp. 170-173). This would then not require a "local" volcanic ash source. The examination of trace metals and heavy minerals, along with any other "tracer" type elements or minerals, could possibly be used to identify the original source of those volcanic sediments.

Following the loss of transport energy and / or upon becoming water saturated, these volcaniclastics would sink to the seafloor and eventually alter into various clay minerals depending on redox conditions. With burial and alteration these volcanic ash layers would serve to release a variety of constituents into the groundwater (i.e., silica, radioactive and non-radioactive elements, and metals). Many of the overlying and underlying strata served as receptors of these leached materials.

Uranium-containing sands and clays, and land-pebble phosphate (i.e., carbonate fluorapatite or francolite) deposits associated with the Florida Hawthorne Group and the Bone Valley Member, respectively, have been described by scientists (Cathcart, 1950, 1955; Altschuler, Jaffe, and Cuttitta, 1955; Scott, 1988, 1990a; Campbell, 1986; Altschuler, Cathcart, and Young, 1994) (Figure 2). The phosphate pebble and gravel deposits contained within the Bone Valley Member are a recognized economic source of uranium (Campbell, 1986, pp. 8-12; Altschuler, Cathcart, and Young, 1994, pp. 52-55; Johnson, 1977, p. 31; Cathcart, 1985, p. 24). While I do not propose a volcanic origin for the phosphate deposits found within the Hawthorn Group, they were affected by the leaching of radioactive elements and other metals from adjacent volcaniclastics. Cathcart (1950, p. 150) speculated that the source of the uranium was from the phosphate and clays associated with it (Figure 3). However, recent research now questions the origin of metals (both radioactive and non-radioactive) from the phosphate deposits.

Swanson (1960, pp. 4-5) previously identified phosphate as a uranium receptor. Current research has revealed that apatite phosphate serves to absorb metals (including radioactive elements [Wright, Conca, Repetski and Clark, 1990, p. 310; Wright, Peurrung and Conca, 1994; Wright, et al., 1995]). Thus, the phosphate has absorbed and concentrated metals and radionuclides which have leached from the radioactive element and metal containing volcaniclastics. This research showing radioactive element and metal absorption by phosphate supports my s belief that the radioactive elements were derived from one or more volcanic ash layers (i.e., several units within the Hawthorne Group Clays), and not from the phosphate itself.

The Hawthorn Group of West Central Florida: The Bone Valley Member

It has also been suggested by Uniformitarians that uranium sandstone ore bodies form as a result of groundwater dissolution, transport, and precipitation of that element from source areas (e. g., mudstones, hydrothermal vents, vein deposits and **volcanic ash layers)** into the sand and sandstone lenses (Fischer, 1950, p. 1; Denson, Zeller and Stephens, 1955; Keller, 1979, pp. 428-430; Fisher and Schmincke, 1984, p. 329; Pettijohn, Potter and Siever, 1987, p. 463). The Bone Valley Member consists of phosphorite gravels and sands mixed with variable percentages of quartz sand and clay (Scott, 1985, p. 34), which vary in thickness from less than a foot to over 50 feet (15 meters) (Johnson, 1977, p. 30). The unit is believed to have become radioactive due to the replacement of calcium within apatite, by uranium via ion exchange (Altschuler, Cathcart, and Young, 1994, p. 54; Cathcart, 1985, p. 24; McKelvey and Nelson, 1950, p. 49). The Bone Valley Member also contains an interesting mix of both marine and terrestrial vertebrate bones (Scott, 1986,342; Scott, 1990b, pp. 330-331) which are radioactive due to their containing uranium, thorium, and radium. All of these radioactive elements are suggested by the author as having been derived and transported, via groundwater, from volcaniclastics which originally composed various units within the Hawthorne Group (Figure 4). This explanation better fits evidence which suggests that certain layers within the Bone Valley Member and the surrounding Hawthorne Group are more radioactive than others, and is based on the volcanic origin and subsequent migration of some of the radioactive isotopes from the adjacent Hawthorne Group into the sands and fossils deposits of the Bone Valley Member.

The Young-Earth Flood Model

The young-earth Flood model suggests that the global stratigraphic column was constructed rapidly and only within a few thousand years (mainly during the Flood). Physical evidence supporting this interpretation exists in the form of hundreds to thousands of vertical feet of volcaniclastic deposits which have altered to form many of the shales and clays we see today. This concept is radically different from the millions of years of uplift and erosion proposed by uniformitarians. In many cases, evidence for the rapid development of various sections of the stratigraphic record can be documented by their elemental or mineral constituents (e.g., radioactive elements, trace elements, and heavy minerals) which were part of the original volcaniclastic deposit. Additionally, as previously cited, many of the radioactive shale and clay layers are found as laterally continuous units which extend over thousands of square miles (e.g., Swanson, 1960, p. 7; Levorsen, 1967, p. 529; Frazier and Schwimmer, 1987, p. 237), and this clearly fits within a description of a volcanic ash fall. Kauffman (1988, p. 628) has found a direct connection between individual volcanic ash beds (i.e., bentonites) and organic carbon enrichment intervals in sedimentary units of the Western Interior Basin of North American. All of this information supports the catastrophic formation, via volcanic sources, for these radioactive sedimentary units.

The I am suggesting that the radioactive Chattanooga and Hawthorn Group volcaniclastics were added to the stratigraphic section at different periods of time within the Flood Event Timeframe (see Froede, 1995). It is beyond the scope of this paper to explain when and how these two stratigraphic units were deposited. However, the differences between the two units can clearly be seen by their variation in composition and the different tectonic settings in which both are found.

These specific stratigraphic sections clearly warrant additional study within the framework of the young-earth Flood model.

Differences in radioactivity for the various shale and clay layers is proposed as reflecting the amount of flushing that the volcanic deposits have experienced. As previously stated the "older" shales contain higher levels of radioactivity and would suggest rapid and deep burial with little water circulation occurring within them during or following the Flood. Many of the "younger" shales and clays have undergone greater flushing and were probably reworked following their deposition. These processes exposed the volcaniclastics to greater opportunity for leaching silica and metals (i.e., radioactive and non-radioactive), both during and after the Flood.

The fact that both the Chattanooga Shale of Tennessee and various units within the Hawthorne Group of Florida contain what are viewed as economic grades and quantities of uranium, together with other radioactive elements, can best be explained using the evidence supplied by their radioactive composition. Whether or not the Uniformitarians view these deposits in this manner has no bearing on the time frames suggested by their model. The young-earth catastrophist must suggest valid and defendable mechanisms for the rapid development of the stratigraphic column within the time frames required. The successful use of a scintillometer and gamma-ray logs (Ettensohn, Fulton, and Kepferle, 1979; Glover, 1959), in defining the radioactive profiles of organic-rich shales, and the gamma-ray logs across the radioactive aluminum phosphate zones (Alschuler, Cathcart, and Young, 1994, pp. 52-53), suggests a means of determining where the altered volcaniclastics can be located both in outcrop and in the subsurface (see also McKelvey and Nelson, 1950, pp. 50-52; Frazier and Schwimmer, 1987, p. 297; Miall, 1990, p. 75). This information could then be used to map the various shale and clay layers, which are of volcanic origin, in an attempt to better understand the depositional environment as we construct it within the framework of the young-earth Flood model. Volcanic ash layers can serve as excellent stratigraphic markers in determining chronostratigraphic equivalence (Miall, 1990, p. 96; Kauffman, 1988, p. 618). The use of volcanic ash layers to "date" specific events within the young-earth Flood model, however, must be based on more than paleontology (Froede, 1994b).

Conclusions

The uniformitarian model uses millions of years and some aspect of tectonism (i.e., uplifted areas) to explain the source(s) of sediments and the associated facies found in the vertical stratigraphic section of the Southeastern United States. A volcanic origin for many of these sediments becomes a serious possibility as one seeks to account for the high levels and patterns of radioactivity in many of the region's shales and clays. The volcanic ash origin for radioactive clays and shales better fits the young-earth Flood model. It allows for catastrophic depositional events to explain the radioactive shale and clay deposits, as well as the rapid construction of the overall vertical stratigraphic sequence.

The uniformitarian model for radioactive shale or clay is based on either long term exposure of the pre-lithified clays and shales to radioactive elements in seawater or the occurrence of radioactive heavy minerals derived from igneous intrusive sources and no longer found within the clay. These models fail to provide a satisfactory explanation for the occurrence of high concentrations found in only certain marine clays and shales. Additionally, these radioactive source theories fail to defend the uniformitarian model for a specific type of facies to explain its development.

The author suggests that the alteration of a volcanic ash better explains the occurrence of radioactivity found in the marine clays and shales around the earth, as well as the Chattanooga Shale of Tennessee and various units within the Florida Hawthorne Group.

Additional studies should be undertaken in an attempt to determine the original chemical composition of the volcanic ash (e.g., rhyolitic, andesitic or basaltic). Trace element analysis (e.g., Hildreth, 1979) along with heavy mineral analyses (e.g., Weaver, 1963) might also provide the location of volcanic sources and lend overall support to a volcanic origin for these radioactive deposits.

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LETTERS TO THE EDITOR

A Reevaluation of Genesis 8:1-3

I find the discussion on the Flood in the Letters to the Editor of the March 1996 issue of the Quarterly to be very interesting. Two points of view on the timing of certain events are given with both sides having their reasons for holding their view. I am pleased that both sides agree that the Biblical record is the ultimate piece of evidence that must be satisfied. The physical record can sometimes be interpreted to favor both points of view. Froede (1996, p. 235) expressed this belief saying, "The young-earth creationist stratigraphic column must be reconstructed within the framework of the Biblical record."

Garner, et al. (1996, p. 233) state the problem, saying, "Oard's proposal is that essentially all dinosaur trackways and nesting sites were formed during the first 150 days of the Flood." Then they give their evidence that those sediments "should be assigned to the post-Flood era." I favor this later date on biblical grounds.

Let us review the first 150 days of the Flood.

The canopy, or whatever it was that held the water that fell to the earth for the Flood's first 40 days must have been equally distributed around the globe. If there had been no rain up to the Flood there must not have been any wind, only light breezes, during that time. Thus, when God "opened the windows of heaven," the rain must have fallen straight down everywhere around the globe. When the canopy was empty from day 40 onward, the sun caused evaporation. That water must have formed clouds, the first appearance of them, which eventually released the water as rain. Thus, the normal hydrological cycle that we know today was started. Winds probably started but not violent ones. The atmosphere must have been universally warm and the water that covered the earth was undoubtedly warm. Therefore, today's storm patterns did not materialize. These conditions continued until day 150 of the Flood, Genesis 7:24 "And the waters prevailed upon the earth a hundred and fifty days."

"Gabar," the Hebrew word translated prevailed, means to have strength, be strong, powerful, mighty and great. Those words indicate that the Flood was still building up in strength. The windows of heaven shut after 40 days but the fountains of the deep must have kept on pouring up water through day 150.

Then on day 151 God made several changes as are listed in Genesis 8:1-3.