Fossil Wood From Big Bend National Park, Texas (Dawson Creek Region) Part V—Origin and Diagenesis of Clays

Emmett L. Williams, Robert L. Goette, William G. Stark and George T. Matzko*

Abstract

Petrified and charcoalified woods were collected from the Dawson Creek region of Big Bend National Park. The results of the various tests conducted on the fossils were reported in Parts I–IV of this series along with a creationist interpretation of petrifaction and charcoalifaction. Samples of the clays, in which the fossil woods were located, were gathered with permission of the Park Service. Tests were performed on the clays to determine their origin and the nature of diagenetic processes acting upon them. The clays are believed to be of volcanic origin. The original volcanic ash was altered to form bentonitic clays. This alteration probably occurred in the late stages of the Flood or soon thereafter in a post-Flood temperate climate in Trans-Pecos Texas.

Introduction

Fossil wood was collected from the Dawson Creek region of Big Bend National Park, Texas (Figure 1) in order to study the material chemically and to examine the structure of the wood. The history of the field work as well as the geologic setting in which the fossils were located was discussed in Williams and Howe (1993). The mechanism of silicifaction, the possibility of rapid petrifaction, and an authochthonous vs. allochthonous origin for the fossils were presented (Williams, 1993a). The data obtained from chemical analysis of the charcoalified and petrified (silicified) wood specimens were reported and then explanations for these phenomena were presented in Part III of the series (Williams, Matzko, Howe, White and Stark, 1993). Throughout the papers, all chemical data and collecting site studies were interpreted within a young earth/Flood model. The fossil wood was examined by optical microscopy and scanning electron microscopy (Williams, Howe, Matzko, White and Stark, 1995). The lack of growth rings in the specimens was noted and explanations were suggested. Also the possibility of a post-Flood climate change was explored arid its effect on the silicifaction of the buried wood was examined.

The investigation of the clays in which the charcoalified and petrified wood is buried is discussed in this report. We could find no analyses of these clays in the literature, thus we conducted the various tests discussed in later sections to determine the type of clay and its properties. We suggest mechanisms for the origin of the clays to possibly determine the conditions under which the wood was preserved. A glossary of certain geological terms used in this paper is provided after the acknowledgments.

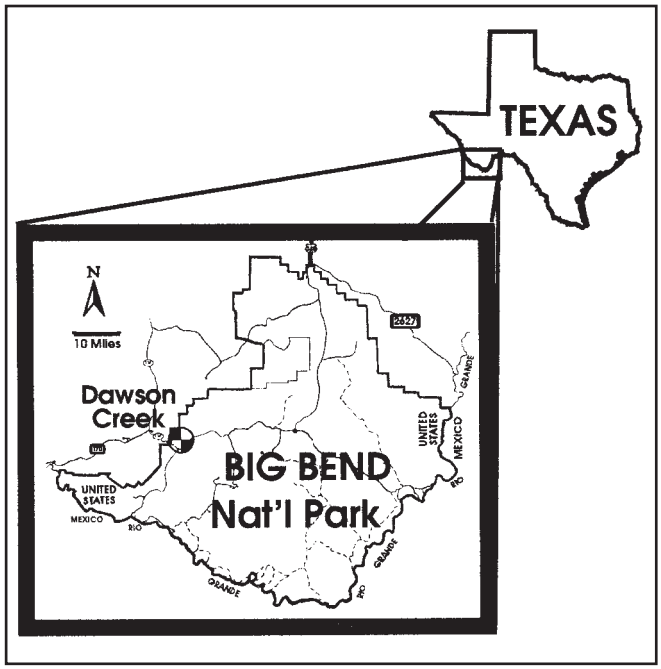

Figure 1. The location of the Dawson Creek region of Big Bend National Park, Texas where the field work in this report was conducted.

*Emmett L. Williams, Ph.D., 7312 Club Crest Drive, Flowery Branch, GA 30542-5590.
Robert L. Goette, Ph.D., 215 Karen Court, Niceville, FL 32578-2613.
William G. Stark, A. S., 942 Traymore Drive, Norcross, GA 30093.
George T. Matzko, Ph.D., 10 Berryhill Road, Greenville, SC 29615.
Received 9 October 1997; Revised 2 January 1998.

Table I. Clay Collection Sites.

Clay Mound Designation	Wood Type at Locale	Geologic Formation	Reference to Past Reports (See also Part IV of series)
M1 (Figure 3)	charcoalified wood (Figure 4)	Aguja	Part III (Figures 1 and 2)
M2 (Figure 5)	"dark stained" petrified wood (Figure 7)	Aguja	Part III (Figures 5 and 6) Specimen 19
M4 (Figure 8)	"light stained" petrified wood (Figure 9)	Javelina	Part III (Figures 11 and 12) Specimen 25

Field Work

Three specific sites in the Dawson Creek region of Big Bend National Park (Figure 2) were chosen from which to collect the clay samples. These locations yielded either charcoalified or petrified (silicified) wood. The type of fossil wood found at each location is given in Table I.

Samples of weathered and unweathered clay were gathered at clay mounds Ml, M2, and M4 (Figures 3, 5, and 8 respectively). Two of the mounds (Ml and M4) evidenced colored bands on their exterior surfaces. However, digging into the mounds revealed that all of the unweathered clay in a particular mound was uniformly the same color. The exterior colored bands originated from weathering. This situation is similar to what was experienced by McBride (1974), who attributed the color of certain rocks in northeast Mexico to weathering. Various minerals and organic material present in the rocks determined the color, but the pigmentation was enhanced by weathering processes. Appendix I has an extended quotation from the McBride article.

Materials and Methods

Clay Samples

Weathered samples were gathered from the exterior surface of a mound. Unweathered material was collected at depths of 6 to 12 inches below the weathered surface layer. A LaMotte model EP soil sampling tube was employed in removing the clay specimens.

Clay Color

Color determinations were done using Munsell soil color charts. The colors of the unweathered clay and petrified wood found within the mound are in Table II.

pH Measurements

pH measurements were performed according to ASTM specification D4972-89, Standard Test Method for pH of Soils. The tests were conducted using a HANNA H19219 microprocessor bench pH/°C meter.

Table II. Clay and Petrified Wood Coloration.

Clay Mound	Clay Color	Petrified Wood Coloration
Ml	10YR 5/2 (U)* (grayish brown)	None at location
M2	10YR 5/6 (U) (yellowish brown)	3/ (very dark gray) 4/ (dark gray) 10YR 5/2 (grayish brown) 10YR 3/1 (very dark gray)
M4	10YR 7/4 (W) (very pale brown)	10YR 8/2 (very pale brown) 10YR 8/3 (very pale brown) 2.5YR 8/2 (pale yellow)

*U–unweathered
W–weathered

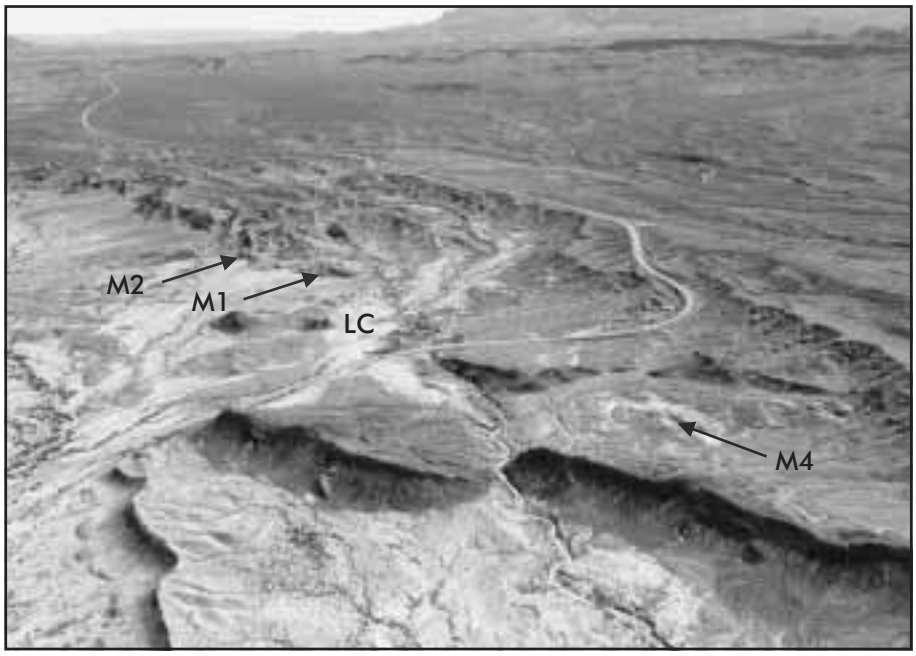

Figure 2 Aerial view of Dawson Creek study area, Park road winds eastward (top of photograph) toward Panther Junction and westward (lower left of photograph) toward Study Butte, Texas. Base of Chisos Mountains can be seen at the upper right of photograph. Dawson Creek, an intermittent stream "flows" from the left center to the lower right of the photograph. The stream bed is normally dry until the runoff from a local thundershower fills it. Clay mounds designated Ml, M2 and M4, LC–lone column. Photograph by Robert Goette.

Energy Dispersive X-Ray Analysis (EDX)

EDX measurements were conducted on as-received clay samples per Vaughan (1989).

X-Ray Diffraction of Clays

Where necessary, clay samples were pretreated with 30% H_2O_2 in order to remove any organic material. Each sample then was placed in a separate 500 ml beaker to which 20 ml of 10% sodium hexametaphosphate was added. After standing overnight, the sample was disaggregated in a soil stirrer for five minutes. The sample was then placed in a 1200 ml hydrometer and distilled water was added to bring the volume to 1000 ml. After agitation, the sample was allowed to stand for 20 hours. The upper 10 cm was poured off and the clay fraction flocculated by the addition of 10 ml of 10% $MgCl_2$. The magnesium-saturated samples were then concentrated by centrifuging, and slides were made from the resulting slurry. A quantity of 1:3 glycerine-water was added to a portion of the slurry. Slides were also made from the glycerine-treated slurry. Each slide was scanned in a Scintag PAD 2000 x-ray diffractometer equipped with a single crystal graphite monochrometer and copper Kα radiation. Identification of the clay mineral phases and their approximate quantitization was made employing procedures described in Brindley and Brown (1980) and Pierce and Siegel (1969)

Figure 3. Mound Ml as seen from the desert pavement. Dark bands, colored by organic material, in the mound developed by weathering processes. Photograph by Robert Goette.

Figure 4. Small piece of charcoalified wood typical of the fossil wood found in mound Ml. Photograph by Robert Goette.

Test Results

pH of Clays and EDX Spectra

The pH values of the clay samples vary between 3.17 and 8.30. When the clays with low pH values (acid) are compared to the EDX results from the same samples, low pH correlates with the abundance of sulfur in the clay (Figure 10). Likely the sulfur peak on the EDX spectrum indicates that sulfates are present in the clays with a low pH (3.17–4.66).[1] The clays with no detectible sulfur have a weakly basic pH (7.63–8.30) which may be caused by the presence of $CaCO_3$ in these samples. In examining the EDX spectra of weathered clays, it was noted that the sulfur peak was either weak or nonexistent. Possibly as the clay on the surface of the mound is exposed to the infrequent precipitation in the Big Bend region, the sulfates are dissolved in the rainwater and leached from the clays thus increasing the pH of the weathered material.

X-Ray Diffraction Analysis

Three clay mineral phases were observed in each of the samples (Table III). These included a smectite group mineral (montmorillonite), illite (clay mica) and kaolinite. Quartz was also present in each of the samples. The percentages of each component are semi-quantitative only and in-

[1] When collecting either fossil wood or unweathered clay samples during the heat of the day, if the acidic clay comes into contact with a person's hands, blisters can form on the hand because of the acid burn.

Figure 5. Mound M2 as seen from the desert pavement. Photograph by Robert Goette.

Figure 6. View of an 18-inch diameter petrified log within mound M2. Clay sample was collected next to the log about 12 inches into the mound. Photograph by Robert Goette.

dicate the relative abundance of each phase. A typical x-ray diffraction pattern of a clay is shown in Figure 11.

Sample M2 was collected adjacent to the petrified log in Figure 6. The high quartz content may be caused by thermal spalling of quartz particles (Figure 12) from the surface of the log due to weathering processes. Another possibility is that SiO_2 has an affinity for organic material (see Williams, 1993a, p. 107) and a large amount of silica precipitated around the wood as it was petrifying.

Table III. Mineral Phases in the Clay Samples.

Clay Sample	Percent Smectite	Percent Illite	Percent Kaolinite	Percent Quartz
Ml (U)*	59	1	1	39
M2 (U)	24	6	12	57
M4 (W)	65	1	3	31

*U–unweathered clay
W–weathered clay

Discussion of Results

The clay mounds we investigated are part of the badlands in the Dawson Creek region of the Park. Badlands usually consist of bentonite whose major component is montmorillonite (Mason and Berry, 1959, p. 447). Bentonite originates from altered volcanic ash and has the unusual property of expanding several times its original volume when placed in water (Klein and Hurlbut, 1985, p. 429). Thus when exposed to rainfall, the surface clay particles expand considerably so that none of the water penetrates into the interior of the clay. With no moisture available below the surface, plants are unable to grow successfully in the clay. Thus the term, badlands, is used to describe the barren region.

There has been considerable volcanic activity in the Big Bend region (Williams and Howe, 1993, p. 50; Williams, 1993b; Froede, 1995a, c; Froede, 1996; Henry, et al., 1988; Price and Henry, 1988; Henry and Price, 1989; Henry, Price, Parker and Wolff, 1989; Henry, Price, Duex and James, 1992; Henry and Muehlberger, 1996) which evidently generated many regional ash falls.

Next we address the question of whether the volcanic ash, from which the smectite developed, was deposited subaerially or subaqueously. Consider the following remarks on this subject by Chamley (1989, p. 411):

> The term bentonite originally refers to smectite-rich beds mostly derived from tephra deposits. Bentonites usually correspond to subaqueous, mainly marine, smectite horizons,...

Figure 7. Typical "dark stained" petrified wood found in clay mound M2. Some surfaces of this wood were likely charred before petrifaction. Six-inch scale is shown. Photograph by Robert Goette.

Figure 9. Typical "light stained" petrified wood found in mound M4. Photograph by Robert Goette.

Pollastro and Bohor (1993, p. 22) noted that "Smectite...commonly forms from the alteration of glass in saline or brackish environments (e.g., bentonites)." However Weaver (1989, pp. 153-154) explained that

> Montmorillomite can form by the alteration (transformation) of volcanic glass, feldspars, micas, various FeMg silicates and silication of detrital physils... Commonly it is difficult to determine if the montmorillonite is detrital or if it altered in place from transported volcanic material. If it is detrital, as in the Mississippi Delta, then the problem is to determine if it formed under continental conditions, soil and lacustrine, or was derived from older rocks Even for the recent Mississippi Delta deposits it is difficult to determine the

Christidis, Scott and Marcopoulos (1995, p. 63) listed three possible processes for the transformation of volcanic, mainly glass rocks, to bentonite:

> ...a) *in situ* alteration of volcanic glass in aqueous environment b) hydrothermal alteration of igneous rocks and c) deuteric alteration of igneous material involving reactions of vapours and gases with igneous mass.

They further commented that many well-known bentonite formations, such as at Sucker Creek, Oregon, Clay Spur bed in Wyoming and Montana and the English fuller's earth deposits, formed "by means of *in situ* alteration of airborne and water transported volcanic ash in relatively shallow lacustrine and sea water respectively (p. 63). Chamley (1989, p. 174) claimed that "Volcanic rocks weather preferentially into smectite, regardless of climatic conditions if there is sufficient water to allow hydrolytic process."

Figure 8. Clay mound M4 as seen from the desert pavement. This mound consists mainly of claystone. Photograph by Robert Goette.

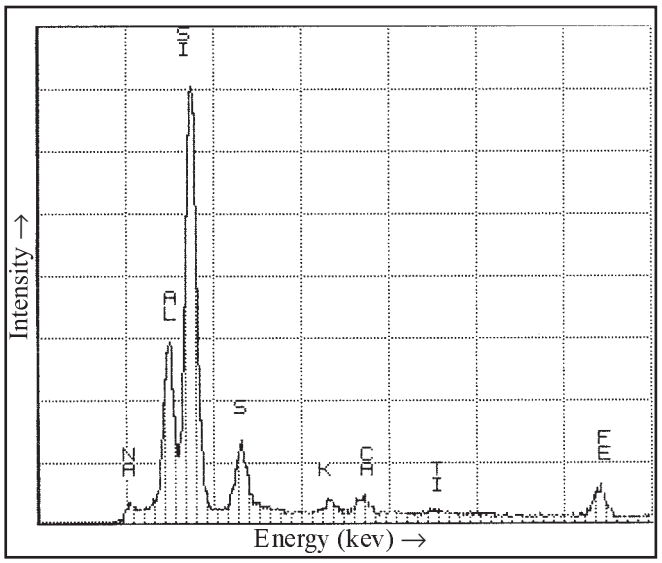

Figure 10. EDX spectrum of unweathered clay sample from mound M2. Note the presence of sulfur peak. Sample has a pH of 3.42.

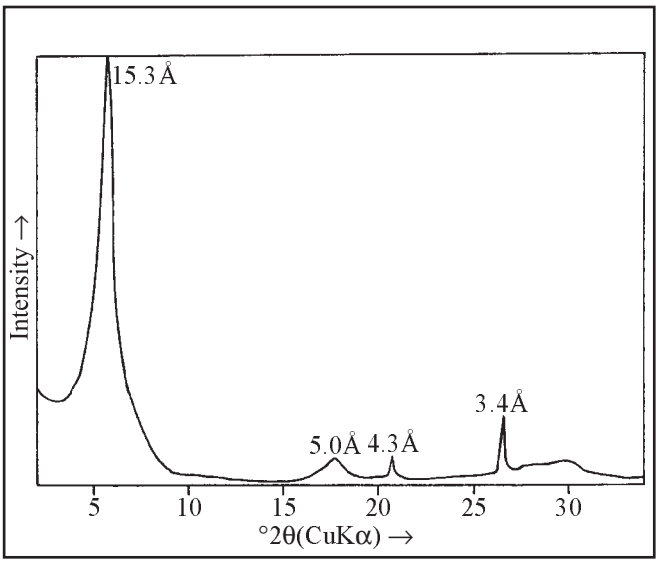

Figure 11. X-ray diffraction pattern of Mg-saturated sample from mound M4: diffraction of x-rays follow the Bragg equation $n\lambda = 2d \sin\theta$ where n = 1, 2, 3, etc., λ = wavelength of incident radiation , d = crystal lattice spacing and θ = diffraction angle.

original source of the montmorillonite. Presumably the ultimate source was primarily volcanic debris created by the extensive Cretaceous to recent volcanic activity in the western United States. This volcanic material was altered to montmorillonite under both continental and marine conditions and tens of millions of years later transported to the delta.

Also Weaver (1989, p. 378), in discussing the large quantity of fresh glass in marine sediments, noted that the volcanic glasses that have been altered to smectite "...are more likely to be from submarine explosions." He suggested that "It now appears that these ash beds, particularly the more acid types, were probably buried to a considerable depth" (p. 378).

Obviously there are many possibilities for the formation of smectite from volcanic ash. To compound the problem, there has been considerable erosion in the Dawson Creek region which has washed away much of the volcanic material that was deposited there in the past. As for the origin of the clays, we suggest the following:

1. The clay in mound M2 was once a deposit of volcanic ash that was transported from a subaqueous eruption in the Cretaceous seaway (actually retreating Floodwater) [see Williams and Howe, 1993, pp. 50-52; Froede, 1995b] to Dawson Creek and the surrounding region. Waterlogged trees, logs and limbs were buried in this deposit and rapidly petrified. The continual retreat of Floodwater from the North American continent eroded the majority of this altered ash.

2. Later a subaerial eruption in the last stages of the Flood (the final retreat of Floodwater) deposited large quantities of hot volcanic ash over beached and waterlogged trees and other woody material that had not been petrified, baking the wood and converting it to fossil charcoal. This ash weathered to form the clay in mound Ml. Severe erosion continued during this period as considerable rainfall provided ample flowing water to remove much of the newly-deposited sediments.

3. Following the withdrawal of Floodwater, the volcanic ash in mound M4 from another subaerial eruption was deposited and altered to smectite in a shallow lacustrine envi-

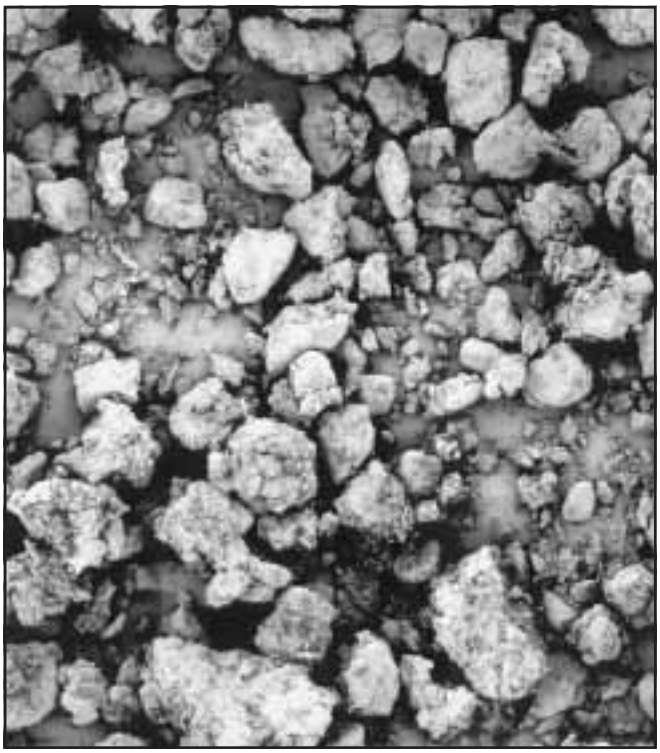

Figure 12 Scanning electron micrograph of unweathered sample from mound M2. The sharp-cornered particles are quartz shards. Micrograph by William Stark. Magnification 40X.

ronment during the temperate post-Flood era (Williams, Howe, Matzko, White and Stark, 1995, pp. 228-229) in Trans-Pecos Texas. The ash would have covered much of the post-Flood vegetation growing in the Dawson Creek region as well as pre-Flood wood that was deposited in the lake. The Big Bend country likely contained several lakes during this time (Williams and Howe, 1996, pp. 92-94) and both pre- and post-Flood wood would have been petrified under the altered ash.

Erosion along Dawson Creek continues into the present time exposing considerable petrified and charcoalified wood. Thundershower activity activates most of the erosion processes now experienced in the area we investigated.

The sequence of events for the postulated formation of clays is thought to have occurred quickly within a limited time period of possibly several decades. (See Appendix II) The authors realize that the actual conditions that developed in Trans-Peoos Texas late in the Flood and immediately afterward are much more complex than the simple model of clay formation and preservation of fossil wood proposed in this paper. These conjectures are considered a first step in describing the events that may have occurred in one of the most fascinating National Parks in the United States. More field work must be conducted to refine or reject these suggestions.

Acknowledgments

The authors thank the many donors to the Creation Research Society Research Fund, interest from which financed a portion of these studies. Appreciation is expressed to personnel of Big Bend National Park for allowing us to collect the clay samples. The opinions expressed in this paper remain solely those of the authors. We are grateful to Carl R. Froede, Jr. for his help and interest in this project.

Glossary

Claystone: an indurated clay having the same minerology and composition of shale but lacking its fabric.

Deuteric: refers to reactions between primary magmatic minerals and water solutions that separate from the same body of magma at a late stage in its cooling history.

Kaolinite: a common clay mineral of the kaolin group: $Al_2Si_2O_5(OH)_4$.

Montmorillonite: a dioctahedral clay mineral of the smectite group: $Na_{0.33}Al_{1.67}Mg_{0.33}Si_4O_{10}(OH)_2{\cdot}nH_2O$.

Physil: an abbreviation form of phyllosilicate proposed to apply to all sheet silicate minerals regardless of grain size.

Smectite: a group of expanding-lattice clay minerals of general formula $R_{0.33}Al_2Si_4O_{10}(OH)_2{\cdot}nH_2O$ where R includes one or more of cations Na^+, K^+, Mg^{+2}, Ca^{+2} and possibly others. The smectite minerals are the chief constituents of bentonite and fuller's earth.

Tephra: volcanic ejecta.

Appendix I

Quotation from McBride, 1974. [p. 760]

Varicolored rocks of the Difunta Group...are composed of detritus derived from a relatively uniform terrane of volcanic rocks and deposited in fluvial, deltaic, and shelf environments. Red, green and purple rocks are restricted to delta-plain facies, whereas the dark colors are present in all facies.

The color of claystone is a function of color mixing of red hematite, green illite and chlorite, and black organic matter; and possibly of grain size of hematite (purple color). Red and purple rocks owe their color to pervasive hematite grain coatings and crystals intergrown with clay; brown rocks owe their color to faint or localized iron-oxide grain coatings; and gray rocks to organic matter and authigenic iron sulfides. Green rocks owe their color to chlorite and illite and to the absence of hematite, organic matter and sulfides. Olive and yellow claystone colors are imparted by color mixing of green clay and black organic matter.

Field relations and petrographic studies indicate that red and purple colors originated through postdepositional reddening of sediment, in part in soil zones on the delta plain, in a sub-humid to semi-arid climate that had seasonal wet and dry periods. Reddening occurred both by aging of hydrous ferric oxide plus staining of grains by hematite pigment formed by oxidation of detrital iron oxide and mafic grains. Some brown siltstone beds were pigmented in a manner similar to red beds, but other siltstone beds developed brown color upon weathering. Green beds formed by bleaching of red (or proto-red) beds by interstitial percolation of reducing water derived largely from fluvial channels overlying the green beds. Olive and gray claystone are predominate in marine facies that contain abundant organic matter and in some delta-plain facies where destruction of organic matter was incomplete.

Appendix II

Rapid Weathering and Hydrolysis of Volcanic Ash

We postulate that the weathering of volcanic ash into clay occurred quickly in the Dawson Creek region of Big Bend National Park. We believe that the original ash was ejected from explosive volcanic eruptions during the waning phase of the Flood or soon thereafter. Thus there was ample water and atmospheric moisture available for hydrolytic processes to operate on the ash.

Weathering progresses faster on volcanic material than on other types of rocks (Chamley, 1989, p. 38). The particle size of ash ejected from volcanic explosions is generally quite small and this increased surface area per unit volume would encourage rapid hydrolysis. Since volcanic ash weathers preferentially into smectite if there is sufficient water to allow hydrolytic processes (Chamley, 1989, p. 174), the availability of water and the fine particle size of the ash would result in rapid alteration. It has been observed that well-crystallized smectite forms on volcanic material as soon

as weathering commences in temperate warm and subarid climates (Chamley, 1989, p. 39). The Big Bend region likely had a warm, and temperate climate soon after the Flood.

Time itself may not be a factor in the alteration of volcanic ash. For instance, glass shards from volcanic activity found in a Mesozoic sediment often were unaltered whereas much of a similar volcanic debris in Quaternary deposits was transformed into smectite (Chamley, 1989, p. 352). We do not accept the uniformitarian time table, but if time is the sole factor in the alteration of volcanic material into clay, then the (older) Mesozoic shards should be in an advanced state of alteration compared to the (younger) Quaternary debris which is not the case.

References

CRSQ—Creation Research Society Quarterly

Brindley, G. W. and G. Brown. 1980. *Crystal structures of clay minerals and their x-ray identification*. Mineralogical Society Monograph No. 5. London.

Chamley, H. 1989. *Clay sedimentology*. Springer-Verlag. New York.

Christidis, G. E., P. W. Scott and T. Marcopoulos. 1995. Origin of the benonite deposits of eastern Milos, Aegean, Greece: Geological, mineralogical and geochemical evidence. *Clays and Clay Minerals* 43:63-77.

Froede, Jr., Carl R. 1995a. Surficial replacement of dinosaur bone by opal in Big Bend National Park, Brewster County, Texas. *CRSQ* 32:11.

———. 1995b. Late Cretaceous epeiric sea or retreating Floodwater? *CRSQ* 32:13-16.

———. 1995c. Thunder eggs: Evidence for subaqueous deposition? (Big Bend National Park, Texas). *CRSQ* 32:101-104.

———. 1996. Evidences of catastrophic subaqueous processes at Goat Mountain in Big Bend National Park, Texas, U.S.A. *CRSQ* 33:115-126.

Henry, C. D., J. G. Price, J. N. Rubin, D. F. Parker, J. A. Wolff, S. Self , R. Franklin and D. S. Barker. 1988. Widespread, lavalike silicic volcanic rocks of Trans-Pecos Texas. *Geology* 16:509-512.

Henry, C. D. and J. G. Price. 1989. The Christmas Mountains caldera complex, Trans-Pecos Texas: Geology and development of a laccocaldera. *Bulletin of Volcanology* 52:97-112.

Henry, C. D., J. G. Price, D. F. Parker and J. A. Wolff. 1989. Mid-Tertiary silicic alkalic magmatism of Trans-Pecos Texas: Rheomorphic tuffs and extensive silicic lavas in Chapin, C. E., and J. Zidek (editors). *Field excursions to volcanic terranes in western United States*. Volume 3: Southern Rocky Mountains. New Mexico Bureau of Mines and Mineral Resources Memoir 46. Socorro. pp. 231-274.

Henry, C. D., J. G. Price, T. W. Duex and E. W. James. 1992. *Geology of the Infiernito Caldera and magmatic evolution of the Chinati Mountains, Trans-Pecos Texas*. Report of Investigations No. 206. Bureau of Economic Geology. The University of Texas at Austin.

Henry, C. D., and W. R. Muehlberger (editors). 1996. *Geology of the Solitario Dome, Trans-Pecos Texas: Paleozoic, Mesozoic and Cenozoic sedimentation, tectonism and magmatism*. Report of Investigations No. 240. Bureau of Economic Geology. The University of Texas at Austin.

Klein, C. and C. S. Hulbut, Jr. 1985. *Manual of mineralogy* (after James D. Dana). Twentieth edition. John Wiley. New York.

Mason, B. H. and L. G. Berry. 1959. *Elements of Mineralogy*. W. II. Freeman. San Francisco.

McBride, E. F. 1974. Significance of color in red, green, purple, olive, brown and gray beds of Difunta group, northeastern Mexico. *Journal of Sedimentary Petrology* 44:760-773.

Pierce, J. W. and F. R. Siegel. 1969. Quantification in clay mineral studies of sediments and sedimentary rocks. *Journal of Sedimentary Petrology* 39:187-193.

Pollastro, R. N., and B. F. Bohor. 1993. Origin and clay-mineral genesis of the Cretaceous/Tertiary boundary unit, western interior of North America. *Clays and Clay Minerals* 41:7-25.

Price, J. G. and C. D. Henry. 1988. Dikes in Big Bend National Park; petrologic and tectonic significance. *Geological Society of America Centennial Field Guide: South Central Section*. Boulder, CO. pp. 435-440.

Vaughan, D. (editor). 1989. *Energy-dispersive x-ray analysis: An introduction*. Kevex Instruments. San Carlos, CA.

Weaver, C. E. 1989. *Clays, muds and shales*. Developments in sedimentology 44. Elsevier. New York.

Williams, E. L. 1993a. Fossil wood from Big Bend National Park, Brewster County Texas: Part II—Mechanism of silicification of wood and other pertinent factors. *CRSQ* 30:106-111.

———.1993b. Cerro Castellan. *CRSQ* 30:119.

Williams, E. L., and G. F. Howe, 1993. Fossil wood of Big Bend National Park, Brewster County, Texas: Part I—Geologic setting. *CRSQ* 30:47-54.

———. 1996. The formation of Santa Elena Canyon, Big Bend National Park: Origin speculations. *CRSQ* 33:89-96.

Williams, E. L., G. T. Matzko, G. F. Howe, R. R. White and W. G. Stark. 1993. Fossil wood of Big Bend National Park, Brewster County, Texas: Part III—Chemical tests performed on wood. *CRSQ* 30:169-176.

Williams, E. L., G. F. Howe, G. T. Matzko, R. R. White and W. G. Stark. 1995. Fossil wood of Big Bend National Park, Brewster County, Texas: Part IV—Wood structure, nodules, paleosols and climate. *CRSQ* 31:225-232.