Vanderbilt Master of Liberal Arts and Science (MLAS)

Capstone Course

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"Camels, Pandas and Saber-Toothed Cats in Tennessee: Fossil Discoveries Weave a Tale"

http://www.tennesseefossilscentral.com/index.html

by

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> **An evolutionary perspective of our place in the history of the earth reminds us that *Homo sapiens sapiens* has occupied the planet for the tiniest fraction of that planet's four and a half thousand million years of existence. In many ways we are a biological accident, the product of countless propitious circumstances. As we peer back through the fossil record, through layer upon layer of long-extinct species, many of which thrived far longer than the human species is ever likely to do, we are reminded of our mortality as a species. There is no law that declares the human animal to be different, as seen in this broad biological perspective, from any other animal. There is no law that declares the human species to be immortal (Leakey and Lewin 1946).**

Picture the Tennessee landscape 4.5 to 7 million years ago (mya), when recognized geographical areas did not exist, humans had yet to make an appearance in the evolutionary chain, and prehistoric species roamed the earth. In the northeast corner of the state in a locale now known as Washington County, a moderately dense forest area provided protection to animal (faunal) and plant (floral) populations (DeSantis and Wallace 2008). The forest surrounded a massive sinkhole, and the resultant lake hosted thirsty creatures (Wallace Interview 2010). Animals stepped out of the tree cover and approached the water's edge at different points. Tapirs, ground sloths, rhinos, weasels, shrews, peccaries, gomphotheres, short faced bears, saber toothed cats, camels, red pandas, badgers, and horses shared the watering hole (Wallace and Wang, 2004). Smaller mammals scanned the space and chose their timing carefully, wary of predators. Salamanders, alligators, snakes, turtles, fish, frogs, birds and beavers added to the animal population at the site (Wallace and Wang 2004). Over the course of thousands of years, the natural cycle of death provided numerous carcasses that scattered around the pond (Wallace Interview 2010). Organic materials and silted clay covered the bones and plants, preventing decay from oxygen and sunlight, and time passed in a geological scale of epochs and periods that modern humans cannot easily fathom. Natural geological events and the nature of folding sinkholes contributed to animal skeletons and plant materials receiving protection from the elements

(Wallace Interview 2010). The unusual combination of mammals sharing the forest and ultimately, the burial ground, would surface millions of years later and create a stir of excitement in the eastern part of the state.

Unearthing these fossils beginning in 2000 at ETSU's fossil site in Gray, Tennessee produced amazing discoveries in the first decade. Researchers determined that the Gray, TN fossil collection ranged in age from 4.5 to 7 mya based on a Teleoceras (pot bellied rhino) that walked the earth between 4.5 million and 17 mya, and the Plionarctos (short faced bear) that existed between 2 million and 7 mya (Wallace and Wang, 2004). The importance of these fossils includes the sheer size of the site, the existence of a vast array of plants and animals in one location constituting an ecosystem, and the fact that Gray represents by far the largest collection of Miocene-era fossils ever found outside of the Gulf Coast or the Far West. The site extends to approximately 5 acres with a depth of 100 feet. Within the Neogene period reside the epochs of Miocene (24 to 5 mya) and Pliocene (5 to 2 mya) (Figure 1). These epochs can best be understood when framed between the disappearance of the dinosaurs (65 mya) and the arrival of humans on the North American Continent (approximately 13,000 years ago) (Figure 1). Each epoch has unique characteristics for climate and geography. The plants and animals changed from epoch to epoch (Figure 1). Researchers can reconstruct the ancient paleoenvironment from processed data to increase knowledge of the Cenozoic era (DeSantis and Wallace 2008). Geologists and Paleontologists know about the variety of faunal and floral species and topography of Tennessee during particular time periods in part due to fossil research. Based on a flurry of scholarly papers written in the first decade of the Gray site excavation, it seems obvious that important discoveries and knowledge will continue from the work being done.

Furthermore, discovery of two new species of vertebrae animals including a new genus and species of the red (lesser) panda, *Pristinailurus bristoli*, and a new species of the Eurasian badger, *Arctomeles dimolodontus* revealed information on migration patterns between Asia and North America (Wallace and Wang 2004). These new carnivores provided a "mammalian example of having the Asian component in North America" (Wallace Interview 2010). The panda and badger pointed to the existence of hypocarnivores, animals in the carnivore taxa (classification group) that obtain only 30% of their diet from the flesh of other animals. Examination of the plant and animal connection, migration patterns over a land bridge between continents, and the climate shift and impact on feeding patterns aid in understanding the significance of these finds.

For instance, researchers previously understood the connection between plants in eastern North America and eastern Asia. D.E. Boufford and S.A. Spongberg described in *Eastern Asian - Eastern North American Phytogeographical Relationships - A History from the time of Linnaeus to the Twentieth Century*, how Carl Linnaeus first pointed out this floral connection in 1750. Many scientists noticed similarities between the forests near the Appalachians in East Tennessee and the forests in Japan and China. Mixed deciduous common qualities include a temperate and humid biome with an uppermost canopy layer consisting of mature trees, a shorter layer of shade tolerant varieties, smaller mature trees and saplings, and a bottom layer of low growing woody plants such as herbaceous varieties that forest browser type animals could eat. New Chinese plants turned up at the Gray dig site. Plants, animals and humans migrated back and forth between Asia and North America over the Bering Land Bridge (The Last Giant of Beringia 2004). Current thinking about the land bridge points to predominantly dry land over the past two million years,

rather than water coverage. The present interglacial period (11,400 years ago to present) produced a sea over the area that connects the Pacific and Arctic Oceans, resulting in certain life forms transitioning between ocean basins. During periods of dry land over the past 70 million years, animals such as mastodon and gomphothere came to North America from Africa and Eurasia (15 mya). Deer arrived in North America 25 mya. Horses and camels traveled from North America to Eurasia which allowed for their survival once they became extinct in North America at the end of the last ice age. Humans migrated over the land bridge approximately 13,000 years ago. In the future, scientists expect that as sea level lowers due to an increase in glaciers over the continents, the land bridge will become exposed again. Research continues into possible impacts of global warming on this natural occurrence. The panda and badger discovered in Gray, Tennessee indicate by age that migration of mammals between North American and Eurasia occurred earlier than once thought (Wallace and Wang 2004). These findings add to the knowledge base regarding historical climate and migration patterns.

Additionally, the Gray site produced in the first decade the largest tapir collection to date, confirming an arboreal environment (Wallace and Wang 2004). Scientists know that tapirs live in forested areas. Researchers learned that the heavily wooded area stretched out to substantial dimensions and maintained an abundant population of animals (DeSantis and Wallace 2008). The age of the Gray collection indicates a time period concurrent with when grasses became abundant on the planet, and this is consistent with the pure C4 consuming gomphothere (DeSantis and Wallace 2008). As the climate cooled during the late Miocene, grass became available, explaining why grazing animals increased elsewhere. This development also supported the theory that the forest and sinkhole area at Gray

offered protection to the animals from the ice age colder temperatures due to its closed, isolated setting and density. According to Steven Wallace, the Teleoceras (rhino) is "considered to be a grazer based on the shape of its teeth, but prior isotopic analysis indicates some taxa as mixed feeders" (Wallace and Wang 2004; MacFadden 1998). Mixed feeders eat a combination of grass and forest type plants. Carbon isotope data from fossil tooth of tapir, rhino, camel, and peccary points to "forest dwelling browsers" that ate plants, further supporting the forest refugium supposition (DeSantis and Wallace 2008).

As an illustration of how researchers take a fossil find and determine age, taxa (group classification) and diet, several scientific processes may be utilized. Tooth morphology, studying the size and shape of teeth, provides a means for interpretation. A carnivore akin to a lion utilizes sharp, slicing teeth to eat and survive. A cow grinds vegetation with blunt, flat teeth. Herbivores eat only plants. Measurement of tooth height and length followed by division of tooth height by tooth length supplies a hypsodonty index (HI) ratio. Graphing HI as the dependent variable against an independent variable (age of the fossil) allows an evaluation using a null hypothesis (DeSantis 2009). Dental microwear analysis of microscopic marks on fossil teeth such as scratches and pits points to a diet of grasses (C4 plants) and leafy browse (C3 plants) (MacFadden, Solounias and Cerling 1999). This type of analysis can shed light on environmental changes such as the appearance of grasses during the Neogene when climate cooled and the impact on animal populations. Additional data obtained from serial samples of rhino, tapir, and peccary teeth and gomphothere tusk revealed information concerning seasonal changes in monthly temperatures and precipitation (DeSantis and Wallace 2008). Carbon and oxygen isotopes indicated minimal variation in monthly temperatures and/or precipitation in East

Tennessee throughout the Neogene (DeSantis and Wallace 2008). Likely less seasonal conditions existed during a portion of the Neogene. Furthermore, the closed wooded area provided cover for animals, allowing them to exist in forest refugia during the time period of Miocene grassland.

Similarly, fossil age and taxa (group designation), result from scientific evaluation. Stratigraphy, the study of rock layers, builds on two basic principles used by geologists to determine the sequences of ages of rocks (containing fossils). The principle of superposition involves younger sedimentary rocks deposited on top of older sedimentary rocks. Cross-cutting relations pertain to any geologic feature being younger than anything else it cuts across. Biostratigraphy involves assigning sedimentary rocks to a known geological period via describing, cataloguing and comparing fossil floral and faunal assemblages. Radiometric age dating revolves around elements containing isotopes with unstable atomic nuclei that tend to change or decay. U-235, an unstable isotope of uranium (parent) undergoes a change in the number of its protons and neurons in the nucleus of each atom, and then becomes a stable daughter isotope. Often rocks contain small amounts of unstable isotopes and the daughter isotopes into which they decay. If these isotopes can be measured accurately, the ratio can be used to determine the age of the rock. Carbon-14 dating on fossils no older than 70,000 years uses the naturally occurring radioisotope. Another assessment method for paleontologists utilizes Phylogenesis (modern Taxonomy) where family trees of particular groups of plants or animals show how species relate to each other. Morphology indicates a study of animal form, specifically bone anatomy/function, muscle reconstruction, and superficial structures such as trunks or horns. All of these testing methods may be utilized by scientists to assign fossil age and group classification.

Consequently, the Gray location provides a current model for relevant data and examination regarding how benefits to the human race outweigh the costs of site protection, excavation, and fossil research. Since 2000, funding for this dig site derived from a combination of the state gasoline tax, a dedicated fund for TDOT, and state and federal grants including a matched grant where ETSU provided money. When the first fossil discovery occurred in 2000, a TDOT road project unearthed fossils in black, rich soil of a type not previously seen in that East Tennessee area. Governor Don Sundquist visited the site to receive a status on the findings. The State Archaeologist, Nick Fielder, officially stopped the road project, in conjunction with the governor, and the road ultimately became rerouted around the fossil area. TDOT performed drill testing to project the perimeters of the black soil area believed to indicate a sink hole formation now containing fossil remains. Randy Bussler with TDOT pulled the financial records and advised that the cost to reroute the project amounted to $129,266. Bussler stated this cost came from the state gasoline tax, a dedicated TDOT fund that receives funding from taxpayers. He explained further that the federal government also receives a portion of the gasoline tax, and the state receives some funds back from the federal government. All road projects in Tennessee come from the gasoline tax fund. This expenditure by TDOT ended their involvement in funding at the site.

ETSU received a $324,000 grant from the National Science Foundation in 2010 to support excavation and research for three years. An $8 million Federal Highway Administration Grant awarded to ETSU in 2002 had to be matched by ETSU with an additional $2 million, for a total of $10 million. The construction of the General Shale Brick and Natural History Museum and Visitor's Center came from this grant. Additional

grants are pending. ETSU organizes an extensive volunteer program related to the dig site. The national publicity attracted free labor by scholars, students and average citizens that wanted to become involved. This important factor must be taken into consideration when reviewing operation costs of the Gray, Tennessee dig site.

Moreover, taxpayers demand and expect an accounting of the allocation and disbursement of citizen financial contributions to and management by government. One of the first financial decisions impacting Tennessee fossils occurred around 1845 when the state legislature passed a tax exemption bill, excluding the display of fossils from all state taxes (Corgan and Breitburg 1996). The new bill evolved as a result of a well digger uncovering a mastodon skeleton in Williamson County that was assembled creatively to resemble a giant human. The mastodon appeared in exhibits dubbed "the giant fossil man", and also "the Tennessean" (Corgan and Breitburg 1996). Scientists exposed the fraud, and the exhibit soon lost its appeal to the public.

Other significant fossil finds in Tennessee did not involve major funding. In the 1940s, a vertebrate paleontologist at the University of Tennessee recovered, identified, and labeled five bones belonging to a hadrosaur (duck billed dinosaur) from the Cretaceous Period, excavated in the western part of the state (McClung site). Roy Young, Curator at the Memphis Pink Palace Museum discussed a museum owned site called Coon Creek near Adamsville, TN where 71.5 million year old fossils turned up from the Cretaceous Period (Interview 2010). These fossils include invertebrates, fossil clams, shells and a mosasaur (large marine reptile). Young also participated in a July 2010 excavation of an alleged gomphothere from the back yard of a Brighton, Tennessee home (Interview 2010). The identification came after tusk examination, and casts sent to other experts should provide

additional information on the find (Young Interview 2010). Calling the excavation a salvage operation, Young stated the museum funded the removal, cleaning, casts and exhibit. The Pink Palace Museum in Memphis currently exhibits those fossils. In reviewing the nature of past Tennessee fossil finds on a smaller scale, the scope of the Gray project and what lies ahead for researchers becomes even more relevant.

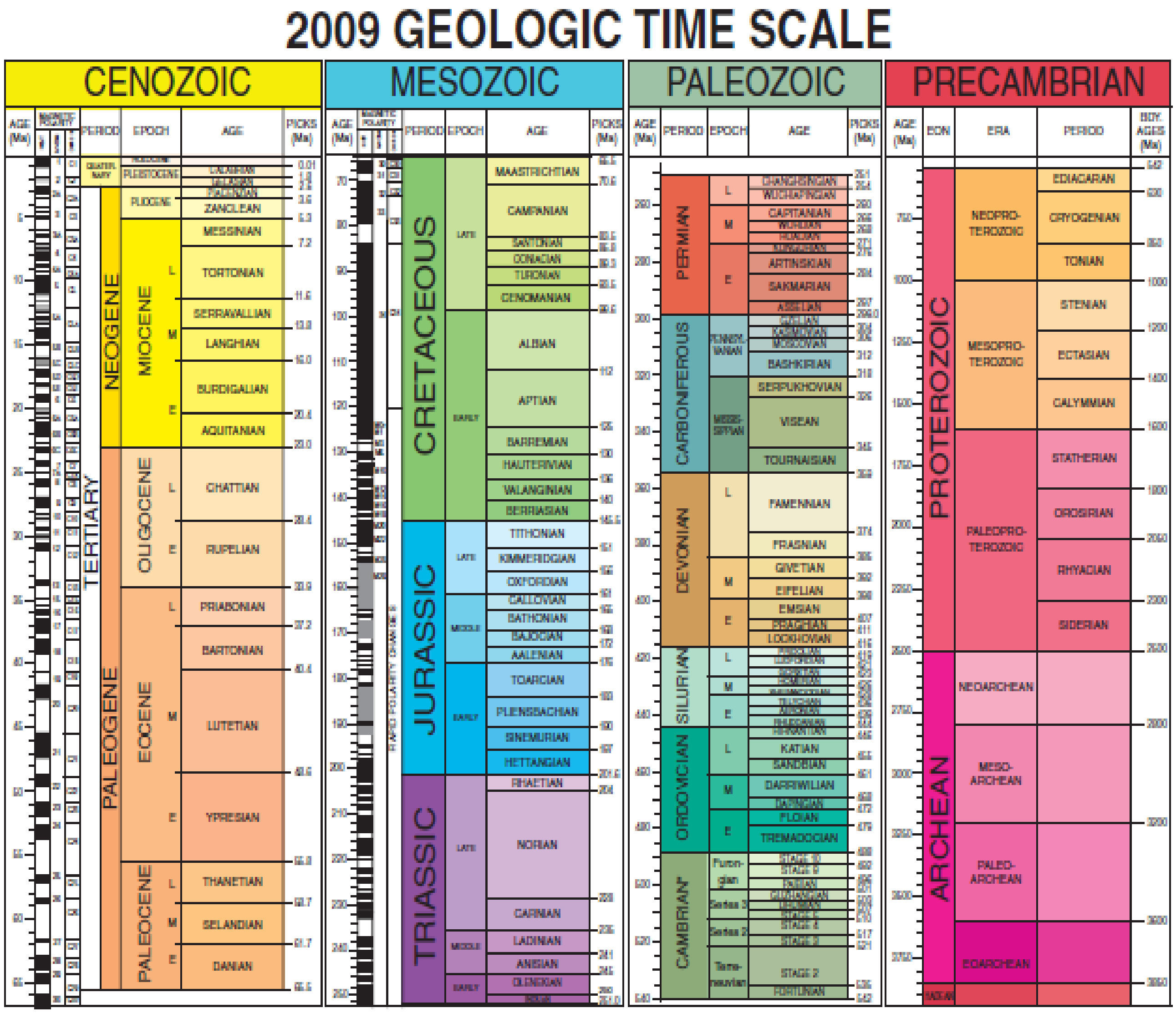
In essence, the question might be asked why fossil site protection, excavation, and research should continue in the face of so many previous discoveries and analysis of the history of the earth. People grapple with starvation, the world economy fluctuates, and competition for funding and resources remains fierce, hotly debated, and often deeply emotional. Programs such as the NASA Space Program receive an enormous amount of federal funding. Highlights of NASA's FY 2011 budget contained the following information: "Top line increase of $6.0 billion over 5-years (FY 2011-15) compared to the FY 2010 Budget, for a total of $100 billion over five years" (www.nasa.gov). In an attempt to cut down on research funding, who would decide which research continues to be funded? What special interest groups would become involved in pushing a decision for their science and research areas?

Likewise, citizens could insist that government reign in financial expenditures, focus on current societal needs, and discontinue research funding, but what about the prospects of future inhabitants on the planet? If present occupants do not take action to understand how our past can provide education on the present and future, then important natural resources may not be saved for future generations. This could be the most important challenge of the human race. What is learned through fossil research adds to the knowledge base on planet earth and ultimately becomes quite significant to future survival.

As humans continue to build on and excavate the Tennessee landscape, additional fossils will turn up. The question of whether or not our state should continue to protect fossil sites and/or support research seems less relevant when we consider that the major source of funding for ETSU's Gray dig site consists of federal grants.

In conclusion, the Gray, Tennessee dig site needs continued research because the location could take 100 years for complete excavation, with only 2% excavated in the first decade and 2010. The education from fossil research on the environment, past ecosystems, evolution, and how it all changed over millions of years remains priceless. Fossil records provide a fundamental understanding of evolution and document the order of appearance of groups, including Homo sapiens sapiens (anatomically modern human beings) and the disappearance of amazing plants and animals. Scientists can continue to learn how plants and species reacted to environmental changes, particularly during times of dramatic global shifts and mass annihilations, and this will contribute to further understanding on how to prevent future extinctions. The exhilaration about discoveries over the first ten years in a project with the potential to stretch out for decades and produce immense new knowledge about the earth's past and the implications for posterity, signaled a social commitment in the State of Tennessee and on a national level. Scholarly involvement and publications remains impressive. Our successors will benefit from the research. Fossil sites belong to everyone as part of national heritage and deserve protection for future generations (Wallace Interview 2010). The Gray location proves an important point, namely that no matter how many fossil discoveries came before 2000 in Tennessee, other states, or other countries, exciting new finds turned up in the past decade at this site, paleontologists continue to be astonished, and more knowledge exists.

Figure 1.



*International ages have not been fully established. These are current names as reported by the International Commission on Stratigraphy.

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