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STUDIES OF INFORMAL GEOLOGIC TIME LEARNING AT THE "TRAIL OF TIME" IN GRAND CANYON NATIONAL PARK

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Introduction

Geologic time, or "deep time" (a term first attributed to Thomas Carlyle and popularized by the author John McPhee), is recognized as one of the fundamental concepts of the natural sciences. It has also been called a "threshold concept": an idea that, once understood, transforms a learner's worldview and serves as a portal to more in-depth study of a subject (Meyer & Land, 2003; Trend, 2008). Without a grasp of the magnitude of the history of Earth and life, it is generally difficult to make sense of biological evolution or the time scales of natural processes of change, many of which are relevant to environmental sustainability. Although geologic time is specifically addressed by the U.S. national and most state science education standards for high school (e.g., American Association for the Advancement of Science, 1993; National Research Council, 1996), many students never engage with it because Earth science is not widely taught at the secondary level in this country (American Geological Institute, 2009).

National Parks and Monuments, many located within spectacular landscapes, offer alternative opportunities for informal learning about geo-

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EAST ASIAN HISTORY AND CULTURE HITS THE U.S. – IN DIFFERENT WAYS

Alison Dineen and Robert Mac West

Two major exhibitions highlighting historic Asian characters, cultures, and significant cultural and political events are currently touring the United States. Our particular locations and personal schedules allowed us to visit both as "typical" guests and then to have time with museum staff to discuss the impact and significance of the exhibitions. The presentations we are discussing here are Genghis Khan at the Denver Museum of Nature and Science from October 16, 2009 through February 7, 2010, and The Terra Cotta Warriors: Guardians of China's First Emperor at the National Geographic Museum in Washington, DC, from November 19, 2009 through March 31, 2010.

These two exhibitions, conceived and developed completely independently and under very different circumstances, nonetheless have both similarities and differences – quite apart from the fact that they both are dealing with major events that emerged in eastern Asia.

As will be detailed in our discussion, both exhibitions have two stories, each featuring a powerful personality who forced major cultural changes and the tangible results of those changes. However, the emphases of the exhibits and their ability to resonate with their audiences are reversed. The Genghis Khan exhibition uses that iconic (and usually despised) 12th Century Mongolian leader as the attractant, with the cultural and political ramifications of his military triumphs very much an unexpected revelation in the second part of the exhibition. The Terra Cotta Warriors exhibition uses the remarkable assemblage of clay statues found near Xian and part of the current iconography of China as the "come-on" for the exhibition. However, once in the exhibition, visitors are presented with a fascinating picture of the unification of China in the 2nd Century B.C. by the youthful emperor Qin.

Thus, in the first instance, the personality (Genghis Khan) is the icon, and the effects

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logic time, natural processes of change, and how human time scales and geologic time scales entwine. Of these, none is better suited to such learning than Grand Canyon National Park, where mile-deep, horizon-to-horizon exposures of rock reveal nearly two billion years of geologic history - an arresting site and teachable moment even to the casual visitor who ventures only to the rim. The idea of establishing a permanent outdoor exhibition on geologic time that leverages the spectacular views from the accessible and well-traveled South Rim Trail occurred nearly two decades ago to longtime Grand Canyon geologic researchers Karl Karlstrom and Laura Crossey of the University of New Mexico, and Michael Williams of the University of Massachusetts. Their persistent effort gradually brought other university researchers, interpretative design and evaluation specialists, and the National Park Service itself as collaborators. Following several planning grants, the Trail of Time Exhibition was funded by the National Science Foundation in 2006.

The Trail of Time, the world's largest interpretive geoscience exhibition (Figure 1; Karlstrom et al., 2008), is now nearly complete and will be dedicated in the fall of 2010. The heart of the exhibition is a horizontal timeline that can be walked along 2 kilometers of the existing paved South Rim Trail; it is marked with inset 5-cm circular bronze markers at one-meter intervals, and 10-cm numerically labeled circular bronze medallions every 10 meters (Figure 2). Each meter along the Trail of Time represents one million years of elapsed time: 1 meter = 1 million years. Another Trail segment leads 315 meters from the Park's own Yavapai Geology Museum to the start of the 2-kilometer main trail. This 315-m segment has a logarithmically increasing time scale that changes from 1 year per meter at its start to 100,000 years per meter at its end, where it dovetails with the main trail. This segment is intended to help Grand Canyon visitors adjust their temporal frames of reference from personally familiar time scales (birthdays, years, and decades), through historic and archaeological time scales (centuries to millennia) to deep time (millions of years).

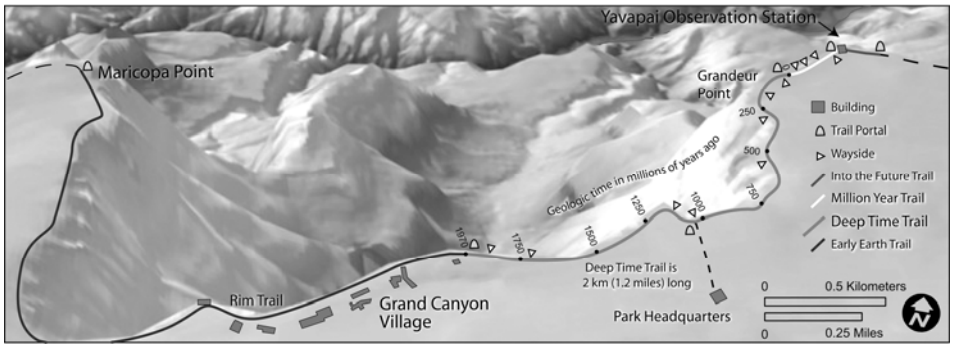

Figure 1. Map of the Trail of Time exhibition at Grand Canyon National Park (from Karlstrom et al., 2008).

Figure 2. Rendering of the Trail of Time (from Karlstrom et al., 2008): small circular markers are spaced at one-meter (one million year) intervals, and labeled medallions (inset) are deployed every ten meters (ten million years).]

At important points on the timeline that correspond to major geologic or cultural events significant in Grand Canyon history, interpretive signage and large, permanently mounted rock specimens are placed to provide context for the quantitative progression of time. Additional interpretive materials (e.g., brochures, publications) and curriculum resources will be made available on-site and online.

Simple linear timelines, forerunners to the Trail of Time, have long been made by geoscience teachers using yardsticks, rolls of paper, or lengths of rope; by marking intervals around a classroom, down a hallway, or along a football field. These have long been used in formal and informal learning settings to teach about geologic time. However, their effectiveness has not been fully assessed. From the start of project planning for the Trail of Time, it was understood that this interpretive exhibition also constitutes a unique and valuable field-based laboratory for research on the use of timelines and other analogical models for informal learning about deep time. Thus cognitive research is an integral part of the Trail of Time project, and, led by Steven Semken of Arizona State University and Jeff Dodick of Hebrew University of Jerusalem, has been ongoing through the development of the Trail.

The "Time Accelerator" Experiments

In advance of the construction of the permanent Trail of Time at Grand Canyon, we conducted two off-site studies (in Tempe, Arizona and Jerusalem, Israel; Semken *et al.,* 2009) to investigate how visitors navigated and interpreted the planned logarithmically changing "time accelerator" trail segment described above. We wished to learn whether visitors understood that the trail was a model timeline, and whether they could make sense of its regular changes in scale. For this experiment we used a scaled simulation of the trail made from a 74-m long by

Figure 3. The experimental "time accelerator" trail at Arizona State University. An identical trail was used for the experiments in Israel.

0.7-m wide strip of durable white paper, to which realistic time markers were affixed at 1-m intervals (Figure 3). The time scale on this experimental trail increased logarithmically every 10 meters, from 1 year per meter at one end to 100 million years per meter at the other. We deliberately exceeded the scale range of the actual Trail of Time to allow study of respondent cognition over a longer expanse of time.

The experimental protocol (described in detail in Semken *et al*., 2009) focused on uncovering behaviors and comments that visitors would be expected to reveal while exploring the actual Trail at Grand Canyon. This was done by asking respondents (40 in Arizona in summer 2007 and 30 in Israel in 2008) to walk from one end of the model timeline to the other, while "thinking aloud" and also responding to questions and tasks posed at certain points by an accompanying interviewer (who was a geologist and geoscience teacher). Each respondent participated individually and was also accompanied by a second researcher who video-recorded the experiment. The respondent was given placards that represented various events or phenomena in Grand Canyon or Arizona history, and one that represented his or her own age. Respondents were asked to place each of the placards at the correctly corresponding point in time along the timeline. While engaged in these tasks, respondents were also asked purely mathematical questions about the timeline and its scale changes. All of these responses were recorded and subsequently transcribed, and the exact placard placements made by respondents were noted and recorded. These data were compiled and coded by the research teams in Arizona and Israel.

Findings from both experiments (Semken *et al.,* 2009) showed that when the time corresponding to each point along the timeline is clearly indicated with a marker, respondents immediately grasp the logarithmic nature of the timeline and can understand it, even if the points where the scale increases are not marked by additional signs. We concluded that the predictable, logarithmic increase in scale will cognitively prepare visitors to understand and navigate the main Trail of Time with its constant 1 million year per meter scale. This desired effect will be enhanced at Grand Canyon by the interpretive signage and rock displays, which contextualize time within actual events. Thus, our research has directly informed the design and placement of time markers along the actual Trail of Time in advance of its construction.

The Trail of Time Experiments

The Trail of Time became a functional exhibition at Grand Canyon in the spring of 2009 when the permanent bronze time markers were installed along the 2-kilometer main trail segment. The Trail is more cognitively complex than the off-site simulations used for the earlier experiments because here, visitors are invited not only to traverse and make sense of a horizontal timeline, but to reconcile it with the vertical record of time and past environments encoded by the rock layers exposed in Grand Canyon. Mixed-methods research is now underway along the main Trail of Time to determine (1) how easily Park visitors can reconcile the horizontal and vertical representations of time, (2) whether they can grasp the concept of deep time, (3) whether they can understand two basic principles the Trail of Time is designed to teach: superposition (in an undisturbed stack of rock layers, the youngest is at the top) and lateral continuity (corresponding layers on opposing sides of the canyon were originally continuous before being separated by the downcutting river), and (4) whether they understand that the different layers in the Canyon walls represent changes in past environments through time.

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The first stage of this research consisted of semi-structured interviews (Figure 4) conducted along the Trail of Time (with a permit from the National Park Service) in the summer of 2009. Permanent interpretive wayside signs and rock displays were not yet installed at this time, so temporary but accurate versions of these displays were placed at appropriate places to render the Trail of Time as realistically complete as possible. The research team (one interviewer and one recorder) stationed themselves at two waysides characterized by especially rich vistas, and solicited visitor responses to five questions (Frus *et al*., 2009) designed to test visitors' comprehension of the geological landscape before them (in particular, the relative geologic time, superposition, and lateral continuity visible therein) and the function of the Trail of Time exhibition. While the interviewer drew the respondent's attention to the Canyon and the Trail and audio-recorded the exchange, the second researcher took notes on the respondent's answers and comments.

Figure 4. ASU researchers conducting an interview along the Trail of Time.

The recordings were subsequently transcribed, verified by comparison with the written notes, and coded to yield quantitative (percentage correct responses to the questions) and qualitative (visitor explanations and other observations) data. Preliminary analysis of the quantitative results (Frus *et al.,* 2009) indicates that not only do most visitor respondents understand the function of the horizontal timeline, but they can also correctly relate its horizontal representation of time to the stratigraphic (vertical) encoding of time in the walls of Grand Canyon. A majority of respondents were also able to correctly explain the significance of superposition and lateral continuity. Work is now underway to characterize and classify visitor preconceptions and recommendations obtained in these interviews. These will be used in the final stage of the Trail of Time project: the development of on-site and online interpretive materials and programs for visitors.

Implications for Informal Geoscience Education and Interpretation

Our findings and conclusions (some still preliminary for the on-site experiments) indicate that a thoughtfully designed (i.e., appropriately sited, adequately marked and signed but not obtrusive) outdoor timeline trail is an effective means of teaching curious National Park visitors about the magnitude of geologic time, the processes that form rocks and shape the Earth's crust, and the elaborate history that can be read directly from landscapes such as the Grand Canyon. Millions of visitors will encounter and learn from this exhibition, but the potential impact is far greater as interpretive specialists from other parks have expressed strong interest in reproducing the Trail of Time in their own settings. These informal geoscience education efforts are important for improving public understanding of societally important topics that involve extended time scales, such as climate change, fossil-fuel sustainability, waste disposal, and extinctions.

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References

American Association for the Advancement of Science (1993). *Benchmarks for science literacy*. New York: Oxford University Press. 448p.

American Geological Institute (2009). Pulse of Earth science: National status of K-12 *Earth science education, state by state*. Retrieved 01 December 2009, from http://www.agiweb.org/education/statusreports/2007/index.html.

Frus, R., Semken, S., Dodick, J., McNeil, J., Frus, A., & Bowles, Z. (2009). A preliminary study of public understanding of geologic time principles conducted at the Trail of Time interpretative exhibition in Grand Canyon National Park [Abstract]. *Geological Society of America Abstracts with Programs, 41*(7), 486.

Karlstrom, K., Semken, S., Crossey, L., Perry, D., Gyllenhaal, E. D., Dodick, J., Williams, M., Hellmich-Bryan, J., Crow, R., Bueno Watts, N., & Ault, C. (2008). Informal geoscience education on a grand scale: the Trail of Time exhibition at Grand Canyon. *Journal of Geoscience Education, 56*, 354-361.

Meyer, J., & Land, R. (2003). *Threshold concepts and troublesome knowledge: Linkages to ways of thinking and practising within the disciplines*. Retrieved 05 January 2008 from University of Edinburgh website: http://www.etl.tla.ed.ac.uk/docs/ETLreport4.pdf.

National Research Council (1996). *National science education standards*. Washington, DC: National Academy Press. 272pp.

Semken, S., Dodick, J., Ben-David, O., Pineda, M., Bueno Watts, N., & Karlstrom, K. (2009). Timeline and time scale cognition experiments for a geological interpretative exhibition at Grand Canyon. *Proceedings of the National Association for Research in Science Teaching,* Garden Grove, California.

Trend, R. (2008). *Deep time, a critical barrier, an anchor, or a threshold concept?* Retrieved 15 November 2008 from http://geo-thresholdconcepts.blogspot.com/ 2008/09/2nd-international-threshold-concepts.html.

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(politics, social structures, etc.) the revelation; in the second instance, the effects (warriors) are the icon, and the impetus for their development (the Qin dynasty) the revelation.

Given these fascinating similarities and differences, let's look at the two exhibitions.

Terra Cotta Warriors

The Terra Cotta Warriors: Guardians of China's First Emperor exhibition opened with considerable fanfare at the National Geographic Museum in Washington, DC, in November 2009. While the life-size terra cotta sculptures featured number just fifteen (including musicians, a hefty (headless) strongman, horses, and a variety of warriors, accompanying artifacts and text illuminate the gritty and engrossing sub-themes of China's unification under Emperor Qin Shihuangdi, who ruled from 221 B.C. to 210 B.C.--as well as the immense-beyond-belief tomb complex and its cultural contents that have fascinated the world since Chinese farmers accidentally discovered them near Xian in 1974.

Co-organized by the Bowers Museum, Santa Ana, CA, the Houston Museum of Natural Science, and the National Geographic Museum, the exhibition content was guest-curated by Dr. Albert E. Dien, professor emeritus, Stanford University. National Geographic is the final venue for this exhibition; a different version of the exhibit was recently at the High Museum in Atlanta.

Many, if not most, adult (as well as younger) visitors have at least seen pictures of these serene, aloof, and individually-unique terra cotta (clay) sculptures before. It is, perhaps, this visual familiarity along with intense curiosity about the emperor's tomb that facilitates visitors' engagement with the supporting cultural objects and themes in the exhibition.

After being herded in a timed-entrance ticket line (this is the first admission-charged exhibition in the history of the museum) ringing the exterior of the National Geographic building, one enters a foyer space with photographs, a coat check, and acoustic guide rental counter. Visitors then briefly line up again to enter the first rather small gallery, offering a 360-degree, in-your-face encounter with a stunning terra cotta cavalry soldier and horse. Cleverly, the exhibition gives this dramatic introduction to what you've purchased a ticket to see and then immediately transitions into the historical narrative about China's first emperor Qin Shihuangdi—about whom it is presumed most visitors know little—offering context and meaning.

On the day we visited, a rainy weekday afternoon and reportedly less crowded than at other times, the galleries were quiet—obviously this would likely not be the case when school-age groups are present. One suggested possibility for the hush may well have been the lengthy explanations provided on the labels and acoustic guide tour—visitors tended to listen or read rather than engage in conversation.

The wall and label text includes fulsome detail. An interactive map of China's "Warring States" period provides a visual timeline for visitors of all ages on the building of the Chinese empire. The concept of nation-building is explored and the administrative means by which this was accomplished examined, including the imposition of a common script, measures, taxes, laws, and coinage. A display of early coins (from the collection of the American Numismatic Museum), some of which looked more like hooks and knives, demonstrates the utility of standardized coins with holes in the center that allow them to be strung and carried easily. The mundane notion of standard axel sizes for wagons makes sense in that irregular ruts in dirt roads break wooden wheels and hinder the efficient transportation of goods. The consideration of these factors is an "aha moment," offering an understanding of systems used to both control and unify principalities and peoples.

Further along, Terra Cotta Warriors considers cultural beliefs, architectural conventions, and the Emperor's elaborate preparation for the afterlife. The incredible tomb complex included a pleasure palace for the Emperor's amusement in his next life, including running rivers believed to have been filled with mercury. Two graceful bronze birds, a goose and a swan, from Qin Shihuangdi's mausoleum have been included. A map of the tomb complex, constructed over a period of thirty-six years, offers graphic evidence of the site's incredible proportions—19 square miles—most of which is unexcavated. The 1,000 terra cotta sculptures unearthed to date are believed to represent one-sixth of the total. [For those who have had the singular experience of visiting the site (and, fortunately, that includes Mac and Jean West), this array of clay figures is absolutely staggering.]

Necessarily, the accouterments of war are also described and displayed. The powerful crossbow used by Qin's army, points to the brutal, bloody aspects of nation-building and was a technological advantage. The robes, tunics, armor, belts, buckles, hairstyles, and shoes of the sculptures are descriptive of their roles/status as archers, charioteers, infantry, officers, and generals, as well as musicians. Hand positions on some indicate actual swords held, but stolen when the empire floundered after Qin's death.

The question of how the terra cotta sculptures were created is demonstrated through an appealing series of three-dimensional models of the artisans working in assembly-line fashion (think of the wonderful Diego Rivera murals in the Detroit Institute of Arts that represent the automobile assembly lines of the 1930's). The hollow segments made from molds and solid pieces are joined and then moved forward to include the

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