Phase One of Formative Evaluation for

THE TRAIL OF TIME
AT GRAND CANYON NATIONAL PARK

for
University of New Mexico and Grand Canyon National Park

Eric D. Gyllenhaal, Ph. D., and Deborah L. Perry, Ph. D.
Selinda Research Associates, Inc.

December 2004
# TABLE OF CONTENTS

Acknowledgements ........................................................................................................ iii
Abstract .......................................................................................................................... iv
Executive Summary ....................................................................................................... v
Introduction ................................................................................................................... 1
Methods and Methodologies ....................................................................................... 10
  Methodology ............................................................................................................ 10
  Methods ................................................................................................................ 10
  Respondents ........................................................................................................... 13
  Limitations .............................................................................................................. 13
  Project Approval ...................................................................................................... 14
Results ........................................................................................................................... 15
  Visitors’ Understandings and Feelings about Grand Canyon and the *Trail of Time* .... 15
     Visitor Engagement with the Grand Canyon ...................................................... 15
     Visitor Engagement with the *Trail of Time* .................................................... 15
     Visitors’ Developing Understandings of the *Trail of Time* ............................... 19
  Visitors’ Understandings and Feelings about Geological Concepts Related to the *Trail of Time* ...29
     Geologic Time in the Abstract ......................................................................... 29
     The Cutting of the Canyon ............................................................................... 33
     The Time Significance of Rocks in the Grand Canyon ..................................... 36
     How Layered Rocks Form ............................................................................... 41
     The Grand Canyon as a Geological Phenomenon ......................................... 43
Conclusions and Discussion ......................................................................................... 45
  What Works and What Doesn’t about the Prototype Trails? ............................. 45
  Learning Outcomes in Informal Settings .............................................................. 47
  Developing Goals and Objectives for the *Trail of Time* .................................. 49
Recommendations ......................................................................................................... 52
  Recommendations for Continued Development and Evaluation .................... 52
  Recommendations for Revising the Prototype *Trail of Time* ......................... 54
References ..................................................................................................................... 59
Appendix A: Topical Framework ............................................................................... 63
Appendix B: Visitor Observation-Interview Protocol ............................................. 66
Appendix C: Respondent Data ................................................................................... 70
Appendix D: Expedited Approval for NPS-Sponsored Public Surveys .................... 73
ACKNOWLEDGEMENTS

We thank the National Science Foundation for its generous support of this project.

We thank Karl Karlstrom and Laurie Crossey, Co-Principal Investigators for the *Trail of Time* project, for the help they provided during this process. Our thanks also go to the *Trail of Time* advisory team for its insight and input and to the many students who helped set up the prototype trail for us to test.

We are grateful to the National Park Service staff who helped in many ways, especially Ellen (Sissy) Seeley, Interpretive Specialist from the Grand Canyon National Park, who contributed in many ways, and Brian Forist, Research Associate with the Social Science Program, who helped with preparations for our study.

We also recognize the assistance we received from our co-workers at Selinda Research Associates, Inc. including Michael Petra, who assisted with project management, and Barbara Mastrolia, who took notes at telephone meetings and edited this report.

Finally, we gratefully acknowledge the visitors who participated in this study. Their willingness to interrupt their visits to the Grand Canyon and give so generously of their time is greatly appreciated.
ABSTRACT

The Trail of Time is an interpretive walking trail being developed along the South Rim of the Grand Canyon. The Trail of Time uses visitors’ experiences of the Canyon to create a deeper understanding of geologic time and to explain events and processes that shaped the Canyon. The University of New Mexico contracted with Selinda Research Associates, Inc., of Chicago to complete the first stage of a proposed three-stage formative evaluation of the Trail of Time. Selinda Research Associates used its expertise in informal learning and naturalistic methodology to guide this study. The goal of the first-stage formative evaluation was to evaluate the overall layout of the Trail of Time and to get a sense of whether visitors understood the timeline aspect of the Trail of Time.

In two days of observing and interviewing visitors who used a preliminary rough version of a prototype Trail of Time at Grand Canyon, we were impressed with the amount of attention visitors paid to the tick marks and labels along the Trail of Time and with the energy they devoted to trying to make sense of them. While most respondents realized the Trail of Time markers had something to do with time and understood some aspects of the timeline concept, most did not fully understand that the Trail of Time was an abstract timeline superimposed on the Canyon’s rim until the researchers explained it to them. There were many indications that visitors will understand the timeline concept with appropriate and adequately spaced interpretation. There were also many indications that visitors wanted to connect the Trail of Time to landforms on the rim and within the Canyon, and many visitors incorporated aspects of the Canyon’s erosion into their developing theories about the Trail of Time. However, with respect to the prototype Trail of Time, labels about geologic events seemed too widely spaced and too sparsely explained. Although improved introductory exhibits near the trailheads would have helped some visitors, other visitors began paying attention to the Trail of Time somewhere beyond the trailheads, implying that the basic concept of the Trail of Time will need to be explained at several points along its length. The final version should help visitors realize that the Trail of Time is a timeline that lets them feel the immensity of time as it relates to story of the Grand Canyon. The challenge will be to accomplish this goal through relatively unobtrusive interpretation placed at wide intervals along a course where visitors enter and exit at many different locations. The Trail of Time has the potential to help visitors fill an important gap in their understanding of the Earth’s history, especially since most visitors lacked perspective on the immense amount of time it took to carve the Canyon.

Selinda Research Associates recommends that project development continue with four major steps, the first three steps preparing for the fourth: (1) include a professional designer on the team; (2) develop a “big idea” for the Trail of Time based on Beverly Serrell’s model; (3) completely develop and evaluate one Trail of Time segment (introductory exhibits, time-scale update stations, and waysides) so that it can stand on its own; and (4) conduct rapid prototyping formative evaluation of this segment, with iterative testing and revisions on-site. Specific recommendations are included about developing and placing interpretative signage along this next-stage prototype. Finally, in addition to the on-going formative evaluations, we recommend that the project team set aside adequate funds for both remedial and summative evaluations.
EXECUTIVE SUMMARY

Background on the Trail of Time. The Trail of Time is an interpretive walking trail being developed along the south rim of the Grand Canyon, from Yavapai Observation Station through Mather Point and Pipe Creek Vistas and on to Yaki Point (Fig. 1 in the body of the report). It uses visitors' experiences of the Grand Canyon to provide motivation for understanding geologic time and uses the Canyon’s vistas and rock layers to illustrate and explain events and processes that shaped the Grand Canyon.

The prototype Trail of Time consisted of approximately 3,000 brass-colored “tick marks” taped down at one meter intervals along the paved Rim Trail along the south rim of Grand Canyon (Fig. 2) and included two main segments. The Time Accelerator segment (from Yavapai to Mather) focused on the last six million years, when the Grand Canyon was eroded. It was designed to let visitors incrementally progress from human (years) to geologic (millions of years) time scales, and thus it had an expanding time scale, with one meter equaling first 1, 10, 100, 1,000, 10,000, and then 100,000 years; each change was marked with a scale-change station (Fig. 7). The main Trail of Time segment (from Mather to Pipe Creek Vistas) was scaled with each meter representing one million years; the information from the Time Accelerator was repeated in compressed form in the first six meters (Fig. 6). This segment of the Trail of Time identified and gave the ages of the different rock layers in Grand Canyon (Figs. 8, 9).

Background on the evaluation. The University of New Mexico contracted with Selinda Research Associates, Inc., of Chicago to complete the first stage of a proposed three-stage formative evaluation of the Trail of Time. The goal of the first-stage formative evaluation was to evaluate the overall layout of the Trail of Time and get a sense of whether visitors understood the timeline aspect of the Trail of Time, as well as investigate visitors’ interest and the previous knowledge they brought to the experience. Only limited interpretive information was provided to visitors at this stage in the evaluation (e.g., taped-down brochures at the starts of the Trail of Time (Figs. 3, 4), and limited information about geologic events along the Trail of Time (Fig. 8). No wayside exhibits, detailed interpretive signs, or other explanations about the Trail of Time were provided with this early-stage prototype, although we did give visitors a draft of an informational brochure during their interviews. The research question for this study was: “By watching and talking with visitors who engage with the prototype trail and accompanying brochure, what can we learn that will help us improve the effectiveness of the Trail of Time exhibit in its goal of helping general visitors further their understandings of geologic time and the connections between time, the visible rock record, and the landscapes at Grand Canyon?”

Methodology and methods. Selinda Research Associates used its expertise in informal learning and naturalistic methodology to guide this study. Qualitative methods were used to investigate visitor behavior and reactions to the Trail of Time and to answer the “how” and “why” questions underlying respondents’ beliefs, experiences, and behaviors. The study used observations and depth interviews with purposively selected visitor groups. Data analysis was an on-going process using a modified inductive constant comparison approach (Lincoln & Guba, 1985). In two days of data collection at Grand Canyon, we observed 89 general visitors in 38 groups and interviewed at least one member from 33 of those groups.
Visitor engagement. Almost all the visitors we talked with expressed awe, wonder, and even spiritual feelings at their experience of the Grand Canyon, and they seemed particularly impressed by the immense depth and width of the Canyon. Some visitors told us that time was one of the first things they thought of as they looked at the Canyon, especially the time it took to form the Canyon. We were impressed by the amount of attention visitors paid to the tick marks and labels along the Trail of Time, and by the energy they devoted to trying to make sense of them. By far the most common physical engagements with the Trail of Time were (a) looking down at the markings along the Trail of Time, the labels on the path, or the scale-change stations while walking, (b) stopping to look more closely, and (c) sometimes pointing at labels or tick marks. Many respondents told us that they first started walking along the Trail of Time somewhere beyond the trailhead, or that they did not notice the tick marks until sometime after they began walking the Trail of Time. At least initially, visitors’ intellectual engagement with the Trail of Time seemed mostly about puzzling out the meaning of the tick marks, often coming up with tentative theories, but sometimes not. Social engagement around the markers seemed to be mostly talking about the meaning of the markers, discussing the scale-change stations, and reading aloud and discussing the occasional signage about events and rock units. The most common emotional engagements with the Trail of Time were (a) interest and curiosity about the tick marks and limited signage along the Trail of Time and (b) frustration about not being able to make sense of the Trail of Time and understand why it was there, based on the very limited interpretation available with this first-stage prototype.

Visitors’ ideas and feelings about the Trail of Time. Most respondents indicated a strong desire to understand the markings and signs on the Trail of Time, including what the individual markings represented, why they had been placed there, and what visitors were supposed to get out of them. Most respondents realized the markers had something to do with time and understood some aspects of the timeline concept, such as the direction in which time became younger and that there was a scale, with one step equaling a unit of time. Most visitors, however, did not develop a full understanding that the Trail of Time was an abstract timeline superimposed on the Canyon’s rim, and few noted the changes in scale along the Time Accelerator. Instead, visitors used the evidence available along the Trail of Time to develop tentative theories about its meaning making creative use of the limited signage and the positions of the tick marks relative to the Canyon, which they analyzed using their own prior knowledge about rocks and erosion. Because most visitors’ theories about the Trail of Time were incomplete or incorrect in important ways, we developed a knowledge hierarchy to portray the range of visitor understandings of the Trail of Time. We also discuss how visitors’ learning about the Trail of Time compares with learning in other informal settings.

Helping visitors understand the Trail of Time. In our conversations with visitors, we found that an effective way to explain the concept of the Trail of Time was to compare it to a timeline in a history book, perhaps because this implied an appropriate level of abstraction (helping visitors realize that tick marks did not relate to a particular place in real space). Ultimately, it seemed that the story of the Canyon’s rocks and landforms gave meaning to the Trail of Time. However, with the Trail of Time prototype, explanation of geologic events seemed too widely spaced and too sparsely explained for most visitors to figure out that the Trail of Time had a story to tell about the Grand Canyon’s past. Although improved introductory exhibits would have
helped many visitors, our findings suggest they will not be sufficient for those visitors who join the *Trail of Time* or begin paying attention to it somewhere beyond the trailheads. The final version of the *Trail of Time* should communicate to visitors that it is a timeline that lets them *feel the immensity of time* as it relates to the story of the Grand Canyon. The challenge will be to accomplish this goal through relatively unobtrusive interpretation placed at wide intervals along a “porous” route (i.e., one that visitors enter and leave all along its length). It will also be a challenge to move visitors beyond their initial desire to link every tick mark to a specific point along the *Trail of Time* or vista from that point, and to capitalize on this desire at key locations (where key geologic features are visible from a certain marker).

**Trail of Time segments.** Because of the porous nature of the *Trail of Time* and lack of sufficient interpretation, most visitors did not realize that there were two *Trail of Time* segments with different time scales and different stories to tell. Along the Time Accelerator portion of the *Trail of Time*, most visitors did not seem to notice or talk about the changes in scale, and therefore did not get confused by them. This may be because visitors focused more on the small labels that told them where they were in time rather than on the step-equivalent scale at any point. Alternatively it may mean that the scale change concept was substantially beyond what most visitors were able to make sense of on their own. In some ways the scale-change stations actually helped visitors make sense of the *Trail of Time*. Because they were scattered along the Time Accelerator, visitors were much more likely to see the scale-change stations than the information at the trailheads. This suggests that the *Trail of Time* would benefit from time-update stations that incorporate useful aspects of the scale-change stations by giving visitors periodic reminders (a) that they are walking on a timeline, (b) what a step means, (c) how far they are from the beginning and the end, and (d) why it matters (i.e., what the *Trail of Time* is trying to tell them about Grand Canyon’s geology). Many visitors at Mather Point (between the main segments) ignored the markers and instead concentrated on the views and vistas. This may be a positive aspect of the *Trail of Time*, as it shows that, for many short-term visitors, the tick marks did not distract from the aesthetic aspects of the Grand Canyon. However, those who did notice the tick marks at Mather Point often did not walk very far along the *Trail of Time*, so they had a harder time figuring out what the tick marks meant.

**Connecting the *Trail of Time* to the Grand Canyon.** There were many indications that visitors wanted to connect the *Trail of Time* to landforms and elevations on both the rim of the Grand Canyon and within the Canyon. Many visitors incorporated aspects of the Canyon’s erosion into their developing theories about the *Trail of Time*. However, many visitors seemed more interested in the aesthetic qualities of the Canyon’s rocks than in understanding the rocks as geologic features. Visitors’ understanding of the rock layers seemed more tentative and incomplete than their understanding and theories about the cutting of the Canyon.

**Visitors’ understanding of geoscience concepts.** This report combines our findings from the formative evaluation with information from the geoscience education literature to discuss the public’s understanding of several geoscience concepts so that the *Trail of Time* team can better understand the multiple knowledge levels that visitors bring to the Grand Canyon. These include geologic time in the abstract, the cutting of the Grand Canyon, the time significance of layered rocks, how layered rocks form, and the Grand Canyon as a geologic phenomenon.
What works about the prototype **Trail of Time**? The *Trail of Time*’s tick marks and signage intrigued visitors, and they were willing to devote quite a bit of effort to figuring out what the marks represent. Respondents seemed to understand the basic idea of a timeline once we explained it. This indicates that the timeline concept will be within most visitors’ comprehension, assuming adequate and frequent interpretation. Visitors who first noticed the tick marks and labels somewhere beyond the trailhead used important clues at the scale-change stations as they tried to make sense of the *Trail of Time*. Once visitors understood the concept behind the *Trail of Time*, they applied their understanding in interesting ways, such as telling us how many million years they had hiked and using the timeline to keep track of where their cars were parked. Visitors seemed very interested in how the Grand Canyon formed, although their theories about erosional processes were often incomplete or incorrect. Because most visitors lacked perspective on the immense amount of time it took to carve the Canyon, it seems that the *Trail of Time* has potential to help them fill an important gap in their understanding of the Earth’s history.

What does not work as well about the prototype **Trail of Time**? The markings and signage available with this first-stage prototype did not take visitors far enough along their journey to understanding the *Trail of Time*. Visitors joined the *Trail of Time* all along its length or first noticed the tick marks at some point well beyond the trailhead, and even those who entered at the ends may have missed the initial interpretation at the trailheads because of the low level of signage. As a result, visitors working with the limited signage developed some creative, yet often incorrect theories about the *Trail of Time*. Although labels along the prototype very briefly explained some events in the Canyon’s prehistory and gave names and ages of rock units, this was not enough to give full meaning to the *Trail of Time*, even for those who figured out that it was a timeline. Both the Canyon-cutting story and the story of the Canyon’s rocks will need to be told with more episodes, including clear and detailed explanations and illustrations of the geologic events and processes. The geoscience education literature suggests that visitors will need quite a bit of help to understand the story told by the Canyon’s rock layers. There were indications that scale changes along the Time Accelerator might add an additional barrier to visitors’ understanding the *Trail of Time*. In addition, the evaluators are concerned that adding too much human prehistory and history to that segment of the *Trail of Time* might dilute its messages about the cutting of the Canyon, and further confuse visitors. In particular, at Mather Point plaza and Yavapai Observation Station, it seemed that many visitors did not walk far enough along the *Trail of Time* to make sense of it or to experience it in meaningful ways. Finally, it may be hard to channel visitors’ tendency to link each tick mark to the place where it was taped and to get them to think of the *Trail of Time* as an abstract timeline draped over the landscape.

**Learning outcomes in informal settings.** To help the team formulate goals and objectives for the *Trail of Time*, the full report discusses recent research about informal learning, detailing the types of learning and learning-related outcomes that evaluators and researchers commonly encounter in informal settings, like museums and parks. We recommend that the project team reformulate the *Trail of Time*’s goals and objectives to include the full range of learning outcomes that take place in informal settings.
Recommendations for continuing development and evaluation. Selinda Research Associates recommends that project development continue with four major steps, the first three steps preparing for the fourth: (1) include a professional designer on the team; (2) develop a “big idea” for the Trail of Time based on Beverly Serrell’s model; (3) completely develop and evaluate one Trail segment at a time (introductory exhibits, time-scale update stations, and waysides) so that it can stand on its own; and (4) conduct rapid prototyping formative evaluation of this segment, with iterative testing and revisions on-site. Among other things, this next stage of formative evaluation should help determine appropriate formats for the time- and story-update stations and appropriate frequencies for the timeline’s tick marks. A third stage of formative evaluation, a few months later, can test the next prototype version of the remaining segment of the Trail. We also recommend that the project team develop a long-term, multi-faceted publicity/marketing/advertising plan. It will be important that the Trail of Time become part of what visitors to the Grand Canyon expect to see. Finally, we recommend that in budget planning, the project team set aside funds for both a remedial and a summative evaluation. The goal of the remedial evaluation would be to find out which aspects of the completed Trail of Time are working well and which aspects are not, in order to recommend changes to the exhibition that can improve its effectiveness. The goal of the summative evaluation would be to investigate how well the finished exhibition accomplishes its stated goals and objectives.

Selinda Research Associates will be providing a more complete evaluation plan along these lines for inclusion in the National Science Foundation proposal to the Informal Science Education program.

Recommendations for revising the prototype Trail of Time. Based on our findings, Selinda Research Associates makes a series of recommendations for improving the effectiveness of the Trail of Time, which can be tested during the next two stages of formative evaluation. Specifically, we recommend keeping the Trail of Time as two separate segments with separate foci and identities, tentatively titled the Canyon Cutting Trail and Rock Formation Trail. We recommend giving each segment a clear storyline that gives the timeline meaning. We recommend locating the Trail of Time’s introductory exhibits just a bit past the points where visitors have committed to walking the Trail of Time and developing a strategy that gives visitors periodic reminders about where they are in time, using numbers, words, and graphic aids. We recommend giving visitors more strategically located and focused interpretative signage, with more depth of explanation about basic concepts than was possible during the first phase of formative testing so that visitors can better understand both the Trail of Time concept and the stories that give the Trail of Time meaning. We also recommend adding a break in the Trail of Time at Mather Point, with no tick marks along the most-used parts of the “plaza.” Finally, we recommend that Trail of Time be developed so that visitors can achieve basic understandings of the timeline and key geologic concepts based on the markings and signage alone. The accompanying brochure and volunteer docent programs should be seen as adding to and extending visitors’ understandings of these key concepts, in ways detailed in the recommendations section of the full report.
INTRODUCTION

Background on the Project

The Trail of Time [Trail] at the south rim of the Grand Canyon is being planned as an interpretive walking trail that uses visitors’ experiences of the Grand Canyon to provide motivation for understanding geologic time. The Trail uses its vistas and rock layers as examples to illustrate and explain events and the processes that shaped the Grand Canyon.

A recent formulation of the geoscience interpretation goals for the Trail states that, “Grand Canyon, one of the world’s premier geologic wonders, provides emotional and intellectual motivation for visitors to develop deeper understanding of geology, the science of the Earth.”

Sub-themes identified within this overall goal include:

- **Grand Canyon, carved in the last 6 million years, is a relatively young landscape that exposes an ancient rock record.**
- **Rocks preserved in the Canyon walls and side canyons are a record of 1.84 billion years of geologic time and changing earth environments.**
- **Geological time provides the framework for understanding Grand Canyon’s sequential geological stories: 1) continent formation, 2) Great Unconformity and Grand Canyon Supergroup, 3) Paleozoic strata, 4) regional uplift during the Laramide orogeny that formed high plateaus, and 5) incision of the Grand Canyon by the Colorado River, and other ongoing geologic processes that continue to shape the region.**
- **Grand Canyon geologic studies, through application of the scientific method, continue to provide the backdrop for precedent-setting geological research to answer scientific questions concerning the history of the earth and nature of the processes that shape it** (Karl Karlstrom, personal communication, September 27, 2004).

Description of Prototype Trail and Brochure

The Trail of Time is an interpretive walking trail being developed along the south rim of the Grand Canyon, from Yavapai Observation Station through Mather Point and Pipe Creek Vistas and on to Yaki Point (Fig. 1). In its final form, it will use visitors’ experiences of the Grand Canyon to provide motivation for understanding geologic time, and use its vistas and rock layers to illustrate and explain events and the processes that shaped the Grand Canyon.

The prototype Trail was a giant timeline superimposed along the south rim of the Grand Canyon. It consisted of approximately 3,000 brass-colored “tick marks” taped down at one meter intervals along the paved Rim Trail (Fig. 2). It was comprised of two main segments:
Figure 1. Shaded relief map of the South Rim of the Grand Canyon showing segments of the Trail of Time and associated geographic features. (Graphic by Laurie Crossey.)
Figure 2. Prototype Trail of Time, showing three brass-colored tick marks (two of them circled) and a date marker, next to the closest tick mark.

- The Time Accelerator, along a paved section of trail between Yavapai Observation Station and Mather Point. This section focused on the last 6 million years, when the Grand Canyon was eroded. The accelerator was so named because it has an expanding time scale, with one meter equaling first 1, 10, 100, 1,000, 10,000, and then 100,000 years, in an effort to portray the jump from human time scales to deep time.

- The main Trail of Time, from Mather Point to Yaki Point, which is projected to include the entire geologic history of the Grand Canyon region (a paved section stretching from Mather to Pipe Creek Vistas) and also the rest of the geologic history of Planet Earth (a currently unpaved section running the rest of the way to Yaki Point). The section is scaled with each meter representing 1 million years to portray “the steady heartbeat of geologic time.”
These two segments, along with geographic features of the South Rim, are marked on the map in Figure 1. In addition to the tick marks every meter, the prototype Trail included:

- **Very informal introductory exhibits** posted near time zero at Yavapai Observation Station (Fig. 3) and Mather Point (Fig. 4). These exhibits consisted of laminated graphics from the draft brochure (approximately 11 x 17 inches), including trail maps and an idealized geologic cross section through the Canyon’s major rock units.

- **Smaller introductory labels** near the beginning of the Time Accelerator (Fig. 5) and the main Trail of Time (Fig. 6). These included the initial scales for the trails (“1 step = 1 year” and “1 step = 1,000,000 years,” respectively), and a one-meter long timeline for the most recent million years at the beginning of the main Trail (Fig. 6).

- **Date markers** taped down to the trail every 10 meters using two-sided tape (e.g., “2040 AD” in Fig. 2 and 5). Once the dates reached the millions, the units were abbreviated, as in “10 m.y. ago.”

- **Scale-change stations** located periodically along the Time Accelerator segment of the Trail (Fig. 7). These stations repeated the name, “Trail of Time,” and gave both the “date” at that point (in this case “10,000 BC = 12,000 yrs ago”) and the scale in each direction (in this case “1 step = 100 yrs” walking toward the present and 1 step = 1,000 yrs” walking toward the past).

- **Interpretative labels** with names and short descriptions of events and/or rock units from Grand Canyon’s prehistory, which were placed at appropriate places along the timelines. These labels were laminated and taped directly onto the asphalt trail (as in Fig. 8).

- **Samples of rock types** with rock-unit names and ages engraved into them (about 8 by 10 inches and an inch thick). We placed one of these markers along the Trail of Time during the second day of prototype testing (Fig. 9).

In addition to the markings and signage along the Trail, the evaluators had access to multiple copies of a draft version of the interpretive brochure that we could hand to visitors as part of the evaluation process. This brochure included (a) short written descriptions of the Trail, including information on “How to Walk the Trail of Time”; (b) a cover photo of the Canyon with major rock units outlined in white and labeled; (c) a shaded-relief map with the basic segments of the trail marked and labeled; (d) a “Generalized Rock Column” showing a diagrammatic cross-section of the Grand Canyon’s major rock units and a time scale with dates and names of the geologic periods; (e) a larger fold-out map (11 by 17 inches) that explained the Time Accelerator and described some major “Geologic Themes along the Trail of Time,” including when rock layers were deposited and Canyon cutting began.

Long-term plans for the Trail include additional pamphlets, books, audio technologies, and electronic media that will be available for purchase, plus a Virtual Trail of Time Web site. These materials were not tested during this first phase of formative evaluation.
Figure 3. Introductory exhibit at Yavapai Observation Station.

Figure 4. Introductory exhibit at Mather Point, near the beginning of the main *Trail of Time*. This includes two versions of a trail map and an idealized geological cross-section of the Canyon’s rocks.
Figure 5. Beginning of the Time Accelerator, showing the first two tick marks spaced one meter apart.

Figure 6. Beginning of the main *Trail of Time*, showing the meter-long timeline for the first one million years.
Figure 7. Example of a scale-change station along the Time Accelerator.

Figure 8. Interpretive signs along the prototype Time Accelerator (left) and main Trail of Time (right).
Background on the Evaluation

The University of New Mexico contracted with Selinda Research Associates, Inc., of Chicago (SRA) to complete the first stage of a proposed three-stage formative evaluation of the Trail of Time. The purpose of phase one was to test the overall concept for the Trail. Our goal was to determine how well visitors understood and related to the concept of geologic time as portrayed along the prototype Trail of Time and in the Canyon itself, and to get some idea of how well they understood and related to the events in Grand Canyon prehistory as described at individual stops along the Trail. Given these goals, the research question for this first phase of the formative evaluation was phrased as follows: “By watching and talking with visitors who engage with the prototype trail and accompanying brochure, what can we learn that will help us improve the effectiveness of the Trail of Time exhibit in its goal of helping general visitors further their understandings of geologic time and the connections between time, the visible rock record, and the landscapes at Grand Canyon?” This research question was the starting point for a more extensive topical framework (Appendix A), which described in greater detail the questions we have tried to answer during the phase one formative evaluation.

Based on the findings of this first phase of formative evaluation and a survey of the relevant geoscience education literature, we propose modifications to the prototype Trail of Time concept. This includes ideas that can be prototyped for orientation information/devices at the beginning and end of the Trail and along the Trail, and general formats for labels/descriptions of events at individual stations along the trail. These revisions can be tested during the next two stages of formative evaluation.

Phase two of the formative evaluation is projected for summer 2005, when there are more family (and other social) groups with children, and it has been proposed that the third phase of the
formative evaluation be conducted shortly before design and fabrication begins. We discuss possible alternatives to this approach in the recommendations section of this report.

Once the *Trail* is completed and opened to the public, there will be additional phases of remedial and summative evaluation as appropriate.
METHODS AND METHODOLOGIES

People often confuse methodology and methods. In this study we will refer to methodology as the overarching paradigm or framework that will guide the study. Methods will refer to the specific data collection strategies or techniques.

Methodology

Selinda Research Associates used its expertise in informal learning and naturalistic methodology to guide this study. Naturalistic methodology is often contrasted with positivistic or scientific methodology (Lincoln & Guba, 1985) and is based on a different set of assumptions (Rau, 1990). The goal of naturalistic methodology is to provide a holistic understanding of an exhibition or program from a variety of perspectives. It usually includes collecting data from a variety of sources and triangulating that data to develop a thorough understanding of the subject of investigation. This approach to visitor research is particularly useful in a national park because visitors enter the park with varied experiences, interests, and levels of knowledge. Rather than looking for an “average” experience, naturalistic inquiry aims to describe the range of experiences and understandings. As such, it provides a powerful tool for exhibit and program planners concerned with reaching complex audiences.

One strength of naturalistic evaluation is that unanticipated findings often emerge from the data. This type of inquiry allows for the researcher to follow up on threads and themes that characterize how visitors think about their experiences. This approach also allows the project team to develop a rich understanding of the ways in which visitors may react to, interpret, and learn from Trail of Time.

Methods

Data were collected and analyzed throughout the study, and the analyses continually informed the data collection process. Qualitative methods were used to investigate visitor behavior and reactions to the Trail of Time and to answer the “how” and “why” questions underlying respondents’ beliefs, experiences, and behaviors. In accordance with standards for rigorous naturalistic methodology, we used a smaller sample size than one would find in many positivistic methodologies. While in some research paradigms this is cause for concern, it is one of naturalistic methodology’s strengths. By studying fewer cases in more depth, we were able to develop a more complete and meaningful understanding of the visitor experience than would be possible collecting less information from a larger number of respondents.

Respondents for the observations-interviews were purposively selected (Miles & Huberman, 1994). In purposive sampling, each respondent is handpicked for certain characteristics. The goal of this sampling technique is to talk with respondents who are as different from each other as possible in order to elicit the widest range of responses as possible. Understanding the experiences of a broad range of visitors is particularly important in parks, because these institutions are concerned with reaching multiple audiences, intergenerational groups, and traditionally underserved populations. Most respondents were selected based on the attention they paid to the trail markings or signage. Other factors, such as group composition, age, gender, and apparent race and ethnicity also played a role in selecting respondents.
This study used two data collection strategies: Unobtrusive observation and depth interviews. Whenever possible, these techniques were used in tandem, with unobtrusive observations followed by a depth interview. Each of these data collection methods is described below. All our interactions with visitors were guided by a visitor observation-interview protocol (Appendix B), developed from the topical framework and in consultation with the Social Science Program of the National Park Service.

Unobtrusive Observations
We began our data collection by observing visitors using the Trail of Time. We usually found a place where interesting behaviors seemed to be taking place, such as near a scale-change station or interpretative label, and then we stood as unobtrusively as possible on the side of the Trail away from the Canyon. To focus our observations we looked at four types of visitor engagements with the Trail: Physical, intellectual, social, and emotional. These four types of engagements were not—and are not meant to be—mutually exclusive.

- **Physical engagements** were all the physical things visitors did with the Trail, for example, walking, standing and talking, resting, pointing, reading, spending time, ignoring, etc. These were not predetermined categories of behavior. Rather we noted the variety of things respondents did, which were then categorized during analysis and described in meaningful ways.

- **Intellectual engagements** were all the ways in which visitors engaged with the Trail in cognitive and intellectual ways. Intellectual engagements included the ways visitors talked about, processed, and made meaning of their experiences.

- **Social engagements** were the ways in which visitors engaged with each other within the context of the Trail. Social engagement included verbal exchanges as well as body language. Research indicates that most informal science learners learn not from the exhibit itself but from each other (Diamond, 1986). Because we were interested in the educative experience at the Trail, we paid special attention to the extent to which and ways in which visitors engaged socially, paying particular attention to active meaning making within visitor groups.

- **Emotional engagements** were all the ways that visitors engaged emotionally with the Trail. Research indicates that the emotional content of experiences is an important aspect of how visitors remember, reflect on, and process their visits (Anderson, 2004). We paid special attention to evidence of surprise, satisfaction, and other evidence that connections between the Trail and the Canyon enhanced visitors’ emotional engagement with Grand Canyon. This category also includes frustration induced by unsuccessful attempts to make meaning from the sparsely interpreted prototype of the Trail.

Depth Interviews
Depth interviews were open-ended and free flowing. We had a standard opening statement and a list of questions to guide the conversation, but not all questions were asked of all respondents, and additional questions were asked depending on the issues and topics that emerged during the
conversation. We approached most respondent groups along the Trail, after we had observed them looking at or talking about the tick marks or signage. We started most conversations by asking respondents about the behaviors we had just seen, and then most conversations flowed from what respondents told us about their engagement with the tick marks and signage and their reactions to the Canyon.

Sometimes we introduced the idea of time to the conversation when it did not come up spontaneously, usually by asking respondents if they had thought about time before they encountered the tick marks, or by asking them if their first look at the Canyon had brought to mind anything related to time. When respondents expressed confusion or misconceptions about the Trail or its geologic concepts, we gently tried to guide them toward a more complete and accurate understanding of the timeline concept behind the Trail. Although we tried introducing the brochure at various points in the conversation, we found it was most effective when we handed it to respondents after we had explained the Trail’s timeline concept and could point out particularly relevant graphics that explained aspects of the Trail. At the end of the interview, respondents were thanked for their time and given a small token of appreciation.

**Data Analysis**

Data analysis for this study has been an on-going process using a modified inductive constant comparison approach (Lincoln & Guba, 1985). The method takes each unit of data and systematically compares it to all previous units of data. Data analysis took place at four junctures.

- **First level.** The first was during the actual observation/interview. As data was gathered in the field, preliminary understandings were developed and tested with respondents.

- **Second level.** The second level of analysis took place after the interview and/or observation was completed. The researcher sat down to write up a debrief by hand in a field notebook. The debrief included a brief description of the group and why it was chosen; a summary of the data collection session; and the researcher’s interpretation of the session, comparing it to previously collected data. At the same time, the researcher also developed questions to be explored in subsequent data collection sessions, including any special areas of interest that should be explored.

- **Third level.** The third level of analysis took place at the end of the day, when the researcher sat at a laptop computer and composed a formal summary of the day’s data collection, including a more in-depth analysis of the findings.

- **Fourth level.** The final level of analysis occurred after the researcher returned from the field and had access to the full data set, plus the relevant geoscience education literature. At this point the researcher reviewed all the data and began writing the final report.

As the analysis proceeded, we triangulated findings from the formative evaluation with research from the geoscience education literature and with evaluation studies conducted at other parks and in museums. The geoscience and science education literature included a number of studies about people’s understanding of geologic time (e.g., Ault, 1982; Dodick & Orion, 2003 a & b; Trend,
Selinda Research Associates, Inc. 13

1998, 2000, 2001, 2002) and of people’s understanding of rocks and how they form (e.g., Ault, 1984; Dodick & Orion, 2003 a & b; Ford, 2003; Frodeman, 1996; Kusnick, 2002; Libarkin & Kurdziel, 2001). The evaluation literature included both front-end studies about museum visitors understanding of geologic time and formative evaluations of attempts to communicate geologic time to museum visitors (e.g., Hayward, 1992, 1993; Marino, Harvey, Loomis, & Sundine, 1994). These references were mostly drawn in a collection maintained by the senior author, who also maintains a classified bibliography of geoscience education research studies at the following Web address: http://www.museumdeveloper.net/understanding/underprehist.htm

Respondents

Respondents included visitor groups to the south rim of the Grand Canyon. All respondents were part of the larger universe of the general visitor as defined by the Grand Canyon National Park Comprehensive Interpretive Plan, May 2002. Our main criterion for choosing groups to interview was seeing someone in the group pay attention to the tick marks or interpretive signs. When possible, we also tried to achieve a balance among types of groups (adult only, families with children, and visitors on their own) and racial and ethnic background.

We spent two days collecting data at Grand Canyon, including approximately 12 hours of contact with visitors (both observations and interviews). More information about the respondents is tabulated in Appendix C. We observed 89 general visitors in 38 groups, consisting of 77 adults (apparently 18 years and older) and 12 children. This included roughly equal numbers of males and females. Out of 35 attempted interviews, two groups refused to talk with us. We talked with at least one member from the 33 remaining groups as part of a depth interview. Racial diversity in our sample was limited, in part because of the nature of the audience and in part because of difficulty communicating with non-English speaking visitors. Of the 35 groups listed as white, at least seven were composed of visitors who were not native to the United States. Their countries of origin included Australia, England, the Netherlands, Poland, and Scotland. We also observed and interviewed some members of a school group at Yavapai Observation Station, but we did not include that data in our summary data because that was not part of the target audience for this phase of the study.

Limitations

Due to limited resources, this study was necessarily limited in scope. For instance, when conducting an evaluation study using naturalistic methodologies, it is standard practice to continue collecting data until a state of redundancy is reached. Redundancy is the point at which no new information is gleaned despite repeated attempts to elicit additional findings. We seem to have achieved redundancy on many of the issues listed in the topical framework, such as the effectiveness of the prototype markings and signage and visitors’ understanding of the cutting of the Grand Canyon. However, we received a more limited range of responses in some areas of the study, such as visitor understanding of the rocks layers and their formation and of geologic time in the abstract.

The first prototype of the Trail of Time was very roughly developed, and the interpretative labels were very incomplete, thus this was very much an early-stage formative evaluation. We have to keep this in mind when interpreting the data. Whatever problems visitors had understanding the
Trail and its geologic concepts may have been due to the incomplete interpretation, rather than to the inherent difficulty of the concepts or problems with the timeline analogy behind the Trail. For that reason, we continued to probe visitors developing understandings of the Trail and related concepts as we explained the timeline concept and discussed their understandings of the Canyon’s rocks and landforms. These depth-interview findings, which in many ways seemed more like a front-end study than a formative evaluation, are factored into our conclusions and recommendations for the continued development of the Trail.

Finally, where appropriate in the report, we supplement our formative evaluation findings with research from the geoscience education and visitor studies literatures, and we identify issues that warrant further exploration during later stages of formative evaluation.

**Project Approval**

This evaluation project was approved as OMB Approval #1024-0224 (NPS #04-058) Grand Canyon NP Trail of Time Exhibit. A copy of the completed approval form is attached as Appendix D.
RESULTS

Visitors' Understandings and Feelings about Grand Canyon and the *Trail of Time*

*Visitor Engagement with the Grand Canyon*
Almost all the visitors we talked with expressed awe, wonder, or even spiritual feelings at their experience of the Grand Canyon. Many visitors talked about the immense size of the Canyon, although they seemed to have difficulty coming up with comparisons that gave it meaning. The need to come to grips with the size of the Canyon may be one reason why visitors seemed so intrigued by evidence of humans and their constructions in the deep Canyon. It may also explain why visitors searched for comparisons for both the size of the Canyon and the emotional experience of seeing it in person. Attempts at this varied from the mundane ("It’s much bigger than Niagara Falls") to the creative ("You expect to see this much rock up in the air, not down below"). Some just gave up, like the visitor who called his relatives by cell phone to tell them, "Words can’t describe it!"

When we discuss visitors’ ideas about the cutting of the Grand Canyon, it will be important to remember how impressed visitors were by the size of the Canyon; that may explain some of their difficulties with understanding how it formed. It is useful to know that some visitors expressed surprise at the great width of the Canyon, which far surpasses its depth. Some of the visitors’ more creative ideas about the formation of the Canyon may be attributed to their need to explain its width, as well as its depth.

Many respondents (although not a majority) told us that *time* was one of the first things they thought of as they looked at the Canyon, even before they first noted the time markers along the *Trail*. Most of these visitors said they had been thinking about how long it took to make the Canyon, or how long ago it happened. Some visitors also commented about the immensity or incomprehensibility of the time it took to make the Canyon. Most of these visitors did not have an accurate understanding of the time involved, although some had developed fairly accurate understandings based on interpretation available in the Park or other previous experiences.

*Visitor Engagement with the *Trail of Time*
We were impressed by the amount of attention visitors paid to the tick marks and labels along the *Trail of Time*, and by the energy they devoted to trying to make sense of them.

**Physical engagement**
By far the most common physical engagements with the *Trail of Time* were (a) looking down at the markings along the *Trail*, the labels on the path, or the scale-change stations while walking, (b) stopping to look more closely, and (c) sometimes pointing at labels or tick marks. Although we saw many visitors stop and briefly read the *Trail* signage at the Yavapai end of the Time Accelerator or at the Mather end of the *Trail of Time*, few visitors we talked to along the *Trail* specifically mentioned reading those labels.

When we saw visitors step off the distance between tick marks, it most often was because they wanted to demonstrate to us that the tick marks were spaced more widely than most people
normally step. We saw one man kick at a marker; he later told us that was because he thought it was litter.

Many respondents told us that they first started walking along the Trail somewhere beyond the trailhead, or that they did not notice the tick marks and labels until sometime after they began walking the Trail. These visitors completely missed the introductory interpretation placed at the Yavapai and Mather trailheads, and they had to make sense of it based on evidence available along the body of the Trail. It seems that explanatory exhibits at the beginning and end of the Trail are not going to be enough to help all visitors understand what it is and what it means. Visitors will need sufficient explanations of the concept of the Trail of Time periodically along its length.

**Intellectual engagement**

Initially, visitors’ intellectual engagement with the Trail of Time seemed mostly about puzzling out the meaning of the tick marks, sometimes coming up with tentative theories, but sometimes not. We were impressed that most of the visitors we talked with really wanted to understand the markings and signs on the Trail. They wanted to know what the individual tick marks represented, why they had been placed there, and what visitors were supposed to get out of them. This suggests that the Trail has the potential to fulfill visitors’ desire to better understand the Canyon and how it formed.

Most visitors we talked with realized the Trail markers had something to do with time, but that realization alone was not enough to satisfy them. Since they did not find much evidence along the Trail to explain the tick marks, they used what evidence they had to develop tentative theories about the meaning of the Trail. Visitors’ theories made creative use of the limited amount of information available to them along the Trail, including positions of the tick marks relative to the Canyon and the limited signage, and also incorporated their previous experiences and knowledge about rocks and erosion. Most visitors’ theories were incomplete or incorrect in important ways, for example:

- **Linked to place.** Visitors often tried to link the meaning of a tick mark to its exact place along the Trail. They wanted the marker to tell them something about where they were standing, or what they were seeing from that point. We give examples under the next few bullet points.

- **Linked to elevation.** Visitors sometimes linked the tick marks to the elevation of the Trail at that point, or to elevations in the Canyon. For instance, one respondent guessed that the tick marks showed the depth that the cutting of the Canyon had reached at that time. We give other examples of links to elevation in the next two bullet points.

- **Erosion.** Visitors usually included some reference to the erosion of the Canyon in their theories about the Trail markings. Two groups walking along the Time Accelerator guessed that the tick marks showed how far back the Canyon had been cut at that point in time, and another guessed that the marks showed “how much stuff had been washed away” to make the Canyon. Yet another respondent stated rather emphatically that the tick marks showed “when this part of the Canyon formed – about 10,000 BC.” A few
visitors linked the tick marks to the processes they saw as responsible for the Canyon’s erosion, such as the respondent who guessed that the tick marks must show “how fast the glacier moved.” Another group guessed that the tick marks showed what “level the water was at that point in time.” This explanation was based on a theory about canyon cutting that had the Canyon filled with water as it eroded, by analogy with what the respondents knew about the undersea Baltimore Canyon.

- **Rocks.** Visitors’ theories about the Trail of Time sometimes mentioned the rocks in the Canyon walls. For instance, one group said they wondered if the tick marks might stand for rock layers in the Canyon, and another said time markings were related to the ages of the rock in the Canyon; however, these theories were advanced along the Time Accelerator portion of the Trail, where the dates were much younger than the true ages of the rocks. One respondent guessed that the tick marks meant steps down into the Canyon – go down 100 steps, get to 100 million-year-old rock. Another respondent (one of the few who said anything about the scale changes) speculated that the markings were linked to the depth of the Canyon, and the scale changes showed that the same thickness of rock represented more or less time. Another respondent talked about the rock layers as benchmarks for erosion, speculating that the date markings told what rock level (i.e., how deeply) the cutting had reached at that time.

- **Metaphor.** Visitors who figured out that the Trail of Time was a timeline occasionally looked beyond the literal meaning for the time markers to find the metaphoric value of the Trail. These few respondents linked the Trail to the immensity or incomprehensibility of the amount of time it took to make the Canyon.

Overall, we see these theories as smart visitors trying to make sense of a prototype exhibition that was short on interpretation. Once visitors had started to figure out the time elements of the Trail, they still were not satisfied. They also wanted to know what the people who placed the tick marks were trying to accomplish with them, or what story they were trying to tell. Also, visitors’ alternative understandings of the Trail were of great interest to us because they revealed some visitors’ thinking about nature trails in general, the Grand Canyon itself, and the processes that formed it. We will describe visitors’ tentative theories about the Trail and the formation of the Canyon in the later sections of the report (Knowledge hierarchy for visitor understanding of the Trail of Time and The Cutting of the Canyon).

Once visitors started to make sense of the Trail, they seemed to enjoy applying what they had figured out during the rest of their hikes. For instance, when we encountered visitors after our initial interviews, some commented about the how far they had walked in terms of millions of years. Walking back toward Mather, one respondent said, “We only made it out to 980 million years, and then we had to turn back.” We also heard from Park staff that some visitors used the dates along the Trail to remember where their cars were parked (Ellen Seeley, personal communication, October 18, 2004).
Social engagement

Social engagement around the tick marks and labels mostly seemed to be talking about the meaning of the *Trail* markings, discussing the scale-change stations, reading aloud, and discussing the occasional signage about geologic events and rock units.

Among all-adult groups, some visitors explained their developing theories to others in their group, leading to short discussions. One visitor, who was walking along lecturing his companions about the age of the Canyon, explained the time markers with confidence (although he gave them an alternative meaning to what was intended). However, most visitors’ theories about the time markers were expressed very tentatively, if at all. Also, there were some complaints and expressions of frustration about the lack of explanation about the markers within social groups (and more of that to us, during interviews).

We observed a number of parents talking with younger children about the *Trail of Time*. One parent, whose family earlier had participated in a ranger-led program, seemed confident enough to try to explain the *Trail* markers with her children. We overheard another parent tell his teenage son to “pay attention to the events” on the labels and then talk with him about a “glacial advance” that could have occurred at that time. We also heard a boy, about eight years old, ask his father, “What’s 6,000?” The father answered, “I think there’s a chart or map you are supposed to have.” An adolescent boy, who had been talking with his family about “millions and billions of years,” told us he had read those numbers on a sign at Mather Point. We also overheard several families with young children talking about birthdays along the Time Accelerator. One boy mentioned looking for his birthday while at about 10,000 years before the present, and then someone made a joke about his Mom’s age. Birthdays seemed to be a point of identification among the younger visitors along that section of the Time Accelerator.

Among groups that we had not observed discussing the *Trail*, some told us they had discussed the markers earlier during their hike, or even the previous day. One group told us they had been trying to figure out the *Trail* since the previous afternoon. However, most of the conversations we overheard along the *Trail* were about the Canyon itself, or about personal matters. It seemed that most visitors could only go so far with their conversations about the *Trail*, given the limited interpretative information that was available.

Emotional engagement

Most respondents, at some point during their interviews, discussed their emotional reactions to the beauty, size, colors, and other attributes of the Grand Canyon. As noted earlier, the completed *Trail of Time* is intended to build on visitors’ emotional engagement with the Canyon and not detract from it.

The most common emotional engagements with the *Trail of Time* were (a) interest and curiosity about the tick marks and limited signage along the *Trail* and (b) frustration about not being able to make sense of the *Trail* and understand why it was there, based on the very limited interpretation available with this first-stage prototype. Some respondents’ frustration was expressed in somewhat angry tones. A few respondents who had begun to figure out the metaphoric value of the *Trail* expressed their awe at the immensity of time it took to make the
Canyon. However, we doubt many felt that way before we had confirmed their interpretation of the Trail’s meaning.

Two groups expressed disappointment and a bit of anger with the Trail because its message conflicted with their religious beliefs. We interviewed one couple and tried to interview another who we overheard complaining that the date markers did not fit with their beliefs in a Biblical time-scale for the age of the Earth.

**Visitors’ Developing Understandings of the Trail of Time**
In this section, we describe in greater detail how visitors seemed to be making sense of the Trail of Time, and how far along they seemed to get with their developing understandings. We also describe how visitors’ learning along the Trail fits in with current theories about informal learning. Finally, we describe some findings about visitors’ learning along specific segments of the Trail.

**How visitors tried to make sense of the Trail of Time**
When visitors were figuring out the Trail on their own, they seemed to advance through a series of steps that helped them begin to make sense of it. In this section we discuss some of those steps; in the next, we arrange these steps into a knowledge hierarchy.

- **It’s about time.** This included figuring out that the periodic date markers (e.g., Fig. 2) refer to time (e.g., m. y. ago = million years ago). Most respondents got that far, but there was some uncertainty, a few wrong guesses, and a few visitors who said they could not even begin to figure it all out. Wrong guesses for “m.y.” included “millennia” and “miles and yards.”

- **It’s about flow of time.** This step included figuring out that time “flowed” or decreased in one direction – to time zero. Many respondents got this far.

More difficult things for visitors to figure out seemed to include:

- **Time got really large.** After they figured out that there was a time zero, visitors also had to figure and/or find out that the times got really large if you kept going in the opposite direction from time zero. That discovery was important, because it helped visitors begin to think more deeply about the immensity of time.

- **Tick marks.** As noted earlier, many visitors had trouble figuring out exactly what the unlabeled, evenly spaced tick marks stood for. Respondents came up with all kinds of guesses, most of them far from the teams’ intentions. Perhaps the most difficult thing for visitors to realize was that almost all the tick marks along the Trail—labeled and unlabeled—were not directly linked to the place where they were inscribed along the path.

- **Events and features.** Many visitors had trouble finding and/or figuring out that there were geological events/features marked by larger labels, and that the times on these labels (a) fit into the flow of time shown by the markings and (b) related to something that happened here at the Grand Canyon in the past.
• **It’s a scale.** Some visitors told us they had begun to think of the *Trail* as some kind of scale, although they had not always developed that idea fully when stopped for an interview. Sometimes respondents said they had seen the word “scale” in a label, but others seemed to figure it by analyzing other evidence.

Visitors who figured out most or all of the above points had most of what they needed to understand the timeline concept behind the *Trail*, although some still needed time to reflect on or discuss the evidence before they put all the pieces together. Our interviews often provided that opportunity for reflection.

When interview respondents did not understand the *Trail of Time*, we did our best to explain it to them toward the end of the interview. The timeline concept seemed to be a good way to explain the *Trail* with just words, perhaps because it implied an appropriate level of abstraction (helping visitors realize that tick marks did not relate to a particular place in real space). We often asked, “Remember seeing timelines in history books? This is a timeline like that, but laid out along a trail on the ground.” That often got visitors thinking in the right direction. It also helped when we could point toward Yaki Point and say, “That point is where the timeline begins, 4.6 billion years ago when the Earth formed.” However, the timeline concept did not work for everyone. For instance, one respondent insisted that timelines had to be vertical; he was confused by the idea of a horizontal timeline.

Ultimately, it seemed that past events—the story of the Canyon—gave meaning to the *Trail of Time*. However, with the prototype *Trail*, these events seemed too widely spaced and too sparsely explained for most visitors to figure out that the *Trail* had a story to tell about the Grand Canyon’s past. For instance, one group said they walked from about 7 million years ago to 3 million years ago along the Time Accelerator; however, because they had missed the one marker about the beginning of Canyon cutting, they were not able to figure out why someone had put all those marks on the *Trail*.

Several respondents asked if they had missed explanatory exhibits at the beginning of the *Trail*, implying that they might have gotten the idea if they had seen clear explanations when they began. Although improved introductory exhibits may have helped many visitors, our findings suggest they will not be sufficient for other visitors who join or begin paying attention to the *Trail* somewhere beyond the trailhead.

When we gave people the draft brochure, they seemed hopeful that it would help them clear up their confusion about the *Trail of Time*. We usually explained the timeline concept first, and then gave respondents the brochure. We found that the large foldout map helped visitors understand the size-scale of the *Trail*, and the many events marked on the map gave visitors the impression that the *Trail* told a story. A few respondents started reading through the brochure on the spot, but others looked it over and said it would be more appropriate for later, when they could sit down and study it. A few respondents who had experience with geologic cross-sections liked the one in the brochure, but the big trail map with events marked seemed most useful to most respondents.
Many visitors, even those who understood the timeline concept, found themselves stumbling over and getting confused by the large numbers used to measure geologic time. When looking at or thinking about one number, they wound up saying another number. For instance, one couple was confused by the step-equivalent sign at the beginning of the Mather to Yaki section because they misinterpreted 1,000,000 as “ten million years.” We also stumbled over number terms as we tried to talk with visitors about the age of the Canyon’s rocks. Other evaluators who have studied visitors’ comprehension of large numbers have noted this problem. In conducting formative evaluation for the Field Museum’s Life Over Time exhibition, Hayward (1992, 1993) found that less than half of his sample recognized that 3.5 billion, 3 billion 500 million, and 3,500 million were different ways of writing the same number. As the Life Over Time exhibit team used to say, “People get their -illions mixed up” (Eric Gyllenhaal, personal communication, November 3, 2004).

Knowledge hierarchy for visitor understanding of the Trail of Time
When visitors show a range of understanding of an exhibit or concept, as they did for the Trail of Time, one useful way of describing such data is through the development of a knowledge hierarchy (Perry, 1989, 1993). A knowledge hierarchy presents a range of visitor understandings about a certain topic, based on the assumptions that (a) there is an internal knowledge structure inherent in an exhibit topic, and (b) this hierarchy is located at the intersection of the exhibit developer's and the visitor's organization and understanding of the topic. Thus, a knowledge hierarchy is simply a description of the range of visitors' pre-existing understandings about a topic within the context of the planned exhibit. It emerges from the data, rather than being predetermined by the researchers. It usually describes six or seven levels of understanding, which characterize a full range of how visitors think about a topic, usually by increasing levels of sophistication, representing, in manageable form, virtually all visitors' understandings about that aspect of the topic. As such, knowledge hierarchies are a way of helping us address the needs and interests of a greater proportion of our multiple audiences.

The structure of knowledge hierarchies tends to follow the following pattern (adapted from Perry, Garibay, & Gyllenhaal, 1998). This example has six levels, although five and seven level hierarchies are sometimes more appropriate.

Level 0: "Don't know and don't care." Visitors at this level often have not thought much about the topic and have not developed any particular interest in it. Visitors at this level can develop a curiosity about topic; it is just that they have not thought about it much on their own.

Level 1: "Don't know, but I was wondering." These visitors have formed questions about the topic in their minds, but they have not yet developed answers to their questions.

Level 2: These visitors are interested enough in the topic that they have formed some understanding of it, but their ideas are unsophisticated, largely incomplete, and sometimes incorrect in important ways.

Level 3: These visitors have a fairly accurate basic understanding of the topic, although they may be fuzzy or sometimes incorrect on the details.
Level 4: These visitors have a more sophisticated and accurate understanding of the topic and may articulate detailed information about one or more aspects of it. These visitors often have a particularly strong interest, background in college-level courses, or direct experience working with the subject.

Level 5: These visitors have a very sophisticated understanding of the topic, and include people who have studied the topic extensively or have chosen a career related to the topic.

Later in this report we will present knowledge hierarchies for several geoscience concepts represented along the Trail of Time. At this point, however, it seems useful to consider a knowledge hierarchy that we developed for the Trail of Time itself.

Level 0: "I don't know what those tick marks on the trail are, and I don't care." By convention, visitors would be placed at this level because they had expressed little interest in the markings and signs they found along the Trail of Time. In practice, groups that had just arrived at Mather Point and had not yet noticed the tick marks started out here, as did the gentleman who said he kicked at the markings because he thought they were litter. However, once a group noticed the markings and signs, they rarely stayed at Level 1 for long.

Level 1: "I don't know what those tick marks and signs are, but I'm curious." These visitors had seen the tick marks and did not know what they were about, but they were curious. Most respondents seemed to quickly reach this level, but once they started to develop their own theories about the tick marks, they jumped to the next level.

Level 2: Developed some ideas about the tick marks on the trail, but they are incomplete or incorrect. Many respondents had either reached this level before the interview or achieved it as we talked with them what the tick marks meant. These visitors had a range of alternative understandings about the Trail. Some of them were beginning to figure out that the Trail was a timeline, but they still had some misunderstandings about what that meant. For instance, many respondents wanted to link the periodic markings to (a) the elevation of the Trail at that point, (b) events that took place at that specific point, or (c) landscape features they could see especially well from that point. Other visitors on this level were coming closer with their guesses about the Trail but were unable to confirm what they had figured out on their own. Most visitors at this level were frustrated to some degree, and some were getting angry. Also, we would place the two groups that said they believed in Biblical time here, because they understood enough about the Trail to realize that it conflicted with their beliefs.

Level 3: The tick marks and signs are part of a timeline with a beginning and end, and the trail markings are part of that timeline. These visitors (a) had the basic idea that the Trail of Time was a timeline; (b) knew that it had a beginning (at the present)
and guessed that it had an end (but most did not know what that was); and (c) did not try to link the meaning of the tick marks to a specific spot along the Trail or on the Canyon wall. To reach this level, visitors had to realize that the Trail was an abstract timeline draped along the rim of the Canyon, and that the location of the tick marks was relative to the timeline rather than features or events in the Canyon. A few respondents had reached this level before we explained it to them, and many seemed to reach it once we explained the timeline concept. At least two respondent groups applied this knowledge to the rest of their walk along the Trail, based on their comments when we met later in the day.

Level 4: The timeline tells about events that formed the Grand Canyon. This level could include respondents who found labels that helped them link the timeline to geologic events like the cutting of the Canyon. We talked with a few groups who seemed to have reached this level on their own, and we helped a number of others reach this level by showing them the trail map inside the brochure.

Level 5: The timeline is a metaphor for the immensity of geologic time. This level could be reserved for those respondents who go beyond a literal understanding that the Trail is a timeline toward an understanding of the Trail’s metaphoric meaning. In other words, the Trail got them thinking about and even feeling the immensity of time as it related to the Grand Canyon. Several respondents reached this level after we explained the timeline concept. Note, however, that our explanations only got them to Level 4—then they jumped to Level 5 on their own.

Level 6: The Trail of Time is a tool for helping visitors learn about “deep time,” which is a key concept in geology, biology, and astronomy. This level might be reserved for geologists and educators who have a complete understanding of the Trail and what it is trying to accomplish. Note that the Trail’s interpretation should not try to teach visitors on this level new facts and concepts about geologic time (although they may pick up a few details about local geology). Rather, it could inspire them to use the Trail, its Web site, or similar resources in their own teaching.

Most respondents were at Level 1 or 2 at the start of the interview, and most moved up a level or two during the interview. Adults and older children certainly seemed capable of understanding the timeline concept, the story of the Canyon, and even the Timeline’s metaphoric meaning when we explained it to them. The challenge will be to explain the Trail of Time concept through relatively unobtrusive interpretation placed at wide intervals along the Trail.

Also, it is important to understand that this hierarchy describes the current situation that we found along the Trail. By restructuring the goals and interpretation along the Trail, the project Team may also restructure the resulting knowledge hierarchy. For instance, one goal for the next stage of the project might be to combine the current Levels 3, 4, and 5 in ways that make it possible for more visitors to reach a new Level 3 understanding that combines the timeline, story, and metaphoric value of the Trail. In other words, with the final version of the Trail of Time, perhaps many more visitors will realize that the Trail is a timeline that lets them feel the immensity of time as it relates to story of the Grand Canyon.
Again, the challenge will be to accomplish this goal through relatively unobtrusive interpretation placed at wide intervals along a “porous” Trail (i.e., one where visitors enter and leave all along the Trail). It also may be difficult to move visitors away from their desire to link tick marks to specific points along the Trail.

Visitor learning about the Trail of Time
As visitors tried to make sense of the Trail of Time and the Canyon’s geology, they often developed incomplete or incorrect theories to explain what they saw, which they often expressed to us in a tentative or questioning way. These theories seemed to combine:

• **Interpretation** available along the Trail, such as the trail markings and signage,

• **Visitors’ observations** about how these features related to the landscape and rocks along the Trail, and

• **Visitors’ previous knowledge** about geologic phenomena, such as erosion by rivers, glaciers, wind, and large bodies of water (such as lakes and oceans).

We saw and heard many examples of visitors applying things they had learned elsewhere to their developing understandings of the Canyon and Trail of Time. These examples included applying observations, facts, and concepts that visitors had learned:

• **At Grand Canyon** visitor centers, at the Imax theater near the entrance to the Park, on ranger walks, and during helicopter tours, and

• **Far from the Canyon**, including in school, at other parks, and in their everyday lives.

This illustrates the value of explaining things to visitors in these informal settings. These facts and concepts stuck with visitors, and they were able to remember and apply them later during their visit to Grand Canyon. However, even with their pre-existing knowledge, visitors needed more help to figure out the timeline concept and the Canyon’s geology. Without appropriate help, they often came up with alternative understandings that were incomplete or incorrect from a scientific perspective. We discuss the details of visitors’ developing understandings later in this report (e.g., *Visitors' Understandings and Feelings about Geological Concepts Related to the Trail of Time*).

For now, we point out that visitors’ alternative understandings of science concepts have been studied extensively in museum settings and discuss some implications of those studies. For instance, Lucas (1993) gives numerous examples of people “constructing knowledge from fragments of learning” (p. 134) in out-of-school settings, including incidental learning from television programs and more purposeful attempts to learn from museum exhibits. Lucas shows how laypeople can draw on ideas learned from a variety of informal sources as they try to make sense of an exhibit or idea. He also includes several examples of how concepts accidentally juxtaposed through poor wording or placement of exhibit labels can confuse or confound visitors’ thinking, resulting in misunderstandings about the exhibit.

*Selinda Research Associates, Inc.*
Roschelle (1995) focuses specifically on how visitors construct new knowledge from what they already know, and he describes three implications for exhibit teams:

- **Seek to refine prior knowledge**, rather than attempt to replace it (p. 40). “Prior knowledge is properly understood not as the cause of errors or success but as the raw material that conditions all learning” (p. 41).

- **Anticipate a long-term learning process**, of which the short-term exhibit experience forms an incremental part (p. 40).

- **Remember that learning depends on social interaction**, and that conversations will shape the form and content that learners construct (p. 40).

Given Roschelle’s (1995) caveats, it is important to note that many visitors who come to national parks seem to be involved in a long-term learning process about the parks. Recent survey results (Cothran, 2004) suggest that two-thirds of visitors to Grand Canyon obtained information about the Park and surrounding area before their visits, and that they consulted many sources of information as they planned their trips, including the Internet (37% of fall, 2003 visitors said they used it for pre-trip information), Grand Canyon National Park Web site (22%), and TV programs and documentaries (18%). Although it is not clear how many Grand Canyon visitors had attended to geologic information before their visits, we learned in our front-end evaluation study in Yellowstone National Park that many visitors attended to multiple sources of information about the geology of Yellowstone before, during, and even after their visits (Gyllenhaal, 2002).

We described Yellowstone visitors as building a kind of “island of expertise” about the Park (Gyllenhaal, 2002). Crowley & Jacobs (2002) introduced the term “island of expertise” to describe an area of relatively deep and rich knowledge that people develop when they are passionately interested in a topic. Although Crowley & Jacobs apply this concept to children, it also seems to describe many of the adults we talked with at Yellowstone and Grand Canyon National Parks. In keeping with Roschelle’s (1995) emphasis on social interactions, Crowley & Jacobs (2002) emphasize the role that parents play in their children’s development and maintenance of knowledge, both as mentors and co-explorers on the road to a shared island of expertise. We found parents who were playing a similar role in their children’s learning about Yellowstone and Grand Canyon. We also found examples of adults mentoring other adults as they learned about the park and of adults sharing as they explored the park together. Park rangers also seemed to take on a mentoring role for some visitors.

According to Cothran’s survey (2004), many Grand Canyon visitors also visited other parks in the area, including Zion, Bryce Canyon, the Painted Desert, Petrified Forest, and Monument Valley (which were all visited by between 15 and 30% of the Grand Canyon respondents). Thus laypeople with an interest in geology may develop an archipelago of expertise about regional geology. Perhaps one goal of the *Trail of Time* can be to help these visitors find links between these individual islands.
Because many visitors seem to be involved in a longer-term learning process about the Park and surrounding area, the “incremental” role played by exhibits like Trail of Time can be particularly important and effective. But can exhibits help visitors reformulate their misunderstandings about the Park and its geology? In studies of exhibits that specifically tried to change visitors’ alternative understandings of science concepts, researchers have found that:

- **Formative evaluation of prototype exhibits is critical.** Iterative prototyping-and-evaluation can improve visitor learning dramatically (Borun, Massey, & Lutter, 1993; Mintz, 1995).

- **Labels must be tested iteratively, as well as the prototype exhibits.** Inappropriately worded labels can reinforce or increase visitors’ misunderstanding of science concepts; however, careful testing of alternative label texts can help exhibit teams guide visitors’ understandings in scientifically appropriate ways (Borun et al., 1993; Mintz, 1995).

We hope the project team will take those findings to heart as they continue to develop the Trail of Time.

**Time Accelerator, main Trail of Time, and the transition between these two segments**

As noted in the introduction, the prototype Trail of Time was divided into several segments, and we had specific questions we wanted to answer about each of them.

**Time Accelerator**

With the Time Accelerator, we wanted to know, “To what extent do [visitors] notice and react to the changing time scale? In what ways does this changing scale enhance or confuse their understanding of geologic time?” In short, the answer to the first question was that most visitors did not notice or talk about the scale changes as such, so they did not get confused by them. Because most visitors had only a tentative grasp of the idea that the Trail was a timeline, they had little reason to wonder why the time scale would be changing.

In fact, the scale-change stations on the Time Accelerator segment (e.g., Fig. 7) actually helped visitors make sense of the Trail, because they were scattered along the Time Accelerator and because trail-walkers seemed much more likely to see the scale-change stations than the information at the trail heads. The aspects of the scale-change stations that seemed to help included:

- **Step equivalents.** The statements that equated a “step” to a unit of time were often cited as an important clue.

- **The title, “Trail of Time.”** The repeated “Trail of Time” seemed to set some visitors on a journey to understand why the Trail was called by that name.

- **“Scale.”** A few visitors mentioned that the word “scale” helped them think of time scales.

- **Arrows.** The arrows may have helped give some visitors a hint of the continuity of the Trail and the flow of time.
Based on these findings, the *Trail of Time* would benefit from some kind of time-update station that incorporates the useful aspects of the scale-change stations to give visitors periodic reminders (a) that they are walking on a timeline, (b) what a step means, (c) how far they are from the beginning and the end, and (d) why it matters (i.e., what is the *Trail* trying to tell them about Grand Canyon’s geology). These time-update stations should also find ways to help visitors realize that each individual, unlabeled tick mark is where it is because it is part of the abstract timeline, not because there is something particularly important about the place in space.

Another thing we discovered about the Time Accelerator segment was that most visitors had not seen any of the labels that described events in the formation of the Canyon. This may have been because the interpretive labels taped to the asphalt were too inconspicuous (especially when other visitors were standing on them!) or because visitors had not yet passed any of them (at least not since they had developed an interest in the *Trail*). This suggests that the next phase of the *Trail* development will need more strategically placed interpretative labels, and that they may need to be more conspicuous.

*Main Trail of Time*

There were no scale changes on the Mather to Yaki part of the *Trail of Time*, except at the very beginning. That may help explain why only a few visitors we met on this section of the *Trail* had figured out the entire timeline concept on their own.

Because few visitors understood the basic idea of the *Trail*, it was hard for us to answer the following questions from the topical framework: “In what ways do [visitors] relate to the length of the *Trail*, and to opportunities to view the end of the *Trail* from the beginning, and from intermediate points? Do they comprehend that the first 10 meters of the main *Trail* is a repeat of the Time Accelerator segment?” We can say that once we had explained the timeline concept, visitors seemed to appreciate it when we pointed to the end of the *Trail* at Yaki Point. We can also say that when we met visitors an hour or more after our initial interviews, they talked about their *Trail* experience in ways that suggest they really understood the timeline concept. No one we talked with on the main *Trail* realized there was an overlap between the two *Trail* segments, probably because most of them did not recognize that there were two segments (until we explained it to them).

*Transition between the two segments*

The main questions we wanted to answer about the transition area at Mather Point was, “Is there a smooth conceptual transition between the Time Accelerator and the main *Trail of Time*; do visitors see it as one trail, or as two separate trails?” and, “Does the change of scale or the short distance between the two segments confuse [visitors], or does it help them make a conceptual jump between human and geologic time scales, or both?” However, because most visitors had only a vague idea that there was a timeline called the “*Trail of Time*,” it does not make sense to think in terms of the conceptual transition between the two segments. Nobody we talked with realized there were two segments with different scales.

There were some important differences in visitors’ experiences of this transitional segment compared to the major segments of the *Trail*. When visitors from the parking lots or bus stand first walked out onto the Mather Point “plaza” area, they often did not notice the markings on the

*Selinda Research Associates, Inc.*
ground. Also, many visitors to this area did not walk very far along the Trail, so they were less likely to encounter interpretive signage than visitors to the other segment of the Trail. That means that visitors who did notice the tick marks at Mather plaza had a harder time figuring out what they meant.

**Connecting the Trail of Time to the landforms in the Canyon**

The topical framework asks, “In what ways and to what extent do visitors talk about landforms in the Canyon as they walk along the Trail?” There were many indications that visitors really wanted to connect the Trail to landforms on both the rim of the Canyon and within the Canyon. For instance, many respondents incorporated aspects of the Canyon’s erosion into their developing theories about the Trail, and others asked questions about the Canyon’s erosional history. Many of the connections that visitors made on their own were incomplete or incorrect, so it seems that a key to a successful Trail of Time will be to help visitors make these connections in appropriate ways. With that in mind, we discuss visitors’ understanding of the Canyon’s erosion in greater depth in the section entitled, The Cutting of the Canyon.

**Connecting the Trail of Time to the rocks in the Canyon**

The topical framework asked, “Do visitors see a connection between the Trail of Time markings and rocks in the Canyon, and if so, how do they talk about it?” Overall, it seemed to us that visitors were more interested in the aesthetic qualities of the rocks (and the erosional history of the Canyon) than in rocks as geologic features. For instance, many visitors discussed the beauty and colors of the rocks, and some discussed the rock layers as marking the level to which the Canyon had cut at various times, using the layers essentially as benchmarks for the erosional history of the Canyon. However, visitors did express some interest in the connections between the Trail markings and Canyon rocks, because some visitors asked specifically about such connections and others included them in their theories about the Trail.

Visitors’ understanding of the rock layers seemed more tentative and incomplete than their understanding and theories about the cutting of the Canyon. When visitors discussed the rock layering, they seemed just as likely to use terms like “levels” and “striations” as they were “layers” and “strata.” Several respondents told us about the time significance of these rock layers, including an amateur archeologist and a man in his 60’s who said he first learned these concepts in high school. However, most visitors did not seem to have given much thought to the time aspect of the Canyon’s rocks before we brought up the subject.

When we talked with visitors about the names and dates on the rock formation labels (Fig. 8) and the engraved rock sample (Fig. 9), many guessed that the names were related to the rocks in the Canyon, mostly because the rock formation names often included names of rock types (e.g., “Coconino Sandstone”). Although most respondents said they did not recognize the proper names on the labels, a few with previous experience with the Canyon said they recognized the names. For instance, respondents said they recognized some of the proper names because they had gone to the Imax theater near the Park entrance, seen exhibits in the Park, or “sat up front” on a helicopter tour of the deep Canyon. One local respondent recognized some names as Native American tribes and/or geographic locations (counties, schools), but not as rock formation names.
Once we started explaining the connections to the visitors, we saw more interest in the Canyon’s rocks. At that point respondents wanted to make the links between rock names and what they saw in front of them. However, in giving these explanations, we came to realize that whenever rock formation names are used, visitors will need to be given detailed graphical or other support about where to find them in the Canyon.

We discuss visitors’ understanding of the Canyon’s rocks in greater depth in the sections entitled, The Time Significance of Layered Rocks in the Canyon and How Layered Rocks Form.

Visitors' Understandings and Feelings about Geological Concepts Related to the Trail of Time

One of the primary goals for the Trail of Time is to “present geoscience interpretation at multiple knowledge levels so each visitor can enhance their knowledge of Grand Canyon geology” (Karl Karlstrom, personal communication, September 27, 2004). This section uses our findings and the geoscience education literature to explore how laypeople think and feel about some of the major geologic concepts that may be portrayed along the Trail. So that the exhibit team can better understand the multiple knowledge levels that visitors bring to the Grand Canyon, we develop preliminary knowledge hierarchies for some concepts. We will look in detail at five major concept areas:

- Geologic time in the abstract
- The cutting of the Grand Canyon
- The time significance of layered rocks
- How layered rocks form
- The Grand Canyon as a geologic phenomenon

Geologic Time in the Abstract

A major goal for the Trail of Time is to place the Grand Canyon’s geologic stories within the context of the Earth’s history and geologic time. It is hoped that visitors will:

- Understand that the exposed rocks are old, but the Canyon is geologically young.
- Know that less than half the Earth’s history is visible in Grand Canyon.
- Understand that human history is short compared to geological time (Karl Karlstrom, personal communication, September 27, 2004).

Dodick & Orion (2003b) point out that the concept of geologic time can be broken down into two concepts:

- Temporal framework. Dodick & Orion describe this as “a passive temporal framework in which large-scale geological and biological events occur,” which they see as depending on the connections people make between events and time. Educational researchers and evaluators have investigated this aspect of geological time using what Dodick & Orion call “event-based” studies, which often investigate people’s understanding of the entire history of the Earth (e.g., Hayward, 1992, 1993; Trend, 1998, 2000, 2001, 2002).

- Logical understanding. Dodick & Orion describe this as “an active logical understanding of geological time used to reconstruct past environments and organisms based on a series
of scientific principles.” Educational researchers have investigated people’s logical understanding of time relationships using what Dodick & Orion call “logic-based” studies, which investigate the cognitive processes that people use to solve problems involving geologic time (e.g., Ault, 1982, 1984; Dodick & Orion, 2003 a & b).

We discuss temporal frameworks in this section of the report, and the logical understanding of geologic time in the section entitled, The Time Significance of Rocks in the Grand Canyon.

Based on our discussions with visitors and a review of the literature, there seem to be a number of elements to building a temporal framework for geologic time, including:

• **Things that happened.** Events that happened sometime in the past can interest people in and of themselves, even if they do not have a real time framework on which to hang them.

• **Simultaneous or not.** When more than one event happened in the past, it is important to know which, if any, happened at the same time.

• **Order of events.** If events did not all happen at the same time, then it is important to know which happened first, and which happened next.

• **Grouping of events.** It is also important to group events that happened during more or less the same time span, rather than just looking at single events and specific points in time.

• **Absolute durations.** People may get a general feel for durations of events expressed in vague terms (e.g., “millions and millions of years ago”). They begin to deal with absolute time when they attach *real* numbers to the events (such as dinosaurs going extinct 65 million years ago).

To some degree these elements of geologic time represent a hierarchy of understanding. You first must know what happened before wondering what happened before or after. The before-and-after relative sequence of geologic history was discovered long before geologists understood the absolute durations of geologic time. However, evidence cited below suggests that people with an interest in the distant past quickly learn at least *something* about each of the elements of the “hierarchy.” In other words, they have, to some degree, internalized a temporal framework for the past. They know some of the things that happened in the past, they have ideas about the order of events, they group some events together, and they have some rough ideas and maybe some specific estimates about absolute timing of events. Thereafter, achieving a more scientific understanding becomes a question of learning about all the elements more or less simultaneously: Adding events, getting the order right, filling in gaps, and coming up with more accurate dates on an absolute scale. Somewhere along the journey to understanding there may be “a-ha” moments, when people realize the immensity of geologic time, but it is not clear when those happen.

Based on research by Ault (1982), Trend (2002), and others, plus unpublished evaluations Hayward (1992, 1993) and Marino, Harvey, Loomis & Sundine (1994), it seems that most
people’s internalized time frameworks are distorted relative to the scale constructed by professional geologists. For instance:

- **Things that happened.** There are indications that defining certain events for visitors may not be straightforward. For instance, Marino et al. (1994) found that visitors to the Denver Museum of Natural History “had different opinions about the beginning of life and the definition of what ‘life’ is….Some visitors would ignore illustrations of microbial and plant life, saying that life on Earth began with the first animals” (p. 10).

- **Simultaneous or not.** There is evidence that laypeople do not necessarily distinguish events in time the way geologists do. For instance, surveys conducted for the National Science Board (2004) found that almost half of American adults agree that the earliest humans lived at the same time as dinosaurs. Many people also do not distinguish between the ages of formation of the Earth, the Sun, and the Universe (i.e., the “Big Bang”), including children in Portugal (Marques & Thompson, 1997) and England (Trend, 1998) and pre-service and practicing teachers in England (Trend, 2000, 2001).

- **Order of events.** Ault (1982) found that even elementary-school children have the logical ability to deal with this aspect of geologic time. However, Trend found that children (1998) and adults (2000, 2001) tend to get confused about the order of certain geologic events, such when the Ice Age occurred relative to dinosaurs and the origins of humans, and the sequence of formation of the Universe, Sun, and Earth.

- **Grouping of events.** Trend (1998, 2002) drew some tentative conclusions about how children and adults group events in the past, finding, for instance, that adults think in terms of more groups of events than do children. We would like to see more research on this topic, including investigations of the role that dinosaurs play in children’s and families’ developing understanding of time periods. Children’s books and anecdotal evidence suggest that children (and their parents) may begin their journey of understanding by first recognizing a “time of the dinosaurs,” safely before the present, then discovering periods of life after and before the dinosaurs, and perhaps finding reasons to subdivide “dinosaur times.” However, we are aware of no formal research that supports that proposition.

- **Absolute durations.** Many people seem to underestimate the age of really old events in Earth history, even when they do not subscribe to a Biblical-time creationist perspective. For instance, Oversby (1996) surveyed primary and secondary students and pre-service teachers in the south of England about a variety of geological topics, including the age of the Earth. Answers in the billions of years increased with the age and experience of the respondents, from 18% for primary students, to 32% for secondary students, 75% for pre-service teachers in the arts, and 92% for pre-service teachers in the sciences. Oversby pointed out the inaccuracies in younger children’s answers may have been due to their difficulties in dealing with large numbers. In surveys of adult visitors to the Field Museum of Natural History in Chicago, Hayward (1992) found that, “Visitors recognize that life on Earth began some enormous number of years ago, but do not have a good sense of when that was, nor do they easily discriminate one enormous number from another (e.g., millions, hundreds of millions, billions)” (p. 1). Hayward found that, “Roughly 35-45%
dated the earliest life they could think of as at least 500 million years ago; this increases to 50% who said at least 100 million years ago” (1992, p.2). About 10% of Hayward’s respondents said life began less than a million years ago. In a later study, Hayward (1993) asked museum visitors how many years had passed from the beginning of life until dinosaurs. About a quarter of his respondents “were ‘in the right ballpark’ (billions, but not over 4 billion)” (p. 1). About a tenth overestimated this time, but more than half underestimated, and another tenth said they did not know.

We should point out that only 10% to 15% of the Field Museum’s audience could be classified as “hard core” creationists (e.g., Hayward, 1996), so these results seemed to reflect a lack of knowledge about geologic time rather than an acceptance of Biblical-time creationist views. Looking for similar data from the American public, we found references to Gallup polls from the early 1980s and 1990s that found almost half of the American public agreed with a statement that “humans were created by God about 10,000 years ago,” and this percentage increased into the early 1990s (cited in Matthews, 2001). However, a more recent survey found that, although slightly less than half of American adults agreed that “human beings, as we know them today, developed from earlier species of animals,” almost 80% agree that “the continents on which we live have been moving their location for millions of years and will continue to move in the future” (National Science Board, 2004). We are not sure how to interpret this. Perhaps most Americans will accept the idea of an old Earth, as long as it is not linked to statements about human evolution. Alternatively, many survey respondents may have ignored the references to time in these questions, answering instead based on their beliefs about human evolution and acceptance of “continental drift.”

How can the Trail of Time help visitors improve their internalized temporal frameworks for the history of the Earth? Supplying visitors with factual information, such as the age of Canyon landforms and rocks and the age of the Earth itself will be a start, but it will take more to help those facts stick in visitors’ heads. We will delay our discussion of learning outcomes until later in this report (“Learning Outcomes in Informal Settings”). For now, we will point out that the Trail of Time concept provides visitors with a large-scale analogy or metaphor for the geologic time scale, which may give visitors cause to reflect on and revise their own internalized timelines.

Certainly there is precedence for this approach in the geoscience education literature, including papers where authors described analogies that teachers could use with their students (e.g., Hume, 1978, described a 66 volume “Encyclopaedia of Time,” plus calendar, movie, and other analogies) and a paper that advocated letting students develop their own metaphors for geologic time (Ritger & Cummins, 1991). In the field of informal education, based partly on Hayward’s (1992, 1993) recommendations, the Field Museum presented multiple metaphors for geologic time in the first section of Life Over Time, including interactive timelines, with ropes to pull and cranks to turn, and a “time opera” that played at the push of a button. The exhibit seemed to have at least some impact on visitors. When visitors were shown a photo of this first section as they exited the 20,000-square-foot exhibit, 90% of respondents said they remembered seeing it, and almost 70% remembered it was about time. About a quarter of respondents gave “peak” answers to this last question, remembering that it showed the immensity of time or how long ago things happened (Hayward & Hart, 1996).
Coming up with graphics to support the Trail of Time concept may prove to be a challenge. Looking for the best timeline to use in an exhibit, the Denver Museum of Natural History completed a series of formative studies to test alternative versions of a timeline for their Prehistoric Journey (Marino et al., 1994). When they tested a “Time Spiral” based on a U. S. Geological Survey publication, Marino et al. found that (a) the circular nature of the spiral confused visitors, (b) visitors had difficulty applying information from the spiral to answer questions, (c) the lack of illustrations along some parts of the spiral implied to visitors that nothing was known about those time intervals, and (d) the names for the time periods were useful only to visitors with previous knowledge. Seeking an alternative approach, Marino et al. used a card sort activity to test visitor preferences for four more linear time scales to be placed on exhibit labels. Visitors preferred the simplest and most linear approaches. After several more stages of testing, about 80% of respondents were able to extract correct information from the final timeline (Marino et al., 1994). (We can send copies of this publication to interested team members.) These findings suggest that we will need to test and revise any graphical timelines developed for the Trail of Time.

The Cutting of the Canyon
A major goal of the Trail of Time is to show how the convergence of a series of geological factors helped form the Grand Canyon, including broad regional uplift of the rock units and a major river flowing from high mountain elevations through an arid landscape. It is hoped that visitors will:

- **Visualize that the land rose as a broad plateau while at the same time the Rocky Mountains were being compressed to form mountain ranges.**
- **Identify that erosional forces and climatic forces worked in conjunction with the Colorado River to form Grand Canyon, primarily the width, temples, cliffs, terraces, and other features identified** (Karl Karlstrom, personal communication, September 27, 2004).

As noted earlier, during the formative evaluation there were many indications that visitors were very interested in how the Canyon was eroded and that they wanted to connect the Trail to landforms within the Canyon. In addition, many visitors told us about their theories of how the Canyon formed. These theories, which many visitors seemed to have developed on their own, were often incomplete or incorrect. It seems that a key to a successful Trail of Time will be to help visitors find appropriate ways to (a) understand the processes of erosions that formed the Canyon, and (b) connect these processes to the timeframe presented by the Trail of Time.

Some visitors’ ideas about the formation of the Canyon seemed more accurate than others. For instance, respondents often talked more about “erosion” than “canyon cutting,” and perhaps that is a better term. As some visitors noted, it takes more than just a river cutting down to make something as wide as the Grand Canyon.

Most visitors who talked about erosion said they were thinking about water or, more specifically, the Colorado River, eroding the rock, although some wondered how the river could do it on its own. Some respondents seemed pretty certain it could have done it, but others expressed disbelief, especially when they compared the Colorado River that they had seen downstream from the Canyon with larger rivers they had seen back home.
We encountered a range of other theories about the processes that eroded the Canyon.

- **Catastrophic forces.** One respondent guessed that an asteroid crash might have formed the Canyon. A believer in Biblical-time said he thought others attributed the Canyon to the “Big Bang,” but he did not accept that theory.

- **Glaciers.** Some respondents brought up the possibility that glaciers played a role in carving out the Canyon. That might seem like a useful theory to visitors who remembered the broad valleys widened by glaciers in other parts of the western United States.

- **Lakes.** Some respondents discussed the Canyon’s erosion as if it was *filled* with water to the brim as it eroded. One group made an analogy to the undersea Baltimore Canyon where the husband went fishing. (Undersea canyons really can erode through water currents and mudslides, so this seemed like a sound idea to them.)

- **Wind.** Visitors trying to explain Canyon widening sometimes said they suspected that wind erosion was involved. When one visitor saw wind-blown sands discussed on the Coconino Sandstone label, he immediately started describing how those wind-blown sands could have eroded the Canyon walls.

- **Meanders.** Another visitor who was puzzled about the width of the Canyon wondered if the Colorado River had widened its valley by meandering.

We were left wondering if visitors’ theorizing might have been more accurate if they had a better perspective on the immense amounts of time available for the Colorado River to erode the Canyon. For instance, some visitors seemed to want to have *really big forces* create the Canyon, often very quickly. Not only does the *Trail of Time* need to tell these visitors that the Canyon has been eroding for 6 million years, it also needs to help them realize that 6 million years is a really, really long time. With 6 million years, even a seemingly modest force (like the Colorado River) has enough time to accomplish the job. Perhaps, in retrospect, saying “Young Canyon, old rocks” is not such a good idea, and least along the part of the *Trail* that discusses the erosion of the Canyon.

Respondents discussed a range of erosional processes that could have contributed to the cutting of the Grand Canyon. We did not have time to discuss erosional processes with visitors in depth, so we turned to the geoscience education literature in hopes of finding some useful perspectives on this issue. However, as Dove (1998) points out, there has been little research on how students and others understand weathering and erosion. Dove (1997) found that 16- to 19-year old students in the United Kingdom realized that weathering takes place *in situ*, but that erosion generally involves movement of the erosional agent and/or transportation of the eroded material. Alternative understandings by these students included beliefs that erosion happened all the time, but that weathering was intermittent and that weathering could not be prevented, but erosion could. Also, instances that geologists would think of as erosion sometimes were misclassified weathering because “the weather” was involved (e.g., erosion by wind-blown sand was considered weathering by some). It is not clear if any of these findings would apply to visitors’
thinking about erosion in the Grand Canyon. However, the project team might think about what
distinctions they want to draw between weathering and erosion, and project evaluators will need
to watch out for possible alternative conceptions by visitors during later stages of the evaluation.

The erosion of the Grand Canyon was initiated when forces within the Earth started lifting the
Colorado Plateau well above sea level, and a few visitors incorporated ideas about uplift into
their explanations of the Grand Canyon. One respondent talked about “being able to walk across
here” at one point before the Canyon was cut, and then talked about uplift and the Colorado
River. He mentioned that he had learned that elsewhere in the Canyon.

Although no visitors that we talked with brought up the idea that the Grand Canyon’s dry climate
might have contributed to the erosion of the Canyon, those who talked about erosion by wind-
blown sands may have implicitly included climate in their theories. Of course, theories that
involve glaciers also imply a climatic component.

It seemed that visitors developed most of their alternative understandings of Canyon cutting on
their own or through discussions with their groups. However, recall the short discussion earlier
in this report of how “concepts accidentally juxtaposed through poor wording or placement of
exhibit labels can confuse or confound visitors’ thinking.” We were reminded of this when we
noticed that the long label at the first meter to the Mather to Yaki segment (Figure 6) showed at
least three “Time of Glaciation” zones and also mentioned basalt dams, with no further
explanation. Given that some visitors incorporated glaciers and lakes into their theories about
the Canyon, we wonder if the team should be very careful when they mention these geologic
processes. Perhaps these mentions should be qualified by statements like, “Although glaciers
never even came close to the Grand Canyon, waters that melted from them…..,” or “After the
Canyon had been cut to almost its current depth, lava flows dammed the Colorado River…..” Of
course, such statements should be tested during later stages of the formative evaluation.

Given what the project team explained to us about the cutting of the Grand Canyon, we wonder
if a Level 3 understanding of Canyon cutting might look something like this: “For more than
five million years, the Colorado River and its tributaries have been carving the Grand Canyon
through rock layers that were gradually uplifted from near sea level.” Note the emphasis on
time, continuity, and uplift. Given that as Level 3, the rest of the knowledge hierarchy might
look something like this:

**Level 0:** "I don't know, and I don't care." Visitors at this level had little prior knowledge
about and/or interest in the geologic processes that formed the Grand Canyon. They
had not thought about them in any great detail, and erosional processes did not seem
to be something about which they were curious. Perhaps some tourists who did not
walk on the Trails and some Biblical-time Christians would belong here.

**Level 1:** "I don't know, but I'm curious." These visitors said they did not know how the
Canyon was formed, but they were curious. As they explored the Park, they may
have been wondering why the Canyon was so deep and wide, and why the rocks came
in so many interesting shapes. However, most respondents were at least curious
about how the Canyon formed, and at least during the interview, many expressed ideas that would move them to Level 2.

**Level 2: Some knowledge, but it's incomplete or incorrect.** These visitors were interested enough that they had developed a theory or hypothesis about how the Canyon was formed. Although often reasonable, their understandings were incomplete or incorrect. For instance, some visitors on this level wanted to have **really big forces** create the Canyon, often relatively quickly (e.g., asteroids, glaciers). Some visitors also felt the Colorado River alone could not cut that deep, and others imagined the Canyon completely filled with water that somehow helped form the Canyon. Some visitors on this level also realized that they needed a theory to explain the widening of the Canyon, but the forces to which they attributed this widening were not enough to do the job (e.g., wind erosion). It may be significant that some of the processes noted above are also **wide** (e.g., lakes and glaciers), which may be an attempt to carve out the depth and width of the Canyon with a single process. Finally, given some of the misunderstandings on Level 2, the team will need to very carefully word labels that discuss glaciers, lakes, and windblown sand, so they do not inadvertently reinforce some visitors’ alternative understandings.

**Level 3: Basic understanding of how the Grand Canyon was cut to its current depth**

This level should be reserved for visitors who realize that, for more than five million years, the Colorado River and its tributaries have been carving the Grand Canyon through rock layers that were gradually uplifted from near sea level. To help visitors reach this level, they need to believe that 6 million years is a really, really long time, so that seemingly modest forces (like the Colorado River) have enough time to accomplish the job.

**Level 4: Also understand the processes that widened the Canyon.** These visitors would understand that additional erosional processes helped to widen the Canyon, and that these processes include the effects of weather and gravity on the walls of the Canyon.

**Level 5 and 6: More sophisticated understanding of the erosion of the Grand Canyon.**

Although we did not talk with any general visitors on these upper levels of the hierarchy, we suspect that Level 5 and up visitors may understand the role that dry climates played in shaping these erosions processes and their results, know something about the concept of parallel retreat of cliff faces, or show a range of other understandings more typical of people who have studied erosion and geomorphology in school or worked with these concepts as part of their career.

Perhaps we will be able to refine this knowledge hierarchy during later stages of formative evaluation, and then apply it to the summative evaluation of the *Trail of Time*.

**The Time Significance of Rocks in the Grand Canyon**

As stated earlier, one of the objectives for the *Trail of Time* is for visitors to “understand that rock layers record different Earth environments through time.” A goal for Grand Canyon interpretation overall is that visitors will be able to identify five major “sets” of Grand Canyon
rocks by their distinctive physical characteristics, tectonic settings, age, and fossil records (Karl Karlstrom, personal communication, September 27, 2004).

During the first stage of the formative evaluation, we were unable to talk with visitors in depth about their understanding of layered rocks and rock-forming environments. Therefore, we will turn to the geoscience education literature to give some structure to our findings on these topics. For the purposes of the Trail of Time, there seem to be at least two interrelated themes: (a) Visitor understanding of the time significance of the rocks layers that visitors see in the Canyon, and (b) visitor understanding of the processes and environments that formed the rocks that they see in Grand Canyon. Unfortunately, as we reviewed our findings and the literature, it seemed to us that most people’s understandings of these concepts are so under developed that it is difficult to separate them, at least at lower levels of the knowledge hierarchies for these concepts. So, we begin with a general discussion of how people think about rocks, and then try to develop knowledge hierarchies based on this discussion.

Several researchers have found that both children and college students think very differently than geologists do about these topics. In analyzing stories that college students wrote about how rocks formed, Kusnick (2002) found that even students with previous college coursework in geology still tended to interpret geologic processes in ways that seemed distorted by their pre-existing beliefs. Their rock-formation stories seemed to be produced by four major “conceptual prisms” that distorted much of what they had been taught about geological processes:

- **Rocks are relatively small and discrete.** Kusnick (2002) points out that when geologists think, “rock,” they envision either a category of Earth material (like limestone or sandstone) or a large-scale, continuous mass within the Earth (like the Kaibab Limestone or Coconino Sandstone). Although laypeople may also use the term “rock” to mean a category or type, to most people a “rock” is a much smaller bit of material, commonly something they can hold in their hands. Even larger bodies of rock seen in the field are often considered to be discrete chunks embedded in a mass of dirt and stones (Ault, 1984). In other words, many laypeople do not understand the concept of bedrock. For example, Ault (1984) describes some of the problems that third and fourth grade students visiting a canyon in New York State had grasping “the deposition of bedrock in layers and the subsequent removal of a ‘gorge-worth’ of the bedrock by erosion” (p. 90), despite the fact that the whole point of their trip had been to visualize the once-continuous layered bedrock. Kusnick points out that the question, “How did this rock form?” can have very different meanings for geologists and non-geologists. “The geologist translates the question as ‘To what category of rock type does this sample belong, and what is the process by which rock in that category forms?’ Many students translate the question to mean, “How did this sample get to be a pebble?’” (Kusnick, 2002, p. 34)

- **Rocks forms on human scales of time and space.** Kusnick (2002) found that her students thought about geologic processes as happening on human scales of space and time. Even when her students could quote the age of the Earth correctly, they still talked of rocks as forming on amazingly short time scales, leading Kusnick to question the effectiveness of many of the ways in which teachers illustrate the immensity of deep time. Ault (1984) discusses the difficulties children have recognizing the large-scale physical
patterns that exist today (e.g., continuous bedrock layers), let alone the past physical changes these patterns represent.

• **The Earth is stable.** Many of Kusnick’s college-aged students saw landscapes as unchanging. For instance, they believed that hand-specimen rocks formed where they are found (so any rock in a stream must be sedimentary, even a granite transported there from somewhere else). They also tended to believe that any changes to the stable Earth involved catastrophic events, like “weathering” by earthquakes or explosive volcanic activity (Kusnick, 2002). Although the Grand Canyon seems like a good place to try to change this view, we talked with several visitors who talked as if the Canyon had formed in the past, and it was essentially completed.

• **Humans dominate Earth-shaping processes.** Kusnick (2002) found that many of her students had “difficulty imagining a world operating independently of human activity. When they envision the geologic world, humans are in the foreground” (p. 36). For instance, even after instruction, about 30% of her students “cited human intervention in weathering and transporting” in their stories about rock formation (p. 36).

How can these distorting prisms be reconstructed into ways of viewing the world that are more consistent with geological science? Kusnick (2002) claims that,

> The schooling experiences that most dramatically shape the belief systems of the budding geologist are experiential: Field camp, problem-solving field trips, and the apprenticeship of graduate school. These experiences require an immersion in the thought patterns of geology, building core beliefs about the nature of the geological world (p. 38).

Kusnick closes by pointing out that traditional models of geological education often introduce these sorts of experiences at the senior level of college or graduate school, but that much earlier “authentic experiences can help students avoid misconceptions that may be difficult to overcome later in their education” (p. 38).

Dodick & Orion (2003 a & b) describe and analyze students’ understanding of the logical principles that enable geologists to assemble abstract time frameworks from scattered outcrops of rocks, such as **actualism** (“the present is the key to the past”) and the principles that describe time relationships among layered rocks (**original horizontality** as sediments are deposited, **superposition** of younger layers on top of older ones, and **correlation** of outcrops in different localities that are of the same rock strata or age). When they tested Israeli secondary students’ abilities to use these principles, they found that high-school-age students did significantly better than junior-high-age students, although certain types of interpretations proved difficult for students of all ages. For instance, younger students had problems interpreting age by superposition when the rock layers had been folded, but this was not as big a challenge for older students. On the other hand, “even students with a background in geology put undue emphasis on both size and numbers of layers when considering the age of geological layers.” For instance, they often “portioned the strata into equal portions of time, almost as if they were units on a
ruler” (p. 436). (This reminded us of the Grand Canyon visitor who guessed that the tick marks meant steps down into the Canyon – go down 100 steps, get to 100 million-year-old rock.)

For the Trail of Time, the question is how can we use findings like these to help guide the development of effective wayside exhibits about the Canyon’s rocks. One way is to use these findings to aid in the development of knowledge hierarchies about important concepts, like how rocks form and the time significance of layered rocks. Regarding visitors understanding of the time significance of rock layers, we did not learn as much about this as we had hoped on our two days of field work, in part because there were so many issues related to the Trail itself and to the cutting of the Canyon (see above). Also, we would have needed simpler graphical examples to use when we talked with visitors about this subject; the cross section in the brochure was too complex to talk much with visitors who had a low level understanding.

Given what we currently know, here is a very preliminary knowledge hierarchy for visitors’ understanding of the time significance of layered rocks.

**Level 0:** "I don't know, and I don't care." Visitors at this level had little prior knowledge about and/or interest in the rocks as evidence of past times, although they often were impressed by their beauty and shapes and/or by the evidence they provided of “God’s greatness.” They had not thought about the time significance of the rocks it in any great detail, and it was not something about which they were curious.

**Level 1:** "I don't know, but I'm curious." These visitors did not know much about the rocks they saw in the Canyon, but they were curious and wanted to know more. As they explored the Park, they may have been wondering how old the rocks were or what it was like when they were forming, but they did not find or develop answers to their questions.

**Level 2:** Some knowledge, but it's incomplete or incorrect. These visitors were interested enough that they had developed a theory or hypothesis about the rocks in the Canyon. Although often reasonable, their understandings were incomplete or incorrect. For example, when visitors read labels about processes that formed the rocks in the distant part, they sometimes imagined these processes were still taking place (e.g., the Coconino sands were still blowing in the wind). Some more possibilities from the literature:

(a) Visitors at this level may not have a concept of bedrock. They may see rock outcrops as isolated bodies floating in a matrix of dirt and gravel. If you point to a boulder of limestone and tell them it formed 250 million years ago, they may think the boulder formed 250 million years ago, rather than imagining the origins of either the larger body of rock to which the boulder was once attached or the material that makes up the boulder.

(b) They may also think of the boulder as having formed more-or-less in place, in a relatively recent time. They may believe, for instance, that pebbles in a stream bed can grow to boulder size, in place, as new sediment accumulates and sticks to them (e.g., Kusnick, 2002)
Deborah Perry’s initial experiences in the Canyon suggest that she started out at this level (Deborah Perry, personal communication, October 3, 2004). Students’ thinking on these topics is described in the geoscience education literature (e.g., Ault, 1982, 1984; Ford, 2003; Kusnick, 2002).

Getting to the next level probably requires more than the accumulation of facts (although that may be part of the process). It may also take overcoming what Ault (1984) called a “critical barrier,” a key concept that underlies a whole branch of science. In this case, the critical barrier may be the concept of bedrock. If that is so, what better place to develop a concept of bedrock than the Grand Canyon?

**Level 3:**  **Basic understanding of the layered rocks in the Canyon.**  Visitors on this level would:

(a) Have at least a basic concept of what geologists call “bedrock.” That is to say, they realize that the rock layers in the Canyon walls are widespread and continuous over long distances and once ran continuously through the now-empty space occupied by the Grand Canyon.

(b) They would also understand that each of these continuous layers formed at (about) the same time in the distant past.

(c) They might also realize that many rock layers can be recognized and named throughout the park by matching them to cliffs, slopes, and benches. With a bit of visual help, they would be able to pick out some of the most distinctive layers, like the Coconino Sandstone “bathtub ring” and the Kaibab Limestone on which they were standing. We talked with a few visitors who had learned enough elsewhere that they were approaching this level of understanding.

**Level 4:**  **Deeper understanding of the time significance of layered rocks.**  These visitors realized that the oldest rocks were deeper in the Canyon and sometimes understood something about the major unconformities in the Park and their significance as “gaps” in the geologic record of the Park. Respondents who seemed to have reached this level included an Australian tour guide and the mother of a geophysicist. Achieving this level required an understanding of the basic principles of stratigraphy, such as original horizontality (sediments are deposited as horizontal layers over a large area) and superposition (upper levels are younger). Ault (1984) found that, although the children could apply this sort of logic to familiar situations like compost heaps, they had great difficulty applying these concepts to layered rocks seen in the field. Dodick & Orion (2003b) found that high-school-age students did better than junior-high-age students at applying these principles in an abstract testing situation. They also found evidence that geological fieldwork improved older students understanding of spatial relationships as they relate to time (Dodick & Orion, 2003a).

**Level 5:**  **Familiar with the major rock layers in the Park and their significance.**  These visitors would have learned the major rock layers by name and would know in general terms when the major layers were formed. We did not meet general visitors on this level, but we talked with one tour guide and heard about other tour guides who seemed to be on this level.
Level 6: Sophisticated understanding and appreciation of the layered rocks both in the Park and in a regional context. These visitors would think about the rocks like geologists do.

Perhaps we will be able to refine this knowledge hierarchy during later stages of formative evaluation, and then apply it to the summative evaluation of the Trail of Time. We will also be on the lookout for geoscience education literature that might give us insight into how laypeople think about unconformities and tilting and metamorphosis of sedimentary rocks, which we may be able to incorporate into later stages of the evaluation.

How Layered Rocks Form
One of the objectives for the Trail of Time is to help visitors “understand that rock layers record different Earth environments through time” (Karl Karlstrom, personal communication, September 27, 2004). More specifically, it is hoped that visitors will:

• Be able to identify five major “sets” of Grand Canyon rocks by their distinctive physical characteristics, tectonic settings, age, and fossil records.
• Learn some of the depositional environments recorded in Grand Canyon’s rock record and be able to relate these to modern day environments elsewhere in the world.
• Learn how the exposed rock layers and formations reveal information about the diverse environments and conditions under which they formed (Karl Karlstrom, personal communication, September 27, 2004).

As with the time significance of rocks, we did not learn as much about topic as we had hoped. What we learned left us wondering if the rim is the best place to talk in detail about sedimentary processes with visitors, since (a) visitors usually would not be able to see the many scales of evidence that geologists use to tell how a rock formed, and (b) too much detail on smaller-scale processes may distract visitors from what should be their primary mission: Understanding the continuity and time significance of rock layers. Instead, we wonder if the best approach to discussing rock formation along the Trail of Time would be to focus on the widespread nature of past rock-forming environments, because that would focus visitors’ attention on a size-scale that can link the formation of rocks to the time-significance of rock layers. However, this tentative recommendation needs extensive testing during later formative evaluations.

Given our limited knowledge in this area, here is a preliminary knowledge hierarchy for visitors understanding of rock-forming environments.

Level 0: "I don't know, and I don't care." Visitors at this level had little prior knowledge about and/or interest in how layered rocks formed. They had not thought about it in any great detail, perhaps because it was not something about which they were curious. We suspect that many Canyon visitors fall at this level, although they may jump a level or two as you talk with them about the subject.

Level 1: "I don't know, but I'm curious." These visitors did not know how layered rocks formed, but they were curious. As they explored the Park, they may have been wondering how the rocks they were seeing came to be. Reaching this level is
significant, because these visitors acknowledge that there is something to be learned about how the layered rocks in the Canyon came to be, but they have not really started to develop explanations on their own or based on things they have read and seen.

Level 2: Some knowledge, but it's incomplete or incorrect. These visitors were interested enough that they had developed a theory or hypothesis about how a given rock type came to be, perhaps because they were familiar with terms like “limestone” or “sandstone” or because they saw a fossil or two in an exhibit or along a trail. Although often reasonable, their understandings were incomplete or incorrect. Some possible structure within this level might include:

(a) If you point to a rock and ask how it formed, visitors on this level might talk about the formation of the chunk of rock (boulder, pebble, etc.) rather than discussing the stuff the rock is made of or the once continuous body of rock from which it broke. This can be seen as a symptom of their lack of a concept of bedrock (see above).

(b) Visitors on this level may have a few ideas about the processes and environments where rocks form, but their ideas are not sufficient to account for the major rock types in the Canyon. For example, they may know about volcanoes, but not the shallow seas where many of the Park’s limestones and shales formed.

Level 3: Basic understanding that layered rocks formed from previously dispersed materials, like sand and shells. These visitors may remember learning about the formation of sandstones or limestones while in school, or from earlier encounters with exhibits and park naturalists.

Level 4: Realize that particular rock types formed in particular environments in the distant past. These visitors would be developing the kind of understanding that will help them link the formation of sedimentary rocks to the continuity and time significance of layered rocks.

Level 5: Understand the role that burial plays in preserving and cementing ancient sediments, and that uplift plays in their subsequent exhumation. These visitors are beginning to understand the role that tectonic setting plays in the development of the Canyon’s rock walls.

Level 6: Sophisticated understanding and appreciation of the processes and environments in which layered rocks form, both in the Park and in a regional context. These visitors may have taken advanced coursework in geology, or may have developed and followed up on a strong interest in geology or paleontology as adults.

As we stated earlier, this knowledge hierarchy is very preliminary.
The Grand Canyon as a Geological Phenomenon

One of the goals for the Trail of Time is to orient visitors to the scale, immensity and diversity of Grand Canyon. Visitors will

- Be exposed to the length, depth and width of the Canyon.
- Gain a perspective of the entire Grand Canyon.
- Understand the diversity of the rock units that can be seen from the south rim and how they shaped the landscape.
- See how the landscape varies in different parts of the Canyon from the east end with Marble Canyon’s steep, narrow walls to the west end’s broad open expanses (Karl Karlstrom, personal communication, September 27, 2004).

The project team also wants to communicate that there are many scientific questions remaining about the specifics of the origin of Grand Canyon and that these questions are the focus of ongoing research. Visitors will

- Realize the importance of an area like Grand Canyon to continue to be preserved for a scientific laboratory and visitors’ enjoyment.
- Understand the scientific method by examining evolving hypotheses for Canyon history.
- Understand that, building on our already vast knowledge of the geology of Grand Canyon, there are important and exciting research questions being researched today, and opportunities for new insights to emerge from future research (Karl Karlstrom, personal communication, September 27, 2004).

Given the short time we spent talking with visitors in the Canyon about these topics, our findings in this are rather sparse. We can say the following:

- **The immensity of the Canyon.** As stated earlier, visitors seemed very impressed with the depth and width of the Canyon and were very interested in any evidence of human activities in the deep Canyon which could give them perspective on its scale.

- **Uncertainties about visitors’ awareness of scientists working in the Canyon.** Our previous experience with visitors to a natural history museum demonstrated how little they knew about scientists working behind the scenes at the museum (Perry & Forland, 1995); however, more recently we discovered that visitors to Yellowstone National Park expected that scientists were at work behind the scenery (Gyllenhaal, 2002). Yellowstone visitors could even describe some of what scientists did in that park, based on what they had seen watching a Discovery Channel special and in various exhibits around the park. However, they did not have a good grasp on the motivations behind the scientists’ research (Gyllenhaal, 2002). So, we are uncertain where Grand Canyon visitors would fall on a potential hierarchy about scientists working in the Park. Would they be mostly Level 0 or 1, like many visitors we talked with at the Field Museum of Natural History, or closer to Level 2 or 3, like many visitors we talked with at Yellowstone National Park?

- **Most lay people show little understanding of the scientific method.** Repeated studies by the National Science Board (e.g., 2004) have demonstrated that most adult Americans show little understanding of the experimental approach to science. For instance, when asked to explain how a scientific study is conducted, their responses usually do not include
such ideas as theory testing, experimentation, and rigorous, systematic comparison. Most Americans had difficulty interpreting the results of an experiment, although they performed a bit better on a task that investigated their understanding of simple probability (National Science Board, 2004). Of course, the geological sciences have their own approaches to the scientific method, which also must account for the historical nature of this science (e.g., Dodick & Orion, 2003c). Interpretation of rocks in the field adds another level of complexity to geological methods; even extensive classroom studies only begin to prepare students for independent fieldwork (e.g., Frodeman, 1996).

We hope the project team will keep these issues in mind as they formulate goals and objectives in this aspect of the study. It seems that visitors would appreciate perspectives on the Grand Canyon’s size and scale. However, it is less certain how far the Trail of Time can take them on their journey to understanding scientific research in the Canyon.
CONCLUSIONS AND DISCUSSION

What Works and What Doesn’t about the Prototype Trails?

During our observations of and interviews with visitors along the Trail of Time, we were repeatedly impressed by visitors’ interest in the tick marks along the paved Trail and their discussions surrounding them. There were clear indications that visitors will be interested in interpretation to help them understand more about the geology and geologic time of the Grand Canyon. Following is a brief outline of some aspects of the prototype Trail of Time that seemed to be working particularly well:

• **Intriguing idea.** Visitors were intrigued by the tick marks and signage, and they were willing to devote quite a bit of effort to figuring out their meanings.

• **Not too distracting.** For many short-term visitors at Mather Point, the tick marks did not distract from the aesthetic aspects of the Grand Canyon.

• **Made sense once it was explained.** Visitors seemed to understand the basic idea of a timeline once we explained it to them and illustrated it with the large trail map inside the brochure.

• **Periodic explanation helped visitors’ understanding.** Because the scale-change stations were dispersed all along the Time Accelerator, visitors who first noticed the tick marks somewhere beyond the trailhead used important clues at the scale-change stations as they tried to make sense of the Trail of Time.

• **Enjoyed applying it to their hikes.** Once visitors made sense of the Trail, they applied their understanding in interesting ways, like telling us how many million years they had hiked and using the timeline to keep track of where their car was parked.

• **Interested in Canyon cutting.** Visitors seemed very interested in how the Grand Canyon formed, although their theories about erosional processes were often incomplete or incorrect.

• **Filled a gap in visitor understanding.** Because many visitors lacked perspective on the immense amount of time it took to carve the Canyon, it seems like the Trail of Time will help them fill an important gap in their understanding of the Earth’s history. Visitors need that understanding to help them believe that the tiny speck of Colorado River in the far distance could have carved the Grand Canyon.

As with any prototype exhibit, it is important to also pay attention to those areas that did not work as well so that the exhibit can be revised and ultimately improved. Here are some aspects of the Trail of Time that did not seem to be functioning as well. Some may be easy to fix, but others present more of a challenge:
• **Too little explanation of the timeline concept.** The markings and signage available with this first-stage prototype *Trail* did not take visitors far enough on their journey to understanding the *Trail of Time*. As a result, visitors working with the limited signage developed some creative, yet often incorrect theories about the *Trail*.

• **Timeline explanations not strategically placed along the porous *Trail*.** Visitors joined the *Trail* all along its length or first noticed the tick marks at some point well beyond the trailhead, and even those who entered at the ends of the *Trails* often missed the initial interpretation at the trailheads.

• **Visitors weren’t finding the story of the Grand Canyon.** Although labels along the prototype *Trail* very briefly explained some events in the Canyon’s prehistory and gave names and ages of rock units, this was not enough to give full meaning to the *Trail*, even for those who figured out that it was a timeline. Both the Canyon-cutting story and the story of the formation of the Canyon’s rocks need to be told with more episodes, including clear and detailed explanations and illustrations of the geologic events and processes.

• **Large numbers confused some visitors.** As noted earlier, when visitors were confronted with numbers in the millions and billions, they tended to “mix up their -illions.”

• **Understanding the Time Accelerator.** There were indications that the scale changes along the Time Accelerator might add an additional barrier to visitors’ understanding the *Trail of Time*, and the evaluators are concerned that adding too much human prehistory and history to that segment of the *Trail* might dilute its messages about the cutting of the Canyon, and further confuse visitors.

• **Didn’t walk far enough.** Especially at Mather Point plaza and Yavapai Observation Station, many visitors did not walk far enough along the *Trail of Time* to make sense of the *Trail*’s timeline concept or to experience it in meaningful ways. For short-term visitors to the South Rim, an alternative approach using stand-alone wayside exhibits might be a more appropriate way to whet their interest in the age and geologic history of the Canyon.

• **“Reading” rock layers seems harder for many visitors.** Our findings, in light of the geoscience education literature, suggest that visitors will need quite a bit of help to understand the story told by the Canyon’s rock layers. Many visitors were at Level 0 or 1 with regard to geoscience concepts about layered rocks.

• **Linking tick marks to specific spots.** Many visitors wanted to know how each marker related to the place where it was taped to the *Trail*. They were looking for specific interpretation about specific places or views along the rim at that point. It may be hard to channel visitors’ tendency to link each tick mark to the place where it was taped to the *Trail*, and to get them to think of the *Trail* as an abstract timeline draped over the landscape.

Solving the first three challenges seems fairly straightforward and, in fact, solutions that address these issues are already being planned as part of the interpretation that will accompany the
completed *Trail of Time*. Successfully addressing the later challenges will require thoughtful and creative responses from the team. In the recommendations section, we will make specific suggestions about how to meet these challenges. The next stage of formative evaluation should test solutions to these challenges for at least one segment of the *Trail*.

**Learning Outcomes in Informal Settings**

We want to help the team formulate goals and objectives for the *Trail of Time* in light of recent research about informal learning. With that in mind, it seems useful to formulate a list of the sorts of learning and learning-related outcomes that evaluators and researchers commonly encounter in informal settings, like museums and parks. The following list was compiled based on the literature and modified to fit our experiences at Grand Canyon.

- **Remembering previous experiences and existing understandings.** One interesting aspect of our interviews at Grand Canyon was hearing visitors talk about things they had done and learned in the past. Here are some of the kinds of “remembering” we witnessed:
  - Remembering past experiences at the Canyon and elsewhere.
  - Recognizing or recalling terms, facts, or concepts learned in the past.
  - Reliving old feelings at the Canyon and elsewhere.

  This remembering played an important part in visitors’ developing understanding of the Canyon. As we discussed earlier, visitors start constructing new knowledge from what they already know (Roschelle, 1995), and they look for personal connections to give their new understandings meaning in their lives.

- **Adding to visitors’ “experience banks.”** Ansbacher (2002) cites evidence that, “An exhibit that is engaging or impressive may yield an experience that will be retained in memory – added to the ‘experience bank’ – yet not be processed by the visitor. Such experiences may lie dormant forever, or they may be recalled and processed at a later time when triggered by new experiences” (p. 4). Several researchers have looked more closely at the retention of multi-sensory memories of immersive experiences. For instance, based on an analysis of 400 stories that museum professionals told about “significant, memorable, pivotal museum learning experiences,” Perry (2002) defined a type of learning termed “**wrap-around learning.**” “Wrap-around learning is learning that you feel with your whole body and via all your senses; learning that you can wrap your arms around” (p. 24). Of course, National Parks also create memorable experiences. Perhaps the project team can try to influence what visitors remember about their experiences. That can include:
  - Calling Park visitors’ attention to important aspects of the experience (perhaps on the level of awareness, even if not on the level of understanding why they are important).
  - Influencing the interactions with other members of their group in ways that will have meaning relative to our goals.
  - Making sure that visitors associate positive emotions with the experiences.

- **Visceral learning.** Visitors often process, make sense of, and learn from their experiences while still within an exhibit. In some cases they can articulate this sort of learning almost immediately; in other cases, although they know they have taken away *something* from an
exhibit experience, they cannot quite put it into words. For instance, Perry (2002) described **visceral learning** as “learning which is located inside the body: It’s a gut feeling, and internal understanding, a way of knowing that has little to do with intellect or cognition” (p. 23). Likewise, Ansbacher (2002) calls this **physical knowledge** and says it “does not involve conscious processing, but the idea of physical knowledge goes further to include acquiring an intuitive understanding – a ‘gut feeling’ – about some aspect of the world and the way it works” (p. 4). Ansbacher argued that, “Physical knowledge will usually not be verbalized by the individual, but it serves as an essential foundation for the later development of formal knowledge with understanding” (p. 4).

- **Sparking an interest.** Another outcome of a museum experience may be the sparking of an interest in something in which the visitor previously had little interest (Ansbacher, 2002; Perry, 2002; Falk et al., 2004). Perry cites instances where interests developed through museum experiences developed into lifelong hobbies or even careers. By sparking interests, National Parks can share credit for learning that visitors undertake at places and times that are far from their initial park experiences.

- **Becoming aware.** Ansbacher (2002) and Falk et al. (2004) describe a category of learning that includes opening up the possibility of learning about something new to the visitor (awareness). Visitor quotes used to illustrate this category include: “It…opened my mind to what was happening” (Falk et al., p. 181).

- **Gaining perspective.** Falk et al. (2004) describe a category of learning that includes gaining a different way of thinking about something that may have been previously experienced or learned (perspective).

- **Gaining knowledge and developing intellectual skills.** This is the classic “cognitive domain,” which includes knowledge and the development of intellectual skills. Butler (2002) subdivides this domain into the following hierarchy or levels of competence: Remember, understand, apply, analyze, evaluate, and create.

- **Remembering feelings, developing values, and changing attitudes.** The traditional “affective domain” includes a range of emotional aspects of learning, including values, feelings, appreciation, and attitudes (Butler & Serrell, 2001).

- **Delayed learning.** When visitors draw on their Park experience banks sometime after their visit, **delayed learning** can take place. As Perry (2002) describes, “Delayed learning takes place over long periods of time, often unbeknownst to the learner, and only becomes obvious many months or often years after the initial experience” (p. 23). In a National Park context, delayed learning becomes even more important when one considers that family and other groups may continue to discuss what they saw and did long after the original experience. For instance, parents may help their children recall park experiences as they try to make sense of other aspects of their worlds.

Table 1 (on the next page) relates the **Trail of Time** knowledge hierarchy, developed earlier in this report, to the list of learning-related outcomes just discussed. It makes the point that some
learning outcomes are most likely and most important at specific levels of the hierarchy, while other outcomes can occur at all levels of a knowledge hierarchy (although they may differ in detail for visitors on different levels).

- **Experience banks, wrap-around learning, and physical knowledge can be developed at almost all levels.** A rich experience results in many types of outcomes for visitors on all levels of the knowledge hierarchy. However, we suspect that the content and interpretation of visitors memories and physical knowledge—including what they pay attention to and how they process their experiences—will vary greatly according to where visitors are on the knowledge hierarchy.

- **Interest, awareness, and perspective.** Sparking interest and increasing awareness are will be most important on the lowest levels of the knowledge hierarchy, but may also have some influence on specific aspects of higher-level understandings as well (e.g., awareness of a previously unfamiliar aspect of the topic). To us, perspective implies some pre-existing understanding, so it might become more important on higher knowledge levels (Level 3 and up).

- **Knowledge, understanding, and intellectual skills.** Even when the their theories turned out to be incomplete or incorrect, many visitors still were applying a range of higher-level intellectual skills as they tried to understand how the Grand Canyon was eroded and why it is so deep and wide. They took the evidence they saw, combined it with things they had learned elsewhere, and sometimes created their own theories to explain the Canyon’s development. The key to re-developing the Trail of Time will be to **provide visitors with the knowledge and understandings they need to bring their theories more in line with the scientific understanding** of the Grand Canyon’s development through time.

**Developing Goals and Objectives for the Trail of Time**

We hope the project team will reformulate the Trail of Time’s goals and objectives to include the full range of learning outcomes that take place in informal settings. Here are some examples that could serve as starting points for the discussion. (This is not an exhaustive list.)

- **Remembering previous experiences and prior knowledge.** Three suggestions here: (a) Find ways to help visitors recall relevant information that they have learned elsewhere in the Park, in school, and in their everyday lives. (b) Think about appropriate ways to “set up” the Trail of Time experience using the Web site, visitor centers, and other interpretation that visitors may encounter before walking the Trail. (c) Try to avoid tapping into inappropriate memories and knowledge (e.g., be careful when mentioning glaciers and lakes).
Table 1. Types of learning related to a knowledge hierarchy for the *Trail of Time*.

- **Adding to visitors’ “experience banks.”** Help shape what visitors remember about their Grand Canyon experience by calling their attention to, for instance, the continuity of the rock layers along the Canyon’s walls and across the Canyon’s breadth.

- **Visceral learning.** Help visitors *feel* the six million years that they walked along the Canyon Cutting Trail, and the 4.6 billion years along the Rock Formation Trail.

- **Spark an interest.** Give visitors who arrive at Level 1 reasons to pay attention to the geologic aspects of the Canyon.
• **Become aware.** Help visitors (especially those on Level 2) become aware of the importance of geologic time in understanding the Canyon as it is today, and as what it was like in the distant past.

• **Gain perspective.** Help visitors gain new perspectives on the immensity of geologic time and what that means for understanding the geologic processes that shaped the Canyon.

• **Gain knowledge, develop understanding, and practice intellectual skills.** Identify key facts and concepts about the Canyon’s geology, and then reiterate and reinforce them at many places along the *Trail of Time.* In other words, give visitors ready access to the knowledge and understandings they need to bring their theories more in line with the scientific understanding of the Grand Canyon’s development through time.

• **Remember feelings, develop values, and change attitudes.** Several suggestions here: (a) Use formative evaluation to ensure that the *Trail of Time* will be remembered as a positive experience (rather than a difficult or frustrating one). (b) Consider ways to allow visitors with alternative beliefs to express their feelings about the *Trail* in appropriate ways, perhaps through comment cards that may be eventually be posted in visitor centers. (c) Be aware that, although many visitors’ beliefs about “deep time” will not be changed by the *Trail of Time,* some visitors will be open to reconsidering their thinking about geologic time based on this experience.

• **Delayed learning.** Develop the brochure, Web site, and other off-site interpretation in ways that can help visitors continue to learn from their Grand Canyon experiences long after their visit to the Park.
RECOMMENDATIONS

Recommendations for Continued Development and Evaluation

Selinda Research Associates recommends that project development continue with four major steps, the first three steps preparing for the fourth:

1. **Expand the project team.** We recommend that the team expand to include an exhibit designer, from either the National Park Service or a private contractor, as soon as funding is available. The creativity and insights that a professional designer can bring to the project will be invaluable as the team moves to the next stage of exhibit development. The project team should consider ways to structure exhibit development and design that will ensure continued oversight of both exhibit content and interpretive style.

2. **Develop a “big idea” for the Trail of Time.** We recommend that the team should develop a “big idea” that combines the timeline, story, and metaphoric value of the Trail into a single sentence. According to Beverly Serrell (1996), a big idea provides a single focus that unifies all parts of an exhibition. It states concisely the plan for the exhibition, including its theme, story, or communication goal, plus sets the tone and limits the content of the exhibition.

   A big idea is a sentence—a statement—of what the exhibition is about. It is a statement in one sentence, with a subject, and action, and a consequence. It should not be vague or compound. It is one idea, not four. It also implies what the exhibit is not about. A big idea is big because it has fundamental meaningfulness that is important to human nature (p. 1).

   The big idea provides an unambiguous focus for the exhibit team throughout the exhibit development process by clearly stating in one noncompound sentence the scope and purpose of the exhibition (p. 2).

   Examples of what Serrell considers to be appropriate big ideas include, from a planetarium, “Most of what we know about the Universe comes from the messages we read in light,” and, from a zoo, “A healthy swamp—an example of a threatened ecosystem—provides many surprising benefits to humans” (p. 3). Although Serrell also recommends that the big idea is “the first thing the team, together, should write for an exhibition,” in our experience most teams need to devote quite a bit of effort and time to develop an appropriate big idea for their exhibition.

3. **Develop and test one segment at a time.** We recommend that the team completely develop and evaluate one Trail segment at a time (introductory exhibits, time-scale update stations, and waysides) so that it can stand on its own. Specific recommendations for how to revise the prototype Trail are included in the next section.
4. **Conduct rapid prototyping to formatively evaluate each segment.** We recommend that, during the next stages of formative evaluation, the team conduct rapid prototyping of each completely developed segment, with iterative testing and revisions on-site. Among other things, this next stage of formative evaluation should help determine appropriate formats for the time-update stations and wayside exhibits and appropriate frequencies for the timeline’s tick marks. In some cases, the team may want to develop alternative versions of labels and graphics in advance to answer specific questions that arise during development and design. However, evaluators should also bring equipment needed to revise labels and graphics in the field, so that they can test preliminary recommendations in the field.

Additional recommendations for the continuing development of the *Trail of Time* include the following:

5. **Develop goals and objectives for the *Trail of Time* that encompass the full range of learning outcomes that can take place in informal settings.** See the section entitled *Developing Goals and Objectives for the Trail of Time* for some specific suggestions.

6. **Develop a long-term marketing plan for the *Trail of Time*.** We recommend that the project team develop a long-term, multi-faceted publicity/marketing/ advertising plan. It will be important that the *Trail of Time* become part of what visitors to the Grand Canyon expect to see. One way to achieve this will be to develop a thoughtful and well-constructed plan to systematically and deliberately get the *Trail of Time* into guidebooks, brochures, Web sites, and tour company promotions. This will be an important part of the dissemination of the *Trail of Time*.

7. **Budget for remedial and summative evaluations.** We recommend that, in budget planning, the project team set aside funds for both a remedial and a summative evaluation. Although both of these evaluations would take place after the *Trail of Time* has been completely installed and opened to the public, they would have different goals.

   a. **Conduct remedial evaluation.** The goal of the remedial evaluation would be to find out which aspects of the *Trail* are working well and which aspects are not, in order to recommend changes to the exhibition that can improve its effectiveness. A remedial evaluation is predicated on the assumption that the exhibit team both has set aside funding to implement changes to the exhibition (about 10% of the budget is standard practice) and has maintained the infrastructure required to develop, design, produce, and install those changes.

   b. **Conduct summative evaluation.** After the exhibition team has had a chance to examine and implement the recommendation of the remedial evaluation, the summative evaluation can take place. The goal of the summative evaluation would be to investigate how well the finished exhibition accomplishes its stated goals and objectives. The findings of the summative evaluation will (a) let funding agencies know whether their investments in the exhibition are producing the desired result, (b) help the National Park Service plan future exhibitions and programs at Grand Canyon.
and elsewhere, and (c) inform the field of informal science education as a whole about the effectiveness of the Trail of Time concept in this context.

Selinda Research Associates will provide a more complete evaluation plan along these lines for inclusion in the National Science Foundation proposal to the Informal Science Education program.

Recommendations for Revising the Prototype Trail of Time

Based on our findings, we make a series of recommendations about the continuing development of the Trail of Time, including the number and locations of trails, how to help visitors understand the concept of the Trail of Time, and ways to develop individual segments of the Trail.

1. **Keep two separate trails.** We recommend keeping the Trail as two separate segments with separate foci and identities, tentatively titled the Canyon Cutting Trail and Rock Formation Trail

   - The **Canyon Cutting Trail**, from Yavapai to Mather Point, could focus on the story of the cutting of the Grand Canyon within the framework of the last 6 million years. The primary purpose of this segment might be to help visitors appreciate, understand, and “feel” the time dimension of the cutting of the Grand Canyon by telling the story of how the Canyon’s rocks were uplifted and eroded. We recommend that interpretation here explain the range of processes that weather and erode the Canyon’s rocks, so that visitors can understand both the deepening and widening of the Canyon. Although “young Canyon, old rocks” may be useful for the Mather to Yaki segment, along the Canyon Cutting Trail the team should emphasize that 6 million years is a very, very long time – more than enough time for the Colorado River to carve the Grand Canyon (with help from weathering and gravity, of course). Based on our findings about visitors’ understanding of Canyon cutting detailed in The Cutting of the Canyon section of this report, perhaps the big idea for this part of the Trail should be, “Given enough time, even a familiar, everyday process like stream erosion can make something as incredibly huge as the Grand Canyon.” As stated earlier, there were indications that the scale changes along the Time Accelerator might add an additional barrier to visitors’ understanding the Trail of Time; if the team decides to continue to develop the Time Accelerator concept, then its effectiveness and consequences should be a major focus of the next stage of formative evaluation.

   - The **Rock Formation Trail**, from Mather Point to Yaki Point, could tell the story of the rocks at Grand Canyon and how they fit within the framework of the 4.6 billion year history of the Earth. The primary purpose of this segment might be to help visitors appreciate, understand, and “feel” the time dimension of the Grand Canyon as it relates to the story of how the rocks in the Canyon formed. Secondary purposes should be to help visitors think more about the geologic “events” and past environments that are represented in the Canyon, how they are represented (by rock and landforms), and how they relate in time. We recommend that the wayside exhibits on this segment provide just enough
information about the processes of rock formation that visitors can understand the time significance of the rock layers, and that, whenever a rock formation name is used in a wayside exhibit or other label, visitors have access to visual aids that help them locate that unit in the Canyon.

The tentative names for the Trail segments are for convenience only. We do not recommend that the project team actually use them. The final names might take into account visitors’ tendency to talk about the “erosion” of the Canyon and should avoid the ambiguity of the term “formation” (which could mean both how the rocks came to be formed and a level in the hierarchy of formal names for stratified rocks).

2. **Develop stand-alone exhibits at Mather Point.** Because our findings suggest that many short-term visitors to this area would not really benefit from the Trail of Time concept, we recommend that the team not place tick marks at the Mather Point “plaza” but instead develop several stand-alone exhibits for this area. These exhibits would explain key geoscience concepts (like the cutting of the Canyon and age of the Canyon’s rocks) and motivate visitors to hike the full Trail of Time. Visitors should be able to make sense of these exhibits whether they encounter one or more of them, and the exhibits should make sense regardless of the order in which they are encountered.

3. **Relocate introductory exhibits.** We recommend locating the introductory exhibits just a bit past the point where it seems that visitors have committed to actually walking some length along the Trail. That means they should not be right next to the Yavapai Observation Station, for instance, but perhaps 50 to 100 meters down the Trail toward Mather Point.

4. **Periodically remind visitors of the timeline concept.** We recommend coming up with a strategy that gives visitors periodic reminders about where they are in time, using numbers, words, and graphic aids. At these time-update stations, visitors should (a) be reminded where they are in time, (b) which way the present is, (c) how far back in time this segment goes, and (d) what a step in the present means relative to time in the past. The team should also plan to test alternative approaches to helping visitors make sense of large numbers of years.

5. **Strategically locate and focus interpretative signage.** So visitors can understand both the Trail of Time concept and the stories that give the Trail meaning, we recommend giving visitors more strategically located and focused interpretative signage, with more depth of explanation about basic concepts than was possible during the first phase of formative testing. Interpretation along the Trail should be sufficient for Level 1 and 2 visitors to reach a Level 3 understanding of both the Trail of Time concept and the main story told along that section, without reference to a brochure and without explanation from a ranger or docent. This means the team will need to develop a strategy that provides periodic reminders of where visitors are in the geologic story for that segment, as well as where they are in time. These reminders should come frequently enough that visitors’ minds do not wander too far, and they do not start to miss the point of the Trail.
Story updates might be combined with the time-update stations in some cases, but, depending on the needs of the story, they sometimes may be free standing.

Finally, we recommend that *Trail of Time* be developed so that visitors can achieve basic understandings of the timeline and key geologic concepts based on the *Trail* markings and signage alone. The accompanying brochure and volunteer docent programs should be seen as both supplementing and extending visitors’ understandings of these key concepts. We make the following more specific recommendations about the brochure and docent program and about off-site interpretation for the *Trail of Time*.

6. **Refine the brochures to accompany the *Trail of Time***. Because so many visitors were intrigued and puzzled by the tick marks, signage along the *Trail* should be sufficient for even Level 1 visitors to reach a Level 3 understanding of both the *Trail of Time* concept and the main story told along that section, without needing to refer to a brochure. Keeping this in mind, we recommend that the brochure be redesigned to meet the following recommendations

   a. **Increase awareness and interest in the Trail**. By advertising the *Trail of Time* in visitor centers, bookstores, and other places where visitors gather ideas about what to see and do in the Park, the brochure can plant the seeds for learning along the *Trail*.

   b. **Summarize the stories**. The brochure can pull together in one place the separate events dispersed along the *Trail*, so that visitors can read and reflect on the whole story in one sitting.

   c. **Provide a different perspective**. By including a trail map, the brochures will allow map-savvy visitors to understand at a glance how the *Trail’s* timeline relates to the landforms along the South Rim.

   d. **Support delayed learning and connections to other parks**. By providing something to read after hiking the *Trail*, the brochure can help visitors complete their understanding of concepts that they missed along the *Trail* and reflect on how those concepts might apply to other times and places (including, perhaps, to other National Parks and Monuments in the region).

   e. **Provide cautious introduction to Level 4 concepts**. For a few select concepts, the brochures might try to take visitors a level or two higher on the knowledge hierarchy. For instance, the brochure might include additional information about the erosive power of the Colorado River and about the concept of unconformities, helping visitors jump from Level 3 to Level 4 for these selected concepts.

   On the last point, we emphasize the word “cautious.” The brochure should not become a place to put all the concepts and graphics that did not make it into the *Trail* signage.

7. **Develop live interpretation for the *Trail of Time***. Although visitors should be able to figure out the basic concepts behind the *Trail of Time* using only signage along the *Trail*,
additional interpretation can provide complementary, more in-depth information about concepts dealt with along the Trail, and can give visitors the chance to check their developing understandings with more knowledgeable Park Service volunteers or rangers. Current plans include developing a carefully crafted program to train volunteer docents to interact with visitors. Based on our findings for this study and on our experiences working with docents in museum settings, we recommend that this training include:

a. **Respect visitors’ thinking, even when it’s wrong.** Although visitors’ alternative understandings about the Canyon may seem strange to those with more solid understandings of geological processes, docents should learn both to respect the thought that goes into visitors’ theories and, in a sensitive way, help them identify where they have gone off track.

b. **Show sensitivity toward those who don’t accept scientific explanations.** Based on our relatively short experience on the prototype Trail, it seems likely that volunteer docents will encounter visitors who express disappointment or anger with an exhibit that depicts anything over 10,000 years old. We recommend that, as the team and Park Service develop training sessions and materials for volunteer docents, they should consider ways to help docents interact with visitors who do not accept the scientific explanation for the age of the Earth. Most visitors who believe in a “young Earth” are not going to change their minds, but they may appreciate the opportunity to have their views heard by a representative of the Park Service.

c. **Provide support for answering visitors’ factual questions.** As rangers know and evaluators soon discover, once visitors find someone to answer their questions, they will ask about a vast range of issues. The team should consider ways to give docents access to Park-Service approved answers to these sorts of questions, perhaps using hand-held electronics.

d. **Help visitors make connections.** As docents talk with visitors, they should try to help them make connections between the Park’s geology and other places where they may encounter erosional processes and layered rocks, both at other parks in the region and in other parts of the world.

e. **Provide on-site supervision and support for docents.** In our experience, a successful docent program will require training both in factual information and concepts, and in interacting with visitors as well as continuous mentoring and modeling of docents out on the Trail.

8. **Provide off-site interpretation for the Trail of Time.** Long-term plans for the Trail include a Virtual Trail of Time Web site and additional pamphlets, books, audio technologies, and electronic media that will be available for purchase. Although we do not have specific recommendations about these forms of interpretation, we hope they will be developed with an understanding of how informal learning actually takes place. One way to do this might be to follow up on the Trail of Time experience in ways that will
help visitors connect what they see in the Grand Canyon to other parks in the region and to the erosional processes and bedrock geology that they may encounter back home.
REFERENCES


APPENDIX A: TOPICAL FRAMEWORK

Topical Framework

Trail of Time Phase One Formative Evaluation
October 1, 2004

== FINAL==

Proposed Research Question

By watching and talking with visitors who engage with the prototype trail and accompanying brochure, what can we learn that will help us improve the effectiveness of the Trail of Time exhibit at achieving its goal of helping general visitors further their understandings of geologic time and the connections between time, the visible rock record, and the landscapes at Grand Canyon?

The overarching research themes for this first evaluation will be:

1. To learn how visitors understand the interconnections between the Time Accelerator and the Main Trail segments. Does the change of scale or the short distance between the two segments confuse them, or does it help them make a conceptual jump between human and geologic time scales, or both?

2. To investigate how visitors understand the conceptual relationships between the linear time line they are walking on and the vertical stacking of rock layers in front of them.

3. To learn how we can (a) help visitors understand that the canyon and its landscapes are young (last 6 million years), but the rocks exposed in the Canyon walls are old (up to 1,840 m.y.) and (b) tell stories of earlier stages in the geologic evolution of the region.

Proposed Questions

With no brochure or other interpretation:

1. How do visitors initially notice the ToT meter markings (tic marks)? What do they say? What do they do? What do they think the marks represent? In what ways do visitors notice and discuss the ten-meter marks (with age labels)? What do they think the age labels represent? How do they respond to the ten-meter marks that have events/interpretation written on them?

[By studying these questions, we will develop a greater understanding of and appreciation for where visitors are entering the picture. These questions will help get us
out of our way of thinking about what we are trying to do, and put us in the visitors’
shoes.]

2. In what ways and to what extent do visitors talk about the rocks and landforms in the
Canyon as they walk along the Trail? In what ways and to what extent do visitors talk
about time aspects of the Canyon, in either relative or absolute terms (i.e., in years)? Do
they see a connection between the Trail of Time markings and rocks in the Canyon, and
if so, how do they talk about it?

[These questions illuminate how much work we need to do to get folks into a frame of
mind to think about geology and geologic time.]

3. After they initially notice the ToT marks, what is the range of ways visitors that engage
with them? What things do they do, think about, and talk about?

[This question identifies all the different ways visitors naturally use the marks, again
without judgment as to whether or not they are using them in the right way. These
questions again put us in the visitors’ shoes.]

After introducing the brochure:

4. How does introducing the brochure or brochure elements change the visitor experience?
What do they do differently? What aspects of the brochure do they use, and how do they
relate them to the Trail and to the canyon? What things do they talk about and think
about once they have the brochure? What things are confusing to visitors? What
questions do they have?

[The purpose of these questions is not to test the effectiveness of the brochure, but rather
to use the brochure to see how visitors respond to some guidance and interpretation.
These questions illuminate how easy/difficult it will be to help move visitors along their
ladder of understanding, and will begin to identify language that will enhance their
understandings, and also the language that will confuse them.]

Exhibit Segment 1: Time Accelerator

5. Once visitors understand that this is a trail of geologic time, how do they understand the
Time Accelerator in particular? To what extent do they notice and react to the changing
time scale? In what ways does this changing scale enhance or confuse their
understanding of geologic time? Is there a smooth conceptual transition between the
Time Accelerator and the main Trail of Time; do visitors see it as one trail, or as two
separate trails?

Exhibit Segment 2: Geologic History of the Grand Canyon:

Selinda Research Associates, Inc.
6. Once visitors understand that this is a trail of geologic time, how do they understand this section of the Trail? In what ways do they relate to the length of the Trail, and to opportunities to view the end of the Trail from the beginning, and from intermediate points? Do they comprehend that the first 10 meters of the main trail is a repeat of the Time Accelerator segment? How do they react once they reach the section of the Trail where rocks they are standing on correspond in age to the time markers on the Trail (Kaibab Limestone- 250 Ma), or where rocks below them correspond to the time markers (Tapeats Sandstone- 525 Ma)

7. In what ways do visitors talk about how they, themselves, conceptualize geologic time (through metaphors or other means)?

Entire Trail:

8. In what ways and to what extent do visitors talk about understand the segments of the trail? How many segments do they recognize, and how do they talk about them? Do they understand that there are two separate segments of the exhibit with complementary goals and objectives? How do they describe the purposes of these exhibits?

9. In what ways do visitors engage with the time markers and the events labeled along the trail, and how do they interrelate the two? In what ways do they relate the Trail to the rocks and landscape in the Canyon?

10. How do visitors understand and talk about the Trail and what it means to them and members of their groups? What personal connections do they make to their own lives? What stories do they tell about how they relate to geologic time, and about other places they have encountered these ideas?

11. Based on what we’ve learned during this study, what recommendations can we make about further development of the Trail of Time exhibition?
APPENDIX B: VISITOR OBSERVATION-INTERVIEW PROTOCOL

Trail of Time Front-end Evaluation, Grand Canyon National Park
OMB Approval #1024-0224 (NPS #04-058)
On-site Visitor Observation-Interview Protocol  Draft 1  October 1, 2005

A. Contact Script [For participant observations and interviews]

Example of contact script: I notice that you are viewing the tick marks on the trail. This is a prototype of the Trail of Time geology exhibit, designed to help visitors understand Grand Canyon geology and Geologic time. We are doing a study and would appreciate your input. This study has been approved by the National Park Service and the Office of Management and Budget. I have information on that approval if you would like.* Responses are voluntary and anonymous. It would take about 20 minutes to participate in the study. Would you be willing to participate?

If "NO:" Thank you. Enjoy your visit to Grand Canyon National Park.
If "YES:" May I record our conversation on tape?
If "YES:" Proceed with interview, recording interview on tape.
   If "NO:" Proceed with interview, recording responses by hand.
   *(Hand out Additional Information if requested)

B. Questions 1-5: Topic Area 1—Individual Characteristics

We almost never asked the questions in B and C directly (because many visitors will provide answers to them without our asking as the conversation proceeds). The interviewer sometimes also asked or made notes about educational background and extent of geologic familiarity, but will not ask standardized questions about these topics.

1. Where you are from?
2. What type of group are you with (family, friends, tour group, with or without younger children; ages of children, etc.)
3. What is your age
4. What is your ethnicity (Hispanic/Latino or Not Hispanic/Latino)
5. What is your race: (American Indian or Alaska Native, Asian, Black or African American, Native Hawaiian or other Pacific Islander, White?)

C. Questions 6-10: Topic Area 2—Trip/Visit Characteristics

1. How long have you been in Grand Canyon National Park on this trip?
2. Is this your first visit to the Park?
3. Is this your first visit to this particular trail?
4. Is Grand Canyon National Park your primary destination on this trip?
5. How are you getting around within the Park on this trip?

D. Initial Observations (unobtrusive and/or participant):

With no brochure or other interpretation: NOTE
• How do visitors initially notice the ToT meter markings (tic marks)?
• What is the range of ways visitors that engage with the meter markings? What things do they do, think about, and talk about?
• What do they seem to think the markings represent?
• In what ways do visitors notice and discuss the ten-meter marks (with age labels)?
• What do they think the age labels represent?
• How do they respond to the ten-meter marks that have events/interpretation written on them?
• In what ways and to what extent do visitors talk about the rocks and landforms in the Canyon as they walk along the Trail?
• In what ways and to what extent do visitors talk about time aspects of the Canyon, in either relative or absolute terms (i.e., in years)?
• Do they see a connection between the Trail of Time markings and rocks in the Canyon, and if so, how do they talk about it?

After introducing the brochure:
• How does introducing the brochure or brochure elements change the visitor experience? What do they do differently?
• What aspects of the brochure do they use, and how do they relate them to the Trail and to the canyon?
• What things do they talk about and think about once they have the brochure? Does it change the way they talk about the landforms, time aspects of the Canyon, and the connections between the Trail and Canyon rocks?
• What things are confusing to visitors? What questions do they have?

Exhibit Segment 1: Time Accelerator
• To what extent do they notice and react to the changing time scale?
• In what ways does this changing scale seem to enhance or confuse their understanding of geologic time?

Exhibit Segment 2: Geologic History of the Grand Canyon:
• In what ways do they relate to the length of the Trail, and to opportunities to view the end of the Trail from the beginning, and from intermediate points?
• Do they seem to comprehend that the first 10 meters of the main trail is a repeat of the Time Accelerator segment?
• How do they react once they reach the section of the Trail where rocks they are standing on correspond in age to the time markers on the Trail (Kaibab Limestone- 250 Ma), or where rocks below them correspond to the time markers (Tapeats Sandstone- 525 Ma)
Entire Trail:
• Is there a smooth conceptual transition between the Time Accelerator and the main Trail of Time? How many segments do they seem to recognize, and how do they talk about them?
• In what ways do visitors engage with the time markers and the events labeled along the trail, and how do they interrelate the two?
• In what ways do they relate the Trail to the rocks and landscape in the Canyon?

E. Follow-up Interview:

Script: I notice that you are viewing the tick marks on the trail. This is a prototype of the Trail of Time geology exhibit, designed to help visitors understand Grand Canyon geology and Geologic time. We are doing a study and would appreciate your input. This study has been approved by the National Park Service and the Office of Management and Budget. I have information on that approval if you would like.* Responses are voluntary and anonymous. It would take about 20 minutes to participate in the study. Would you be willing to participate?

Protocol: Now, back to those marks on the trail. What were you thinking [or talking about] as you looked at them? [Probes: How did you first notice them? How were you able to figure out what they meant? Also probe about changes in meaning, and different types of markers, if necessary. Probe: Did the Trail remind you of any other times or place where you have thought about the distant past?]

Some visitors tell us that this Trail seems different from others in the Park. If you were going to describe this Trail to someone back home, what would you tell them?

Please tell me about the signs beside some of the markers. Will they help people figure anything out about Trail? How about the rocks in the Canyon? [Probe about what still confused them.] Did the names on the signs mean anything to you?

I noticed you looking at the brochure. Did any parts of the brochure help you figure about things about the Trail? What parts of the brochure helped the most? What parts weren’t very clear? What things about the Trail and the Canyon still seems confusing?

Now there seems to be one part of the Trail here, and another over there. In your thinking, do those two parts fit together? What helped you figure that out?

[If they used the Time Accelerator] Tell me about the markings in this part of the trail. If another visitor asked you to explain them, what would you tell them? Is there anything you found confusing? Is there something you understand better after walking this part of the Trail?

[If they used the Geologic History of the Grand Canyon segment] As you walked down the Trail, what did you notice? What did you think/talk about as you walked? Is there anything you found confusing? Is there something you understand better after walking this part of the Trail.

Did you look ahead [or back] to the end of the Trail you walked along? [If so what did you see?] Did you see any places where you could link the markers along the Trail to the rocks you could see in the Canyon? [If so] please tell me what you thought about at those places.
What was the best part of the Trail for you? If you could change one/two things about the Trail, what would they be?

Back home, do you think much about the distant past? [probe: If you read a story about a new dinosaur discovery, what parts, if any, would you be likely to remember?] When you think about the past, how do you imagine those times? How do you imagine the time passing? [probe for metaphors, etc.] Have you ever heard anything about how scientists figure out how old things are?

F. Closing  Do you have any questions for us? [Thanks, and token of our appreciation.]

----

Handout available to visitors upon request:

**Trail of Time Front-end Evaluation Study, Grand Canyon National Park**
Expedited OMB Approval 1024-0224 (NPS #04-058)
October 3-5, 2004

This additional information is provided to visitors upon request.

OMB Approval number: #1024-0224
Expiration Date: 04/30/2005

Person Collecting and Analyzing Information: Karl Karlstrom, University of New Mexico, Albuquerque, NM, 87131, 505-277-4346.

16 U.S.C. 1a-7 authorizes collection of this information. This information will be used by park managers to better serve the public. Response to this request is voluntary. No action may be taken against you for refusing to supply the information requested. No personal data will be recorded. You may direct comments on the number of minutes required to respond, or on any other aspect of this survey to:

Information Collection Clearance Officer,
WASO Administrative Program Center
National Park Service
1849 C Street, NW
Washington, D.C. 20240

Selinda Research Associates, Inc., Chicago, Illinois, USA
# APPENDIX C: RESPONDENT DATA

<table>
<thead>
<tr>
<th>Date</th>
<th>#</th>
<th>DC</th>
<th>Total</th>
<th>AF</th>
<th>AM</th>
<th>CF (age)</th>
<th>CM (age)</th>
<th>Group Type</th>
<th>R/E</th>
<th>Data Type</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>100404</td>
<td>1</td>
<td>EDG</td>
<td>8</td>
<td>1</td>
<td>1</td>
<td>3 * 12</td>
<td>5 * 12</td>
<td>School</td>
<td>W</td>
<td>Obl</td>
<td>Yavapai</td>
</tr>
<tr>
<td>100404</td>
<td>2</td>
<td>EDG</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>8</td>
<td>Family</td>
<td>W</td>
<td>Obl</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100404</td>
<td>3</td>
<td>EDG</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100404</td>
<td>4</td>
<td>EDG</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100404</td>
<td>5</td>
<td>EDG</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100404</td>
<td>6</td>
<td>EDG</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>I</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100404</td>
<td>7</td>
<td>EDG</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>Alone</td>
<td>W</td>
<td>Obl</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100404</td>
<td>8</td>
<td>EDG</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>Alone</td>
<td>W</td>
<td>I</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100404</td>
<td>9</td>
<td>DLP</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Ob</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100404</td>
<td>10</td>
<td>EDG</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100404</td>
<td>11</td>
<td>EDG</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>13, 10</td>
<td></td>
<td>Family</td>
<td>W</td>
<td>Obl</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100404</td>
<td>12</td>
<td>EDG</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>Alone</td>
<td>W</td>
<td>Obl</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100404</td>
<td>13</td>
<td>EDG</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100404</td>
<td>14</td>
<td>EDG</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Ob</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100404</td>
<td>15</td>
<td>EDG</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100404</td>
<td>16</td>
<td>EDG</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>~9, ~7</td>
<td></td>
<td>Family</td>
<td>W</td>
<td>Obl</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100404</td>
<td>17</td>
<td>EDG</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100404</td>
<td>18</td>
<td>EDG</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100404</td>
<td>19</td>
<td>EDG</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100504</td>
<td>1</td>
<td>EDG</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Trail of Time</td>
</tr>
<tr>
<td>100504</td>
<td>2</td>
<td>EDG</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Trail of Time</td>
</tr>
<tr>
<td>100504</td>
<td>3</td>
<td>EDG</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Trail of Time</td>
</tr>
<tr>
<td>100504</td>
<td>4</td>
<td>EDG</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>Alone</td>
<td>W</td>
<td>Obl</td>
<td>Trail of Time</td>
</tr>
<tr>
<td>100504</td>
<td>5</td>
<td>EDG</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Trail of Time</td>
</tr>
<tr>
<td>100504</td>
<td>6</td>
<td>EDG</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Ob</td>
<td>Trail of Time</td>
</tr>
<tr>
<td>100504</td>
<td>7</td>
<td>EDG</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Trail of Time</td>
</tr>
<tr>
<td>100504</td>
<td>8</td>
<td>EDG</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Trail of Time</td>
</tr>
<tr>
<td>100504</td>
<td>9</td>
<td>EDG</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Trail of Time</td>
</tr>
<tr>
<td>100504</td>
<td>10</td>
<td>EDG</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Trail of Time</td>
</tr>
<tr>
<td>100504</td>
<td>11</td>
<td>EDG</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Mather</td>
</tr>
<tr>
<td>100504</td>
<td>12</td>
<td>EDG</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>~11</td>
<td>~16</td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Mather</td>
</tr>
<tr>
<td>100504</td>
<td>13</td>
<td>EDG</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>~12</td>
<td>~9</td>
<td>Family</td>
<td>W</td>
<td>Obl</td>
<td>Mather</td>
</tr>
<tr>
<td>100504</td>
<td>14</td>
<td>EDG</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>~11</td>
<td>~16</td>
<td>Family</td>
<td>W</td>
<td>Obl</td>
<td>Mather</td>
</tr>
<tr>
<td>100504</td>
<td>15</td>
<td>EDG</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100504</td>
<td>16</td>
<td>EDG</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100504</td>
<td>17</td>
<td>EDG</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td>Adult</td>
<td>As</td>
<td>Obl</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100504</td>
<td>18</td>
<td>EDG</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>~13</td>
<td></td>
<td>Family</td>
<td>W</td>
<td>Ob</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100504</td>
<td>19</td>
<td>EDG</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>~8</td>
<td></td>
<td>Family</td>
<td>W</td>
<td>Ob</td>
<td>Accelerator</td>
</tr>
<tr>
<td>100504</td>
<td>20</td>
<td>EDG</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td>Adult</td>
<td>W</td>
<td>Obl</td>
<td>Yavapai</td>
</tr>
</tbody>
</table>
Key
Date = MM/DD
# = Interview number
DC = Data collector  (EDG = Eric D. Gyllenhaal, DLP = Deborah L. Perry)
Total = talked with and observed
AF = Number of female adults in group
AM = Number of male adults in group
CF = Number of female children in group
CM = Number of male children in group
Group type
  Family (with younger children)
  Adult (includes adult children),
  Tour
  Alone
R/E = Race/ethnicity
  AA = African-American
  As = Asian
  NA = Native American
  W = White
Type = Type observation or interview
  Ob = Observation only
  ObI = Observation and Intercept Interview
  I = Interview only
Section: Section of the Trail
  Yavapai = Just outside Yavapai Observation Station
  Accelerator = Time Accelerator (Yavapai to Mather segment)
  Mather = Mather Point, between the two main segments
  Trail of Time = Main Trail of Time (Mather to Yaki segment)

Summary Data

The following totals do not include the school group interviewed at Yavapai on October 3:

<table>
<thead>
<tr>
<th>Date</th>
<th>Total groups</th>
<th>Total Respondents</th>
<th>Total AF</th>
<th>Total AM</th>
<th>Total CF</th>
<th>Total CM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td>18</td>
<td>41</td>
<td>19</td>
<td>16</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Day 2</td>
<td>20</td>
<td>48</td>
<td>19</td>
<td>23</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>38</td>
<td>89</td>
<td>38</td>
<td>39</td>
<td>7</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of Group</th>
<th>Number of Groups</th>
<th>Number of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td>15+</td>
<td>62</td>
</tr>
<tr>
<td>Family with children</td>
<td>4+</td>
<td>23</td>
</tr>
<tr>
<td>Tour</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Alone</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Note: Some adult groups included parents with their children 18 years or older.
<table>
<thead>
<tr>
<th>Apparent Racial Identity</th>
<th>Number of Groups</th>
<th>Number of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Indian</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Asian</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Black/African American</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>White</td>
<td>36</td>
<td>82</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Section of the Trail</th>
<th>Number of Groups</th>
<th>Number of Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>At Yavapai</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Time Accelerator</td>
<td>23</td>
<td>52</td>
</tr>
<tr>
<td>At Mather</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>Main Trail of Time</td>
<td>10</td>
<td>23</td>
</tr>
</tbody>
</table>
APPENDIX D: EXPEDITED APPROVAL FOR NPS-SPONSORED PUBLIC SURVEYS

This evaluation project was approved as expedited approval 1024-0224 (NPS #04-058) Grand Canyon NP Trail of Time Exhibit. In bound copies of this report, a printed copy of the completed form follows as the final pages of this report. For PDF copies of this report, the completed form is available as a separate PDF entitled “1024-0224 (NPS #04-058) Grand Canyon NP Trail of Time Exhibit.”