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Analysis of Northern California's Potential Geotourist Sites for Effective Informal Geoscience Education that Address the Earth Science Literacy Initiative's Big Ideas

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By

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Geotourism is becoming more popular and can play a critical role in creating literacy in communities. Moreover, the Big Ideas of the Earth Science Literacy Initiative can be used within signage to address literacy. Because all citizens should have a basic knowledge of Earth Science in order to make informed decisions that relate to Earth Science, geotourism can be used as a way to increase Earth Science knowledge, along with other positive outcomes related to communities' increased well-being. A careful investigation of N=59 geosites reveals that signage can be used to increase this knowledge but that there is a deficit in the number and quality of the signage present at some of these sites. A gap has been uncovered regarding the efforts to teach Earth Science.

DEDICATION

To my family and friends who supported me, giving moral support and also support on my field excursions. My husband Michael, thank for making this happen; and my son Gus, for coming along on some field excursions and helping with surveys, and mostly for his patience. And to all of those 'cheerleaders' out there: You stayed 'til the end! This thesis was important to me and so you made it happen. Thank You.

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CHAPTER I

INTRODUCTION

Geotourism is a relatively new type of tourism that centers on the geology of a landscape. It has been growing in recognition since its name was first coined in 2002, by the Center for Sustainable Destinations of the National Geographic Society (Joly, et al, 2009) in response to the need to incorporate the idea of "sustainable tourism". Geotourism is different than 'ecotourism', which is defined as "responsible travel to natural areas that conserves the environment and improves the well-being of local people" (The International Ecotourism Society, 1990). Geotourism is aimed at providing tourists with two things: enjoyment, coupled with a deeper understanding of the geology and the Earth Sciences (Newsome and Dowling, 2010). Geotourism encompasses this but is not limited to it. Geotourism captures the "sense of place" and depending on the definition used, includes all aspects of a place's identity. Agriculture, archaeology, paleontology, geology, biology, culture, history, and any additional factors that help define that particular area are included in the term "geotourism". The Center for Sustainable Destinations of the National Geographic Society created a charter by which they defined the concept of geotourism (Appendix 1). This global template is designed for nations but can also be adjusted for signature by provinces, states, or smaller jurisdictions, and for endorsement by international organizations.

Geotourism defined

There are other definitions of geotourism, besides the one presented by the Center for Sustainable Destinations. Ross Dowling of Australia stated in the "Emergence of Geotourism and Geoparks" (2006), that geotourism's primary focus is on a place's geology, and enjoying these features in a way that "foster(s) environmental and cultural understanding, appreciation and conservation, and is locally beneficial" (p. 227). This definition stated the geology is the primary focus of the activity, that understanding the geology can help to understand the culture, and that it may lead to appreciation and conservation of the place. Whichever definition is used, the sustainability of the place and the inclusion of the community are encompassed, such that the entire "place" flourishes. However, the National Geographic Society's charter does not exclusively focus on geology's role as the essence of a place. Indeed, urban geotourism is a venue with great possibility. For example, Montreal was the first city to accept and adhere to the geotourism charter, adopting it in 2007. However, for this research, the geology is focused upon as the main attraction or goal of geotourism, especially as it relates to Earth Science education. This study will favor geotourism as put forth in the above-presented charter, in that it needs to be sustainable and beneficial to the communities involved, but will always have a high degree of focus on the geology of the area, as presented by Dowling and Newsome (2006).

Statement of the problem

Geotourists expect to learn about the geology of the landscape and to have an experience of that geology. John Falk, an informal educational researcher, noted that 95% of all learning takes place outside the classroom (Education Week Webinar, 2011).

Therefore, informal education provides an important part of any individual's or any society's science education. According to Falk, "learning is continuous and cumulative" and "we spend less than 3% of our lives in formal instruction settings" (Education Week Webinar, 2011). Contrary to what seems intuitive, people learn much about science outside of the classroom. This makes geotourism a valuable activity when considering the education of people with regards to science. Geotourism may have important and significant consequences for Earth Science education. The National Science Foundation stated that the Big Ideas of Earth Science are concepts and ideas that every citizen should know, specifically "policy makers, educators, students, and the general public" are the focus of the document that was reviewed by leading scientists of every category (Wysession, et.al, 2012). As yet, geotourism in northern California has not focused on addressing these ideas. Currently, there are few studies of California geotourism as they relate to geoscience education. A study that would inventory possible geotourism sites and activities and investigate the potential Earth Science education at these sites will fill a gap in the study of geotourism.

CHAPTER II

LITERATURE REVIEW

Since geotourism is relatively young field of study, published research is sparse and typically discusses the practice of the industry. However, it is important to examine geotourism in light of how it could function best. Therefore, the literature investigation for this research includes a general overview of geotourism, informal learning (with a discussion of traditional learning), Earth Science Literacy Initiative's nine Big Ideas for Earth Science education, and the Oregon Paleo Lands Institute, or OPLI, case study model for geotourism.

Geotourism

To create broader understanding of how geotourism operates within communities, The Center for Sustainability of the National Geographic Society has created a geotourism charter. This document outlines the suggested attributes that sites and communities should have in order to be regarded as sustainable. There has been steady interest in applying the ideas in this document by geotourism sites because geotourism is growing in popularity and in recognition. Tourism centers including the Four Corners region, Greater Yellowstone, the Sierra Nevada, Baja California, Norway, Honduras, Montreal, and Vermont are using it today.

A geotourism area or region, according to the charter, would include places that possess some type of local history, culture, geology, or some other feature that the general public would want to come and investigate. A community would be involved in developing the security, safety, and preservation of the attraction. In addition, the community would become educated about its "geotourism". The site would need to be a place that has the community's interest.

The advantages of geotourism over the earlier ideas and models of tourism, such as ecotourism, are that it is a more holistic approach to visiting an area. It broadens the scope of interest. It also invites in other aspects of the area that were up to this point dismissed. When compared to ecotourism, geotourism involves the community in a way that causes the community to thrive and grow, inviting in new business, and keeping current businesses healthy in that they are able to amend their products to support the tourism in their area. When compared to ecotourism, geotourism covers a wider range of stakeholders, which enhances the local economies. One potential problem lies in the possibility that not everyone in the community may want to embrace the idea. Many people in an area may want to keep traffic levels to a minimum and may be threatened with new growth. These people will need to be persuaded that the tourism will not affect them in adverse ways. The community should be sure that there aren't individuals who will actively work against the geotourism model.

Geotourism is an idea that can take the geographic feel of an area and translate it into education, entertainment, and the ability to appreciate the resources that are present in a particular area. It is inclusive, not exclusive, and generates community support, interest, and development. The opportunity to re-design an area's identity will help the community fiscally, the general population's education and appreciation, and can provide the vehicle to sustain natural, cultural, and historical resources of a region.

Geotourism charter

According to the Center for Sustainable Destinations of the National Geographic Society and the geotourism charter, (Appendix A), geotourists enjoy their activities by varying them daily. Day One may be dedicated to culture and history and how that relates to the geology. Day Two, geotourists may move into the field, to hike and see the unique flora, fauna, geology, and places of interest. Geotourists might be families or groups of families, and include all backgrounds. According to the charter, in order to be a member, a place must be accessible to persons with a range of disabilities.

To be able to develop geotourism and participate in the geotourism charter, a place would ideally have a wealth of different attributes. It would not be necessary to limit requirements to a specific number, with the more the better. There should be some aspect about the place that makes it unique in its own right. Examples include old mining towns, paleontological quarries where new specimens are being unearthed, or a region with good hiking that includes mild climates and interesting flora. It may just be a historical site that has been expanded in such a way as to include other aspects of the 'place'.

According to the charter, a site must possess *Integrity of Place* (p. 1). This could ultimately include the development of a type of infrastructure that would blend well with the place and enhance its natural setting. Using the materials available to the local area would naturally improve the development of an infrastructure, give it a unique character, and improve local economy by creating a market to provide the materials.

Those who accept the charter agree to abide by any International Codes. The World Tourism Organization's Global Code of Ethics for Tourism, and the Principles of the Cultural Tourism Charter are a set of principles the charter embraces, and adherence to them specifically is an expectation of the charter.

The charter suggests *Market Selectivity* (p.1). Key resources are identified with the purpose of finding ways to create interest and to develop the resources in ways that enhance the community, the resource, and the education of the tourist. Some considerations in market selectivity include the uniqueness of the resource. Perhaps there is a specific fossil located at the site. There may be an interesting geologic history or a colorful local history or a culture that has grown up around and because of the resource. These should be researched and developed in ways that could later be marketed in positive ways to persuade visitors to explore it.

The idea of geotourism may be filled with opportunities for local economies. To promote *Market Diversity*, the charter dictates that food, lodging, visitor centers, and shopping become needed. This surprising but very real aspect of geotourism naturally creates development. Caution should be used to keep the new developments in line with the geotourism charter, so that the site's sense of place remains honored. The use of local materials will not only help the local economy but will highlight the place's identity, and help to create the needed motivation to build the needed infrastructure (p. 1).

One thing that the charter has identified as being paramount to the success of the tourism is *Tourist Satisfaction*. In order for tourism to keep growing, tourists need to be encouraged to return. It would be best if these geotourists told their friends and family so that they too could visit. In order for these growth processes to occur, it is paramount that tourists are having the best possible experiences.

According to the charter, *Community Involvement* will provide even more resources as the community acquires a new focus. In order to develop the site's marketability, communities should base tourism on its community resources, as much as possible. For instance, if a mountain range is the attraction, then restaurants with a mountain lodge theme would be an example of tourism based on community resources. Professional advice might be found within the community, and the opportunity for everyone in the community to be involved yields the opportunity to create the needed buy-in.

The *Community Benefit* would be a natural consequence of the adherence to the charter. When the community becomes a working partner with the new tourism identity, new jobs, community pride, and a "knowing of one's heritage" turn into a new possession for the community. Strategies that emphasize benefits to the community should be encouraged.

Another principle identified by the charter as important to sustain healthy tourism is the *Protection and Enhancement of Destination Appeal*. This concept requires that communities provide upkeep and ongoing assessment of how well the endeavor is working. Tourism should enhance the community, keeping it in a healthy state. Smart business decisions by the community about tourism can keep the endeavor working smoothly. Any needed support for this upkeep should be sought and also provided, when able.

The charter next lists *Land Use* as important for consideration. Best practices in the area of development and land use should be studied and followed so that the place's sense of identity is not lost due to new development. For example, a high-rise hotel would not fit it in a place like the Grand Canyon for many reasons, such as the character and atmosphere of the natural setting. This charter article should be given adequate and repeated attention, lest the very reason for the development of tourism opportunity be removed.

One definition of sustainability is that an endeavor be able to keep at its current rate of production. If *Conservation of Resources* are not observed, then there will be a point at which they run out and this may spell ruin for the tourist activity. Additionally, best practices dictate that resources be maximized and used frugally that they may be preserved for future generations and that businesses remain able to take advantage of their availability. It is also an attractive tourism characteristic.

To be successful, the charter cites proper planning to help create both short-term and long-term goals that are viable. Again, the notion of geotourism being a holistic endeavor that utilizes all possible resources to enhance the identity of the place, proper use must be made of the local businesses, including their development, if the endeavor is to be successful. Future planning for all areas must be wisely considered with the new tourism focus in mind. At all times, sustainability must be kept in the forefront of the planning.

Interactive Interpretation occurs when the community begins to engage visitors. At all times, community involvement should be encouraged by giving the community appropriate and accurate information so that residents can assume responsibility, and with it, a sense of pride in their location.

Finally, the charter advises that *Evaluation* should be conducted regularly and adherence to the principles that are outlined in the charter be examined (p. 2). To see that this is done honestly and effectively, an outside independent agency may be called in to perform this activity, but it may be more productive if the citizens themselves take responsibility. All results should be made public to all stakeholders, and if possible, regular meetings to discuss findings should be held.

Informal education

Geotourism is aimed at providing tourists with two things: enjoyment, coupled with a deeper understanding of the geology and the Earth Sciences (Newsome and Dowling, 2010). Enjoyment and education act as a partnership in geotourism. Because geotourism generally occurs outside of the classroom and because geotourism is by nature an experience that is chosen by the geotourist with the educational experience in mind, it has special meaning in the field of informal learning. This type of informal learning is often referred to as free-choice learning, because the tourist chooses to learn while engaging in the activity (Falk, et al, 2009). Falk (2005), a science educational researcher who investigates informal learning, stated “most environmental learning is not acquired in school, but outside of school through free-choice learning experiences” (Falk 2005, p. 266).

In traditional classrooms, lessons are built around concepts that are central to the lesson. When a lesson is presented in small, disconnected parts that have no connection to the big picture, children are forced to learn by rote (Novak, 2009, pp. 15 and 19). This method of acquiring knowledge has been found to be good in the short run, when an exam must be taken, but fails long term, because connections to other concepts have not been made (Mintzes, et al, 1998). In learning that is retained, information must be used in other situations or contexts so that the learner can see how it relates to the big pictures. This theory of learning is called constructivism. Researcher Joseph Novak (1998) stated that meaningful learning occurs when the student is able to apply new information to prior learning, or to solve new problems (p. 19), and in Murphy (1997).

Unlike the typical classroom, the geotourist's classroom is comprised of a broad demographic: young and old, male and female, assorted disabilities, and highly educated as well as those with only a high school education. It is open to all and enjoyed by many. Because free-choice learning is driven by the learner's own motivation, it is an effective teacher and merits close inspection. Free-choice learning is important in this thesis research because it addresses effective educational experiences for the geotourist. The following summarizes free-choice learning and how it relates to the geotourist.

Epistemological Approaches

There are many views on learning and cognition as it relates to learning. Epistemology is that branch of philosophy that is concerned with knowing or knowledge. The views concerning epistemology are varied: they include theories such as empiricism (knowledge through experience), and rationalism (knowledge through pure thinking). One of the best known and widely accepted theories of knowledge is constructivism. Constructivism proposes that the learner "constructs" knowledge, meaning the learner builds upon prior knowledge or background knowledge and experiences (Matthews, 2000). As individuals develop, they construct their perceptions of the world, adding and modifying their ideas of reality as they grow and have different experiences. According to Matthews, the individual continually tries to make meaning out of experiences and processes that are important issues with respect to the individual, be it personal or academic. Mental models of reality are created in parts, and comprise the whole of an idea or concept. Facts are not important, but concepts are, as they relate to the construction of meaning.

The constructionist theory has accumulated a lot of support in the science education community. Varieties of constructivism includes Vygotsky's social constructivism, and Kuhn's philosophical constructivism, although there are many more. The constructivist's views are not limited to education, but have widespread application ranging from learning, teaching, science education, and curriculum (Matthews, 2000). Constructivism's educational influence reaches national curriculum and teaching policy.

Educational theory and its use in geotourism

Jean Piaget, a psychologist during the 20th century, was a pioneer in cognitive psychology, specifically genetic epistemology. Piaget proposed four stages of development as constructs for an individual's acquisition of knowledge. These stages begin with an infant, who is focused on developing sensorimotor development (Huitt, 2003). This stage lasts from 0 to 2 years of age. Next, is the preoperational stage from age 2 to 7, whereby egocentrism and magical thinking dominate the individual's thinking. Beginning around age 7, a concrete stage is active. This stage is characterized by logical thinking, and egocentrism is no longer dominant. The final stage of development is known as the formal operational stage, and it is supposed that the individual is capable of abstract reasoning. A point that may be assumed here is that informal learning is taking place immediately after birth and continues throughout one's life. From this perspective, classroom learning seems of small importance to the acquisition of knowledge for an individual.

Lev Vygotsky was a critic of Piaget's and was skeptical of the rigid stages, and thus proposed the Zones of Proximal Development (ZPD) as a theory. In ZPD, Vygotsky asserted there is a point at which a division can be made between a learner needing little support to perform a task, and needing a lot of support to perform a task (Harland, 2003). One way this support comes is by way of an adult in a classroom, which is appropriate for that setting. However, for education outside the classroom, this type of support may or may not be available in that form. In some situations, such as in outdoor education, there may be an interpretive ranger present to help the learner (or geotourist) make connections. Other times, such as with the case of a museum, placards with commentary may fill this role.

Meyers (2005) suggested that a "modification" of Vygotsky's theory be made, and John Dewey's approach to learning be adopted. He stated that Dewey hypothesized that learning would take place when it was practical and satisfied a need for a solution (Dewey, 1916). If knowledge were to be valid, it had to be useful. Meyers (2005) stated that Dewey believed informal learning was the most dominant way that people learned: in learning by doing, and learning by experimentation. Others have noted the same: "Free-choice learning for a child is predicated on social involvement and is grounded in everyday experience and interaction; that is, it is neither abstract nor removed from their life and home" (Kola-Olusana, 2005, p. 299).

If the above were to be valid in Dewey's philosophy, it would have to be useful, and solve a problem. For the geotourist, the questions come easily enough. In order for the geotourist to feel successful, the answers—or at least connections to them—should be provided. This may occur in assorted ways. Online websites may be important for those who are inclined to research. In the case of the accidental tourist, signage might be invaluable to convey the needed information so that the individual is able to acquire some interesting bits of information, if not significant concepts.

Informal Education and Free-choice Learning.

There are clear similarities and differences when comparing formal education with informal education. Things that are pertinent to consider are where, when, and how these two delivery methods take place, what the learning expectations are, and how each educational setting is best created.

Formal education is guided by format, or curriculum. It should be carefully scaffolded, with the learner's experiences carefully planned. The learner is assessed afterward, and often before, for knowledge gains, comprehension, and reasoning abilities. Classroom learning can be rigid, in that the spontaneity and curiosity that occur during lessons are not always well-received by the classroom teacher because of a need to adhere to content and schedules. Even though flexibility in the classroom may be valued, it is not always possible when following a preset curriculum.

Informal education or free-choice learning occurs in various settings, which are often far-removed from the traditional classroom. Formal and informal education look different in practice because expectations of student outcomes are different. Traditional formal education has very clear expectations for learning, while the learner determines informal learning experiences and any expectations. While learner motivation is often an issue in a traditional classroom, it is typically not an issue at an informal educational site.

Expectations for learning outcomes differ in informal education as compared to traditional classroom learning. In a classroom, a test score might be the outcome, while in informal learning, solving a problem like fixing a car might be the outcome. Constructivism is still very important in both. As a classroom learner proceeds, her/his learning is structured in a way that draws on background experiences, intuition, and scaffolded lessons that construct a concept. Informal education aims at practical learning for immediate use or satisfaction of the learner. Informal learning will often bypass much of the structured teaching, and instead immediately address at the purpose of the learner's inquiry.

Places of Informal and Free-choice learning

The list of ways in which environmental learning occurs is long and includes a multitude of organizations, sites, clubs, venues, media, and outdoor educational system like Boy Scouts or the Sierra Club. Some of these are museums, libraries, television, radio, chats with friends, the Sierra Club, aquariums, the World Wide Web, and even Elder Hostels. There are many more (Falk, 2005) because informal learning takes place everywhere. Museums, zoos, outdoor education experiences, after school programs, and even media programs are places where informal education takes place.

Museums have long been a place of learning, where objects are collected and categorized and studied, and where people are able to come and observe the culmination of scholarly works that surround objects. These centers of accumulated objects, ideas and wisdom have prodigious experience in displaying their objects and describing them. As such, they are in a very good position to convey knowledge (Kola-Olusana, 2005). That said, learning is not always effective in these places. There have also been studies on how to display knowledge so that tourists can build upon their prior knowledge and learn about the topic (Wandersee and Clary, 2007).

Because informal learning often occurs outside of the classroom, a higher proportion of adults are involved in it as an activity. This does not mean that children do not take part, however, since museums are open to all ages. Some museums, such as the Hawaii Children's Museum are designed primarily for children and geared toward them. Museums and outdoor learning situations are especially good as family-oriented activities. There are many that are free of charge, such as the Smithsonian museums in Washington D.C.

Educational outcomes

It is difficult to measure what amount or type of learning takes place outside of a controlled setting. Indeed, the intended lessons very often are secondary to other chance events that are instructive. Learning comes with many different types of experiences. Learning outcomes from informal settings come in many different forms and are varied in unexpected ways. Learners are driven by curiosity, a need to enrich one's mind, current events, and by necessity.

John Falk described one study where a large group of people were questioned and asked if they thought they were knowledgeable about science (Falk and Friedman, 2011). Most of those questioned were positive in their responses, indicating they thought of themselves as having a reasonable amount of scientific knowledge. However, when these same people were given a general science test, the scores indicated that they did not know as much as they perceived themselves as knowing. This is most likely because the average person's knowledge of science does not come from a formal scientific education but of some other informal, free-choice learning venue. Falk believed it was probable that these same persons would be able to elaborate on some aspect of science that would indicate they were scientifically knowledgeable, but that knowledge was based on some personal interest, event, or other free-choice learning experience. This underscores the premise that learning is done to satisfy curiosity or to solve a problem (Falk, 2011).

The importance of Informal or Free-Choice learning

In their webinar (Falk and Friedman, 2011), two presenters, John Falk, Professor of Free-Choice Learning at Oregon State University, and also the Director of Center for Research on Lifelong STEM learning (science, technology, engineering and math), and Alan Friedman, a former director and CEO of New York Hall of Science, gave a lengthy and revealing overview of informal learning called "Learning Outside the Classroom". Falk believed that contrary to what seems intuitive, people learn science outside of the classroom. They do it because it is fun, or they need to solve a problem, or just because they are fascinated (Falk and Friedman, 2011).

People become interested in science because of experiences that occur outside of the classroom. In fact, according to Falk, of the Nobel laureates interviewed, 75% claimed they got their initial passion for science outside the classroom. Because of their interest, they found they needed to perform better in school. Follow-up and support of these budding interests, especially in early adolescence, can lead to long-term interest in science (Falk and Friedman, 2011). As to how this is accomplished, Friedman believed that science should be dealt with at a level of understanding that the learner possesses

(Falk and Friedman, 2011). The learner will pursue his/her own sophistication, as interests are piqued.

Cultural factors are important to whether people will engage in informal learning experiences at museums and national parks. If there is no one around who is interested in science or goes to science learning centers, the probability is high that children will not go either. Efforts to make outdoor education look attractive and making sure people have a good time when they are out there will go far in cultivating personal informal learning trends (Falk and Friedman, 2011).

There are many organizations that are very good examples of how best to provide informal education. These organizations can be thought of as a sort of “best practices” guideline, because they are superior in what they do. No Child Left Inside is one organization that was formed to educate the United States Congress on the need for environmental educational experiences. Another, the North American Association of Environmental Education, states their mission is to advance environmental education and support educators. There are many ways to promote informal learning experiences outdoors. A search of the Internet will yield sites like citizensci.org, amateur astronomy sites, mineral collecting, and gardening sites. These informal education sites have an easy forum on the Internet because it is free and many people are interested in sharing their passion for their own informal learning on environmental topics.

Educational Summary

The art of learning and the science of learning have evolved much over the years. After an identification of how people learn (epistemology), came constructivism, and research on how information is built upon or scaffolded by the learner. Educators acknowledged they must mold their lessons into carefully planned experiences from which a student could gain knowledge. In the not-too-distant past, it was assumed that valid education occurred only at seats of learning, in the classrooms. As science progresses, so does the study of learning. It is now evident that classrooms are important tools from which people get formal lessons in science. But it is equally evident that the need for informal, ongoing stimulation in all areas, including science, will not only provide entertainment, but will actually provide the interest from which students can take hold of their learning and keep moving forward. After all, 95% of the learning experiences that students have occur outside of the classroom.

Earth Science principles

"The Big ideas" in Earth Science

The Earth Science Literacy Principles (Wysession, et al, 2012) is a document of 4000 words that frames the initiative to create an Earth Science-literate public. The document identifies nine "Big Ideas" that encompass concepts each citizen should know and understand by adulthood. Each of the "Big Ideas" have concepts that support and develop the ideas. The ideas and their supporting concepts represent the accumulation of Earth Science research to date. The authors believed that the ideas are critical to finding ongoing solutions to numerous real-world issues such as climate literacy and natural disasters. They expect the Big Ideas in this document will help to shape geoscience education. This document is being used in textbooks, informal education environments such as museums and educational videos, and has been used to brief lawmakers on Capitol Hill (Wyession, 2009). The document's usefulness has already being proven. It has been used as a reference document in the case of the Texas school board in a discussion about evolution. Prior to the document, it seemed to some of the public that the scientific community appeared conflicted regarding the theory of evolution. The document's existence firmly underlines the science community stance and shares the scientific debate as a process that is rigorous and as such, supports the argument for evolution (Wyession, 2009).

It is important to know about the Earth Science principles and the 'Big Ideas' that emerged from those principles so that informal and free-choice learning opportunities can be created. It is imperative for people to know how their actions affect the planet. Many people live unaware that a landfill that has been built near them, how it was built, what the landfill contains, how many landfills there are in the area, and what the landfill's capacity for interacting with the environment is. Many people don't realize there is a very large body of plastic in the Pacific Ocean that is approximately twice the size of Texas. People are unaware of it, and so do not understand how it affects the health of the ocean today and in the future. And if they don't understand these interactions, they may be less aware of Earth's influence on people.

Educators are in the best position to provide the layperson with the information to create a literate society, and thus, give us Earth Science literacy (Earth Science Literacy Principles, 2009). It takes an understanding of these complex processes, their effects, both past and in the future, to translate these ideas into meaning. Earth Science principles and the Big Ideas that emerge from them provide the basis for informal learning about the environment and other outdoor education. Free-choice learning can be utilized so that the layperson can understand about the planet s/he lives on.

Big Idea number one

The first big idea is that scientists can have confidence in their knowledge and understanding of their area of expertise because of proven scientific methodologies. Some of the underlying concepts include the need for Earth Scientists to develop solutions to society's needs such as climate change, hazard studies, and the location and recovery of natural resources. Scientists use Earth Science principles to understand how the planet works. Earth Scientists perform modeling studies, experiments, analyze data, and propose theories in order to study the Earth. They must use indirect methods to create many of their hypotheses, because there are no direct means to study some processes, such as the structure, composition, and the dynamic nature of Earth's interior. Charles Lyell (1830) summarized Hutton's work (1788) and endorsed "uniformitarianism", commonly stated as "the present is the key to the past", in conjunction with other principles to investigate the past and make predictions about the future. Scientists model processes in order to explain their observations. These models undergo peer review for a rigorous process of scrutiny. As more is learned about our planet, we should expect this document to evolve along with the science that it describes.

Big Idea number two

The Earth is 4.6 billion years old. Earth materials, like rocks and fossils, and careful study of structure, sequence, and radioactive decay rates, provide data that permit us to understand active geologic processes, and therefore, the Earth. By studying rocks, we have found evidence for the formation of our solar system in meteorites and moon rocks. We know from fossils that life appeared on Earth 3.5 billion years ago, whereas *Homo sapiens* (humans) have only been here as a species for 0.004% of Earth history

(Earth Science Literacy Principles, 2009). There have been both gradual and catastrophic changes such as the formation of supercontinents, sea level, and climate change (gradual), and earthquakes, volcanic eruptions and associated processes, and meteorite impacts (catastrophic). Because we study many aspects of Earth Science we find much evidence that underscores that the Earth is old.

Big Idea number three

The third big idea highlights the four interacting spheres: the biosphere, geosphere, atmosphere, and lithosphere. We can visualize Earth processes in terms of energy passing between spheres or interacting with another sphere. Energy flows in cycles, like the water cycle, the carbon cycle, and the nitrogen cycle. We can think of Earth and its processes in terms of spatial scales and temporal scales, among which the four spheres interact. Earth systems are always in flux—they are dynamic. The Earth system is one of equilibrium; changes in one system affect the other systems, sometimes in ways that are hard to predict.

Big Idea number four

Earth is constantly changing. Changes are occurring through hydrologic, physical, chemical, and biological processes, and these changes can be explained using universal laws.

Big Idea number five

Earth is a water planet, and Earth is the only planet in the solar system with liquid water. Because we have liquid water, life exists on Earth. The hydrologic cycle illustrates how water cycles through all of the spheres and is stored in streams, lakes, oceans, and glaciers.

Big Idea number six

Life on Earth is evolving and the Earth is affected and modified by this life. The fossil record supports this idea. Life has flourished and suffered extinctions, over and over again throughout time. We study Earth systems, populations, and species to learn about how life have evolved and reacted to ever changing conditions. By studying the fossil record, we know that there has been great biological diversity in the past. Life on Earth impacts all of Earth's spheres. The physical and chemical properties of life affect the geosphere, hydrosphere, and atmosphere, and lithosphere. Multicellular organisms are responsible for the level of oxygen on Earth today.

Big Idea number seven

Humans need resources. This need for resources drives human civilization and the course of history. The geology of an area will determine what resources are available. Human populations have repeatedly settled at areas near the best resources, so they could have food, commerce, and other societal needs. Some resources are renewable, but many are not. Significantly, they are not distributed equally around the planet.

Big Idea number eight

Natural hazards affect human lives. These hazards result from many different types of processes, both normal Earth processes, and human-induced processes. Most people are aware of many and may have direct experience with a few of them: tsunamis, earthquakes, mudslides, fires, floods, hurricanes, and tornados. Humans cannot eliminate these many of these hazards, but scientists are working on reducing their impacts. Through planning, damage can be minimized. It is essential for human populations to become literate about Earth Science so they can make informed decisions about the environment, laws, and planning.

Big Idea number nine

Humans alter the Earth. We have become a geologic agent capable of affecting our planet, altering natural processes. Scientists documenting these changes are trying to understand what it all means. An Earth Science-literate public will go far in making sure we are good stewards. Everyone is responsible---everyone, everywhere. Each person must assume responsibility for the Earth and this begins with becoming literate.

Oregon Paleo Lands Institute

Oregon Paleo Lands institute is an example of successful geotourism. As such, it can serve as a benchmark against which northern California geotourist sites are developed. The Oregon Paleo Lands Institute (OPLI) is a 503(c) (3) nonprofit organization dedicated to promoting and preserving the geologic and living history of the John Day Fossil Beds National Monument. It is a source of education about Oregon’s geologic past for tourists and the communities that live nearby and who support OPLI. OPLI headquarters is located in rural Fossil, Oregon. Travelers can enjoy many different types of activities while learning about the landscapes that they travel through from this central location. OPLI is special in that it has taken an economically depressed rural community and capitalized on its fossil resources and rich geologic history to bring economic and educational development to the region. This institute is a model of how geotourism is described in a community and how an area's geology and natural history can be advantageous.

OPLI was created to enhance the development of geotourism opportunities in the region, bringing economic development to the towns of rural Wheeler County in eastern Oregon. Oregon State has a population and median wage of 3,825,657 and $50,165, respectively (U.S.Census Quickfacts, 2010). Wheeler County, as of 2009, has a population of 1363 persons, down from the 2000 census of 1,547. The median income is $32,231, with 16.8% living below the poverty level (U.S.Census Quickfacts, 2010). According to the geotourism definition, an area's community and economy should be favorably affected by the adoption of geotourism (Center for Sustainable Destinations, 2010). In the town of Fossil, where there is already a small guest ranch and a few inns (Richards, 2009), new services have begun to develop. The institute, which dedicated its new field center on September 12, 2009, has a bookstore and travel center. It serves as the headquarters for the OPLI organization. The town of Fossil hopes the field center will be a resource for travelers and community supporters (Bajandas, 2009).

The involvement from the communities has been favorable. Mitchell School in nearby Mitchell, Oregon, has participated in the creation and development of OPLI by working with a California-based artist on preparing a metal plesiosaur sculpture (Figure 2.1). This Cretaceous marine creature was found in 2003 in the region's fossil beds and the sculpture is now being showcased at the field center. Funding for the Plesiosaur project comes from various community sources: a charitable trust; a family fund, the Oregon Community Foundation, and Wheeler County Title III (OPLI website, 2010).

Figure 2.1 Metal plesiosaur created by Artist Larry Williams and the students at Mitchell school for the Oregon Paleo Lands Institute.

(Photo courtesy of Oregon Paleo Lands Institute; Photographer Anne Mitchell, OPLI website).

Residents of the community are also reacting favorably. The plesiosaur built by the Mitchell school students took several months to create. During this time, teachers taught students about natural history, welding, and art. In the end, one of the most valuable consequences of the project will be the education the area residents receive about the natural history of where they live.

Support for OPLI

Support for OPLI comes from many different sources. Oregon Solutions is an organization whose mission is to help develop sustainable solutions for the communities of Oregon. As such, they are fervent supporters of OPLI. In 2001, the organization awarded OPLI with the first Oregon Solutions award. The support given by Oregon

Solutions helped to redevelop the high school into the new OPLI headquarters (Oregon Solutions Projects Central Oregon. (2010).

Oregon Solutions is focused on supporting the educational value of nearby ranching organizations, helping to define and support sustainability in ranching and supporting efforts toward the restoration of streams on the Pine Creek Ranch, which is the property of the Confederated Tribes of Warm Springs. Other support from Oregon Solutions has been focused on creating a National Park Service interpretive center for the John Day Fossil Beds, whose cost was an estimated $8.3 million. These projects were undertaken in order to create partnerships, jobs, and educational tourism for the area of central Oregon (Oregon Solutions, 2010).

The Small Business Administration provided a grant for $250,000 that mostly covered the building of the field center in Fossil (The Bulletin, 2009). This money was appropriated with the help of Oregon Senator Ron Wyden. Other small businesses have also donated services. Artist Larry Williams helped students from Mitchell school create the plesiosaur sculpture. Finally there have been many donations and gifts from members who helped provide the rest of the $50,000 that was used for the creation of the Visitor Center in Fossil.

OPLI programs and activities

One of the children and family programs offered through the center is Science Saturdays for Kids. The program introduces fun ways to interact with the center's exhibits and provides hands-on activities, including a fossil show-and-tell. The fee for the program is $1. Other programs include the very popular Science, Art, and Geologic Exploration (SAGE). In this program, children learn about aspects of nature and art. This is an inquiry-based program that occurs outdoors. Families and children of all ages participate and the program includes writing, reading, math, science and art (OPLI-Children and Family Programs, 2010). Groups from 6 to 10 people have the opportunity to use microscopes, GPS devices, and cameras to investigate the John Day Fossil Beds Monument. The children also work on creating a youth field guide for the program, including information for the SAGE program's link on the center's website.

Focus is also given to the residents of Wheeler County, in an effort to teach them about the areas they live in and the resources that are present. The effort is made to support healthy ecosystems while making educational opportunities available for the residents. Stream restoration is one of the key projects that will be addressed.

Classes

According to the website, one of the various outreach activities the center offers are classes. Included is a *Water Color Painting and Nature Journal Writing in the Palisades* experience, wherein students are guided to develop their skills in observation, using watercolor, sketching, or writing. All of the supplies are included with the course. Students explore the John Day Fossil Beds, so the program also includes easy hikes with colorful vistas (Figure 2.2). The experience covers two days, over a weekend and the published price is $75 for one day, and $125 for both days.

Figure 2.2 Big Basin Member of the John Day Fossil Beds.

(Photo courtesy of Oregon Paleo Lands Institute, Photographer Ellen Bishop, OPLI website).

Wildflowers and Photography in the Painted Hills can be enjoyed by taking a class led by a geologist/photographer/botanist. Students learn geology, photography, and plant life of the area. This experience is a one day event.

Fossils and Invasives is a two day program, occurring over a weekend and includes lunch, dinner, and music. During this class, the focus is on regional geology, fossil hunts, and the making of a map of to help control invasive species. The evenings are a time to relax with a BBQ dinner and live music beneath the stars.

The center also features a program called *The Active Cascades: Mt Hood*. This is a weekend excursion in which hikers explore glacial history and the volcanics of the region, with stops at active vents. This trip is geared toward physically fit geoutourists, as the trip requires a good amount of physical exertion and tolerance of high elevation.

Other programs are designed for cyclists. *The Geologic Cycle-in the John Day Basin* is a road cycling tour with plenty of variation in elevation. The town of Spray serves as a base camp while cyclists explore the geology and natural history of the region.

Beyond the classes, OPLI sponsors various hikes into the John Day Basin. There are several day hikes, or a custom hiking trip can be arranged. Some of the hikes include *Spring Day Hiking Trip into the Painted Hills Unit, Summer Day Hiking Trip into the Sheep Rock Unit, Summer Day Hiking Trip into the Clarno Unit, Summer Day Hiking Trip into the Painted Hills Unit, Fall Day Hiking Trip into the Sheep Rock Unit*, and *Fall Day Hiking Trip into the Clarno Unit*. Hikes are between one and three miles.

Educational opportunities and the "OPLI" website

One of the focuses of the Center is the educational value of the long, undisturbed geologic history of the basin and its record of climate change throughout time. The OPLI website features various links to the geology of the region. There is a link to the *Current Earthquakes in the Pacific Northwest*. The link leads to real-time data on earthquakes, tsunamis, and seismograph records in the Pacific Northwest. There is a *Global Earthquakes* link that provides information concerning magnitude, locations and other data for earthquakes in the world. This link is hosted by the United States Geological Survey (USGS), Earthquake Hazards Program. *Plate Motions and Climates Through Geologic Time* supplies paleomaps, tectonic plate animations, and climate changes over geologic time. The maps have detailed information concerning sea level change, mountain belts, and lowlands.

Other links carry information about the *John Day Fossil Beds National Monument*, the *Columbia River Gorge and the Great Floods*, *Plesiosaurs*, and even a baby plesiosaur animation. There are also links on *Ichthyosaurs, Columbian Mammoths*, *Smilodon*, the *History of Horses*, and *Metasequoia.* All of these sites contain scientific information about various aspects of the topic, ranging from Ice Age mammals to the swimming styles of ichthyosaurs.

Climate change has been recorded by the rocks and fossils of the basin in fine detail. Because of this, the institute is able to shine a light on the past, present, and future of these changes. The institute provides educational value by supplying four documents on climate change: “Climate Change of the Columbia Basin,” “Mt. St. Helens,” “Pacific Northwest Climate Change,” and “Wheat and Sulfur.” Each of these are scholarly articles, giving the geotourist an in-depth look at the state of climate change in the region.

Geology

The OPLI website overviews the last 400 million years, as it relates to the Pacific Northwest. The topics that are covered are regional geology, geologic history, common fossils, Wheeler High School fossil beds, and the John Day Fossil Beds. There is also a place for favorite geologic sites that will be added to as popularity of tourism activities develop. These sites include scholarly works about the different geologic formations, the geologic history of the John Day basin, fossil flora and fauna, common fossils of the Wheeler High School fossil bed, and a link to the *John Day Fossil Beds National Monument* website.

The website also contains information of *Food and Lodging*, *Exploring the Region, Field Center News* and *Function*. There is information concerning future plans for the center, the need for ongoing support, how to become a member, the OPLI store, Podcasts, a virtual tour, OPLI partners and supporters, and how to contact OPLI. The web address is http://www.paleolands.org/find/time/here.

Opportunities

Wheeler County has the opportunity to showcase eastern Oregon's beautiful landscapes that were created by diverse geologic processes. They have the opportunity to educate travelers, bringing economic relief to a depressed region, by serving as a focal point for tourists. The community has already begun to become educated about the natural history, and is learning how to promote sustainable ecosystems, so this has been a benefit to the community in multiple ways. OPLI has and will continue to provide a venue for the community to bond, and provide residents of Oregon and many other areas with recreational ideas and the service infrastructure needed for the geotourism industry to develop.

Conclusion

The Center for Sustainability by the National Geographic Society has created the geotourism charter in order to enhance and further develop geotourism (Appendix A). Geotourism has multiple effects on communities. Not only can it help to develop a community's economic opportunities, but also it may provide for the geoliteracy of our citizens because of the natural informal education it can give to visiting geotourists. These sites of geological importance can be utilized in a geotourist plan to address several of the Big Ideas of the Earth Science Literacy Initiative. Oregon Paleo Lands Institute provides a real world example of how geotourism operates. Because of this, it can serve as a benchmark for geotourist sites identified elsewhere.

CHAPTER III

METHODOLOGY

Geotourism can play an active and effective role in educating people on the Big Ideas in Earth Science. People visit unusual landscapes as a way to relax, have fun, and spend time with friends and family, and a trip to a new and interesting place can promote questions in the visitors' minds about how the landscape evolved. After an outdoor adventure, many people arrive home to conduct some post-vacation research into the areas visited. It is my belief that these moments can be used to further the causes of geotourism and the advancement of education in the geosciences. In Northern California, there are numerous sites where the Big Ideas in Earth Science could be used as teaching opportunities. The problem becomes the identification of these sites for the best "outdoor" classrooms that provide recreation that is at the heart of tourism. Several questions need to be answered in order to answer the question "Which potential geological sites in Northern California could promote geotourism and provide effective geoscience education".

Boundary of study

First, the geographic boundaries of Northern California need to be determined. There are many ways to divide California. One way that may be useful in this study is by looking at population centers (Metcalf and Turplan, 2011). Demographic trends project two megaregions in California. One is the southern basin where Los Angeles and other major population centers are growing. The other megaregion, or possible megalopolis, is a major, growing urban population center extending from the San Francisco Bay area up highway 80, into Sacramento, from the San Francisco Bay area and into the Central Valley along highway 580, and south, down Interstate 5 and highway 99 to Fresno and beyond. There seems to be no official or agreed upon boundary for the Northern-Southern California boundary in the literature. For the purposes of this study and because it is helpful to include those populations likely to be encountered while doing the study (as indicated in the megalopolis model), the boundary area for this study that will be designated "Northern California" will be that area north of, and including Fresno, and the Sequoia-Kings Canyon (Figure 3.1). In addition, some of the surrounding areas north and south of both borders, and east and west of them, may be included because of their proximity to major geological features and/or events associated with them. One example that illustrates this situation might be the northward progression of volcanism of the Cascade chain. Another example might be due to the Native Americans who made use of the lava tubes at the Lava Tubes National Monument, and who, in their resistance of the Cavalry, freely moved across what are now political boundaries.

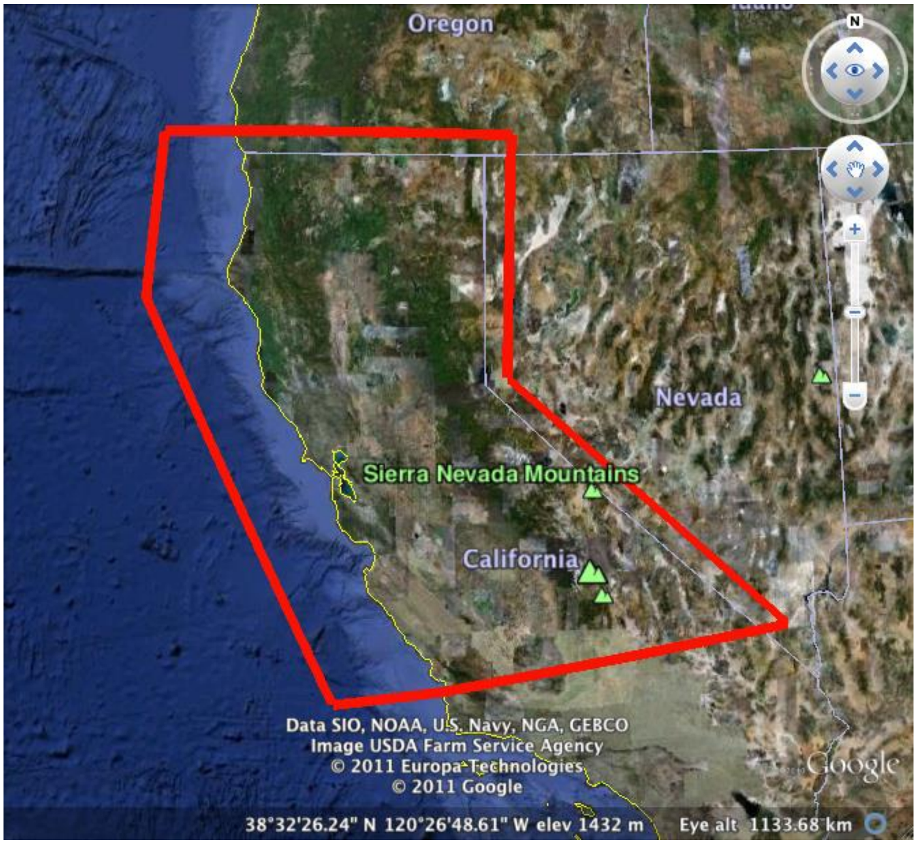

Figure 3.1 Boundary area of study:

The Oregon-California border will be the northern boundary. The bold line in red will be the southern boundary. The study will remain within California, but at all state lines, there may be some geographic spillover, depending on a geosite's limits (Google Earth, November, 2009).

Potential geological sites

A potential geosite must have appeal for the geotourists. This can be accomplished through some interesting physical feature, process, or phenomenon that is occurring now, or which has occurred in the past. For example, Yosemite National Park has an array of features and processes that draw a visitor: rock domes, glacial lakes and waterfalls, and the Merced River. As geotourists stay and experience Yosemite, they learn there is more depth to the geology than they first thought. The same could be said for many sites in California, though arguably, not on the same level. In short, there should be some unusual geologic feature demonstrating some aspect of the geosciences in order for a site to qualify as a geotourist site.

Choosing potential geosites will be dependent upon what the geotourist wants to experience. Geotourists like to hike, take pictures, and collect rocks and fossils, and learn about the geologic processes that are at work on and below the Earth's surface. There should be a variety of options at each site. If there is only one option at the site, it will need to be very spectacular for the geotourist to want to return. For example, consider the case of Mt. Whitney. This is a popular hike for those who are avid hikers with a high degree of expertise and fitness. This hike would not be included in the geosite list because it is too constrained to appeal to a wide range of geotourists. To locate the geosites of this study the following methodology was used:

1. Review of California and National Parks. It was necessary to investigate various hikes, tourism activities, geology programs, and vista points, and to record them with regards to popularity, rigorousness, and other variables.
2. Review of selected hiking books of California. The hikes were selected based on their rigorousness, length, popularity, and location.
3. Internet search of California geotourism. Selected sites could be included in this study.
4. Search California community colleges and universities for field courses in geology. There is much knowledge about California geology at these institutions and thus knowledge about possible geosites.

5. Review of geologic guidebooks from professional clubs that print information on potential geosites.

The geotourist

One definition of geotourism is the travel to those areas that showcase the geology and geomorphology of an area, and include infrastructure that support the natural landscape and the visitor (Center for Sustainable Destinations, 2011). Understanding this is important because it constrains who will visit the area. The identification of the geotourist will aid in the locating of the geosites and in the promotion of the geotourism. Geotourists can be subdivided into two groups:

1. Those who actively research an area with the intent to learn more about it, including but not limited to those who search for more rigorous, adventure-type activities such as hiking.
2. The general tourist who has an interest in the natural landscape, and who may encounter the geosite by accident.

These two groups need to be separated because of the different ways in which each group selects sites to visit. The members of one group may prefer to research their trip and plan according to the geosites' geologic processes, facilities, location, or any number of reasons. The other geotourist might be one who has come to the geosite with no prior information about it. This geotourist might have arrived because they needed a place to rest and the nearby landform looked inviting, and they may have no prior knowledge of geology, but an interest in the landscape for various personal reasons. Because the focus for arriving at the geosite is different, and these two tourist groups may have different educational backgrounds, there will need to be a diversity of treatment when it comes time to promote the geosite. Geotourists were surveyed at various geosites in order to determine basic characteristics, interest, and sources of information for the geosite being visited. (See Appendix B for Geotourist Survey and Mississippi State University IRB approval documentation.)

The Earth Science Literacy Principles (ESLP)

All people within a community must have some basic level of understanding about Earth Science principles, in order to be able to cope with the many natural events that can and do occur. Some people however, are extremely interested in their natural surroundings and take it upon themselves to learn as much as they can. These people will often become the geotourists that this research focuses upon. However, many people do not have even a basic understanding about how things occur in nature. Great opportunities are present at the geosites that may help these individuals understand a little about how the Earth operates. According to the Earth Science Literacy Initiative (2009), the nine "Big Ideas" or concepts that have been targeted as those that will deem a population 'literate in the Earth Sciences" are

1. Scientists know what they know because of a proven methodology
2. The Earth is 4.6 billion years old
3. Earth is a complex system of interacting rock, water, air, and life
4. Earth is continuously changing
5. Earth is a water planet
6. Life evolves on a dynamic Earth and continuously modifies Earth
7. Humans depend on Earth for resources

8. Natural Hazards pose risks to humans
9. Humans significantly alter the Earth

Site specific geologic concepts

Each geologic site has its own unique geologic history and it is this history that is responsible for the landform, process, or phenomenon that is represented. It was necessary to identify the geologic concepts that are represented at each site. To do this, site visits were necessary, as well as the reconstruction of the geologic history of each site. This helped determine which Big Ideas in Earth Science the site best addresses. For example, with Yosemite National Park, a preliminary analysis revealed that several Big Ideas can be addressed in the park:

1. *Igneous Rock Formation and the Rock Cycle* (Big Idea 4.6- Earth Materials take many different forms as they cycle through the geosphere).
2. *Glaciations* (Big Idea 4.6- Earth Materials take many different forms as they cycle through the geosphere; Big Idea 4.8- Weathered and unstable rock materials erode from some parts of Earth's surface and are deposited in others).
3. *Rivers* (Big Idea 4.1- Earth's geosphere changes through geological, hydrological, physical, chemical, and biological processes that are explained by universal laws; Big Idea 4.8- Weathered and unstable rock materials erode from some parts of Earth's surface and are deposited in others).

4. *Erosion* (Big Idea 4.7- Landscapes result from the dynamic interplay between processes that form and uplift new crust and processes that destroy and depress the crust; Big Idea 4.8- Weathered and unstable rock materials erode from some parts of Earth's surface and are deposited in others).

Further investigation identified the informal science education opportunities at Yosemite. As this example shows, there typically exists more than one geological concept at each geotourist site that can be effectively addressed. (If there is not more than one geological concept, then the potential as a geosite was reconsidered).

Promoting geotourism

After concluding what is present at the identified sites by visiting them, and interviewing visitors to ascertain what is important to them, it was possible to determine what was needed in the form of informal science education at each site. Each site will require a different and unique response. This research identified the best vehicles for informal education and publicity for the geosites.

Because there will be a difference in geologic background from one geotourist to the next, there should be an array of challenging materials available, ranging from geologic histories, suggested reading, and explanations of the Big Ideas that can be demonstrated at each geosite. Publicity of the site should include a brief overview of what the geotourist might find at the site, including facilities and other tourist infrastructure. There should be an account of the geologic phenomena that provides the draw for the geotourist.

While there are several ways a geotourist may plan their tourism trip, the most obvious and convenient way to do this might be by browsing the internet. Therefore, this research included identification and analysis of websites that describe the visited geosites. A web presence for a geosite can provide quick information for the potential geotourist, along with the ability to compare geotourist sites quickly and easily. Providing the potential geotourist with pertinent information about Northern California geosites could effectively promote geotourism in this area. Items that may be included could be topographic maps, weather maps, geologic maps, and road maps. These could be available in downloadable formats. For teachers and students who would like to utilize the educational opportunities at the geosites, lessons and activities for K12 geotourists in downloadable format would be helpful. Geosites' websites were analyzed for the presence of this information and resources.

For the accidental tourists who find themselves at the geosite because of a delay in the trip such as for a rest stop, there could be a variety of ways in which to entice the visitor to venture into the geosite. Investigation of the geosite's facilities included the analysis of signage, and whether educational and effective signage that addressed the Big Ideas of Earth Science Literacy was present.

Comparing Northern California geosites against Oregon Paleo Lands Institute

The Oregon Paleo Lands Institute (OPLI) has taken a region in eastern Oregon that was experiencing severe economic downturn, and that had lost its major economic earning capability, and created a new economic asset for the area. What had once been a place with no foreseeable way of developing any industry, OPLI used the rocks with their fossil treasures as a turning point for the region to re-invent itself economically. Although much of the land in Northern California is urban and has a firm economic base, there are still rural communities of Northern California that find themselves in a similar predicament as that of Wheeler County, Oregon. The answers to the primary question in this research, “Which potential geological sites in Northern California could promote geotourism and provide effective geoscience education", can be compared against the OPLI model. The final component of this research identified similar activities for Northern California that OPLI has created for Eastern Oregon.

Summary of research

There are several questions that this research investigation addressed. This study can succinctly be summarized as

1. Location and identification of geotourist sites in Northern California
2. Analysis of each site for its potential informal geoscience education, especially those that address the Big Ideas in Earth Science literacy.
3. Identification and possible design of effective signage and/or web-based informal education that may help promote informal geoscience education and geotourism.
4. Comparison of potential geotourist sites in Northern California against the Oregon Paleo Lands Institute case study example.

CHAPTER IV

GEOSITE DATA

California is diverse in its geology; hence it is necessary to organize the geosites in some way, especially due to the large numbers of sites. It is appropriate to approach this organization according to geologic provinces. Although the number of geosites is large, there is still the probability that some sites have been overlooked, both because of the need to cover the most dramatic cases, but also, simply because some sites have not yet been identified by the researcher. What follows is an overview of some of California's best geosites.

It is important to note the most important geosites and the attributes that make the sites important to geotourism. This chapter is organized by province and a table introduces important geosites (Table 1). For each site, an overview of the geology type is given (Table 2), followed by tourist infrastructure. The table is an overview of the geology of what types of geologic features one might find, such as seismic features, volcanic features, caves, erosional features, depositional features, engineering and mining features, igneous structures, the availability and legality of collecting, and the presence of fossils. The infrastructure is based on the available lodging, parking, community support, trails, disabled access, and signage, ease of access, level of difficulty, and whether a web page could be found that provided useful information for the geotourist. (Website information is available in Appendix C and a data spreadsheet for this study is available in Appendix D).

Table 4.1 The organization of Chapter Four by Geosites

Provinces						
Klamath	**Cascade**	**Modoc**	**Basin & Range**	**Sierra Nevada**	**Great Valley**	**Coast Ranges**
Castle Crags	Mt. Shasta	Medicine Lake Highlands	Death Valley	Gold Country	Knights Ferry	Pacific Coast Beaches
		Lava Beds N.P.	Hot Creek	Northern Mines	Table Mountain	Pt. Reyes
			Panum Crater		Madera Mammoths	San Andreas Fault
			Glass Mountain	Tuolumne River		Black Diamond Mine
			Jackrabbit Mine	Sequoia-Kings Cyn N.P.	Panoche Hills	Mt. Diablo
			Long Valley Caldera			Lake County
			Tree Kill Zone			Napa County
						Pinnacles N.P.

Table 4.2 Geosites and their landscapes

	Volcanic Landscapes	Seismic Landscapes	Fossil Landscapes	Coastal Landscapes	Water Landscapes	Mountain Landscapes	Desert Landscapes	Mining Landscapes
Castle Crags						X		
Mt. Shasta	X					X		
Medicine Lake Highlands	X	X						
Lava Beds N.P.	X	X					X	
Death Valley	X	X	X		X	X	X	X
Hot Creek	X	X			X		X	
Panum Crater	X	X					X	X
Glass Mountain	X	X					X	X
Jackrabbit Mine							X	X
Long Valley Caldera	X	X					X	
Tree Kill Zone	X	X			X	X		
Gold Country		X				X		X
Northern Mines						X		X

Table 4.2 (Continued)

Tuolumne River	X				X	X		X
Sequoia-Kings Cyn N.P.					X	X		
Knights Ferry					X			
Table Mountain	X				X	X		X
Fairmead Fossils			X					
Panoche Hills			X					
Pacific Coast Beaches			X	X				
Pt. Reyes		X		X				
San Andreas Fault		X						
Black Diamond Mine								X
Mt. Diablo			X			X		
Lake County	X	X			X	X		X
Napa County	X	X						
Pinnacles N.P.	X	X						

Province #1: Klamath Province

Klamath Province Geology

The Klamath Province is made up of rugged mountains composed of belts of metamorphic rocks, probably the same rocks as those in the Sierra Nevada Mountain Range (Alt and Hyndman, 2000). Because the topography is so rugged, this province is not very populated, the average town being around 3,000 people. These rocks date back to Ordovician and Devonian times and were probably emplaced during the Antler orogeny. Because of the rugged nature of the terrain, I include only one geosite for the Klamath Province in this chapter. Doubtless, there are more, but I am not yet aware of them.

Geotourist Support in Klamath Province

Because this is a rural province, staying for more than a couple of days is probably more suited to campers, RVs and motor homes. Parking is minimal in most places, unless you are on BLM land or a forest road, and then parking will be found as it comes. There will not be community support for geotourism because the communities are far-flung. Only small towns exist which may be due to the rugged topography, and those populations are approximately 3,000 persons and less. Trails are non-existent in most places unless in a State Park or other governmentally controlled park. Disabled access and signage are not present for the most part. It is difficult to access most places since everything is so far out of the way. The only major highway in the province is Interstate 5, which runs north-south. The level of difficulty for any activity is moderately difficult to difficult. Web pages on geotourist sites are limited. Castle Crags is the only geosite in this province that I have found, though undoubtedly, there are more. The state park system runs a very good website for Castle Crags and it is referenced in Appendix C.

Geosite: Castle Crags Geology

The Crags are composed of granite. Erosion has uncovered them, leaving their jointed nature exposed to the world (Figure 4.1). The less resistant material at the joints was the first to weather out, leaving the appearance of these crags. This is what many granitic bodies would look like if they had lost their soil cover. The granite was intruded by the Trinity Ophiolite Complex and sits within serpentinite. In addition to these two very different lithologic environments, there are metamorphic rocks, such as schist nearby. The granite may have been sitting beneath the ophiolite, within a mass of the schist. These rocks are very similar to those found in the central metamorphic belt in the Sierra Nevada (Alt and Hyndman, 2000). The rocks in the Klamath Mountains (often referred to as the Klamath block) are genetically very similar to those of the Sierra Nevada (Alt and Hyndman, 2000), and the two mountain ranges may have been formed at the same place and time, the Klamath rocks having been transported to its present location after formation. Hiking around the area yields great views, one of the most spectacular being of Mt. Shasta to the north.

Figure 4.1 Photo of Crags at Castle Crags State Park.

Photography by Kimberlie Theis. The air quality is diminished due to fires raging in the nearby Cascade Province

Geotourist Support for Castle Crags

This state park contains tent sites and trailer sites for lodging, including ample parking. Being in a rural place, there is not necessarily community support, because there are not many communities. Those closest reside in another province; Castle Crags is near the border of the Cascade Province. The park contains many trails and they are well kept by park employees. The handicapped access includes parking and restrooms. Throughout the park, there is plenty of signage and much of it is intended to educate the geotourist about the geology and natural history of Castle Crags. It is very easy to get to places of interest within this park and the park itself is very easy to access, as it rests beside Interstate 5. The internet contains a large amount of information on the park and the state park system includes a map of the trails, camping, brochures, images, and videos. The park webpage also contains the global positioning system (GPS) coordinates of the park and other information that a traveler might find helpful. For example, it is suggested that geotourists dress according to the seasons, and it gives directions, dates and hours of operation, and phone numbers.

Province #2: Cascade Province

Cascade Province Geology

The most striking feature about Cascade geology is its volcanism, its tall stratovolcanoes or composite cones rise above the valley floor. All three volcanic rock types are found within this province. Volcano types include *cinder cones, stratovolcanoes* (*composite cones*), and *plug domes* (the *shield volcano* is present in the Modoc Province). Geosites that are included in this province are Pluto's Caves, the Dwinnel Dam Quarry, the Deer Mountain Tephra Cone, and Mt. Shasta. At Mt. Shasta, the sites include Bunny Flat, the Old Ski Bowl, the Brewer Creek Trail, and beside Mt. Shasta, Black Butte. Elsewhere in the vicinity are the Ash Creek Debris Flow, the Hummocky Territory north of Mt. Shasta, and the Whaleback, which is a mountain with a good view and a nice hike. Next, Mt. Lassen is described. There, Chaos Crags and Chaos Jumbles are of interest, along with Hot Rock, The Devastation Area, Lassen Peak, Lake Helen, Bumpass Hell, and finally, the Sulfur Works.

Geotourist Support in the Cascade Province

It is easy to generalize about geotourist support in this region, because the area contains many geosites that are popular to geotourists and their families. The communities of the area have shops that cater to tourism. There are parks and motels, camping and RVing, and there is evidence of the tourism theme all over the province. Parking can be an issue, since it is a rural area, but usually there is enough. The area caters to hiking, but trails can be rugged, because of the topography, and upkeep is difficult because winters can be hard. Disabled access is not regularly present. The level of difficulty of the trails ranges from easy to very difficult, and warnings are made for those who plan to trek upon the glaciers. Signage is minimal, probably due to lack of fiscal revenues. Web pages abound regarding the many different activities and geology. (See Appendix C for a website that overviews Cascade geology.)

Geosite: Pluto's Caves Geology

Geologic features here include volcanic features (Figure 4.2), caves, and sand accumulation. Collecting is permitted. There are two caves, whose coordinates are N41 34’ 03.3”; W122 16’ 57.6” and N41 34' 05.1"; W122 16' 57.2".

Figure 4.2 A cave entrance at one of Pluto’s Caves.

Photography by Kimberlie Theis. This is a cave system.

Geotourist Support at Pluto's Caves

The nearby town of Weed is the most likely urban area used to get supplies. There is no camping at the caves, but anywhere there is BLM land, the problem can solved. The nearby communities are the folks who are knowledgeable about the caves and the ones to talk to with questions concerning them.

Parking at Pluto caves is available but one may need to be able to navigate dirt roads with ruts and crevices in order to find a parking spot, depending on the approach. There are several entrances to these caves and so different places to park (Figure 4.3).

Figure 4.3 Parking at Pluto's Caves.

Trail markers can be found near the parking but the ease of access is difficult depending on what entrance you use. It is necessary to take dirt roads that are littered with volcanic boulders and ruts. But the drive is worth it. Getting into the caves requires traversing boulders. (Photography by Kimberlie Theis.)

Figure 4.4 A trail marker, marking the trail for one of Pluto’s Caves.

Photography by Kimberlie Theis.

The trails are good in some places, but only a mere hint of a trail in other places. Disable access in not available. There is some signage regarding the caves, but the area would benefit greatly by more.

In summary, this is not the easiest site to get to, but it is there for hikers who enjoy caving. The difficulty of hikes is easy, but that is because it is difficult to go fast. Boulders litter the way, forcing hikers to slow down. The Klamath National Forest hosts a web page, dedicated to Pluto’s caves. There is one website in particular which links to the National Forest Service (Appendix C, Search for Pluto’s Caves.)

This site contains some signage, including signs that point the way to Pluto's Caves, although some of these are difficult to see. Upon arriving at the geosite, there is a little explanation of the site (Figures 4.5, 4.6a and b). There are no brochures on hand for geotourists. The National Forest Service maintains a short profile of Pluto's Caves on its website.

Figure 4.5 Information is given for cave usage.

Photography by Kimberlie Theis

Figure 4.6 (A) An attempt is given to direct geotourists to Pluto's Caves.

The other photo (B) documents detailed information about the caves. Photography by Kimberlie Theis.

Geosite: Dwinnel Dam Quarry

Normal access is to park on the road outside of the housing development and clubhouse at N 41 32' 08.2"; W 122 22' 24.0, and then a hike up a hill about 200 meters before a turn to the right. Walk across the dam to the northern end of the quarry. This is an avalanche block composed of volcaniclastic breccias, tuffs, and sediments from ancestral Mt. Shasta. If the quarry is inaccessible go to the parking lot of the clubhouse (built for the houses around the lake), and look into the interior of the quarry. The coordinates of the parking lot at the clubhouse are N 41 32' 08.2"; W 122 22' 24.0" and the elevation here is 2,778 feet (846 m). The location is a park residing at Lake Shastina. It is possible to stand in the parking lot, near the lake, and look northwest to the quarry. Other access may be possible by walking along the lake edge to get closer to the quarry rocks

Dwinnel Dam Quarry Geology

The avalanche block consists of interlayered volcaniclastic breccias, tuffs, and sediments (Figure 4.7). This is the inner wall of an avalanche of ancient Mt. Shasta. Also noticeable is the normal faulting. This geosite is important because it demonstrates many of the Big Ideas, discussed in Chapter 5.

Figure 4.7 Close-up of Dwinnel Dam Quarry stratigraphy.

These rocks tell a story of deposition from nearby Mt. Shasta. Not all angles could be captured in one photo. Faults and unconformities present. Photography by Kimberlie Theis.

The hummocky features in the distance are likely part of a massive ancient debris flow from ancient Mt. Shasta (Figure: 4.8).

Figure 4.8 The hummocks in the background are likely part of an immense ancient debris flow.

Photography by Kimberlie Theis

Geotourist Support at Dwinnel Dam Quarry

There is lodging in the nearby town of Weed. Parking is available near the quarry and in the clubhouse parking lot. Access to the quarry is moderately difficult if traversing along the lake. It is necessary to traverse boulders to get to the quarry. The other way involves walking along the dam. The average citizen of Weed is unaware of the quarry's geologic importance. Thus there are not any trails. Disabled access is not present, nor is there signage about the geologic history of the quarry. There are no real web pages concerning geotourism of the quarry.

Geosite: Deer Mountain Tephra Cone

At Deer Mountain Tephra Cone geotourists park in the snowmobile parking lot and take a short hike to a berm. Here you can observe a feeder dike at the center of the tephra cone. There is a difference in color between the center and the flanks, and an angular unconformity between the tephra layers (Figure 4.9). Dr. William Hirt, at Siskiyous Community College stated the center of the feeder dike is composed of dense olivine and plagioclase-bearing andesite and the flanks are scoriacious material (Hirt, 2007). Also, the unconformity marks two different eruptive episodes. Note that there is not any evidence of erosion or soil development, pointing to the possibility that not much time elapsed between these eruptions.

Figure 4.9 An unconformity in the rocks.
Photography by Kimberlie Theis.

Geotourist Support at Deer Mountain Tephra Cone

There is ample parking at this geosite. Community support is present but not nearby. Trails are present (Figure 4.10). There is signage for the snow park (where most of the parking is) but there is not any interpretive signage about the tephra cone. There are no brochures. Access to the site is very easy. Collecting is permitted. Websites for the geosite are limited to research articles (Appendix C)

Figure 4.10 A road marker states some of the uses of this route.
Photography by Kimberlie Theis.

Georegion: Mt. Shasta

Mt. Shasta is part of the Cascade Range, a series of stratovolcanoes that stretch from British Columbia to Northern California. Mt. Shasta is the most massive of the Cascade volcanoes. It volume is nearly 500 cubic kilometers. It is not the southernmost volcano. That honor belongs to Mt. Lassen. Mt. Shasta is 65 miles south of the Oregon border. It reaches 14,162 feet (4317 m) above sea level. Mt. Shasta owes its shape to its eruptive history (Figure 4.11). The present volcano has been erupting since 200,000 years ago, but is 600,000 years old. Its most recent eruptions have been at the end of the Pleistocene 10,000 to 12,000 years ago.

Figure 4.11 Mt. Shasta has a typical conical shape, along with other cones immediately next to it.

Photography by Kimberlie Theis.

The Cascades stand on top of basalts that are 12 million years old. The range is here because of the subduction zone off the coast of northern Californian that stretches up into Canada. There are lots of other types of volcanoes here: cinder cones, shield volcanoes, and plug domes are present.

Since Mt. Shasta is so high, it is glaciated. Because of this, and because of summer storms, Mt.Shasta experiences mudflows and debris flows.

On Mt.Shasta, there are 4 cones that represent 4 different eruptive periods. There is the Sargent's Ridge cone that forms the southeast part of the mountain. There is the Misery Hill cone that grew on top of the northwest flank and was active just before and after the end of the Pleistocene.

Shastina cone is a separate peak. The eruptive period lasted only a few hundred years. Hotlum cone crops out mostly on the northeast side of the mountain and may have erupted while Shastina was erupting. The summit dome may have grown only 200 years ago. Shasta has erupted on the average of every 600 to 800 years, since the Pleistocene.

On and around Mt. Shasta, one can see examples of diverse rock types such as basalts, basaltic andesites, andesites, dacites, and such processes as pyroclastic flows, debris flows, lava domes and flows, tephra and more.

In Quaternary times, the single composite cones or stratovolcanoes of the Cascade Range include about twenty peaks from Mt. Garibaldi in British Columbia, south to Mt. Shasta, in California. Mt. Lassen is a Cascade volcano although it is not a stratovolcano, but a plug dome. Various landforms associated with active volcanism can be found on and around Mt. Shasta. In addition, Mt. Shasta has undergone glaciation during Pleistocene time.

From the south, Mt. Shasta looks more like a series of peaks, which is indeed what it is. It has undergone at least 4 major eruptive-destructive processes in the last half million years. From the south, it is easy to see Hotlum cone, the tallest, Shastina, on the right, which developed in a series of eruptions around 9,800 years ago. In the center, you can see Misery Hill, an eroded crater rim, much older than the others. The longest glacier in California flows between Hotlum and Shastina and is about 2 miles (4.4 km) long.

Geosite: Brewer Creek trail

This geosite is important because it gives walking access to Mt. Shasta's glaciers (Figure 4.12). Glaciers have incredible erosive power, plucking frozen rock and debris beneath them, hollowing out cirques, leaving behind knife-edged arêtes, and piling up huge masses of ground up rock, leaving unsorted debris, polished rocks, and scratches to mark their presence. Mt. Shasta has experience debris flows, avalanches, mudflows, lahars, and pyroclastic flows. A very large debris flow occurred 300,000 to 350,000 years ago and carried material for 55 kilometers, covering Shasta Valley (Hirt, 2007). Other notable flows have occurred more recently, such as the Whitney Creek debris flow. After a warm summer rain in August, 1997, the streams became filled with water, and the quickly muddied water became a dense slurry with the ability to carry immense boulders. These boulders took out a bridge on the lower slope. These dangerous flows pose huge hazards to human populations because of the frequency and ability to move anything in their paths.

Figure 4.12 Trail signage for Brewer Creek Trail.

Photography by Kimberlie Theis.

Geotourist Support for Brewer Creek Trail

Access to the trail is made by driving. One piece of advice is to have high clearance in your vehicle. Access is difficult. Getting to the trailhead is difficult, and the trail itself is moderate to difficult in intensity. There aren't any campgrounds anywhere near the trailhead but there is room for parking in the surrounding area. This is a well-established, if somewhat poorly marked trail (Figure 4.13). The signage to the trailhead is mostly obscured, but at the trailhead itself, it is well marked (Figure 4.14). The signage is minor in the surrounding flatlands. Geologic explanations are brief.

Figure 4.13 Signage before Brewer Creek Trail.

Photography by Kimberlie Theis.

Figure 4.14 Trailhead signage at Brewer Creek Trail.

Photography by Kimberlie Theis.

Geosite: Black Butte

Black Butte is a very prominent, dark colored, steep sided cone adjacent to Mt. Shasta. It erupted approximately 9,500 years ago, and can be compared to Shastina, as both were formed at around the same time. It is a hornblende dacite plug dome, reaching 6,325 feet (1927 meters) elevation. It is a highly visible landmark in the area, and was used as a Forest Fire Lookout because of its 360 degree views. Many of the area locals consider this hike one of their favorites. It is 5.2 miles (8.3 km), roundtrip. In addition to its volcanic origins, Black Butte has such steep sides and the angle of repose keeps all materials in its balance (Figure 4.15). The visual effect is striking. The location of the trailhead turnoff is at N41 20' 5.6.2"; W122 18’ 51.9" while the trailhead itself is N41 22’21.7”; W122 20’ 26.1”.

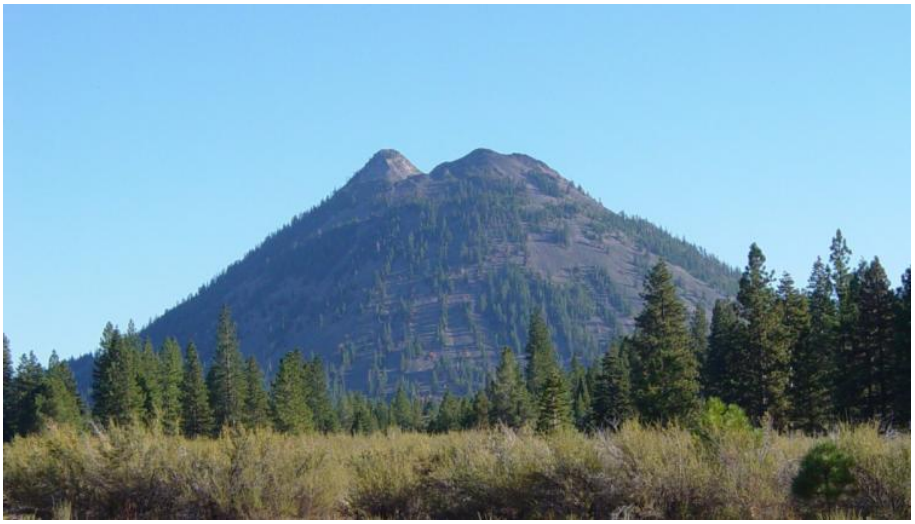

Figure 4.15 Black Butte is a steep sided Cinder Cone.

Photography by Kimberlie Theis.

It is seen from far off because of the flat land surrounding it (Figure 4.16) and it has been photographed doubtless many times.

Figure 4.16 Photograph of Black Butte at sunset.

Photography courtesy of Wikicommons.

Geoourist Support for Black Butte

The trail is well marked, once you find the trailhead (Figure 4.17). It may have been my navigation but I found it difficult to find the trailhead. Once I did, the trail was quite visible (Figure 4.18). There is plenty of parking at the trailhead. The community seems to embraces its iconic presence and the trail, which was built by the Civilian Conservation Corps, is well maintained. There is no disabled access, and signage is not prominent, either when trying to find the trailhead nor when finally at the trailhead. It is not only difficult to get to, but there is an elevation gain of 1,845 feet. Because of this, the hike is considered moderately difficult. There are no brochures available at the trailhead. The only website available that contains pertinent information is a Wikipedia page (Appendix C).

Figure 4.17 A trail sign, pointing the way.

Photography by Kimberlie Theis.

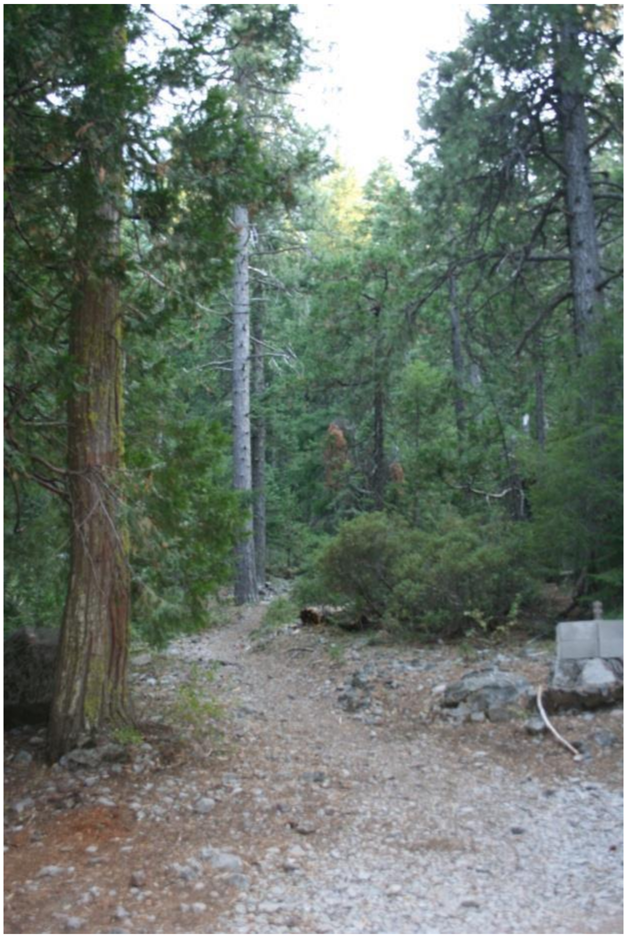

Figure 4.18 The actual trail to Black Butte.

Photography by Kimberlie Theis.

Geosite: Bunny Flat at Mt. Shasta

The important points about Bunny Flat and Avalanche Gulch are the hazardous nature of the area. These locations are on Mt. Shasta, a few miles up the mountain. Once considered a good place for a ski resort, it was pointed out that the area, which was then targeted for recreation, was in the path of a well-worn recurring avalanche (Figure 4.19). Conditions above the site are just right for debris to come down, and it does so, on a very regular basis. This can be seen by the nature of the material on the ground, and by the valley shape below the parking lots (Figure 4.20).

Figure 4.19 The debris of an avalanche path.

Photography by Kimberlie Theis.

Figure 4.20 The area below the avalanche pathway.

Photography by Kimberlie Theis.

Volcanism in this region is a consequence of the plate boundaries, specifically, the Juan de Fuca plate subducting beneath the North American plate. This subduction zone has been going for 35-40 million years. The magma beneath the surface has given rise to the Cascade volcanic arc, whose major eruptive periods are between 17 and 35 and 0 to 12 million years (Hirt, 1999).

As you look north, you will see Avalanche Gulch, which is a popular hiking trail. The ridge on the gulch is composed of andesitic lavas and breccias that emerged from the Sargent's Ridge Cone. At Thumb Rock, at the top of the ridge, the deposits dip northward, away from a crater that was located at the head of Mud Creek. At the head of Avalanche Gulch, there are steep, reddish cliffs. These are the Red Banks that are a mass of andesite, dacite, and banded pumices that originate from the Misery Hill activity, 9,700 years ago. The arête is due to Pleistocene glaciation. Looking down the mountain, it is possible to see flattened trees. This flattening occurred when a slab avalanche sheared off and uprooted these trees in January 1977.

The main things that geotorists should be aware of here are 1) the age relationship between the Misery Hill and Sargent's Ridge deposits: Misery Hill cone laps onto the glaciated Sargent's ridge making Misery Hill younger; 2) Avalanche Gulch has a glacial cirque, a rock glacier, and lateral moraines extending out and down from it (toutistsdrive across one of them when they visit); 3) the Red Banks pumice stretches across the top of Avalanche gulch and was the last material to be erupted from the Misery Hill events. It contains andesite-dacite clasts and this pumice indicates the zone reservoir from whence it came (Hirt, 2011).

At Bunny Flats, one may identify glaciated areas. It is also a good time to review hazards associated with volcanism, especially when it comes to humans. Finally, there are environmental implications of having a ski resort here at Bunny Flats.

Geotourist Support for Bunny Flats

There really is not any tourist support for these locations. The parking lots were built long ago, when the ski resort was still a possibility. No one maintains them now. There are trails leading up to the summit of Mt. Shasta and signage of a geologic nature and other natural history is sprinkled lightly around, with no big emphasis on the geology. Any lodging would be found in the town of Weed or Shasta. Disabled access is present but it was unintentional. The ease of accessing Mt. Shasta by foot is presumably difficult, depending on one's physical abilities. There are various web pages that can be accessed, which talk about wilderness permits, and camping, but nothing else for Bunny Flat. The only website found on Bunny Flats was the Avalanche Weather station (Appendix C).

Geosite: The Old Ski Bowl at Mt. Shasta

From the parking lot, one can observe the lavas and pyroclastic breccias in the walls of the Ski Bowl. This was the core of the Sargent's Ridge cone (Figure 4.21). Looking to the southwest, Castle Crags is visible, with its Jurassic granitic intrusions of the gabbros and peridotites of the Trinity Terrane. The peridotite from this terrane also partially underlies part of Mt. Shasta.

Figure 4.21 Sargent's Ridge Cone with Thumb Rock and Shastarama Point. Photography by Kimberlie Theis.

This stop is intended to show the interior of the Sargent's ridge cone, the opposing dips of the Thumb rock and Shastarama Point. This should allow the geotourist to mentally "reconstruct" the old cone. There are also tephra deposits from Mount Shasta's latest eruption, 200-250 years ago. There is a brass survey marker that is used to measure changes in the shape of the mountain (Hirt, 2011).

Shastina and Black Butte pyroclastic flow deposits can be sorted out by:

1. three diamicton flows that are pre-Shastina in age. These are identified based on their cobbles and their clay-rich matrices.
2. three Shastina pyroclastic flows identified by their pyroxene and dacite clasts in the gray ash matrix;
3. Black Butte flows (2) that are identified by their vesicular hornblende clasts in the yellow ash matrix.

There is neither signage nor any brochures at the Old Ski Bowl, but the ranger station is nearby. However, there are ample web pages that give detailed information about this site, including the geologic history and also trail information (Appendix C).

Geosite: Hummocky Territory

Drive along Highway 97 and as you cross the hummocks, it is highly suggested to stop for photos. This is a classic example of mass wasting processes, yet it was not recognized for a long time. Once the area could be photographed from the air, it was shocking to find out the extent of this very large and very dangerous debris flow (Figure 4.22).

Figure 4.22 The hummocky area is an ancient debris flow that has moved over 55 kilometers.

Photography by the United States Geological Survey.

The really important point to note is that Mt. Shasta is the most massive of the Cascade volcanoes and it looks small in this photograph, which means that the photo was taken from a long distance away. The hummocks are slabs of the original volcano which were carried away. The fact that the matrix supported that very large material for a very long distance raises questions about its nature.

Geosite: Ash Creek debris flow

This debris flow is the consequence of the rapid melting of snow at higher elevations. In 1977, snow and ice on Wintun Glacier melted rapidly. The debris flow began high in the canyon at the foot of the glacier, and scoured the canyon of Ash Creek, and then spread out across flatter plains (Figure 4.23). The distance covered was 20 kilometers. The margins have levees and the flow is about 5 meters thick at those places. The flow killed the trees by covering the roots and suffocating them.

Figure 4.23 Ash Creek Mudflow.

Photography by Kimberlie Theis.

Most mudflows occur, not in wintertime when there are frequent storms that drop sizeable quantities of precipitation that are both solid and liquid, but in the late summer, when temperatures have increased and melting occurs at the toes of the glaciers. Often what happens is that a summer storm comes through, and mixes with the already melted deposits at the glacier and a slurry of mud and debris begin to make their way downslope. As you can see from the photos, the problem is "sizeable" (Figures 4.24 and 25).

Figure 4.24 Ash Creek Debris Flow. The depth of the flow can be discerned.

Photography by Kimberlie Theis.

Figure 4.25 This photo shows the width of the creek.

Photography by Kimberlie Theis

In addition to the mudflows, summer storms can also bring lightening and that means fire. Fire season here is very serious, as was indicated in earlier photos.

There are no signs, no trails, and no parking, for this stop. There is no community support and most geotourists would not seek out this site because it is difficult to get to and yields no hiking or other recreational draw. The reason this site is important is because of the many debris flows that occur on a volcano like this one and the danger they bring to anyone in the area who might be caught unaware. There are several web pages (Appendix C) regarding this and other debris flows which talk about the historical events.

Geosite: The Whaleback

This hike takes you up to 8,528 feet (2559 m). The Whaleback is a cinder cone, and has a collapsed center. The view from here is unobstructed, much the same as with many other views in the area (Figure 27). There is no real trail, because cinder cones, especially young cinder cones, do not hold trails. Just walk up the side, usually at an angle, making your way in whatever direction suits you. Cinder cones near Mt. Shasta and all over northern California are relatively young, because the volcanism is ongoing. Cinder cones are steep sided, composed of cinders, and are relatively similar to all other cinder cones, at least in their appearance.

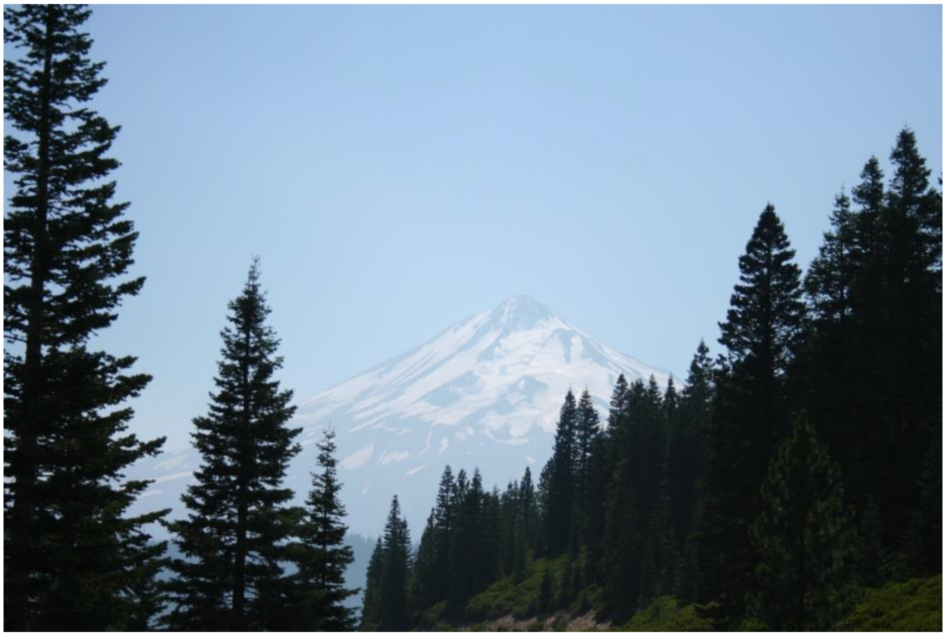

Figure 4.26 The view from the Whaleback.

Photography by Kimberlie Theis.

Geotourist Support for the Whaleback

There isn't any support for this geosite by the community, as it is a little further afield than the previous hikes. There is no camping, no signage, and no disabled access. The ease of access is easy, provided the tourist is not discouraged by long drives. This drive takes you into the wilderness, yet is still close enough to Mt. Shasta to be in the same vicinity. The level of difficulty is moderate for the hiker who is in good health. There are a few web pages that mention the Whaleback, as it is considered a good hike, but there is not much written otherwise. The geology appears to be confined to volcanism; there aren't any signs of glaciation that I can see but it certainly is possible, if not probable, given its elevation.

There is some signage but none of the interpretive kind. There are no brochures to give to geotourists. There are several websites that can educate the geotourist about hiking the trails (Appendix C)

Geosite: Mt. Lassen

Lassen Geology is interesting in that it is the southernmost of the Cascade volcanoes (Figure 4.27). Unlike the other volcanoes which are *stratovolcanoes*, Lassen is a *plug dome*. Plug domes often form inside of *composite cones*, as a final stage of eruption. But Lassen was far from over, and has erupted since it was built, with its last eruption in 1914. The eruption continued into 1915, and then continued to erupt steam on and off until 1921. Mt. Lassen is the remnant of a much larger stratovolcano "Mt. Tehama". Geologists extrapolate that this former volcano was over 11,000 ft (3353 m) in height. The Tehama volcano probably erupted about 450,000 years ago (Alt and Hyndman, 2000). It continued at intervals until it sank into its caldera about 350,000 years ago. These were rhyolite eruptions. Brokeoff Mountain and Mt. Diller are all that is left of ancient Mt. Tehama. Lassen rose as a plug dome in the caldera of ancient Mt. Diller. It is one of the largest plug domes and is made of dacite.

Figure 4.27 Mt. Lassen and Chaos Crags

Chaos Crags, which are the craggy places in center of mountain, and Chaos Jumbles, the unconsolidated debris in the foreground. Photography taken from WikiCommons.

Geosite: Chaos Jumbles and Chaos Jumbles

The Crags are the spiky protrusions up on the mountain. The Jumbles are a very large mass of jumbled up boulders that cross the roadside in places.

The Jumbles are composed of dacite with plagioclase crystals. Chaos Crags is a lava dome that geologists say probably erupted around 1700, but that prospectors say was still steaming during the 1850's (Alt and Hyndman, 2000).The explosion of the dome is what created this mass of broken rock. This is not a lava flow, but an avalanche rockfall. This rockfall caused Manzanita Lake on the other side of the road to become impounded, along with some others lakes.

Signage is present at the visitor's center but not at the Jumbles or the Crags. Brochures are also available at the visitor's center. There is signage present for many of these stops, such as Hot Rock, and Bumpass Hell, in the thermal area. In fact, there are warning signs, telling of dangers to skin and clothing if one comes too close.

Geosite: Hot Rock

On the night of May 18, 1915, there was a large steam explosion from the vent on Mt. Lassen. The volcano erupted lava bombs (or more accurately, lava boulders), huge chunks of lava that melted the snow and ice that was on the summit. This melted snow and ice and hot lava rocks created an 'avalanche of mud' called a lahar. This lahar moved swiftly downslope, bringing a massive boulder to this place (Figure 4.28). The mud continued down Lost Creek and Hat Creek, to wash out the homesteads on Hat Creek.

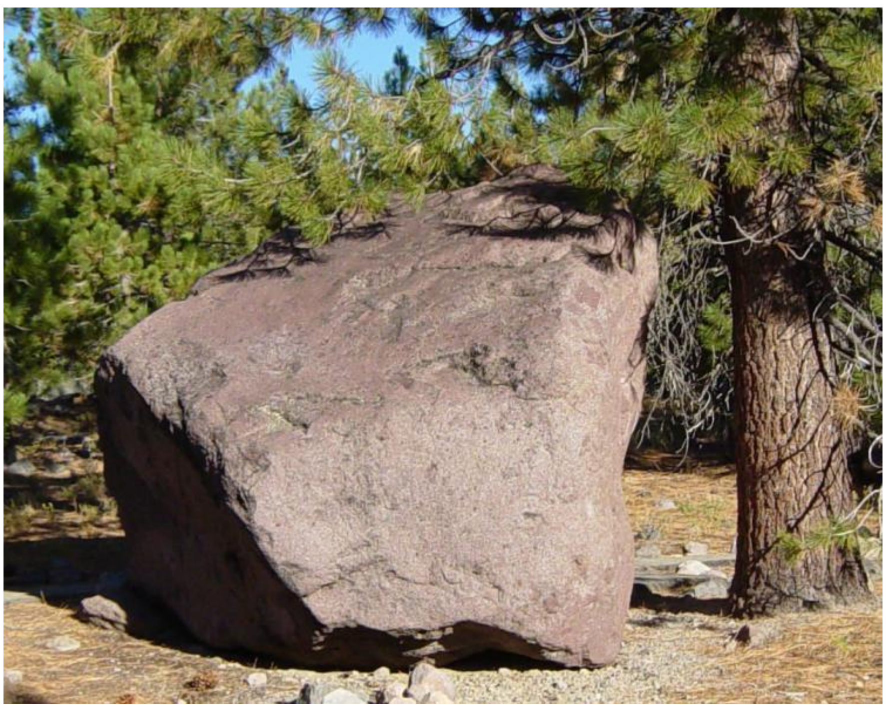

Figure 4.28 The product of a lahar.

Photography courtesy of Wikicommons.

Geosite: Devastation Area

This carnage was caused by a pyroclastic flow that would have come down the mountain at breakneck speed (Figure 4.29). This flow occurred after the mudflow. It appears that these surroundings have experienced not one, but two major devastations.

Figure 4.29 This is the Devastated Area at Mt. Lassen.

The area in the foreground is broken volcanic rock and trees are beginning to come back into the area. Photography taken from WikiCommons.

Geosite: Lassen Peak

Lassen Peak is a popular hike for geotourists. Mt. Lassen is the most southern of the Cascade Range volcanoes. Its most recent eruptive activity was between 1914 and 1921 (Alt and Hyndman, 1995). It formed as a series of other volcanic landforms, including shield volcanoes, cinder cones, and a stratovolcano, and created the former volcano known as Mt. Tehama, which collapsed as a caldera, leaving behind Brokeoff Mountain and other remnants. Lassen Peak is a plug dome of dacite composition. The mountain has generated lahars, pyroclastic flows, has been glaciated, supports hydrothermal volcanic features, and is a very popular site for both geotourist and geologists. Hiking is very good, as are the views.

Geosite: Lake Helen

Lake Helen is a glacially carved lake. The water is incredibly blue. This is a popular place to picnic and stick ones feet in the icy cold water. No brochures are available at the site.

Geosite: Bumpass Hell

The trail to Bumpass Hell takes you to a variety of springs, fumaroles and mud pots. At the top of the trail, hikers can note the signage. It instructs the reader to look for Brokeoff Mountain and also Mt. Dillard. If the reader runs both of his or her hands out in front of her, along their flanks, she will see where the two of them would have joined. This would have been ancient Mt. Tehama.

Next, the geotourists should look down at the surface they are standing on and note the sheen. It is there because this surface has been overrun by glaciers. The polish is glacial polish, and the straight marks or indentations are striations, or places where the glacier would have dragged frozen stones along the bottom and carved into the bedrock.

From here, the hike is very rewarding, with striking views. At the end, the geotourist will see (and smell) fumaroles, hot springs, and boiling mud pots (Figure 4.30). The black in the mud pots is graphite.

Figure 4.30 Photo of Thermal Area at Bumpass Hell.
Photography taken from Wikicommons.

Geosite: Sulfur Works

Here, the springs and the fumaroles come close to the road. Geotourists are warned by signage to be very careful since the sulfuric acid can harm your eyes, mucous membranes, and possibly even your clothing. The smells are overpowering in many places in this area, and caution is advised.

Province #3: Modoc

Modoc Province Geology

The Modoc province is dominated by basaltic volcanism. Cinder cones, fissure flows, and lava tubes dominate this region. Medicine Lake Highlands, a very large shield volcano, along with Glass Mountain, a very large ridge of obsidian, reside here. Lava Beds National Monument has protected a large portion of land, providing recreation to geotourists in the form of lava tubes, stories of Native Americans, and volcanic scenery. Some of the landscape in this province is covered with forest though much of it is not, but is dry desert.

Geotourist Support for the Province

There are not a lot of towns out here, so if tourists are looking for that kind of lodging, they may need to continue to a different province. The real lodging for the geotourist is in the camping, tenting, and RVing. Parking is where you can find it, and is usually ample due to this province’s sparse population. The roads are well maintained, but many of them are dirt forest roads. There is not much traffic nor is there much community support for geotourist activities in the way of shops that cater to tourists. This is a rural province and farming is prevalent when the land is not BLM land. There are a few trails, but those that are present are scattered throughout the province or located on National Park land. Disabled access is not always present, but some of the BLM recreational sites may have some, like at Medicine Lake. The area does have signage scattered about, but would benefit by well-crafted signs, explaining to the visitor what he or she is witnessing and experiencing. These places are fairly easy to get to by car, and mostly, you don't need four wheel drive. There are various levels of difficulty in the hikes. Caution is needed when climbing obsidian domes such as Glass Mountain, and when entering caves. Hard hats are strongly suggested.

Geosite: Lava Beds Geology

Lava Beds National Monument is located in the northernmost portion of the state. It was made a monument in 1935 so that its young volcanic features could be preserved. Lava Beds National Park sits on the northern flank of California's largest shield volcano, Medicine Lake Highlands, and because of its history relative to the Modoc Indian War of 1872-1873, it is an area of wide interest and recreational activity.

It is squeezed between the Cascade province and the Basin and Range province in what is known as the Modoc Plateau. The volcanism that occurs here is due to Basin and Range extension. Magmas have risen up through normal, or North-trending fractures to create the Medicine Lake Highland shield volcano.

A N-trending fault scarp has allowed the down-dropping of the Tule Lake Basin. Other normal fault features like scarps are visible. Medicine Lake volcanism is related to Cascade volcanism in that these lavas are the products of back arc volcanism.

Donnelly-Nolan (2000) chronicled the geologic history of the area:

Gillem's Bluff lavas > 2,000,000 years

Medicine Lake volcano (entire history) 500,000 years

Prisoners Rock and The Peninsula 275,000 years

Tuff of Anderson Well 180,000 years

Schonchin Butte Andesite 62,000 years

Mammoth Crater and Modoc Crater 30,000-40,000 years

Fleener Chimneys, Devils Homestead Basalt 10,500 years

Basalt of Black Crater 3,025 years

Cinder Butte, Callahan Basaltic Andesite 1,110 years

Little Glass Mountain Rhyolite 1,065 years

Geostop: Petroglyph Point

In the southeast part of the basin, there is a prominent cliff. It is about 300 feet (91.44 m) high and the only landform of height around. A chain link fence encloses the cliff. Upon close investigation, it is possible to see many petroglyphs (Figures 4.31 and 32). The material they are found in is a tuff, erupted 270,000 year ago. The cliff is undercut at the bottom. This is because Tule Lake was much larger, until it was drained for agricultural use in 1905. The cliff was carved as waves undercut the tuff. Each shelf represents a different lake level. There are more than 5000 petroglyphs here and this panel is believed to be one of the largest concentrations of petroglyphs in the United States. They are believed to be 2,500 to 4,500 years before present (Lee and Hyder, 1990). The artists had to row out to this island and carve into the soft rock. The area faces destruction from not only windblown sand and silt, but from vandalism too.

Figure 4.31 The petroglyphs found here are among the largest concentrations found in the United States.

Photography by Kimberlie Theis.

Figure 4.32 The wall is cut from tuff that was undercut from nearby Tule Lake. Artists carved the petroglyphs from 2,500 years BP to 4,000 BP.

Photography by Kimberlie Theis.

Geostop: Captain Jack's Stronghold

The Modoc people held siege here for months during the Modoc Wars, before the Calvary could finally starve them out. The natives could hide in the *a'a* rocks, and pop up and pick off the cavalrymen one at a time. It was the perfect place to hide because the Cavalry could not get to the Indians (Figure 4.33). Geotourists who walk the trails are able to pick out some 'blinds' where the Cavalry could hide from the attackers and where Captain Jack stayed with his family.

Figure 4.33 The trail to Captain Jack's Stronghold, where attackers were held off, as the Modoc people hid in the a'a rocks.

Photography by Kimberlie Theis.

It turns out that the stronghold was so successful because the place they chose to defend was at a series of *schollendomes* (pressure ridges) and scarps that encircle the valley where they were encamped. These places were natural places to defend. The site had access to food and water, and an escape route. The reason the Cavalry finally succeeded was because there was a traitor in the ranks that gave away the Modoc location in return for amnesty. It is possible to learn more of the story at a website (Appendix C).

Geostop: Gillem's Camp

This is the site where the cavalry stayed during the Modoc wars. It is a prominent, rugged escarpment, with as much as 500 feet (152 m) of relief. The stop marks the edge of the Basin and Range extension. There is a normal fault here, exposing a lava flow that is 2 my old (Hirt, 2000). The park service has signs that describe the site. More information can be found for all of the sites at the visitor's center. There are also many websites that give detailed information about the conflict and other information. One website describes the site in detail (Appendix C).

Geostop: Devil's Homestead Flow turnout

The site provides an excellent view of a'a lava (Figure 4.34). The most notable concept is that the cavalry were trying to cross this! It was found impossible in the end. The flow is Holocene in age and covers 4.3 cubic kilometers. Because the composition of the basalt is similar to that of Valentine Cave, it is believed to be about 10,000 years old. As the lava travelled and cooled, the toe of the flow developed a texture reflecting conditions that it was flowing under (a'a flow). There are signs guiding you to a turnout and also those describing what can be seen (a'a). Any brochures about the site could be obtained at the visitor's center. Among the several available websites that contain information about the Devil's Homestead, there is one which may appeal to those with an interest in geology (Appendix C).

Figure 4.34 The a'a lava of the Homestead Flow.

Photography by Kimberlie Theis.

Geosite: Fleener Chimneys

This is a good view of some spatter cones (Figure 36). They form when the lava flow is still in its infancy. The lava erupts as "spatter" (soft masses of lava). These masses travel short distances through the air, and are therefore still hot when the land near the vent. They pile up there and partially fuse back together. These *spatter cones* often form in a line at the fissure eruptions. Sometimes, some of them become blocked and then they are no longer active (Hirt, 2007).

Some of the spatter cones appear in conjunction with some excellent examples of *pahoehoe* lava, which reflect the hot, volatile-rich character of an early stage. The Fleener cones formed 3 deep holes over the conduit (chimneys). The openings are as deep as 50 feet (15 m).

There is signage that describes the site, but you must get brochures at the visitor's center. To learn more about the spatter cones, geotourists can visit the website (Appendix C).

Figure 4.35 A spatter cone at Fleener Chimneys.
Photography by Kimberlie Theis.

Geosite: Schonchin Butte

This very large cinder cone is made of andesitic cinders (Figure 4.36). The butte is 600 feet (183 m) taller than the valley floor. It used to be a fire lookout. There is a bit of a hike here, 0.7 miles (1.1 km) but it is uphill and hot, so geotourists should bring plenty of water and be in good physical condition. At the top of the cinder cone, visitors will be able to pick out Medicine Lake Highland to the south, Mt. Shasta to the west, the Modoc Plateau to the east, and the Warner range appears with the Modoc Plateau. The ridges above Crater Lake peek out to the north. In the foreground are Gillem's Bluff, Tule Lake graben, and plenty of lava flows and spatter cones. There are informative signs at the base of the butte but no brochures. There are several good websites that explore this geosite (Appendix C).

Figure 4.36 The image of Schonchin Butte.

Schonchin Butte is a very large cinder cone in Lava Beds National Monument. The photo is blurred because of the smoke of many fires occurring throughout northern California. Photography by Kimberlie Theis.

Geosite: Skull Cave

This cave (Figure 4.37) has a floor that is permanent ice and it will feel delightfully cool compared to Schonchin Butte. Geotourists should bring jackets and flashlights. Skull Cave got its name from a pile of human and animal bones that were found in a pit in the eastern part of the cave. Skull Cave is the master tube that transported lava for Modoc Crater. There are informative signs describing the ice in the floor of the cave. Finding a website for this site is a little tricky because there are other "Skull Caves". One of the websites for this particular site is noted in Appendix C.

Figure 4.37 Cave entrance to Skull Cave.

Photography by Kimberlie Theis.

The cave dimensions are some of the biggest in the park. The opening is about 60 feet (18 m), and the reaches that are accessible are as much as 100 feet (30m) in diameter. There are two elevation levels but one has collapsed. This is where the bones were found. Ice is here year round because of the circulation Cold winter air collects in the pits just above and sinks to displace the warmer air. In summer, the circulation does not occur, so the cave does not warm.

Geosite: Heppe Cave

These caves are on the main tube system, just a few hundred meters from the vent. This is one of the largest collapse features. The collapse is 51 meters across, 21 meters deep. Some of the fallen blocks are as big as an automobile. There is a seasonal pond at the bottom of the upper cave. Because the basalt is fractured, it allows rain and snowmelt to infiltrate the surface. During the winter, this water is present as ice. This pond is possibly the largest body of water in the park.

There are signs at Heppe Cave but there were not any brochures. Websites are not readily available for individual caves. One must find information about Heppe Ice cave within other sites that discuss Lava Beds National Monument.

Geosite: Mammoth Crater

Figure 4.38 Mammoth Crater is a very large collapse structure.

This is a pit crater. It is the source of 70% of all lavas in the park (Figure 4.39). Photography by Kimberlie Theis.

There are a few signs for this crater, but no brochures. Nor are there many web pages, partly because there is another Mammoth Crater on the east side of the Sierras. One link does take one to a video that is informative (Appendix C).

Georegions: Medicine Lake Highlands and Glass Mountain

Medicine Lake Highlands has experienced 17 different known lava flows in Holocene times. One of these flows is that of Glass Mountain (Figure 4.39), one of the more recent eruptions at 1300 years B.P. (California Division of Mines and Geology, 1966). It is the not the youngest flow of the Medicine Lake Highlands (MLK). Many are as young as 200 years (Alt and Hyndman, 2000).

Interesting geologic features include the surrounding volcanics and probable Monument (in fact, this is one road out of the park). Correlating ages with the volcanics of the park seems reasonable. Medicine Lake Highlands volcanics occurred 500,000 years ago.

It is possible to observe the flow banding in the rock, a concept related to viscosity. Geologic features found here include seismic features, obsidian flows, probable caves, lava flows. Collecting is allowed. Geotourists will be able to collect various specimens of obsidian, pumice, and scoria at Glass Mountain.

Figure 4.39 Edge of Glass Mountain Flow.

Photography by Kimberlie Theis.

Geotourist Support for Glass Mountain

The only lodging near Glass Mountain would be that of camping on BLM land, or at Lava Beds National Monument, which is relatively close. Parking is available and you can find it off the side of the road. Signage for this unique location is minimal and the ease of access is easy to moderate if one is willing to take a drive.

The United States Department of Agriculture is the proprietor of the website, and some minor web searching yielded some rockhounding sites that are sanctioned by the USDA as collecting sites. Permits are needed and there is a limit to how much you can collect for personal use. There were several spots that were set aside for this in the Modoc National Forest.

Province #4: Basin and Range Province

Basin and Range Province Geology

High mountains and low valleys are what determine the overall geology of the Basin and Range Province. They trend north to northeast, from the Sierra Nevada Mountains, and continue east to Utah, where the Colorado Plateau begins with its horizontally-lying sedimentary layers. The Basin and Range is part of a continental province, besides being a local one in California. As California continues to be slowly dragged to the north and west, the basins are still forming. The crust is stretching, allowing the down-dropping of basins relative to adjacent uplift of blocks. These uplifted blocks are called horsts and the downdropped blocks are called grabens. The Basin and Range Province is a classic example of early continental rifting that began 30 million years ago and continues today. Detachment faulting, or low angle normal faulting, is classic here, with well described "turtleback" formations appearing in Death Valley (Collier, 1990). These turtlebacks are exhumed basement rocks that are rising as the weight of mountain ranges are removed from them. They received their name based on their characteristic turtle shell shape. Extension in this region has been going on throughout the Eocene, and alongside extension, magma is allowed to rise to the surface. Bimodal volcanism is widespread. Crustal thickness here is about 17 kilometers in some places, compared to over 50 km at the adjacent Sierra Nevada orogenic belt (Heimgartner, et al. 2006). It would seem to be straightforward geology, but that is a false idea, easily believed due to the horst and graben block model. The rocks contain layers that are missing, changed, reworked, and dropped into other places.

Geotourist Support in the Basin and Range Province

The Basin and Range province is, for the most part, a rural place, owing to the desert-like conditions. It is generally a hot, dry climate so large populations will be sparse. But there are some localities, like Bishop, that have relatively large populations, but even these places are small compared to most standards. It is due to this population issue that the smaller towns need to depend more on tourist support. Each geosite will be unique in its geotourist support. For the most part, the settlements around the geosite will contain lodging, gas, visitor information, and restaurants. Since the area is rural, this paragraph serves as the Geotourist Support review for the entire province (with the exception of Death Valley National Park), unless there is specific information available for that site. In those cases, the support will be noted at the time of the description discussion.

Geosite: Bodie

Bodie is a gold and silver mining ghost town situated over a magma chamber. Super-heated water from the hot rocks surrounding the magma escaped through the existing fault system to precipitate minerals such as gold and silver into quartz veins near the surface (Chesterman, 1986). This hydrothermal feature allowed for a great deal of ore to be deposited and mined in the late 1800's. There is some nearby camping and the closest actual lodgings at the town of Lee Vining, 31.2 miles (50.2 km) to the south. Bodie ghost town is maintained by the California State Park system but is somewhat out of the way (Figure 4.40). Once there, the general public can find ample parking, restrooms, souvenirs and tours. A full webpage detailing the hours, features and history is available through the state.

Figure 4.40 Bodie Ghost Town north of Mono Lake.

Photography by Kimberlie Theis.

Geosite: Mono Lake

Mono Lake is a highly saline body of water (Figure 4.41). A closed system, it has no natural outlet, and concentrates any rainfall or snowmelt. The lake supports large populations of Gulls and other migratory birds. These birds come to feed on the brine flies that breed there. Also in the water are brine shrimp. The lake is famous for its *tufa* towers that rise up from the lake bottom. These towers are created when dissolved calcium comes into contact with carbonate gas seeping up from springs in the rocks below. As the calcium and carbonate ions combine, tufa towers begin to form and eventually rise to the surface of the lake. As the level of the lake changes, the towers grow vertically and are exposed. Visitors to the tufa towers will find a ranger station, a raised boardwalk, pamphlets and displays citing the bird and wildlife of the area. Along the boardwalks, which are accessible to all abilities, are signs denoting the change in water levels. These fluctuations are the result of the water diversions by Los Angeles, which still struggles to obtain sources of water. Eventually, a court ruling saved Mono Lake from these water acquisitions, stating the lake must reach and maintain a certain level. This was very important to the wildlife that live on the islands in the lake, since low water stands left bird sanctuaries open to predatory animals. Also there are explanations of the conservation efforts currently in place to ensure the preservation of this lake posted in the signage.

Figure 4.41 Mono Lake as seen from the distance. It survives in an arid environment and is highly saline.

Photography by Kimberlie Theis.

Geosite: Volcanoes by Mono (Panum, Inyo Craters)

Panum crater is a rhyolitic dome that formed in an area experiencing many rhyolitic eruptions, which included Inyo Craters. It is the furthest north and youngest of the features, having erupted 600 years ago. It has typically steep sides made of pebble sized and larger pieces of rhyolite. A dome exists inside of the crater. A dirt road grants visitors access to the trail heads that lead to the rim and excellent views of the entire Mono basin. This area is very warm during the summer months and there is little to no available natural shade. There are two unpaved sandy trails, one taking you around the entire rim of Panum crater and another shorter trail leading to the plug dome. Inyo craters are aligned north-south and these three phreatic (steam) explosion craters are on the summit and south face of Deer Mountain. Surprisingly, these three craters formed within days or even hours of each other despite their difference in appearance.

Geosite: Obsidian Dome

Inyo craters, Obsidian Dome, Glass Creek Dome, and Deadman's Creek Domes were built by the extrusion of lava, following more violent pyroclastic and steam eruptions (Figure 4.42) (Alt and Hyndman, 2000). The unusual north-south alignment of these and other domes is due to the vents running in that direction.

Figure 4.42 Obsidian Dome and Flow.
Photography by Kimberlie Theis.

Geosite: Long Valley Caldera

The Long Valley Caldera's sheer size at 20 by 10 miles long (32km x 16km) gives excellent testament to the immense volume of the Bishop Tuff eruption some 760,000 years ago, that left ash as far away as Kansas. Called a super eruption, giving way to resurgent doming in the central portion of the caldera, the last real eruptive activity was about 500,000 years ago. In the earliest part of the resurgent doming the caldera was filled by a sizable lake. This body of water left telltale strandlines on the walls and domes. Continuing to be thermally active, as evidenced by the hot springs and fumaroles found in and around the area, it has shown significant changes throughout its history. Casa Diablo, a geothermal power plant, is the result of those continuing activities and generates electricity. Since the caldera covers such a large area and is geologically diverse with several small towns and the resort town of Mammoth at its edges, it offers many geotourism opportunities and the various communities in and around it offer excellent educational and recreational sites. Several locations have educational signs, trails, and restrooms and are all accessible to most any visitor.

Geosite: Horseshoe Lake Tree Kill Zone

One clue to the geo-enthusiast and to scientists alike that magma is on the move in a particular area is the presence of increased carbon dioxide ($C0_2$) and/or sulfur dioxide ($S0_2$). This is the case in the Horseshoe Lake area (Figure 4.43). A sudden dramatic increase in both of these gasses killed approximately an acre worth of trees in a semi-circle around the lake. This high gas level also posed a serious threat to the humans who used to fish in the lake. Gas emissions occurred in 1988-89 and coincided with a marked increase of seismic activity in the area, warning scientists to keep a close eye on the area. There is parking and portable toilets in the area, but on any given day access may be limited and even denied due to gas levels.

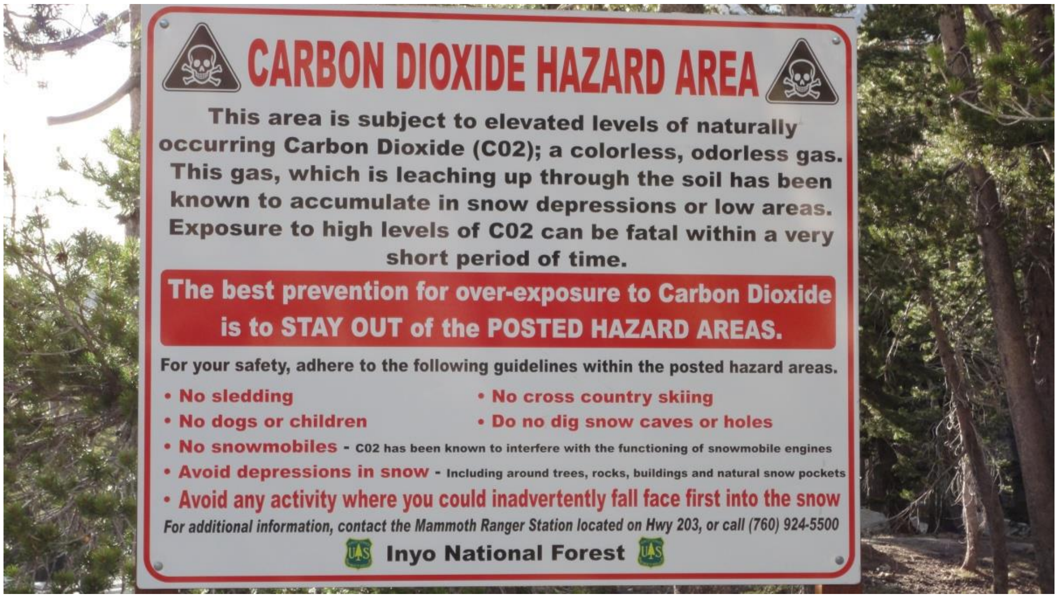

Figure 4.43 A sign warning tourists that there are invisible gases present. Photography by Kimberlie Theis.

Geosite: Mammoth Mountain

Mammoth Mountain is a volcanic dome composed of rhyolite and dacite in Northern California, and sits on the southwest rim of the Long Valley Caldera. The area is rich with geological and recreational activities (Figure 4.44). The visitor's center is well-staffed with knowledgeable people, and is equipped with educational materials. Diverse wildlife, good facilities and well-maintained trails come together to make a highly accessible geotourism location. Mammoth Mountain was last volcanically active at 57, 000 years ago. The mountain contains at least 35 mafic vents connected to one magmatic system, which is separate from the Long Valley Caldera chamber and the Inyo chamber. Recent volcanic unrest facilitates the need for monitoring of the seismic and volcanic progression to assess possible hazards. The USGS describes their array of field sensors as dense in this location. There is a sizable community, food, lodging and medical facilities. Individual sites usually have at least "good signage" and restrooms except for the most remote or isolated areas.

Figure 4.44 Beautiful Mammoth Mountain is full of tourist's interests. Photography by Kimberlie Theis.

Geosite: Devils Postpile

Devil’s Postpile has a very photogenic array of columnar-jointed basalt. This is an example of a long, slow magma cooling process. Around 80, 000 years ago, in the same time period as the eruptions that created Mammoth Mountain, a voluminous basalt lava flow partially filled an area near the Middle fork of the San Joaquin River. The columns that formed are between 2 and 3 feet in diameter (0.6 to 0.9 m) and are 60 feet long (18.29 m) and are a result of the specific material’s cooling tendencies. An ice age caused glaciers to move through the area, leaving a polish and some striations on the top exposure of the formation. The hexagonal nature of the basalt’s cooling can be viewed as if it were purposely displayed. There are several educational plaques, articles of signage.

The area has restrooms, camp grounds and the trail is maintained by park services. This place is accessible to all but the seriously disabled or elderly.

Geosite: Hot Creek

Hot creek is in a gorge of a rhyolite lava flow. The creek begins in Mono County and is known as Mammoth Creek. It passes through the Long Valley Caldera, which has the near surface magma body, and picks up heat from the underlying rocks whose groundwater has been superheated. As it strains up through cracks in the earth, it locally heats the creek giving it the local name, Hot Creek. Water builds up mineralization in some places, forcing the water through a different route, and breaking through rock in others. Because of this, water temperature can change very quickly. The current water temperature in the hot parts of the creek is a concern for those using the creek as recreation, and has been for the last several years. Care must be exercised when swimming in this beautiful geotourist retreat, for pockets of scalding hot water may suddenly take the visitor by surprise (Figure 4.45). Not surprisingly, deaths have occurred, as visitors ignore posted danger signs and warnings to keep out of certain areas. But if the signs are given due consideration, the creek is considered safe enough. The U.S. Forestry Service manages this popular feature and its recreational area. There are clear and concise educational and warning signs advising visitors of the often extreme temperatures of the creek (Figure 4.46). At 93°C or 200°F the creek can pose a significant burn danger. It has a well-worn and easily traversed trail for someone who can walk comfortably up and down a slight grade. Restrooms and changing rooms are available and parking is good. Community support is a 30 minute drive, but restaurants, markets, gas, and lodging are available, as well as shops.

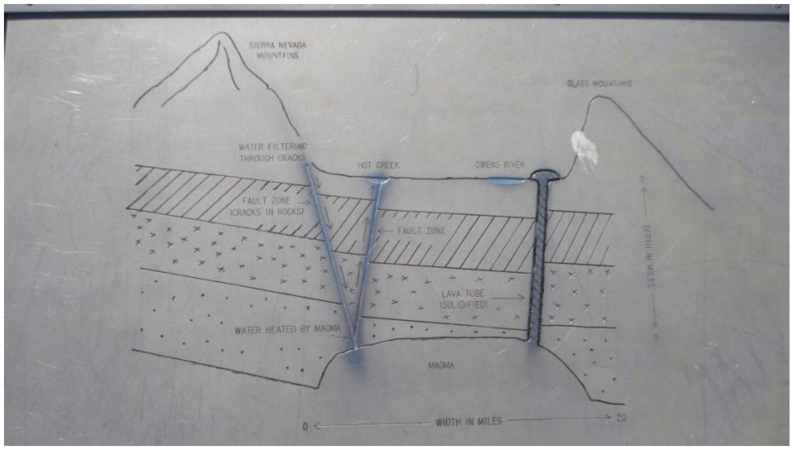

Figure 4.45 Hot Creek Signage depicting magma body proximity.

Photography by Kimberlie Theis.

Figure 4.46 Hot Creek was once a favorite swimming hole.

The area has experienced movement of the near surface magma body, increasing water temperatures. In addition, the rocks themselves have evolved in their appearance and position. Photography by Kimberlie Theis.

Geosite: Bishop Tuff

A depositional feature of ash, the Bishop Tuff is evidence of a massive pyroclastic eruption that created the Long Valley Caldera 760,000 years ago (Alt and Hyndman, 2000) and 700,000 years ago (Bailey, et al., 1989). The sheer volume was estimated at over 50 cubic kilometers (12 cubic miles) of tephra that fell as ash. Also 700,000 cubic meters of magma erupted in a pyroclastic flow and due to the extreme temperatures when it fell, it was welded into a welded tuff. In some places there are as many as eight identifiable layers, easily distinguished from one another in the weld. Bishop Tuff has been found as far away from its source as Nebraska and Kansas. The Bishop Tuff can be easily accessed by traveling north from Bishop on Highway 395 and roadside turnouts offer several points to walk out on the tuff and observe the various layers. The deep layers of Owens Gorge offer a good showcase of the geology. While there are signs at various locations there is no formal Bishop Tuff location.

Geotopic: Wineglass Features and Alluvial Fans of the Eastern Sierras

In the processes of both uplift and erosion that create and eventually destroy mountains, two features that are related to each other and yet are both unique and visually identifiable are alluvial fans and wineglass canyons. On the Eastern or “rain shadow” side of the mountains where stream gradients in the Sierra Nevada mountain range drop quickly, sediments terminate in a distinctive depositional form. This sediment distribution, called an alluvial fan, spreads out from a steep pile at the base to a more gently sloping semi-circle, very much resembling an apron. Larger alluvial fans can sometimes merge to form continual slopes of alluvial material called *bajadas*, such as those found along the Panamint Mountain Range. Most of the year, the rivers and streams that feed the alluvial fans are dry, and the water is generally delivered in the forms of flash floods. Rains delivering vast amounts of water in a short time can deepen channels or slot canyons. A slot canyon is always more narrow than it is long and the distinctive 'V' shape gorge at the top gives the appearance of the a wine glass with a deep stem. These shapes are often the result of faulting, as one side of the fault lowers, leaving the slot, and taking with it, the debris.

Geosite: Death Valley

Death Valley National Park is a favorite to geologists and geotourists alike because there aren't any trees or soil to cover up the rock record, and deciphering what has been occurring is much more accessible than in areas with heavy biologic growth. Death Valley contains many geologic features, including faults (of every kind), sedimentation, erosion, mountain building, lakes, missing lakes, underground streams and volcanic landforms. It is a hot dry place, which turns out to be why the place even exists. It is so hot and dry, there are salts, everywhere. There is a vast salt flat from an ancient evaporated lake, known as Lake Manly, which was left over from the pluvial lakes. Faulting has left plenty of interesting features, such as cinder cones that have been sliced in half. Wineglass features occur when a fault moves and carries one side of a block up, creating height. Any streams coming out from the high place would be elevated as well. A long, skinny, 'stem' then forms. When a storm comes and dumps debris through the stem, the bottom of the wineglass takes its typical circular shape from the debris. In Death Valley, the valley itself gets 'down-dropped' as the geometry between faults is such that the valley keeps getting lower and lower. Badwater, California is at the edge of the saltpan in Death Valley and is the lowest place in the Western Hemisphere. It is also the hottest.

Geotourist Support for Death Valley

Death Valley must be experienced. There is camping, RVing, and even a modest lodge, and a less than modest hotel. There is plenty of parking. Community support is available, but the communities are pretty far away. In fact, there would not be much to the communities at all if it were not for Death Valley. It is not easy to access in that it is very much out of the way of any civilization. The roads are in good shape to get there. Once you get there, you should plan to stay for a while. There are so many trails that explore many different things, like fossil Titanotheres, and marble canyons, natural bridges expanding over canyons, and pleasant walks through washes. Truly, there are too many different types to mention. The park is being kept safe for the geotourist by the National Park Service and there is a visitor's center that can tell you much about the place. Anywhere you go, you may locate interesting signage, and educational materials. The level of difficulty experienced by any one person could be easy or extremely difficult.

Geosite: Mosaic Canyon

This canyon is the drainage for Tucki Mountain, one of Death Valley's several "Turtlebacks" or exposed metamorphic core complexes. Uplift, erosion, and faulting all conspired to create this canyon. Over millions of years, the drainage followed faults and slowly exposed the marble. Flash floods have scoured and polished the marble. The canyon contains dry waterfalls, slides, and exposures of folds. The rock, boulders, and sediment empty out onto the Tucki Mountain Alluvial Fan, which gently lowers to the elevation and site of Stovepipe Wells at its foot. A mile or so east are the Death Valley dunes, which could have been a topic by itself, and was created as winds come from 4 directions and drop their load, creating a star dune, among others. There is parking, at both places, but no facilities. It is within the National Park, and has some signage. The town of Stovepipe Wells contributes community support, as well a campsites and RV spaces, facilities that include showers, a lodge, a small store, a gift shop, swimming pool, and a restaurant. Driving up to Mosaic Canyon is easy, but it is along a gravel road, constructed out of the fan. The hike can be easy to intermediate, depending on your level of energy. As is true in all desert situations, geotourists should bring plenty of water, and a hat.

Geosite: Jackrabbit Mine

The Jackrabbit mine is located just outside the town of Bishop., and is located on Bureau of Land Management (BLM) land. The tungsten steel ore mine is a good place to look for accessory ore minerals such as epidote and garnet deposits. The area is located up against the Sierra Mountain Range in some low hills, called the Tungsten Range. There is no community support, but there are trails, and some signage composed by the Bureau of Land Management (BLM). Trails are everywhere and many go nowhere. A GPS device is a good tool to carry, as well as plenty of water. Tourists should watch out for rattlesnakes. The mining area is fairly easy to get to as one would drive over dirt roads which are level. The trails are all very easy to hike.

Province #5 Sierra Nevada

Sierra Nevada Province Geology

The diversity of this province makes it a high volume geotourist destination. The province is a favorite for backpackers, campers, fishermen, hikers, bikers, and countless other enthusiasts. It is difficult to combine this vast province into several remarks that describe it. That being said, several of the more prominent geotourist sites can be outlined. First, the province is underlain by a truly massive granite batholith. Because this granite has been uplifted and eroded, some very beautiful scenery and popular geotourist activities are present. The granite has been uplifted to heights well over 14,000 feet. (4,267 m). Alpine glaciation has carved arêtes, hanging valleys, U-shaped valleys, created moraines of rubble, and littered the high country with paternoster lakes. Glaciers are present in some of the highest places. The granite has been carved in places with striations. There are places that show the bright sheen of glacial polish. Erratic boulders can be found in glaciated landscapes. *Roche Moutonnée* are also present in some of these landscapes, particularly in meadows. Alpine lakes, hanging valleys, and rounded domes reveal the underlying plutons. Moraines alter river courses. Domes have been uncovered.

The metamorphic rocks of the Sierra Nevada, here as sediments prior to the emplacement of the granite, lend a different character to lower lying elevations. Ribbon cherts are present in stream beds and in the walls of various canyons that run through this metamorphic sequence. In places, limestone has been altered to marble and have caused caves to form in the foothills. Marble haystacks occupy the Sierran town of Columbia, with unknown quantities of gold most likely lying beneath them and the adjacent town.

Faulting has had immense effects. Some faults are the contacts for exotic terrane and adjacent rocks. Observance of rock types here will undoubtedly leave the geotourist with many questions. Other faults are the contacts for huge quantities of gold. It is here that the Gold Rush of California began. The complex story of so much change surely has been repeatedly told many times. Mining progressed and changed as an industry along these contacts. The land supported hundreds of thousands of people as they roamed over the hills. Ghost towns mark many of their historical remains.

The Pacific Coast Trail treks along the high places of the Sierra Nevada Mountain Range. The foothills below these high places now contain man-made lakes and dams, holders of water for the populations in the valley below. There are man-made lakes, with water skiers and fishermen. The slopes that collect snow are used for snow skiing. There are many types of mining that took place here. Quarries yield important and valued resources. Marble and slate is produced in large quantities.

Table Mountain, a classic example of an inverted stream of the ancient Tuolumne River, is a popular hikers' destination in the spring because of its display of wildflowers. The geomorphic feature is that of a river filled with lava, and with the stream banks eroded, only the hard lava riverbed provides evidence of its existence. Other important features include road cuts and even mountains, which are held up by a beautiful greenish rock, California's state rock, *serpentinite*. It is present not only in the Sierra Nevada province, but all over the state. It often points to complex rock associations, unique to California.

Geotourist Support in the Sierra Nevada Province

Parts of the Sierra Nevada are wild, and few humans live there. These places are likely to have camping and parking (where tourists can find it), but the chances of a motel would need to be planned, and one would have to travel, in some cases for many hours. Each of the sites will have their own particulars. (See Appendix C) Community support for many of the sites is strong, and the Sierra Nevada has its own geotourist mapguide, which is supported by the National Geographic Society, and which complies to their description of what geotourism is (See Chapter 2). The communities benefit from the advertisement of the mapguide. Trails can be found all through the mapguide, as they do in this study also. Depending on the site, one could find disabled access. The Column of the Giants, in the high country near Sonora Pass, has cement trails, with rails, and viewing areas that cater to people with disabilities. Other sites are more primitive, like Natural Bridges, near New Melones Lake. Both have pit toilets, but Natural Bridges' trails are meant for hikers with sturdy walking skills. The signage also changes with each site. Column of the Giants has very interesting text about the watershed and what happens to the Stanislaus River as it progresses downslope. Natural bridges has very little signage, but is protected by the Stanislaus National Forest. Access to each of the sites depends on where you are coming from and the site you are trying to access. Some are at the end of well cared for highways, yet are hours away. Others are nearby, but access requires 4 wheel-drive, the knowledge of the area, the ability to work a Global Positioning System (GPS), or some other challenge. Thus, ease of access will change, depending on the site.

The level of difficulty depends on the hiker. Some people are naturally talented at placing their feet, and can move very quickly. Others will need to move more slowly and may be hindered by elevation changes required by the site in order to get to it.

The Sierra Nevada locals have done a lot of work, in order to bring the geotourist to their respective sites. Many have participated in constructing the mapguide, which seems quite detailed. Geotourists can choose between five categories for exploration: adventure, connect and engage, culture and heritage, local flavor, and natural beauty.

Geosite: Donner Pass geology

There are erosional features here at Donner Pass as well as a lake, and visible glaciation (Figure 4.47). Igneous structures are present in the form of domes and collecting is possible.

Figure 4.47 Donner Lake from the southern end.

Photography by Kimberlie Theis.

Geotourist Support at Donner Pass

There is lodging in the area because of the ski resorts. Parking is very good and community support is reasonable for this isolated place. Camping and trail systems are unknown. Handicapped access is available. Signage is good and is often historical in nature. There are no brochures available at this site. It is more of a "region", than a localized site, in that it is possible to wander for great distances, and from no particular starting point. The "ease of access" to various points in the area can be both difficult and moderate depending on your destination. The level of difficulty is unknown but probably difficult. Backpacking is probably the most popular summertime activity, while winter time activities are definitely snow skiing. There are many websites available for this place, since it is a notorious place in American and especially California history (Figure 49). Search for "The Donner Party" to get the story. (Appendix C).

Figure 4.48 Donner Pass signage.

Photography by Kimberlie Theis.

Georegion: Highway 120 to Yosemite geology, and the Tuolumne River

The geologic story here is of the metamorphic rocks of the western slope of the Sierra Nevada, being uplifted, and then cut through by the downcutting of the Tuolumne River. There are granite bodies that increase in number as the proximity to Yosemite increases. There are many serpentine bodies that are indicators of ocean rocks. These tend to be at the lower elevations, and there are terranes of rock, composed of island arcs that have been added to the North American continent. There are also indications of Pleistocene glaciation that change in character as the elevation changes. Alpine glaciation is found in the high elevations, that and moraines and exotic boulders, along with paleosols that can be identified. Erosional features are found everywhere, and in the high elevations, consist of unloading and exfoliation. Depositional features are chiefly caused by river deposition and glaciation.

Geotourist Support along Highway 120 to Yosemite, and the Tuolumne River

Lodging along the road to Yosemite is limited to towns, but there are several places along the Tuolumne River that contain campgrounds, such as Tulloch Lake, which even has cabins for rent, and several places between Buck Meadows and the Yosemite gate, such as Yosemite Lakes Lodge. Parking along Highway 120 can be found at turnouts and vista points. The federal park system and the Army Corps of Engineers run some of the parks found along this highway. You can find trails anywhere you can find a park. At these parks, there is usually disabled access, and signage is provided at each of the parks, although they don't often comment on the geology. It's very easy to locate many of the interesting places on this stretch of road. However, there are some places that are a bit harder, such as Table Mountain (hiking). The level of difficulty for hikes can range from very easy to difficult (steepness).

Georegion: Lake Tahoe geology

Seismic features are present in the Lake Tahoe area as normal block faulting. The basin that forms between the Carson Range and the Sierra Nevada range is the down-dropped block, and is lower in elevation than the Carson basin on the other side of the range (Schweickert, 2003). Lake Tahoe is the second deepest lake in the United States. Its water comes from rain and snow melt, and the water leaves the basin by evaporation and by the Truckee River, which runs through Reno, NV. There are erosional and depositional features, present, and glaciation is abundant (Figure 4.49.

Figure 4.49 A glacially placed boulder called a glacial erratic.
Photography by Kimberlie Theis.

Collecting is allowed in certain places. The lake was formed after a volcanic eruption and glacial moraines dammed up one end of the lake (Figure 4.50). Research shows (Moore et al., 2006; Ichinose, 2000) that tsunamis and seiches can occur in the lake, due to its depth, and have left traces of an ancient seiche event from 7,000 to 15,000 years ago.

Figure 4.50 Emerald Bay which is enclosed partially by glacial moraine. Photography by Kimberlie Theis.

Geotourist Support for Lake Tahoe

There are plenty of hotels and motels nearby but there is also ample camping at Lake Tahoe. Parking is everywhere but you may find it difficult to park if you're driving around the lake. The community supports tourism and shops are abundant. Trails are common and well-marked and there is ample disabled access. It's very easy to get where you want to go here but the level of difficulty in some of the hiking can range from easy to difficult. The parks support tourists by providing interesting signage at breathtaking views (Figure 4.51).

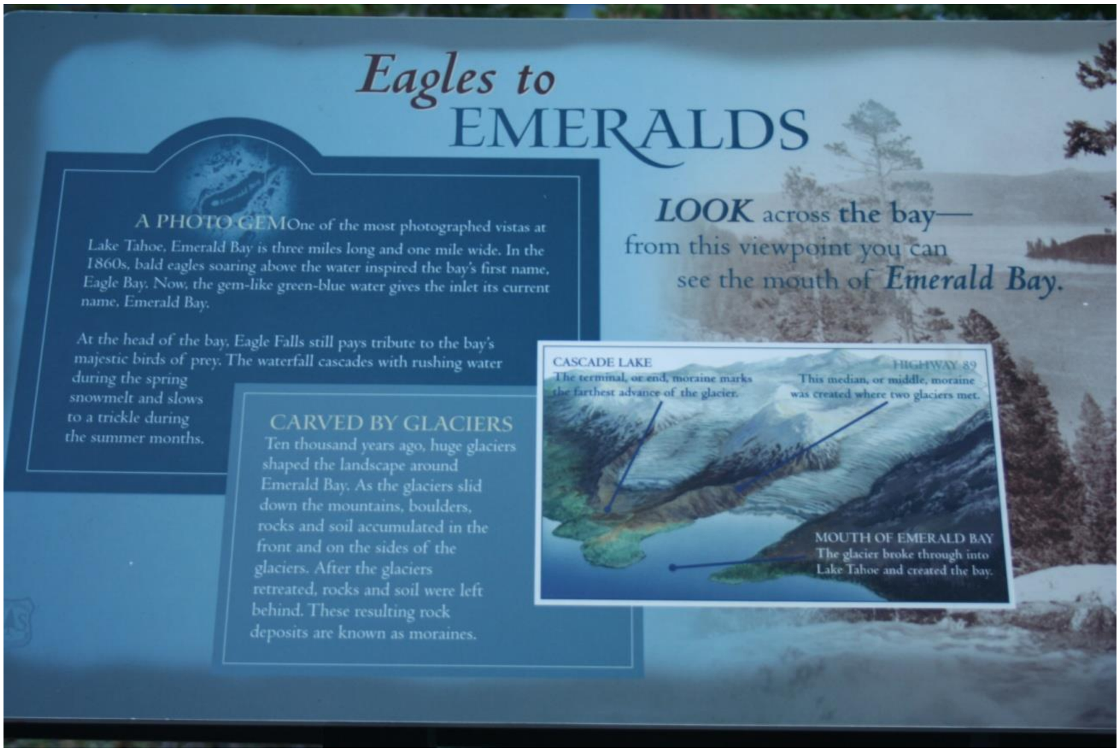

Figure 4.51 Signage at parks.

Photography by Kimberlie Theis.

At many of the parks, there will be plenty of informative signage, because these parks cater to the large tourist population. It is unlikely there will be brochures, especially away from any parks. Brochures can be found at the Chamber of Commerce, along with volumes of information geared to helping the tourist decide how to spend their time. One of the many websites that can help geotourists explore the area is in Appendix C.

Geotopic: The California Gold Rush

This topic carries many subtopics and places. The Yuba Goldfields (Figure 4.52) were characterized by dredge mining, a type of mining that left scars on the landscape that will not dissipate for 100's and 100's of years.

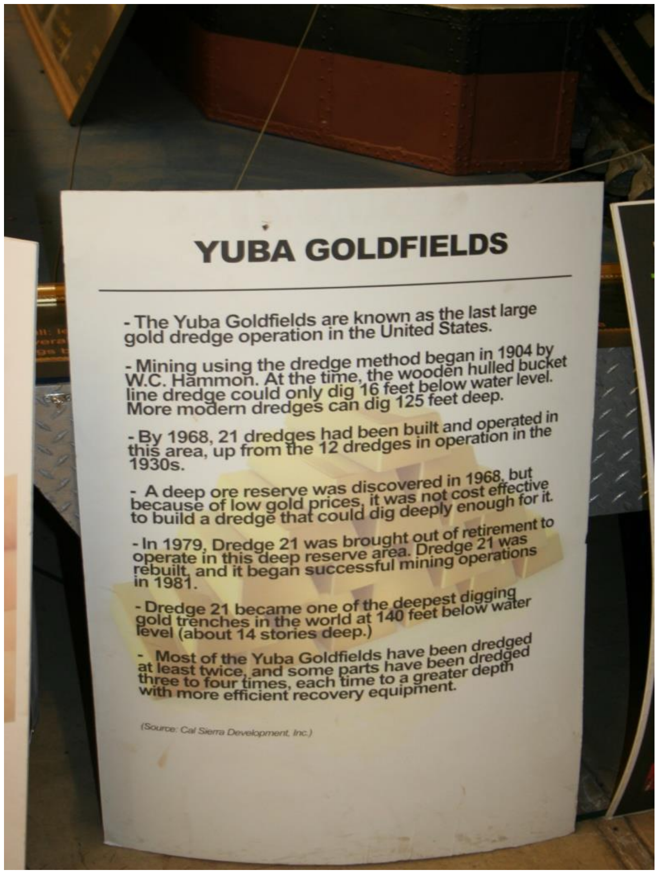

Figure 4.52 A sign at the North Star Mining Museum describing mining history. Photography by Kimberlie Theis.

Geosite: North Star Mining Museum

Because of the nature of the geologic region it is probable that there are seismic features in this area, none of which are readily visible. Mining features, materials, and equipment are apparent everywhere (Figure 4.53). Igneous structures were being emplaced in the crust and at the same time, superheated fluids that had concentrated gold, silica, and other minerals, were deposited in the crust. Miners were able to follow veins of these minerals and fortunes were made and lost.

Figure 4.53 A Berdan grinding pan at the North Star Mining Museum.

Photography by Kimberlie Theis.

Geotourist Support for the North Star Museum

This museum has a parking lot and there is plenty of lodging in the town of Grass Valley. This museum has a large quantity of mining equipment and records of mining history (Figure 4.54). The community supports this museum and there is plenty of signage leading one to the museum and around and inside the museum and its contents. The North Star Museum is very easily accessed. Brochures are available inside of the museum. The mapguide for the Sierra Nevada has a section on the North Star mine (Appendix C).

Figure 4.54   North Star Pelton Wheel.

Photography by Kimberlie Theis.

Geosite: Empire mine geology

The geology here is very similar to the North Star Mine geology and the text won't be duplicated here.

Geotourist Support for the Empire Mine

The Empire mine is part of the state park system, and as such, it has community support, parking, handicapped access, very good signage, and it's very easy to access (Figure 56). It is a Historic Park, with lots of mining history and is very much worth seeing. There is a model in the park office. There is handicapped access.

Figure 4.55 Sign at the Empire Mine.

Photography by Kimberlie Theis.

Geosite: Malakoff Diggins

The geology here is due to emplacement of gold fields by Paleogene rivers. The site became important in the gold rush because of the hydraulic hoses used to get the gold from hillsides. Water was shot through a narrow hose, which pressurized it, and sufficient force was applied to the hillsides, and sediment was washed down the slopes into sluice boxes, where the gold was separated.

Geotourist Support for Malakoff Diggins

This site is run by the state of California as a Historical Park. There is no lodging in the area, nor is there any camping nearby. It is well kept but is very “out of the way', and as such is difficult to access. There is little community support because it is in such a rural place. There is handicapped access with plenty of signage in many places within the historical district (Figures 4.56-58). This is a ghost town that is being kept up by the state.

There are brochures available in various places. Some of the buildings are open during business hours. One website that is available is found in Appendix C.

Figure 4.56 A water monitor (hydraulic water hose) which removed hillsides in order to get at the gold.

Photography by Kimberlie Theis.

Figure 4.57 One of the hillsides that were washed down by the hydraulic hoses.

Photography by Kimberlie Theis.

Figure 4.58 North Bloomfield, once known as Humbug.

Photography by Kimberlie Theis.

Geosite: Goodyear's Bar

Although there is nothing at the present site, there are few more famous sites than Goodyear's Bar, where the placer mining took place with frenzied activity (Figures 4.59and 60).

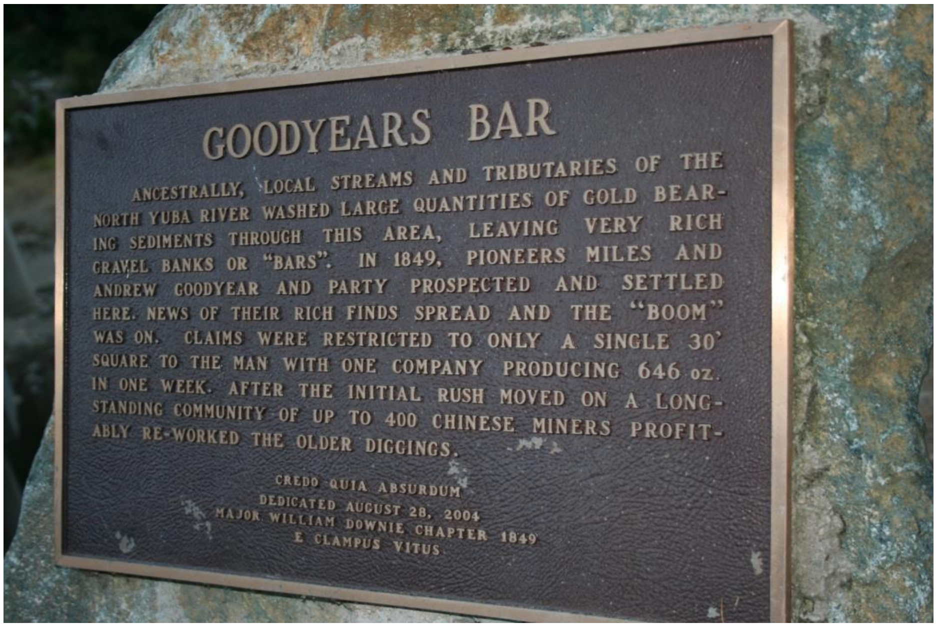

Figure 4.59 This photo is taken on the roadside at a lonely turnout. Photography by Kimberlie Theis.

Figure 4.60 A model of a dredge, which was a form of mining that lasted well into the 20th century.

Photography by Kimberlie Theis, taken at North Star Mining Museum.

Geotourist Support for Goodyear's Bar

This is a lonely spot on the road. There is nothing nearby except a road marker and the river. The nearest buildings are not visible and one would not guess at any populations here now. There is no community to support it, but the Clampers did erect the monument. There is no lodging, except the bed and breakfast at the old hotel. There is no camping. There is no disabled access. This place is aptly described as "out of the way". There are not any trails visible, but this is the trailhead of the North Yuba Trail, connecting Downieville to Indian Valley. There are no brochures available. But there is a webpage in the Sierra Nevada Mapguide, telling of this historic place's role in the Gold Rush (Appendix C).

Geosite: Hornitos

The geology of Hornitos has been covered by the text on the Gold Rush, with the added fact that fractures adjacent to the Melones Fault were the host rock for the gold and for the superheated waters, that the silica and gold were deposited in. The fault was the contact between an island arc and the continent. .

Geotourist Support at Hornitos

Being a ghost town, there is not any lodging in or around the town. There are campgrounds within 10 to 15 miles, and New Melones Reservoir is not far away. There is plenty of parking around town, and the little community here does not really support any tourism. However, there are restroom facilities for tourists on one of the streets and they are kept in very nice condition. There are not any trails in the area, and hiking is discouraged due to the mining hazards. There is disability access. This area was where famous people such as Studebaker (car) and Ghirardelli (chocolate) were able to get their starts. One building has a fence around it, and the walls are in various levels of disrepair. But there is a very nice sign describing how Ghirardelli started out here. The area is fairly easy to get to for a town that lies off the beaten path. The level of difficulty for this site is easy. A website is included in Appendix C.

Geosite: Columbia Geology

Despite being “gold-rich”, the people of Columbia were at a disadvantage for producing gold from its placer deposits because there wasn’t any water in the area, making the working of the deposits very difficult. In order to remedy this problem, early miners built an aqueduct from 60miles (96.56 km) away, leading to the deposits, thereby making it possible to mine the gold. The rocks in the area are marble, a metamorphic rock. Features called "haystacks" are located all over the town of Columbia (Figure 4.61). Because the deposits of gold were so rich, a town quickly grew up. The gold beneath the town, in the karst marble, tended to collect in potholes and other cavities within the karst. Miners would often try to get at the gold beneath the town.

Figure 4.61 Old miner's shack amid the haystacks.
Photography by Kimberlie Theis.

Geotourist Support for Columbia

There are some motels in Columbia, and camping in the nearby countryside is easy to get. The parking is very good. Community support is also very good and this community thrives on its tourism base. There are short trails to walk around, but the main focus is the ghost town itself. There is disability access. This town is very easy to get to, and the level of difficulty for walking around is easy. There are plenty of signs describing the town and various points of interest (Figure 4.62). There are many websites to choose from (Appendix C).

Figure 4.62 Columbia Historic Park map.
Photography by Kimberlie Theis.

Geosite: Sequoia-Kings Canyon

This National Park has been referred to as "The Other Yosemite Valley" and has a long standing relationship with naturalist and author John Muir. This park is known for containing Mt. Whitney, the highest peak in the lower 48 states, along with eleven other high peaks that top 14,000 feet. The park is filled with backcountry, containing the Sierran Crest and much of the eastern side of the Sierra Nevada range. Its granitic rocks have been glaciated repeatedly and the canyons show the U-shaped features. There are limestone caverns within the park boundaries, along with tremendous stands of Giant Sequoia. It is truly a place without compare.

Geotourist support for Sequoia Kings Canyon

There are choices for lodging in this park that include lodge rooms, campsites, and RV sites. There are not communities in very close proximity, but those that are near seek to outfit the park visitors. There are many trails in the park and they are marked with signs. There are many signs explaining various features in the park and these are kept up by the park service. The disabled have plenty of access throughout the park. The park can be a distant drive, depending on what entrance you are using. The level of difficulty for park trails and attractions varies from easy to difficult. A website can be found in Appendix C.

Province #6: The Great Valley Province

The Great Valley Province Geology

The story of the geology of the Great Valley of California is one of deposition from late Jurassic, throughout the Cretaceous, and into the Paleocene (Bartow and Nilsen, 1990). The sediments were washed from the mountainsides of the Sierra Nevada and from uplifted Coast Ranges. These sediments have resulted in distinct formations, in the area of Turlock, Modesto, and Riverbank, California. The Modesto, Riverbank, and Turlock Lake formations are all made of glacial outwash sediments. These formations continue north and south, but may go by different, local names. The sediments themselves were deposited as the glaciers washed their fine sediments down into the valley. In the area just east of Oakdale, there are hills that rise high above the valley floor. These are glacial outwash fans that have been partially removed as erosion from the Stanislaus River undercuts and erodes them.

Rivers cross the valley as they come out of the Sierras (Figures 4.63, 4.64). The rivers have often been held back by man-made dams when the reach the valley floor. They continue, when not being dammed, to join the San Joaquin River, which flows north from places like Fresno, Merced, Modesto, and Ripon, to meet up with the San Joaquin-Sacramento delta. In the northern part of the valley, rivers flow out of the mountains, get contained by dams. They flow into the Sacramento and American Rivers, meet and flow into the Sacramento delta. Both San Joaquin and Sacramento deltas access an outlet at San Francisco Bay, and then the Pacific Ocean.

Figure 4.63 Rivers of the San Joaquin

Figure 4.64 Rivers of the Sacramento Valley

These images were taken from Wikipedia.

Other special attributes of the Great Central Valley include fossils that have been found beneath the surface sediments. At Madera County, specifically, the Fairmead Landfill, an important collection of Pleistocene Megafauna was found and continues to be excavated. Since the excavation of fossils appears to have no end in the immediate future, a visitor center has been built, and geotourists can visit to observe the various fossils that have been uncovered, and to learn about the habitat, climate, and other important information concerning the lives of these fantastic creatures. It is truly an exciting place to visit. Other formations in the valley have yielded similar finds, such as the Temblor formation and the Moreno formation, found on BLM land (Bureau of Land Management) in the Panoche and Tumey Hills. Because it is BLM land it is open to all.

Conifers, hadrosaurs, and mosasaurs, dating back to the K-Pg (Cretaceous-Paleogene) boundary at 65 million years, have been found and are presumably present, along with a wealth of other creatures, including plesiosaurs (sea dwelling reptiles) and sea turtles.

Geotourist Support in the Great Valley

Geotourist lodging in the Great Central Valley will range from camping, RVing, or available motels. Motels are accessible but arrangements should be made. Camping won't always be accessible, nor will a space for an RV or trailer. When planning an itinerary, geotourists should research the planned site to see what kind of lodging is available. Parking is available, but weekends can be busy, so it's best to check. There isn't much community support for most activities. Most good trails will be at parks, where they are regularly cared for. Sometimes, as with Natural Bridges, the trail will be rough. Disabled access is available on government lands, such as visitor centers. Signage is usually available at visitor centers, but less so if there is not some form of governmental support. If there is no government support, the signage, if any, will be of low quality. Most of the time, places are very accessible because most places are accessed by driving. The level of difficulty is easy to moderate with very little elevation change. There are several websites that comment on activities in this study.

Collecting is permitted at the Panoche and Tumey areas, but a permit is required. Madera Mammoths at Fairmead Fossil Discovery Center has a very good site, with many other sites that lead to the Fossil Discovery Center. The signage at the Fairmead Visitor's Center is very good and strives to engage all levels of interest. The situation on signage at the Panoche and Tumey locations is unknown.

Georegion: Knight's Ferry – Table Mountain

There is no lodging at Knight's Ferry, a day use area. There is parking and community support from the nearby town of Oakdale. There are trails and handicapped access. There is signage also. This location is very easy to get to and the level of difficulty is easy.

Table Mountain, a classic inverted stream of latite lava, is a volcanic feature. Erosional features are present. Miners used to perform a type of mining called "coyote-ing". It was a very deadly form of mining and did not last long. Collecting is allowed.

Geosite: Table Mountain

This is a classic inverted stream that is a major landform in the area. It crosses two provinces, the Sierra Nevada and the Great Valley, adjacent to the mountain range. The name "Dardanelles" refers to a long, narrow strait in Turkey, and is known for famous battles, due to its strategic ability to force armies into a narrow space to get the upper hand. The long, narrow character of the Dardanelles held the volcanic rock, as it flowed down the ancient Stanislaus River. The lava flowed across Eocene gravels (containing gold), down the river channel, and onto the valley floor. The volcanic rocks then were uplifted and the sides eroded. All that remains of the ancient river are the mineral rich volcanic rocks. The banks that once surrounded other, older rocks are now eroded (Figure 4.65). Today, hikes on top of the flat topped mountain are a popular springtime event.

Figure 4.65 Classic inverted stream morphology at Table Mountain.

Photography by Kimberlie Theis.

Geotourist Support at Table Mountain

Lodging near Table Mountain is available at Jamestown, the nearest town. Camping is available throughout the foothills and at Don Pedro Reservoir, just a few miles away. There is parking near the trailhead, but the dirt road that leads to the trailhead can be rutted. Four wheel drive might be needed in winter months. The community knows about the trail but it is not a tourist attraction that gets much attention. The trail is rough and disabled access is unavailable. The ease of access is dependent on the season. There are signs near the trailhead that indicating the presence of the trail, but there are no signs that explain the origins of the geologic feature. The trail ascends a steep slope to the top of the mountain. Once there, the trail is fairly flat and the level of difficulty is easy. Web pages are available (Appendix C).

Geosite: Don Pedro Reservoir

Don Pedro reservoir sits over the metamorphic rock of the Sierras and accreted terrane adjacent to it. The Melones Fault runs directly through the northern part of the reservoir, trending east to west. There were once mining entities and a town in the valley that houses the lake, but it has been covered up by the water. The rocks show the presence of various near-shore rock assemblages, such as an island arc, pillow basalts, and folds. The Sierra Nevada has several foothill reservoirs, of which Don Pedro is representative. Lake levels have dropped considerably in California and at Don Pedro, a mining operation has emerged from beneath the water (Figure 4.66). There is also the town of Jacksonville, but it has not yet emerged. The filling of reservoirs and covering up of old towns and other historical buildings is a fairly common occurrence along the Mother Lode area.

Figure 4.66 Emerging mine from the waters of Lake Don Pedro.

Photography by Kimberlie Theis.

Geotourist Support for Don Pedro Reservoir

Lodging is limited to surrounding towns unless camping is the goal. There is plenty of parking around the lake. The nearby communities support the lake and cater to visitors. Trails in the area are sparse and unattended. There is no disabled access. There is not much signage because most of the tourism is focused on water sports. The reservoir is easy to find. The level of difficulty is not easily categorized. If one is looking to hike, a path must be made and this would make access difficult. (See Appendix C for the website.)

Coast Ranges Geology

Another diverse province is the Coast Ranges Province. The ranges are that part of tectonic morphology that comprising the accretionary wedge, whereby the lip of the continent scrapes sediments from a down-going subducting plate. This took place during Mesozoic time (National Association of Geoscience Teachers, 1979). These sediments are part of the Franciscan Melange, a badly mangled, disturbed and distorted packet of sediments. Along with the sediments came other formations of rock such as ophiolite sequences. The Coast Ranges are one place that scientists can study these. Del Puerto Canyon empties into the Great Valley and retreats back into the mountains, and contains one of these ophiolite sequences. There are also mining resources near there, of chromite and quicksilver, minerals that were mined during World War II and were important resources.

This province contains part of the San Andreas Fault. It and some of its associated secondary traces, cause geomorphic features can be easily identified. Sag ponds, shutter ridges, offset features, linear ridges, and fault scarps are easily identified by the knowing eye. Point Reyes, Ca, has an Earthquake Walk, with signage documenting the 1906 earthquake, explaining features that are present (Figure 4.67). Other important places that faulting and its resulting landforms are produced include Hollister, and Pinnacles, which are both popular places to visit, especially for geotourists.

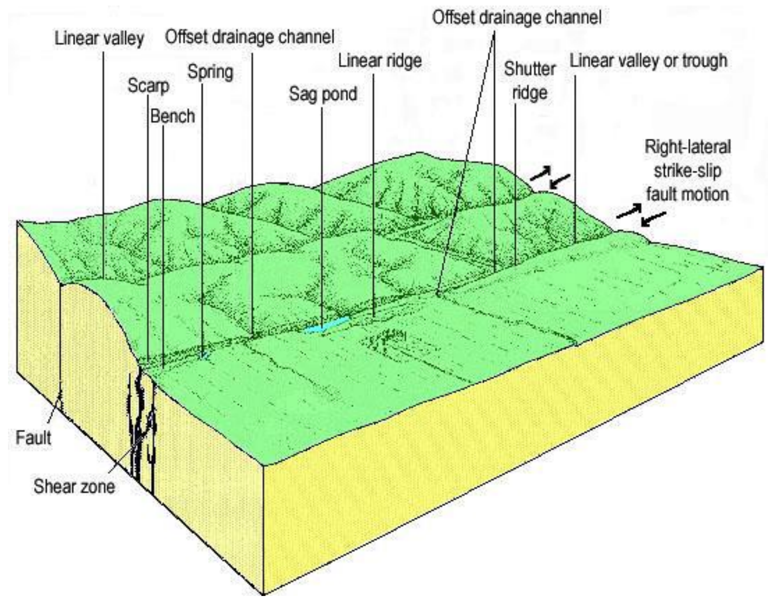

Figure 4.67 Terminology of fault zones. (United States Geological Survey)

The Coast Range province is composed of much sedimentary rock, making it home to fossils, such as microfossils and larger species, such as ichthyosaur. There are quarries and mines throughout the province. At Black Diamond Mine, the resource is a very clean sandstone, of very high quality. The mine is no longer in production and the area is a preserve, with hiking and biking trails. Many rocks of the province tend to be on the friable side, and wintertime can mean scores of mudslides and slope failure.

Closer to the edge of the continent, beaches and redwoods supply plenty of recreation for Californians. Marine terraces separate watersheds. Cliffs overlook strips of rock and stretches of sand. Tide pools, caves, seastacks provide geotourists with hours of activity. The rocks beyond the beach's edge are home to sea lions. Old lighthouses provide a variety of scenery and activities.

Inland, farming land has given way to urban development in many cases. However, the Napa Valley, Sonoma Valley, and other like-situated valleys have managed to turn their farmland in liquid gold, into the flavors of rose, and chablis. The opportunities to take a tour to learn why these soils are so special to the wine industry are frequent and can even be expensive. One will need to shop wisely to find the right tour. Robert Louis Stevenson roamed these parts back in his heyday. There is a park dedicated to him, and also a Petrified Forest, with a tree named after him. If the tour of a winery or a walk in a Petrified Forest proves unsuitable, there is a geyser that can be visited for just a few dollars. Indeed, just over the mountain, one can take a tour of The Geysers, a volcanic district that mines steam from the rocks, to provide geothermal energy.

California is a very large state. Some geosites have been inadvertently left out and this research can be improved with future documentation.

Geotourist Support in the Coast Range Province

Whether geotourists plan to go to the ocean or hike Mt. Diablo, there will be plenty of lodging, parking, and community support. For many years, people have been coming here to get away from it all. There are a variety of opportunities, for lodging and activities. Many trails are accessed from the coast highway. Beaches are be part of the State Park system and will be monitored by them, although support by the government has been drastically cut. Signage will be sparse in most places, unless you are in a park like Big Basin, which has created and maintained a lot of signage. These places can be difficult to get to (ease of access), but once there, the level of difficulty should relax. Web pages are common for most geosites in this province (Appendix C).

Geosite: Overlook at Golden Gate Bridge followed by Marin Headlands across the bay

San Francisco was a rural outpost from 1775, when the first Spanish ship sailed near the rocks that would become known as the “Golden Gate”. In 1849, shouts of “Gold!” rang through the streets. This site begins at a city whose growth was tied to that unique California event. But California’s northern half has a history that is removed from the Gold Rush. Indeed, it is “The Hidden California”. The tectonics that are responsible for the Gold are also responsible for the geology of the north.

It should be suggested that geotourists take time to view the bridge and the surrounding land and water. They should observe Alcatraz, the prison that earned the nickname “the Rock”. This island-prison was the home of ‘The Birdman of Alcatraz”, Robert Stroud. Other famous criminals such as Al Capone, Machine Gun Kelley, and Doc Barker, the son of Ma Barker, all spent time here. The prison was considered inescapable because of the cold bay water, which ranges between 46 and 73 degrees Fahrenheit (8 and 23 degrees Celsius). While looking across the bridge, note that the location of the next geosite is specifically the headland beaches that face the Pacific Ocean. Tourists stop here to take in the invigorating marine air. Geotourists stop to see the folded chert beds and the pillow basalts at the beach outcrop (Figure 4.68).

Figure 4.68 Ribbon Cherts at Marin Headlands.

Geosite: Marin Headlands

The red chert here is about 2 to 10 cm thick and is composed of alternately interbedded dark red shales. Many outcrops along the road show the intense folding that contain chevron folds. The cherts are folded because of their interaction with a subduction zone that was once just offshore, and which is now a transform boundary. The cherts contain abundant radiolarians, little siliceous shells that can be seen with a hand lens. The shells' age, taken at the bottom of the sequence, is about 200 million years old. The youngest radiolaria here date at 100 million years old (Figure 4.69). This tells us that this sequence of ribbon cherts represent 100 million years of deposition (Elder, 2001).

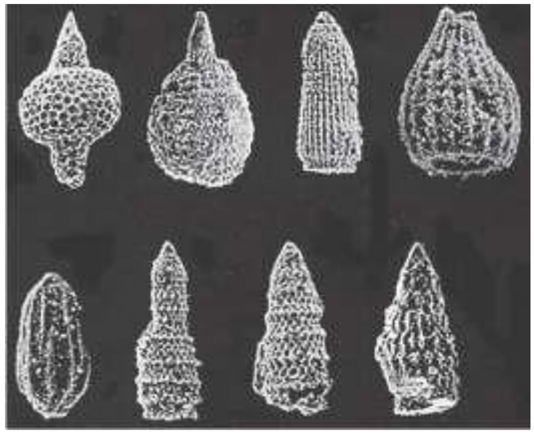

Figure 4.69 Scanning electron micrographs of Radiolaria from Marin Headlands (from Elder, 2001).

Geosite: Pillow Lavas

The geotourist should hike down from the trailhead at Marin Headlands Beach, and at the bottom of the stairs continue right to the end of the beach. At the end of the beach there is an outcrop. Rounded boulder-type structures are found in a matrix composed of like material.

The rock type is basalt. These rocks are often formed at spreading centers but can also be associated with oceanic island flows. The structure is a pillow basalt. It is a unique paleohorizontal indicator because the bottom or keel is flattened (this is due to underlying rock) and the top is rounded. This site is a good one because the proximity of the ocean helps the imagination create the environment in the mind. This outcrop is also very well-formed and the pillows can be clearly seen.

Geosite: Earthquake Trail and Visitor Center at Pt. Reyes National Seashore

The geotourist can walk the trail first, and then visit the visitor's center. Don't forget the camera. It is a good idea to try to identify as many fault related features as one can. The walk was constructed to highlight the 1906 earthquake fault. Offset here is impressive, as shown in the pictures. The author is standing at the top of some steps and offset here is not immediately visible. However if you look behind her and to the right, you can see that the fence continues back and up. The author is standing very close to the fault line (Figure 4.70).

Figure 4.70 Photo of effects from the 1906 earthquake.

Photography by Kimberlie Theis of offset fence.

Facts about the earthquakes

The 1906 earthquake occurred at 5:12 am on April 18, 1906. The uppermost portion of the San Andreas Fault was involved and the length of the strand is 296 miles (476 km) and stretched from San Juan Bautista to Cape Mendocino and the triple junction off the coast (The Great 1906 San Francisco Earthquake, 2012). The theory of Plate Tectonics had not yet been recognized and the offset and the length of rupture had contemporary geologists scratching their heads. There was no idea of a transform boundary at that time and the sheer magnitude of offset and rupture was staggering. Reid (1910) would later form his elastic-rebound theory from this earthquake.

The ground shook for 20 to 25 seconds, followed by stronger shaking that lasted from 45 to 60 seconds. Modified Mercalli Intensities ranged from VII to IX the length of the rupture, extending as far as 50 miles (80 km) inland ("The Great 1906 San Francisco Earthquake", 2012)

Sediment filled areas, especially those that were wet, fared the worst, for their experience of the shaking was greatly intensified. The principle hazards of the earthquake were not limited to ground shaking. Indeed, stoves that had been overturned often caught nearby draperies afire. Because the ground rupture was so severe, water pipes were broken. The fires that engulfed the city did far more damage than any falling brick. Estimates of fatalities were far below reality, since the Chinese population was not ever considered, due to their persona non grata status.

Geosie: Nicasio Valley Road

There are geomorphic landforms related to faulting/earthquakes. Geotourists should look for linear valleys, sag ponds, shutter ridges, and offset features

Geosite: Petrified Forest

Petrified trees at the Petrified Forest in Calistoga, California are pine and giant redwood (*Sequoia sempervirens*) (Figure 4.71a). These redwoods are not to be confused with the giant sequoia (*Sequoiadendron giganteum*) (Figure 4.71b), which is the largest of all living things and is widely dispersed in California, having approximately 75 groves along the western Sierra Nevada range. The Coast Redwood lives in the Coast Ranges of California and the northwest and is a close relative to the giant sequoia. Both these species may have ancestry back into the Mesozoic. Conifers at that time were widespread in the northern hemisphere. They probably evolved 100 million years ago alongside cycadeoids and ginkgos. During the Paleocene and Eocene, a cooling trend probably led to their widespread distribution. Paleogene sequoia forests were found between latitudes of 34 and 58 degrees (1 and 14 degrees Celsius) (Snyder, 1992). The forest today is mixed woodland.

Figure 4.71 A) *Sequoia sempervirens*, from Britanica. B) *Sequoiadendron giganteum*, from CSU Monterey Bay.

At Calistoga, the cause of fossilization was burial by volcanic ash. The trees fell to the southwest, indicating a probable northeast source for the ash blast or a paleoslope to the southwest. This paleoslope is evident by some of the trees' placement of their tips being closer to the surface than their trunks. It is believed this is the original orientation of the paleoslope. The blast was may have been similar to that from Mt. St. Helens. The ashflow tuff, a unit within the Sonoma Volcanics, is dated at 3.19 to 3.34 m.y.o. (Everndon and James, 1964). The type of petrifaction is by replacement, and the material is silica, specifically chalcedony. The trees range from 8 feet (2.5 m) in diameter and can be hundreds of feet high. There is a 20 minute nature trail walk with descriptive displays at each stop. The first stop is a collection of logs from around the area, showcasing the gray-white color and growth rings of the original trees. There are outcrops of volcanic ash (tuff).The first tree on the trail is called the "Pit Tree" and it is the only pine tree that was found petrified. Its presence indicates the paleoclimate was moist. The tree is so named because it had to be excavated from the tuff to expose it. Other trees include "The Giant", which is an extinct species of redwood and cousin to the ones that live here today. Still others include "The Queen", which has an oak tree growing out of it, and "The Monarch", which is the largest intact petrified tree found in existence. There is also "The Robert Louis Stevenson" tree (Figure 4.72), which has a good display of growth rings and also has drusy quartz about its surface. The whole process of petrifaction took tens of thousands of years. It was uncovered, first by natural erosional processes, and then when people who stumbled onto the trees began excavating them. Today, excavation is done with a backhoe.

Figure 4.72 The Robert Louis Stevenson tree, Petrified Forest, California. Photography by Kimberlie Theis.

Geotopic: Soils of Napa Valley.

Possible tours might include Pine Ridge Winery, Rutherford, Bennet Lane wineries, and Sterling vineyards (Figure 4.73).

Figure 4.73 Napa Vineyards.

Photography by Napa Tours, 2011.

Visiting the Napa Valley, the geotourist could learn about what goes into making fine wines. Climate and soil are the two main factors in growing grapes leading to fine wines. A geotourist could learn about the geology and climate that makes Napa Valley such a great place for grapes. They might visit an underground wine cellar, walk through a vineyard, or listen to a foreman talk about rootstocks and soil. Any tour should include factors of the winemaking process and where the wine is stored until it is ready to be sold. At the end of the tour, there may be opportunities to taste some wines. The geotourist should have the opportunity to do it again at 2 or 3 different wineries, so they might learn the major ideas needed when making wine, and to see how the soil and climate affect each winery.

Geosite: Geothermal Energy at the Geysers

Geothermal energy takes the heat from the subsurface and converts it into energy. This energy comes from the decay of radioactive elements in the rocks. It is then transported to the surface through magma and hot springs. There are roughly 3 different ways to do this: Dry steam, Flash steam, and Binary cycle methods. At the Calpine Geysers, the geotourist will learn about all three, including what method is being used at the Geysers (Figure 4.74). Geothermal energy is important as an alternative fuel. California is trying to be a leader in the development of alternative energies. Calpine, the developer of geothermal resources at the Geysers, has developed 15 wells. These wells generate enough electricity to power a city the size of San Francisco.

Middletown-Calpine Offices Visitor Center offers presentations on geothermal energy. Geotourists should next take a tour of the Geysers, and visit a geothermal power plant, well pad and cooling tower. The tours are conducted by Calpine employees, and the guests are provided information on the geothermal operations at the Geysers, geothermal power plants and brief history of the Geysers.

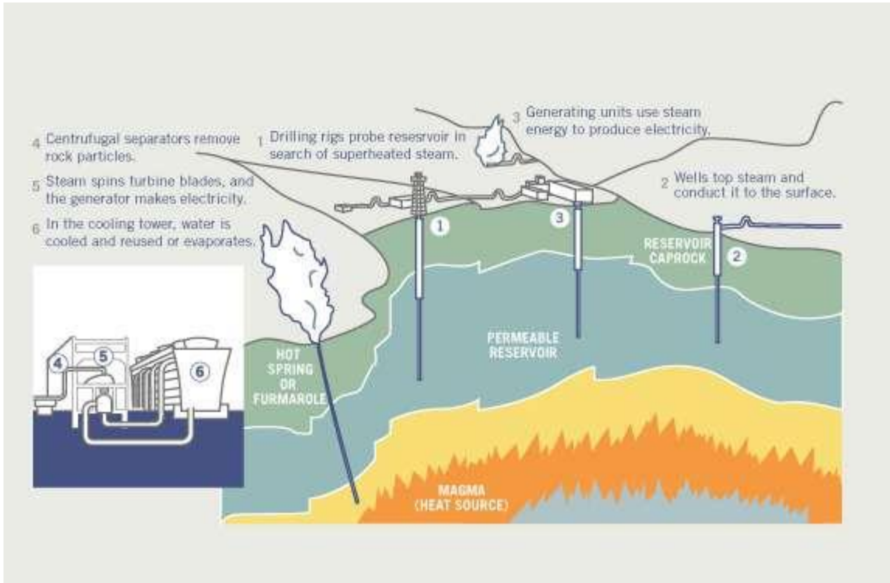

Figure 4.74 Drilling Wells, after Calpine, 2011.

Geosite: Clearlake State Park

This is an ideal spot from which to discuss the volcanics at Lake County. A geotourist could go to the lake at the Day Use area, and look out at Soda Bay. Soda Bay gets its name because one can actually crawl around the rocks in the water and feel heat coming up. There is a natural soda spring in this location and in many others, in the lake, and in the rocks of this region. Soda Bay used to be a favorite of picnickers and swimmers and was a popular little community in its heyday, because there were soda "baths" out in the bay. One would take a rowboat and go out and climb into the concrete rectangular baths. They are now torn down, but the springs survive. Other topics to cover here might be the environmental impacts of the usage of the lake by boaters, fishermen, industry, and farming. The lake has been impacted by each of these groups. Eutrophication of the lake and ways to alleviate some of the stresses that the lake endures are real issues that must be dealt with by anyone who has an interest in the lake (Figure 4.75).

Figure 4.75 Algae in Clearlake.
Photograph taken from County of Lake website, County of Lake, 2010.

Clearlake volcanism has occurred 1 to 2 million years (Hearn, et al, 1995).The lake itself occupies a structural basin, the product of the San Andreas fault and its transpressional stresses, and the eruption and subsidence of the Clear Lake Volcanics (Enderlin, 2007) The lake is a naturally eutrophic lake, meaning there is an abundance of live plants in the lake. Because of this, the lake is a favorite among fisherman. The lake undgoes an algal bloom twice a year, in spring and late summer.

Geosite: Moss Beach

It may be a surprise to learn that the beach is not called Moss Beach, the name of the town. The beach itself is Fitzgerald Marine Reserve. The interesting features for the geotourist at this beach are the folded rocks that observed only at low tide. The folds that occur at the surface of the beach are very large. Because the folds are only revealed at low tide and because of the topographic highs and lows, accessibility is tricky. This site "brings home" the immense forces of the Earth and of Plate Tectonics and is a perfect site for beginning geology students. The tide pools are the big feature that draw tourists.

In the website for Moss Beach (Appendix C), and under Natural Features, there is mention of "Complex Geology". Of course, there are maps on this page, along with other features such as lodging, dining, and park fees. While looking at other websites, I could not immediately find any that refer to the folds.

Geosite: Patrick's point State Park

This geosite provides camping, parking, community support for the park, along with well-kept trails, handicapped access, ample and detailed signage. A feature of this site is its easy access.

The really stunning feature about this geosite ise the many seastacks in every stage of erosional decay. There are remnants of Native American villages. There is evidence of much lower sea levels. In the middle of the park, inland, there are seastacks that sit on top of the marine terraces on which one can walk around. Both erosional and depositional features are found here. Classic beach zones and coastal erosion are present with sand accumulation. Collecting is permitted. There is camping here, parking, and community support for the park, along with well-kept trails, handicapped access, ample and detailed signage. The park is very easy to get to but there are not many urban areas nearby.

Geosite: Point Lobos State Park

This park is known for both its erosional and depositional features. Sea lions are often present and can be identified by their barking. The paths are well maintained. The tilting of rocks can be seen and the rocks are conglomerates, composed of unsorted, rounded cobbles. From the cliff, an eroded sea stack is visible. Eroded concretions are abundant. The conglomerate is sorted. What at first appears to be a developing soil shows pebbles and small cobbles. Up close there are good places to take strike and dip of the beds, which are at a slight tilt. The bedding can seen up close. Active erosion is causing the "cliff" to retreat and this is occurring throughout the park. Coordinates here are N36; 30.801; W121, 56,630, with the elevation at 31 feet or 10 meters.

Geosite: Mt. Diablo

The geology of Mt. Diablo is very interesting. Scientists once thought that Mount Diablo was the southernmost Cascade volcano. Studies now show that Mount Diablo is an anticline, rising from the action of two strikes flip faults on either side of the mountain, forming a buckling. These faults are related to the San Andreas Fault system. There is a bridge in the park called Fossil Ridge where early life-forms have been exposed.

There are three campgrounds at Mt. Diablo and parking is abundant. The park system supports this geotourist site and there are many maintained trails. Handicapped access and signage are both maintained and the park is easy to get to. The level of difficulty for the hikes varies. The Park service maintains a webpage.

Geosite: Black diamond mine

There are faults within the park, but they may be inactive. Depositional features include extremely clean sandstone that was once mined and used to make glass during its peak years. There once were active mines and tunnels here because of high grade coal that is found here.

Black Diamond Mine Regional Preserve offers no lodging but plenty of parking for hikers. The parks system protects this place and there are plenty of trails that are marked with signs. The park is easy to get to and the level of difficulty in hiking includes all levels.

Geosite: Pigeon Point

Pigeon Point is the site of a lighthouse built in 1872. It is still active, though it has been updated. Currently, it is in need of structural repair, since some of the upper cornice has come loose and fallen. Although it is still in working condition it is closed to the public. One is welcome to stroll the grounds and there is a hostel for those who are looking for lodging.

The lighthouse and hostel are two attractions at Pigeon Point. There is parking and lodging and there are trails, although it is unclear if there is beach access. There are tours of the grounds during the week. The local community consists of nearby seaside towns that support tourism. Signage concerning the lighthouse and other historical events is present. Pigeon Point is easily accessed if one is driving Highway 1 which is the coast highway. The trails are easy unless a beach access is chosen. In that case, one would have to descend the marine terrace that the lighthouse and hostel are sitting on. Park service may not monitor that trail, so at times it may be treacherous and care must be taken. This is a California State Historical Park. Facilities are available. The coordinates to Wilder Ranch Trailheads are N36, 57.607; W122 El, 67

Geosite: Ano Nuevo

Ano Nuevo is a Natural Preserve and a popular place to view elephant seals year round. The pups are born from December to February. Seals shed their fur during the spring and summer. This is another seaside beach that is supported by the California State Parks service. This beach is open year-round, except during the arrival of pregnant females from December 1 to December 14. The towns of the area cater to the seaside activities. Walks and tours are always available. Camping and lodges are always nearby. Parking is very good. Handicapped access is present. The beach is easily accessed from Highway 1. The walks are only difficult through the loose dry sand. A web page gives more information (Appendix C).

Geosite: San Juan Baptista

San Juan Baptista is a California Mission town. The mission itself rests upon a very large fault scarp. Fourth graders from all over northern California make field trips here every year. What they don't normally learn is the geologic history of this place. There are stairs leading down to the bottom of a fault scarp that looks out into row after row of planted crops. The scarp itself is very large and it is difficult to get a feel of the immensity of the vertical offset unless you are here. It is even hard to describe in pictures. The town's history contains (relatively) large earthquakes and immense damage was done in places that sit on unconsolidated sediments.

The town is now a historical site and caters to tourists so there is ample parking, lodging, facilities, restaurants, and handicapped access. There are walking trails, and some signage explaining major historical points. One webpage presents a walking tour and it is included in the appendix. This place is easily accessible with a low level of difficulty.

Geosite: Hollister-Dunne Park

The sleepy town of Hollister, California is set off the beaten path. Its claim to fame is that it is the Earthquake Capital of the World, but it shares this title with a couple of other small California towns, who also rest on a trace of the San Andreas Fault. The town rests on the Calaveras Fault, a splay off of the San Andreas. The fault runs north-south, and any streets that run east-west are susceptible to some offset, as is present at Dunne Park. Offset is present on retaining walls, curbs, fences, sidewalks, housing foundations, and any other linear feature that is around. This is a good place to walk around to spot offset, and driving in the area is also a good activity to spot larger geomorphic features such as shutter ridges and linear valleys.

This is a small town and not really a tourist spot so care and consideration to the homeowners is recommended. There is plenty of parking and if you are so inclined, there are motels in the area. There are no marked trails or signage, pointing to anything geologic. You have to depend on your own discerning eye and research in advance of the visit. The town itself is easily accessible and the level of difficulty is easy. A webpage can be found in Appendix C.

Geosite: Pinnacles National Park

A trailhead to Condor Gulch and High Peaks begins near the Bear Gulch Visitor's Center. The trail leads to some caves made of tumbled boulders. The Pinnacles National Park sits on part of the Neenach Formation, which is located in Bakersfield, California.

There was a volcano that lay directly on the San Andreas Fault. Half the volcano is now here at Pinnacles State Park, while the other half is located 200 miles (321 km) south of here in Bakersfield. Seismic features make up a large part of the Pinnacles story, having moved half of a volcanic neck 200 mile (321.87 km) along the San Andreas trace, leaving the other half of the volcanic neck somewhere near Bakersfield California. Large boulders have fallen into a slot canyon, creating large caves which are home to that population. Igneous structures include the volcanic neck.

There's camping at Pinnacles and plenty of parking. While the community supports this park it is very isolated and off the beaten path. There are several well marked trails with handicapped access and good signage. Because of the park's isolation the ease of access is difficult. The level of difficulty is moderate.

Geosite: Sea Cliff State Beach

Day Use passes can be used for any State Beach on the day you bought it. Fossils can be found in the cliff, which is composed of interbedded muds/sands. There is a concrete ship, the SS Palo Alto, which sits on the beach at shoreline. The beach is depositional but the cliffs are eroding. The fossils are present in the cliff walls but collecting is not encouraged.

There are plenty of motels in the area, but camping at this beach is limited to trailers. There is plenty of parking but competition is fierce and it is not uncommon to park a few blocks away in order to use the beach. The community is supportive of the beach and there are trails, disabled access, and lots of signage. This beach is easy to get to and easy to use because the surrounding area is level.

Geosite: New Brighton Beach

When visiting just about any of the State Parks or Beaches, one can expect that the first website to come up will the California State Parks website. As was the case of Castle Crags, so it is with New Brighton State Beach, and it was the first site to come up. When calling the state beach's phone number, the information is always the same. Park information including various addresses and phone numbers, directions, and weather. But this situation is different than the one for Castle Crags. It is a very popular beach.

There are tide pools. It must be accessed at low tide to be able to get to a good cliff where fossils is present. Geotourists can come and admire the tide pools. At New Brighton Beach there are cliffs overlooking the ocean. Engineering features are present to dewater the cliffs, prolonging the lives of the houses (and the people who live in them). Fossils can be found in the cliff walls. There is no collecting.

The camping at New Brighton Beach is highly sought after. There are hotels nearby. There are very large parking lots and the beach is run by the parks system. Trails are maintained and there is disabled access, with lots of signage concerning park rules, facilities, and trails. While driving to this beach is fairly easy, it is difficult to get to the actual beach because you have to descend a very steep marine terrace.

CHAPTER V

RESULTS

After site visits and data collection, data were analyzed in order to determine the education effectiveness of the investigated geosites in northern California. The data consist of geosites ranging from the California-Oregon border, to an imaginary line drawn across the state at the latitude of Sequoia-Kings Canyon and Death Valley, on the eastern side of the Sierra Nevada Mountain Range. The geosites were chosen for geologic interest to geotourists and for their ability to support and enhance the Big Ideas of the Earth Science Initiative (ESLI, 2009). This chapter discusses how the Big Ideas are addressed at various geosites.

Because the data set is so large, the choice was made to focus on a subset of the most interesting sites, as determined by the researcher. For these geosites, the geomorphic feature or process, such as volcanoes or mining, will form the category. The Big Ideas easily accessed at the site will be identified and discussed with specific examples. However, the sites will undoubtedly have many more applications than those discussed.   Geosite analysis includes the discussion of how public literacy can be supported by the Big Ideas of the Earth Science Literacy Initiative (ESLI, 2009). Finally, the California geosites will be compared to the Oregon Paleo Lands Institute.

Signage is the main way that the effectiveness that Earth Science education can be assessed. Not all sites carried signage, and not all sites that had signage had good signage.

The signage that was available for the topic of geology was assessed and the sites were included in Table 3. The number of geosites is difficult to assess, since more than one site was included in one overall geosite, georegion, or park. For example, Lava Beds National Park has more than 20 stops that were made to assess the signage. The number of geosites visited were roughly over 59, and it should be remembered that many sites combine more than one site.

Table 5.1 Geologic Signage with scores

	Plutos Caves	Brewer Crk	Petroglyph Point	Lava Beds N.P.	Medicine Lake Highlands	Castle Crags
Big Idea 1. Earth scientists use repeatable observations						
Big Idea 2. Earth is 4.6 billion years old.						X
Big Idea 3. Earth is a complex system of interacting rock, water, air, and life.						
Big Idea 4. Earth is continuously changing.	X	X		XXXXXXX XXXX	X	X
Big Idea 5. Earth is the water planet.				XXXXXXX XX		
Big Idea 6. Life evolves on a dynamic Earth and continuously modifies Earth.			X	X		
Big Idea 7. Humans depend on Earth for resources.			X	X		
Big Idea 8. Natural hazards pose risks to humans.						
Big Idea 9. Humans significantly alter the Earth.						
Geology Signage?	1	1	1	12	1	1
Good, Fair, Poor Signage scores	Good	Fair	Fair	Good	Good	Good

Table 5.1 (Continued)

Jackson	Columbia	Panum Crater	Hot Creek	Tree Kill Area	Earthquake Crack	Mono Lake	Bodie	Basin and Range	Death Valley
				X		XXX			
							X		
						X	X	XX	
		X	XX		X				
		X					X		
						XXX			
						X	XX		
		X	XX		XX				
1	1	1	2	1	1	13	1	1	2
Poor	Poor	Good	Good	Poor	Good	Good	Poor	Fair	Good

Table 5.1 (Continued)

Sequoia-Kings Cyn N.P.	Column of Giants	(Table Mountain) Tuolumne River	Empire Mine	Humbug Mine	Goodyears Bar	Malakoff Diggins	Northern Mines	Kennedy
	X							
	X							
		XX		X	X	X	XXXXXX	XX
							X	
								X
	1	2	1	1	1	1	9	2
	Poor	Fair	Poor	Poor	Poor	Fair	Good	Fair

Table 5.1 (Continued)

San Mateo Coastline	Pt. Reyes	Crescent City	Patricks Pt	Old Faithful Geyser	Petrified Forest	Yosemite	Lake Tahoe	
X			XX					
	XX	X		X		X	X	
					XXXXXXXX XXXX			
X	X	X						
1	8	1	3	2	8	6	1	2
Poor	Good	Fair	Good	Good	Good to Poor	Good	Good	Good

Analysis of Signage by Criteria

A criterion for assessing the signage was devised by ranking the signage as 'good', 'fair', and 'poor'. A 'good' score was given to signage that explicitly addressed the big ideas, and gave information that was descriptive and quantitative (Figure 5.1). A sign was scored as 'fair' if it addressed the big idea, but did not give much descriptive information (Figure 5.2). A sign that did not mention a big idea or provide a description but was still geologic in subject scored 'poor' (Figure 5.3).

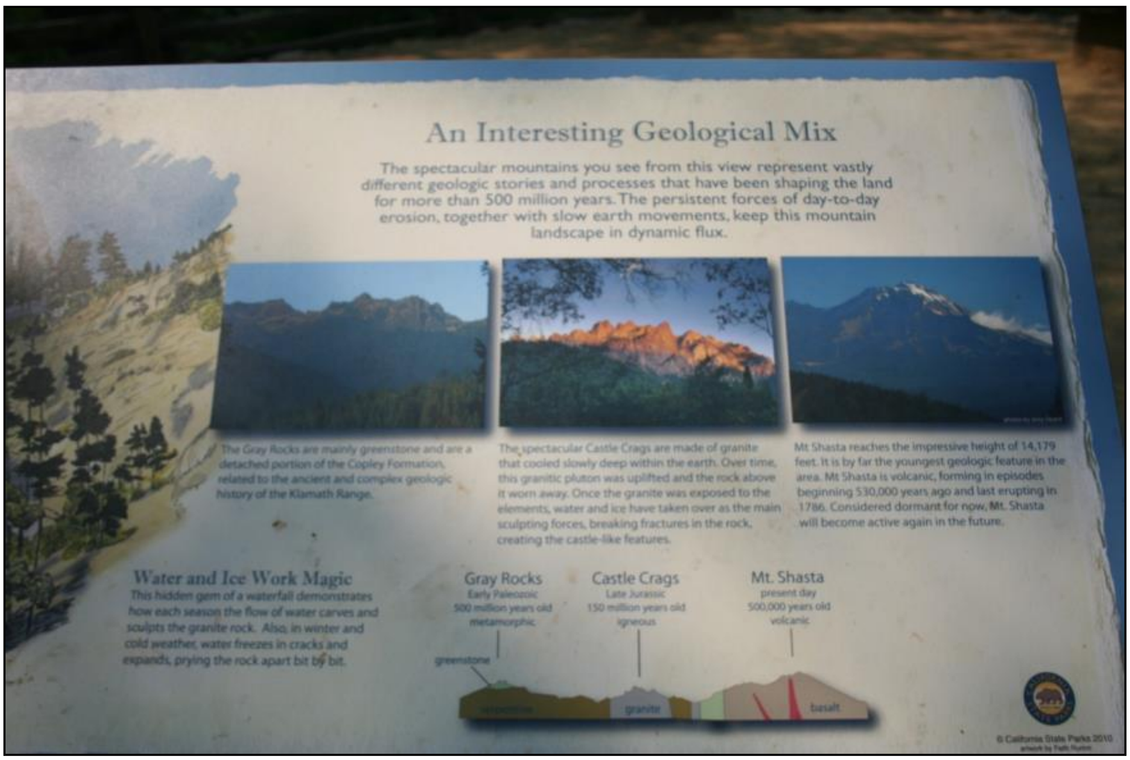

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Figure 5.1 An example of "Good" criteria due to its explanation of the processes and addressing the Big Ideas.

Photography by Kimberlie Theis

Figure 5.2 This photo is an example of a "fair" score because it addresses the geology but does not give much in the way of explanation of processes.

Photography by Kimberlie Theis.

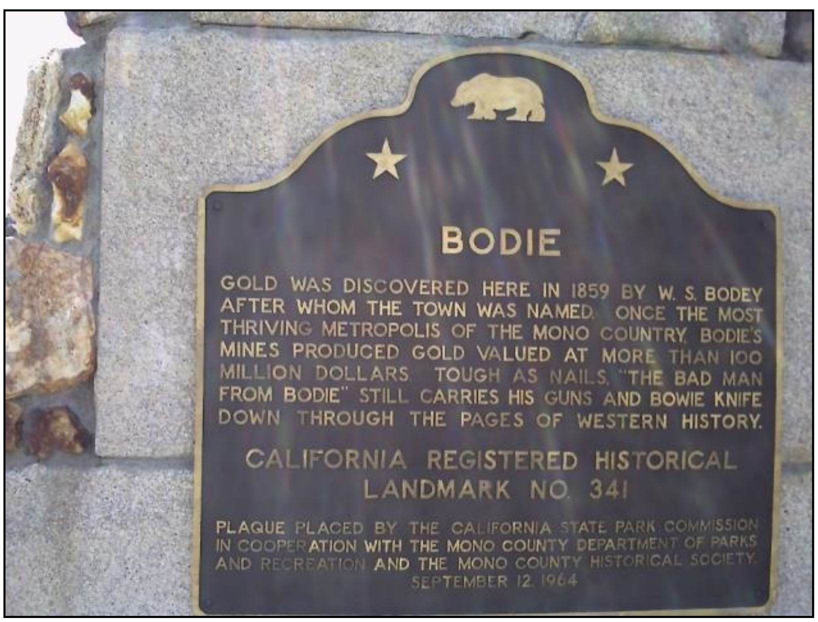

Figure 5.3 This photo mentions gold and so in included in the geology signage. But the lack of discussion of any processes give it a score of "Poor".

Signage Discussion

For the Castle Crags signage, there is only one, but it is a good one, and is shown as the example for "good" in the criteria examples shown above. Medicine Lake Highlands also has only one sign, and it too is a good one. But this area could support more, as could Castle Crags. Lava Beds National Park has several signs and many of them meet the criteria of good, but not all. There is a higher density of signage at this park due to its status as a federal park. Some of these signs meet all of the criteria of being able to address the Big Ideas and to discuss processes that are occurring. At Petroglyph Point, there is only one sign, and it states that the pictures were carved into ash but does not go on to talk about any of the processes. Brewer Creek has a sign that talks about glacial activity but the amount of the information is very light. At Pluto's caves, there is not much signage concerning the geology, but there is one sign, produced by the federal department of the parks, and it discusses cave formation and its relation to Mt. Shasta. This sign is a good sign. Death Valley, another federal park, also has signs. Not a lot, but the ones that are there explain processes. The Basin and Range is explained in some of the Long Valley Caldera signage and at Mono lake. At Mono Lake, there is a lot of signage concerning the geology, along with the signage of the plants and animals. There were several signs that explained various processes such us petrified springs There was some Basin and Range discussion but it was not in-depth. At Bodie, the commentary focused on the metropolis and the Badmen of Bodie. This sign was the example of a "poor" sign, since it did not explain any process. The reason it was included in the geology signage was because it did mention Gold. Mostly, the commentary focused on human interaction. At the Earthquake Crack, there is a sign that explains that the crack is really a fissure. This sign was scored as "good". At the nearby 'tree-kill' area, the signage was poor. There was only a sign warning people to be very careful, and in essence, scaring them away. That is an appropriate sign, but the cause of the difficulty is geologic in nature and a sign could have explained that. At Hot Creek, there is also ample danger due to scalding waters. Besides a graphic showing the position of the magma body and the springs, there is other signage explaining the situation. Panum crater has a very good sign showing the creation of the volcano. But Columbia, where much gold mining was done, there is practically no signage showing the geology. At Jackson Mine (Argonaut Mine), there is a map showing the implements and situation of nearby mines, and this sign is done by hand, by someone with interests in the mines. There is a kiosk showing hand drawn pictures of the Kennedy-Argonaut situation. The Kennedy signs are descriptive in their text. At the northern mines, such as North Star, there is a beautiful museum that houses artifacts from the gold rush era, and which has several signs explaining many different geologic processes. Malakoff Diggins is a northern mine that was very famous, and that has federal money funneled into it. For all of that, the Malakoff sign is an example of "fair" signage, due to its mention of geology, and brief discussion of a giant monitor. At Goodyear's Bar, there was not much to the sign, in fact there were more questions than answers, but the imagination led to learning. At Humbug mine, the sign is a plaque placed there by the Clampers. The Empire mine did not have too many signs either, and it was mostly historical. The Tuolumne River did not have any signage except for at the Column of the Giants, where it had several beautiful signs about water as a resource. It also talked about the volcanic eruption that allowed lava to fill the river and displaced all of the water, and creating Table Mountain.

Geomorphic Features and the Big Ideas of the Earth Science Literacy Initiative

Volcanic Landscapes of Northern California

Volcanic landscapes hold a wide variety of processes that can be taught to geotourists. Volcanoes not only go through an eruptive sequence, but they also have associated processes that are separate from eruptions. These processes include lahars, mudflows, and debris flows, and are oftentimes caused by separate and varied forces. Hydrothermal features can release sulfuric gases and geothermal process can drive turbines to produce electricity. Volcanoes have different shapes, eruptive patterns, rock products, and levels of hazard. Some collect large amounts of precipitation.

Therefore, the Big Ideas that can best be taught at one of these landscapes may differ due to the individual characteristics of the volcanoes themselves. Most volcanoes eject matter into the atmosphere in the form of ash and ejecta, causing the interacting of the geosphere and the atmosphere, and these events can be very significant, such as the Long Valley Caldera eruption, 700,000 years ago, that placed ash as far away as Kansas (Bailey, et al, 1989). This ash would have consequences for climate, if only at the local level. More probably it would yield more important hazards. This eruption most definitely altered ecosystems, by killing plant matter, if not the creatures in the ecosystems. This is all part of the third Big Idea, which states that "Earth is a complex system of interacting rock, water, air, and life (Wysession, 2012).

The fourth Big Idea states the Earth is constantly changing. Volcanic landscapes easily support this concept. Volcanic landscapes are often mountainous, such as a stratovolcano, but cinder cones, shield volcanos, or fissure flows are often smaller, rounder, or even flat, and their eruptions are characteristically different from the others, depending on the type of volcano. They can cause widespread changes to geosphere, biosphere, and atmosphere, and each is different from the others, and even different from its own historical eruptions.

Volcanoes easily demonstrate the seventh Big Idea which says the Earth provides resources that humans depend on. Building materials such as volcanic rocks, household goods like pumice, hot springs for recreation, and steam from the heat of underground magmas provide materials and technologies that are becoming more and more important. They can even hold freshwater in aquifers for later use such as at the Modoc Plateau (Ferriz, 2002).

Volcanoes are well known for the natural hazards that can suddenly rip away a bridge, a mountain, or cover a town, which is Big Idea eight. In fact, volcanic hazards are common in volcanic landscapes. Mt Shasta hosts a very large, long debris flow that covered all the land north of the mountain. Sudden summer showers can melt glacial ice on Mt. Shasta, which sends a slurry of mud and rocks down creeks and ravines, where at the bottom, late towns, like Shasta City.

There are various geostops in the vicinity of Mt. Shasta. Most stops do not have signage explaining the landscape. Brewer trail is one site that has some minor signage which explains important information about glaciers, but there are no pamphlets and the information is brief. This site and many others in the area would greatly benefit from new attempts to informally educate the public and improve general geoliteracy. Pamphlets, booklets, and signs could all be effective means by which informal education is achieved. In addition, this may result in new economic opportunities through the area if geotourism is adopted by the community. National Parks like Lassen and Lava Tubes have signage and pamphlets. Some of the signs do teach about the geology. For example, signage at Lassen teaches about the hot rock that was carried away in a slurry of mud. Another at Lassen teaches about glacial polish, and another teaches about noxious gases from the volcano. At Lava Beds, a sign teaches about Mammoth Crater being the source of all of the lavas in the park. None were found to explicitly support the Big Ideas of the ESLI while learning about volcanoes, though.

An important lesson that can be taught to students coming to this landscape has to do with the interaction of spheres. An appropriate lesson might list each sphere's characteristics and domain's. Then, a listing of volcanic processes could be created, followed by a short attempt at identification of where spheres interact, and which ones would be affected for each volcanic process. The use of a graphic organizer would be helpful at this point, as one volcanic process may affect more than one sphere. A thorough discussion of the effects and implications would be important. In this way, Big Idea number three could be taught.

Seismic Landscapes of Northern California

One may not think of seismic landscapes as places for geotourist opportunities. Indeed, there are several places that are able to use their seismic characteristics educate the public. In California, the major fault is the San Andreas right-lateral strike slip fault.

The San Andreas Fault can use the first Big Idea to teach geotourists about earthquakes and seismic landscapes. The use of charts, statistics, prior study, and data already collected are all tools that are used in the first Big Idea and which can be used to propose or teach a multitude of lessons starting at how to triangulate the epicenter and to determine the types of waves produced.

Big Idea eight deals with natural hazards. Earthquakes are natural hazards and these occur along the San Andreas Fault, which runs through Pt. Reyes National Seashore. Pt. Reyes National Seashore has an earthquake walk that teaches about earthquakes and shows the offset in a fence line. The geotourist can walk up the steps to investigate. The signage points out the offset or most geotourists might not ever notice. But after reading the sign, it is easy to pick out the fence and the offset. Pt. Reyes can also support teaching of Plate Tectonics (Big idea two), and actually has several signs that attempt to explain the theory to children and adults.

Pinnacles National Monument contains the rocks of half a volcano, the other half having been left behind in Bakersfield, 200 miles (322 km) to the south. Both of these parks attempt in their own way the teaching about seismic landscapes. Pinnacles has signage but it is very minor (at least on the west side) and does not attempt the Big Ideas. The nearby town of Hollister has no signage at all, but is famous in the geologic community for its many examples of offset. There are offset sidewalks, concrete walls, fences, and houses that show damage. It is a rather famous segment of the San Andreas Fault, known for its 'fault creep'. To the researcher's knowledge, none of nearby Pinnacles National Park's signage or visitor's centers mention fault creep. The signage that Pinnacles has is in the form of a small signs, mostly pointing out trails, and stating the length to the next trailhead. There is a small visitor's center on the west side of the park. The east side of the park has been renovated and reportedly has quality signage and presentations, but was not known at the time, so was not visited. The town of Hollister does not have any signage nor any way to teach about the apparent fault creep that takes place there. Since the half volcano at Pinnacles arrived at its current placement through the vehicle of fault creep, it is very surprising there isn't more information on it. This is a missed opportunity that would be fixed should the Big Ideas be adopted as a format for signage and other ways to relay important information.

The fourth Big Idea, which says the earth is always changing, is illustrated with the movement of fault creep, in the Hollister and Pinnacles examples. The movement may be slow, or it may be quite noticeable. Surely, after seeing the streets of Hollister, the change is apparent.

The eighth Big Idea, that natural hazards pose risks to humans, can be demonstrated by teaching geotourists about building construction laws, slope failure, and shaking. The Alquist Priolo Act is legislation that is meant to protect the public from building on lands that have a high risk for being damaged in an earthquake of a given size. A persistent example of slope failure is Devil's Slide on the ocean side of the San Francisco Peninsula.

San Andreas Lake is a long linear lake, just above another linear lake, Crystal Lake. These lakes are reservoirs of drinking water for the area. No construction is allowed near here because these lakes lie on the trace of the San Andreas Fault. It would be dangerous to build here. These reservoirs are run by water companies. They have running paths to walk and run along. Some people come to bird watch. These places have no signage indicating the presence of the fault and have missed an opportunity to teach geotourists about geoscience.

Pt Reyes, Pinnacles, Hollister, and Crystal Springs all have their websites that attempt to disseminate more information. Crystal Springs and San Andreas Lake websites talk about the water that is stored there and not much else. They are regional parks and point readers to view the tree varieties, with no mention of geology. Pinnacles National Park website also avoids the topic of the fault, but does admit it is there and the source of the volcano's movement. No other details are given regarding earthquakes. It seems odd that Hollister, the un-park, should have the most websites, with mention of the fault, the action of fault creep, and the fact that it is the Calaveras Fault, a segment of the San Andreas that the town is sitting on. Finally, Pt. Reyes admits in signage the existence of the fault, and on its webpage, contains one paragraph about it. All of these facts lead to the question of "Why don't they talk about the fault?"

A lesson for this landscape could start by identifying a Big Idea, such as number one, to teach about. Faults have different types of movement. Normal faults are associated with extension, reverse faults are associated with compression, and strike slip faults have transverse motion. An oblique fault combines compression and transverse. Teachers often have to carry teaching materials to each geosite. For this one, compare the rate of movement at different segments of the fault using real data that would be brought along. Learn that different places along faults move at different rates. This also sets up the idea that when enough stress builds up, the 'big one' will occur.

Fossil Landscapes of Northern California

In Northern California, fossil landscapes exist in hidden and lesser known locales. One of these is the Panoche Hills of Fresno County, in the Moreno Shale of the Diablo range. The area contains fossils of the Cretaceous, and also of the Oligocene and Miocene (Bureau of Land Management, 2010). The Fossil Discovery Center of Madera County opened when a landfill at Fairmead, California began uncovering diverse and plentiful megafossils of the Middle Pleistocene. In the Kettleman Hills, King's County, Plioceneage freshwater and marine fossils of California's coastal areas contain Neogene and Cretaceous rocks which often contain fossils (marine). Del Puerto Canyon, in Stanislaus County contains the Moreno Shale and has yielded a mosasaur among its best fossils. Mt. Diablo in Contra Costa County yields fossils from the Jurassic to the late Miocene from a variety of environments. The Petrified Forest, west of Calistoga in Napa County, is home to trees that were preserved when ash from a nearby erupting volcano fell from the sky.

The Big Ideas that these fossils can address include the second Big Idea which states that Earth is 4.6 billion years old. This Big Idea fits because Earth history is recorded and arranged according to the fossil record. Stratigraphy is based on fossils, which can be used to age date the rocks in time and space.

The third Big Idea concerns interacting of spheres, and can be taught because we find the biosphere represented in the geosphere. Fossils are often composed of calcium carbonate ($CaCO_3$), a main constituent in marine and other rocks. Finally, the sixth Big Idea says that life evolves on a dynamic Earth and constantly modifies Earth. We are able to see the different environments and ages of rocks and these often have very different fossils. It's easy to see how very different life is today, when compared to the fossils of millions of years ago. The presence of algae or any plant fossils, reminds us that our atmosphere was not always oxygenated, and that living organisms played a major role in creating an atmosphere that would sustain life.

At the Fossil Discovery Center, there is excellent teaching of the kinds of creatures found there, that include a multitude of activities, videos, and handouts, all supporting learning. Young children enjoy the Mock Dig activity. There is a paleontologist who works at preservation of the fossils and artifacts behind a windowed room. The website has several videos showing how these creatures may have lived. Their website gives information about the age of the rocks, the environment that was present, and talks about the different fossils found. Some of the information is very detailed. At the Petrified Forest, there is signage that explains how the trees came to be preserved but mostly, the explanation is done through an online pamphlet and a self-guided tour pamphlet.

At each of the other sites, signage is missing, pamphlets do not exist, and the locales are only able to be found by with luck and knowledge. There are websites that support learning at the Panoche Hills and Kettlemen Hills. The Bureau of Land Management provides a website for the Panoche Hills. The information on the page gives details about the environment at the time of fossilization, and the different types of fossils found. At Kettleman Hills, the website does the same but focuses mainly on what types of fossils were found there, giving photos of each. They indicate the Kettleman Hills site is no longer open to the public.

A lesson involving fossils could teach about Big Idea number six. Questions should be posed that could be answered by looking around or by reading signage. What were the conditions during the Pleistocene? What were the local temperatures? How much solar radiation reached the planet? Was in direct or indirect? What were the conditions that brought the Ice Age to bear? Because of these conditions, life was forced to conform to cold and dry. what kind of adaptations would these conditions best support? What types of life would not do well? How long was the Pleistocene? What was the life like on Earth as the Pleistocene progressed? What kinds of life were prevalent? Around the world? Here? How do we know? Some of the questions will go unanswered but it is important to ask them anyway. In this way, curiosity may be fostered.

Coastal Landscapes in Northern California

Each of the coastal geosites in this study has diverse characteristics associated with it. Marin Headlands has striking folds in bedded cherts, which contain radiolarians. At the beach level, there is an outcrop of pillow lavas. This beach site illustrates fossil life (Big Idea six), plus those concepts that teach about Plate Tectonics (Big Idea two). Big Idea three and four may be accessed because it is so apparent here at the headlands that the atmosphere, the water, the land, and Earth's creatures all comingle. This environment offers the chance to ask "How do they comingle?" Other Big Ideas that teach about processes occurring along the coast are five, six, eight, and nine. These Big Ideas state that Earth is a water planet, life evolved on Earth, natural hazards exist at these places, and humans alter the Earth. It is not hard to see these things when we think about the fact of the world's oceans, the radiolarians in the rocks have evolved and changed, natural hazards of slope failure which is constant along the beach, and the Golden Gate Bridge, sitting boldly to the south.

Patrick's Point has beautiful sea stacks of every size and stage of erosion, including those that are far inland. Typical coastal processes of wave and currents occur. The really important Big Ideas here teach about constant change (Big Idea four), interacting spheres (Big Idea three), the water planet (Big Idea five), and natural hazards (Big Idea eight). The signage at Patrick's Point briefly talks about the Miwok Indians who used the place, but there was no mention of the sea stacks. The sea stacks are a prominent feature and are very hard to ignore. This researcher found no signage that suggested the presence of the Big Ideas. The park's webpage talks about harbor seals and the primitive peoples, and mentions the sea stacks, but only briefly. The state park system may deal with the geology of the parks in their interpretive programs. There was no other evidence of them.

Crescent City, along the northern California coast, is rather famous for the damaging tsunamis that tend to inundate the harbor and low lying areas. The eighth Big Idea, which talks about natural hazards, is the main geotourist topic here, although others could be mentioned. Fitzgerald Marine Reserve can illustrate the teaching of the first Big Idea, and also the second, which concerns the topic of plate tectonics (the presumed possible cause of the tsunami, and Big Idea two); It can also support the interaction of spheres (Big Idea three), the idea of constant change (Big Idea three) and the fact that the earth is a water planet (Big Idea five).

Pt. Lobos is another beach where folded rocks in various juxtaposition placements can serve to teach about plate tectonics and Big Idea number two. Sea Cliff and New Brighton beaches teach about coastal processes (Big Idea four), natural hazards (Big Idea eight), and how humans can alter the landscape (Big Idea nine). Point Lobos can teach about Plate Tectonics since there are folded rocks. A sign showing tectonic processes would be a good beginning. Sea Cliff and New Brighton easily teach about cliff instability. Since this is also a safety issue, the two topics could and should be addressed together, accessing Big Ideas eight and nine.

Crescent City Harbor has a large sign that shows before and after pictures of the tsunami caused by the Good Friday Earthquake at Anchorage, Alaska in 1964. The quality of the signage is good. They show before, during, and after photographs. More pamphlets would be appropriate because the billboard is the only signage in the area, and most people want to take something away. If the pamphlets were not detailed or well written, due to the inclination to discard pamphlets, they might be thrown away.

Seacliff and New Brighton beaches are also state beaches but neither of these have effective signage or pamphlets to teach any of the Big Ideas. Moss Beach (the town) and Fitzgerald Marine Reserve have pamphlets that are issued at the visitor's kiosk. One of the pamphlets is a self-guided tour of the tide pools. Signage could be added for better effect. The visitors may notice the very large fold in the rocks beneath their feet. If signage was there, it could answer some of their questions.

Finally, Marine Headlands does not remark in any fashion about its resources (the folded rocks of the radiolarian chert and the pillow basalts). Both signage and pamphlets could be used to excellent effect to educate geotourists on Earth Science Literacy. Because radiolaria are fossils, Big Idea six is supported. Folds and bedded chert make the ability of Plate Tectonics to be taught. But pillow basalts belong in the Big Idea two category, as they suggest the forming and tearing away of oceanic lithosphere. The questions of how the rocks were folded, where the radiolarians came from, what they are, what the pillow basalts are, and what do the rocks mean, could be answered in signage containing some of the Big Ideas.

A suitable lesson for coastal areas might be about Big Idea four, and constant change. The tides and sea level are never at rest. The shoreline and even the life present are always changing. The object for a lesson here could be to collect data about each of these at different times of day, month, and year. A year-long study could show how a class wide study with their date support this concept. Students would need to design the study, choose, dates, and decide how to present data.

Rivers, Lakes, and Ground Water in Northern California

This category is underrepresented with regards to geosites. The Merced and Tuolumne rivers both have headwaters in the High Sierras of Yosemite National Park. The Stanislaus River has headwaters near the Dardanelles volcanoes (extinct) above Sonora on Highway 108. The three rivers as geosites display unique characteristics for the geotourist. The rivers of Northern California teach several of the Big Ideas, and have their specific characteristics and history.

Table Mountain, an inverted stream, is part of the earlier Stanislaus River. Here, the river demonstrates the interacting of spheres (Big Idea three) when lava (lithosphere) from the Dardanelles filled and displaced the water in the river (hydrosphere). Also important to note are the natural resources (Big Idea nine) sought by miners (biosphere), eager to get at the gold (lithosphere) that lay beneath the flow. They died while trying to get to it. In addition to natural resources, this geosite can teach about natural hazards (Big Idea eight), especially slope failure, since this is the reason many miners died. The mining technique called "coyoteing," where they tried to tunnel beneath the flow to get at the gravels, resulted in slope failure. Other Big Ideas that can be addressed here include that rivers can and do change (Big Idea four). In the Sierra Nevada Foothills, reservoirs have been added for flood control and recreation, such as Don Pedro in the foothills near Modesto, CA. Earth is a water planet (Big Idea five), and the rivers and reservoirs are examples of this. Lessons could be created studying the length and slope of the river, its uses. Finally, rivers can also be used to record and study the uplift of the Sierras (Big

Idea one). Researchers use Pleistocene aged units and measure the tilt, and from this they obtain the rate of uplift. These ideas and many like them would help the general public to think about the geology in their area, increasing their geoliteracy levels.

The rivers of the landscape may be illustrated with Big Ideas one, three, four, five, seven, eight, and nine. The Merced and Tuolumne rivers experienced severe flooding (Big Idea eight) in their histories. This is a significant opportunity to teach the eighth Big Idea. Signs have been placed at the Merced River inside of Yosemite Valley, just downstream from its headwaters that show how deep the water got during that storm. These signs are small, and strategically placed, and tend to be overlooked if there is not great interest. The rivers teach that Earth is a water planet (Big Idea five). The water is also considered an important resource (Big Idea seven). Rivers constantly erode their banks and levees (downstream), and their levels fall and rise (Big Idea four). Humans are dependent on them. Thus, we build dams to control their flow, and provide resources for drinking and recreation (Big Ideas eight and nine). Most rivers have dams along their courses (Big Idea nine- humans alter the landscape).

Column of the Giants on the Stanislaus River includes good examples of signage, explaining the history of the place and water use. There is a sign that supports the Big Ideas. It talks about the history of Donnell's Dam (present here), and how Oakdale and the San Joaquin Irrigation District used the terrain natural terrain to construct the dam (Big Ideas four, five, seven, and nine). The sign claims that everything people do affects something else. Nature, time, and human needs are what created the place and it will continue to do so. It says that water is precious and reminds us that we need to conserve and protect it. There is a good website that explains the geology. No pamphlets are available. At Table Mountain, there was no signage explaining the geologic history. There is a need for signage and pamphlets exploring the Big Ideas. The Merced River has signage in Yosemite National Park that illustrates flood levels. The other Big Ideas are missing all along the rivers we visited. This researcher expects to find similar results for all northern California rivers that weren't included in this investigation. All can be supported by the Big Ideas one and three. During flood season these calculations can become incredibly important. In the winter of 1997 to 1998, the dam at Don Pedro had to be supported by plywood across the top of the dam to keep the water from spilling into the river and creating bedlam downstream. That plywood was the only thing that kept the water where it was, saving hundreds of thousands of people from disaster downstream.

Two important lakes in California, and several reservoirs in the foothills, are noteworthy. Don Pedro reservoir outside of Oakdale, CA, recently revealed an old mining operation as water levels dropped in response to the severe drought in this part of the country. A common occurrence in the Mother Lode, towns were abandoned as the new reservoirs filled with water. History is being covered and uncovered. The events can serve to teach about Big Idea one. The capacity of the reservoir is calculated using a mathematical formula, and the research behind water storage is done by scientists using scientific principles. Big Idea three can be taught because large amounts of water are stored in reservoirs used by people, for flood control and recreation. Reservoirs are fed by snowmelt. All of this nicely illustrates the interaction of biosphere, hydrosphere, lithosphere, and atmosphere. Big Idea four can be taught, since the Earth is constantly changing as the availability of water during droughts floods is dramatically altered. Big Idea five states the Earth is a water planet; Big Idea seven states humans depend on Earth (and its water and minerals) for resources; Big Idea eight is addressed through droughts and floods, which are natural disasters; and finally Big Idea nine, which states that humans alter the earth, is clearly apparent, considering the construction of dams, mining operations, and towns. In all of the signage, I saw only state parks and the similar that contained signage. This signage, while interesting, for the most part, did not address the Big Ideas of the ESLI.

Clear Lake in Lake County, is California's largest lake that is completely within its borders. Lake Tahoe is larger and deeper, but its boundaries cross into the state of Nevada. Clear Lake is known for its recreation and its bi-annual algae growth. Most tourists are dismayed and do not understand it. Lake Tahoe is clear and blue and does not experience algae growth. What are the differences that make the two lakes so different? This could be a lesson, studying the two.

Big Idea one can be demonstrated as scientists try to answer questions about possible natural hazards at Lake Tahoe, or how to control the algal growth at Clear Lake. Big Idea three states spheres interact and Big Idea five refers to Earth being a water planet. The interaction of spheres is very important at Clear Lake, considering algae growth. The idea of a water planet is clear, especially as we humans consider out intimate relationship with it and how it affects our needs. The algae growth represents the biosphere at Clear Lake. Big Idea seven can be demonstrated at Clear Lake, which has fishing, mining, and farming interests. Clearlake has pear and grape agriculture. This is probably the source of nutrients to for the lake, but I suspect the problem is even more complex.

Lake Tahoe is considered a spectacular resource (Big Idea seven). The presence of glaciers during the Pleistocene gives Lake Tahoe some very important features, like moraines that dam water and create lakes. Big idea eight, which covers natural hazards warns about the presence of seiches, especially at Lake Tahoe. Each time there is an earthquake, the water in Lake Tahoe reacts. Sometimes it reacts by creating sloshing motions in the lake basin. Residents worry it will happen in this fault-bound basin.

There is good signage around Lake Tahoe (though it does not address the Big Ideas). The signage at Clear Lake is absent. The same is true for pamphlets. The newspaper constantly talks about groundwater issues. For example, where the researcher lives in the West, political parties make promises for water to farmers, who are dependent on water, while many people are being ticketed for being wasteful. Each group thinks it needs the water and has the right to it, yet the wells are growing dry and new well permits are being granted. This is a real-world application of Big Ideas three, four, five, seven, eight, and nine. There are many websites for Lake Tahoe, less so for Clear Lake. Lake Tahoe proves to be very interesting because of the tsunamis and seiches and there are several good websites that record them. Some of them talk about possible mega-tsunamis.

Groundwater has been ignored, which is unfortunate. The reason for this is because there are no geosites that specifically addressed this resource. The topic is still very important, especially with regard to natural hazards of drought (Big Idea seven), humans altering the landscape (Big Idea nine), and natural resources of drinking water and agriculture (Big Idea eight). These Big Ideas should be introduced whenever the opportunity arises. At none of the sites that the researcher visited were these topics addressed. Because droughts continue in the West, this topic is increasing in importance.

Lessons that could address the Big Ideas could center on the study of droughts, or the study of groundwater recharge, or even a specific groundwater system or aquifer. Big Idea seven says we need resources and water is a resource. The western states suffer from drought and need to find ways to save water. A simple water budget could be constructed showing input, output, and whatever remains. Identify a basin. Students would need to identify ways water is removed from a basin. Also, they need to figure out what inputs there are. Whatever is left is the balance of water. What is the population of the basin's community? Convert the rest of the water to gallons per person.

Mountain Landscapes in Northern California

There are many diverse geosites throughout California's mountains. These ranges result from plate tectonics movement. The mountain ranges include the Klamath Mountains, the Cascade Range, the Coast Range, Mt. Diablo, and the Sierra Nevadas. Specific geosites investigated include Castle Crags, Sequoia – Kings Canyon, the Column of the Giants, Columbia, Donner Pass, and Lake Tahoe Mountain.

The Big Ideas associated with various sites may or may not include Big Idea two, because they involve plate tectonics, which is why the mountain range is there. A suitable lesson is to explain how Plate Tectonics functions, and to use the Sierra Nevada Mountain Range as an example. The third Big Idea is important as the diversity of the mountains become known. The mountains, air, water, and creatures are all intricately connected and dependent on each other. A possible lesson for this is to ask HOW these are interconnected and dependent, using a specific place. Big Ideas four (constant change), five (water planet), seven (earth resources), eight (natural hazards), and nine (humans alter the earth) can all appropriately and in like fashion support learning at these landscapes.

Signage is good at Castle Crags, and Column of the Giants. The geology is explained at both of these, and water is included at the Column of the Giants, which is adjacent to the Stanislaus River. As such, both can support learning of Big Ideas. Column of the Giants can teach about water and plate tectonics, a changing earth, and interacting spheres, Big Ideas three, four, and five. Castle Crags teaches plate tectonics, interacting spheres, a changing earth, and natural disasters, Big Ideas three, four, five, and eight. Yet, like most other places, the signage is focused on just a few things, disregarding other learning opportunities. If these two places had signage that addressed the Big Ideas that are possible, there would be several more signs. The others do not host signage that demonstrates any Big Ideas nor do any provide pamphlets. Websites are very good for the Sierra Nevada Range, which hosts its own geotourist map. The map comes together with themes, such as archeologic sites, historic sites, points of interest, museums, and natural areas, to name a few. In order to find the geological sites, it is necessary to 'turn off' many of the possible search themes. After all possible 'clutter' is omitted from the geomap, there is still a high number of geologically based sites to choose to visit. The geomap cites many different opportunities to experience and learn about many different geoscience opportunities, and thus, tries to address the Big Ideas. Castle Crags has a good website illustrating its geologic history. Mt. Diablo has a very good website. There are many websites illustrating geologic histories of the Coast Range, the Sequoia – Kings Canyon National Park, Columbia State Park, Lake Tahoe, and Donner Pass. One sight on the Coast Range was written by a class of biology students. Teams got together and wrote overviews of each of the chapters. The reader gets five or six teams' viewpoints of the book's chapters, which contain geologic overviews. The book is one about California's biology. The National Park Service's website on Sequoia-King's Canyon has a geologic overview, a page on karst systems, and one on water resources in the park.

Teaching about the mountains easily begins with plate tectonics and the fourth Big Idea. The physical features of the plate boundaries as laid out in plate tectonic theory can be modeled using the topography and rock units of the area in question. The Sierra Nevada is a magmatic arc. The Great Valley is the forearc basin. The Coast Range is the accretionary wedge. Students can use the real plate boundaries of the North American plate to model plate tectonic theory. Identify all parts and create a physical model. Add as much detail as possible such as age of rocks, dates of emplacement, and show what happens in the process (scraping of sediments from down-going plate).

Desert Landscapes in Northern California

Many geostops fit into more than one landscape. In California, there is an abundance of volcanoes in the desert. It makes the geosites more diverse to the geotourist and to this study. Mono Lake fits the rivers and lakes category but is very different from the other lakes because it is a highly saline lake. It also precipitates calcium carbonate rock towers, called tufa towers. It is the nesting place for the California Gull, probably due to the plentiful food source of brine shrimp and brine fly. It has two volcanic features – Negit Island and Black Point.

Most of the Big Ideas are appropriate to teach at this site. For example, society's needs are easily illustrated. Big Idea one is easily illustrated when considering the Supreme Court findings at Mono Lake. The Supreme Court has logged a ruling that the water level may not fall below a certain level (Big Ideas three, four, and five). Many scientific studies have been done on this lake due to the California Gull, which feeds on the brine shrimp and brine flies. If the water level gets below a certain point, a natural land bridge is uncovered and leaves Negit Island, where the Gulls nest, open to predators (Big Ideas seven, eight, and nine). Signage is present that educates the geotourist to this environmental situation and the visitor's center carries more information that is in-depth.

Big Ideas one, three, and four are appropriately targeted here. The stratigraphy of the surrounding area provides age dating of the rocks and of the lake itself. Big Idea three illustrates all of the spheres because of the water and the life therein. Big Idea four says Earth undergoes constant change, and this place experiences change for every season. Big Idea five nine is supported by legislation in effect due to Los Angeles and Lee Vining fighting for water rights.

Other desert geosites are Bodie, the California State Park ghost town and old gold mining district. Highway 395 has diverse volcanic activity and is located in the Basin and Range province, or the desert. Hot Spring, Death Valley, Jackrabbit Mine, Panum Crater, Long Valley Caldera, Wineglass features, Alluvial Fans, The Bishop Tuff, and Convict Lake are all in the desert. Lava Beds in northernmost California is also in the Basin and Range. The Big Ideas that may be possible include big idea numbers one, two, three, four, five, six, seven, eight, and nine. Each site will have its own teaching opportunities. Not all will be appropriate but all should be considered.

Signage is good in Bodie, Mono Lake, Hot Springs, and Death Valley, which is to be expected because they are either state parks or federal parks. Some sites do not have signage and would greatly benefit from some, such as Jackrabbit Mine (epidote) on BLM land. Websites are common at many sites and some give good information about climate, the geology, and maps. In fact, in most cases, the webpages carry more information than the signs. The Mono Lake webpage is a good example. It carries tabs on science, education, protection, restoration, and more. The Big Ideas can be teased from these pages. For example, the fourth Big Idea states that Earth is a world of water, which is the main topic at Mono Lake. But many times, they lack in-depth discussion about geologic processes. Most of the time, webpages are concerned with historical accounts. Bodie's website from the California State Park system is a good example of this.

Big Idea eight is about natural hazards, which are a real issue in the desert. There is active volcanism at the East Side of the Sierras. Create a hypothetical situation where a volcanic eruption is imminent. There are different kinds of volcanoes and so, different kinds of hazards. What kinds of dangers are present? Who will be affected by each of the volcanic hazards? Students could create different situations based on the different volcanic type. Identify the different hazards and the level of hazard the processes create. What should happen to the people? Should they be evacuated? Why or why not? Do this for various volcanic types and other hazards.

Mining Landscapes in Northern California

All mining concerns are important in California. Not all mines visited in this study are included in the narrative. Some included are Malakoff Diggins, Good Year Bar, Columbia State Park, the North Star Mine, the Empire Mine, Black Diamond Mine, and the Jackrabbit Mine. Some sites are cared for by the State or Federal Government and have signage that is intended to engage the geotourist, though signs that address the Big Ideas are appropriate and a discussion with examples follows.

The seventh Big Idea, “Humans depend on Earth for resources” can be demonstrated at all mining geosites. Resources are generally renewable or nonrenewable, and usually distributed unevenly around Earth, often the focus of money, politics, and global society. Water has become a significantly important resource in the western United States, which is one reason why scientists speak in terms of groundwater “banks" (Ferriz, 2002). One more reason is because they work like banks, storing water for later use. Industry and life are dependent on these resources.

Big Idea number five could also be included when the topics of groundwater and other conservation issues arise.

Big Idea number nine, “Humans significantly alter the Earth”, is important when considering the ways humans use to get at resources. Various types of mining include open pit mining, which leave huge open scars on the land after removing mass quantities of rock, processing the rock, and then placing the rock elsewhere. Hard rock mining is the tunneling beneath the Earth’s surface to get at the resource. Explosives and large amounts of lumber are used to create and fortify tunnels. There are various types of surface mining, such as dredging. This type creates or takes a body of water and a dredge, and moves across a landscape, scooping up unconsolidated sediments, placing them on the dredge. The gravels are processed, and then dumped into a large pile of rounded cobbles, called dredge piles. Landscapes that have experienced this are then undesirable until the dredge piles are removed. These are just a few ways that mining alters the Earth. Hydraulic mining removes mountains and hillsides, and the sediment is deposited in the rivers and streams downstream. Arsenic, sulfuric acid, and cyanide are some of the toxic compounds used to separate the ore and are often found in surface water after mining stops. They are not usually removed and provide plenty of teaching opportunities throughout the Mother Lode region. Understandably, since bad press is never good, signage is not present at these areas. However, there could be safety signs. At the water pipe and air tunnel that drains the Josephine Mine, there is a small warning sign saying the water is toxic and not to drink it. Since the signage is not present, the Big Ideas are only possibilities.

If the geosite is part of a state park, there is usually signage about how the mine worked, although comments are limited in breadth and depth. Malakoff Diggins has many signs, but they usually contain brief statements, such as the occupants of a cabin, or the items in a schoolhouse. The sites will focus on one or two ideas and that is all. Signage is usually limited to one sign per topic. If the geosite is not part of a government entity's holdings, then no signage or pamphlets will usually exist. However, there is maybe historic information posted on websites that address these sites. But, this does not guarantee that the Big Idea's will be addressed. Interestingly, out of all of the signage that was photographed, the teaching of the Big Ideas was not usually an element. For example, many mine pamphlets and other signage, especially at the State Parks, such as Kennedy Mine, or Malakoff Diggins, or the Empire Mine, talked about numbers. These were in terms of how much gold was taken out, or how many dollars it translated to. Or often, the signage and pamphlets and displays were focused on methods of mining. Some, like Columbia State Park, vividly describe what life was like during the Gold Rush. Columbia is a town that 'gets into character' and there are performances of miners being jailed for drinking too much. Unfortunately, almost none of it focused on any of the Big Ideas. A skilled educator could tease the Big Ideas from the geosite, which is often the case. For those without their resident teacher in tow, citizens are missing opportunities to develop the principals that create literacy.

Mining lessons concern Big Idea number seven. There are many different kinds of resources associated with different types of geologic situation. Once the type of resource is identified, the types of mining can be identified. Often there are associated minerals that are also resources. Students can research what types of mining that are associated with various types of ore. Next, they can find out about different accessory minerals. Create a table. Are the accessory minerals important? Can they be used or are they important in other ways?

Survey Data

While visiting the geosites, at least 10 of the sites were available for giving geotourists surveys to complete. These sites are Crystal Caves at Sequoia-Kings Canyon National Park, Pinnacles National Park, Lava Beds National Park, the Eastern Sierra region, San Andreas Lake, Pt. Lobos Wildlife Refuge, New Brighton beach, Marin Headlands, Pigeon Point, and Pt. Reyes National Seashore. The number of surveys given, Appendix C, totaled fifty seven, and these were surveyed for various information such as the effectiveness of signage, levels of education, topics learned about, ages of visitors, vacation habits, and frequency of visits. The totals to each question are listed in the Appendix C. Of the information that could be important to this study, it was found that signage, ages, topics of expected learning, frequency of visitation, and ways to choose trails are some of the most important things to be considered here. Signage can be totaled and percentages considered (Table 4). Most people found the information interesting and at an understandable level. But the signage effectiveness started declining when considering whether there were new topics, and information for children. Thirty-six percent think improvement in signage is needed and that is significant when you consider the lack of signage covering the big ideas (Table 3), which is 28 percent of all geologic signage.

Table 5.2 Survey on Signs

Signs (per cents)				
Found signs interesting	Found new information	Information was understandable	Information was appropriate for children	Improvement is needed
77.2	59.6	75.4	50.9	36.8

The surveys showed that most of the geotourists are composed of nearly equal groups of male to female, but ages seem to favor the twenty six to forty age range at about fifty percent. Most geotourists have some education with the highest ratio being thirty five percent college educated. But this must not be construed to mean they are already literate in Earth Science, unless that is what their degrees are in. However, forty seven percent of the surveys showed that Earth Science classes had been taken. Again, this does not mean one is literate, perhaps only that they preferred Earth Science as a required class. The surveys were split almost evenly between vacation time and leisure time as when they visit the geosites. Vacation time criteria was anything over five days, while leisure time was under five days. Almost thirty percent of geotourists visit some geosite every month or two. This could be significant in that it could be seen as a frequent opportunity to learn. Geotourists mostly get their destination information from the internet (forty three percent) and this number could be seen as important for making sure there is enough good information available for each geosite. If the websites for the geosite do not contain valid information, much harm could be done to literacy. Time spent researching is limited to less than a day (nearly sixty percent). This shows there won't be many opportunities to get the right information. Geotourists visit the state parks more than other national parks (seventy one percent). The most popular form of camping is by tent (thirty five percent). Forty percent of geotourists depend of ranger talks to get information, but seventy seven percent end up on the trails, pointing to the importance of signage. Fifty percent of the geotourists bring their camera, and it can be assumed that photos of signage are at least sometimes taken. The purpose of coming to the geosites are sixty five percent vacation but twelve percent end up at a geosite just by driving through. Most geotourist have expectations of learning something along the trail. Seventy seven of the surveys showed that they expected to learn about geology, sixty one percent expected to learn about plant life, thirty six wanted to learn about astronomy, and seventy five wanted to learn about animals. Twenty eight wanted to learn about meteorology. Of the geotourists surveyed, fourteen percent spent an hour taking time to learn about their finds at home. Twelve percent spent a whole day learning. Fifteen percent said they just collect and nothing else. When traveling to geosites, those accompanying the geotourist are twenty two percent children, fifty two percent friends, fifty percent spouses, and six percent said they come alone. When asked about choosing trails, fifty four percent depended on park brochures to help them choose. This could also be an important learning opportunity if Earth Science is a topic in the brochure. Fifty percent choose their trails based on level of difficulty, and fifty percent choose them based on scenery. Sixteen said wildlife was an important factor. Whether these are important for conveying the Big Ideas is up to the interpreters and their ability with signage. Finally, seventy eight percent of the geotourists survey stated they came to the sites intentionally. This would seem to be important when considering the marketing of information.

A Comparison with the Oregon Paleo Lands Institute

The Oregon Paleo Lands Institute (OPLI) is an organization that addresses the need for geotourism in central northern Oregon. Having undergone economic downturns, it is important for this area to find ways to revitalize its economy. Geotourism was seen as the answer. The community exists in several different places within the area near Wheeler County. The people here all helped to create a new opportunity for the region by putting in lodging, markets, and visitor's centers, and it seems to be working. Community involvement has been favorable. The visitor's center, called OPLI, was first built and opened on September 12, 2009. The center exists to enable the community and visitors to enjoy and explore the unique geotourism opportunities afforded here. OPLI has created a sophisticated program of classes, activities, and experiences that cater to a traveler's needs or to anyone who might want to learn about the area.

The economic downturn, turned upturn, is creating learning opportunities citizens. Oregon's geological past has become a source of learning, and economic gain, as geotourists sleep in motels and campgrounds, eat in restaurants, and shop at places of business.

Some of the classes for the public are Science Saturdays, where each weekend, new ideas focus on ways kids can interact with the science program. Classes are created that are geared to various diverse learning styles, such as combining Art with Nature. There are hiking programs, and photography is always a popular activity. OPLI provides a class that teaches both photography and about the landscape. Fossils are included in various fossil hunt activities.

Each of these geotourist activities can be used in California to illustrate the Big Ideas of the Earth Science Literacy Initiative (ESLI). The combination of sustainable geotourism, coupled with effective informal education that targets Earth Science Literacy can result in improved geoliteracy as well as increased tourism. OPLI has proven the geotourism idea is sound as seen through the upturn of their economy from 1998 to 2014. However, the researcher is not aware of any organizations that are ready and willing to fund a venture such as OPLI.

There are farms in many of the areas of Northern California, especially in the Klamath Province and other "farming economies" that are in financial need from geological events such as water shortages. There are many areas in the region that would greatly benefit from a solution like this. California compares favorably to Oregon in the number of geosites. California is also quite diverse in the array of geosites. While not all sites in California can teach about every Big Idea, there are many which can teach about a fair amount of them, as already shown. Thus, California has a very large opportunity to engage the public in terms of Earth Science literacy, and in terms of creating and developing economies that focus upon geotourism.

Summary

Northern California contains numerous and diverse landscapes and places which can be termed “geosites” or “georegions”. In this study, numerous sites were visited but 59 geosites are being considered for discussion. Not all were discussed in detail because of the large number. Yet, these were only a fraction of geosite opportunities that exist.

Many of these geosites can teach geotourists about Earth Science. The Big Ideas of the Earth Science Literacy Initiative are what geoscientists and community partners have concluded are the principles that each citizen should know about Earth Science to be “literate at a base level in the field of Earth Science” (ESLI, 2009, p. Citizens should understand these principles so that they can make educated decisions about questions involving the Earth, money, politics, and global society.

In all of the geosites, the search was for signage and pamphlets. At home, the search was for information for the geosite on the World Wide Web. The results of the search for signage were that most of the parks that were supported by federal or state governments had signage. In fact, these were usually the geosites that were able to have "good" signage. If the site was not funded by them, the chances for signage or pamphlets diminished greatly. This was not true for posting of information about the place on the Web. The next thing investigated was if the signage supported the Big Ideas. Unfortunately, signage was often about trail distances, natural history, including animals and plant, but the geologic processes that were apparent were often ignored. Sometimes processes were mentioned in the signage and pamphlets. Twenty eight percent of the geosites with geologic signage, had "good" signage, but these were usually because of federal or state money. Sometimes the signage spoke about the geologic resource that was present giving specific information about the item, but not the process by which it came to be. Occasionally, the signs would support a Big Idea. Less often, the signs would cover more than one Big Idea. No doubt, the reason for this was cost. The proprietor needs to have signage with as much information as possible, without obscuring the success of the sign. Of all of the sites with signage, about fifty seven percent had geologic signage. The amount of "good" geologic signage in "all sites considered" is about 28 percent. The amount of "good" signage of geologic signage considered is about forty eight percent.

There are many places in the area covered in this study that have the potential to be developed for geotourism and for informal education. These sites – if properly interpreted through the Big Ideas of the Earth Science Literacy Institute – could yield more opportunities to create an Earth Science literate public. National Parks and State Parks were included in order to give a realistic cross section of geosites and to show what could be done, if time and money were spent. As already stated, most of the sites lack signage that supports the Big Ideas. They may have signage that is interesting, and even important but it seems like a very large learning gap has been uncovered, since the Big Ideas are not covered. Signs should be available that support the Big Ideas of the Earth Science Literacy Initiative (ESLI). In the few places where this did occur, the signs were interesting, informing, and successful in terms of balance.

Oregon Paleo Land Institute is a model that can be adopted to add to a place's economic health and conservation. It was created for an area in Oregon that experienced economic downturn after the logging industry faltered. OPLI was able to bring new economic power to the area by redefining its resources. The area now hosts geotourist activities. Industries that cater to geotourists have begun to appear.

There exists the possibility that California could do the same. In nearly every geosite, there exists the opportunity to reevaluate the geosite in terms of the Big Ideas. Nor does informal education need to be expensive. Pt. Reyes National Seashore engaged school children to produce art for their signage. Citizens could be enlisted to volunteer various skills they possess to create whatever is needed. The Chamber of Commerce could find ways to encourage new business owners to come to the area. Signage, pamphlets, and websites could be created that illustrate how each place can teach the Earth Science Literacy Initiative's principles. Government entities or others could be used to disperse the information. There are other entities, such as the World Wide Web that would be very cost effective when economic barriers prevent much money from being spent. The literacy of the public is within reach in some of the most economically threatened areas of California. There are many poverty-level economies in rural California- the places where some of the most beautiful geotourism exists. These places could be redefined, according to their resources. If the resources became the focus of the economy, there would be more tourism in the area. With tourism would come tourism dollars. This could and probably would create jobs and wealth. But the most important increase would be in the knowledge of the communities. As the communities increase in monetary gain, literacy in Earth Science would accompany the new product. In fact, it would be in the community's best interest to become more geo-literate.

CHAPTER VI

CONCLUSION

This study is about geotourism, especially the geotourism of Northern California. The resource that is the geology of California has created a diverse landscape. The fact that California is beautiful is not new. The fact that California can serve as a classroom for the education of the public to learn Earth Science may not be new, either. The investigation of multiple sites with regards to geological process, outdoor signage, websites, brochures, and the study of how they might support informal education of Earth Science may in fact, be new. I visited more than fifty nine geosites and visitor's centers. The results of the study support the idea that California has a valuable resource in its diverse landforms, and they are probably an untapped resource for the education of the public of the Big Ideas of the Earth Science Literacy Initiative.

The untapped resources are geosites that anyone can use. The activity called geotourism has been popularized by the National Geographic Center of Sustainable Destinations, which created a document that encourages communities to create new opportunities that can transform geologic resources into learning resources. Geotourism includes communities, and is about the "the place". With the addition of the Big Ideas, it is also about what the resource can teach. Geotourism teaches sustainability as it focuses on landforms and processes. The geosites can and do teach about the Big Ideas of the Earth Science Literacy Initiative (Wysession, et al, 2012). Researchers who study informal learning have already stated that 95% of learning comes from outside the classroom (Falk, 2005). The geotourist can be young, old, male or female, educated, and uneducated. Informal learning takes place outside. Dewey said "if knowledge was to have value, it needs to be useful." (Meyers, 2005, page 11). Geotourism is learning by doing, and experimentation and its value comes with educating citizens about Earth Science.

The merits of this research are clear. Northern California has an abundance of geosites and georegions. These geosites are resources themselves as they help teach the community about Earth Science. As shown in the research and discussed in Chapter five, nearly all of the sites have the ability to support informal learning of the Big Ideas of the Earth Science Literacy Initiative. In addition, of all of the sites visited (over 59), a significant number of sites failed to teach this information in their signage or even on a website, although they were equipped to do so.

These geosites are an untapped resource for learning. The literacy of the public can be increased by introducing the Big Ideas through appropriate signage. In addition to these resources for learning, these sites may prove to be resources for economic gain. When compared with the Oregon Paleo Lands Institute, it was found that Northern California could use that model and create a tourism economy in many areas of economic need and that it need not be a difficult or expensive endeavor.

Signage and brochures can be positive factors in supporting the geotourist to learn about the area around them and can include directions, campfire talk schedules, and clothing suggestions. They can also contain vital information for the geotourist to read in order to gain knowledge. It is not difficult to create lessons to about the Big Ideas and these geosites. There are an unknown number of ways that the Big Ideas could be addressed, especially since there are so many geosites.

Web pages are also of positive value to geotourists. Of the geotourists surveyed (59 geosites with 57 surveys returned), many of them admitted they looked online at the places they would visit. This provides an opportunity to again, teach about the Big Ideas. If a community decided to adopt geotourism in their area, a webpage might help popularize and advertise their presences. Also, the surveys showed that geotourists are often educated and this could be taken into consideration when planning. However, the purpose of teaching the Big Ideas are to educate all citizens, educated or not, and this needs to be considered also.

The Big Ideas of the Earth Science Literacy Initiative are the basic suggested knowledge that all citizens should have. One definition says that "scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making" (National Academy of Sciences, 1996, p. ix). If the Big Ideas were incorporated into informal learning, citizens would be better educated and able to make better decisions for themselves where it concerned the environment.

This study is incomplete, in that the number and places of the geosites are incomplete. Many sites went unvisited and more are unknown to this researcher. More work could be done here, as well as with the study of geotourists themselves. Models of specific lessons for the landscapes also could be created and dispersed.

Future research in this area could include the exploration of Southern California using the same methods. In addition, there may be projects already proceeding where a community was able to adopt the Big Ideas and created opportunities as a town and endeavored to change the economic climate of the community.

New ways of presenting the Big Ideas could also be explored. For example, a very simple and rough lesson could be a simple worksheet created for geotourists so they could identify any of the Big Ideas they might be able to see occurring in the landscape.

The impact of properly interpreted geosites could be significant. It would be dependent on what the geosites, the organizations in California, similar to OPLI, do to inform the public.

Informal learning is incredibly important, especially in areas such as Earth Science. Areas with high degrees of diversity could lead to high levels of informal learning in a small time frame (the amount of time it takes to visit the place). This is true for adolescents, young children, and adults. We can tremendously impact our citizen's futures by helping them become more Earth Science Literate. The Oregon model has taken an economically depressed situation and turned it into economic opportunities. With work and dedication, the same or similar situations can be reproduced in Northern California.

Implications for future research

Although the scope of this study is large for Northern California, there remains countless sights to visit. Other ways of organizing the geosites may uncover new sites. For example, if someone were to cover a province in terms of the Big Ideas that were represented, or rather, covered by already placed signage or other documentation, there could be new sites to visit. In fact, reorganizing the way geosites are viewed may prove worthwhile. In addition to the geosites already covered, the area of Southern California seems like a promising area of study.

The weaknesses in this study are that there are many geosites that were not visited because they were unknown or were not within the range of the planned visits. The sites that were visited were also not fully documented because of time restraints. Record keeping methods could be improved, as well. However, if science learning does occur outdoors, California is missing many natural opportunities.

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APPENDIX A

NATIONAL GEOGRAPHIC GEOTOURISM CHARTER AGREEMENT

This global template is designed for nations but can also be adjusted for signature by provinces, states, or smaller jurisdictions, and for endorsement by international organizations.

Geotourism is defined as tourism that sustains or enhances the geographical character of a place – its environment, culture, aesthetics, heritage, and the well-being of its residents.

The Geotourism Charter

WHEREAS the geotourism approach is all-inclusive, focusing not only on the environment, but also on the diversity of the cultural, historic, and scenic assets of _______, WHEREAS the geotourism approach encourages citizens and visitors to get involved rather than remain tourism spectators, and WHEREAS the geotourism approach helps build a sense of national identity and pride, stressing what is authentic and unique to________, THE UNDERSIGNED parties to this Agreement of Intent commit to support these geotourism principles, to sustain and enhance the geographical character of _________—its environment, culture, aesthetics, heritage, and the well-being of its residents:

Integrity of place: Enhance geographical character by developing and improving it in ways distinctive to the locale, reflective of its natural and cultural heritage, so as to encourage market differentiation and cultural pride.

International codes: Adhere to the principles embodied in the World Tourism Organization's Global Code of Ethics for Tourism and the Principles of the Cultural Tourism Charter established by the International Council on Monuments and Sites (ICOMOS).

Market selectivity: Encourage growth in tourism market segments most likely to appreciate, respect, and disseminate information about the distinctive assets of the locale.

Market diversity: Encourage a full range of appropriate food and lodging facilities, so as to appeal to the entire demographic spectrum of the geotourism market and so maximize economic resiliency over both the short and long term.

Tourist satisfaction: Ensure that satisfied, excited geotourists bring new vacation stories home and send friends off to experience the same thing, thus providing continuing demand for the destination.

Community involvement: Base tourism on community resources to the extent possible, encouraging local small businesses and civic groups to build partnerships to promote and provide a distinctive, honest visitor experience and market their locales effectively. Help businesses develop approaches to tourism that build on the area's nature, history and culture, including food and drink, artisanry, performance arts, etc.

Community benefit: Encourage micro- to medium-size enterprises and tourism business strategies that emphasize economic and social benefits to involved communities, especially poverty alleviation, with clear communication of the destination stewardship policies required to maintain those benefits.

Protection and enhancement of destination appeal: Encourage businesses to sustain natural habitats, heritage sites, aesthetic appeal, and local culture. Prevent degradation by keeping volumes of tourists within maximum acceptable limits. Seek business models that can operate profitably within those limits. Use persuasion, incentives, and legal enforcement as needed.

Land use: Anticipate development pressures and apply techniques to prevent undesired overdevelopment and degradation. Contain resort and vacation-home sprawl, especially on coasts and islands, so as to retain a diversity of natural and scenic environments and ensure continued resident access to waterfronts. Encourage major self-contained tourism attractions, such as large-scale theme parks and convention centers unrelated to character of place, to be sited in needier locations with no significant ecological, scenic, or cultural assets.

Conservation of resources: Encourage businesses to minimize water pollution, solid waste, energy consumption, water usage, landscaping chemicals, and overly bright nighttime lighting. Advertise these measures in a way that attracts the large, environmentally sympathetic tourist market.

Planning: Recognize and respect immediate economic needs without sacrificing long-term character and the geotourism potential of the destination. Where tourism attracts in-migration of workers, develop new communities that themselves constitute a destination enhancement. Strive to diversify the economy and limit population influx to sustainable levels. Adopt public strategies for mitigating practices that are incompatible with geotourism and damaging to the image of the destination.

Interactive interpretation: Engage both visitors and hosts in learning about the place. Encourage residents to show off the natural and cultural heritage of their communities, so that tourists gain a richer experience and residents develop pride in their locales.

Evaluation: Establish an evaluation process to be conducted on a regular basis by an independent panel representing all stakeholder interests, and publicize evaluation results.

APPENDIX B

GEOTOURIST SURVEY, IRB AGREEMENT, AND LETTERS TO CLUBS AND COLLEGES

Demographics: check mark

1. Gender

Male _____

Female _____

2. Age group:

18-25 _____

26-40 _____

41-55 _____

56-65 _____

Over 65 _____

3. Highest Level of Education

High School _____

Some College _____

College Graduate _____

Post Graduate _____

Master's Degree _____

PhD _____

4. Check any courses you've taken:

Geology _____

Earth Science _____

Geoscience _____

Astronomy _____

Physical Geography _____

Plant Science _____

Environmental sciences _____

Meterology _____

Vacations/Travel Habits

5. How many times per year do you visit a park or other wilderness locale: (Indicate the approximate number)

Vacation (more than 5 days) ____

Leisure time (less than 5 days)____

Frequency:

Every weekend or almost every weekend _____

Every month or two _____

Every 6 months or so _____

Every year or so _____

Over 2 years _____

Over 5 years _____

6. Where did you get most of your information about this geo-site and what source did you find most helpful? _______

Internet ____

Recommendation ____

Tourist magazines or travel books ____

College classes ____

Time spent researching :

< 1 day ____ (mins or hours)

1 week ____

1 month ____

6 months to a year ____

More ____

7. Check all places you have visited

Yosemite NP _____

Yellowstone NP _____

Grand Canyon NP _____

California State Parks ____

8. While vacationing or engaging in leisure activities, do you ever:

Camp: RV / Tent / Cabin

Participate in Park Ranger talks and other activities ____

Go for hikes ____

Enjoy photography ____

Stay in camp and enjoy doing nothing ____

9. Why did you come to this geo-site?

Vacation ____

Driving through ____

10. What kinds of things do you learn about when you visit an outdoor setting?

Geology ____

Plant Life ____

Astronomy ____

Animal Life ____

Meteorology ____

11. If you collect rocks or fossils or some other item, how much time do you take time to learn about them when you return home?

1 hour ____

1 day ____

I month ____

More ____

I just collect ____

12. When you travel to a geo-site, like this one - Whom do you generally bring with you?

Children ____

Friends ____

Spouse ____

Come alone ____

Geosites

13. If you hike / bike: How do you choose what trails you decide to try?

Park brochures ____

Level of difficulty ____

Geologic formations, waterfalls, caves, etc. ____

Wildlife, biology reports ____

Signage / Plaques / Historical markers

14. Did any of the signs have any of these characteristics?

Interesting: Y / N

Address identifiable concepts: Y / N

Introduced new concepts to you in the process of explaining this geo-site: Y / N

Addressed concepts at a level that was understandable yet sophisticated enough to teach you something new: Y / N

Addressed children as well as adults: Y / N

Improvement needed: Y / N

15. Did you come to this place intentionally or by accident?

Yes ____

No ____

Optional Information:

Name:________________________________

Zip Code

____

Phone number:

____

E-mail:

____

Mississippi State University
Informed Consent Form for Participation in Research

Title of Research Study: Analysis of Northern California's Potential Geotourist Sites for Effective Informal Geoscience Education that Address the Earth Science Literacy Initiative's Big Ideas

Study Site: Various Geosites within Northern California, including Lava Tubes National Monument, Mt. Shasta, Mt. Lassen National Park, Yosemite National Park, Sequoia-Kings Canyon National Park, Pt. Reyes National Seashore, and other unidentified geosite localities.

Researchers: Kimberlie R. Theis, Mississippi State University, Geosciences

We would like to ask you to participate in a research study.

This study will inventory possible geotourism sites and activites and investigat the potential for Earth Science education. This study will fill a gap in the research on geotourism and Earth Science education.

If you participate in this study, you will take a survey that is designed to identify who the geotourist is in terms of interests, education, and other factors. The survey will take about 15 minutes to complete. Examples of the questions include "What brings you here? What is your favorite outdoor location? How much time do you spend researching a trip?"

There are no foreseeable risks to the participant by taking the survey and participating in the study.
Participants will be helping to fill a gap in the study of Geotourism and Earth Science education. If enough attention can be brought to the value of geotourism and its role in Earth Science education, monies may be made available to create new materials designed to enhance the geotourists experience.

No incentives will be offered.

You must be at least 18 years of age to participate.

Confidentiality

The participants may be photographed while actively participating the in the act of geotourism. Names will be stripped from any records and randomly generated numbers will be used as identification.

Questions

If you have any questions about this research project, please feel free to contact Kimberlie Theis at 209-417-0055 and kimtheis@yahoo.com.

You may also contact Dr. Renee Clary, Mississippi State University, 662-268-1032 x215 and rclary@geosci.msstate.edu.

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Voluntary Participation

Please understand that your **participation is voluntary.** Your **refusal to participate will involve no penalty or loss** of benefits to which you are otherwise entitled. You **may discontinue your participation** at any time without penalty or loss of benefits.

Please take all the time you need to read through this document and decide whether you would like to participate in this research study.

If you decide to participate, your completion of the research procedures indicates your consent. Please keep this form for your records.

______________________________ Participant Signature	__________ Date
______________________________ Investigator Signature	__________ Date

4/4/12

Dear (Club Officer):

I am a master's student at Mississippi State University within the Teachers in Geosciences program. I live in California and I am writing my thesis on potential geotourism opportunities within Northern California. I am specifically studying how the Big Ideas of the Earth Science Initiative can be effectively addressed in informal learning sites.

I am currently trying to identify field sites used by geosciences instructors in Northern California, and also by Geology clubs. I would sincerely appreciate any help you could give me. I am looking to identify any geosites that your club visits in the Northern California region. If you could identify 3 sites for me, and tell me about the activities that you do when there, it would be such a great help, and a positive contribution to the Geosciences.

I am very happy to provide additional details about my research if needed. Thank you for your time and consideration.

Respectfully submitted,

Kimberlie Theis

Telephone: 209-417-0055

E-mail: kimtheis@gmail.com

4/4/2012

Kim Theis Masters

Thesis Project

[redacted]

Field Geology Sites Poll

Prof. ______________________

Please take a moment to fill in your answers, attach additional sheets if needed. Any insights or information your can offer will be invaluable to my research =)

List in order of importance your top 3 Geological sites in N. California, based on where you take, or would take your Earth Science students. (Fresno being the southern border)

1.____

2.____

3.____

Keeping in mind your assigned value please use a sentence or two to describe their appeal to your academic program – What examples of geological processes each site best illustrates.

Site in order listed above

1.____

2.____

3.____

*Should you prefer to respond digitally please use this format, (with your top 3 sites listed in order of their importance followed by your comments in the same order.) e-mail your response to [redacted]

Please feel free to include any additional information you feel is relevant to quality geology field studies.

Thank you for your time and assistance, your input is vital to my success.

Sincerely,

DATE

Dear Professor XXXX:

I am a master's student at Mississippi State University within the Teachers in Geosciences program. I live in California and I am writing my thesis on potential geotourism opportunities within Northern California. I am specifically studying how the Big Ideas of the Earth Science Initiative can be effectively addressed in informal learning sites.

I am currently trying to identify field sites used by geosciences instructors in Northern California, and I would sincerely appreciate if you could provide me with a brief list of the publicly accessible sites that are incorporated within your geoscience courses, and the major geological concepts that are taught at each site.

I am very happy to provide additional details about my research if needed. Thank you for your time and consideration.

Respectfully submitted,

Kimberlie Theis
[redacted]

APPENDIX C

WEB PAGES WITH SCORES

Scores follow criteria for the signage as laid out in Chapter Five. A score of "No mention" was given to the sites that had no mention of the geology

Location	Scores (Good, Fair, Poor)	Web Addresses
Castle Crags	No mention	http://www.parks.ca.gov/?page_id=454
Cascade Province	Good	http://en.wikipedia.org/wiki/Cascade_Volcanoes
Pluto's Caves	Fair	http://www.fs.usda.gov/recarea/klamath/recreation/otheractivities/recarea/?recid=13176&actid=102
Deer Mtn Tephra Cone	Fair	http://www.siskiyous.edu/shasta/geo/fig7.htm
Black Butte	Fair	http://en.wikipedia.org/wiki/Black_Butte_(Siskiyou_County,_California)
Bunny Flats	Poor	http://www.shastaavalanche.org/weather/forecasts/current-bunnyflat
Mt. Shasta Ski Bowl	Good	http://hikemtshasta.com/mount-shasta-trails/old-ski-bowl-trail
Ash Creek Flow	Good	http://www.siskiyous.edu/shasta/env/glacial/mud.htm
The Whaleback	Poor	http://rvhpa.org/site-guide/whaleback/
Captain Jack's Stronghold	Poor	http://www.sierranevadageotourism.org/content/captain-jacks-stronghold-lava-beds-national-monument/sieF813559E558B22224
Gillem's Camp	Fair	http://explore.globalcreations.com/places/gillems-camp/
Devil's Homestead	Good	http://www.molossia.org/volcanology/lavabeds.html
Fleener Chimneys	Good	http://geotripper.blogspot.com/2010/01/other-california-fleener-chimneys.html
Schonchin Butte	Good	http://en.wikipedia.org/wiki/Schonchin_Butte
Skull Cave	Good	http://explore.globalcreations.com/places/easy-caving-in-the-lava-beds/
Mammoth Crater	Good	http://www.youtube.com/watch?v=xtkKaDLK0B4
Glass Mountain	Good	http://en.wikipedia.org/wiki/Medicine_Lake_Volcano
Donner Pass	Poor	http://en.wikipedia.org/wiki/Donner_Pass
Lake Tahoe	Good	http://en.wikipedia.org/wiki/Lake_Tahoe#Geology
North Star Mine	Good	http://www.sierranevadageotourism.org/
Goodyear Bar	Good	http://www.sierranevadageotourism.org/content/goodyears-bar/sieB80C3198C6B0738D6
Hornitos	Poor	http://en.wikipedia.org/wiki/Hornitos,_California
Columbia	Poor	http://www.visitcolumbiacalifornia.com/
Sequoia-Kings Canyon	Good	http://www.nps.gov/seki/naturescience/geology_overview.htm
Don Pedro	Poor	http://en.wikipedia.org/wiki/Don_Pedro_Reservoir
San Juan Baptista	Good	http://geologycafe.com/fieldtrips/san_juan_bautista.html

APPENDIX D

DATA SPREADSHEET

Supplemental data can be found in Data Spreadsheet file due to size of spreadsheet. This is a .pdf file, landscape orientation, (named THEIS_Data_Spreadsheet) created in Microsoft Excel, on November 4, 2012.

APPENDIX E

CODED SURVEYS

Demographic Questionaire	By Percent									
Question 1		Question 2				Question 3		Question 4		
Male	61.40	Ages	19.30	18 -25	Level of Education	12.28	High School	Courses Taken	22.81	Geology
Female	54.39		50.88	26-40		28.07	Some College		47.37	Earth Science
			19.30	41-55		35.09	College Graduate		5.26	Geoscience
			15.79	56-65		14.04	Post Graduate		17.54	Astronomy
			8.77	over 65		21.05	Master's Degree		17.54	Physical Geography
						7.02	Phd		21.05	Plant Science
									28.07	Environmental Science
									1.75	Meteorology
	Question 5			Question 6			Question 7			
Vacation (more than 5 days)	50.88		Obtain information	43.86	Internet	Places visited	63.16	Yosemite NP		
Leisure (Less than 5 days)	54.39			24.56	Recommendations		36.84	Yellowstone NP		
Frequency	17.54	Every weekend		12.28	Tourist Magazines		49.12	Grand Canyon NP		
	28.07	Every month or two		3.51	College Classes		71.93	California SP		
	14.04	Every six months								
	17.54	Every year			Time spent researching					
	3.51	Over 2 years		59.65	<1 day					
	0.00	Over 5 years		12.28	1 week					
				3.51	1 month					
				1.75	6 mos to year					
				1.75	More					
	Question 8			Question 9			Question 11			
Mode	15.79	RV	Purpose of visit	64.91	Vacation	Collected	14.04	1 Hour		
	35.09	Tent		12.28	Driving through		12.28	1 Day		
	17.54	Cabin					1.75	1 Month		
				Question 10			0.00	More		
	40.35	Ranger Talks	Learning expectations	77.19	Geology		15.79	I just collect		
	77.19	Hikes		61.40	Plant Life					
	50.88	Photography		36.84	Astronomy					
	26.32	Stay in camp		75.44	Animal Life					
				28.07	Meteorology					
	Question 12			Question 13			Question 14			
Who comes with you?	22.81	Children	Choosing Trails	54.39	Park Brochures	Signage	77.19	Found signs interesting		
	52.63	Friends		49.12	Level of difficulty		59.65	Found new information		
	50.88	Spouse		49.12	Scenery		75.44	Information was understandable		
	6.00	Come alone		16.00	Wildlife		50.88	Information was appropriate for children		
							36.84	Improvement is needed		
	Question 15									
Did you come here intentionally	78.95	Yes								
	10.53	No								