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ADULT EDUCATION IN A MUSEUM SETTING REQUIRES REINFORCEMENT

Judy Ann Lowman
California State University - San Bernardino

ADULT EDUCATION IN A MUSEUM SETTING

REQUIRES REINFORCEMENT

A Thesis

Presented to the

Faculty of

California State University,

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In Partial Fulfillment

of the Requirements for the Degree

Master of Science

in

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and Mathematics Education

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by

Judy Ann Elkins Lowman

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ABSTRACT

This thesis addresses adult education in a museum setting and measures adult learning during and after a museum visit. While a number of studies have investigated the impact of museum visits on children's learning, there are few studies on adult learners. This thesis is an initial effort to fill that gap. Qualitative data were gathered through interviews with 24 adult visitors at the Victor Valley Museum in Apple Valley, California. The objective was to determine which exhibits were found to be of greatest interest to the visitor. Follow-up interviews were conducted four weeks later to measure retention. The qualitative data were grouped by responses and compared to the demographic data to reveal any relationships. The study found that while adult visitors may initially learn new information during their museum visit, the information is not retained; learning must be reinforced. The solutions offered to achieve this reinforcement are reflection, follow-up interviews, and additional museum visits.

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CHAPTER ONE

INTRODUCTION

Background

Formal education occurs at schools. Science education occupies only one period of a six hour day during a 180 day school year for children (Yager & Falk, 2008) and less for adults who chose not to take formal science classes. Owing to the limited time spent in school, most learning takes place at outside venues. It has been shown that learning is continuous and cumulative, and is constructed from the school experiences as well as the more numerous interactions with other people, viewing TV, playing, extracurricular activities, and reading (Falk, 1999). Travel is also an important learning experience. One important site of learning is a museum. Today in the United States, 2 of every 5 people visit a museum at least once a year (Falk, 1999); in 2004, natural history museums had about 50 million visitors (MacFadden, et al, 2007). In museums, visitors are free to select things to view and move at their own speed and in their own direction (Ambrose & Paine, 2006). That is they have selected to learn during their leisure time, i.e. free-choice learning (Falk, 1999).

The role of museums in education has been the topic of contention since the time of the earliest public museums (Jevons, 1883). Discussions on how to educate the visitor has lead to the polarization of museum professionals into two exclusive philosophical camps. In the first, exhibitions are arranged systematically or so to produce an emotional impact (Jevons, 1883) and educate through stimulating the visitors' interest (Greenwood, 1893). This has been challenged as not educational (Jevons, 1883). Today, followers of this philosophy mostly exhibit in art museums. In the second, exhibitions are planned to be educational with objects explained clearly and contextualized (Rea, 1907; Greenwood, 1893; Rennie & Williams, 2006b). Objects in this type of museum become teaching tools, often stronger than the written word (di Cesnola, 1887; Special Committee of the American Association of Museums [SCAAM], 1969; Barbour, 1912). As such, museums provide a unique learning environment (SCAAM, 1969). This philosophy is embraced by most science oriented museums as well as history museums and historic homes.

Many museums have special areas that are frequented by children in hands-on play to educate. For example, the San Bernardino County Museum has a special building to house their educational programs and school buses are frequently seen in the parking lot. Another example is the Oregon Museum of Science and Industry where children can program robots or build bridges in the Turbine Hall; they even have the Science Playground for children six or under.

Statement and Purpose

Museums are places of potential education. Their role in education of adult visitors is not well known because adult learning in museums is an understudied area (Grek, 2009). A few studies have included adults. Examples of these include a study of learning about evolution (MacFadden, et all, 2007), a study of "touch tables" in teaching about conservation in a Swiss zoological garden (Lindemann-Matties & Kamer, 2006), and a dissertation about approaches to adult learning in underrepresented groups (Grek, 2009). These few studies did not concentrate on adult learning, but on either topics presented or tools used by the museum.

Most investigations have focused on children. Studies have addressed the role of children playing during museum visits (Henderson & Atencio, 2007) and the development of worksheets for children's school fieldtrips (Mortensen & Smart, 2007). Some studies have included parents, but the main emphasis was the children's learning (Allen & Gutwill, 2010; Palmquist & Crowley, 2007). In the 1969 Belmont Report, the Committee (SCAAM, 1969) acknowledged that some children are object-minded and learn best from tactile sensory input. As a result of the Belmont Report, many museums established educational services geared to children that may include mobile museums, classroom visits, and special collections that are loaned to schools (Ambrose & Paine, 2006). While this produced a true learning environment for children, adult education is not addressed in these programs. This thesis addresses adult education in a museum setting.

Theoretical Basis

Learning is cumulative and continuous with flashes of insight occurring when connections are made between new and old concepts (Falk & Dierking, 2000; Falk, 1999; Rennie & Johnston, 2007). Life-long interactions between a person and their environment is important for learning (Falk & Storksdieck, 2005). People connect new ideas, concepts, and experiences with prior knowledge (Merriam, 2008). The theoretical basis for learning in a museum is best explained by a blend of Illeris' Three Dimensions of Learning and the Contextual Model of Learning developed by Falk and others (Falk & Dierking, 2000; Falk & Storksdieck, 2005). While the Contextual Model was developed to understand learning in a museum, both theories emphasis that learning is social. Learning in a museum is very social because most visitors arrive in groups and/or interact with docents and other visitors (Ambrose & Paine, 2006; Falk & Storksdieck, 2005; Falk & Dierking, 1992).

Illeris' Three Dimensions of Learning model recognizes that there are social, cognitive, and emotional aspects of learning and all must be considered (Merriam, Caffarella & Baumgartner, 2007; Illeris, 2002). The Contextual Model of Learning embraces the complexity of learning. It labeled the aspects of learning as sociocultural, personal, and physical; however, it also considers these aspects to be part of a continuum (Bamberger & Tal, 2006; Falk & Dierking, 2000). This model also assumes learning is constructed from dynamic structures of experience and knowledge and it takes time (Falk & Dierking, 2000). Therefore, learning in a museum setting may not be immediate or perceived as learning by the visitor.

The type or structure of learning will be influenced by the situation such as everyday life, school, or a visit to a museum. The situation also includes the content and emotion involved and by the features of the learner: e.g. age, gender, interest, background (Illeris, 2002). The features of the learner are especially important in what is learned during a museum visit, because it is free-choice learning. During free choice learning, the individuals choose to learn about things that interest them (Bamberger & Tal, 2006). At museums, they select the exhibits from which to gain knowledge and create their own experiences (Rennie & Williams, 2006a; Rennie & Johnston, 2007; Hohenstein & Tran, 2007; Falk & Dierking, 1992).

Limitations

All learning takes time because learning is some form of change and change does not occur instantly (Rennie & Johnston, 2007; Bamberger & Tal, 2008). It may take days, weeks, or even months before the concepts that are seen at the museum are connected to prior knowledge (Falk, 1999). Therefore, learning is difficult to measure at the time of the visit. Because a museum visit is a single learning event, museum learning also relies on the post-museum visit activities. If the visitor has similar experiences with the material that was seen at the museum, the learning is reinforced and retained (Rennie & Williams, 2006a). Newer studies are now stressing the follow-up interview to help measure learning. The major limitation to determining learning from the museum experience in this study will be the number of visitors who are willing to be interviewed and especially the number of visitors who are willing to participate in the follow-up interview.

Definitions

There are many definitions of museums and most people picture a formal, grand structure whose halls echo with footsteps. Not all museums are so structured. As defined by the United Nations Educational, Scientific, and Cultural Organization (UNESCO), a museum is a place that culturally valued objects are studied, preserved, and exhibited for the good of the entire community. In addition to an edifice housing various cultural objects, the American Association of Museums (AAM) considers the following scientific venues to be museums: planetaria, aquaria, and zoological and botanical gardens (Burcaw, 1997). Defining what constitutes learning is difficult (Falk & Dierking, 2000). Learning may be defined as the results of study, the process of new concepts making connections with prior knowledge, or the interaction between a person, material, and their social environment (Illeris, 2002). For this thesis, learning is defined as a change in attitude or behavior as a result of the museum visit or the retention of facts.

CHAPTER TWO

LITERATURE REVIEW

Evolution of Museums as Places of Learning

The Library of Alexandria was the first institution to be called a museum. Built by Demetrius of Phaleron around 270 BC (Burcaw, 1997) and supported by Ptolemy I and later members of his dynasty (McNeely & Wolverton, 2008), the Library was a place for scholars to study. It was dedicated to the Muses; hence, the term "museum" was used for the Library complex (Trumble, 2003; McNeely & Wolverton, 2008). In the seventeenth and eighteenth centuries, French scholars tried to determine the essence of the Library of Alexandria (Lee, 1997). They failed to locate the Library; the location is not known even today. Literature is the only source of information about the Library (Trumble, 2003). The French used the literature to define the Library as a group of scholars who study various subjects in the arts, sciences, and literature; from this, the word "museum" came to mean a group of scholars and the building they study in (Lee, 1997). It did not include the collections and it was not a place for public education.

Western museums began as collections of rich and royal families. The collections were called cabinets of curiosities, closets of rarities, or Wunderkammer and the size of the cabinets varied with the wealth and status of its owner. These collections were comprised of a very diverse array of materials that included Roman and Egyptian antiquities, historic memorabilia, art, rare objects, fossils, fauna, flora, minerals, and scientific instruments (Impey &

MacGregor, 1985). The cabinet of Johann Kenntmann contained about 1600 objects such as minerals, shells, and marine animals; students came to study his collection (Hagen, 1876).

Museums were initially formed from cabinets that were given to an institution such as a university; the cabinets were used by their students. One of the earliest museums was Ashmolean Museum in Oxford established about 1683; it contained the cabinet of curiosities of John Tradescant, gardener to Charles I. However, it was not open to the general public. One of the oldest public museums in Europe was the British Museum established in 1753; it opened to the public in 1759 (Trustees of the British Museum, n.d.). After this, public museums began to grow in number. One such museum was the Liverpool Public Museum which resulted from the merger of two cabinets, the Derby Natural History Collection and the Mayer Archaeology and Ethnology Collection. In its first year, 1851, almost a quarter million people visited it with the museum open only four days per week (van Keuren, 1984). Museums were very popular, but they were not learning intuitions.

In 1859 the Medical College of Alabama in Mobile added a museum; they considered it necessary for teaching technical and scientific classes (Howard, 1982). However, to most people a museum was considered a place to amuse the public; education was not considered important. In 1864, J. Edward Gray, Keeper of the British Museum's Zoological Department, suggested that museums have two collections: one for public viewing and one for study by scholars (van Keuren, 1984). In the 1880s, Sir William Henry Flower also proposed a "new" museum where the public exhibits were separate from the research areas (Flower, 1893). However, this time the idea brought changes in the way museums exhibit objects (Lucas, 1908). These "new" museums brought objects to the public to inspire interest (Ambrose & Paine, 2006). They also brought nature to the people by grouping animals in life-associations (Barbour, 1912; Baker, 1922).

Dewey expressed the importance of museums in the educational environment throughout his writings (Hein, 2004). In 1896, he established an experimental school, the Laboratory School in Chicago, and the children attending spent one and a half hours each week at a museum. Dewey was also instrumental in making education a part of the museum mission statement (Schwarzer, 2006). However, museum professionals have often lamented that museums are not recognized as educational institutions with growth potential (Falk, 1999; Rea, C. M., 2008; Rennie & Williams, 2006b).

Peabody Museum of Salem was initially established as the East India Museum in 1799 and by 1821 had over two thousand objects, many from the Pacific Ocean islands (Hagen, 1876; Whitehill, Shipton, Tucker & Washburn, 1964). In the 1860s, the Peabody Academy of Science purchased the building and collection of the East India Museum. In 1915, the museum changed its name from Peabody Academy of Science to its present name, Peabody Museum of Salem (Whitehill, Shipton, Tucker & Washburn, 1964). By 1969, this museum had about 100,000 specimens. They were also changing exhibits from the older style based on the philosophy of presenting items of wonder to an educational style more in keeping with modern times; e.g. the shrunken heads were not being displayed for the curiosity effect, but were incorporated into an ethnological display with related cultural items (Williams, 1969). While this change was in keeping with the ideas of the "new" museum, it did not establish a true learning environment.

The Academy at Drexel was established as the Academy of Natural Sciences of Philadelphia in 1812 and opened to the public in 1828 (Academy of Natural Science of Drexel University [ANSDU], 2012; P R Newswire [PRN],2012). It was the first museum in the United States to exhibit a dinosaur skeleton. Today it has over 17 million specimens, including dinosaurs (PRN,2012). It was also far thinking; it began to hold classes for children in 1932 and established an Environmental Research Division in 1948 (ANSDU, 2012). di Cesnola (2008) views museums such as the Academy as a place to reinforce instruction.

The impetus for increased education in museums was the 1969 Belmont Report (Genoways & Andrei, 2008). In the report, the Committee (SCAAM, 1969) acknowledged that some children are object-minded and learn best from tactile sensory input; real objects have a strong impact in educating visitors. Museums may be seen as places of object teaching and visual education (di Cesnola, 2008; Baker, 1922). As a result of the Belmont Report, many museums established educational services geared to children that may include mobile museums, classroom visits, and special collections that are loaned to schools (Ambrose & Paine, 2006). While this produced a true learning environment for children, adult education is not addressed in these programs.

Learning

Piaget suggests learning grew from our ancestors' need to survive and this was achieved by staying in equilibrium with the environment. When something changes, a person adapts, actively adjusting, or assimilating by constructing or modifying cognitive structures. Nissen proposed that in addition to Piaget's ideas, human learning is cumulative (Illeris, 2002). Others (Falk & Dierking, 2000; Falk, 1999; Rennie & Johnston, 2007) also see learning as cumulative and continuous with flashes of insight occurring when connections are made between new and old concepts.

While science has not produced a satisfactory explanation of how we learn, it has now recognized that the learning process is more complex than first thought (Falk & Dierking, 1992). People connect new ideas, concepts, and experiences with prior knowledge (Merriam, 2008). Studies on learning were abundant in the twentieth century; adult learning was of great interest and the first studies were conducted to determine if adults could learn (Merriam, 2003). In his seminal paper, Lorge (1963) reported that learning ability does not decline with age. It is now known that learning is the result of a life-long interaction between a person and their environment (Falk & Storksdieck, 2005). Yet after years of investigation, we do not have an unifying theory of adult learning (Merriam, 2003).

Learning Theory

Andragogy, the science and art of adult education was proposed by Knowles (1968) and was widely accepted. It is based on five assumptions: adults are independent and self-directing learners; adult learning is aided by their vast experiences; adult learning is related to changes in life's positions; adult learning is problem centered, e.g. goal oriented; and adult learning is internally motivated (Falk & Storksdieck, 2005). Because we learn throughout life, we progress as learners. Learners become more self-directing, build on their experiences, learn skills to deal with real-life responsibilities, concentrate on problem solving, and have more internal motivation (Kiely, Sandmann & Truluck, 2004; Merriam, Caffarella & Baumgartner, 2007). Most of the andragogy concepts are intuitive. Adults should be treated like adults, be allowed to share their knowledge, and be involved in planning their education (Knowles, 1968). This concept is used in many adult education venues, such as California State University, San Bernardino.

Andragogy has been criticized. Its status as a true learning theory has been challenged; yet it is also recognized as a contribution to adult education (Merriam, 2003). Andragogy's assumptions may not be exclusive to adults. It has been shown that even preschool children are goal oriented and goal orientation is carried over into adult behavior (Iacoboni, 2009). Human maturity traits develop at various points in time during human development (Merriam, 2003; Knowles, 1968). Some children develop into internally motivated individuals early in life and are self-directing, learning about topics that interest them. On the other hand, some adults are motivated to obtain additional education only for job retention or advancement (Merriam, 2003). Prior knowledge is not an exclusive adult trait. Children growing up with cell phones and the Internet may be more proficient at working with the growing technological advances than many adults who grew up with landlines and bound encyclopedias.

Learning theories have been proposed by McClusky, Jarvis (Merriam, Caffarella & Baumgartner, 2007), Mezirow (Taylor, 2008), and Clark and Rossiter (2008), However, these are not well suited to informal learning in a museum setting. The theoretical basis for museum studies is best explained by a blend of Illeris' Three Dimensions of Learning and the Contextual Model of Learning developed by Falk and others (Falk & Dierking, 2000; Falk & Storksdieck, 2005).

Illeris' Three Dimensions of Learning model recognizes that there are cognitive, emotional, and social aspects of learning and all must be considered (Merriam, Caffarella & Baumgartner, 2007; Illeris, 2002). People begin their socialization with the interactions between baby and mother or another primary caregiver; the mother/caregiver brings the social constructs to the child. That interaction and those that follow occur in a social environment. It is in this arena that a person develops the biological-based structures, i.e. their cognitive skills and emotional patterns (Illeris, 2002). Illeris (2002) and Merriam, Caffarella & Baumgartner (2007) diagram this model as an inverted isosceles triangle with the cognitive dimension on the upper left, emotion dimension on the upper right, the social dimension is the acute angle at the bottom, and learning in centered in the triangle.

Learning events begin with interactions that may be characterized as perception, transmission, experience, imitation, and participation. Perception is viewing the world; transmission is receiving information; experience is a broad term and may include perception and transmission; imitation and participation are activities to obtain knowledge (Merriam, Caffarella & Baumgartner, 2007; Illeris, 2002). Any learning event will have one or more of these interactions. Learning is accomplished by an internal psychological process that can be cumulative, assimilative, or accommodative. Cumulative processes construct new knowledge or skill structures, while assimilative processes add to existing structures. In accommodating processes, existing structures and patterns are rearranged; this may occur with new learning events or by reflection on existing knowledge. Illeris (2002) also recognizes that the type or structure of learning will be influenced by the situation (e.g. everyday life or school), by the content and emotion involved, and by the features of the learner (e.g. age, gender, interest, and background). The features of the learner are very important in what is learned during a museum visit.

The Contextual Model of Learning embraces the complexity of learning. It assumes learning is constructed from dynamic structures of experience and knowledge. This takes time (Falk & Dierking, 2000). The dynamic nature of learning leads to changes in a person's contexts over their lifetime (Falk & Storksdieck, 2005). While the contexts are labeled personal, sociocultural, and physical, they are also a continuum (Bamberger & Tal, 2006; Falk & Dierking, 2000). The Contextual Model was developed to understand learning in a museum. Any museum visit is comprised of cognitive, affective, and social interactions (Bamberger & Tal, 2008). Leaning in a museum is frequently very social as visitors arrive in groups and/or interact with docents and other visitors (Ambrose & Paine, 2006; Falk & Storksdieck, 2005; Falk & Dierking, 1992). In postulating their Situated Learning Theory, Clark and Rossiter (2008) have reached similar conclusions; they see learning occurring in social interactions within their contexts.

Learning in Museums

The mission of museums as seen by SCAAM (1969) is to share knowledge and to provide a pleasant environment. Visitors go to museums for several reasons. Practical considerations such as cost and weather are valid reasons. Even as early as 1883, museums were observed to be well attended on rainy days (Jevons, 2008). Rabb (1968) considers the least expensive form of public recreation to be a visit to a zoological garden. When asked today, most people patronizing museums said they came for education; entertainment was the second most popular answer (Falk & Dierking, 2000; Rennie & Williams, 2006a). These reasons are not mutually exclusive. Increasingly, Americans have a goal of leisure-time learning; surveys show an increase from 14% in the 1970s to 45% in the 1990s (Falk, 1999). Leisure-time learning is free choice learning during which the individuals choose to learn about things that interest them (Bamberger & Tal, 2006). At museums, the visitors select what they want to learn (Rennie & Williams, 2006a; Russo, Watkins & Groundwater-Smith, 2009; Rennie & Johnston, 2007); they create their own experiences (Falk & Dierking, 1992) and they are internally motivated. Therefore, free choice learning is personal and idiosyncratic (Falk & Dierking, 2000; Bamberger & Tal, 2006); this precludes asking specific questions about exhibit content to determine if learning took place. Yet asking people to report on what they have learned, e.g. to self-report, is not accurate and they may report more learning than actually occurred (Diamond, Luke & Uttal, 2009).

Falk and Dierking (2000) noted that museum attendees tend to have high levels of education because they value learning. This value of learning will be passed on to their children because many adults bring their children and grandchildren to museums. Children who attended museums with parents typically bring their children to museums when adults.

Learning in a museum is affected by various factors; not least is the museum itself. Visitors need to feel welcome and comfortable with the physical layout (Rennie & Johnston, 2007; Falk & Storksdieck, 2005). Crowds, noise, and other contingencies associated with the exhibition affect the educational potential of the visit (Screven, 1993; Falk & Dierking, 1992). For example, during a visit to the Auburn Aquarium of the Americas in New Orleans, a parent with child was seen rushing past an exhibit of albino alligators saying they were just statues. This was most likely due to the crowd and uncomfortable temperature within the facility; neither he nor his son learned about the albino alligators.

Learning is also affected by various interactions including those with docents and other visitors (Falk & Dierking, 2000; Falk & Storksdieck, 2005). Learning is social and most people arrive at a museum in groups (Falk & Dierking, 1992; Ambrose & Paine, 2006). Family groups are most the most common visitors at children's museums, zoological gardens, and science and technology centers, and to a lesser extent at natural history and history museums (Falk & Dierking, 1992). The social aspect of learning is an important consideration in the Three Dimensions of Learning theory and the Contextual Model of Learning; this is the reason these two learning theories are applicable to learning in a museum. Social activities have a scaffolding effect as visitors interact with each other and with the exhibit (Bamberger & Tal, 2006; Rennie & Johnston, 2007). Individuals that interact with each other and explain an exhibit to each other are practicing a type of megacognitive strategy, which is a characteristic of expert thinkers (Donovan, Bransford & Pellegrino, 1999).

The most important factor that affects learning in a museum is the visitor. Each individual brings with them prior knowledge, attitudes, experiences, and expectations. These are part of the visitor's agenda which influences learning (Falk & Dierking, 1992; Bamberger & Tal, 2008; Falk & Dierking, 2000). The visitor's motivation is important in their viewing selection, time spent, and strategies used to see the exhibition; thus individual motivation is also a control of learning (Rennie & Johnston, 2007; Falk & Dierking, 2000, Falk, Moussouri & Coulson, 1998). Learning that does occur may include factual information; the visitor may learn about issues and events. In addition, museum visits may lead to developing a new interest or changing the visitor attitudes on various subjects (Diamond, Luke & Uttal, 2009). That is, museum learning is important.

CHAPTER THREE

STUDY DESCRIPTION AND METHODS

Study Description

Adult learning was studied at the Victor Valley Museum in Apple Valley. While the museum was opened in 1992, it became a part of the San Bernardino County Museum System in 2010. At that time new exhibits were installed. The adults visiting the museum had no prior experience with the new exhibits. This gave a better indication of the learning that occurred during a single museum visit.

Learning in a museum setting is learner directed and is guided by their interests (Diamond, Luke & Uttal, 2009). Thus, the evaluation objective was to determine what was found to be interesting to the visitor through qualitative interviews. These were open-ended narratives. This is an indirect study of learning. When acceptable by the visitor, a follow-up interview was conducted to determine retention and/or changes in attitudes or behaviors. This is a direct study of learning.

Methods

Adult visitors were selected at random and asked if they would participate in the study. The only two criteria for inclusion in the study were that the adult visitor was there by choice and spoke English well enough to communicate. Those visitors that volunteered for the study were interviewed at the end of their visit. The interview questions and the demographic questionnaire are in Appendix A.

The interview consisted of two phases. First was an oral interview to elicit their opinions of the museum's exhibits. This interview was an unstructured/ informal conversational interview and probing/ follow-up questions were used to obtain more detail. The museum has numerous collections exhibited, but most could be grouped into three main themes of exhibition: geological, natural history, and local history. The small size of the museum exhibits limited the selection of interesting exhibits which aided in data analysis.

The second phase was a questionnaire about demographic data. These data include reason for their visit, if they have been to the museum before, who came with them, and their occupation, hobbies, gender, and age. Space was provided for contact information if they agreed to a follow-up interview. Contact information was the choice of the visitor: telephone number, email address, or mailing address. Contact information was destroyed after contact or two weeks from attempted contact, if there was no response.   Contact was only attempted once so as to not intrude on the visitors.

The qualitative data were grouped by similarities of responses. These groups were established through induction to allow a more content sensitive grouping (Diamond, Luke & Uttal, 2009). All data was collected before any analysis was performed. The data were compared to the demographic data to determine any correlations.

CHAPTER FOUR

RESULTS

Visitor Profiles

In an effort to determine adult learning during a visit to a museum, interviews were conducted between February13 and May 24, 2014 at the Victor Valley Museum in Apple Valley. This museum is open Wednesday through Sunday and interviews were conducted on all days except Wednesday; the Wednesday that interviews were attempted, the museum received no visitors. The majority of interviews were conducted on weekends; Sundays provided 43% and Saturdays provided 40% of the interviews. Visitors in the 66-or-older age group were most numerous; see Table 1. No one was interviewed in the 18-to-25 age group. A staff member suggested that the age ranges of the interviewees were representative of the visitor profile of the museum; the museum kept no records of visitor demographics to use to verify this trend. Social media and the Internet have started to change the focal point of learning from institutions to web searches and sharing information over the Internet (Russo, Watkins & Groundwater-Smith, 2009), which may explain the lack of young adults at the museum. While the interviewees were random visitors who agreed to the survey, the tabulated results show an equal number of female and male visitors.

Table 1. Number of Visitors by Age Group

Age Group	Visitors
18-25	0
26-30	5
31-35	3
36-40	1
41-45	2
46-50	1
51-55	2
56-60	3
61-65	5
≥66	8

Seven visitors had been to the museum before but not since the exhibits changed in 2010. One visitor was at the opening of the "new" museum, but did not come into the exhibition area. Another had attended six or seven events but had not seen the exhibits. This visit was the first time for the remaining twenty one visitors. Thus, each visitor had no prior experience with the newly installed exhibits.

Visitors came to the museum for different reasons including the weather and to bring children to the museum; see Table 2. Weather included a day too windy to play golf and a day too hot to be outside. Children brought were frequently grandchildren and at least one great grandchild. These children are the future generation of museum visitors, because children who are brought to museums frequently bring their own children (Falk & Dierking, 2000).

Table 2. Reasons Visitors Came to the Museum

Reason	**Visitors**
Accompanying a person who wanted to see the museum	3
Curious	3
In AAA book	1
Interest in Local Area	3
Noticed/Driving by	3
Planned Visit	4
Take Child(ren)	8
Visiting Area	2
Weather	3

Museum attendance is a social activity and most people attend with others (Falk & Dierking, 1992; Ambrose & Paine, 2006). During this study, twenty five (≈83%) of the interviewed visitors were accompanied by children and/or adults. Six came with children, ten came with adults, and the remaining nine interviewees came with both children and adults. Only five visitors came unaccompanied.

Data were collected on occupations. All analyses of data was done after all interviews to insure uniformity. Occupational data were grouped into eight categories. While most are self evident, the distinction between blue collar and trades/professional categories was based on the education required; blue collar occupations required little more than instruction or minor on the job training, while trade/professional occupations required either extensive training or some advanced education. For example, the blue collar occupations include custodian and letter carrier, while the trade/professional occupations include electrician and graphic designer. See Table 3.

Indirect Learning

Falk and Dierking (2000) said that "we learn about…things that we almost already know"; Falk (1999) also considers learning in museums to consolidate and reinforce prior knowledge, that is to be conformational. Thus it is important to consider what the visitors found familiar. Occupations are not necessarily the best indication of what a visitor learns in a museum. One visitor, an English teacher with a minor in history found the history very interesting. This is a tenuous connection since the minor in history was probably taken because of an interest in history and not necessarily for employment. No other occupation had any bearing on what the visitors found interesting.

Table 3. Visitor Occupations

Occupation	Number of Visitors
Blue collar	3
Business	8
Education	4
Homemaker	2
Law Enforcement	1
Medical	2
Student	2
Trades/Professional	8

Interests and hobbies are often more important to the visitors' learning. For example, the visitor who likes free-style rock climbing was especially interested in the diorama of Red Rock Canyon and the visitor who likes old pictures associated these historic pictures of the area with their childhood. In general, interviewed visitors had numerous interests including reading, camping in sub-zero weather, basketball, and playing games. Many diverse activities had commonality and could be grouped: e.g. outdoor activities include such things as fishing, exploring, gardening, and hiking. Amateur radio includes science, outdoor activities, and socializing so it could not be put into any group; cooking and weaponry are also not easily grouped with other activities. See Table 4 for visitor interests.

Visitors to the museum were asked which of the exhibits were more interesting and least interesting. Based on the answers given by visitors, the exhibits have been grouped into simple categories: animals, back area pictures, Dale Evans/Roy Rogers/movies, desert/desert life, dioramas, fossils, geography of San Bernardino County, geology, local history/pictures, the meteorite, and Native American exhibits. The animals exhibited include a video of the desert tortoise, video and pictures of a variety of birds, and various taxidermic animals exhibited in multiple contexts. During the time of the interviews, the back area pictures were adjacent to an underdeveloped portion of the museum that is allocated for rotating exhibits from Apple Valley and neighboring cities (Almager. 2014. personal communication.); the first of these exhibits has now been installed.

Dale Evans and Roy Rogers were residents of Apple Valley and this exhibit explores their influence in the area and their connections with the Apple Valley Inn. Also, in this exhibit are their associations with various celebrities, movies, and photographic equipment. Desert/desert life is exhibited in parts of an Arctic climate exhibit, the Death Valley exhibit, and a desert diorama. Portions of the text panels show adaptions that allow plants and animals to survive the desert climate; examples of these plants and animals are also present.

Dioramas are part of several exhibits; two discuss desert climate of the Arctic and adaptations for desert life. There are also several large images of local rock formations and the desert diorama exhibited with taxidermic animals.

Several fossils are exhibited, but the most significant is a partial mammoth skull with tusks that were found in the area; these are shown as if they were being removed from the ground. The replica of a titanothere (Brontothere) skull is another important fossil because this relative of the horse, taper, and rhinoceros lived in California. The skull measures 78 cm long, has nasal horns 20 cm high, and rises to an impressive height of 62 cm at its back crest.

The geography of San Bernardino County is represented by maps showing the Mojave Trail and similar trails, locations of Native American Tribes, and the locations of several cities and features of San Bernardino County. Geology exhibits include a video of the San Andreas Fault/earthquake safety, fault and geological maps, minerals and their properties, some typical rocks, an impressive specimen of native copper from Michigan, and a large Brazilian geode containing amethyst crystals. Local history/pictures show early events and people in Apple Valley and neighboring mining and farming areas; these are adjacent to and flow from the Dale Evans/Roy Rogers exhibit. The meteorite is a replica of the Old Woman Meteorite which is exhibited at the Desert Discovery Center in Barstow and weighs 2,750 kg. The Native American exhibits show artifacts, dress, and information on traditional life styles of some local peoples. This information is exhibited in cases holding pottery, baskets, and jewelry, and a mannequin wearing traditional dress. In addition, there are text panels displaying various food sources and basket weaving. Petroglyphs are reproduced in one exhibit area and the Newberry twig figures are exhibited in two cases.

All areas of the museum were liked by at least one visitor except the back area pictures; one visitor said they were just pictures and not interesting. See Table 5. However, visitors selected four of categories both as the most interesting and as the least interesting of the exhibits in the museum; these selected categories are animals, Dale Evans/Roy Rogers/movies, fossils, and geology.

Table 4. Visitor Interests

Interest	Number of Visitors
Amateur Radio	1
Areas of Science	4
Cooking	1
Creative Activities	8
Family	3
Games	2
Home Improvement	4
Mechanical/Vehicles	5
Movies/Music	2
Outdoor Activities	9
Reading	4
Socializing	2
Sports	2
Travel	3
Volunteering	2
Weaponry	1

The animals were most interesting to five people, but least interesting to three. Positive comments indicated that people like animals. One visitor who likes big cats was especially interested in the mountain lion perched on a "rock ledge" over visitors' heads. Negative comments suggested that they had seen many of these animals when alive and therefore, more interesting than the taxidermic ones. The animals were not always labeled, which probably had a negative effect on visitor interest and their potential for education. For example, the bats would have had a more positive effect on visitors if identified and if given a brief signage explaining the importance of bats in insect control.

The exhibit featuring Dale Evans, Roy Rogers, and movies were favored by four, familiar to four other people, and disliked by three visitors. Two visitors indicated that they watched their shows as children. One of which liked Dale Evans' dress but was disappointed that Roy Rogers' shirt was not the usual shirt he wore on television; the visitor's father referred to it as that "old dirty shirt". One visitor was familiar with Dale Evans and Roy Rogers because they attended the same church. One visitor liked the movie stars that historically visited the area and another considered them self a movie buff. Those who did not favor this exhibit had seen the Roy Rogers/Dale Evans movies or suggested it was before their time. Another visitor thought making a connection to the movies was done too often and took away from the museum. Some of the movie stars were not identified well nor were they placed into historical context; this would have made this exhibit more educational.

Table 5. Visitors Who Liked the Exhibits

Exhibit	Number
Animals	3
Back Area Pictures	0
Movies Exhibit	4
Desert/desert life	3
Dioramas	2
Fossils	2
Geography	1
Geology	14
Local History	6
Meteorite	4
Native American	3

The fossils were more interesting to two visitors and two visitors did not find them very interesting. One visitor liked dinosaurs and so liked the fossils, perhaps not understanding that all the fossils in the museum were Cenozoic. One visitor was impressed that the mammoth was found in the area, but another thought it did not belong in the desert; perhaps that visitor did not connect the Ice Age lakes in the Death Valley exhibit or the Ice Age Lake Manix panel as an expression of a different climate when the mammoth lived in the area. It would be easy to inform visitors about the climate change with a small diorama or text panel near the mammoth exhibit showing a herd of mammoths near one of the Pleistocene lakes in the Mojave Desert.

The geology exhibits impressed fourteen people but not seven. Many visitors were impressed by the beauty of the minerals and one by the complexity of minerals. The minerals were selected for their variety and well developed external form; large text panels explained multiple aspects of minerals including crystal structure, physical properties, and optical properties. The mineral text panels were well done, but contained large amounts of information that could lead to museum fatigue (Falk & Dierking, 1992). The cone shaped geode at a little over one meter in length was impressive to several visitors; its very large opening is 74 cm across. One visitor enjoyed the San Andreas/earthquake safety video; the video was well made and Dr. Lucy Jones of the United States Geological Survey and emerita Professor Tanya Atwater of University of California, Santa Barbara appeared in it. Another visitor, who had recently moved to the area, liked the information on the fault locations; that visitor was happy to see that they did not live on the San Andreas Fault. One visitor just found the geology fascinating. Some of those who did not enjoy the geology exhibits were familiar with faults and earthquakes, because they had lived here all their lives or found the information available elsewhere. Some visitors were just not into science or rocks. The local rocks were especially not interesting to one visitor who said they did not belong in a museum. The local rocks could have been more interesting by giving more significant information about them and giving a location where the visitor could see the rocks in the field.

The dioramas were of interest to four visitors who like to hike, walk, or travel. Another visitor, who liked to hike, found the desert/desert life exhibits interesting. They were probably interested in these items because they were familiar or places they would enjoy exploring. Three of the visitors who found the geological exhibits interesting has an interest in geology, is a rock hound, and has interests in outdoor activities. One visitor who found the Native American exhibits interesting also likes turquoise and Native American culture; two exhibit cases contain turquoise jewelry. Another visitor who was born in the area expressed interest in the local pictures, especially the historical views. This was probably of interest because the visitor could see the changes that had occurred in the community. One visitor who liked to read express a strong interest in the reading room, which is not part of the exhibition area, but is a library open to the public free of charge. As such, the reading room is a great asset to the community. The books in the reading room are nonfiction and provide an educational experience to readers.

The Dale Evans/Roy Rogers/movies exhibit was of interest to one visitor who liked old western movies and possibly had seen some of their movies or television shows. Two visitors who preferred viewing historical or true to life movies/television showed an interest in the history of the area. This is a simple link between their leisure time interests and the information available in the exhibit. No other link was found between the preferred genre of movies/television and interests in the exhibits.

Visitors were asked if anything was familiar. In addition to Dale Evans, Roy Rogers, and the movie history of Apple Valley, eight visitors found desert plants/animals to be familiar. One specifically mentioned the badger and said they had seen a larger one in Texas, while another visitor was familiar with the musk-ox in the Arctic exhibit. Six visitors found some rocks/minerals to be familiar as well. The old pictures of the area are sometimes found in various businesses such as restaurants and therefore, were familiar to four of the visitors. These connections with things of interests and/or familiar indirectly suggests the potential for some learning.

Rennie & Johnston (2007) suggest that something new and interesting may induce people to "try to make sense of it in terms of what they already know". Learning involves linking things to what a person already knows and adults have an abundance of stored information (Illeris, 2002; Lorge, 1963). To discern what was new to visitors, they were asked about things that surprised them. One visitor was very surprised to see the exhibit explaining the Arctic is a desert. The snow that infrequently falls there lasts decades or more, and so gives the impression of a more stormy area. Another visitor was shocked to see the huge camera in the movie history area; that camera with its support measures 1.84 m long and including base, stands 1.87 m high. Six visitors were surprised by the fossils, and the mammoth and titanothere were specifically mentioned. The size of these fossils is very impressive. The mammoth is the size of a modern African elephant and the titanothere could reach 2.4 meters in height at the shoulder (Romer, 1966). While one visitor was surprised by the geode, another visitor was surprised by the diversity of minerals. Two visitors were surprised by the meteorite. Plants and animals surprised four visitors; they were especially interested in the creosote ring, the desert tortoises, and the burrowing owl. The creosote ring forms by the parent bush dying and the roots sprouting new plants. Thus, the DNA of that individual plant lives on for thousands of years, which would impress anyone. Tortoises are not usually associated with the desert by many people, so that can be surprising. A bird living in a burrow is also a surprise to those not familiar with this little owl. These surprises have the potential to impart knowledge.

See Appendix E for some photographs of exhibit areas that the visitors specifically mentioned and other exhibit photographs.

Direct Learning

Learning has been defined in this study as a change in attitude or behavior as a result of the museum visit or the retention of facts. While twenty four visitors provided contact information, only six responded to the follow-up interview. Of these visitors, four were female and two were male. Those who remembered some items from their visit were not able to give much detail. This may be due to the visitors not reflecting on the experience which is frequently the case (Falk, 1999). Their answers were vague; this was especially true of the email replies. See Table 6 for the visitors' age group and the synopses of their answers.

The visitor who remembered the mammoth bones brought a grandchild to the museum to see the bones and also mentioned discussing them at a later time. This probably resulted in learning by both grandparent and child. However, the child had an interest in dinosaurs and the large bones of the mammoth probably were interpreted as a type of dinosaur. Visitors to the San Bernardino County Museum in Redlands often confuse the mastodon exhibit as part of the dinosaur exhibit. It appears that many visitors do not know the distinction between these large animals.

The visitor who remembers some of the history, replied that the move into the area had not allowed the time to seek out more information; when time is available, this person will probably reinforce their experiences at the museum and learn from the visit. One visitor remembered the experience as a pleasant visit; this is one of the goals that the Committee (SCAAM, 1969) established for museums and a pleasant experience was provided by the museum. Other than these successes, there is little evidence for learning and that may be explained by remembering that a visit to a museum is a single event and therefore, not realistic for learning (Bamberger & Tal, 2006). This was the first time for all visitors to see the new exhibits. For a visit to a museum to produce solid learning, the visitor must have the new information reinforced (Anderson, Storksdieck & Spock, 2007). However, Diamond, Luke, and Uttal (2009) suggest that museum learning may be implicit and difficult to determine because the visitor may not be aware of this knowledge. Months may go by before the visitor realizes that they have learned from their museum visit; this insight may come when something similar to the museum information is experienced. Also, since learning in an informal setting such as a museum is not a conscious activity (Illeris, 2002), it may not be readily measurable.

Table 6. Follow-up Visitor Age Group and Response

Visitor Age Group	**What the Visitor Remembers**
26-30	Fossils, Native American Culture
31-35	Animals
61-65	History Old Pictures, Local Fossils, Pleasant Visit
≥ 66	Mammoth Bones

CHAPTER FIVE

SUMMARY, CONCLUSIONS, RECOMMENDATIONS

Summary

Indirect Learning

Learning in museums consolidates and reinforces prior knowledge (Falk, 1999). Because all visitors found something of interest, they have the potential to learn from their visit to the museum. Twenty-eight (≈93%) of the visitors found something familiar; they have the potential to have prior knowledge reinforced from their visit to the museum. One of the two that did not find something familiar was visiting from another state and perhaps they learned about California, because learning can be stimulated by new information (Rennie & Johnston, 2007). Twenty-three (≈77 %) visitors found something new and surprising in the museum and therefore, have potential to learn.

Direct Learning

Learning was expressed by one of the six visitors who participated in the follow-up questionnaire; this was the visitor who discussed the mammoth bones with a grandchild. A second visitor indicated that additional information would be sought, but was not able to do so because of the move into the area; this visitor remembered some of the local history. The other four visitors who answered the follow-up questionnaire may have learned some things in a vague manner; this may be implicit learning (Diamond, Luke, & Uttal, 2009). Even the visitor who only remembers the visit as a pleasant time may recall some information when related information is encountered.

Conclusions

Visitors have the potential to learn from the museum exhibits, but one visit is not always enough to establish learning. Because human learning is cumulative (Illeris, 2002) and is constructed from dynamic structures of experience and knowledge (Falk & Dierking, 2000), museum learning will occur when material viewed at the museum is reinforced. Encountering similar material is not always immediate. This study may have shown more learning if follow-up interviews were conducted after a few months or if second follow-up interviews were conducted. It should also be noted that fifteen (50%) of the adults who were interviewed brought children to the museum. Children who visit museums with their parents or grandparents typically bring their own children to museums; thus learning may occur in another generation of visitors.

Suggestions

The Reading Room is a community asset and should be promoted. It could be used as the site of book club meetings and the goodwill generated could increase the museum's presence in Apple Valley. Increasing the museum's community presence could also increase visitations. The Reading Room can be especially important to the senior residents in the facilities bracketing the museum. Often seniors do not have easy access to local libraries and most senior living facilities have limited library collections. The museum staff could hold an open house for their neighbors and introduce the Reading Room to them. Because the books within the Reading Room are nonfiction, they have a great potential to educate the readers.

Signage should be provided where missing. Things by themselves are interesting, but to be educational, information must be available. Many of the animals have no signage. Two examples follow. There is no signage to identify the bats and nothing to educate the visitor about their role in insect control. This bat appears to be the Yuma myotis (*Myotis yunanensis*) which is very similar to the related little brown bat (*Myotis lucifugus*) found further north of the desert. The Yuma myotis has duller fur than the little brown bat and hunts over water which the Mojave River does provide in several areas. The exhibit case containing the tortoise and *Opuntia* should identify them and explain how the *Opuntia* is used not only for tortoise food as the exhibit suggests, but also has been used by people from early Native Americans to present; the cactus shown appears to be the prickly pear, *Opuntia littoralis*, and both its pads (nopales) and fruit (tunas) are eaten.

The history of the area is very interesting, but one visitor found it a bit confusing. It could be improved by providing a timeline and better signage to identify past celebrities with their achievements; some of the younger visitors might not recognize many of the stars, even Roy Rogers and Dale Evans. The camera and potato plow worked well in this area, but a few more facts about each might improve their educational abilities. Suggested information that would be educational could include an explanation of why the camera was so large. Other information could include information of how potatoes grow and the need for the special plow to harvest them.

The mining history is missing a large amount of information, but since the local mining company (Mitsubishi) was completely uncooperative, there is little than can be suggested to improve the exhibit as it stands, except to identify the carbonate rocks in the display case. Perhaps, adding some of the historical mining information about the area may enhance this exhibit: e.g. the importance of the stamp mills at Oro Grande. See more information in Appendix C related to mining in the Mojave Desert.

The mineral area contains a large amount of information. Trying to absorb it all takes some time. There is no seating. Combining that much information with the visitor having to stand to read the panels could lead to museum fatigue (Falk & Dierking, 1992). Providing space for a bench or two may require one wall to be pushed out. Since three of the four walls are not bearing walls, that would not be that difficult to engineer. One major error in information needs to be corrected; it is located on the Rock Cycle panel. The descending plate does not melt as indicated in the illustration. This hypothesis has been refuted, but still persists in older books. One of the first studies that showed this to be in error was Wilshire (1984) who discussed metasomatism of the mantle. The release of volatiles that produce the metasomatism above the descending plate would lower the melting temperature in the mantle wedge and induce melting, as shown by Bowen (1956) in his seminal work on igneous rocks. Yet the magmas produced are not significantly lower in temperature, indicating a more complex process. It has been suggested that the descending plate drags some of the mantle wedge downward causing convection that brings hotter mantle toward the surface; thus magma is produced by introducing volatiles and by decompression of the upwelling mantle (Blatt, Tracy & Owens, 2006). That may be too much material for the exhibit, but just saying that magma is produced would be sufficient to correct the information error.

Publications should be available to provide visitors with additional information to reinforce learning from the exhibits. Because of the policy of only using publications printed in conjunction with the museum, local scientists and historians should be encouraged to write short books and/or articles for the museum. The museum has published the book Newberry Cave by Davis and Smith (1981). This contains a comprehensive description of the cave, natural materials, and artifacts found. To promote the sale of these materials, a small sign should be placed with the exhibit cases of the Newberry stick figures. It could be as simple as "A publication about this exhibit is available; see front desk for details". The generic wordage would allow the sign to be moved to different exhibits as needed and/or when the publication becomes unavailable.

The most important and final suggestion would be to remove the Death Valley exhibit and replace it with an exhibit on the Mojave River. Since only a very small and rarely visited portion of Death Valley National Park is in San Bernardino County, the exhibit is not fully relative to the museum's mission statement. The Mojave River occupies much of the Mojave Desert and therefore

San Bernardino County, so it is a better centerpiece. A panel with information on Afton Canyon and Ice Age Lake Manix is already in the museum exhibit area and should be incorporated into the new exhibit. The new exhibit could be called "The Mojave: the River that Grew in Your Own Backyard". Background information is given in Appendix C; exhibit design suggestions are found in Appendix D. Photographs of the Mojave River are shown in Appendix E. The background material and photographs could supply information to produce some booklets that could be sold at the front counter. The booklets would reinforce the learning from the exhibit.

APPENDIX A

INTERVIEW QUESTIONS AND DEMOGRAPHIC QUESTIONAIRE

Oral Interview

Did you enjoy the museum?

Was the museum what you expected? Why or why not?

What exhibit was the most interesting to you? What made it interesting? Can you elaborate on that?

Did you see anything that surprised you?

Did you see anything that was familiar to you?

What exhibit was the least interesting to you? What made it uninteresting? Can you elaborate on that?

Demographic Survey

Why did you decide to visit the Victor Valley Museum today?

Have you been to this museum before? If so, how many times?

Who came with you today? Check all that apply.

- o No one
- o Family under 18 years of age
- o Adult family
- o Friends

What is your occupation? If retired, what was your occupation?

Please list any hobbies:

What genre in movies and television do you prefer?

Please give your gender:

Please select the appropriate age range:

- o 18-25
- o 26-30
- o 31-35
- o 36-40
- o 41-45
- o 46-50
- o 51-55

o 56-60

o 61-65

o 66 or older

If you would be willing to give a follow-up interview in 4 weeks, please provide your contact information; telephone number, email address, or mailing address. If you do not want to be contacted, please leave this blank.

Follow-up Interview Questions:

Have you been back to the museum since your visit four weeks ago? If so, what exhibit was of interest this visit? If not, will you revisit the museum in the future?

Did any questions regarding the exhibits come to your mind since the visit?

What do you remember about the visit four weeks ago?

Have you looked for any additional information about what you saw at the museum?   If so, were you successful in finding what you wanted to know?

Any suggestions for future exhibits?

APPENDIX B

DATA

Interviewees' Answers to Questions

Inter-view #	gender	age	occupation	interests/hobbies	genre	visits	expected	accompanied by
1	male	56-60	general contractor	solo/freestyle rx climbing	action	1st	yes, small	no one
				sculpting, hiking, cooking	historical			
				camping in sub-zero				
2	male	51-55	custodian	working around house	westerns and old movies	3rd or 4th	no, totally	family, adult &
					with life messages		different	child

Inter-view #	gender	age	occupation	interests/hobbies	genre	visits	expected	accompanied by
3	male	46-50	truck driver	reading, writing	horror	1st	more than expected	family, adult & child
4	female	56-60	teacher	all outdoor activities e.g. gardening	old westerns this week all	1st	not sure what to expect	adult family
5	male	>66	broadcasting instructor	fishing , motorcycles	adventure, syfi, crime	1st	yes, geology	adult family

Inter-view #	gender	age	occupation	interests/hobbies	genre	visits	expected	accompanied by
			at college		historical		animals	
							missing photos	
6 +	female	26-30	unemployed	volunteer c community	old black/white movies &	2nd or 3rd	yes, was here	family adult & child
			account rep	& church	early color movies		years ago	
7	female	41-45	housewife	her kids	all	1st	small town so	children
							small size	

Inter-view #	gender	age	occupation	interests/hobbies	genre	visits	expected	accompanied by
8	male	36-40	student of theater arts/	being outdoors c nature	comedy, educational	3rd	no, more variety	no one
			army national guard	socializing c elderly	history, travel, cooking			
					culture			
9	male	41-45	electrician	rx hounding, 4-wheel	syfi, documentaries	2nd	yes, similar to Redlands	family, adult &
				drive vehicles			but smaller	child
10	male	26-30	graphic designer	drawing, movies, music	horror, documentary	1st	yes, about area	adult family

Inter- view #	gender	age	occupation	interests/hobbies	genre	visits	expected	accompanied by
				sports, apt?			pictures/artif acts	
11	male	31-35	installation tech	model building, hiking	mystery	1st	more than expected	family, adult &
				off-road driving				child
12 +	male	31-35	pest control owner	Xbox, star wars, classic	syfi, drama	1st	no, more Victor Valley	child
				cars			history, actual science	

Inter-view #	gender	age	occupation	interests/hobbies	genre	visits	expected	accompanied by
13 +	female	61-65	nurse	genealogy, old pictures	everything: history channel	2nd, years	no, more old things	family, adult &
					cooking channel, NCIS, old	ago	needed	child
					car shows, WWII			
14	male	31-35	student/ was campus	archery, gun range,	action/adve nture, comedy	1st	yes, been to other	child

Inter-view #	gender	age	occupation	interests/hobbies	genre	visits	expected	accompanied by
			security officer in SB	learning about survival,	suspense, thrillers, horror		museums, smaller	
				family				
15	male	>66	credit analyst	hiking, outdoor activity,	documentary eg discovery	1st	no, smaller , need more	no one
				exploring via hike/drive	channel		area material	
16	female	>66	retired, medical field	reading, traveling,	comedy, sitcoms, historical	1st	more than expected	family, adults

Inter-view #	gender	age	occupation	interests/hobbies	genre	visits	expected	accompanied by
				camping	drama, period pieces		esp. wildlife, Victorville	
							mammoth	
17	female	61-65	letter carrier for USPO	hiking, photography,	documentary, biographical	1st	no, more than expected	family, adults
				rock hounding			esp. fossils	
18	female	>66	retired, school cafeteria	reading, walking	comedy, news,	2nd	yes, but bigger now	family, adults
			worker		biographies			

Inter-view #	gender	age	occupation	interests/hobbies	genre	visits	expected	accompanied by
19 +	male	61-65	retired, painted 747s	Chess!, horseshoes, darts,	syfi!, westerns, drama about	1st	no, expecting more	no one
				cards e.g. hearts, spades,	horses esp. racing, historical		about people/animals/	
				pinochle, blackjack	movies, Vikings,		Indians, caves	
20	female	61-65	Pharmaceutical sales	reading historical & civil	no TV, well made movies of	2nd/1st	no, removed exhibit of	no one

Inter-view #	gender	age	occupation	interests/hobbies	genre	visits	expected	accompanied by
			manager	war, hiking/camping,	all types -- no profanity	prior 2010	husband's uncle	
				cleaning house, being				
				with family, exercise				
21	female	26-30	office assistant in	drawing, basketball	action, comedy	1st	no, better, colorful	family, child
			customer service					
22	female	26-30	customer service Lowes	music, camping, day	documentaries, true stories	1st	no, bigger, more info	boy friend, children

Inter-view #	gender	age	occupation	interests/hobbies	genre	visits	expected	accompanied by
				dreaming, making various	syfi, suspense, cartoons,			
				things eg clothing, jewelry	Travel, Food, Hgtv			
23	female	51-55	none	arts and crafts, making	country movies & music	1st	no, more exciting	family, adult
				jewelry, going places with				
				mother				

Inter-view #	gender	age	occupation	interests/hobbies	genre	visits	expected	accompanied by
24	female	>66	retired business owner	volunteer work, daughter	old movies, action TV,	1st	no, expect less quality	family, adult
				cooking, crocheting	intrigue			
				citizen group at VVC				
25 +	female	61-65	controller	sewing, gardening	public TV, Hgtv, golf,	1st	in some ways, lots of info	family, children
					football			

Inter-view #	gender	age	occupation	interests/hobbies	genre	visits	expected	accompanied by
26 +	female	>66	high school English	travel, MBA fan	basketball, music variety	6-7 times	better	family, child
			teacher/history minor		shows, news, historical, WWII	programs		
27	male	26-30	math teacher - middle	yard work at new house,	no TV, kids movies, older clean	1st	yes, had been to the	family, adult &
			and high school	astronomy, math	movies, nature		Redlands museum	children

Inter-view #	gender	age	occupation	interests/hobbies	genre	visits	expected	accompanied by
28	male	>66	law enforcement	geology, ham	news, A&E, Discovery,	1st	no, among the top	family, adult
					American Pickers, Antique			
					Road			
29	female	>66	cosmetologis t	painting, crafts eg needle	Animal Planet, Nat. G. horror	1st	yes, very educational	family, adult & child
				point, gardening, humming	housewives		the purpose of a	
				birds			museum	

Inter-view #	gender	age	occupation	interests/hobbies	genre	visits	expected	accompanied by
30	male	56-60	truck owner, operator	girl friend, motorcycle,	sport esp NASCAR	1st	yes, it's a museum	girl friend
				anything mechanical				
				wheels				

interview #	reason	most interesting exhibit	least interesting exhibit	familiar	surprised
1	local interests	red rx canyon, birds	too broad of an area	old pictures	no
		visual of canyon	wanted within 40-50 miles		

interview #	reason	most interesting exhibit	least interesting exhibit	familiar	surprised
2	interested in things	earthquake video/plate tectonics	fossils	plastic casts	no
	that surround my life	rx & minerals with different shapes		some minerals	
		meteorite density/weight			
3	noticed for first time	faults, new info on valley	nothing	animals	camera size
		meteorite		cactus	wooden frame
		scavenger hunt for kids			proximity to fault

interview #	reason	most interesting exhibit	least interesting exhibit	familiar	surprised
4	whim, not from California	large geode, earthquake pictures	labels not on minerals	Dale Evens dress	geode
	to see where I am at	Dale Evens dress, N. Am artifacts	Roy Rogers dress shirt was		
		minerals	not one wore most of the time		
			which father called old dirty shirt		
5	my cousin wanted to see it	artifacts, geology, foot prints	would like buttons to push for more	desert sand, lizards, Joshua tree	not more people
	so did I	meteorite from space	information	general features of area	

interview #	reason	most interesting exhibit	least interesting exhibit	familiar	surprised
		reading room: like to read			
6 +	to take the children	N. Am pottery because likes	Dale Evens, Roy Rogers because	musk-ox	meteorite
		turquoise & culture, fossils	not of that time		
7	her 3 kids wanted to come	history of Apple Valley, movie stars	nothing	rattle snake, coyote	fossils in high desert
		that came esp. Roy Rogers & Dale			
		Evens			

interview #	reason	most interesting exhibit	least interesting exhibit	familiar	surprised
8	in area, verison tower	movie material because movie buff	nothing	N. Am artifacts from other	rx formations
		Roy Rogers, big buffalo (?musk-ox)		museums	
9	curious, buy scientific papers	history of area because family has	animals least but still interesting	geological material from on-line	creosote
		lived here since grandparents		some minerals	some minerals
10	was intending, perfect day to	Apple Valley material, model home	earthquakes/faults - info available	pictures of town, rxs, mining	wildlife - tortoises

interview #	reason	most interesting exhibit	least interesting exhibit	familiar	surprised
	come to the museum	TV screen c pictures, related to	other places		
		historical places			
11	wanted to take daughter	geological because rx hound,	climate, this is a desert so it is dry	geology, rx of area, animals of	history/fossils of area
		N. Am. because in background		area, N. Am. Stuff because loves	more than expected
				history	
12 +	too windy for golf	desert wildlife because like animals	fault lines because lived in So Cal	nothing	geode, meteorite
			all life		

interview #	reason	most interesting exhibit	least interesting exhibit	familiar	surprised
13 +	bring grand kids	old pictures of area when young	none, love museums	some old pictures, animals, birds	nothing
		because born here, geology			
14	haven't been to museum in	mountain lion, fossils because likes	regular rxs, see every day so don't	N. Am. stuff saw as kid when visited	not really anything
	couple of years, wanted to	big cats and dinosaurs	need in museum	place where sold/ lived, roadrunner	some of the old photos
	bring son			also saw as kid	and pottery

interview #	reason	most interesting exhibit	least interesting exhibit	familiar	surprised
15	saw when driving by	early Victorville canal, moving into	nothing, maybe Las Vegas Wash	most seen somewhere before	no book about area
		area and wants to know about it			
16	curious	dioramas, tiny bird	rxs, never interested in them	Death Valley & Joshua Tree exhibits	mammoth, Arctic is a
				been there	desert
17	Always wanted to come in	geology/stones, plants and animals	nothing	from out of town aka state	mammoth

interview #	reason	most interesting exhibit	least interesting exhibit	familiar	surprised
	and family visiting	that survive in desert			
18	curious	dioramas, originally from Alaska	nothing	Roy Rogers, Dale Evens, attended	mammoth
				church with them	
19 +	wanted to come for 10 years	Indian actives because has a	birds, Mother had hummingbird	stones, geodes know about	fossils found here
	has property in area	grinding stone, petroglyphs,	feeders, seen roadrunner		
		mammoth found here			

interview #	reason	most interesting exhibit	least interesting exhibit	familiar	surprised
20	wanted to see exhibit about	geology/paleo	nothing	Dale Evens & Roy Rogers as part of	amount of minorities in
	uncle who was athlete like			area history	historical exhibit
	son,				
21	spend time with son and show	geology/geode, meteorite, rxs	back part just pictures	animals of area, maps	Dale Evens & Roy
	him the history of area				Rogers costumes
22	boy friend wanted to visit	gems, history of area,	maps, earthquake - afraid of	old boxer did report on him in high	titanothere

interview #	reason	most interesting exhibit	least interesting exhibit	familiar	surprised
			them	school, Hollywood history	
23	mother brought, wanted to see	meteorite it came from space	nothing	badger - bigger one in Texas	not sure
	things for self	gems made by Earth			
24	at opening but didn't get in	4 deserts in California/ only in N. Hemi	Hollywood connection	minerals - worked for company with	bones, pottery in such

interview #	reason	most interesting exhibit	least interesting exhibit	familiar	surprised
	until now	Mojave is smallest	lessens the museum, too much	minerals exhibit	good shape
			is made of it		
25 +	thought might be interesting	geology - fascinating	nothing	Roy Rogers, heard about in high	desert tortoise didn't know
	local history			school	they could live is desert
26 +	brought great grandson to see	history of area, Roy Rogers & Dale	plate tectonics - not into science	desert animals	nothing - visit lots of
	animals, bones	Evens - childhood heroes			museums

interview #	reason	most interesting exhibit	least interesting exhibit	familiar	surprised
27	hot day, wife wanted to visit,	geology, relevant to area	animals - seen alive before	pictures of old Victorville - often as	not actually on the San
	open on Saturdays			decorations in restaurants	Andreas fault
28	between visits to family, in AAA	minerals - complexity, history of	Roy Rogers - seen his movies	borax, fossils, animals	burrowing owl hunt on
	book	people of area & how they survived			the ground
29	to bring granddaughter	minerals & rxs, also interest to child	nothing, because love to learn	gems	Southern mammoth

interview #	reason	most interesting exhibit	least interesting exhibit	familiar	surprised
					tusk from Victorville
30	seen before and decided to stop	all, nothing special	mammoth, didn't fit in a desert	Roy Rogers in Apple Valley	no

interview #	returned	will return	questions	remember	new info	suggestions
6 +	no		no	fossils, Indian culture	no	more displays in back, hands on

interview #	returned	will return	questions	remember	new info	suggestions
12 +	no		no	animals	no	celebrities
13 +	no	yes	no	old pictures, local fossils	no	more history of Apple Valley,
						pony express, Oro Grande
						various farms of area
19 +	no	yes	no	history of area	too busy	none
					/moved into area	

interview #	returned	will return	questions	remember	new info	suggestions
25 +	no	no	no	pleasant	no	make a time line easier to follow
26 +	no	yes	no	mammoth bones	no	more info on area

APPENDIX C

BACKGROUND MATERIAL FOR MOJAVE RIVER EXHIBIT

Geology

Before the Mojave River Existed

Prior to the uplift of the San Bernardino Mountains and the development of the Mojave River, Mojave Desert streams flowed toward the south through the area now occupied by Cajon Pass and into the Los Angeles Basin (Knott, el al, 2008). Sediments from this stream system, the Cajon Valley Beds and Crowder Formation, are exposed in Cajon Pass by the erosion of Cajon Creek. The Miocene to Late Pliocene south flowing stream system drained much of southern and central Mojave Desert. Its primary headwaters may have been near Iron Mountain. The highly weathered, low relief surface of the Mojave Desert produced a braided stream system with a major channel now buried beneath Southern California Logistics Airport, formerly George Air Force Base (Cox, Hillhouse, & Owens, 2003).

Initial Ancestral Mojave River

In the Late Pliocene, at approximately 3.5 Ma, the ancestral Mojave River started to form as the Transverse Ranges began to uplift along the San Gabriel Fault (Knott, el al, 2008; Cox, Hillhouse, & Owens, 2003). These mountains were uplifted in a series of blocks with thrusting and oblique slip along several faults including the San Andreas (Spotila, 1998). Sediments from the growing San Bernardino Mountains were transported by the ancestral Deep Creek from at least the Big Bear area and perhaps as far away as the headwaters of present day Santa Ana River. As the mountains were growing, basins formed within the Mojave Desert; the Victorville Basin developed at approximately 2.0 to 1.5 Ma during the onset of rapid uplift of the San Bernardino Mountains. The initial terminus of the ancestral Mojave River was the Victorville basin; up to 1300 m of sediment were deposited in this depression. During the Pleistocene at about 1.5 to 1.0 Ma, the uplift of the San Bernardino Mountains began to slow and the Santa Ana River captured the probable headwaters of Deep Creek. The increase in precipitation in the mountains from 1.2 to 1.0 Ma as well as an increase in sediment coming from Summit Valley through the West Fork tributary of the Mojave River aided in filling the Victorville Basin (Cox, Hillhouse, & Owens, 2003).

Ancestral Mojave River Extending Northward

The Mojave River began to flow out of the Victorville Basin around 500 ka and flowed through a channel developed by the old southward drainage. The new terminus of the growing river was Harper Lake; here it formed a delta. Harper Lake appears to have been the main terminus for the Mojave River for only about 75 ka, after which it flowed to the east and into Manix Basin; the eastward deflection could have been caused by the original southward paleoslope (Cox, Hillhouse, & Owens, 2003) or movement on northwest-southeast right-lateral faults (Enzel, Wells & Lancaster, 2003). Sediment deposits suggest that the Mojave River could have alternated between Harper and Manix Lakes with flows into the Manix Basin becoming more dominate. There is also the possibility of the Mojave River flowing into Lucerne Valley at this time; now the Mojave River and Lucerne Valley are separated by a low divide (Cox, Hillhouse, & Owens, 2003).

Ancestral Mojave River and Lake Manix

Lake Manix was comprised of four sub-basins; Coyote, Troy, Manix, and Afton. The original geometry has been modified by deposition of fluvial and deltatic sediments that separate the sub-basins today (Reheis, Miller & Redwine, 2007; Enzel, Wells & Lancaster, 2003). The initial Lake Manix developed in Manix and Troy sub-basins. Water would overflow into Coyote sub-basin when the lake level was greater than 541 meters above sea level (masl). Thus, the control of the water level in Lake Manix was the ridge between Coyote and Manix-Troy sub-basins and the amount of water reaching the area; periodically, some water may have been diverted to Harper Lake. The first waters to form a lake arrived in the Manix Basin about 450 ka (Reheis, Adams, Oviatt & Bacon, 2014). However, the lake was not continuously full during the Pleistocene; there were eight known major high stands that correspond with glacial conditions in the mountains and elsewhere (Reheis, Miller & Redwine, 2007). During the last glacial maximum and perhaps at other glacial advances, the storm track typically crossed Southern California between ≈34^0 to 35^0 N; that is, it crossed the Transverse Mountains and Southern Mojave Desert (Enzel, Wells & Lancaster, 2003), rather than further north as it does today. During the interglacials, less rain fell in the San Bernardino Mountain headwaters and the lakes lowered or dried. Thin alluvial fans with paleosols (Reheis, Adams, Oviatt & Bacon, 2014) and weak soil development along the lake margins (Reheis, Miller, M^c^Geehin, Redwine, Oviatt & Bright, 2015) marked the dry stands of Lake Manix. With few glaciers within the San Bernardino Mountains, Lake Manix water level fluctuations responded to stream flow and evaporation, thus providing a good record of the Late Pleistocene climate (Reheis, Bright, Lund, Miller, Skipp & Fleck, 2012; Wells, Brown, Enzel, Anderson & McFadden, 2003; Reheis, Miller, McGeehin, Redwine, Oviatt & Bright, 2015). Information contained in the sediments of Lake Manix indicate that most moisture came from winter storms in the Transverse Mountains until about 130-80 ka (marine isotope stage 5). At that time, summer monsoonal storms began to occur; this extra water allowed lakes to persist into the interglacials (Reheis, Bright, Lund, Miller, Skipp & Fleck, 2012). Higher lake levels are also correlated with cooler sea surface temperatures and coastal plants that required more moisture; pollen studies produced information on the plant communities (Reheis, Miller, McGeehin, Redwine, Oviatt & Bright, 2015).

Lake Manix Extends into Afton Sub-basin

Afton sub-basin began to fill with lake water from Lake Manix around 185 ka when the Buwalda Ridge to the west of the Afton sub-basin breached catastrophically. This ridge was comprised of a sheared fanglomerate, which was overtopped causing the failure (Reheis, Adams, Oviatt & Bacon, 2014; Reheis, Miller & Redwine, 2007). The shearing of the fanglomerate was produced by left-lateral movement on the Manix Fault; this fault can also be seen in Afton Canyon (Nagy & Murray, 1996). Prior to this event, Afton sub-basin received only locally derived waters (Reheis, Bright, Lund, Miller, Skipp & Fleck, 2012). The failure of Buwalda Ridge left large (≈2m in length) blocks of lake sediments mixed chaotically with brown playa muds from further upstream.

Above this layer, the fining sediment contains volcanic ash dated at 184 ka (Reheis, Adams, Oviatt & Bacon, 2014) providing a minimum date for this event.

After Afton sub-basin became part of Lake Manix, the water level rose10-15 m and reached the highest stand of ≈543 masl (Reheis, Miller & Redwine, 2007). This did not indicate more water than usual; it was caused by less space available for the water (Cox, Hillhouse, & Owens, 2003). Evidence suggests that Lake Manix was frequently shallow (Reheis, Bright, Lund, Miller, Skipp & Fleck, 2012). The area of the Mojave River between Deep Creek and Barstow was being reworked and a large amount of sediment was entering Lake Manix. Much of this material was deposited as a delta; today, those sediments form a ridge that separates Coyote and Troy playas (Cox, Hillhouse, & Owens, 2003). The infilling produced a shallow lake and reduced the storage space needed for the river water (Reheis, Adams, Oviatt & Bacon, 2014; Reheis, Bright, Lund, Miller, Skipp & Fleck, 2012). It was this reduction of space that lead to the overtopping and failure of Buwalda Ridge (Enzel, Wells & Lancaster, 2003).

<u>Afton Canyon Forms</u>

The continued infilling of Lake Manix caused water to begin to flow eastward out of the Afton sub-basin. An abandoned spillway south of Afton Canyon may have been the original discharge site (Wells, Brown, Enzel, Anderson & McFadden, 2003). It is not known if the formation of Afton Canyon was as catastrophic as the failure of the Buwalda Ridge. There are terraces in the canyon that may be interpreted as the result of episodic erosion over thousands of years (Enzel, Wells & Lancaster, 2003). However, no recessional shorelines are recognizable (Reheis, Miller & Redwine, 2007) and the terrace soils are not distinct enough to determine their origin (Reheis, Adams, Oviatt & Bacon, 2014).

Formation of Afton Canyon is not well constrained, but it is a young feature (Enzel, Wells & Lancaster, 2003). Cox, Hillhouse, & Owens (2003) estimated the failure of the eastern edge of Afton basin occurred at 18 ka, which is in agreement with dates found for the Lake Mojave downstream of Afton Canyon; however, newer work suggests 25 ka is a more probable date (Reheis, Adams, Oviatt & Bacon, 2014). The sediments from the erosion of Afton Canyon are present in a deltatic plane east of Afton Canyon; the plane probably formed during a time of high groundwater in that area (Enzel, Wells & Lancaster, 2003). This plane has been called the Mojave River Sink by Lancaster & Tahakerian (2003), the Mojave River Fan Delta by Wells, Brown, Enzel, Anderson, and McFadden (2003), and the Mojave River Wash on the map of San Bernardino County (Automobile Club of Southern California, 2002); the map name will be used in this exhibit because the map is available to visitors to the museum. After the formation of Afton Canyon, Mojave River water could still enter Coyote sub-basin upriver from Afton Canyon. River water could also enter East and West Cronese, Soda, and Silver basins below Afton Canyon. Water entering East Cronese north of the Mojave River would fill until 2 m deep, then the water would flow into West Cronese (Reheis, Bright, Lund, Miller, Skipp & Fleck, 2012).

Lake Mojave

Prior to the integration of Soda and Silver basins with the Mojave River, Lake Mojave was filled by water coming from the area between Cima Dome and Providence Mountains (Wells, Brown, Enzel, Anderson & McFadden, 2003). However, about 180-125 ka (marine isotope stage 6), there is no record of a lake in these basins while there was abundant water in other lakes; thus, it has been suggested that the drainage area was not sufficient to maintain a lake (Knott, el al, 2008). It is also not well known if or how Soda and Silver basins were connected to other lakes prior to the Mojave River integration. It has been suggested that water flowed out of Death Valley through the Amargosa River and into these basins, but related oxidized orange-brown sediments are not consistent with lake sediments (Knott, el al, 2008) and evidence does not support a mega-lake Manly that could discharge into the Amargosa River (Enzel, Wells & Lancaster, 2003). It has also been suggested that during the last glacial maximum at about 20 ka, water from these basins formed Lake Mojave, which was 287-288 m deep and probably drained north toward the Amargosa River and Death Valley (Enzel, Wells & Lancaster, 2003). If Afton Canyon formed during the earlier suggested time of 25 ka, then this water would have come from the Mojave River system. While the origin of the early lake is unclear, there are two documented Mojave Lakes that are known to be related to the Mojave River; Lake Mojave I, which existed between 18.4 and 16.6 ka and Lake Mojave II, which existed between 13.7 and 11.4 ka. Wells, Brown, Enzel, Anderson, and McFadden (2003) suggest that Lake Mojave II developed after Afton Canyon formed, had increased sediment that filled Soda basin, and was more turbid and colder than the prior lake in these basins. Smaller lakes existed between these two high lake stands; but there were also severe drying events with the greatest at 15.5 ka that is marked by large mud cracks in filled with eolian sediment.

Eolian Activity

Eolian Processes

As the climate changed from the wetter Pleistocene to the modern desert, flow in the Mojave River decreased, lakes dried, and the vegetation cover decreased. The Mojave River bed became a source of eolian sediment. Normal winds are able to move sand (1/16 to 2 mm) and smaller particles out of the dry river bed; today this occurs after floods. The smaller particles, silt and clay particles (1/256 to 1/16 mm and < 1/256 mm, respectively) (Marshak, 2004) would be suspended in the turbulent wind while the larger sand grains would move by saltation. The word saltation comes from the Latin "salta" meaning to leap; during saltation, sand grains are picked up by the wind, carried a short distance, and then fall to the surface giving the appearance of playing leap frog. The silt and clay may be carried high into the air while sand is usually lifted only a meter or two. When the wind velocity decreases or the wind is blocked by a bush or other object, the sand falls to the surface; then it is able to form its own wind block also called a zone of flow separation, allowing more sand to collect. As the sand builds up into a large pile, the upper edge will fail if steep enough and sand will avalanche down the side away from the wind (Schenk, 1990b); this is called the slip face. The slip face is the steeper side of a dune. As the sand continues to saltate up a dune and then avalanche down the slip face, the dune migrates downwind.

Sand may accumulate in a flat sheet; however, the sheets can collect enough sand in areas that dunes may form. Dunes may be very complex in shape, but some simple shapes can be recognized; dunes also climb onto other dunes and this complicates shapes. If the wind does not vary much the barchan, transverse, and parabolic dunes may form. Barchan dunes are u-shaped with the u open downwind; that is the horns of the dune point in the direction the wind blows. The slip face of a barchan dune is on the inside of the u. Transverse dunes are linear with the wind blowing across the dune (Schenk, 1990a); "trans" is Latin for across. The slip face of these dunes is on one long downwind edge of the dune. Where there is vegetation that impedes sand movement the parabolic dune may form; these dunes are also u-shaped but the slip face is on the outside of the u. The horns of a parabolic dune are stabilized by vegetation and point into the wind; that is, the plant roots hold the sand of the horns in place. With the horns of the parabolic dune stabilized, the horns become elongated as the dune migrates.

In areas where there is some variation in wind direction, longitudinal or seif dunes may form. In both, the wind blows roughly parallel to the dune's length and they have two slip faces, one on each side (Schenk, 1990b). The longitudinal dune has a linear form. The seif dune is similar but has a small curved barchan-shape on the upwind end; this dune is named after the Arabian knife with a curved blade. The longitudinal and seif dunes can migrate slowly. As the wind patterns become more complex, star dunes may form. In these dunes, the sand tends to build upward (Schenk, 1990b) and the dunes do not migrate.

<u>Mojave Desert Eolian Deposits</u>

As is true in all deserts, eolian sediments and landforms are widespread in the Mojave Desert but not dominate. The large and impressive Devil's Playground has active barchan dunes up to 5 m tall and some seif dunes (Norris & Webb, 1990) as well as stabilized sand ramps and sheets. Kelso Dunes began as sand sheets and accumulated additional sand that comprises the 14 dune units of different sizes, spacings, alignments, and types (Lancaster & Tahakerian, 2003). These dunes have evolved over time and under different wind regiments.

Eolian sediments that originated in the Cronese basin have formed climbing and falling dunes on the adjacent mountains. The better known "Cat Dune" is a falling dune on the east side of Cronese Mountains. The sand saltated up the other side of the mountain and is now sliding down the east side. As with most of the Mojave Desert dunes, eolian activity was more aggressive toward the end of the Pleistocene and early Holocene; e.g. the "Cat Dune" formed between 24 and 8 ka. This is due to less fine grained sediment available for the wind to erode after this time. As the wind erodes sand and smaller clasts, it leaves behind larger clasts as lag deposits; gravel lag fields occur on the Mojave River Wash, an important source of eolian sediment for the Devil's

Playground and the Kelso Dunes. Today, episodes of increased eolian activity occur after major floods of the Mojave River, which bring in more fine grained sediment (Lancaster & Tahakerian, 2003).

Hydrology

Mojave River System

The Mojave River is the only important large drainage system in the Mojave Desert (Peirson, 1970; Cox, Hillhouse & Owen, 2003). Its drainage occupies an area of about 9500 km^2 (Enzel, Wells & Lancaster, 2003). The headwaters in the San Bernardino Mountains comprise <5% of the drainage but supply >90% of the water flowing in the river (Wells, Brown, Enzel, Anderson & McFadden, 2003). The San Bernardino Mountains at $\approx 34^0$ N intersect only a few of the winter storms because the modern storm track is further to the north. Even as such, the mountains do average over 1000 mm of precipitation annually (Enzel, Wells & Lancaster, 2003). Orographic lifting removes most moisture from the winter storms, so much less precipitation is received downstream; e.g. Victorville receives an average of 125-150 mm and Silver Lake receives only 75 mm annually (Enzel, Wells & Lancaster, 2003). Summer storms are usually associated with tropical cyclones and the isolated rainfall does not contribute to Mojave River floods (Faye, 1956). Most of the summer rains occur in August and downstream of Barstow, i.e. in the east (Wells, Brown, Enzel, Anderson & McFadden, 2003).

The main tributaries of the Mojave River are Deep Creek (aka East Fork) and West Fork; Deep Creek drainage is nearly twice the area of West Fork drainage. West Fork traverses the alluviated Summit Valley while Deep Creek arises in Holcomb Valley and flows over less alluviated terrain. The discharge of Deep Creek increases rapidly after rain storms due to thin soil overlying impervious bedrock common to its valley (Peirson, 1970; Faye, 1956). While the snow pack does not seem to increase the peak stream flow (Faye, 1956), it does feed the groundwater that later discharges into the mountain streams; thus Deep Creek is perennial until joining West Fork to form the Mojave River. The steam draining the Lake Arrowhead area also carries groundwater to Deep Creek (Drylie, 2010).

There are three reservoirs in the headwaters of the Mojave River that store water. Lake Arrowhead is recreational and has only minor impact on the discharge of the headwaters; Lake Gregory does not seem to be involved in storage (Webb, Berry & Boyer, 2001; Lines, 1996). Lake Silverwood and the Mojave River Forks Reservoir are impounded by Cedar Springs Dam and the Mojave River Forks Dam, respectively; these dams were completed in 1971 (Lines, 1996). Lake Silverwood is part of the State Water Project and must release any natural input of water into the Mojave River (Orr, 2008). The Mojave River Forks Dam is only for short-term storage of water during extreme floods and releases the water within a few hours (Mojave Water Agency, 2004; Lines, 1996); it seems to attenuate the extent of flooding. The fish hatcheries below the Forks release water that is usually used for irrigation and only excess water enters the Mojave River. The construction of a golf course in 1994 increased the need for irrigation from the hatcheries' discharge so water enters the river only in the winter; during winter there is less use of groundwater and lower evapotranspiration (Lines, 1996).

Historical Flows and Floods

Historically, there were swamps and surface flow in the Mojave River. Today, there are only two areas that tend to have consistent surface flow: the two Narrows in Victorville and Afton Canyon. The Upper and Lower Narrows are perennial, but Afton Canyon has been observed not to have surface flows some late summers (Lines, 1996; Peirson, 1970). After 1931, surface flow of the Mojave River at Barstow only occurs during storm runoff and during floods (Lines, 1996). Documented floods occurred in 1903, 1905, 1907, 1910, 1914, 1916, 1921, 1922, 1938, and 1943 (Frye, 1956). The largest measured flood occurred in 1938 which was not an El Niño year; it would have been caused by atmospheric-river storms often referred to as the pineapple express, because the storms originate in the Hawaiian area of the Pacific Ocean. Floods associated with El Niño years include 1891, 1905, 1916, 1978, 1983, 1993, and 1998. During these floods, water reached the terminus of the Mojave River, Silver Lake (Webb, Berry & Boyer, 2001). Peirson (1970) reports that flood water occupied Silver Lake for several weeks in 1938 and for several months in 1969. The latter year was not reported as a flood year suggesting storms were not a closely spaced series. During the 1983 flood, the Mojave River overflowed in the Lenwood area and water reached Harper Lake, the initial terminus of the river after it escaped the Victorville basin. There is no historic record of West Cronese receiving flood waters; thus, East Cronese never was over 2m deep (Lines, 1996). On the average, some significant flooding occurs every five years and is important to the remaining riparian vegetation (Webb, Berry & Boyer, 2001). The smaller floods do little major damage but are very inconvenient to residents. In 2004, the Rock Springs Road bridge over the Mojave River was washed out which caused major traffic problems for about 11,000 drivers (Orr, 2008). It has been replaced with a low water crossing that was closed due to high water levels in 2006 (Standish, 2006).

Flood Plain Aquifer

Water that flows into the Mojave River is lost from the river mostly by infiltration in the area between Victorville and Barstow; here the groundwater table in some places is often less than 15 m below the surface of the river bed (Mojave Water District, 2004). During early spring of 2015, water was visible in the channel in the Helendale/Silver Lakes area indicating the groundwater table was at or very near the surface. Further downstream, the water table drops to lower levels after crossing the Calico-Newberry Fault.

The sediments below the Mojave River bed form the flood plain aquifer. This aquifer is comprised of Pleistocene and Holocene river alluvium that fines downstream. As such, the lower portion of the river does not have significant infiltration, but usually little if any water reaches this section. Most of the water entering the aquifer is removed by groundwater pumping; transpiration by phreatophytes also depletes the groundwater (Lines, 1996). The invasive nonnative tamarisk or salt cedar (*Tamarix ramosissima*) has become a major member of the riparian vegetation along the river and has replaced most of the mesquite (*Prosopis sp.*) in the Barstow area (Webb, Berry & Boyer, 2001); the tamarisk is also a phreatophyte know to lower groundwater levels (Wilken, 1993). The groundwater table has been documented to have declined in the latter part of the 1900s. This is of concern because not only the wildlife of the riparian zones use the water, but the groundwater also provides domestic and irrigation water for users between the Forks and Victorville and to a lesser degree, between Barstow and Camp Cady (Webb, Berry & Boyer, 2001).

Pleistocene to Holocene Changes

Pleistocene Climate and Flora/Fauna

The Pleistocene climate of the Mojave Desert alternated between cool, wet glacial stages and warmer, drier interglacial stages (Kulongoski, Hilton, Izbicki & Belitz, 2009). During a glacial stage, a high air pressure system would developed over the Laurentian and Cordilleran ice sheets and displace the storm track southward (Kulongoski, Hilton, Izbicki & Belitz, 2009; Oreme, 2008). The Pacific Ocean off of the west coast of North America was warmer, producing conditions similar to El Nino weather patterns. Lower solar insolation would prolong the El Nino effects, resulting in atmospheric-river storms entering the area (Kulongoski, Hilton, Izbicki & Belitz, 2009). These storms would be similar to the large storms that produce flooding in the modern Mojave River (Enzel, Wells & Lancaster, 2003), but there were more of these storms in the

Pleistocene. Also, lower evapotranspiration rates and cloudy conditions would have been common in the Mojave Desert at this time (Koehler, Anderson & Spaulding, 2004; Reheis, Miller, M^{c}Geehin, Redwine, Oviatt & Bright, 2015). The resulting climate was about 4-6 ^{0}C cooler than today (Kulongoski, Hilton, Izbicki & Belitz, 2009; Reheis, et al, 2015; Holmgren, Betancourt & Rylander, 2010), but with a smaller temperature range due to atmospheric moisture which mitigates changes in temperature. Thus, while the average temperature was lower, the absolute winter temperature at night did not drop as low as it does in the desert today ; additionally, the cloudy skies would keep the summer high temperature during the day lower than today (Ackerman & Knox, 2007).

The wetter and cooler climate supported a pinyon pine (*Pinus monophylla*) and juniper (*Juniperus sp.*) woodland over much of the higher elevations of the Mojave Desert and adjacent Great Basin (Nilsson, 1983; Jefferson, 1987); the pinyon pine and Utah juniper (Juniperus osteosperma) may have grown as low as 800 m, while today they are restricted to elevations above 1,800 m (Jefferson, 1987). Associated with this woodland were oak (*Quercus sp.*), sagebrush (*Artemisia sp.*), and mountain mahogany (*Cereocarpus ledifolius var. intermontanus*), among others (Koehler, Anderson & Spaulding, 2004; Holmgren, Betancourt & Rylander, 2010). The lower slope around Lake Manix and probably much of the Mojave Desert were covered with a juniper and sagebrush savanna (Jefferson, 1987). This savanna also contained wolfberry (*Lyciium cooperi*), Mojave sage (*Salvia mojavensis*), and mesquite (*Prosopis juliflora*) (Koehler, Anderson & Spaulding, 2004). The common reed (*Phragmites communis*) and single leaf ash (*Fraxinus anomala*) grew in riparian areas (McDonald & Jefferson, 2008). These various plant communities supported the mega-fauna of the Pleistocene: e.g. mammoths (*Mammuthus sp.*), horses (*Equus sp.*), camels (*Camelops sp.* and *Hemiauchenia sp.*), and ground sloths (*Nothrotheriops sp.*). Mastodons (*Mammuth sp.*) are not known from the Mojave Desert (Springer, Scott, Sagebiel & Murray, 2010; Scott & Cox, 2008; McDonald & Jefferson, 2008), which is either a bias of preservation or the woodland was insufficient to provide enough graze for large herds that could provide fossils.

<u>End of the Ice Age</u>

The end of the last glacial stage brought rapid warming of the atmosphere and the migration of the storm track northward (Reheis, Bright, Lund, Miller, Skipp & Fleck, 2012). As the storm track moved northward, less moisture reached the Mojave Desert causing the plant communities to evolve into more xeric associations. The mesic communities became restricted in distribution; e.g. the mesquite (*Prosopis juliflora*) and arroyo willow (*Salix lasiolepis*) are confined to lands adjacent to springs and perennial streams. In some areas, junipers persisted into more desert-like temperatures when sufficient groundwater was present; e.g. Lucerne Valley had junipers up until 7800 y BP (Koehler, Anderson & Spaulding, 2004) and today, small stands of juniper-pinion woodland exist in protected areas such as on the north side of Black Hill, just north of Pioneertown.

As the Mojave Desert dried, the plant community changed. Mesic plants such as Perry pinyon pine (*Pinus quadrifolia* aka *P. juarezensis*) are now found only at higher elevations (Holmgren, Betancourt & Rylander, 2010). During the late Pleistocene, plant communities began to include the creosote (*Larrea tridentata*), bur-sage (*Ambrosia dumosa*), and Joshua tree (*Yucca brevifolia*) (Koehler, Anderson & Spaulding, 2004). The oldest known creosote clone in the Mojave Desert is the King Clone that is 11,700 years old (Jorquera, Nadeem & Crowley, 2012). The bur-sage and Joshua tree arrived about 10,000 years ago (Koehler, Anderson & Spaulding, 2004); some evidence suggests the Joshua tree arrived south of the Mojave Desert in the Joshua Tree National Park as early as 13,800 years ago (Holmgren, Betancourt & Rylander, 2010). During the middle Holocene, warm weather grasses (C_4) and the Utah agave (*Agave utahensis*) arrived in the Mojave Desert. These indicate an increase in temperature, decrease in winter rains, and an increase in monsoonal rains (Koehler, Anderson & Spaulding, 2004; Holmgren, Betancourt & Rylander, 2010).

<u>Mass Extinction</u>

The Pleistocene to Holocene transition coincides with a mass extinction of the mega-fauna. One attractive theory is the Pleistocene overkill, in which human hunters were the cause of the extinction (Bulte, Horan & Shogren, 2006; Diniz-Filho, 2004); the hunters did not need to kill all animals, but reduce their populations to non-viable numbers. Surovell, Waguespack, and Brantingham (2005) have compelling evidence that elephants and their extinct relatives (proboscidean) were specifically hunted and persisted into the Holocene only in areas with no evidence of human hunters; they also suggest that living elephant numbers are decreasing due to human involvement.

However, an event as large as the extinction of the mega-fauna most likely has multiple causes. The shasta ground sloth (*Nothrotheriops shastensis*) probably succumbed to the climate change. Its last known diet consisted, in part, of xeric plants: e.g. globemallow (*Sphaeralcea ambigua*), mormon tea (*Ephedra nevadensis*), salt brush (*Atriplex sp*.), and yucca (*Yucca sp*.). While the sloth adapted to the new vegetation, the temperature extremes may have cause the extinction (McDonald & Jefferson, 2008). Moisture in the air intercepts the infrared radiated by the Earth, thus mitigating cooling at night; without the Pleistocene moisture present, night temperatures would plummet to below freezing in the winter (Ackerman & Knox, 2007). Late Pleistocene sloths were more massive than early sloths, so they could retain more body heat. Their remains in the Late Pleistocene are all associated with caves in which the temperatures are constant at the average annual temperature. However, these thermoregulation measures were not sufficient and this species went extinct (McDonald & Jefferson, 2008).

While the shasta ground sloth did not migrate into warmer areas, many other mammals did respond to climate change and relocated, resulting in an ever changing community of organisms (Graham, et al., 1996). This response would lead to competition for resources. Bison (*Bison antiquus*) were found in the Mojave Desert late in the Pleistocene and originally they were rare at sites such as Camp Cady (Jefferson, 1987). Prior to the Rancholabrean Land Mammal Age, bison were represented by *Bison latifrons*, a relatively solitary animal that preferred more forested habitat. These bison were replaced by the aggressive herding bison, *Bison antiquus*, which preferred the more open environments that the Mojave Desert provided at the end of the Pleistocene. This may have been an important factor in the extinction of the Pleistocene mega-fauna (Scott, 2010).

Holocene

The Holocene desert climate does not provide habitats that will sustain very large animals. Today the bighorn sheep (*Ovis canadensis*) and mule deer (*Odocoileus hemionus*) are the largest herbivores in the Mojave Desert; they tend to inhabit the more mountainous areas. At around a meter tall at the shoulder, these herbivores are much smaller that the Pleistocene mega-fauna. While the fossil evidence is rare, both species lived during the Pleistocene (Stovall, 1946; Anderson & Wallmo, 1984). The desert cottontail (*Sylvilagus audubonii*) and black-tailed jackrabbit (*Lepus californicus*) are important species that were present in the late Pleistocene (Chapman & Willner, 1978; Best, 1996); they were often food for the Native Americans. The three most common predators today are the mountain lion (*Puma concolor*), bobcat (*Lynx rufus*), and coyote (*Canis latrans*) (Reid, 2006); the bobcat and coyote are known from the Pleistocene (Lariviera & Waltson, 1997; Bekoff, 1977). All of the predators are much smaller than the saber-toothed cat (*Smilodon sp*.) and dire wolf (*Canis dirus*) common in the Pleistocene.

Mojave River and Its Connection With Mining and Railroads

Gold Rush

The 1848 discovery of gold in the Great Valley caused a large influx of people into California. While most came from the eastern United States, many arrived from other countries including Australia, Canada, and China. During the gold rush, San Francisco became a cosmopolitan city with the influx of so many peoples; California became a state; and railroads began to be built (Rolle & Verge, 2008). Railroads were highly competitive. Many lines were built, traded, merged, sold, and abandoned (Walker, 1978), which resulted in numerous name changes; for clarity, present day names will be used for extant railroads.

Gold in California was first found in placer (alluvial) deposits and was easy to remove by picking it up or panning. Since gold has a specific gravity (sp. g.) of 15.0 to 19.3, it easily remains in the pan as a miner would slosh out the common sedimentary grains of quartz (sp g. = 2.65) and the feldspars (sp. g. ≈ 2.65); it is even easy to remove the detrital pyrite (sp. g. = 5.02) (Hurlbut, 1971). However, as the easy gold was depleted, miners began to extract gold from lodes including gold embedded in quartz veins. These had to be mechanically separated. One of the more efficient methods was to use a stamp mill. At these mills, the ore was placed at the bottom of a rectangular structure and a weight was dropped from a considerable height; this resulted in crushing the ore. The fine gold was then separated by being treated with mercury, which dissolved the gold. The gold was recovered by distilling the mercury (Stwertka, 2002). Miners collected the recovered gold and reused the mercury. However, between 10 and 30%

could be lost to the environment in the process of distilling the mercury (Alpers & Hunerlach, 2005). Mercury is a heavy metal and as such, is poisonous to humans and other higher life forms; it combines with enzymes within the body and restricts their function. Also, mercury is especially harmful to the nervous system. It is accumulative, so absorption of small amounts can build up to toxic levels over time (Stwertka, 2002). The environments of old mining areas have various degrees of pollution, even today (Alpers & Hunerlach, 2005).

As the gold in the Great Valley, Sierra Nevada, and Trinity Alps was becoming less profitable, other areas of the state were explored. Many would be miners went into other lines of work including farming, raising grapes, and supplying goods to the mines and railroads (Rolle & Verge, 2008). It was not long before the Mojave Desert and adjacent areas were explored. Gold was found in Bear Valley in the San Bernardino Mountains in 1854. Soon after, gold strikes were made in nearby Holcomb Valley and silver was found north of Cushenbury Springs, lower in the mountains (Vredenburgh, 1999).

In 1858, Aaron Lane settled in what would become Victorville and established a trading post and ranch adjacent to the Mojave River in an area that could be easily crossed (Almendral, 2013). While Victorville was built by a river crossing, Hesperia was built by a railroad water station (Hall, 2009). It was the first rail stop on the Mojave Desert coming north from San Bernardino. A large three story hotel was built next to the water tower and railroad. The hotel was popular with train travelers and later, with automobile travelers. Hesperia remained a hub city until it was bypassed by Route 66 in 1926; the hotel closed that same year (Drylie, 2010).

In 1863, John G. Nichols built a road up from the Mojave Desert to his mine east of Baldwin Lake; today, that portion of Highway 18 is known as the Johnson Grade. This road also connected the Rose, Blackhawk, and Gold Mountain mines to Victorville. Thus, Victorville became a mining supply town. The city eventually grew as a ranch town, mining town, and railroad stop and served the communities of Oro Grande, Lucerne Valley, and Big Bear (Vredenburgh, 1999; Almendral, 2013).

In 1868, gold was found near the Mojave River just north of Victorville and the Oro Grande Mining and Milling Company was formed (Miller & Miller, 1986). However, the gold from Oro Grande mines was not very profitable because the ore was comprised of a gold and pyrite intergrowth; the gold would not completely dissolve in the mercury (Vredenburgh, 1999). Their stamp mills were later used for ore from mines near Barstow. In 1885, the Burlington Northern Santa Fe Railroad (BNSF) finished their line between San Bernardino and Waterman Junction. Shortly after this, the town of Waterman Junction was renamed Barstow in honor of Santa Fe's president William Barstow Strong (Walker, 1978).

Silver and Borate Deposits in Panamint and Death Valley

Silver was found and mined in the Panamint area in the 1870s; in 1873, borate deposits were found in Death Valley, but were too isolated to be considered minable (Faye, 1999). However in 1881, when the railroad was completed from Mojave to Needles, Daggett and Mojave became important rail stops. This made the mining of borates in Death Valley profitable. The route taken from the Panamint mines to Daggett was also used by miners from the borax works in Death Valley (Faye, 1999). In 1873, silver was found near Oro Grande at the Silver Mountain Mine. Copper was found in the Ord Mountains and the Ord Mountain Mining District was established at Camp Cady on the Mojave River in 1871 (Vredenburgh, 1999). Camp Cady was a military outpost that served as a storehouse for quartermaster supplies, a Union outpost during the Civil War, and later an outpost for protection from Native Americans (Schoffstall, 2010). Today, the area that held Camp Cady is called the Wildlife Area, Desert - Riparian Habitat. Soon after the McKenzie Mining District was established at what is now Hesperia and included Ord Mountains, Oro Grande, and Victorville mines (Vredenburgh, 1999).

Afton Canyon and the Union Pacific

The Union Pacific tracks extended east to Afton Canyon where the surface waters of the Mojave River were used to supply water to the steam locomotives; Afton Canyon would eventually have nine structures (Rowe, 2009), but now it only contains a campground. From here, the tracks exited the canyon, traversed the Mojave River Wash, ran south of the Devil's Playground, and eastward to intersected the Kelso Wash, where a depot was built. The nearby springs provided insufficient water so the railroad workers dug nine wells at the Kelso Depot to supply water to the trains and to the three thousand citizens who later made the town their home. Kelso Depot was needed to supply helper engines to assist the trains climbing the Cima Dome to the east (Miller & Miller, 1986; Thybony, 2008). Today, the depot is part of the Mojave National Preserve and open to the general public. The Union Pacific tracks are still active, but the more powerful engines of today do not need helper engines to climb up the Cima Dome.

Calico

North of Barstow, the Silver King Mine above Calico was established in 1881. This was the first and richest of the mines in that area. Their ore was taken to the Oro Grande mills about 64 kilometers up river (Vredenburgh, 1999). Finding silver ore in the Calico area started the state's largest silver rush. Other mines at Calico included the Snow Bird, Dragon, Four Aces, Jersey Lily, and Burning Moscow (Miller & Miller, 1986). These were a just few of the approximately forty six mines in an area of approximately 26 km^2 (Leroux & Collins, 1994). In 1884, the Oro Grande Company bought mines in the Calico area and enlarged the stamp mills at Daggett just south of the Mojave River; a new mill soon followed. In 1888, the company built a railroad from the mill to the mainline of the BNSF (Vredenburgh, 1999). The Burcham Mine was the only mine in this area to make a profit mining gold; the other mines extracted gold as a by-product of their silver mining (Mann, 2000).

In 1883 borax was discovered in the Calico area and Francis Marion "Borax" Smith left his operation in Death Valley (Miller & Miller, 1986) because the railroad was only 14 kilometers away, which made the Calico deposits more profitable; by 1886, borax was being shipped by rail (Faye, 1999). One mine on the north side of Calico Playa was Bartlett Mine. Their mules would pull their train up a 2 km track and at the end of the day when the ore was loaded, the mules would be loaded in the last car, and the train would coast back down (Mann, 2000). The town of Borate built-up around these workings that operated until 1906 (Faye, 1999). In 1913, borate minerals were discovered near Kramer Junction, just inside Kern County. These deposits yielded an unknown borate mineral, $Na_2B_4O_7 \cdot 4H_2O$, now known as kernite in honor of the county. Borax, $Na_2B_4O_7 \cdot 10H_2O$ (Miller & Miller, 1986; Hurlbut, 1971), is easily made from this mineral by the addition of water. This find resulted in borate mining moving out of San Bernardino County.

Lead-Silver Deposits

In the late 1880s, silver-lead ore was discovered in the Shadow Mountains, 16 kilometers northwest of Oro Grande. About the same distance east of Oro Grande, the same type of deposit was found and the Sidewinder and Carbonate Mines were established. The Carbonate Mine sunk a 55 meter shaft and struck a rich mass of gold in quartz (Vredenburgh, 1999); they also found a rich deposit of limestone (Miller & Miller, 1986).

Limestone and Other Stone Quarrying

Although less exciting that precious metals, limestone was being mined at quarries near Oro Grande beginning in 1887. The limestone was used to manufacture cement for the real estate boom in Southern California; however, the real estate business collapsed by the end of the 1880s. In approximately 1890, the St. John quarry at the Upper Narrows of the Mojave River was being mined for granite to be used as building stone, curbing, and paving stones. Around 1900, smaller quarries above Oro Grande were producing limestone for use in the refining of sugar beets. In the 1910s, Southwest Portland Cement Company, originally Victor Portland Cement Company, was established. Cement manufacturing is still the leading industry in Victorville (Hall, 2009; Almendral, 2013; Miller & Miller, 1986; Vredenburgh, 1999).

Ludlow and Railroads

Gold was discovered by John Sutter, a BNSF employee who was looking for water about 13 kilometers south of Ludlow (Keeling, 1994; Miller & Miller, 1986). Ludlow became a watering station on the railroad, but because gold not water was found, water was hauled in from Newberry Springs 55 km to the west. The Ludlow gold was exploited by the Bagdad-Chase Mining Company who built a short line railroad, the Ludlow-Southern, to take their ore to the main line of the BNSF (Keeling, 1994). This railroad was sold and shipped to the Philippines in the mid 1930s (Miller & Miller, 1986). Ludlow was also the terminus of the Tonopah & Tidewater Railroad, where it connected with the BNSF. The Tonopah & Tidewater Railroad built the "Big Loop", a circular track that allowed trains to easily turn and return north; this track surrounded the town of that time. From Ludlow, the Tonopah & Tidewater tracks ran north crossing the Union Pacific at the Mojave River Wash; the Union Pacific would not allow a connection with their main line (Serpico, 2013). The community of Crucero ("the crossing" in Spanish) was established where the two railroads crossed and was damaged in the 1938 flood of the Mojave River (Mann, 2004). No structures remain today.

The Tonopah & Tidewater Railroad continued north through what is now Baker, across Silver Lake, and terminated at Rhyolite, Nevada (Serpico, 2013: Mulqueen, 2002); the ruins of Rhyolite are near the upper entrance to Titus Canyon, Death Valley National Park. Baker, originally called Berry after a local prospector, was renamed in honor of Richard C. Baker, an Englishman associated with the Pacific Coast Borax Company and former president of the Tonopah & Tidewater Railroad (Hayes, 2005; Serpico, 2013). However, the town of Baker was originally not an important stop on the Tonopah & Tidewater Railroad. The main supply center for the area was community of Silver Lake at the north end of its namesake (Mann, 1999). Little remains of the town and the railroad was removed in 1942, just two years after it stopped operations. The last use of the railroad was to take the iron rails to Ludlow as scrap to aid the war effort (Mulqueen, 2002), even though the section between Crucero and Ludlow was not being used at that time. The ties and remaining timbers were used by people of the desert with some bridge timbers used in the construction of the Apple Valley Inn (Serpico, 2013).

Waning of Mining in the Mojave

Except for the extraction of limestone used to manufacture cement, most mining in the Mojave Desert has been suspended, with only a few mines operating after the mining boom ended. The Mojave Marl Company mined a marly limestone for use as a soil conditioner in the 1920s and 1930s. A minor gold rush occurred between 1926 and 1934 in the Kramer Hills. A cyanide plant was built at Calico in 1917, but operations ceased by 1935; the town was restored by Walter Knott, of Knott's Berry Farm fame, and now is a county park. The Branch Mine near Oro Grande mined gold and silver until 1935; also near there was a silicified zone in schist that yielded gold and was worked until 1942. Pfizer produced illite, micaceous clay, from mines near Oro Grande until 1987, when competition squeezed them out of the market (Monroe, 1999). The Silver Bow Mine, that opened in the Calico area in the 1890s, was not profitable and closed. However, after WWII it reopened and mined barite from an open pit until the 1980s (Mann, 2000).

APPENDIX D

MOHAVE RIVER EXHIBIT

(ATTACHED AS A SUPPLEMENTARY FILE)

APPENDIX E

PHOTOGRAPHS

(ATTACHED AS A SUPPLEMENTARY FILE)

APPENDIX F

INSTITUTIONAL REVIEW BOARD APPROVAL LETTER

CALIFORNIA STATE UNIVERSITY
SAN BERNARDINO

Academic Affairs
Office of Academic Research • Institutional Review Board

CSUSB
INSTITUTIONAL
REVIEW BOARD
Expedited Review
IRB# 12089
Status
APPROVED

June 25, 2013

Ms. Judy Ann Lowman
c/o: Prof. Joseph Jesunathadas
Department of Science, Math and Technology Education
California State University, San Bernardino
5500 University Parkway
San Bernardino, California 92407

Dear Ms. Lowman:

Your application to use human subjects, titled "Adult Learning in a Museum Environment" has been reviewed and approved by the Institutional Review Board (IRB). The attached informed consent document has been stamped and signed by the IRB chairperson. All subsequent copies used must be this officially approved version. A change in your informed consent (no matter how minor the change) requires resubmission of your protocol as amended. **Your application is approved for one year from June 25, 2013 through June 24, 2014. One month prior to the approval end date you need to file for a renewal if you have not completed your research. See additional requirements (Items 1 – 4) of your approval below.**

Your responsibilities as the researcher/investigator reporting to the IRB Committee include the following 4 requirements as mandated by the Code of Federal Regulations 45 CFR 46 listed below. Please note that the protocol change form and renewal form are located on the IRB website under the forms menu. Failure to notify the IRB of the above may result in disciplinary action. You are required to keep copies of the informed consent forms and data for at least three years.

1) **Submit a protocol change form if any changes (no matter how minor) are made in your research prospectus/protocol for review and approval of the IRB before implemented in your research.**
2) **If any unanticipated/adverse events are experienced by subjects during your research,**
3) **Too renew your protocol one month prior to the protocols end date,**
4) **When your project has ended by emailing the IRB Coordinator/Compliance Analyst.**

The CSUSB IRB has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval notice does not replace any departmental or additional approvals which may be required.

If you have any questions regarding the IRB decision, please contact Michael Gillespie, IRB Compliance Coordinator. Mr. Michael Gillespie can be reached by phone at (909) 537-7588, by fax at (909) 537-7028, or by email at mgillesp@csusb.edu. Please include your application approval identification number (listed at the top) in all correspondence.

Best of luck with your research.

Sincerely,

Sharon Ward, Ph.D.

Sharon Ward, Ph.D., Chair
Institutional Review Board

SW/mg

cc: Prof. Joseph Jesunathadas, Department of Science, Math and Technology Education

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