Can Virtual Field Trips Be Substituted for Real-World Field Trips in an Eighth Grade Geology Curriculum?

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This is to certify that I have examined this copy of a doctoral dissertation by

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and have found that it is complete and satisfactory in all respects,
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Abstract

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This study compares student learning from a real-world field trip with student learning from a virtual field trip. A field trip was designed to show students the way geologists believe the Grand Coulee in eastern Washington State was created. A real-world version and a virtual version (panoramic photographs) were constructed. Participants in the study were eighth grade Earth Science students. At the end of the study it was found that there was no significant difference on the final assessment between the scores of real-world field trip participants and the scores of virtual field trip participants.

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DEDICATION

To my wife and daughter.

Chapter 1

Field Trips: A School Practice Needing Study

Introduction

A real-world geology field trip for middle or high school students can be a valuable educational tool. However, effective field trips are expensive, partly because of the cash needed to pay for transportation, but more importantly because of the considerable content expertise, preparation time, and effort required of the instructor to create and implement an effective trip. This expense often overburdens the teacher to the point that he or she is unable to adequately plan the trip; this pressure can reduce or void the educational value of the trip and increase the possibility of safety risks to participants. Therefore, eighth grade geology field trips are seldom taken and their educational potential is unrealized.

The Puzzle that Motivates the Research

Retaining Learning Opportunities

A principal challenge, then, is how to retain the learning opportunities field trips can provide without overburdening the classroom teacher. The answer may lie in the use of virtual reality field trips. Virtual reality (VR) is defined in *the QuickTime VR Book* as "the essence of reality without being actual reality" (Kitchens 1998 p. 4). Therefore, a person can take a field trip in essence without going on one as a physical person. Since the purpose, or essence, of an educational real-world geology field trip is to allow students to see and study geological features in their real-world context, a VR geological field trip would allow the students to see and study geological features in their real-world context.

Virtual reality always has a three-dimensional element to it and is always computer based (Strickland 2007, Beier 2004, Kitchens 1998). Because VR field trips are computer based they can be customized by classroom teachers. The software program used to create the VR trip should be simple enough that those with a strong basic knowledge of computers can create their own additions to, or subtractions from, a VR presentation. The software should also run on a computer of average performance; that is, one that the teacher would normally have sitting on their desk or otherwise available to them. We will address the VR field trip concept further in the section below entitled "Virtual Reality."

Since virtual field trips exist within a computer program, not the local landscape, curriculum developers could produce field trips as an integrated component of a complete classroom curriculum, removing the burden of creating field trips from the classroom teacher. However, we have no data about the effectiveness of virtual field trips when applied to our situation in eighth grade geology. Therefore, in an attempt to gather evidence for or against the use of virtual field trips in the classroom, we will compare the educational effectiveness of a real-world geology field trip and a virtual geology field trip.

Field Trip Benefits

This comparison is not as easy as one might first believe, for real-world field trips may bring significant benefits, as well as significant expense. Perhaps the most important benefit of a field trip is observing classroom-studied concepts in their genuine real world environments. These genuine environments provide students with added information in a new context and may help students transfer what they've learned in the course to real world application (Council 2000 p.236). This is true whether the classroom study is focused on the creation of chocolates or geological structures.

But there are other benefits of field trips that are important as well. They include social interaction, new terrain to hike (factory corridor or hill side), self-discovery of all types of artifacts, exposure first hand to the reality of the thing (enormous size, complexity, smell, etc.) and contemplation -- time simply to stare out the window on a new and continually changing landscape (city or country). Computerized environments do not affordably support many of these benefits. Therefore, we must examine the components of a real-world field trip and determine which of its many aspects are essential to the creation of an educationally effective experience. To accomplish this we must look at the instructional approach of the teacher that drives the classroom-learning environment, for it is this approach that dictates the role of the field trip in the greater scope of the classroom curriculum.

Classroom Approaches

It has been this author's experience that the ways in which classroom teachers think about their work often range among at least three distinct approaches. One could be described as, "the overburdened teacher who copes"; this is the person who juggles faculty meetings, committee meetings, classroom teaching responsibilities, school fundraisers, and the responsibilities of their own family. These teachers can do "acceptably" if a good quality, comprehensive curriculum is provided and they teach within a content domain that is familiar to them. If they lack these conditions they may gradually become discouraged and their classroom, as well as their personal life, will begin to suffer.

A second type, "the teacher who lacks basic knowledge of their teaching field," has classes in three different subjects to prepare for every school day and they may not know much about two of the three subject areas. Many have no real curriculum for some of the subjects they teach. This lack of curriculum may be due to high computer network costs in the school (which restricts their access to good information) or it may be due to reliance on aging, over-used textbooks. These teachers soon learn to do the best job they can and still survive or they find a different school or profession.

The third type of teacher, "the learning-focused teacher," is consumed with student learning. They may have tried to help out with other school activities at one time, but they have discovered that if students really are to learn they need guidance by a subject content expert (Council 2000 p. 45). They also know that teachers have to have time with their students to assess what learning skills their students have and don't have (Council 2000 p. 10); and they also know that teachers must have time to create and/or find instructional methods and materials that provide their students with real opportunities to understand studied concepts. This type of teacher may refuse to take on other responsibilities that interfere with them doing the best job they know how in their classroom-learning environment. Others often ostracize these teachers for their reluctance to do other school activities. But when learning takes center stage, these teachers are sought out for their expertise in instruction (Wiggins & McTighe 2005). It is this third philosophy that will guide our reasoning as we create the classroom curriculum and the real-world field trip that will enhance it. Also, it is the details of designing and producing the real-world field trip that will guide the construction of our experimental virtual field trip.

Less Is More

Since our classroom is focused on understanding rather than memorization, time constraints force us to take a "less is more" attitude towards curriculum. This attitude "asserts that there is more profit in learning fewer things better than in learning more things poorly… more depth, more connectedness, more relevance… less memorization of isolated facts and concepts…" (Project 2061 1993). We believe an important part of this depth, connectedness, and relevance is to give students the opportunity to transfer concepts studied in the classroom to real world application.

One important way to accomplish this is to take a field trip. In essence our reasoning is that a real-world field trip provides students with the opportunity to see classroom-studied concepts in their genuine real world environments, allowing students to enhance classroom-learned concepts with real world information. This enhancement creates a conceptual depth and complexity of understanding that should be far more useable in real life, and, therefore, more valuable to the student. This enhancement of classroom concepts will become the primary way in which the educational effectiveness of our field trips will be measured.

Success Is a Product of Intense Focus

A critical variable to the success of a well-planned field trip is the success of students in understanding concepts taught within the classroom. If the learning in the classroom has not provided a solid introduction to basic concepts, then there is very little educational reason to take a field trip (Bellan 1998). For this reason, we will look closely at what we know about how people learn and what it takes to create a truly effective curriculum and a classroom learning environment that is intensely focused on providing students with claimable (having enough knowledge from the curriculum and previous knowledge to allow the student to understand and actually learn what is currently be taught) and real life useable learning opportunities.

Our focus on students learning in depth also stems from the belief that when students actually work to understand something, they are also learning how to learn: that is, use prior-knowledge to grapple with new information, work for a deep foundation of factual knowledge, gain an understanding of facts and ideas in the context of a conceptual framework (mental model) work to organize knowledge in ways that facilitate retrieve and application, and learn to explain to yourself in order to improve understanding (Council 2000 p.14-18). Field trips facilitate learning to learn by supplying additional information to students. Importantly, this new information is encoded in the complexities of the real world environment. In our context of geology, this complexity necessitates students selecting and connecting relevant individual geological concepts taught in the classroom to create a supportable explanation as to why the geology of a region is as it is; or, perhaps to check the validity of someone else's explanation.

Moving from Basics to Complexity

In essence, the student is exposed to a simplified version of geology in the classroom. Individual concepts isolated from each other for clarity are studied and defined. Attempts may be made to combine these concepts, but the students are still in the classroom, and the classroom is very different from the geological settings of the concepts under study. Anne Bednar (1992) states that, "The reason that so much of what is learned in school fails to transfer to nonschool environments or even from one subject matter to another is due, in part, to the fact that the school context is so different from the nonschool environment." Certainly we must begin to introduce students to new learning within a proximal range of their current knowledge and prior experience. However, we also want students to be able to apply that new learning in ways that promote deeper understanding of studied concepts, as those concepts appear imbedded in the complex environments in which they are found in the real world (Spiro 1992). The classroom, therefore, is a simplified environment for introduction and the field trip is a real environment, filled with complex interactions. This combination of environments provides for the student claimable, in-depth, and relevant learning opportunities and also greater opportunities to "learn how to learn."

Social Benefits

There is one other component of a real field trip that is of importance to us. That is the aspect of social interaction. The importance of social interaction is often characterized by reference to L. S. Vygotsky's "zone of proximal development." He defines this zone as, "the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers." He also proposes, "an essential feature of learning is that it creates the zone of proximal development; that is, learning awakens a variety of internal developmental processes that are able to operate only when the child is interacting with people in his environment and in cooperation with peers. Once these processes are internalized they become part of the child's independent developmental achievement" (Vygotsky 1978). So the social interaction that happens during a field trip helps students make the learning their own, and make it permanent.

Virtual Reality

As stated earlier virtual reality (VR) is the essence of reality without being actual reality. The more difficult it is to tell that the virtual-something is not the reality, the better the virtual effect. Virtual reality runs a huge gamut from computer-generated panoramic movies to a 3-dimensional computer-generated scene projected into a headset. The headset is designed to keep out the real world, thereby creating a very convincing virtual world (Strickland 2007). Even the ability to feel, smell, and hear can all be integrated into the more convincing of these VR worlds (Wikipedia 2007, Strickland 2007). The cost of creating VR worlds tends to escalate rapidly as those environments add more elements so as to get closer and closer to reality.

Virtual reality has been used increasingly in science teaching over the past couple of decades. Yair, Mintz, and Litvak (2001) described its use for teaching astronomy in primary and secondary schools. Williams, Chen, and Seaton (2000) created VR-based high school physics tutorials enhanced with haptic feedback. Gilbert (2004) discussed the role that VR can play in helping learners create appropriate models for thinking in the sciences. In teaching biology to high school students, Mikropoulos (2006) found that VR environments could help them learn higher level thinking skills. And, in a review that is important for what we're looking at here, Libarkin and Brick (2002) looked at the use of VR in teaching geology. They observed that studies of using visualizations in teaching geology had shown varied results, and commented that, "These disparate findings may be indications that the utility of animations is tied to content and/or pre-existing knowledge, although further research, especially in the field of geosciences, is warranted" (p. 452).

The question of interest here is whether a computer-based virtual reality geology field trip has the same effect on student learning as a real world geology field trip. A very high-technology virtual environment could be created and it would provide a very high degree of similarity with the real world. But a typical middle school is unlikely to have access to expensive, high-level simulators or other VR gear.

This issue of expense reveals a very important consideration. How much reality does our VR geology field trip need to have? The answer is, just enough to match the educational requirements of our real world field trip. Or, more exactly, the virtual experience should have enough features to give students the same essential learning opportunities a real-world field trip would provide (while still providing a teacher-customizable delivery format).

For a virtual field trip to provide the same learning opportunities as a real-world field trip would require the use of panoramas for on the real field trip we look at studied geological features in the context of the landscape around them. The simplest way to provide panoramas in a virtual format I'm aware off is provided by Apple Computer's QuickTime VR. It is not fully immersive. Fully immersive means the participant is engaged fully within the VR world with little or no contact with the real world, such as the headset mentioned above provides (Beier 2004, Ausburn 2004, Strickland 2007). QuickTime VR software packages such as QuickTime VR Authoring Studio, PixMaker, PanaVue Image Assembler, and VRWorx allow teachers to create "desktop" VR environments. Desktop VR environments mean that the graphics are displayed on a regular desktop computer monitor. These desktop VR environments can be created for a modest software purchase ($20.00 to $300.00) plus the cost of a standard digital still camera ($150.00 to $300.00) (Ausburn 2004). The software will work on both Windows and Macintosh computers and requires a minimum of computing power. This low computing power means that the software will work well on computers that teachers generally have available.

QuickTime VR software works "by importing a series of digital still photos and then "stitching" and blending them to create seamless video movies with in-built learner control choices" (Ausburn 2004 p.40). This stitching together of the photographs creates a panorama VR movie.

> "In this movie the viewer seems to be inside a 3D 360-degree physical environment and can move around in the environment as if walking through it. The primary distinction between these VR movies and standard videos is user control. In VR movies, the user takes control of the environment by means of a mouse, joystick, or other device. The user chooses when and where to move and what action to take *(moving left or right, up or down, zoom in or out)*

rather than being controlled by the preproduction decisions of a videographer" (Ausburn 2004 p. 41).

"A panoramic movie is shaped like a cylinder. It has a central point, which is the viewer's perspective. From that one point, the viewer can look anywhere in a circular panorama" (Kitchens 98 p. 18). A panorama does not need to be a full circle; it can be partial. This means that you will not be able to see around you for the full 360 degrees (Kitchens 1998). For clarity, in the case of this project, I have limited the three-dimensional panorama VR movies to include only the features in the landscape that our studies focused on. Several of the panoramic movies are less than 360 degrees.

The Comparison

This study involved a comparison of a carefully designed five-day, in-class curriculum and two versions of a related field trip. One of the field trips was real and the other virtual. Sixty-one eighth grade students in a middle school located near Spokane, WA, (total enrollment of approximately 560 students, 6th through 8th grades, and a staff of 40 teachers) were intermixed for the classroom instruction. Half the students then took the virtual field trip and the others took the real field trip. Both groups took the same assessment and the scores were then compared to determine if virtual trips can provide the same learning opportunities as real-world field trips. Information about this comparison can indicate whether virtual field trips can be prepared along with classroom curriculum to provide a complete prepackaged curriculum, saving more of the teacher's time for student-teacher interaction and guidance as opposed to curriculum development, which would be a plus for everyone.

Comparisons of the instructional effectiveness of mediated environments are not new; they have been carried out for at least 80 years. Schramm (1977) found few differences in learning outcomes between materials presented on television and by a live instructor. Richard Clark, in an often quoted review (Clark, 1983) found that when all other variables are well controlled, there is typically no difference between the learning that results from "regular" classroom instruction and a mediated (film, television) version of the same content. In response to critics of his work, Clark brought further evidence together and argued persuasively that it was not the use of technology that enhanced learning, but rather the intensity and care of the design efforts that commonly go into mediated materials (Clark, 1994). Even Kozma (2000), who often is cited as an opponent of Clark, concedes that design is critical, while also maintaining that technology can provide important "enabling capabilities" (p. 5). Another meta-analysis of studies in distance education (Bernard et al., 2004) found a similar pattern: The quality of the design that went into a program was strongly related to the learning outcomes that resulted. Therefore, we went into this study convinced that whatever we did in developing our teaching environment, we should do it in a way that captured our best thoughts about how to design effective instructional experiences for students.

The content domain used in the comparison was geology. The specific conceptual destination, or learning objective, was to understand the currently accepted geological explanation of the creation of the Grand Coulee, which is located in the central region of eastern Washington State.

Hypothesis

The hypothesis for this study is: There will be no substantial difference in understanding of the currently accepted geologic explanation of the creation of the Grand Coulee between those who take a real-world field trip and those who take a virtual field trip.

Chapter 2

Field Trips in the Context of Fundamental Assumptions about Student Learning

Classroom-Learning Environment: Fundamental Assumptions

Why Do This Study

First and foremost, we already know classrooms are not equal in supplying students with claimable learning opportunities. Therefore, in order to evaluate the effectiveness of a virtual field trip in replacing a real-world field trip, we must carefully define the conditions under which the comparison is to be made. This includes defining in detail the classroom-learning environment. We will consider here a number of factors that are involved in the classroom-learning environment.

Teacher's Attitude

The classroom-learning environment is influenced most by the teacher's attitude towards student learning. In the classroom considered here, the third approach described in Chapter 1 – "focused intensely on student learning" -- reigns. This approach is core to the way in which the classroom curriculum is constructed. And, it is the curriculum that will dictate the purpose, design, and educational value of the real-world field trip, which in turn will guide the construction of the virtual field trip.

How Student's Learn

We will go into some detail below concerning what is known about how students learn and how teachers can facilitate student learning. For it is this information that tells us how to create curriculum that students can learn from more easily and what teachers can do to better facilitate student learning. The details are important here, for they provide the basic argument for taking real-world field trips, and for focusing intensely on student learning, and they also define the conditions under which our comparison will be made.

Understanding Is Encouraged

We believe that students construct their own understanding as they use prior knowledge to grapple with new information and make sense of it (Wiggins & McTighe, 2005; Winn 1999). Mental models, sometimes called conceptual frameworks, arise to represent this understanding (Merrill 1992 p.103). These models are constructed by the student but their emergence can be encouraged by means of a well-thought-out learning path created by a teacher who is a content expert and who knows what academic skills or tools their students have to help them construct conceptual frameworks. In a sense, the learning path is custom made for each individual student, by the teacher, to make sure the path is followable, or manageable, for that student. The learning path has at its end a conceptual destination that is, an intended over-arching conceptual understanding the student is to construct during the course of the entire unit of instruction. If students are to arrive at this destination they must develop an understanding of supporting concepts that are sequenced and thoughtfully presented in the classroom-learning environment. These concepts are analogous to stepping-stones that are used to create a path. Each stepping stone provides understanding of one supporting concept and, if the students truly understand each concept, at the end of the path they will be able to construct their own version (mental model) of the conceptual destination. And, if the learning path has been well prepared for this particular set of students, their version should be very close to that of the teacher's. Of course this will be determined by assessment.

Community of Learners – The Mechanics of the Classroom

Goals of Instruction

Because we believe people construct their own understanding, we are constructivists (Fosnot 2005; Duffy 1992). Therefore the goal of our instruction is to improve the ability of all participants to use the content domain in authentic tasks (Kristinsdottir 2001). That is, we want students to come to a logical or reasoned explanation, description, critique, or solution within the real world application of the content domain. To accomplish this, we build what we define as a community of learners.

Creating Understanding

A community of learners can exist in a variety of settings. The community can be a single classroom (Council 2000 p. 145) or several classrooms where students and teachers share a common curriculum or thread (Tai 2007; Tinto 1993). It can also be a school administration combined with the school's teachers (Black 2007) or the whole school environment (Council 2000 p. 145). A community of learners is based on the concept of collaborative learning (Black 2007) and constructivism (Cross 1998). In a community of learners students form a community that shares and constructs knowledge as they cultivate relationships with their peers and teachers for mutual support (Tai 2007; Council 2000; Tinto 1997).

Constructivism is a learning theory that "contends that each of us makes sense of our world by connecting new experiences to our existing understanding" (Straits 2007, p.58). In the classroom constructivists build "on students' prior knowledge, provide authentic context for understanding, encourages mentally active students, and allows opportunity for social discourse, interaction, and negotiation. In these participatory classrooms, students, manipulatives, and problems are central" not the words of the instructor (Straits 2007, p.59). Constructivist teachers often have students use raw data, which ideally would be collected by the students themselves. They use primary sources -- materials relatively uninterpreted by experts. And, they use interactive methods such as hands-on labs, model building, play acting, field trips, etc., to give students firsthand experience, or as close to it as possible given limits of time, money, and accessibility. These methods, raw data and hands-on labs etc., are used because they help students construct their own knowledge. An example of using raw data might be that instead of reading about the census, students would plan their own, collect the data, and then interpret the results. This method allows students to experience the realities of research, and brings to light many of the uncertainties that make any conclusion less than an absolute fact. Procedural glitches, funding requirements, pre-existing theories, sponsor pressures, assumptions, etc., are all aspects of research that must be experienced to truly begin to create understanding of the work of research. It is important to note here that any learning that is based in understanding rather then memorizing someone else's explanation could be described as research.

Improving Accuracy

In our community of learners, which is made of a single classroom, information is collected, scrutinized, discussed, and explanations are created. To improve the accuracy of the initial explanations, they are presented to others, which forces the presenting student to defend and clarify their thinking. Of course, during this process new perspectives are introduced and considered, new information is added, and supporting evidence is examined for relevance and to determine how much weight each piece of evidence should carry in the creation of an explanation (formative assessment) (Council 2000 p. 154). When models, text references, illustrations, etc., are used as resources, students are made aware that these are the result of others' observations and interpretations, and possibly may be simply speculation (SCIMAST 1994).

Important Information

In our community of learners, teachers seek to know three important things about their students: (1) the students' present interpretation of the world they bring with them to class i.e. their social setting (Straits 2007) (2) their level of prior knowledge concerning the content or issue under study (basic math, geometry, biology, chemistry, geology, etc.) (Council 2000, p. 133) and (3) the intellectual tools the students have acquired so far in their schooling (their reading and writing abilities as well as their abilities at communicating and creating explanations that can be followed logically by others) (Council 2000 p. 133). These three areas of information provide clues to the teacher as to where to start the student's learning path, and how to facilitate their success in the community.

Making Learning Valuable – An Example

Another important aspect of our community of learners is that every effort is made to make the issues studied valuable to the students. This can be done in a variety of ways, but as an example we will use one that provides an insight into the basic idea we're trying to communicate. This example is from *How People Learn*, pages 156 – 157 (Council 2000). This is efficiently written and highlights the essence of a community of learners:

> During the first week of school Barb Johnson asks her sixth graders two questions: "What questions do you have about yourself?" and "What questions do you have about the world?" The students begin enumerating their questions, "Can they be about silly, little things?" asks one student. "If they're your questions you really want answered, they're neither silly or little," replies the teacher. After the students list their individual questions, Barb organizes the students into small groups where they share lists and search for questions they have in common. After much discussion each group comes up with a priority list of questions, rank-ordering the questions about themselves and those about the world.

Back together in a whole group session, Barb Johnson solicits the groups' priorities and works toward consensus for the class's combined lists of questions. These questions become the basis for guiding the curriculum in Barb's class. One question, "Will I live to be 100 years old?" spawned educational investigations into genetics, family and oral history, actuarial science, statistics and probability, heart disease, cancer, and hypertension. The students had the opportunity to seek out information from family members, friends, experts in various fields, on-line computer services, and books, as well as from the teacher. She decides what they had to do as becoming part of a "learning community." According to Barb Johnson, "We decide what are the most compelling intellectual issues, devise ways to investigate those issues, and start off an a learning journey. Sometimes we fall short of our goal. Sometimes we reach our goal, but most times we exceed these goals—we learn more than we initially expected" (personal communication).

At the end of an investigation, Barb Johnson works with the students to help them see how their investigations relate to conventional subject-matter areas. They create a chart on which they tally experiences in language and literacy, mathematics, science, social studies and history, music, and art. Students often are surprised at how much and how varied their learning is. Says one student, "I just thought we were having fun. I didn't realize we were learning, too!"

> Barb Johnson's teaching is extraordinary. It requires a wide range of disciplinary knowledge because she begins with students' questions rather than with a fixed curriculum. Because of her extensive knowledge, she can map students' questions onto important principles of relevant disciplines. It would not work to simply arm teachers with general strategies that mirror how she teaches and encourage them to use this approach in their classrooms. Unless they have the relevant disciplinary knowledge, the teachers and the classes would quickly become lost. At the same time, disciplinary knowledge without knowledge about how students learn (i.e., principles consistent with developmental and learning psychology) and how to lead the processes of learning (i.e., pedagogical knowledge) would not yield the kind of learning seen in Barb Johnson's classes (Anderson 1987).

Barb has what it takes to create an effective community of learners: content expertise, knowledge of the essential learning requirements for her particular class, an instructional methodology to make the curriculum valuable to her class, and a dedication to have her students learn how to learn by seeking out information from multiple sources and by organizing it into explanations, which are actually answers to class inquiries. But there is one more major component of a community of learners not yet mentioned, that of student assessment.

Ongoing Assessment - An Example

In a community of learners student assessment is an ongoing process. It focuses on making the thinking of the individual learner visible to him or herself and to the community. Jim Traveler [1] (an alias), a highly respected math teacher in the Spokane, Washington, area provides one example on how this can be done. Jim has his students work as individuals or in groups of two to seek out explanations in a manipulative-based math curriculum. This curriculum focuses on understanding math concepts, not on memorization, and has all the commonly accepted markers of a well-designed curriculum. Students are introduced to a concept, work on understanding it using manipulatives, and then create a very detailed explanation of how they arrived at their understanding using text and labeled diagrams (both components are required). The students share labeled drawings projected from an overhead transparency, accompanied with an oral explanation by the student or team. In this way a visible path of the student's thinking can be produced, especially if the class watches as the student draws on the overhead. This gives the class the time to grapple with the explanation as it appears a little at a time and to make sense of it before any oral explanation is given. When the explanation is finished, the community discusses whether or not the arguments and supporting evidence actually make sense as a possible answer to the question (formative assessment) (Council 2000 p.154).

[1] Mr. Traveler (an alias) has a Bachelor of Arts Degree in Education with a major in math and a minor in Physics. He also has a Masters Degree in Computer Science. He has taught math for 14 years and is currently teaching math at an alternative high school.

It is important to note that during these discussions, students are typically attentive because everyone has been working diligently to solve the same math mystery. And, after going through this assessment process a couple of times, students are amazed how well they begin to understand math concepts which, in the past, were completely inaccessible to most of them (personal communication).

After the initial discussion, students revise their explanations, tweaking this and that to make better sense of the math mystery under discussion, based on the prior discussion. The resulting explanations are written with greater clarity and the illustrations are more detailed than would have been expected with a more traditional classroom approach. Students exchange their revisions with other students and critique the explanations following a format provided by the curriculum. During this time the room becomes a buzz of discussions as each group tries to understand others' explanations and, in the process, gain more insight into the math mystery for themselves.

After the class critiques, there is another revision time and students create their best explanations. These become the product they turn in to the teacher for his critique. Of course, all during these activities the teacher is always there, available for those who are stuck. During this time he never gives answers, only clues that can be used by the student to get out of whatever conceptual mire that holds them.

The student's concluding explanation (the "test" if you will) turned in to Mr. Traveler is meant to make each learner's conceptual understanding visible to the teacher. The explanations are individually created in class and, to the level of each student's current ability, the work must be thoughtful and "spiffy" (neat and well organized) to be accepted by Mr. Traveler for his critique. The core reason for this assignment is to determine to what extent a learner has achieved the particular conceptual understanding that is the goal of the study. Another reason for the test is to find if the learner has achieved at least the minimum understanding deemed necessary to pass the class. A third reason for giving the test is for the teacher to check the quality of the learning path he or she constructed for these particular learners.

Several weeks can go into this process but every student passes, many with explanations that astound other teachers. Arguments are logical, thorough, and presented neatly and in a well-organized way. Mr. Traveler commonly spends 20 minutes going over each paper, carefully dissecting each one until he understands exactly what is being said. The students have worked very hard to get to their understanding and they are excited to find out if their individual arguments are well done and if they have solved the math mystery. When Mr. Traveler hands back critiqued "final explanations" the room becomes silent as every student scrutinizes each of Mr. Travel's comments. Then the room becomes a mass discussion as students compare their answer with others and debates start anew. There is an additional aspect to this approach: if a student isn't satisfied with his or her final assessment on the concept, then he or she is free to revise once more (there is a small point penalty). And, Mr. Traveler is available after school to help those students fight for their learning.

Rewards

Obviously this type of assessment process requires a content expert, a great curriculum, a teacher who knows how to learn and can teach others how to learn, and an enormous amount of teacher time to stay current with each student's level of understanding. But the rewards can be phenomenal; students are excited about their newfound ability to understand, which makes learning an acceptable activity (if not a favorite one). As their scores on the Washington Assessment for Student Learning (WASL) improve, so also improves their self-esteem (personal communication). (Mr. Traveler has taught in grades five through high school. He always uses the same technique, and always appears to get the same results.)

Our Guide

A community of learners focuses on student learning and the mechanics that allow learning to happen. To the extent that time and resources will allow, the curriculum and pedagogy used for this study will be guided by the image of a community of learners as described above.

We are now ready to look at the way in which the virtual field trip will be constructed and its relationship to the conceptual framework described above.

Construction Requirements For The Virtual Field Trip – A Discussion

The design and construction requirements of our virtual field trip are dictated by the field trip's purpose as it relates to the curriculum. This purpose is to show students how classroom-studied concepts actually appear and are applied in the real world. The intention here is to allow students to clarify and deepen their learning to the point of real-world usability through the experience of the field trip. To do this we must at least be able to demonstrate how the concepts apply to the real-world landscape. Simple photographs could show this. But we also would like to show these concepts as they interact with each other throughout various parts of the landscape. A panoramic view would be better for this purpose; it wouldn't necessarily have to be a 360-degree panorama, but that could be useful at times.

Another component of a field trip is students interacting with each other. We could accomplish this by projecting a landscape panorama on to a large screen in the classroom (approximately 6 feet wide by 8 feet high). This would allow all the students in a class to view the landscape at the same time and discuss it, either all together or in small groups. The software should also allow students to zoom in on and zoom out from the projected landscape, which would provide close views of important landforms and wide views to take in interrelated geologic structures that interact to form the landscape. These features would constitute the minimum physical requirements for our virtual field trip.

There are several software programs capable of creating panoramas for projection. The one chosen was QuickTime VR (Virtual Reality) version 1.0.1 created by Apple Computers (Apple Computer 1992). This program manipulates digitally created photographs and stitches them together to make panoramas up to 360-degrees both horizontally and vertically, if one chooses. This ability can place the class in the center of a virtual ball looking out at a continuous landscape, including looking straight up and straight down.

The software has an additional important ability beyond those listed above: it can create activation buttons hidden within the panoramas. These buttons, called <u>hotspots</u>, are activated when the cursor is moved over them on the screen and the mouse is clicked; information connected to the hotspot is then displayed. The button can be concealed from view even if the cursor is over it, or it can illuminate as the cursor touches it, providing additional options as to how the information connected to the buttons is discovered by the user.

When the hotspot is clicked, a multitude of different things can happen. A movie may play in a small window that opens on the screen, showing some process related to the landform in the panorama. Or, a very detailed close-up view could be brought up in a window allowing close scrutiny of a sediment bed or of an artifact in the landscape. Perhaps an aerial view of the area is shown to help the student better understand the interrelationship between the surrounding area and the area the hotspot sits on. Text, graphs, detailed three-dimensional drawings, animations, and other panoramas can all be accessed by these hotspots to provide more information. Even three-dimensional images of rocks, flowers, artifacts, etc., created using QuickTime VR that allows students to look at individual things from all angles - just as if it was in their hands, can be accessed through hotspots. Of course, the hotspots can also be connected to animations showing huge three-dimensional chunks of the landscape that can be manipulated easily by the students.

However, during the process of actual development of our virtual field trip, when we began to incorporate some of these hotspots, we found they required more computing power than we had available. The necessary equipment (at the time of the research) would have cost approximately five thousand dollars to make the program run without long, distracting waiting periods (10 to 20 seconds). Five thousand dollars is not terribly expensive but more than we had in mind, or in the wallet, for this first step in examining the possible benefits of virtual field trips.

There were also other considerations such as expense of software programs and expertise to create quality graphics and animations, expense of creating short movies of desired geologic concepts and sites, and, as always, time and knowledge to assemble all of the components into a comprehensive package.

At this point we realized the scope of the ideal virtual field trip was expanding, threatening to encompass components of the classroom curriculum. For this study we wanted the software only to emulate the real-world field trip component of the curriculum. We wanted to include teacher and students interacting. The virtual field trip was not intended for students to take alone, at least initially. It was intended to be taken by multiple students and at least one knowledgeable instructor, together, just as a real field trip. Since the teacher would be present to help with instruction and peers are interacting to support each other with understanding, we did not need a great deal of computer magic providing instruction – certainly not anywhere near the amount needed if the students were to use the software alone. Therefore, it was decided that we would limit the use of the software to its more basic abilities, that of stitching and projecting panoramas.

There is one last point to make clear about our design consideration. The virtual field trip was intended to be taken at the end of a classroom unit of study. This simply was the most logical placement to facilitate students seeing how classroom-studied concepts actually appear and are applied in the context of the real world.

Chapter 3

Student Demographics, Instructional Setting, Field Trip Details

Introduction

This chapter gives an overview of the students demographically, their science background in middle school and their science studies in the eighth grade. It also gives a detailed description of the classroom instruction, including methodologies, which the students experienced prior to the field trips and the assessment. Finally, this chapter gives a detailed look at the real field trips as well as the virtual ones.

Demographics

The school is set in a sprawling suburban environment in the eastern part of the state of Washington. The population of the surrounding area is approximately 300,000. The school itself has a population of about 560 students, the vast majority being Caucasian. There are just over 40 faculty members and free and reduced lunches are provided for approximately 50 percent of the student body, which is made up of 6^{th}, 7^{th}, and 8^{th} graders. The school district's total student count is approximately 3,600.

The students who took part in the study were from three Earth Science classes. Earth Science is a required science class for eighth graders. Physical Science is required in the sixth grade and Biology is required in the seventh. The students were 13 and 14 years old (eighth graders), and Mr. Traveler, teaching for his seventh year, was their teacher.

Classroom Work and Teacher Philosophy for Eighth Grade Science

The students had started out the year academically by creating their own definition of science, which included making explanations of an observed phenomenon and building an understanding of the Scientific Method. The students studied and practiced technical writing procedures right from the start of the year to help in recording data, communicating data, and communicating explanations of phenomena between the students. Also, students studied the history of the metric system, which includes the origin of the metric units: weight, linear, surface area, and volume. The density of the atmosphere was next, combined with the powers of ten. Accurate measurement and the concept of ratios were studied next and then a chemistry section was used to apply the concepts of the metric system, accurate measurement, and ratios. An air pressure unit was next. It was designed to make a powerful invisible force visible so it could be studied. Last but not least is the geology unit. It is designed to see and use classroom-learned concepts out in the real world. In this case we used the activities created for this study as the geology unit. Our goal was to be able to explain the creation of the Grand Coulee in eastern Washington State as described by geologists.

It is important to note that Mr. Traveler' science classes are very hands-on. Also, Mr. Traveler focuses on using the scientific method in his classroom. This is done to assure explanations of phenomena are supported by evidence that has been looked at closely and discussed to determine the quality of the evidence. Starting soon after the beginning of the school year the phrase "No Dogma!" is used liberally by teacher and students alike to press for real evidence to support an explanation given.

In Mr. Traveler's class there is a conscious effort made to help students understand the background of things taught. Take the metric system for example. The metric system is about measurement, but where did the units of measurement come from? The first "meter" was estimated to be one ten-millionth of the distance from the North Pole to the Equator as measured by the French at the time of the French Revolution. Of course, only a short distance was measured and math did the rest. However, studying the origin of fundamental things gives a sense of human scale and an understanding of how things can be discovered and/or created and used by people, even something as extensive as a worldwide system of measurement. This understanding opens up the possibility that anyone can come up with an idea, or discover one, which can change the world. And, when that happens, individuals give themselves license to attempt to do almost anything, which Mr. Traveler believes is a good way for students to look at the world.

One more piece of information about the students: they sold Christmas wrapping paper in the fall of the school year (1999-2000) to pay for the transportation needed to go on the real field trips. Their efforts produced enough profit to completely cover the cost of all the four real field trips. Mr. Traveler was very successful in "selling" the field trips and he certainly excited the students about the learning of geology they would do in the spring.

Dates of the Field Trips

The geology unit took 11 days to complete and was given from May 19 through June 5, 2000. The first five days were used for classroom instruction and the remaining six were used to take the field trips, both real and virtual, and give assessments to each set of students. Each real field trip took approximately one 10-hour day. The first real field trip was taken on May 26, 2000, and was about 500 miles in length. The second real trip was taken four days later on May 30, and was approximately 300 miles in length. The real field trip assessment was given on May 31. On June 2 and 5, 2000, the two real field trips were given to those who had been on the virtual field trip.

The virtual field trips were given on May 31. The Camas Prairie portion of the trip was given first and took about 45 minutes. There was a 15-minute break and then the Grand Coulee portion was given. It was about 45 minutes as well. The virtual reality trip assessment was given on June 1.

Instructional Responsibilities

I gave all classroom instruction, and I provided all instruction on the three field trips. This was meant to help with the consistency of the lesson across the different classes and field trips. Mr. Traveler was present as an assistant in all classes and the three field trips.

Classroom Work and Teaching Methods Used Leading to the Field Trips

Both virtual and real field trip groups experienced identical classroom instruction for the first five days of the unit. On the first day, I introduced myself, the study, and the subject of geology. The students were also told which field trip they would be on, the virtual or the real. On the second day we did a lab concerning the way nature can leave evidence for humans to find and use in their explanations of how nature works. On day three, we discussed the findings from the lab and looked into varves. On day four, we discussed waveforms, the Columbia Plateau and the Grand Coulee. On day five, we created a mini-megaflood.

Day One – Friday May 19, 2000 Introduction

The first day of the unit was given to introducing myself and the study, going over the materials that would be needed for the unit, and an introduction to geology. I introduced myself as a doctoral student from the University of Washington in Seattle and said that I had known Mr. Traveler for over a decade. I explained the study as an effort to use large projected graphics (8 feet by 6 feet) to replace a real geology field trip into the countryside. Student reacted to this statement with comments stating they liked real fields, mostly for providing time away from the school.

We planned to have half the students from three of Mr. Traveler's Earth Science classes take the real field trip and half the students take the graphic field trip, which we referred to as the virtual trip. The students were chosen to be on the respective trips by drawing names from a hat. One name was pulled from the hat and that student would be on the real field trip, the next student's name pulled would be on the virtual trip, and so it went until all the names were drawn. The students were then told which field trip they would be taking. At this time we also explained to the virtual field trip participates that they would be taking the same real trips as the real field trip participants once they had been tested for their knowledge concerning the creation of the Grand Coulee in eastern Washington State.

The students were also told there would be two parts to the real field trip. The first part would be to western Montana to a place called the Camas Prairie, which is 60 miles northwest of Missoula. The second part of the real field trip would be the Grand Coulee region of the Columbia Plateau. The virtual trip was also in two parts but on the same day with a fifteen-minute break between trips.

Next students and teacher went through a list of materials. These items were meant to help the students record information they would observe during class and the field trips.

1. Three Ring Binder notebook
2. Paper for the notebook, lined or unlined
3. Writing Tools
    a. Normal Pencils (2)
    b. Colored Pencils (8 box is fine)
    c. Fine Point Black Ink Pen (labeling pen)

Instructors then explained to the students the main reasons for studying geology.

1. We introduced the students to an impressive geological feature in Washington State and to the explanation by geologists of the creation of that feature.

2. We explained that the quality of an explanation is based on the quality of the evidence. Evidence is defined here as specific, organized information that supports an explanation.

3. We indicated that accurate scientific explanations are "messy" to create because the information collected may be chaotic and uncertain. This is due to the difficulty in collecting information and determining what the information means in the context it came from. These uncertainties often make it very difficult to organize such

information into a form that provides supporting evidence for an explanation of something being studied.

During day one the students were attentive and seemingly anxious to get started. When I read the lists telling them which trip, real or visual, they would be going on was seemingly the high point of the class. There was a great deal of clapping and booing as good friends either got to go on the same trip together or didn't.

Day Two – Monday May 22, 2000 Manual and Automatic

Day two centered on the students understanding that nature supplies evidence about its own processes and phenomena. This natural evidence was given the name automatic -- it needed no human help to create it. Evidence that does need human help to create it was given the name "manual." The approach used to teach these concepts of "automatic" and "manual" evidence involved the sorting of sediments. The teaching methodology was a lab where the students sorted sediments in ways that approximate both the "automatic" and "manual" notions of evidence.

First, the students were placed in three groups. Each group received a clear 1-gallon glass or plastic jar, a small bucket of water, stir stick, a four-screen sediment sorter, and 2, 800 ml beakers full of unsorted sediments. Half of each group ("the jar group") used the jar, water, sediment beaker, and stir stick. The other half ("the sorter group") used the four-screen sediment sorter and sediment beaker.

The jar group filled the jar a little over half full with water, and as one of the students stirred the water, another student poured the beaker full of sediments into the jar. The stirring continued until all the sediments from the beaker were going around and around in the jar, then the stirring was stopped and the contents of the jar were allowed to settle on their own. This process mimicked fast running water carrying a large load of sediments. The water then slowed down and it began to deposit its load. The students found that the heavier, usually larger sediments settled to the bottom more quickly then the others, which built a gradient. The gradient had large, same sized sediments on the bottom, with a progression towards the top of sorted smaller and smaller sediments. Geologists refer to these types of sorted sediments as a "graded bed."

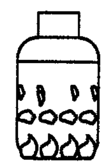


Figure 3.1- Graded Bed

The sorter group used the sediment screen sorter to manually sort the sediments by shaking the sediments through the different sizes of sorter screens.. Here, the sediments are accurately sorted into 5 different sizes, but human help was necessary to build the sorter and to shake the sediments through.

This lab had the real possibility of being very messy; however, the students did a remarkable job of keeping the water and sediments in the jars. The students were also careful about safety issues -- some of the jars were glass -- and they did a good job of dividing their small groups into smaller groups for the 2 different parts of the lab. The clean up was easy, and we managed to be pretty much ready to go by the time the bell rang for the next class. Overall class participation and behavior was excellent. I believe the lab went so well because Mr. Traveler had his students do so many of them throughout the year. And, he insisted they clean up after themselves.

Day Three – Tuesday May 23, 2000 Varves

Day three started with a discussion about day two's lab. The lab was meant to show students that a process such as well-sorted sediment layers can be created both manually and automatically. Of course, humans can sort sediments but it is important to note that nature can, all by itself, sort sediments very well. Humans can use these naturally sorted sediments in a human explanation as evidence of how some geologic feature was created. We also considered whether, if nature carries out one process automatically, could there be others? The answer was a unanimous "yes."

We discussed another aspect of the lab: fast running water can carry large sediments and very slow water can carry only tiny sediments. Standing water, such as a lake, can hold almost no sediments, which means sediments on lake bottoms can be very tiny indeed. The idea of lake bottom sediments led us to another automatic process, one that helps to create glacial lake time-lines. That process depends on varves.

Varves are sediments at the bottom of glacial lakes that form distinctive layers. A varve consists of two layers: a light colored layer of silt and fine sand that forms in the spring and summer; and a dark colored layer of clay that forms in the fall and winter.

Together, the two layers form one year of sediment accumulation, and the resulting varves can be counted in sequence. This provides information about how long the glacial lake existed in that location and helps create glacier time-lines. Varves are very small, within the millimeter range; they are therefore very tedious to count, and it is difficult to be precisely accurate (Picture 1). The layers of varves must be put under a microscope for close evaluation, and even with that the layers are difficult to interpret due to slight color, shape, and thickness differences. However, due to advances in computer hardware, software, and digital video cameras, it is becoming much easier to differentiate color hues and specific layers in the sediments. This makes counting each varve layer an easier task (Chamber 1971) (Alt 2001 p. 26).

During the discussion of Day Two's lab, the students were energized by the "automatic" and "manual" distinction. By the time our discussion was complete, the students realized that without the automatically produced evidence nature leaves, we would have little or no way to develop explanations for the creation of landforms, whether large or small.

Varves were introduced via drawings on the white board. The students copied the labeled drawing from the whiteboard into their notebooks. The instructors placed special emphasis on the fact that the varves contained light and dark layers, and that each varve represented 1 year.

Day Four – Wednesday May 24, 2000

On day four we started by talking about waveforms. This was necessary because the students would need a way to measure waves, or at least to know how waves are measured, on the field trip to the Camas Prairie (Pictures 2&3). Critical concepts here included wavelength and the wave's amplitude. The wavelength is the measurement

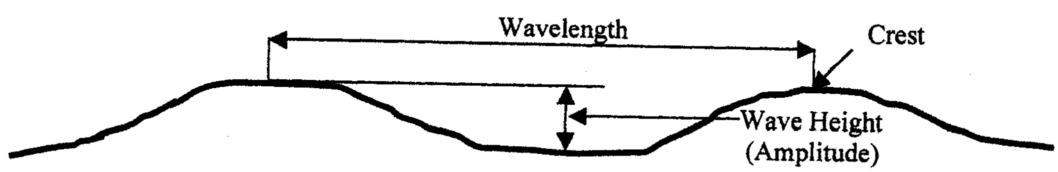


Figure 3.2 - Wavelength

from one point on a wave to the same point on the adjacent wave. The point generally used in the crest of the wave, which is the wave's highest point. The wave's amplitude is the height of the wave measured from the lowest place on the ground between two adjacent waves to the height of the crest measure vertically from the lowest ground point (See Figure 4.2).

We also talked about erratics. Erratics are generally large boulders transported by glacial ice or by floating ice. When the ice melts the boulders are dropped to the ground and there they sit. Sometimes the boulders are extremely large and appear to be quite out of place in the landscape. The students drew a simple rock sitting on top of a landscape in their notebooks to visualize what an erratic looked like.

We also talk about erratics that get buried. These erratics are dropped by glacial ice or fast moving water on the surface where they are buried by other rocks and sediments. When nature or humans uncover them they can look just as out of place as erratics on the surface.

In the gravel beds in the bottom of the Camas Prairie Basin there have been erratics discovered that are five feet across and are completely different from the two-inch flat gravels that make up the Basin floor. These rocks are from the mountains north of the Camas Prairie where glacial ice eroded them. The rocks were than rafted by ice rafts to their present location where they were dropped and buried with gravel. Picture 4 shows some of these erratics in the Basin.

Next, we talked about the Columbia Plateau, the region of the Grand Coulee field trip. The Columbia Plateau essentially runs from the southeastern corner of Washington, north to Spokane, northwest to Pateros, and South to Yakima. This is the southeast quarter of Washington State (Figure 4.3). Basalt makes up the rock that is the Columbia Plateau. The basalt is more than 15,000 (5km) feet deep in the Pasco Basin (Hooper 1989A) and goes to zero feet along the northern border of the Plateau. Along the western edge, the basalt bumps up against the Cascades and, on the eastern border of Washington, the basalt runs into Idaho. The basalt, a dense crystalline igneous rock that forms from lava on the Earth's surface, came from a swarm of fissure volcanoes located in and around the extreme southeastern corner of Washington and the northeastern corner of Oregon (Chamberlain 1994, Tolan 1989).

Fissure Volcanoes are extensive cracks, miles long and yards wide, in the Earth's crust, which lava literally pours out of; it can flow hundreds of miles, filling in valleys and burying hills. These fissure volcanoes in Washington, Oregon, and Idaho produced enough lava to cover 100,000 square miles in the three states, 15,000 of which make up the Columbia Plateau (Weis 1976). This out pouring of lava came in many different flows, each forming a layer of basalt (as many as 300), between 17 million and 6 million years ago (Hooper 1989B).

Sometime during the last 17 million years or so, the lava flows of the Columbia Plateau shifted and tilted towards the southwestern corner of the Plateau, leaving the northeast corner near Spokane at 2,000 feet above sea level and the southern edge near Wallula Gap (Wallula, WA) about 400 feet above sea level. This degree of tilt was more than enough for water to flow down rapidly. Also, during the time of the Plateau's movement, compression forces caused areas of the Columbia Plateau to fold creating, among others, the Coulee Monocline and the Soap Lake fold (Bretz 1959) (Jones 1947).

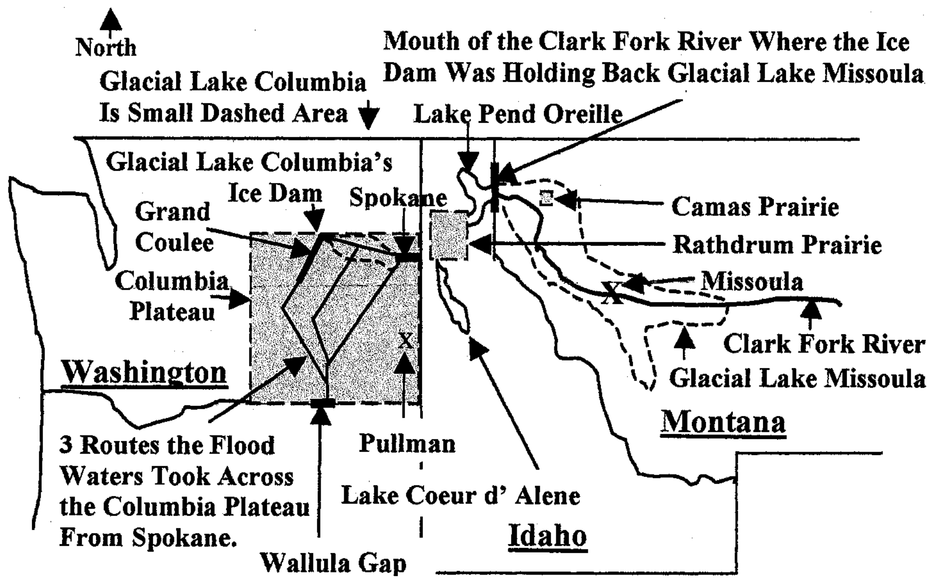


Figure 3.3 – N.W. Map

Sometime around 7 million years ago, a cover of fine soil (silt) began to accumulate over much of the lava field. The accumulation of this silt – called loess today – probably started with sediments from dried up lakes on the folded lava fields and was increased to today's amount by outwash sediments from the last glacial period, which ended approximately 10,000 years ago (Baker 1991 p 219). This loess accumulated to a maximum depth of about 200 feet around present day Pullman (Figure 3.3), and the residents of southeastern Washington today see this fertile loess covered with wheat fields in the spring and summer. This soil covering, or "frosting" as some call it, once did cover much of the Columbia Plateau. Today, some of the frosting has been removed to expose the red scab-like basalt of the ancient lava field beneath. These places are call scabland.

The vast majority of the scabland was created by water between 19,000 C14 yr B.P. (Carbon 14 years Before Present) and 13,000 C14 yr B.P. (Benito 2003); these scabland regions cover much of the Columbia Plateau. However, we wish to look at only a small piece of the scabland and the gigantic geologic feature there. The feature is in the central northern area of the Plateau and it is called the Grand Coulee (Figure 3.3). It is called a coulee because it is a steep sided canyon created by water. And, it is called grand because it is arguably the biggest coulee known.

Model Building

To get an idea of the configuration of the Grand Coulee we constructed a paper model of the area. The size of the paper isn't important as long as it's at least a quarter of an 8.5 by 11" sheet of paper. I drew the separate layers of the model on the whiteboard, keeping the scale of the Coulee's features in scale. We labeled Steamboat Rock, the Upper Coulee (25 miles long) and Lower coulee (15 miles long), the Coulee Monocline, the Soap Lake Fold, the Columbia River, and the location of the Glacier that closed off the northern route of the Columbia.

After everyone had labeled their models and studied them for a couple of minutes, I brought three pieces of 24 inch by 48 inch by 1.5 inch Extruded Polystyrene Foam Insulation Board[2] up front along with a jig saw. The jig saw had a new fine tooth 4-inch blade in it. I then ask for two volunteers from the class and I chose a boy and a girl. They had volunteered to create a model of the Grand Coulee out of the

[2] This Insulation Board is available at home improvement stores.

polystyrene foam board, using the jig saw. We used a straight edge and a pencil to mark the appropriate cuts, put on safety glasses; the students took a minute to practice with the jig saw, and in about 12 minutes we had the parts of a model. The students quickly assembled the parts and everyone began to understand better how the Grand Coulee area looks.

The paper model works very well as an introduction; then, when the bigger model is being assembled, the other students in the class are eager to tell the students putting the model together where and how all the pieces go. By the time both models are done, the students really are beginning to "catch a clue" as to how the Grand Coulee will appear when they see it. It should be noted that, during the classroom portion of this research project, the students were never shown a picture of the Grand Coulee.

The paper models described above also originated from the directions on the instruction sheet describing the polystyrene model (Grand Coulee Model Diagrams- Appendix A). The paper model follows the basic layout of each level by keeping the scale relationships between features the same and by having the individual who is constructing the model make their best guess as to the exact position of the features. Of course, the polystyrene model has measurements to position the features but keep in mind this model is to give the students a basic overview of the layout of the Grand Coulee, nothing more (Pictures 5A&B). Also, there is no scale used on the drawings -- just measurements to keep the relative positions somewhat close to the real ones.

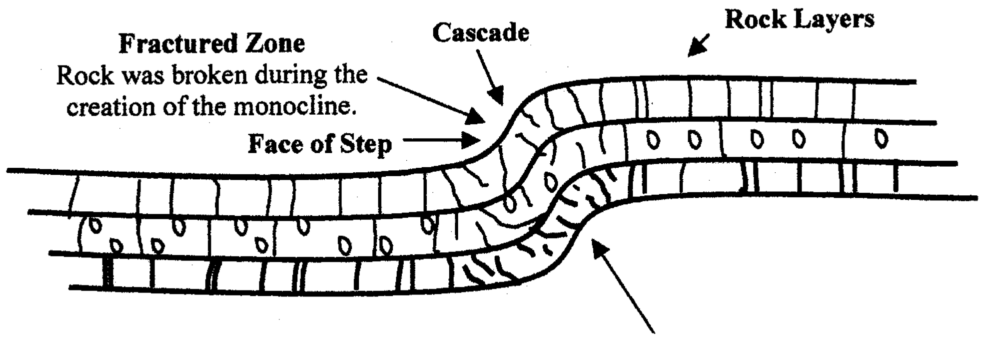
Creating the World's Grandest Coulee

This section tells the creation story of the Grand Coulee and about the water sources that made the Grand Coulee possible. It also tells of the role of basalt in the creation process. I provided this information to the students during the fourth and fifth days of class -- the fourth day included making the models of the Grand Coulee and the fifth day involved creating a mini-model of one of the Glacial Lake Missoula's megafloods.

The polystyrene Grand Coulee model shows two distinct canyons (Picture 5B). One towards the top of the model, the Upper Coulee, and one beneath the first one called the Lower Coulee. The Upper Coulee is about 25 miles long and the Lower is about 15 miles long. A space of about three miles separates the two. The Columbia River comes in from the east, or right, at the top of the model and curves to the north, or top, of the model half way through the model's width. There is a monocline (See Monoclines Figure 3.4) at the end of the Upper Coulee, the step down in the model's middle. This is the Coulee Monocline. There is another fold, the Soap Lake Fold at the end of the Lower Coulee, which is the step down at the bottom of the model. The Lower Coulee fold, named the Soap Lake Fold, is not a monocline. It is an anticline fold. An anticline fold is only one fold (Figure 3.5). The monocline is two folds, one on the top, and one on the bottom. The anticline fold only has the top fold. In this case both monocline and anticline folds acted the same way. They both created cascades that turned into waterfalls (Figures 3.4 & 3.5)

The individual pieces cut from the piece removed to make the Upper Coulee and the piece removed to make the Lower Coulee are used to show the progression of the coulees from their start (Picture 5A). The Upper Coulee started at the monoclinal fold in the middle of the model. The Lower Coulee started at the anticlinal fold at the bottom of the model. Water coming from the north, top of the model, came south over the folds where cascades were formed, which turned into waterfalls by erosion (Cascade Figure 3.4 & 3.5) (Jones 1947).

Cascade
As water flows over the monocline from its upper level a cascade is formed on the slope but because of the fractured rock erosion acts quickly to remove the slope leaving a waterfall.



A monocline is a step-like bend in beds—layers of soil and/or rock—that are otherwise horizontal. Basically it appears as just a step in the landscape but the face of the step slants out instead of being straight up and down.

Figure 3.4 - Monocline

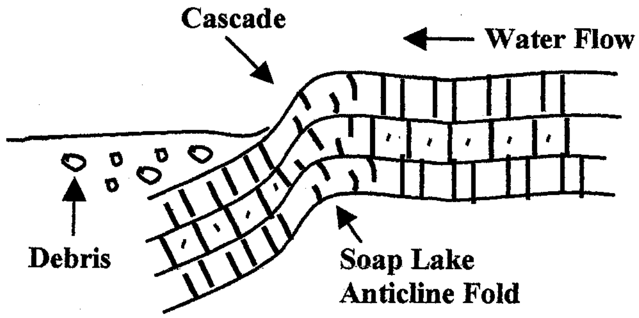


Figure 3.5 - Anticline

The Upper Coulee's monocline fold produced a waterfall that was 800 to 900 feet in height and the Lower Coulee's anticline fold produced a waterfall that was 400 feet in height. The waterfalls, or cataracts, undermining themselves formed the coulees as the waterfall receded upstream from their beginnings at the folds (Waterfalls Figure 3.6) (Bretz 59 p. 28).

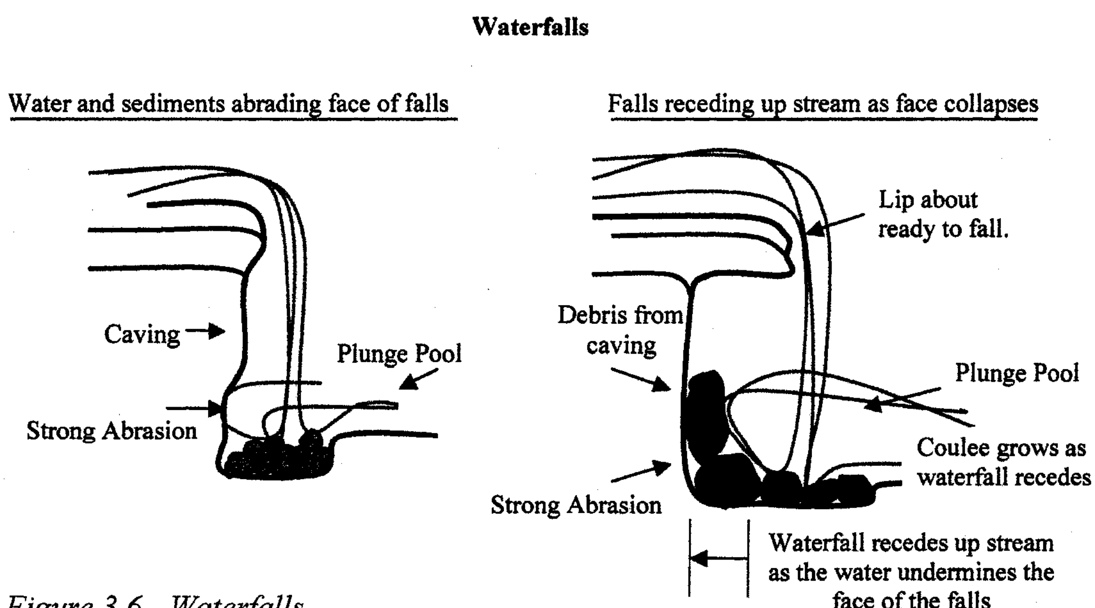


Figure 3.6 - Waterfalls

The water for these falls came from two sources: Glacial Lake Columbia and Glacial Lake Missoula (Figure 3.3). Glacial Lake Columbia was formed by an ice dam right at the head of what is now the Upper Coulee. The present towns of Grand Coulee and Coulee Dam would have been covered by the Lake. Glacial Lake Columbia was at times a large lake, starting at Grand Coulee, following what is today the Columbia and Spokane Rivers to Spokane. From there, at times, the lake would go up through the Spokane valley to Coeur d' Alene Lake (Figure 3.3). And, if the ice dam was high and strong, and if water was available from the glaciers, Glacial Lake Columbia could back up through the Purcell Trench, also called the Rathdrum Prairie (Figure 4.3), all the way to today's Lake Pend Oreille in northern Idaho (Glatzer 1983).

At Lake Pend Oreille, there was another ice dam. A finger of ice from the Purcell Lobe, the local glacier, flowed across what is today's mouth of the Clark Fork River (Figure 3.3) and blocked the Clark Fork river valley. The 2900 square miles of lake area and 500 cubic miles of lake volume—about the size of Lake Erie and Lake Ontario combined—that formed behind this finger of ice (an ice dam) is referred to today as Glacial Lake Missoula (Pardee 1942 p 1594). It is believed that Glacial Lake Missoula's ice dam floated and broke apart at least 40 times (Chambers 71) and perhaps as many as 89 times (Atwater 1986) causing floods of huge proportions. The ice dam at the Clark Fork's mouth, at its highest, held back 2000 vertical feet of water directly behind the dam. The lake its self stretched for approximately 150 miles to the east, filling tributary canyons as the water continued to deepen. When the Clark Fork dam self destructed the water would rush south down the Rathdrum Prairie (Figure

3.3) to Lake Coeur d' Alene where it would head west through the Spokane Valley, following the Spokane River.

At what is now the west side of Spokane, the water would divide into three routes across the Columbia Plateau: the eastern Cheney-Palouse route, the middle Telford-Crab Creek route, and the western Grand Coulee route (Lee 2004) (Figure 3.3). The water taking the Grand Coulee and Telford-Crab Creek routes continued down the Spokane River to the Columbia River heading for the ice dam at the north end of the Upper Coulee -- we'll call this the Grand Coulee ice dam. Obviously when Glacial Lake Missoula water came rushing from the Clark Fork ice dam, somewhere along the route it would run into Lake Columbia, unless the ice dam at Grand Coulee had just recently self destructed releasing all of Glacial Lake Columbia. But if Lake Columbia was waiting behind Grand Coulee's ice dam, an enormous amount of water could be added to the already enormous amount of water from Glacial Lake Missoula[3]. Of course the ice dam at Grand Coulee would be totally over run by all this additional water. This massive amount of water would be deflected by the huge glacial dam at Grand Coulee and be turned south to follow the route leading to 2 gigantic waterfalls, one waiting at the Upper Coulee monocline and the other waiting at the Lower Coulee's Soap Lake Fold.

[3] More information in "The Real Field Trip" section, paragraphs 10 & 11, page 64.

A word about ice dams: they accumulate by themselves and they self-destruct; they are automatic. The dam is created when a finger of ice comes out of the front of a glacier. If that finger blocks a waterway draining glacier melt water, it becomes a dam. If the finger is relatively strong and high, the dam can pile up quit a bit of water before the ice begins to float a little; the water will then break the dam apart, releasing a great amount of water all at once. Of course, if the finger is relatively short and weak, the dam will only hold a small amount of water before it fails. Once the dam fails, it may rebuild itself by re-growing the finger of ice that will once again dam the glacial melt water. And, as the water deepens the dam will once again self-destruct. Since this process can happen many times, it is possible that Glacial Lake Missoula sent many floods to rush over the Grand Coulee's waterfalls, literally tearing the basalt out of the ground and causing horrific undermining beneath the waterfalls. Of course Glacial Lake Columbia's dam broke and rebuilt many times as well, sometimes with the help of Glacial Lake Missoula water and sometimes without it. At any rate, thousands of tons of water did flow south over the Upper and Lower Grand Coulee falls from a combination of Glacial Lake Missoula and Glacial Lake Columbia and head to the Pacific Ocean. The erosional power of Glacial Lake Columbia combined with a portion of Glacial Lake Missoula's water did much of the work to create the Grand Coulee.

There is one more piece of the story that is important. It concerns the role of basalt in the making of the Grand Coulee.

Basalt is a heavy, dense igneous rock that forms from lava on the earth's surface. However, due to the way the lava cools, this heavy dense rock is relatively easy for a massive amount of water to erode. When basalt cools, it forms two types of features: columns, and the entablature. The column diameter can range from 6 inches to 2 feet and they can have from 4 to 7 sides, but commonly have 5. The columns are not stuck together; instead, each stands as an individual, with joints in between. These joints allow water in between the columns to erode the basalt relatively easily.

The other type of feature, the entablature, is a mass of irregular, fractured, jagged-surfaced basalt. Here again, there are fractures that allow water to enter the structure and erode it (Long 86) (Picture 6).

When massive amounts of water rushed over the basalt in the Grand Coulee area, it made its way into the fractures and joints of the basalt. As the water invaded the basalt, it forced piece after piece out of its place and into the water's flow. Had the rock of the Columbia Plateau been something other than the easily eroded basalt (for example, granite, which does not erode easily), the Grand Coulee would have certainly been less grand because of the reduced erosion or, perhaps the Grand Coulee would not have come into existence at all.

Today hydrologists believe that kolks (underwater vertical vortices) were responsible for plucking much bedrock, including the fractured basalt, from under the fastest flows of Glacial Lake Missoula. These very powerful underwater "tornadoes" develop in very deep fast flowing water and create potholes; the largest of these become small lakes as the water abates. It is believed that kolks are responsible for a great deal of the erosion that has taken place along the paths of the Glacial Lake Missoula Floods (Fox 2005, Alt 2001 p 42).

One more piece of information concerning ice dams should be mentioned here. At the time this unit was taught, the explanation for catastrophic failure of an ice dam was that when a certain depth of water backed up behind an ice dam, the ice would start to float allowing the water behind the dam to destroy the dam. However, since that time Matthew Roberts of the Iceland Meteorological Office, Iceland, has researched this topic more fully and has given the following explanation.

Deep at the base of an ice dam massive pressure from the water above can keep the water below from expanding and therefore the water cannot turn to ice. This pressurized water can stay liquid to several degrees below freezing at which time the water is said to be super-cooled.

Glaciers have minute cracks in them from stresses within the ice. Super-cooled water is forced into these cracks by the pressure of the water sitting on top of water at lower depths and the water backed up behind the dam. As the water is pushed into the cracks, water molecules are forced up against the ice creating friction. Friction produces heat, and the heat melts the ice. This process can turn minute cracks into giant ones several feet across which creates a series of tunnels throughout the ice. After this continues for sometime the ice becomes destabilized and is too weak to hold the water behind it back. At this point the dam begins to fall apart and in a very short time there is a catastrophic failure of the dam. The water behind it is released almost all at once (Fox 2005).

Day Five – Thursday May 25, 2000 Mini-megaflood

On day five, we used another model to create a powerful mini-megaflood. This was done by using a plastic 35-gallon stock water trough, 4-inch ABS pipe, chicken wire, and Fix-All (a patching compound available a home improvement stores; when dry it is very resistant to water). The model was of the Camas Prairie, and the valley just north of it called the Little Bitterroot Valley (Picture 7). Both the Valley and the Prairie were completely covered by Glacial Lake Missoula that rested behind the Clark Fork ice dam. These features were so covered that the water was 800 feet above the two passes that separate the valley from the prairie. And, the tops of those passes were and are about 400 feet above the floor of the Little Bitterroot Valley.

The Camas Prairie (Figure 3.3) is located about 60 miles northwest of Missoula, Montana, and there are features in the basin that make it our point of focus. Those features are giant ripples marks (Pictures 2&3) left on the sides and bottom of the basin when the enormous amount of water being stored there was released during one, or more, of the collapses of the Clark Fork ice dam. These ripple marks are as high as 35 feet and up to 300 feet from crest to crest. The size of these ripple marks indicates that a very large amount of water was headed south, above and in the basin, as the water flowed to the valley that drains the basin (Pardee 1942, Alt 2001 p 37).

As we filled the model with water (Picture 7), we discussed the sediment pile left on the Camas Prairie side of Wills Creek Pass (Panorama 3A&B). As the water came through the constricted area of the pass, the water increased in speed allowing it to scour the bottom and sides of the pass. Also, the current rushing through plucked some of the rocks from the floor and sides of the pass. The scoured and plucked rocks and dirt were suspended in the fast running water until the water slowed down after leaving the constricted area of the pass on the Camas Prairie side. As the water fanned out, it slowed down, dropping the heavy, larger sediments first and then progressively dropping the lighter sediments as the water continued to slow. The pile made by the dropping sediments is large and is another indicator that the quantity of water in this region was substantial and when the dam broke the water flowed from the Little Bitterroot Valley side to the Camas Prairie side.

The purpose of the model was to create a powerful mini-megaflood designed to give some idea of how powerful the water was when released by the Clark Fork ice dam (Pictures 7&8). We did this by using Monopoly houses to represent scale. We also constructed a scabland landscape using a piece of plywood 2 feet by 8 feet, and we put a length of two by six lumber along each 8 foot side of the plywood. This created a space between the sides to fill with rock and then place loess on top of them (Picture 8). To let a lot of water go at the same time we used a 4-inch diameter piece of ABS plastic pipe on the trough. Inside the trough, to make the Camas Prairie and Little Bitterroot Valley, we used chicken wire and covered and formed our land features with the Fix-All. We kept the water in the trough by using a threaded 4-inch plug in a threaded 4-inch clean out adapter at the end of our 4-inch 90-degree elbow.

When we were ready to release the mini-megaflood, we put the Monopoly houses on the scabland model and unscrewed the plug. A massive amount of water came charging out of the 4-inch pipe and attacked the scabland model. The tiny houses on what became our scabland were removed with an absolutely overpowering force (Picture 8). The students watched the first house the water would hit after coming through the 4-inch pipe and yelled, screamed, or moaned when the water completely engulfed it and took it for an incredible ride. It seemed that we had given the students some understanding of the might of the water rushing down the Grand Coulee!

The Real Field Trips: The Camas Prairie

Detailed Driving Instructions for the Two Real Field Trips are in Appendix B. This trip was taken on May 26, 2000

1. We headed east out of Spokane on Interstate-90 from the Argonne Street Entrance. The time was about 8 a.m. We traveled 90 miles until we just crossed the Montana border. There we stopped at the Dena Mora rest area for a break and to look closely at the polystyrene model of the Grand Coulee area Pictures (5A&B). The idea was to reinforce the concept of waterfall undermining and why it was so important to the formation of the coulees (Picture 9). A handout describing undermining was given to the students and we discussed the process. We used the polystyrene model's removable coulee pieces to illustrate how the undermining ran upstream leaving a gorge behind. Then everyone got back on the luxury bus and we headed for the 9-Mile Road exit and a look at some Glacial Lake Missoula sediment layers.

We reviewed the Grand Coulee on the way to the Camas Prairie because the day before we had no time to look closely at the undermining process due to the mini-megaflood lab. And, the next time I would see the students after that day would be on the Coulee field trip; I felt it was important to give them time to absorb and reflect on this concept.

2. We arrived at our observation perch above Interstate-90, which is just off the 9-Mile Road exit, about an hour after leaving the Dena Mora rest area. Students took their lawn chairs from the belly of the luxury bus and set them up just inside the freeway barbwire fence, which they had crossed carefully. The students were now standing about 40 feet above the freeway and had an excellent view of the sediment layers on the other side of the freeway. (Panorama 1) The students sat in their chairs so they could stabilize themselves and drew the red and tan sediment layers in their notebook. The red layers are varve sequences from the bottom of Glacial Lake Missoula and the tan layers in between them were complexly bedded sediment layers that formed when the lake sat empty after a collapse of the Clark Fork ice dam. When a new ice dam formed, Glacial Lake Missoula started to fill again and a new series of varves would start to be laid down on the newly formed sediment layer.

3. Chambers and Alt (Chambers 1971, Alt 2001 p 26) found there to be 36 sequences of varves with layers of complexly bedded silt between them. They interpreted the varve sequences as having originated when the glacial lake existed. And, they interpreted the complexly bedded silt as deposits from the Clark Fork River that ran through the Lake's bottom when no lake was present. They counted almost one thousand pairs of light and dark layers in the thirty-six sequences of varves (Picture 1). These thousand varves give evidence that Glacial Lake Missoula was present for at least a thousand years, though it emptied from time to time. In the lowest sequence included 58 varves, meaning Glacial Lake Missoula was present for 58 years before it

emptied. In the highest sequence of varves, there were only nine varves, meaning Lake Missoula was only present nine years before the ice dam destroyed itself and the lake emptied. Chambers and Alt concluded the ice dam at the mouth of the Clark Fork was getting smaller and smaller each time it rebuilt so it collapsed sooner and sooner, possibly because the glaciers were retreating up into Canada at the end of the last ice age.

4. After the illustrations were drawn and information recorded about the sediment layers, we stowed the lawn chairs in the storage compartment of the bus and climbed on board. We headed back the way we came to Interstate-90 and took the eastbound entrance towards Missoula, Montana.

5. From north Missoula, you can see the shoreline marks on Mount Jumbo[4] if you face southeast (Panorama 2). The parallel lines across Jumbo's west face have been defined as Glacial Lake Missoula shorelines. They are best seen in the early morning light or when there is a skiff of snow melting on the mountains. Of course the "shorelines" cross many mountain faces along the shoreline of Glacial Lake Missoula but Missoula is well known as a good place to see them.

[4] Mount Jumbo is directly north of Mount Sentinel. Mount Sentinel borders the University of Montana on the University's east side—the big M is on Mount Sentinel.

6. The students and I discussed the shorelines in terms of how they indicated the amount of water that had once been collected here. The highest shoreline is about 1000 feet above the valley floor on Mount Jumbo and that suggests that the lake elevation was approximately 4,250 (Lee 2004) feet at that time. But we were about 130 miles from the ice dam at the mouth of the Clark Fork. At the ice dam, where the town of Clark Fork is today, the valley's floor is at an altitude of a little over 2,000 feet and that makes the approximate depth of the water at the ice dam 2000 feet! So, when the ice dam broke, 500 cubic miles of Glacial Lake Missoula, about as much water as that contained in today's Lake Erie and Lake Ontario combined, (Pardee 1942) moved towards Washington State through the Rathdrum Prairie. The depth of the water on the Prairie was about 500 feet, and the speed of the water reached close to 75 miles an hour (O'Conner and Baker 1992).

7. After our short discussion and drawing Mount Jumbo with its shorelines into our notebooks we boarded the bus and headed 60 miles northwest to the Camas Prairie Basin. The stop at Mount Jumbo had lasted about 30 minutes.

8. When we stopped near Willis Creek Pass in the Camas Prairie Basin, the students clambered off the bus with lunches in hand and the next 45 minutes were given over to food, chatting and enjoying the scenery. After lunch, the notebooks and colored pencils came out and the students drew the large ripple mark that J.T. Pardee had identified back in 1942 (Pardee 1942). They also sketched the giant sediment pile

directly to the east of us where the flood waters came through Willis Creek Pass. (Panorama 3A&B)

9. We came to the Camas Prairie not to see normal ripple marks but to see huge ripple marks, some of them 35 feet high and 300 feet from crest to crest (Picture 2). And, we came to see the giant sediment pile of Willis Creek Pass. The old two-story house at the south base of the debris pile truly has the scale of a Monopoly house on our mini-megaflood model (Picture 3). We are also here to imagine how much water it would take to make those sorts of ripple marks and debris pile. But that's not all we want to imagine. We are on the north rim of the basin, a little more than 400 feet up from its bottom, which puts us pretty much level with Willis Creek Pass. Geologists believe Glacial Lake Missoula's highest level would have been eight hundred feet above our heads (Alt 2001 p 38).

At the end of the day, we arrived home at approximately 7 p.m.

The Real Field Trips: The Grand Coulee

This trip was taken on May 26, 2000, four days after the Camas Prairie trip.

10. The first part of this day's trip took us to Latah Creek, sometimes called Hangman Creek. Right across the creek from our parking place is a sand wall that displays hundreds of layers of sediment (Panorama 4). These sediments came from Glacial Lake Columbia as it backed up behind the ice dam at Grand Coulee and from Glacial Lake Missoula floods, called Spokane Floods, after they had come down the Spokane Valley to pond in this Hangman Creek area. Also, this is the area into which most of the water from a Spokane Flood would go, leading into the first tract, or path, that led to Wallula Gap-the way out of the Columbia Plateau for water. This tract was called the Cheney-Palouse Tract and it was the farthest east of three tracts. The other two tracts went west from Spokane through Glacial Lake Columbia (Figure 3.3). Remember Glacial Lake Columbia would have been huge and would have backed up behind its ice dam all the way up the Rathdrum Prairie (Figure 3.3). If that much water was behind the Grand Coulee ice dam, and if the Clark Fork River ice dam broke at the front of Glacial Lake Columbia, there would have been an enormous amount of water headed for the Columbia Plateau. When the floodwaters arrived just west of Spokane, which is the northeast corner of the Columbia Plateau, all three of the tracts would have been required to manage the incredible amount of water. Tract two is called the Telford-Crab Creek Tract. It is in the middle of the other two (Figure

3.3). It poured out of Glacial Lake Columbia about half way between Spokane and the Grand Coulee ice dam. It also headed for Wallula Gap. Tract third, called the Grand Coulee Tract, went through the area of the Grand Coulee (Figure 3.3). About a quarter of the water from Glacial Lake Missoula would have gone down the Grand Coulee Tract (Lee 2004).

11. All the tracts ended up in the same place, Wallula Gap (Figure 3.3). It is the only place the water from Glacial Lake Columbia and Glacial Lake Missoula, or any large amount of water for that matter, could go to get out of the Columbia Plateau. The Columbia River, which was present when the floods were happening, had created this 1-mile-wide, 800-foot-deep gap in the Hills that borders the Columbia Plateau on the south. When one or both of the glacial lakes destroyed their ice dams the floodwater would pour down the three tracts to Wallula Gap. However, there would have been so much water it couldn't all go through the opening fast enough to keep all the water flowing at the same speed it arrived. Therefore, a temporary lake formed while the floodwaters flowed through the Gap as fast as they could (Lee 2004). It is said that the lake would exist for 100 days after floodwaters arrived in the area (Shaw 1999 p.608). The lake was called Lake Lewis.

12. The sediment layers were also helpful in showing the students how sediment layers can provide a record of floods, lakes, dry areas, as well as show where beaches were, where faults lay, etc (Panorama 4).

13. At this point, the students finished drawing the sediment wall in their notebook, which took about a half hour, and we were off. Crossing the Columbia River on the Keller Ferry, we arrived at the north side just west of the mouth to the Sanpoil River.

14. The water lines on the canyon walls at Keller Ferry were very distinctive and they provided an excellent example on how water's wave action can cut into the shore to make a series of parallel lines (Pictures 10A&B). We had a short discussion on how this was the model we applied to the parallel lines on Mount Jumbo (Panorama 2) to support our explanation that those lines were water lines, or shorelines, from Glacial Lake Missoula.

15. From the north side of Keller Ferry, we drove north to a ranch overlooking the north end of the Upper Coulee. There is a beautiful view of Steamboat Rock, Banks Lake, the North Dam, and the tubes used to take the water out of Columbia up to Banks Lake.

16. From a viewpoint at the top of a hill on private ranch land (Figure 6), we picked out the North Dam, Banks Lake, Steamboat Rock, the canal bringing the water to Banks Lake from the uplift pipes, and tried to comprehend the sheer size of the north end of the Upper Grand Coulee (Panorama 5).

17. We moved on to the east side of the Upper Grand Coulee to an example of waterfall undermining. The waterfall comes down the face of the coulee into a plunge pool and there was a little room for students to climb up behind the falls. There they could feel the water spray and touch the water as it fell past them (Picture 9). Those students were sitting in the undermined area, which was quite large for such a small waterfall, so the falls either have a great deal more water coming over them at times in the present, or else the undermining was done at some point in the past, when there was more water in the region. Perhaps during the time right after the coulee had formed. The students seemed to have a better idea of what undermining actually is after seeing and sitting in an undermined area. At least that is what they told me as we walked back to the bus.

18. Later, at a viewpoint a bit south of the falls, the students got off the bus to look back up the coulee the way we had just come. The view shows the scale of the coulee quite well (Panorama 6). Also, on the coulee's east wall across from the viewpoint, there was an excellent example of columns in the basalt flow with the entablature (fractured jagged basalt) section right above the columns (Figure 6). We looked and discussed the structure of the flow for a few minutes and then returned to the bus.

19. From the viewpoint, we continued south to Dry Falls Dam at the very end of the Upper Coulee. As the bus crossed the earthen dam, the students had an excellent view of the Upper Coulee's south end. Further along, at the Dry Falls Interpretive Center

viewpoint, we clambered off the bus to enjoy a beautiful view, this time of the Dry Falls (Panorama 7). The point was made that the falls in the Lower Coulee (our current location) were only 400 feet tall, while the falls in the Upper Coulee were 800 feet tall.

20. Another point I made is that the Lower Coulee runs south right down the fracture zone of the Coulee monocline. I made this point using the polystyrene model of the Grand Coulee to show were the Coulee Monocline runs right down the Lower Coulee (Picture 5A&B). I also handed all the students a Fig Newton cookie and asked them to bend, not break, it long ways. As they did so, the filling and crust split open a little bit along the length of the cookie. I compared the splits in the cookie to the bends in a monocline. As the rock layer split, or fractured, around the bends of the monocline, rocks broke and loosened the soil, making space for water to get in and erode much more easily than where there were no fractures. So, when the water came down what was to become the Lower Coulee, it eroded the lower bend of the monocline more quickly than the other rock around it. Therefore, a channel began to form in that bend. And, of course, the channel became wider and deeper as more and more water ran through it. At this point the Fig Newtons were consumed and we boarded the bus to go look at the monocline.

21. We drove south down Hwy 17 1 8/10 miles and turned into Sun Lakes and Dry Falls State Park (Panorama 8). We drove down the driveway for 8/10 of a mile and

the driver turned the bus around (It took a few minutes). By looking northwest up on the side of the hill you can see the rock layers slant down showing the monocline (Panorama 9). Very little discussion was necessary for the monocline was extremely visible.

22. The bus driver then drove us back to Spokane.

The Virtual Trip

This Trip was taken on May 31, 2000

The virtual trip was given to 30 students in one of the school's social studies classrooms. We projected panoramas that could be scrolled across a 6 x 8 foot screen that was in the room. Each panorama was enlarged to fit, as closely as possible, the screen's entire surface. The panoramas were made by taking individual pictures of a landscape and then digitally merging the pictures together to form one continuous picture. This was done using QuickTime VR Authoring Studio 1.1 software on an Apple desktop computer. The images were then transferred to an Apple iBook laptop, and were projected from the iBook through a Liquid Crystal Display (LCD) projector onto the screen.

The students had their notebooks and drawing tools so at each "stop" they could draw the primary structure under scrutiny and label its parts appropriately. At each stop, the discussion included the same material that the real field trip students were exposed to at each of their stops, and the virtual students had a similar length of time to share their thoughts with each other as they studied the graphics. The students took about 40 minutes to complete the drawings and discussion on the Camas Prairie portion of the field trip. They then took a 15-minute break and we took the Grand Coulee portion of the field trip. It took about 50 minutes to complete the drawings and discussion of the Grand Coulee portion.

Virtual Trip Itinerary

23. The varves at 9-Mile Road (matches paragraphs 2 & 3 of this document) – This is a short panorama showing the layers of varves and the layers of sediments deposited between the layers of varves (Picture 1). The river that ran along the bottom of Glacial Lake Missoula when the Lake was empty deposited the sediments. The picture shows exactly the same view of the layers as the real field trip students saw in person (Panorama 1). Discussion included the presence of varve layers inside the red layers and the way in which the river sediment layers show the times Glacial Lake Missoula was sitting empty.

24. Mount Jumbo in Missoula (matches paragraphs 5 & 6 of this document) – This is a medium panorama of the shoreline marks from Glacial Lake Missoula on the west face of Mount Jumbo (Panorama 2). This is exactly the same view as the real trip students saw from Game Trail Street in Missoula. Discussion included the height of the water in the Missoula area, approximately 1000 feet above the valley floor, and the size of Glacial Lake Missoula, which had about as much water in it as Lake Erie and Lake Ontario combined have in them today.

25. Camas Prairie (matches paragraphs 8 & 9 of this document) – There are two long panoramas and two still pictures showing the ripple marks in the Camas Basin and debris pile left at the exit of Willis Creek Pass (Panorama 3A&B plus Pictures 2&3). The views include the same features the real field trip students saw on their field trip. Discussion include the size of the larger ripple marks, 35 feet high and 300 feet from crest to crest, the origin of the debris pile at Willis Creek Pass, and the idea that the water would be 800 feet above our heads if we were standing at the elevation of Willis Creek Pass, which is 400 feet above the basin's floor.

26. Latah Creek, sometimes called Hangman Creek, Sediment Wall (matches paragraphs 10, 11 & 12 of this document) – This sediment wall short panorama is exactly the same view the real trip students had of the sediments (Panorama 4). Discussion with the students included what sediment layers can show us, beaches, faults, etc. and the three paths, or tracts, the water followed from Spokane to Wallula Gap, which was the water's only outlet from the Columbia Plateau.

27. Keller Ferry (matches paragraph 14 of this document) – There were two stills showing the shoreline marks on the Columbia River's banks. Discussion included comparing the smaller well-defined parallel lines at Keller Ferry (Pictures 10A&B) with the much larger poorly defined parallel lines on the sides of Mount Jumbo (Panorama 2). The point was made that today's shoreline marks provide the model we look for to find past shorelines; the big clue is that the lines must be parallel.

28. North End of the Upper Coulee View (matches paragraphs 16 of this document) – This is a medium sized panorama showing a view from just north of the north end of the Upper Coulee (Panorama 5). Steamboat rock is present, the canal bringing water to Bank's Lake from the uplift tubes are present along with many other coulee features. The virtual students saw exactly the same view as the real field trip students. Discussion included the 800-foot vertical walls of the coulee, the amount of basalt removed, and the tenacity of Steamboat Rock.

29. Undermining Waterfall (matches paragraph 1 & 17 of this document) – The view of the virtual students was only of the undermined portion of the waterfall (Picture 9). The focus was the plunge pool and the erosion showing the undermining, so only one photograph showing both was used. Of course the real trip students saw the whole falls, threw rocks in the plunge pool, and felt the falling water on their skin. The discussion included the use of the polystyrene model of the Grand Coulee area. The idea was to reinforce the concept of waterfall undermining and why it was so important to the formation of the coulees. A handout describing undermining was given to the students and we discussed the process. We used the polystyrene model's removable coulee pieces to illustrate how the undermining ran upstream leaving a gorge behind. The polystyrene model was used to reinforce the same concept for the real trip students at the Dena Mora rest area in Montana (matches paragraph 1 of this document).

30. Coulee Viewpoint (matches paragraph 18 of this document) – A medium length panorama was used to show the size of the north half of the Upper Coulee as viewed looking north from the middle of the coulee (Panorama 6). The view for the virtual students was exactly the same as for the real field trip students.

31. Basalt flow structure (matches paragraph 18 of this document) – This view of the columns and entablature is directly across the road from the Coulee Viewpoint (Picture 6). The one still photograph shows exactly the same view as the real trip students saw. Discussion included how easy it was for water to get into the joints between the columns and the fractures in the entablature to erode the basalt quickly.

32. Dry Fall (matches paragraphs 19 & 20 of this document) – Dry Fall was shown on a 360-degree panorama in the classroom. Shown here is a 90-degree panorama (Panorama 7). This panorama is only a quarter of the view the real trip students had when they visited the Dry Fall Interpretive Center Viewpoint. Discussion included the fact that the vertical walls of Dry Fall are only 400 feet so the waterfall was half the size of the 800-foot one in the Upper Coulee. Anther point I made is that the Lower Coulee runs south right down the fracture zone of the Coulee monocline. I used the polystyrene model to show the students where the Coulee Monocline is and I used the same Fig Newton example I did for the real field trip students in paragraph 20 above.

33. Monocline (matches paragraphs 21 of this document) – The monocline view for the virtual students was exactly the same as the real trip students (Panorama 9). Discussion was focused on that the Lower Coulee runs right along the lower bend of the Coulee Monocline.

Chapter 4

Study Design and Methods

General Description of the Research Project

This study compared two methods of presenting real world natural phenomena to eighth grade earth science students. The methods are: (1) a traditional style field trip, i.e., a "real-world field trip," and (2) projected computer-based photographic images that create a "virtual field trip." Sixty-one students took part in this study. All were students in one of three science classes taught by Mr. Jim Traveler - a teacher with an excellent reputation among parents, students, and staff.

The comparison between these two methods was based on the quality of an essay style explanation written by each student. The explanation focused on the natural development of a geologic oddity - the Grand Coulee - located in the central region of eastern Washington State.

Details of the Research Design

The project was divided into three sections. The first was composed of classroom instruction. The second was the field trip, either virtual or real. The third was student response and assessment of that response.

Section 1 - Classroom Instruction

All participants were taught five key concepts during five days of instruction in the classroom. These concepts are related to the fields of sedimentology and geomorphology (landforms) and are core to the present day explanation of the Grand Coulee's geologic development. The students were taught these concepts through the use of models and hands-on labs, allowing them the opportunity to build their own understanding.

During classroom instruction, student understanding was assessed on a daily basis. This process gave the instructors the opportunity to discover and correct any misconception of these very key geologic concepts. Each student created a notebook containing detailed explanation concerning each of the five concepts, as well as information and explanations recorded on the field trip. The use of this notebook for reference by its owner was encouraged at all times, even during the final assessment.

Section 2 - Field Trips

Field Trip: Real

The group of 61 students was divided into two groups, 30 in one and 31 in the other. The students were chosen by lottery (numbers drawn from a box that were matched to individual students, every other drawn number went to the real trip, ditto for the virtual). Students whose parents requested that their student not go on the real field trip were switched with a student from the virtual group. This was a consideration because of the length of the real field trips. Both left at 7 A.M. and returned around 7 P.M. on school days, making important after school activities impossible to attend.

One group took the real field trip and the other the virtual trip. The real field trip was given in two parts: the western Montana trip, which covers 500 miles and three key sites (sediment layers, waterlines or beach lines, and giant ripples marks) and the eastern Washington trip with its 300 miles and six key sites (sediments layers, size of the north end of the upper Grand Coulee, waterfall undermining, basalt structure, heavy duty erosion, and a monocline). Each trip was completed in one day.

During the trip, students looked at sediment deposits and landforms that are the real thing - as opposed to the models they had been studying in the classroom. Their assignment was first to identify the type of sediment layer or landform hidden (or not so hidden) in the topography, and second, to explain under what conditions they may have formed. Students made drawings in their notebooks of the features on site, adding explanations as they were en route to the next site. This allowed students to discuss their ideas with others, sharpening their understanding and articulating their explanations. Their explanatory write-ups were scrutinized for genuine understanding of the currently accepted geologic explanation describing the creation of the Grand Coulee. The explanation needed to include reference to the five examined supporting piece of evidence for the current explanation: sediment layers from lakes, giant ripple marks and beach watermarks (indicating vast amount of water), glacial ice (including transported debris), basalt structure, and waterfall undercutting. Written text, supported by diagrams and labels, needed to provide a logical sequence of thought, leading the reader to an explanation reasonable for the domain of geology. A word of caution is warranted here. Because Mr. Traveler and myself are constructivists, a specified outcome was not demanded; however, supporting evidence and domain-focused convincing arguments were. Students were encouraged to look where they may for information, but their explanation was still judged by geologic domain standards. That didn't necessarily mean the student believed the explanation, just that they understood what the domain has to say and why. It should be noted here that geologic and technology concepts used to create the curriculum and present it were directly tied to the Washington State Science Essential Academic Learning Requirements (EALRs). Particularly EALR 2, Component 2 (2.2) *Nature of Science: Understanding the Nature of Scientific Inquiry* (OSPI 2005).

Field Trip: Virtual

The second group stayed in the classroom. There they were transported via digital panoramic images to the same sites visited by those students on the real field trip. The panoramic images were created using QuickTime VR, a computer application which stitches photographs together. These images can encompass a full 360 degrees in the horizontal and vertical planes, if desired, and allow the user to zoom in and out on any selected area. When the instructor and students agreed it was time to go to the next site, the instructor could transport the class to the next virtual stop.

The way in which these panoramas were presented to the students mimicked what happened on the real-world field trip as closely as possible. The concept was to make the classroom a "virtual bus." Students entered the "bus" and were "whisked away" to each site - via an eight by six foot LCD projection. At each site, every student had the opportunity to control the projected landscape, if they chose. They could scan the panorama and zoom in and out on specific areas of interest. Also, the virtual field trip visited the same sites in the same order as the real-world field trip, with no ability to return to a site once the class has moved on, just as with the real-world field trip. Students shared their thoughts with one another, recording their observations and speculations as to how these features were formed and what they might mean, just as their peers could on the real bus. The students were on board our virtual bus approximately one and a half hours.

Mr. Traveler and I were the instructors on both versions of the field trip, thereby ensuring a consistent monologue. We answered specific questions generated by students, but the answers were given in general terms, meant to provoke closer observation by the students, rather than providing them with currently accepted explanations.

Section 3 - Student Assessment

Assessment of student learning took place after both groups had taken their particular version of the field trip. It was based on the students' ability to provide a plausible geological explanation for the existence of the Grand Coulee. Their essay answers were evaluated using a checklist of concepts (rubric). Of primary importance was the difference, if any, between the quality of explanations given by those who took the real field trip and those who took the virtual trip.

The student's ability to provide a reasonable (using context domain standards) and supported explanation of geologic processes leading to the creation of the Grand Coulee was the main indicator of quality of learning.

Assessment Documents and Reponses

There are three components to the Assessment:

1. Test Question
2. Previous Knowledge Survey
3. Student Feedback Survey

Component 1 - Test Question

Below is a copy of the Test Question handout.

Montana & Eastern Washington Field Trip Assessment

During our field trip through Eastern Washington, we passed through an area with steep cliffs called the Grand Coulee. Many of you asked, "How was the Grand Coulee formed?"

"What an excellent question!", I thought. "All of the phenomena we observed in Montana and Eastern Washington, along with the explanations, will lead to explanations of how the Grand Coulee was formed. Yes!!!!!"

Your task: The Grand Coulee is a geological phenomenon. Explain how it was formed.

Grading Criteria

Title – 4 points
(Entices reader and directly relates to the forming of the Grand Coulee.)

Quick Pic – 2 points
(Entices reader and directly relates to the forming of the Grand Coulee.)

Introduction – 12 points
(This tells the main purpose of the write-up.)

Observations – 12 points
(Any observation made of the Grand Coulee.)

Research & Analysis – 20 points
(This includes any observations of phenomena created in class before the field trip or during both field trips to Montana or Eastern Washington. Pull what you think you can use from your science notebook to support your explanation of how the Grand Coulee was formed, while preventing dogma.)

Best Explanation – 25 points
(Underline each piece of data from your "Research & Analysis" above as you link, weave and sort this data to create your best explanation of how the Grand Coulee was formed.)

Models – 25 points
(Labeled pictures which directly tie to the main focuses of your "Best Explanation" of how the Grand Coulee was formed.)

Figure 4.1 Test Question Handout

Almost immediately after handing out the test, I realized that the time allowed for the Assessment was not sufficient for them to do the Research & Analysis portion in the way I described it on the Assessment page. Therefore shortly after the test had begun, I told the students, verbally and by writing the information on the white board, to include the Title, Quick Pic, and Introduction parts of the Assessment and then simply give me their best explanation as to how the Grand Coulee was formed and to include a graphic illustrating each of their major points. Also, I wanted them to put the events that lead up to the creation of the Coulee in chronological order. I then reconstructed the Grading Sheet or rubric to reflect the new format. However, a few students stayed with the original layout, which also worked out fine with the new rubric. The final rubric is on the next page.

Trip: **Real** or **Virtual** Raw Score Percentage Paper Number ______

Grading Sheet
For **Person's Name**__________________
Montana & Eastern Washington Field Trip Assessment

Title – 4 points	Words entice person to read student's "Best Explanation".	2
	Words relate directly to the forming of the Grand Coulee.	2
Quick Pic – 12 points	Graphics entice person to read student's "Best Explanation".	4
	Graphics relate directly to the forming of the Grand Coulee.	4
	Graphics are neat and well drawn.	4
Introduction – 2 points	Answer: "Explain how the Grand Coulee was formed".	2
Observations – 12 points	Moved within the "Best Explanation". Points removed.	0
Research & Analysis – 20 points	Moved within the "Best Explanation". Points removed.	0

Best Explanation – 40 points Best Explanation of how the Grand Coulee was formed plus 15.
Models/Graphics – 30 points Combine Model points plus 5 within this segment.

Written Concept **At Least One Correct Graphic of:**

Note: Graphics must fit in with student's written explanation.

Sense of Order – Less than 4 out of 6 correct - 4 or 5 out of 6 correct - All correct 0 5 10

Order

1a. Basalt is laid down – Entabular Texture & Columnar Jointing,		5
b. plus Graphic.	Lava to Basalt, (Fissure) Volcanoes, Coulee in Basalt	5
2a. Monocline – Basalt Fell, Weak Zone, Formed Waterfalls		5
b. plus Graphic.	Location(s) of Monocline, Water Path Lower Coulee	5
3a. Glaciers - Shape & Marks of high mountains, Till, Erratics		5
b. plus Graphic.	Melting Supplied Flood Water, Provide Block & Ice Dams	5
4a. Glacial Lakes – Varves, Beach Curves, Water Marks on Hillsides,		5
b. plus Graphic.	Saddle Deposits, Erratics, Tiny Sediments, Glacial Dams	5
5a. Flood Evidence – Scoured Land, Ripple Marks, Coulees, Erratics		5
b. plus Graphic.	High & Low Water Energy, Ripped Up Large Rock	5
6a. Huge Coulees – 2 Water Falls Travel 50 miles up stream, Erosion		5
b. plus Graphic.	Waterfall Undermining, 900 ft. deep, steep sides	5

Models – 25 points (Graphics) Moved within the "Best Explanation". 0

Total Points Received ____
Total Points Possible **88**

Figure 4.2 Test Rubric

Test Scores

Tables 4.1 and 4.2 below present the raw test scores and the test score percentage for both the Real and Virtual groups. The mean of the raw scores and the percentage scores are also presented.

Here are the test scores for A Group – the Real Field Trip

Number Possible = 88

Table 4.1 – Real Group Test Scores

Group A	Test Number	Number Correct	Percentage Correct
1A	16	88	100%
2A	21	72	82%
3A	10	63	72%
4A	3	73	83%
5A	61	88	100%
6A	19	88	100%
7A	35	33	38%
8A	44	50	57%
9A	14	45	51%
10A	25	53	60%
11A	26	73	83%
12A	65	68	77%
13A	34	78	89%
14A	62	48	55%
15A	32	53	60%
16A	31	63	72%
17A	24	48	55%
18A	48	73	83%
19A	37	67	76%
20A	68	54	61%
21A	47	73	83%
22A	46	88	100%
23A	7	63	72%
24A	11	84	95%
25A	64	38	43%
26A	66	68	77%
27A	29	68	77%
28A	8	73	83%
29A	38	83	94%
30A	42	83	94%
	Mean	**66.63**	**76%**

Here are the test scores for B Group – the Virtual Field Trip.

Number Possible = 88

Table 4.2 – Virtual Group Test Scores

Group B	Test Number	Number Correct	Percentage
1B	5	68	77%
2B	55	38	43%
3B	13	53	60%
4B	20	88	100%
5B	4	78	89%
6B	53	88	100%
7B	9	64	73%
8B	28	88	100%
9B	18	53	60%
10B	45	88	100%
11B	33	83	94%
12B	2	68	77%
13B	49	78	89%
14B	23	73	83%
15B	22	68	77%
16B	51	43	49%
17B	54	78	89%
18B	12	53	60%
19B	52	83	94%
20B	60	74	84%
21B	36	88	100%
22B	50	58	66%
23B	58	78	89%
24B	27	83	94%
25B	41	83	94%
26B	57	22	25%
27B	63	73	83%
28B	30	49	56%
29B	15	33	38%
30B	67	76	86%
31B	39	88	100%
	Mean	**68.97**	**78%**

The raw score means shown on these two tables (Real 66.63, Virtual 68.97) show that the learning on the part of both groups is almost identical.

Range of Grades

I had a personal goal that all the students get at least 70% on the test. Therefore I created the following two tables to show the percentage of both Virtual and Real groups that made the 70% mark and how many didn't. An asterisk represents the grade for one student. If the asterisk is under 80% box it means the test score was between 80 and 89 percent and so on for the other percentages. The 70% (A group) and the 71% (B group) in the third row of boxes from the top tell what percentage of the group did 70% or better on the test. The 30% (A group) and the 29% (B group) in the third row of boxes tell what percentage didn't make at least 70%. In the fourth row of boxes the percentages indicate what percentage of the group would have pasted the test – 60% or better – and what percentage would have failed.

Table 4.3 – Range of Grades for Real Group

Range of Grades for Real Field Trip
Group A, 30 Students

10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
		*	*	****	***	**** ***	**** ***	***	****
30%						70%			
20%					80%				

Table 4.4 – Range of Grades for Virtual Group

Range of Grades for Virtual Field Trip
Group B, 31 Students

10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
	*	*	**	*	****	****	**** ****	****	**** **
29%						71%			
16%					84%				

Although I didn't reach my goal of all students getting 70% or better on the test, the Range of Grade tables show how close the grades of the students in the two groups actually are, which provides more proof that there is little or no difference in learning between the Real and Virtual groups.

T-test Results

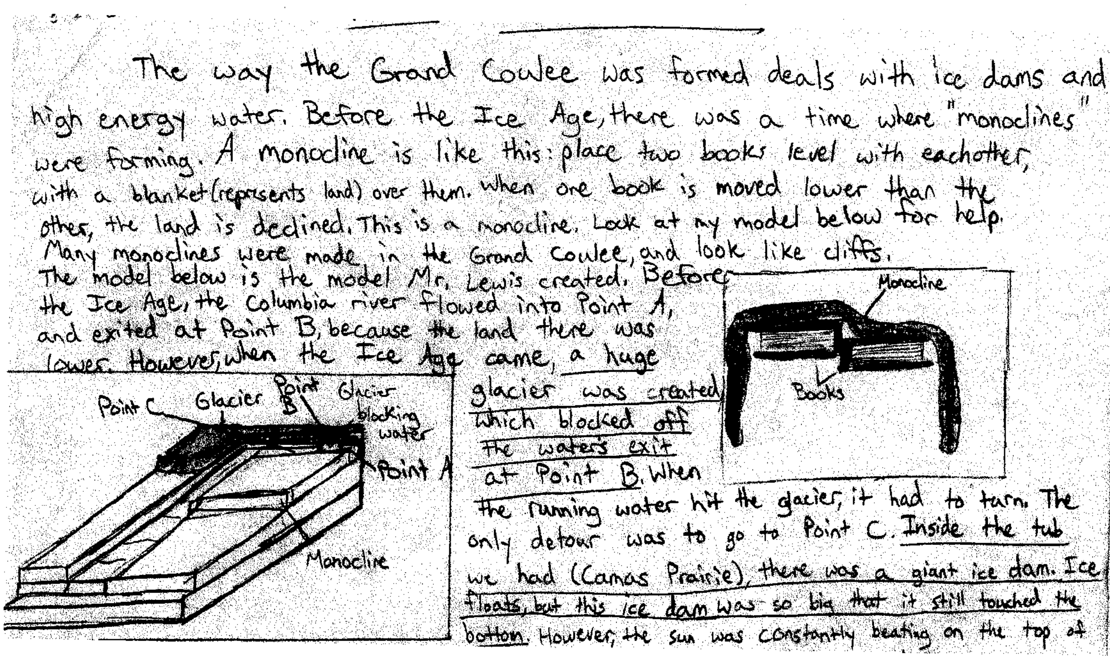
As predicted by the null hypothesis, the experimental group's mean score (68.97) was not significantly different from the control group's mean score (66.63) ($p<05$; t Stat -0.54; t Critical two-tail, 2.00) The probability of random error was greater than .05. The number of members in the Control group (Real Field Trip) = 30, and the number of members of the Experimental group (Virtual Field Trip) = 31.

Excerpts from the Test Section of the Assessment:

I immediately noticed in grading the Assessment Section of the test that the responses were easy to decipher: I could read them without tripping over poorly written words and I could easily follow the logic of the explanations. Also, a large percentage of the graphics were drawn with care and clearly labeled. In my own 14 years experience working with eighth graders, I have varied my standards for student lab write-ups between a "more demanding" and "less demanding" approach. During years when I was "more demanding," I required better reasoned responses and neater graphic work, and in "less demanding" years was a bit more lax. The difference between these approaches was always noticeable at the end of the year, with higher expectations of students yielding better results at the end of the year. During the present experiment, the quality of the explanations and graphics on the assessment were very similar to the lab write-ups of the demanding years. Mr. Traveler, who was my student teacher several years ago, had made quite a demanding year out of the 1999-2000 school year.

Figure 4.3 below is an example of some of the work from the Virtual Field Trip group.

The writing is neat and legible. Sentence structure makes sense and the graphics are carefully drawn and well labeled. Also, the information given in the statements is correct. The graphics are in color on the test.

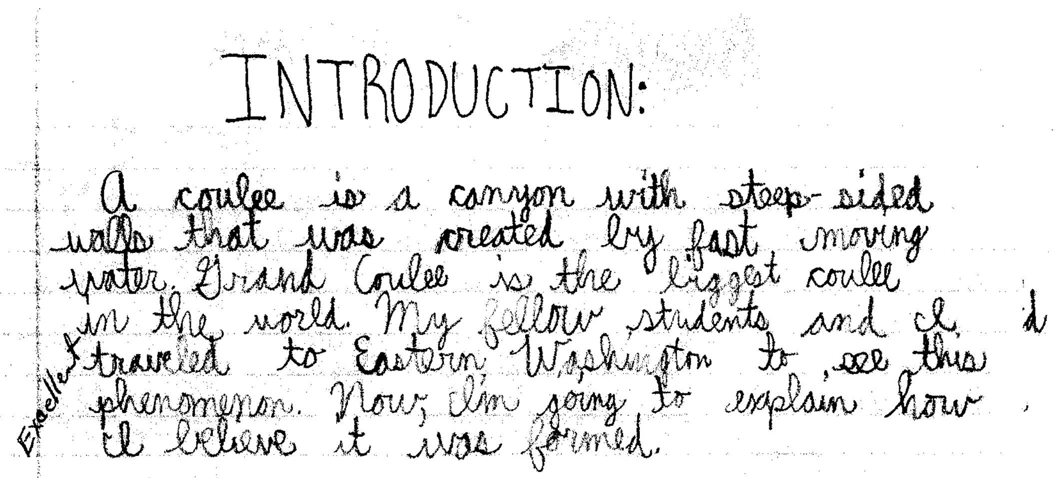


The way the Grand Coulee was formed deals with ice dams and high energy water. Before the Ice Age, there was a time where "monoclines" were forming. A monocline is like this: place two books level with eachother, with a blanket (represents land) over them. When one book is moved lower than the other, the land is declined. This is a monocline. Look at my model below for help. Many monoclines were made in the Grand Coulee, and look like cliffs. The model below is the model Mr. Lewis created. Before the Ice Age, the Columbia river flowed into Point A, and exited at Point B, because the land there was lower. However, when the Ice Age came, a huge glacier was created which blocked off the water's exit at Point B. When the running water hit the glacier, it had to turn. The only detour was to go to Point C. Inside the tub we had (Camas Prairie), there was a giant ice dam. Ice floats, but this ice dam was so big that it still touched the bottom. However, the sun was constantly beating on the top of

Figure 4.3 – Virtual Student Example

Figure 4.4 below is an example of writing without graphics from the Real Field Trip students.

In the Introduction the students were to tell, "the main purpose of the write-up." The required format for the answer was to explain how the Grand Coulee was formed. Here, the student first introduces the reader to what a coulee is and then states why this coulee is the Grand Coulee. The student also tells the reader in general where the Grand Coulee is and then tells us that he/she is going to explain how the Grand Coulee was formed. By supplying this extra information (the location and the introduction to the explanation), the student supplied a more complete introduction using appropriate and interesting information. The concept of providing a more complete introduction, I believe, came from the practice the students received from writing up many experiments during the school year.



INTRODUCTION:

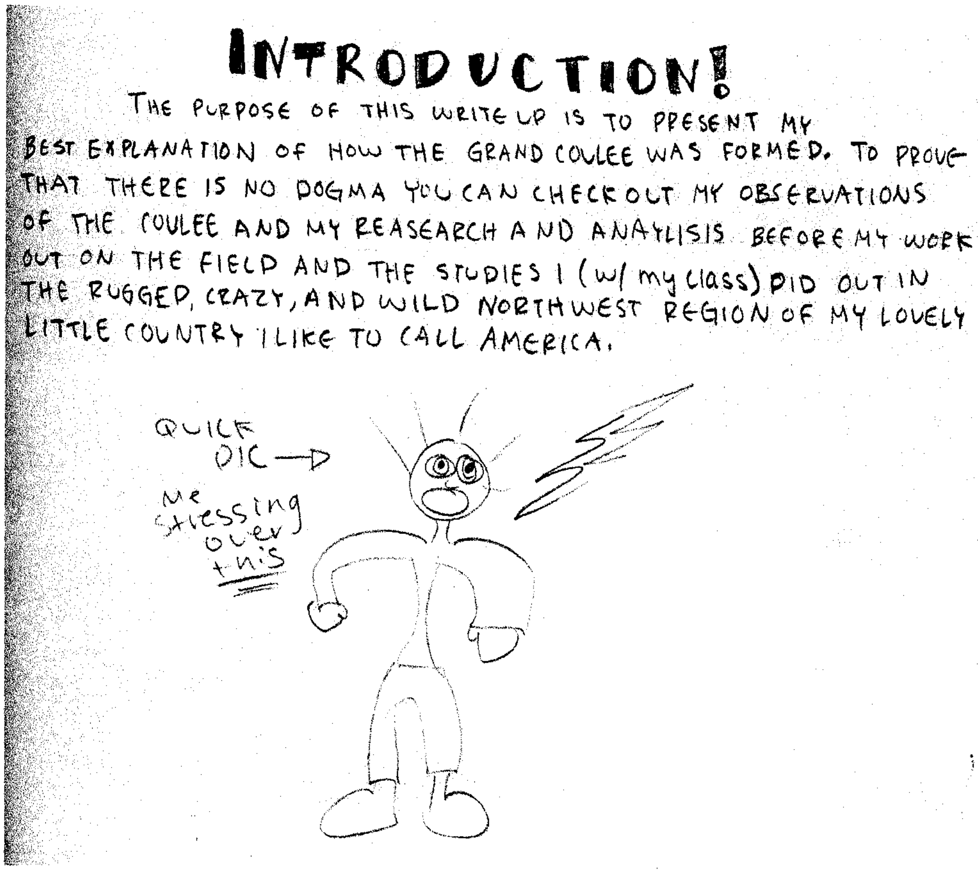
A coulee is a canyon with steep-sided walls that was created by fast moving water. Grand Coulee is the biggest coulee in the world. My fellow students and I traveled to Eastern Washington to see this phenomenon. Now, I'm going to explain how I believe it was formed.

Figure 4.4 – Real Student Example

The point here is that practice in writing essay-type labs and test questions during the school year seems to allow the students to communicate more clearly. Good penmanship, logical statements, and neatly labeled graphics have all been parts of this practice. It is therefore quite possible that they perform better on this assessment due to extensive prior practice in writing clear explanations and supporting the written explanation with carefully done and well labeled graphics.

In figure 4.5 below, a student answers the question, "What is the purpose of this write-up," appropriately in the introduction but also adds that his or her explanation will contain "No Dogma." The "no dogma" comment is reference to Mr. Traveler's class standard of always having the students and teacher supply good evidence to support their explanations. Taking the word of an authority figure without evidence is not acceptable.

This student also makes reference to being stressed out over the test, which was a great reminder to us how much information was given and reinforced over a very short period of time. Maybe the exclamation point after the word "INTRODUCTION!" also signifies that this student is a little apprehensive about getting started on the test.



INTRODUCTION!

THE PURPOSE OF THIS WRITE UP IS TO PRESENT MY BEST EXPLANATION OF HOW THE GRAND COULEE WAS FORMED. TO PROVE THAT THERE IS NO DOGMA YOU CAN CHECK OUT MY OBSERVATIONS OF THE COULEE AND MY REASEARCH AND ANAYLISIS BEFORE MY WORK OUT ON THE FIELD AND THE STUDIES I (w/ my class) DID OUT IN THE RUGGED, CRAZY, AND WILD NORTHWEST REGION OF MY LOVELY LITTLE COUNTRY I LIKE TO CALL AMERICA.

Figure 4.5 – Real Student Example

Figures 4.6 and 4.7 below are two more examples showing the quality of the graphics students produced for the assessment, one from group A, the Real Field Trip Group, and one from group B, the Virtual Field Trip Group. The first graphic is built from the polystyrene Grand Coulee model but the 5000 ft. glacier was the student's add-on. The 3-D drawing is neatly drawn and labeled to show the new parts of the model while leaving the parts I would know unlabeled making the graphic uncluttered.

The arrows show the Columbia River running into the massive glacier blocking the river's normal route and forcing it to flow down through the area where the Grand Coulee formed. This explains the route of the floodwater as it deviated from the river's normal path. The Coulee Monocline (in the middle of the drawing) and the Soap Lake Fold are shown. They are the two areas where the arrows point down and the places the two waterfalls began their undermining forming the coulees. The compass shows the correct directions so the reader can orient him/herself. Also, the text, though uneven, is easy to read and it says the same thing the graphic illustrates, which is how text and graphics should relate to each other.

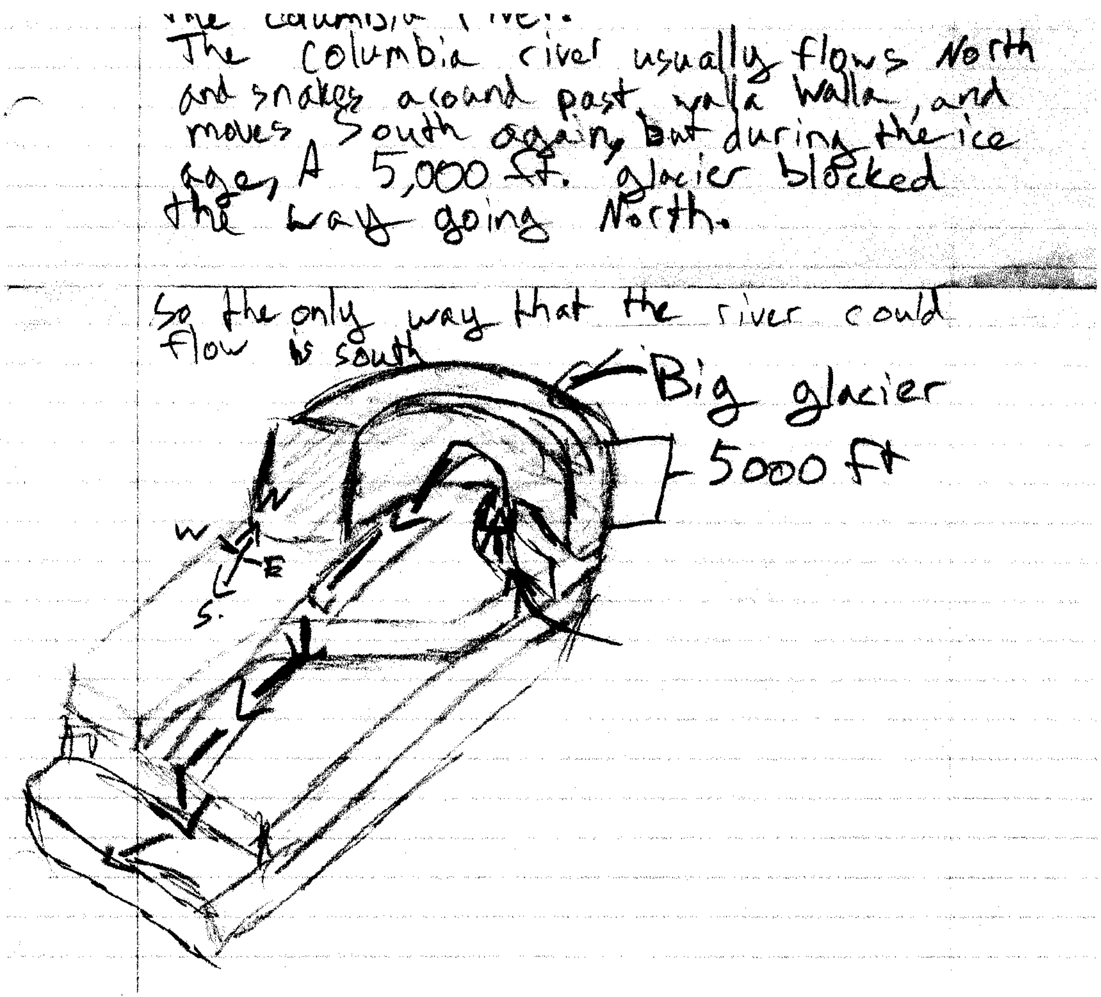


Figure 4.6 – Real Student Example

Figure 4.7 below shows that a Virtual Group student made a substantial effort to show the process of undermining clearly. All the important parts are accounted for, including the turbulence of the water. The neatness allows the student to communicate clearly to the instructor what the student actually knows without guesswork or the possibility of lost points. On the test, the graphic is in color.

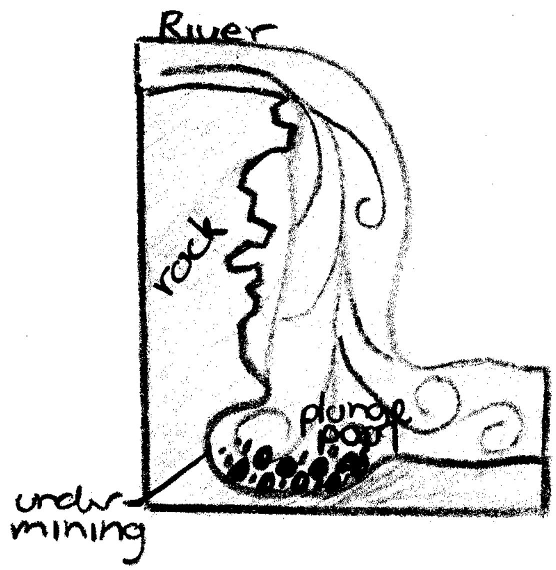


Figure 4.7 – Virtual Student Example

Component 2 – Previous Knowledge Survey

Here is the text of the Previous Knowledge Survey

Previous Knowledge

Think about how much knowledge you knew about the geological concepts listed below before Mr. Lewis began teaching us geology concepts

Let 1 be NO knowledge; 2 be SOME knowledge; and 3 be MUCH knowledge on the scale of 1 to 3 listed below. Circle the number that best represents your knowledge of the following geological concepts:

A). Waterfall undermining

1 2 3

B). Sediment layers such as graded bedding and lake sediments.

1 2 3

C). Glaciers

1 2 3

D). Ice Dams

1 2 3

E). Basalt

1 2 3

F). The Camas Prairie Ripple Marks

1 2 3

G). The Grand Coulee

1 2 3

Figure 4.8 – Previous Knowledge Survey

Table 4.5 – Previous Knowledge Survey Reponses

Real Field Trip Students	% of Concepts	Virtual Field Trip Students	% of Concepts
No Previous Knowledge	48%	No Previous Knowledge	48%
Some Previous Knowledge	46%	Some Previous Knowledge	41%
Much Previous Knowledge	6%	Much Previous Knowledge	11%
	100%		100%

The Virtual Field Trip Students seem to have come to the unit with a slightly larger proportion of students indicating a higher level ("Much previous knowledge") of awareness of the central concepts of the unit than did the Real Field Trip Students.

Component 3 – Student Feedback Survey

Here is the text for the Student Feedback Survey. The remainder of a full page was allowed for response.

Student Feedback on this Geology Unit

Please tell us the parts that you enjoyed in this geology unit and why you enjoyed them. Likewise, tell us any parts of this geology unit that you did not enjoy. Please be specific.

Figure 4.9 – Student Feedback Survey

Below are the responses from the Real Field Trip students. The Virtual Field Trip students did not have a chance to fill out the survey due to schedule changes on the day of the test.

Real Field Trip student responses to the Student Feedback Survey

The Student Feedback Survey was essay only; no choices for answers were given. Table 4.6 below shows the distribution of responses based on absolute number mentioning any particular feature. All responses received are shown here.

Table 4.6 – Student Feedback Survey Responses

Liked		Not Liked	
Learning	8	Amount of time on bus	11
Eating lunch at the park	6	Make drawing of geology	6
Movie on return trip home	4	Having to take a test	4
Grand Coulee	4	Mr. Lewis' talks	3
The bus trip	3	Camas Basin	2
Waterfall stop	3	Short time for test	2
4 wheel driving in trucks	2	4 wheel driving in trucks	1
Camas Basin	2	Bus stops too long	1
Took in more by being there	2	Erratics	1
Montana field trip	1	Short explanation on monocline	1
Being with friends	1	Boring geography	1
Everyone getting along so well	1		

Notable features of the response pattern include these aspects: on the positive side, 19% of the students mentioned they liked eating lunch at the park and 27% mentioned they liked learning about these aspects of geology.

On the negative side, 35% of the students mentioned they didn't like the amount of time spent on the bus and 19% mentioned they didn't like having to draw geology illustrations in their notebooks.

Chapter 5

Results and Discussion

Introduction

In the preceding chapter we compared two groups of 8^{th} grade Earth Science students. Both groups had taken a field trip to the Camas Prairie region in western Montana and to the Grand Coulee region in eastern Washington State. One group, Group A, took a real field trip to the Camas Prairie and the Grand Coulee. The other group, Group B, took a virtual field trip to the same locations. The virtual trip consisted of panoramic photographs displayed on a 6x8 foot screen through the use of a computer and a Liquid Crystal Display (LCD) projector. The comparison was done by examining the two groups' test scores on the same test. The test consisted of one essay question, "The Grand Coulee is a geological phenomenon. Explain how it was formed".

The comparison or study showed that there was no significant difference between the scores of the real field trip students, the control group, and the virtual field trip students, the experimental group.

Basic Significance of the Study

The study showed that by using panoramic pictures on a large screen, eighth grade Earth Science students can learn how geological formations look in the field. They can also see the surrounding context in which the formation sits without going out into the field. In a context of carefully controlled instructional similarity, these virtual experiences are sufficient to allow the students looking at the graphics to achieve test scores that are not significantly different from those of the students who went out into the field on a well planned real field trip.

Why Was there No Difference between Groups?

I believe the two groups' scores were so similar because I used good design practices to avoid pitfalls, according to the research available, in both the Real Field Trips and the Virtual Field Trip.

Two pitfalls of a real field trip mentioned by Klemm and Tuthil are: (1) students can't hear the instructor or other students when a question is asked or a discussion takes place; and (2) "students have a difficult time simultaneously taking in their surroundings making detailed observations, listening to the speaker, and taking good notes while in the field.[5]" (Klemm 2002 p 454)

To avoid these two pitfalls on the real field trips, I was very careful to wait till all students were gathered around and quiet before speaking, I gave ample time when we arrived at a new site for students to get acquainted with the geological feature we were

[5] This reference is two years after we did the study, however we were concerned with these two pitfalls when we did the study and we took the steps written in the text to avoid them. The 2002 reference was the first research we found that addressed these pitfalls.

interested in before talking, and I dedicated time for students to draw the geological feature into their notebooks at each stop as well as providing short, specific notes during a dedicated note taking time at each stop. To avoid these kinds of pitfalls during the virtual field trip I followed exactly the same procedure. The only difference is that the students saw the geological feature in a panoramic view on a large screen rather than in the field.

Bellan and Scheurman (1998) noted five pitfalls of real field trips and five pitfalls for virtual field trips. Both lists are shown in Table 5.1.

The first item in each list is about using experts or computers to baby-sit students on a field trip. In this situation, the teacher may be trying to take a little time off by putting an expert in charge of the class. With the expert in control of monitoring the learning, the teacher can be totally ignorant about the lesson being taught and he or she plays a minimal role in the field trip. The real problem here is the third set of pitfalls -- no advance preparation. The teacher doesn't have the knowledge needed to get the class ready for the learning experience the students will be exposed to. So, the second set of pitfalls come in to play. While an expert speaks to the group of students, they follow along aimlessly without a clue as to what they are really supposed to be doing. A consequence of this may be that the students begin horsing around because they are unfocused.

Table 5.1 – Field Trip Pitfalls

Field Trips and Their Pitfalls Table 5.1

Actual Field Trip	**Virtual Field Trip**
1. Teachers use docents and other curatorial staff as temporary "baby-sitters" to bus loads of students in search of entertainment.	1. Teacher use computers as "baby-sitters" for classrooms of students in search of visual and auditory stimulation.
2. Students approach the trip like a tourist and spend most of their time wandering the grounds and horsing around.	2. Students approach the computer in much the same way they approach television, aimlessly surfing the web and cursorily taking in the sights.
3. Students are poorly prepared for the visual, verbal, or tactile lessons that await them; even the teacher preparation erodes under the contagious excitement of a day out of school.	3. Advance preparation seldom occurs; many teachers use the Internet as an "escape" from the classroom or a carrot to gain compliance from bored or disruptive students.
4. Students cannot glean the intended benefit from an experience away from school because there are too many objectives in the "lesson" and the site is too overwhelming.	4. Students cannot benefit from the computer because teachers view it as a font of infinite knowledge and present students with amorphous objectives such as "get information about…."
5. The actual field trip is seen as an end in itself and there is little or no follow-up on the information gathered during the trip	5. The virtual field trip is seen as n end in itself and there is little or no follow-up on the information gathered during the trip.

In the fourth set of pitfalls, the students have no clear and manageable objectives. The teacher doesn't know the site well enough or the objectives well enough to create activities that will limit the scope of experience at the real or virtual site to a very specific learning objective. So the students, overwhelmed with all the available information, become unfocused because of the teacher's lack of specific guidance.

The last set of pitfalls highlights the possibility that field trips, real or virtual, may be seen as an end in themselves. No real pre-trip preparation to set clear objectives is done, so students wander about unfocused. And, once the students have returned from their trip, there is no follow-up activity to focus on any particular learning objective. The trip most likely was simply a day out of class for the students and teacher with very little learning taking place.

It seemed to me that all five pitfalls may be avoided if the teacher had very specific learning objectives. To provide learning objectives to the students, the teacher must know what is going to be taught and observed on the field trip. The better he or she understands what the field trip is about, the more specific the learning objectives can be. In my case, the particular learning objectives came from a single overall learning objective: that the students learn how the Grand Coulee was formed according to the best contemporary geological evidence and theory. I also wanted to assess the students at the end of the teaching to find how many students actually had a basic understanding as to how the Grand Coulee was created. I wanted the assessment to be fair, which means I would only ask questions that I knew for sure were addressed in the teaching. And, I wanted everyone in both the real and virtual trips to get a 70% or better on the assessment. This was a personal goal.

To enable all the students to achieve the best scores possible I specified 5 learning objectives: know the importance of basalt, know the role glaciers played, understand the importance of glacial lakes, know the role of ice dams, and understand the size of the megafloods. These learning objectives would allow me to circumvent the pitfalls of Bellan and Scheurman; there would be no "baby-sitting" because the objectives are defined, known to all participants, and they focus the curriculum. There would be no aimless wandering around a real or virtual site because the objectives indicate a very clear direction of study. With clear objectives the teacher can prepare field trips that are focused on the objectives and constructed for maximum student learning opportunities. Being overwhelmed by a site would not be a problem because the objectives would limit what was being looked for at either the real field trip sites or the virtual field trip sites. And, with extensive pre-trip preparation to increase the learning potential of the field trip and a major assessment as a post-trip activity, the field trip certainly won't be an end in itself.

Avoiding Further Pitfalls

From my experience, having taken over 1000 students on field trips, I have noted a pitfall of my own that must be avoided. It is that the teacher, being the leader, may not be intimate with all the aspects of the trip in advance. There is nothing that will destroy a field trip's effectiveness so much as a leader who is not sure about some part of the field trip. So what does "all aspects" mean? First it means that the teacher must know the curriculum intimately. The only real way to do that is to have the teacher teach both the classroom and field trip lessons. So, instead of calling in a "Spokane Flood expert" to speak to the class or lead the field trips, the teacher will learn enough about the Floods through papers, articles, books, and experts to become enough of an expert to teach the class and the field trips to the appropriate academic depth.

"All aspects" also means that the teacher knows every detail of the travel component of the trips. He or she learns this by taking the curriculum and dissecting it to discover what places the field trips should go. When the dissection has been done, the teacher must then figure out which of the "should go" places are within the possibilities of the teacher's circumstances. When the possible places or stops are found, the teacher determines the order of the stops, what will be said at the stops, how long a stop will last, the route connecting the stops, and the mileage and duration of the complete field trip. Next, the specifics of the places to stop must be ascertained. Specifics include finding the best possible locations to see the geological feature being studied, a place large enough for a forty-foot bus to park, and a safe place to let forty-eighth grade students and chaperons on and off the bus. Also, there must be room for the group to mill around a little and to have a place to stand or sit to take notes and draw graphics into their notebooks.

If any of these requirements are neglected for any of the stops, there will be a real possibility of disrupting the stop, disrupting the whole trip-to some extent, and disrupting the students' experience with the curriculum.

Planning Details: What It Means to Plan a Field Trip

What follows are examples of what I mean by becoming intimate with the field trips. This is meant to show the depth of the emersion a teacher must have if the trip is to be valuable and to take place without problems.

Becoming intimate with the field trips included studying up on the Spokane Floods, taking two pre-field trips to the Camas Prairie Basin and one to the Grand Coulee region. And, I needed to learn how to take and prepare panoramic views for use in the classroom to create the virtual field trip.

I had studied the Spokane Floods as an Earth Science Teacher several times over the years; therefore I was fairly aware of what the latest research was. Plus, I had taken students on field trips to the Grand Coulee region several times over a period of ten years, so I had a refined field trip almost ready to go. I had never taken a group of students to the Camas Prairie region and I had never taken a panoramic photograph of anything.

To put the finishing touch on the Grand Coulee field trip I drove to the town of Grand Coulee and then north on Hwy 155 just a few miles to the Peter Dan Road. I drove along the road, which parallels the hills just north of the north end of the Upper Grand Coulee. I drove until I found a driveway that lead back to a ranch that appeared to have access to the hill that overlooked the north end of the Upper Coulee. I then drove to the ranch house. I introduced myself and asked if they had access to the top of the hill just to the south of their house. They said they did. I asked if I could take about 40 people, 30 of them being 8^{th} graders, to the top of the hill for a panoramic view of the Upper Coulee, perhaps in four-wheel drives. The aging rancher said, "sure". He then took me for a ride in his four-wheel drive to the top of the hill where there was a perfect panorama of the north end of the Upper Coulee. I took the pictures necessary to create three panorama pictures of the Coulee for my virtual trip immediately. He also showed me different viewpoints from the top of the hill but none were as good as the first one. This took a couple of hours and when we returned to his house I was invited to dinner during which I told him the details of the trip including day and time we would be there.

With the addition of the north end of the Upper Grand Coulee panorama to my already existing field trip of the Coulee region, I had all the features I wanted to see on the Grand Coulee trip covered.

The Camas Prairie field trip was an easy one to layout for there would be only three stops. The first would be at 9-mile road 23 miles west of downtown Missoula Montana on Interstate 90. The second would be in Missoula on the extreme north end of town. The third would be in the Camas Prairie Basin some sixty miles northwest of Missoula. I took my first pre-trip to create and become familiar with the trips route.

Also, I needed to find a place where 40 students could observe the sediment beds at the 9-mile road exist of Interstate 90. The sediments were exposed in a road cut made for Interstate 90. Freeway traffic through the road cut area was traveling at 70 miles an hour or better. I found a dirt road that lead to the bluff overlooking the freeway right at the road cut. All we had to do was park the bus at the end of the 400-foot dirt road, have the student go over the freeway right-a-way fence to a large bluff, and then sit in lawn chairs they would bring along so they could sit, which would stabilize them, and draw the sediments layers in the road cut, which they could see perfectly and still would be 40 feet above the freeway traffic. It was the perfect, safe solution to the freeway danger.

The second stop in north Missoula was easier to discover. I simply went far enough north to get a good view of Mt. Jumbo's west face. Game Trail Road was the perfect place.

The third and final stop would be in the Camas Prairie Basin. I had to look around the Basin for a safe place to park the bus, have plenty of space for the students to rove around during their lunch break, and we needed a great view of the geologic features we wanted to see. With the help of a local farmer I was able to find a dirt road that ran across the upper north rim of the Basin, which provided all three of my requirements. It was at this point I realized I would ask the company supplying the luxury bus to provide us a with a top notch driver for some of the roads on this trip would be difficult to navigate.

Learning how to make panoramic pictures did not require a great deal of additional learning. I knew my way around a camera fairly well and I had all the equipment I needed. I did have to buy the software used to stitch individual pictures together to form the panorama photos. I bought Apple Computer's QuickTime VR Authoring Studio version 1.1. I read the instructions to use the software and they told me everything I had to do to make the panoramas. Basically, you take several sequential photo of a landscape, making sure that each photo overlaps the previous one as you progress across the landscape. Then, since I was using a standard film type 35mm camera, you must digitize the photographs by scanning them on a scanner into your computer. You then can use the software to take the digitized photos and stitch them together to make a panoramic picture. After a little practice you develop the skill it takes to make very acceptable panoramas.

After I had the skill to do the panoramas I took the Camas Prairie trip again and shot all of the pictures I would need for the panoramas for the Virtual Camas Prairie Trip. A day after I took the Camas Prairie trip, I took the Grand Coulee trip and took the pictures I would need for the panoramas of the Coulee areas except for the north end of the Upper Grand Coulee, which I had taken earlier when the rancher gave his permission to use his land. I used those pictures to learn the QuickTime VR Authoring Software.

Our Virtual Field Trip and Other Research on Immersive Environments

In 2000, we decided to use a very low-tech form of a virtual field trip. That is, we would project an 8-foot by 6-foot panorama image on a screen. The image would show a geological feature in the context of its surroundings so students would see the feature as though they were actually at the site. The only additional property of the arrangement was the ability to zoom-in on specific areas of the image to enhance detail.

Originally we had considered more technical configurations for the virtual trip, for example, a student-run piece of software that would allow students to take the virtual field trip independently of the teacher. However, as we investigated this possibility, we didn't see the need to spend the money on software. It seemed that the best way to give students the opportunity to learn about the geological features was to have the teacher lead the class through the virtual field trip just as the teacher would lead the real field trip students through their field trip. However, at the time we found no research to give us a direction as to whether a more immersive environment, the computer-run virtual field trip, would lead to better student learning than graphics shown on a screen. The computer-run field trip would require the students to become familiar with the software, read and listen to the text being read to them, operate the view of the panoramas, zoom in and out on areas of special interest, take notes, and draw into their notebooks illustrations of the geological features being studied at each "field trip stop". This computer-run field trip would be more immersive than the teacher-led virtual field trip because the student would be responsible to proceed to the next screen when they were ready, listen to the text as many times at they felt they needed to understand, zoom in and out on as many parts of the panoramas as they wanted, and they could go through the virtual field trip, in its entirety, as many times as they wanted. In other words, every aspect of the trip was controlled by them, essentially making them more a part of the trip as individuals rather then being an individual in a class all participating together by looking at large pictures on a screen.

Even at the conclusion of our research project, we still were questioning our media, the graphic on the screen with everyone going on the virtual trip together rather than using a software program that one or two students could use in small groups. So we continued to look for research that would confirm that a less immersive and less learner-controlled environment could be at least as good as a more immersive environment for facilitating student learning.

In 2002, two years after our research, an article in the *Journal of Educational Psychology* noted that, "There were no significant simple effects in which students performed better in a more immersive environment than in a less immersive environment" (Moreno and Mayer, 2002). The authors also stated, "Students who learned in more immersive virtual reality environments felt a higher level of presence. However, groups did not differ in their learning outcomes. The increased sense of presence did not lead to increased or decreased learning". So, according to these two researchers, we did not degrade the quality of learning for our students through our use of a less immersive environment rather then a more immersive environment. This finding reinforced our own conclusions about the quality of our research.

Then, in 2005, Lesley Garner and Michael Gallo published an article in the *Journal of College Science Teaching* that compared a virtual field trip designed to be administered by a computer with a physical or real field trip. This was the exact arrangement we had considered using before deciding on having all the virtual field trip students take the virtual trip together through the use of large panoramic pictures. They found when they studied the effect of physical *(real)* and virtual field trips on undergraduate, non-science majors that, "No significant differences were seen in achievement, attitudes (*towards liking or not liking science better because of the type of field trip they took – real or virtual)*, learning styles, interaction between field trip and learning styles, or student's ability to answer questions at different levels." And, "…the findings of this study suggest that both field trips *(real and virtual)* equally prepared students for the achievement exam…"(Garner 2005 p. 17)

These newer studies addressed a lingering concern from our research, Does a virtual field trip administered by a computer prepare students for an achievement exam as well as a real field trip does and, as well as an instructor led field trip using large panoramic photographs? The answer is seemingly, yes.

Organizing Instruction and Creating a Community of Learners

In Chapter 2, I discussed the concept of a "community of learners." This class structure was the one I intended to use and the one that was used. I would like to review here the components that I used in teaching this class; and how they were realized here in each of the field trip settings.

In a "community of learners" model, the first key element is that development of student understanding is encouraged. To facilitate this, a learning path is custom made for the students in the class. The learning path consists of stepping-stones that are really individual concepts needed to take the students to the intended over-arching conceptual destination at the end of the path. In this case, the concepts were learning about the basalt substrate, glaciers, ice dams, glacial lakes, and waterfall undercutting. The conceptual destination was to understand how geologists believe the Grand Coulee was created.

To custom-make this learning path for the students in this class, I collected some information about their prior knowledge in two areas. The first important area of prior knowledge to assess is what the student already knows about the subject that is going to be studied. This gives the instructor an idea where to start the learning path for this particular student. Of course, when you know all of these things about all the students, the one who knows the least sets your starting point.

The second area of prior knowledge to assess is the student's level of mastery of needed intellectual tools. How well does the student read, do they write well, do they draw well, and are they good at communicating? Information about these issues determines the speed at which you can go down the learning path.

One other component to encourage understanding is that our theory of learning is constructivism. This means that we believe students construct their own learning using their prior knowledge to assist them create new understanding. The student creates a mental conceptual framework that combine prior knowledge and the new information they receive from around them. If the teacher has created an appropriate learning path for the particular group of students, the students' conceptual framework should be close to the conceptual framework of the teacher by the time the students reach the end of the learning path (Council 2000 p. 10) (Bednar 1992).

To help the students create their own understanding, hands-on labs are used – examples here included the experiment of settling sediments in the jar. Also, models are used such as the paper and polystyrene models of the Grand Coulee area on the Columbia Plateau. The mini-megaflood model of the Spokane Floods was another example of modeling. And, of course field trips are used to help students apply what they learned in the classroom to real world settings.

What this Study Contributes to Knowledge about Instruction

What did I learn from doing the study that wasn't previously part of what we know about instructional use of field trips? I learned that if an instructor leads his students through a virtual field trip made of large panoramic photographs that the virtual field trip can provide enough information to give students the same academic learning opportunity that a real field trip can provide.

Chapter 6

Conclusions

Introduction

The principal conclusion from this study is that a virtual field trip can be just as effective as a real field trip in facilitating student academic learning. The implication here is that there may be situations where we can replace real field trips with virtual ones. What would indicate the times when we may want to do this? Major factors in our decision would include one or all of the following: accessibility, weather, safety, money, and time. Certainly a field trip to the moon is not an option simply because of accessibility. Weather can be a problem, especially in the wintertime when snow may cover roads (and, in the case of Earth Science, terrain you would like the students to see). Safety is almost always a consideration, but there are times when it becomes more of a deterrent (such as taking a field trip to a local coal mine). The lack of money and time are often used as reasons for not taking a real field trip, but does a virtual field trip really cut down on money spent and time used? Can we conclude that virtual field trips are cheaper and require less time then a real field trip? It depends. Let's look at the reasoning.

Real-World Field Trips: Required Preparations

We'll use our geology trip to the scablands as an example. To create a real field trip an instructor must do several things. First, the subject matter of the trip must be chosen along with the specific concepts the students are to see along the way. Then sites showing examples of these concepts must be found within a reasonable distance of the school. Next a route connecting the sites together must be laid out, along with a 40 foot unloading and loading space at each site that is safe for 30 eighth graders plus their chaperons to get on and off the bus. The approximate length of time for each stop must be determined along with what is to be said at each stop by the teacher. Mileage must be determined so cost for transportation can be closely estimated as well as determining how long the field trip will take. Adding the time to travel the route of the trip along with the times for each stop will give a good estimate of the overall amount of time the trip will take. Next, the in-class curriculum must be laid out carefully on a calendar to determine on what day the trip will be taken. When that is done, to the teacher must make arrangements for a bus to take the trip. (We used a luxury bus for this trip because they were more comfortable than school buses for such long trips and they actually cost less per mile to operate than school buses. They also had a restroom on board.) Permission slips and parent information slips can now be created because you have a date set and you have the cost of the bus per mile and the mileage to figure the cost for each student to take the trip. All the information and permission slips must be copied and sent home, and then collected and carefully checked for all the emergency contact numbers to reach parents if something happens on the trip. A notebook is used to carry all the permission slips along on the trip so all numbers and specific student information are on the bus for possible use. Also, a roster must be made to check the students on to the bus for the teacher and for the office so they know who is on the trip, as per school policy.

Students need to bring on board with them a lunch, some snacks, a notebook to record information in as well as a place to draw illustrations of what is seen, and some colored pencils as listed on the information slip. Appropriate clothes for the day, as listed on the information slip, are also carried by all the students. The teacher has put 5 extra gallons of water on board as well as some 40 snack bars just in case there is a problem that strands them out in an isolated area, which is possible out in the scablands. Also, there are at least 2 cell phones on board. The field trip is now ready to leave for a 10-hour day of adventure. Here is where good teacher preparation really pays off.

Teacher Preparations for the Real-World Field Trip

The teacher has prepared the students in the classroom with appropriate curriculum to help them understand the features that they are to see. The teacher knows where the bus in going to park at each stop; this means there will be no awkward disruptions to suggest that the trip is poorly planned, and also assures that safety does not become an issue. The teacher has incorporated into the lecture specific times to look, listen, draw, and take notes so students don't miss information by trying to do too many things all at the same time. The buses are comfortable with padded, tilt back seats and air conditioning so students don't get overly fatigued half way through the trip. And, lunch is planned to take place in a park right on a lake that has a great beach, grass, trees, playground equipment, restrooms, and multiple picnic tables.

Real Field Trips: Time and Cost Considerations

Now let's figure the amount of time and money to create and take this kind of trip. First we'll assume that decisions have already been made about the curriculum into which the field trip fits. All that must be done is to add the field trip at the end of the unit.

Time

Choosing the concepts the field trip will cover is done taking into account the sites that are available within a reasonable distance of the school. For our scabland trip there were 7 sites and a lunch stop. Some of the sites and the lunch stop came from another teacher's field trip to the same area, which I went on. That took a day. Then there was research to find out as much as possible about the Spokane Floods. Initially that took the reading of 3 books and many articles not only specifically about the Spokane Floods but also on topics related to the Spokane Floods like basalt, undermining, sediment layers, glaciers, and ice dams. This research required a couple years. However, if one divided all the time into 8-hour work days, you would have 1 day for the initial field trip in which I participated, 6 days to research and read the books and articles, 1 day to put the whole story of the Spokane Floods into a field trip form, 3 days of driving to research the best route, which of course includes calculating the mileage for the trip along with finding parking places for the bus at each site, which can be difficult. I was also looking for an example of an undercut waterfall hidden in the side of the coulee and I took a hike to see if it could be worked into the field trip. So the field trip planning to this point has required 11 full workdays.

A further element of preparation is to plan what the students and I would be doing at each stop, and the time that each stop will take. Each stop's time and the time to cover the mileage are added together to give the time the trip will take. Further tasks are to figure out what day the trip will be on and to prepare the permission and information slips and copy them. Then the permission slips must be distributed, collected, checked, and put alphabetically into a notebook. Also a roster must be prepared, which will be the teacher's checklist of students on the bus and the office's checklist for the students gone on the trip. And, emergency water and snacks must be collected and readied for the bus. These tasks add another half a day, so the total time spent on creating the field trip is 11.5 days. Actually taking the 10-hour trip adds another day. We now have 12.5 days to create and take the field trip.

Table 6.1 – Work Done Real Trip

Days	Work Done
1	Go on Other Teacher's Field Trip
6	Research - Books and Articles
1	Put Flood Story Together
3	Planning and Research to Create Best Route
0.5	Permission Slips and Roster
1	Taking the Field Trip
12.5	Total Number of Days to Plan & Take Real Field Trip

Cost

To calculate the total cost for the trip, we need to add dollar amounts to each of the planning and trip elements noted here. These include: cost per mile for the bus, fuel for car trips to find sites and check mileage, and the cost of the snack bars. The bus costs $2.75 per mile and our mileage was very close to 300 miles, making $825.00 the cost of renting the bus. For the trips taken to collect information in the car, there were 2.5 trips, which equals 750 miles. At 24 miles per gallon and a fuel cost of $2.80 per gallon, this yields a trip cost for the teacher of $87.50. The snack bars were $15.00. That is a total of $927.50.

If one includes the salary for the teacher's time to create and take the field trip, the trip reaches into the thousands of dollars. Average Washington State salary is $45,724 for the 2006-2007 school year. Divide that by 180 days of teaching you get $254.00 per day. The field trip required 12.50 days to create, yielding $3,175.00 for the teacher's salary. Now our total cost to create and take the field trip for the first time is $3,175.00 wages plus $927.50 cash out lay, which equals $4,102.50 total cost.

Table 6.2 – Cost Details Real Trip

Amount	Cost Details For The Real Field Trip
$825.00	Bus $2.75 per mile x 300 miles
$87.50	Car 750 miles / 24 miles per gallon = 31.25 gallons $2.80 per gallon x 31.25 gallons
$15.00	Snack Bars
$927.50	**Sub-Total**
$3,175.00	Salary = 12.5 Days x $254.00 per Day
$4,102.50	**Total Cost**

After the first trip is taken the cost of the field trip shrinks to the cost of the bus, snack bars, and about a half day of labor for permission and information slip creation, collection of money, arranging for the bus, and making a roster and notebook of emergency numbers plus a full day's wage for the teacher to go on the trip. This is $825.00 bus cost, plus $15.00 snack cost, plus $127.00 half-day wage, plus $254.00 full-day wage, which equals $1,221.00. There are a few other hidden costs like office staff who has to track the rosters of kids on the trip and teacher's time for dealing by phone or in person with any parents concerns or inquires. However these times are very minimal.

Now we can turn to a calculation of the cost of creating a virtual field trip to the scablands. To create the trip one still has to select the sites, the research still has to be done on the floods etc. It will still be necessary to travel to the sites, most likely two times, to get pictures to make the panoramic photographs, redo the position of photographs that didn't quite come out right the first time, and/or to get more even exposures throughout the whole panorama.

These requirements include 1 day for the field trip I was taken on, 6 days worth of research, readings, both books and articles, and study time. Also, there are 2 days of travel time to photograph the landscapes for the panoramic photographs and figuring out the order of the virtual stops and what will be said at each stop, 2 days to create the panoramic pictures and get them to be the best quality the individual pictures allow, and a hour to take the virtual field trip.

The cost for teacher salary would be 11.125 days at $254.00/day, for a total of $2,825.75.

Table 6.3 – Work Done Virtual Trip

Days	Work Done
1	Go on Other Teacher's Field Trip
6	Research - Books and Articles
2	Put Story Together, Photograph Landscapes, Create Route
2	Create Panoramic Photographs with Software
0.125	Take Virtual Field Trip - 1 Hour
11.125	Total Number of Days to Plan & Take Virtual Field Trip

The cost of the car to take the 2 trips is based on fuel costs for 600 miles at 24 miles/gallon, or 25 gallons of fuel at $2.80 per gallon, for a total of $70.00.

Cost of equipment and software to create and present the virtual field trip includes these elements: The cost of a quality virtual reality software packet is $300.00. This is necessary because the software creates the panoramic photographs. Then there is the cost of a quality computer to run the software and present the panoramic photographs to the students. That is about $1,200. An LCD projector to project the panoramas on a large screen is approximately $800.00. One good quality 6X8 foot screen (needed to project the panoramas on) runs about $300. $300.00 plus $1,200.00 plus $800.00 plus $300.00 brings the cost of equipment and software to $2,600.00.

The total cost of the first time the virtual field trip to the scablands is created and presented to students is $2,825.75 for wages, plus $70.00 for fuel, plus $2,600.00 for software and equipment, which is $5,495.75. The cost of the equipment is variable because a computer to run the software and show the presentation is most likely in the teacher's room already. Most schools already have an LCD projector and there should be a large screen somewhere in the school that would be useable for the presentation. If this equipment is available a saving of $2300.00 could be realized. However, we will assume here that the equipment had to be purchased.

Table 6.4 – Cost Details Virtual Trip

Amount	Cost Details For The Virtual Field Trip
$70.00	Car 600 miles/ 24 miles/gallon = 25 gallons $2.80 per gallon x 25 gallons
$300.00	Software Package
$1,200.00	Good Quality Computer
$800.00	LCD Projector
$300.00	Large Screen
$2,670.00	**Sub-Total**
$2,825.75	Salary = 11.125 Days x $254.00 per Day
$5,495.75	**Total Cost**

Real and Virtual Field Trips: Cost Comparison

To create and take the real field trip initially costs $4,102.50. To take the real field trip again after its initial development costs $1,221.00 per trip. To create and take the virtual field trip initially costs $5,495.75. To take the virtual field trip again after its initial development costs nothing but a couple hours of wages for the teacher. There is also equipment, a computer, LCD projector, and a great screen, that can be used for other projects in the school as well. So, even though the real field trips initial cost is $1,329.75 less than the virtual field trip's initial cost there is $2,300.00 worth of very useful equipment available to the school. (This equipment would, of course, depreciate over time and eventually have to be replaced, but that is beyond the scope of what we are dealing with here.) Also, after the initial real and virtual trips have been developed and taken, the virtual trip only costs $63.50 for two hours of the teacher's time as opposed to the $1,221.00 the real field trip requires.

Table 6.5 – Cost Real Trip 2nd Time and After

Amount	Cost of Real Field Trip 2nd Time and After
$825.00	Bus Cost
$15.00	Snacks
$381.00	Salary = 1.5 Days x $254.00 per Day
$1,221.00	**Total Cost**

Table 6.6 – Cost Virtual Trip 2nd Time and After

Amount	Cost of Virtual Field Trip 2nd Time and After
$63.50	Salary = .25 x $254.00 (2 hours)
$63.50	**Total Cost**

Table 6.7 – Costs Compared

Real Field Trip		**Virtual Field Trip**	
Create & Take 1st Time	$4,102.00	Create & Take 1st Time	$5,495.75
2nd & more Times	$1,221.00	2nd & More Times	$63.50

So, does a virtual field trip take less time and money then a real field trip? If the virtual field trip is to be given only once, the real trip could be cheaper; however if the virtual field trip is to be given several times, it is very definitely cheaper and it certainly takes less time. Of course sometimes factors such as accessibility, weather, and safety may make the virtual trip mandatory no matter what other resources of time and money are available.

Making the Choice: Virtual or Real Field Trip?

So, can we conclude that the virtual trip is the one to take if you are planning a field trip? No, because a virtual field trip provides for academic learning of facts (the

Upper Grand Coulee is 800 feet deep) and concepts (what is undermining) and also is a way to keep cost down and to address weather and safety issues. What happens if the reason for the field trip is to understand how enormous an 800-foot deep by 1-to-5-miles wide drainage channel really is, and to actually imagine a flood coming through the Upper Grand Coulee? For this purpose, the purpose of the field trip would be to impress the actual size of the Upper Grand Coulee and its surroundings in the students. This would mean the students must actually see and experience the size of the coulee. Obviously it would take a real field trip to do that.

Let's look more closely at a real field trip's purpose and how it may differ from a virtual field trip's purpose. Both field trip types are meant to supply students with real world experience to help them understand how concepts studied in the classroom can apply in the context of the real world. Our version of a virtual field trip allows students to see, by way of photographs, actual giant ripple marks, water line marks, undermining of waterfalls, etc., so students better understand the applicability of these concepts in the real world. However, it is difficult for photographs, even enlarged panoramic photographs, to give a sense of the real size of enormous phenomena like a volcano, tornado, or a huge drainage channel. A picture or movie of a volcano shooting lava a 100 feet into the air doesn't actual give the sense of being there and experiencing the heat, wind, and the sense of being in danger that a real field trip would bring.

For students, pictures and movies can add realism to the study of volcanoes, even if the resulting experiences do not have quite the visceral impact that actually being there would. The same kind of effect could happen with the Grand Coulee field trip. If the teacher really wants the students to feel the experience of the floods rushing thorough the Grand Coulee, they can do it better by standing at the edge of the Upper Grand Coulee and looking out over the channel. There, they can feel the wind and see the differences in light and shadow dancing across the abyss. And they can try to understand how big the channel actually is and sense the terror one would have felt if one had been alive when a Spokane Flood actually occurred.

Real Trips Are Sometimes Better

In my opinion, real field trips are still a better choice than virtual trips for understanding the size of enormous phenomena. Also, really being there allows students to locate where these places of interest are so they can bring their family and friends to see the site now and/or in the future. And, there is still the importance of allowing students to use other senses to bring in information for the mind to process. Smell, touch, hearing, and sometimes even tasting add that much more information to the overall experience, which will ultimately contribute to more complex understanding.

The Significance of Teacher Planning in Creating Worthwhile Instruction

One conclusion we can reach from the above comparison between real and virtual field trips is that both require a great deal of teacher time for research and planning in order to create a worthwhile learning experience for students. Readings, talking with experts, study time, finding appropriate sites to visit and creating the route to the sites are all impositions on a teacher's time. This extra time is very difficult to find in a teacher's already-busy schedule, hence in most schools, very few field trips are taken. However, with the findings reported here that virtual field trips provide the same level of student learning as real field trips, we can help teachers by creating virtual field trips. The findings also imply that students could be able to have greater access to a wider variety of field experiences through virtual field trips. By taking more virtual field trips, students will have the opportunity to see in a simulated real world setting more concepts that they have studied in the classroom. Seeing the concepts virtual will enhance their understanding of the concepts, which further implies both better teaching and better learning.

Possibilities for Further Research

How virtual field trips could be used more widely to actually improve learning in a classroom setting would be an excellent area for further research. For example, for which topics is the sort of visual enhancement provided in a virtual field trip most effective? And, what aspects of virtual field trip production yield better learning? Another area of research would be to see how input to the other senses like smell, touch, and sound would affect the outcomes from a virtual field trip. Sound, for example, would be a relatively easy sense to add economically to a virtual field trip. Sound effects of fast-running water, etc., might provide enough added reality to help the students imagine lots of water running through the Upper Grand Coulee.

A more elaborated version of this study might have examined the long-term effects on learning of the students who first took the virtual field trip, then later took the real trip. They experienced a double exposure to the material of the unit, and it would have been interesting to know whether this lead to deeper or more lasting learning. Unfortunately, time and expense did not permit us to follow up on this possibility here.

Also, research might profitably be done on construction of more advanced virtual environments, such as virtual worlds created within a computer and delivered to the students thorough a hooded helmet, gloves, and earphones (or other, even more sophisticated hardware). This is a different level of virtual reality, but as computers become more powerful and easier to program, it may well be that a virtual world could be created economically that would allow students to ride a surf-board sized piece of ice through the Grand Coulee in a Spokane Flood. What an amazing project that could be.

Using Virtual Environments in Education

Implications for the use of virtual environments in education are wide ranging. Teachers can make a connection between classroom-studied concepts and the way the concepts appear in the real world, thus enhancing student understanding. All that is needed is a digital camera, projector, screen, some time, energy, and a little cash to create a virtual field trip showing the studied phenomena in its real world context. Also, any subject can be enhanced by the use of virtual field trips: math, science, social studies, English, even a wood shop or metal shop class can benefit from a virtual field trip. And, since the teacher is creating the virtual field trip, local businesses and geography can be used to supply the real world setting of classroom-studied concepts giving students more familiar examples, which may help them understand more easily the real world application of concepts. It may also help the students to apply the concepts more directly to their world, thus both making their learning more valuable and perhaps inspiring more effort on the students' part to learn.

Another implication for the use of virtual field trips is the possibility of sharing field trips among teachers from different parts of the country or world. A teacher in Wyoming may have made a virtual field trip to several ranches in her area to document what cowboy and cowgirl life is like. In Seattle, there may be an English teacher looking for information on cowboys so her 7th grade class can write essays on what a cowboy's life is like. The Wyoming teacher could list her virtual field trip about cowboys on the school's website, thus allowing the Seattle teacher to do a web search and discover the virtual field trip into the life of cowboys. The Seattle teacher could download the field trip (let's say in this case it is a series of digital slides with a sound track). After looking at the virtual field trip, the Seattle teacher could call the Wyoming teacher to find out more about the real people shown in the virtual field trip. She finds that most the cowboys and cowgirls in the virtual trip are parents of the Wyoming teacher's students. And, the reason the virtual trip to the ranches was made in the first place was to show a school in Florida the ranches and life style of western cowboys.

Through networking and use of each others virtual field trips, teachers and students around the country could be connected and learn from each other. This idea of sharing virtual field trips could be further extended to include a state or regional level repository or listing of available virtual field trips so teachers would have a central place to list their virtual field trips and a place to look for virtual field trips done by others. The example, of course, is fictitious, but it illustrates what is possible with the use of virtual field trips.

Student Engagement in Creating Virtual Field Trips

Virtual field trips also have other broad reaching implications for working with middle level students, eighth grade science students in particular. First eighth graders are remarkably grown up if you allow them to be. They have the ability to do almost anything that is asked of them and for the most part they enjoy doing excellent work. Therefore, their enthusiasm could well be enrolled in creating virtual field trips. A little practice with the digital camera and some serious practice using the stitching software to create panoramic photographs and you have a crew to help create a virtual field trip.

As an example, let's say a seventh grade class in Hawaii would like to compare the volcano they live on to Mt. St. Helens in Washington State. Prior contact between schools has set the stage for cooperation between science teachers, so we plan a summer field trip to Mt. St. Helens and settle on a format for a virtual field trip. We decide we will use panoramic photographs, normal photographs, and movie clips along with a sound track to create our virtual field trip.

We choose to take 16 students to Mt. St. Helens in the middle of July. Students practice taking photographs, both panoramic and normal, they work at stitching their panoramic pictures together using the stitching software, they practice taking video clips and learn how to digital splice clips together to get exactly what they want, they collect money anyway that they can, and they start hording camping equipment. The teacher finds a short bus to get us to the mountain and back.

We leave Spokane in the middle of July as prepared as possible. We camp for a week close to Mt. St. Helens and take hundreds of photos, lots of film clips, and the small film crew takes a helicopter ride over the top of Mt. St. Helens. When we get back to Spokane and the school we carefully put the virtual field trip together and it is awesome.

Yes, this is another fictitious trip, but it would very likely be a powerful learning experience for all those involved. And the whole adventure would be focused around the creation of a virtual field trip that could be used for years both by our sister school in Hawaii and at home.

There is no reason that today's eighth graders with their digital world experience should not become producers, not just consumers, of virtual field trips. Such a project as making a virtual field trip to Mt. St. Helens is a great way to encourage collaborative activity, careful planning, and organization of projects. Students could even plan real field trips based on the way previous classes created their virtual field trips to sites that interested them. A great future research project could be to look at the effect of virtual field trip creation on student learning within these creative classes.

The Growing Complexity of Taking Real-World Trips in Today's Schools

Real-world field trips are truly a difficult methodology to use in today's schools. The possibility of litigation has skyrocketed in the past several years. Also, the increase in fuel costs has tripled the cost per student for taking a real field trip in just the last three years. There is also the time away from school for a day and the increase in teacher preparation effort and time to arrange for the bus(es) and prepare and collect permission and information slips. The time and effort to create a real field trip that fits seamlessly in the classroom curriculum is enormous, as mentioned earlier. The testing and other curricular limitations brought by the No Child Left Behind federal legislation and/or state wide academic testing have put much pressure on teachers to keep a very tightly controlled academic timeline so all required topics are covered.

Real field trips can connect to these new academic requirements, but time, cost, effort, and know-how can be difficult for teachers to address. It may be that virtual reality field trips become the norm simply because of the lesser likelihood of litigation and less teacher preparation time for the virtual trips even though the first time cost, expense, and effort of both virtual and real field trips are about the same. There is also the fact that virtual field trips are much less expensive to take after the first time due to zero bus cost and less effort on the teacher's part to prepare for the trip.

Final Thoughts

We have approached this research with as much care as we could. The three sections of earth science classes where given the same classroom instruction, sometimes to the point of its being verbatim. The dialog with the students at stops on the real field trip were as close to the same dialog we gave to the virtual field trip students as we could possibly make it. We understood that the details were important in this study (as they are in all studies) and we made every effort to dot every "I" and cross every "t." To do accurate research on the Spokane Floods, find stops that were meaningful to our curriculum, and plan for real learning opportunities for the students were our guiding parameters. We feel that it is important for teachers to have an excellent academic background in the areas in which they teach and to have some knowledge of their student's world so they can present accurate and meaningful learning opportunities to their students. We also believe it is the responsibility of teacher preparation programs to prepare teachers with excellent academic backgrounds and teaching methods so they can provide real and meaningful learning opportunities to their students. It is also the responsibility of school principals to place teachers in subject areas that are within their fields of expertise.

In the final analysis, this study demonstrated once again the centrality of good design and careful planning in assuring excellent instructional outcomes. These features appear to trump the specifics of the technology that is used in teaching. The more deeply and thoroughly the teacher thinks about what he or she wants the students to learn and be able to do, the better the results are bound to be. This is not a radical or new finding, but it has gained important additional support via this study.

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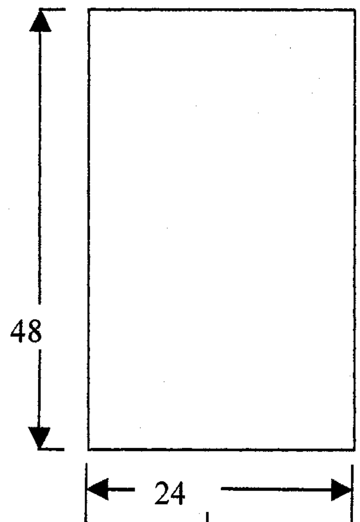
Appendix A: Grand Coulee Model Diagrams

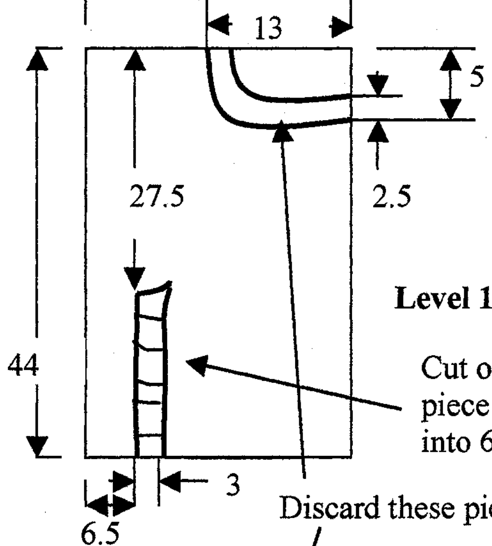
Two Pages
All Measurements Are In Inches.
Read Through Carefully.



Base

See Picture 5A & Picture 5B in Pocket Material for further help.

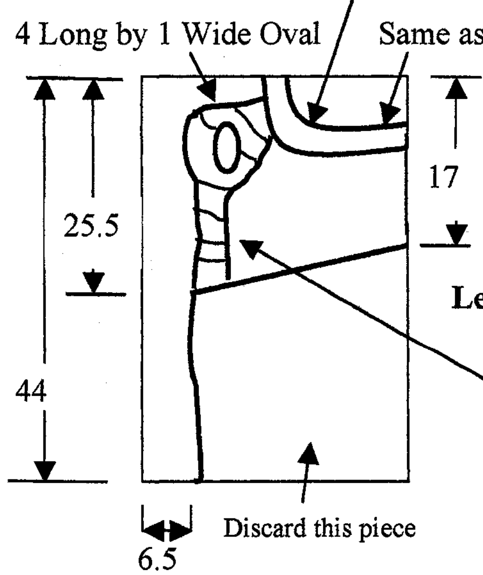
Material is 1.5inch high-density polystyrene foam. It comes in 24 inch by 48 inch pieces in the insulation area of home improvement stores. A jig saw with a fine-tooth 4 inch blade works well to cut the foam.



Level 1

Cut out and remove piece then cut piece into 6 pieces.

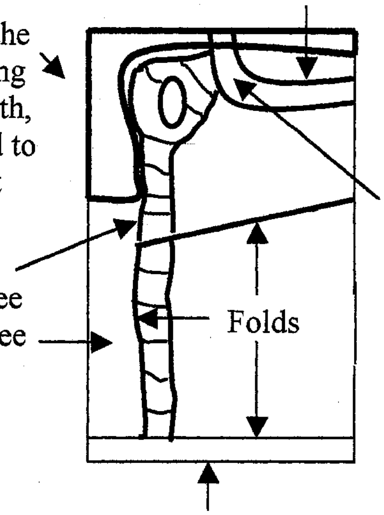
Discard these pieces



Level 2

Cut out and remove piece then cut piece into 8 pieces including the 4inch by 1inch oval. The oval is 9.5 inches from the top of Level 2 to its middle. The oval is 8.75 inches from the left side of Level 2 to its middle. Long way of oval is up and down. The oval represents Steamboat Rock, which is almost a rock island towards the north end (top) of the Upper Coulee. (Steamboat rock is not completely surrounded by water.)

Appendix A - Page 2



This diagram is the Base, Level 1, and Level 2 stacked up like they should be. There is a Level 3 piece as well. It is the Glacier. You may want to add the glacier or not.

To secure all the pieces of the model you'll need 7- 4 x 3/16 inch carriage bolts with a 7/8-inch outside diameter washer at the bolts top and a ½ inch outside diameter washer next to the 3/16 nuts. You'll also need 3- 3 x 3/16 inch carriage bolts with the same washers and 3/16-inch nuts. To find placement of bolts see Grand Coulee Model Picture 5A and/or 5B.

Appendix B:

Detailed Driving Instructions For The Two Real Field Trips

The Real Field Trips: The Camas Prairie

1. Head east out of Spokane on Interstate-90 from the Argonne Street Entrance. Travel 90 miles to just over the Montana border and stop at the Dena Mora rest area. This is a good place for a rest stop and it's a good place for a mini discussion if you want to give additional information to the students. Leave the rest area and head east to 9-Mile exit, which is where the sediment layers left by Glacial Lake Missoula are located.

2. Drive the 77 miles between the rest area and the 9-Mile exit, exit # 82. It takes about an hour. The sediment beds are about a mile west of the exit so you will drive past them as you head for the 9-Mile exit. Take exit 82 and turn north, left, up over the freeway and go around the corner to a small park about a ½ mile from the freeway. You can stop at the park and walk south, through private property, to the bluff that overlooks the freeway and sediment layers. (Note: To get permission to use the private property, try going a little farther down 9-Mile Road. There are a couple of homes there. You certainly want to do this during your pre-trip checkout.) I should tell you the park is new since I took a luxury bus full of students to the sediment layers. There was a dirt road, which was on private property that connected 9-Mile

Road to the freeway bluff. We drove down the road and parked the bus at its end. The students then crossed the freeway fence on foot. They drew the sediments layers in their notebooks while sitting on the lawn chairs they had brought along in the belly of the luxury bus (Panorama 1). However, the road has been removed so the park seems to be the best alternative. Note: If there is just 1 or 2 of you, instead of a busload of students, you can stop right at the sediment layers beside the freeway. There is plenty of room to pull completely off the freeway and then you can look for the varves in the red sediment layers. I have done this with no adverse results.

3.From the bluff go back to your bus and return to Interstate-90 and take the eastbound entrance to Missoula. It is 23 miles to the Van Buren Street exit, #105, in Missoula, Montana. Take the exit.

4. From the Van Buren exit in Missoula turn left on to Van Buren and followed it north. In about a mile Van Buren turns into Rattlesnake, which you follow approximately 1.5 miles further to Lolo Street. Turn left on to Lolo for ½ mile until you come to Duncan. Turn right onto Duncan and continue 1 mile to Game Trail Street. At Game Trail turn the bus around so it's facing south on Duncan and park on the side of the road. From here you can see the shoreline marks on Mount Jumbo if you face southeast. That's looking back down Duncan where you just came from. We talked about the depth of floodwaters and drew Mt. Jumbo into our notebooks (Panorama 2). Next we were off to the Camas Prairie 60 miles northwest of Missoula.

5. Head back down Duncan to Lolo and turned left on to Lolo. Go ½ mile to Rattlesnake and turn right on to it. You are now going south on Rattlesnake. Go about 1 ½ miles and Rattlesnake automatically turns in the Van Buren, which you follow an additional mile to the Van Buren entrance to Interstate-90 west. Take the entrance and drive the 9 miles to exit #96. Take exit 96 and turn right on to Hwy 200. This Hwy goes to Kalispell but we won't go that far on it. Stay on Hwy 200 and drive the 27 miles to Ravalli. At Ravalli turn left to stay on Hwy 200 west. In 20 miles you'll come to a bridge by Perma, your basic two-house town, and turn north across the bridge onto Hwy 382 going north. (Note: The bridge is just east of Perma.) In 7.7 miles you are in front of the school that is the town of Camas Prairie. Continue up Hwy 382 13.4 miles to Willis Pass Road. Willis Pass Road is gravel and was unmarked. It is on the east, right, side of Hwy 382 about 2/3 of the way up the side of the Camas Basin. It does have, or had, a stop sign and it is the only road close to that location. The bus had to back down the road because there was no place to turn 40 feet of bus around where we were on the side of basin. (Panoramas 3A&B maybe helpful to fined Willis Pass Road.)

6. Go south, left, from Willis Pass Road back to Perma via Hwy 382 south. When you arrived at the south end of the bridge just east of Perma turn west, right, on to Hwy 200. Drive 10 ½ miles to Hwy 135 and then follow 135 south the 21.4 miles to St. Regis. There take the St. Regis entrance, #33, to Interstate-90 going west to Spokane.

Drive the 140.4 miles west on Interstate-90 to the Argonne Street exit in Spokane, the starting point of our trip.

The Real Field Trips: The Grand Coulee

7. Start your mileage at the Argonne Street entrance to Interstate-90 going westbound. Go 8.2 miles to Hwy 195, exit #229, and travel south 5 miles to the Hatch Road exit. Turn around at the exit and go north on 195 for 3/10 of a mile. Turn right on to the dirt road that leads into an open field. Drive east a few hundred feet to Latah Creek, sometimes called Hangman, and park. Right across the creek from your parking place should be a sand wall that displays hundreds of layers of sediment (Panorama 4).

8. Next go back to Hwy 195 and turn north, right, and drive the 4.1 miles to Interstate-90. There take the westbound entrance on to I-90. Drive about 1.4 miles and take the Hwy 2 exit. Stay on Hwy 2 westbound through Airway Heights, Reardan, Davenport, and Creston, to Wilbur a distance of 62.4 miles. On the west side of Wilbur turn north on to Hwy 21 and 174 for about ½ mile and then turn right on to Hwy 21. Drive the 14.3 miles to the Columbia River and board the Keller Ferry (Pictures 10A&B). The ferry will take you to the north side of the Columbia just west of the mouth to the Sanpoil River.

9. From the north side of Keller Ferry drive north on Hwy 21 5 miles to Manila Creek Road. Turn west on to Manila Creek (There is a sign that says Grand Coulee and Elmer City). As you drive toward Elmer City Manila Creek Road changes its name to Peter Dan Road at the Okanogan County line. From Hwy 21 drive approximately 13 miles to the driveway of a rancher we met and turn in. The rancher owns land overlooking the north end of the Upper Coulee. There is a beautiful view of Steamboat Rock, Bank's Lake, and the North Dam (Panorama 5).

(Note: We can't give you the name of the rancher but if you ask around someone may give you access to the hills that overlook the Upper Coulee. That's how I did it.) If you simply want to go to the next stop continue west on Peter Dan Road an additional 2 miles. That will take you to Hwy 155 where you turn south, which is left. Also skip paragraph 10.

10. We parked the bus at the rancher's home, put the students in two pick-ups and one Dodge Caravan that we had brought along, and drove the three miles to the top of the hill. (Panorama 5) When we arrived at the first viewpoint we picked out the North Dam, Banks Lake, Steamboat Rock, the uplift pipes, and tried to comprehend the shear size of the Upper Coulee. We then drove to a second stop about a mile down the road where we had a 270-degree view of the surrounding countryside. When we were done looking we returned to the rancher's home on the north side of the hill. The whole excursion took approximately an hour.

11. Turn west from the rancher's driveway on to Peter Dan Road and go 2 miles to Hwy 155. Turn south, left, and go through Elmer City, Coulee Dam, and into Grand Coulee by following the main road, which is Hwy 155, a total of 7 miles to Hwy 174. Turn east, left, on to Hwy 174 and go the 2.8 miles to Spring Canyon State Park. Turn into the Park's entrance and drive down to the Columbia. This is the place for lunch, playground toys, walks on the beach, and playing catch with the football.

12. After lunch go back up the hill to Hwy 17 turn west, right, back to Grand Coulee and Hwy 155. At 155 turn south, left, down the east side of the Upper Grand Coulee 16.8 miles to an example of waterfall undermining (Picture 9). The waterfall is on the east side, left, of the coulee just beyond a Bank's Lake Public Access Area, which is on the west, or right side, of the road. The falls can be seen easily from the Hwy and is back about 300 feet from the Hwy.

13. Next we went to a viewpoint about 1.9 miles south, left, of the falls on Hwy 155 (Panorama 6 and Picture 6).

14. After the stop at the viewpoint continue to drive south to Dry Falls Dam at the very end of the Upper Coulee. As you cross the earthen dam you'll have an excellent view of the Upper Coulee's south end. On the west side of the dam, which is 11.7

miles from the Bank's Lake viewpoint, is Hwy 17. Turn south, left, on to Hwy 17 and drive the 1.9 miles to the Dry Falls Interpretive Center viewpoint (Panorama 7).

15. Turn south, left, out of the viewpoint and drive down Hwy 17 1.8 miles and turn into Sun Lakes and Dry Falls State Park (Panorama 8). Drive down the driveway for 8/10 of a mile and turn around. By looking northwest up on the side of the hill you can see the rock layers slant down showing the monocline (Panorama 9).

16. Go back the 8/10 of a mile to Hwy 17. Turn north, right, and head back the 3.9 miles to Hwy 2. Turn east, right, onto Hwy 2 and cross the Dry Falls Dam and continue 4.2 miles to the Hwy 2 intersection with Hwy 155 where you turn right to continue on Hwy 2, eastbound. Drive 89.6 miles to the entrance of Interstate-90 just west of Spokane. Continue on Interstate-90 9.2 miles to the Argonne Exit in Spokane, the starting place of our trip.

Appendix C: Colored Photographs

Picture 1 – Varves

Picture 2 – Giant Ripple Marks

Picture 3 – Giant Ripple Mark

Picture 4 – Erratic

Picture 5 A&B – Polystyrene Grand Coulee Model

Picture 6 – Basalt Flow

Picture 7 – Camas Prairie Model

Picture 8 – Scabland Model

Picture 9 – Undermining

Picture 10 A&B – Shoreline Water Marks

Panorama 1 – 9 Mile Sediments

Panorama 2 – Mt. Jumbo

Panorama 3A – Camas Prairie

Panorama 3B – Camas Prairie

Panorama 4 – Latah Creek Sediments

Panorama 5 – North End Of Upper Grand Coulee

Panorama 6 – Bank's Lake Turn Out

Panorama 7 – Dry Falls

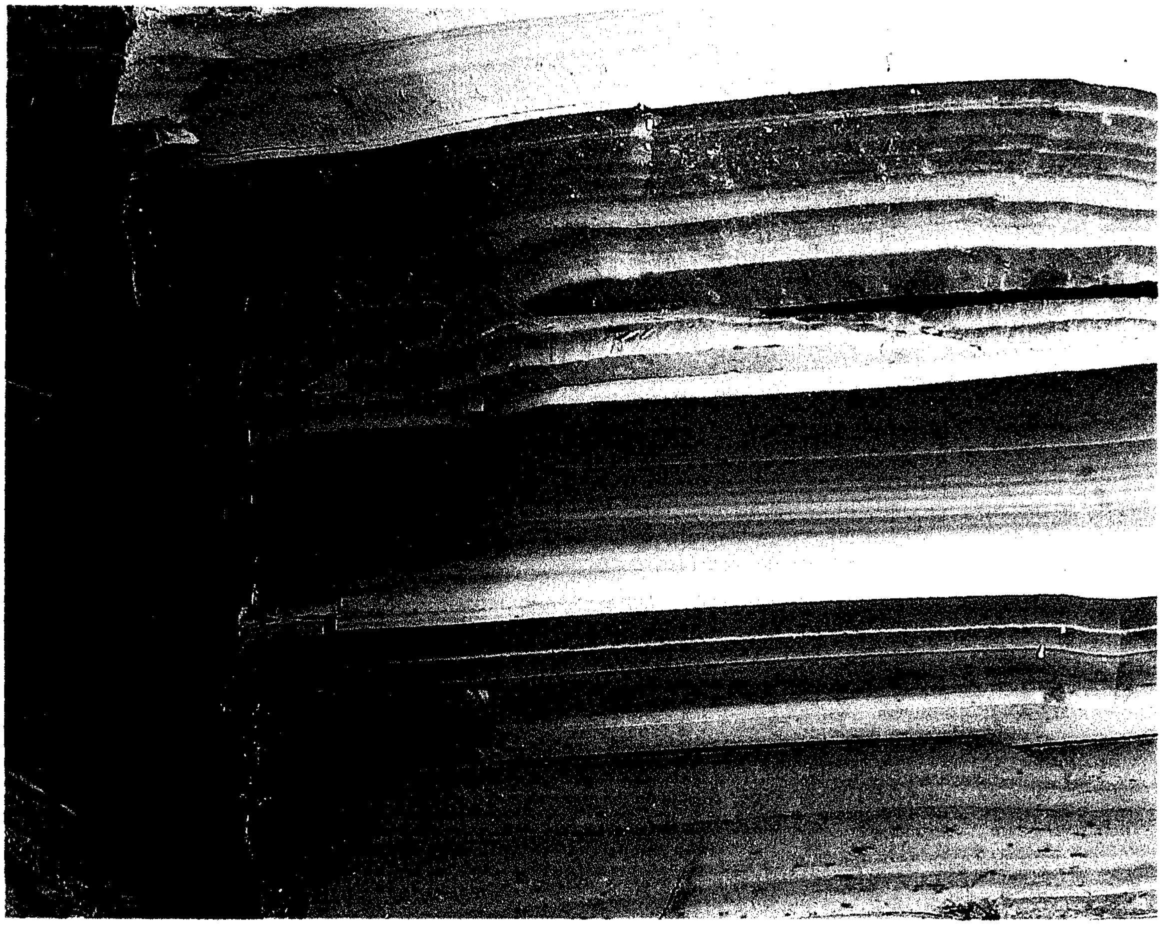
Panorama 8 – Sun Lake State Park

Panorama 9 - Monocline

VITA

Daniel B. Lewis was born in Hot Springs, South Dakota. He has spent a decade and a half teaching Earth Science to eighth graders and several years teaching Science Methods to perspective teachers in Spokane where he lives. At Eastern Washington University he earned a Bachelor of Arts degree in Education and a Master of Education from Gonzaga University. In 2008 he earned a Doctor of Philosophy at the University of Washington in Education.

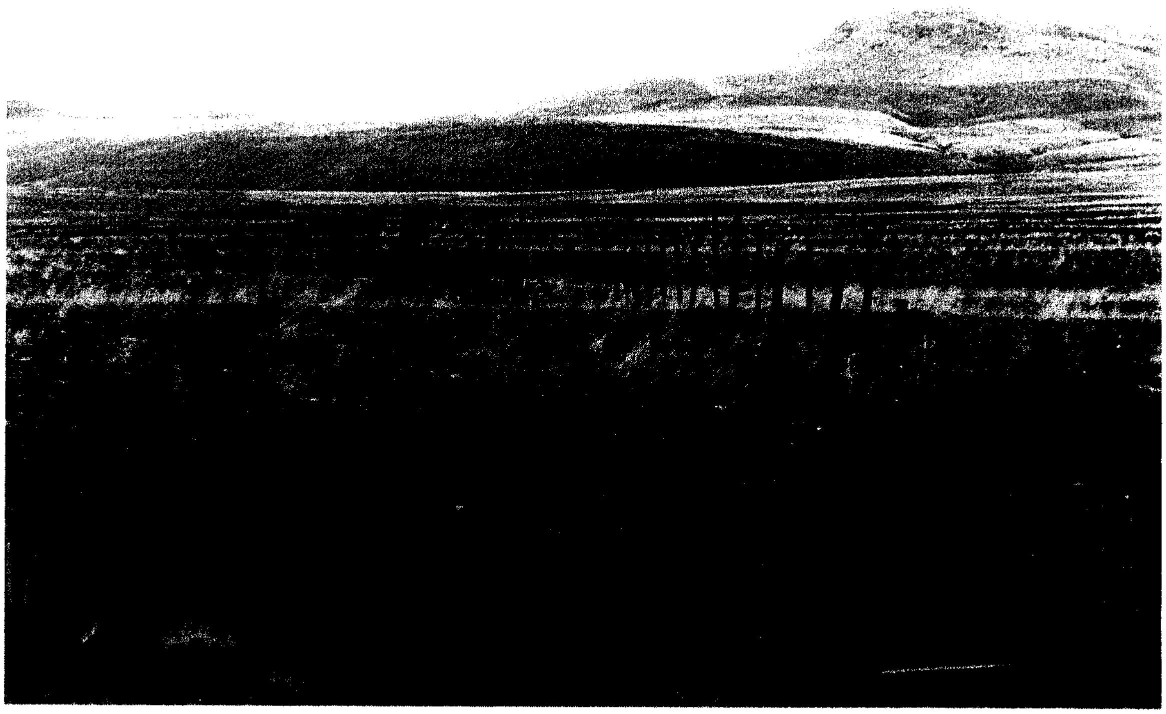
Picture 1 - Varves



Picture 1

Varve Layers – Light Color Is Summer And Dark Color Is Winter, A Light And Dark Layer Together Make Up One Varve Layer Which Indicates One Year. Scale Is Given By The Standard Size (2 to 3mm wide) Blades Of Grass To The Left Of The Picture.

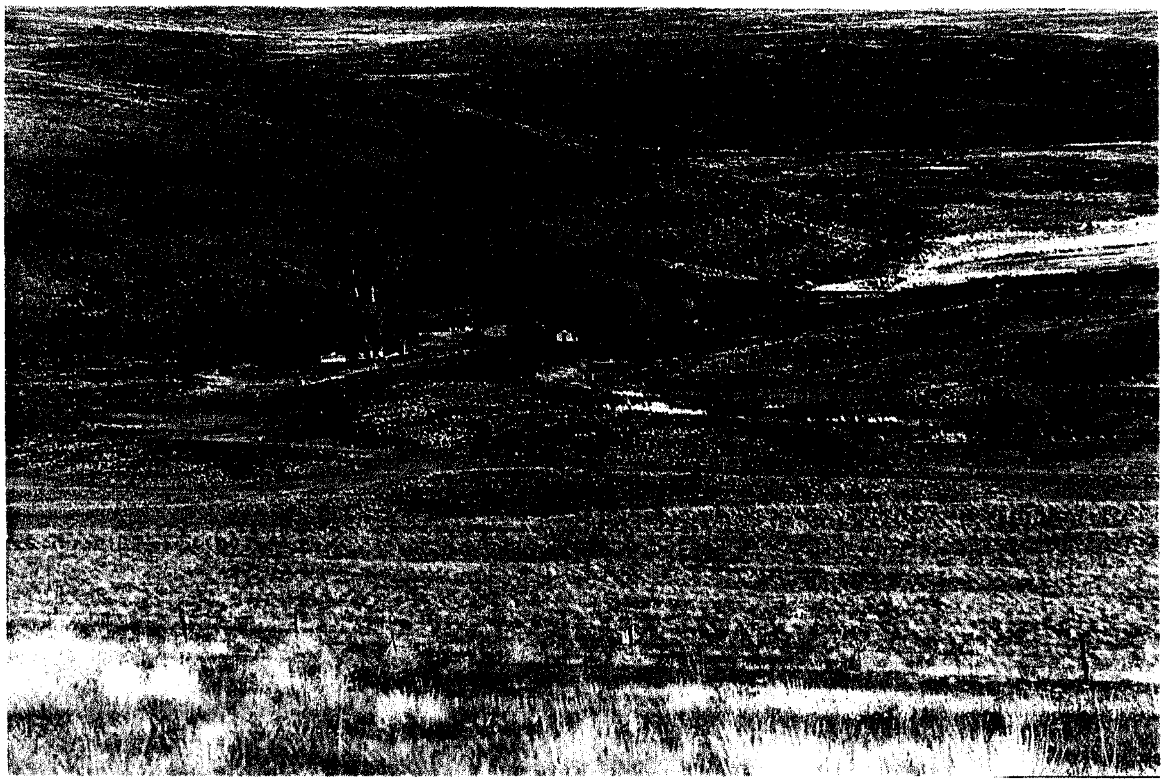
Picture 2– Giant Ripple Marks



Picture 2

Giant Ripple Marks – The Ripple Mark In The Foreground Is 10 Feet Tall And Its Crest is 214 Feet From The Crest Of The Ripple Mark Behind It. This Ripple Mark Is In The Bottom Of The Camas Prairie Basin.

Picture 3 – Giant Ripple Mark



Picture 3

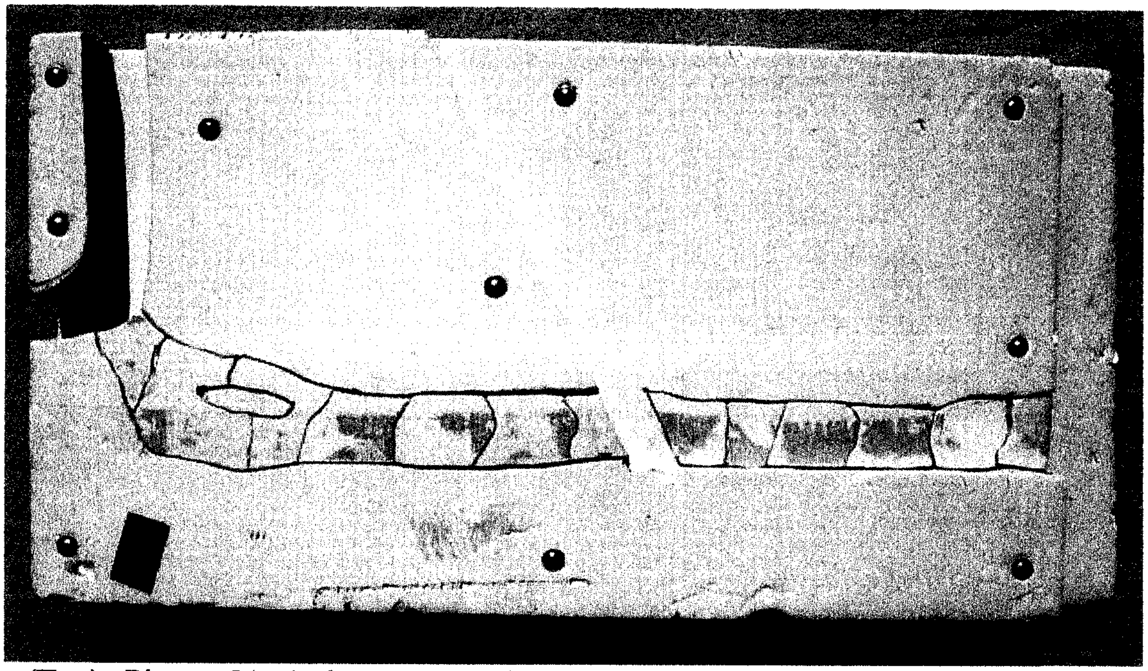
Giant Ripple Mark In The Bottom Of The Camas Prairie Basin.
It Is Believed That The Water That Made This Ripple Mark Was 1,200 Feet In Depth.
The 200-Foot High Front Of The Giant Sediment Pile Is In The Background.

Picture 4 - Erratics

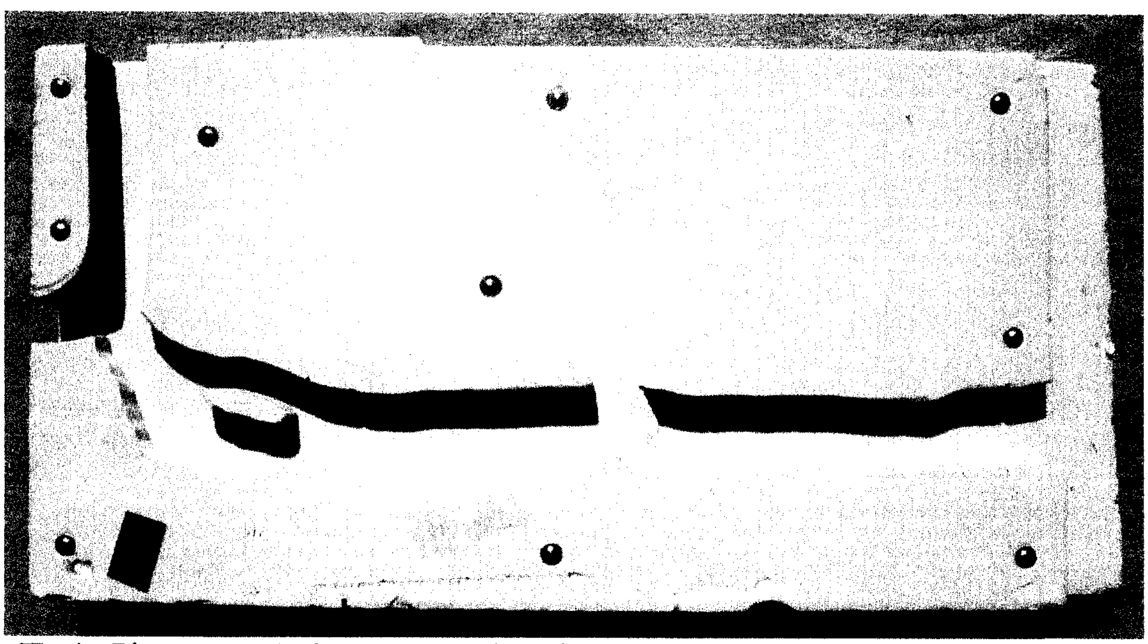
Picture 4

An Erratic Is A Rock That Doesn't Match The Rocks That Are Around It. The Rock Has Been Transported To A New Location By Rafting On Glacial Ice Or By Strong Water Currents. When These Rocks Are Left On The Surface The Larger Ones Appear As Out Of Place Boulders. Smaller Rock Certainly Can Be Erratic But They Are Less Noticeable. Erratics Can Also Be Left Underground In Sediment Layers. When They Are Uncovered As The Ones In The Above Picture Have Been They Appear To Be Out Of Place As Well. The Pile Of The Erratics Above Was Made Of Erratics Found In The Gravel Beds Of The Camas Prairie Basin 8 Miles South Of Hot Springs, Montana On County Route 382. Here You Can See The Different Size Of Erratics Although They Can Be Much Larger. The Gravels Surrounding The Embedded Rock Are The Two-Inch Flat Gravels That Occupy The Area.

Picture 5A&B – Polystyrene Grand Coulee Model

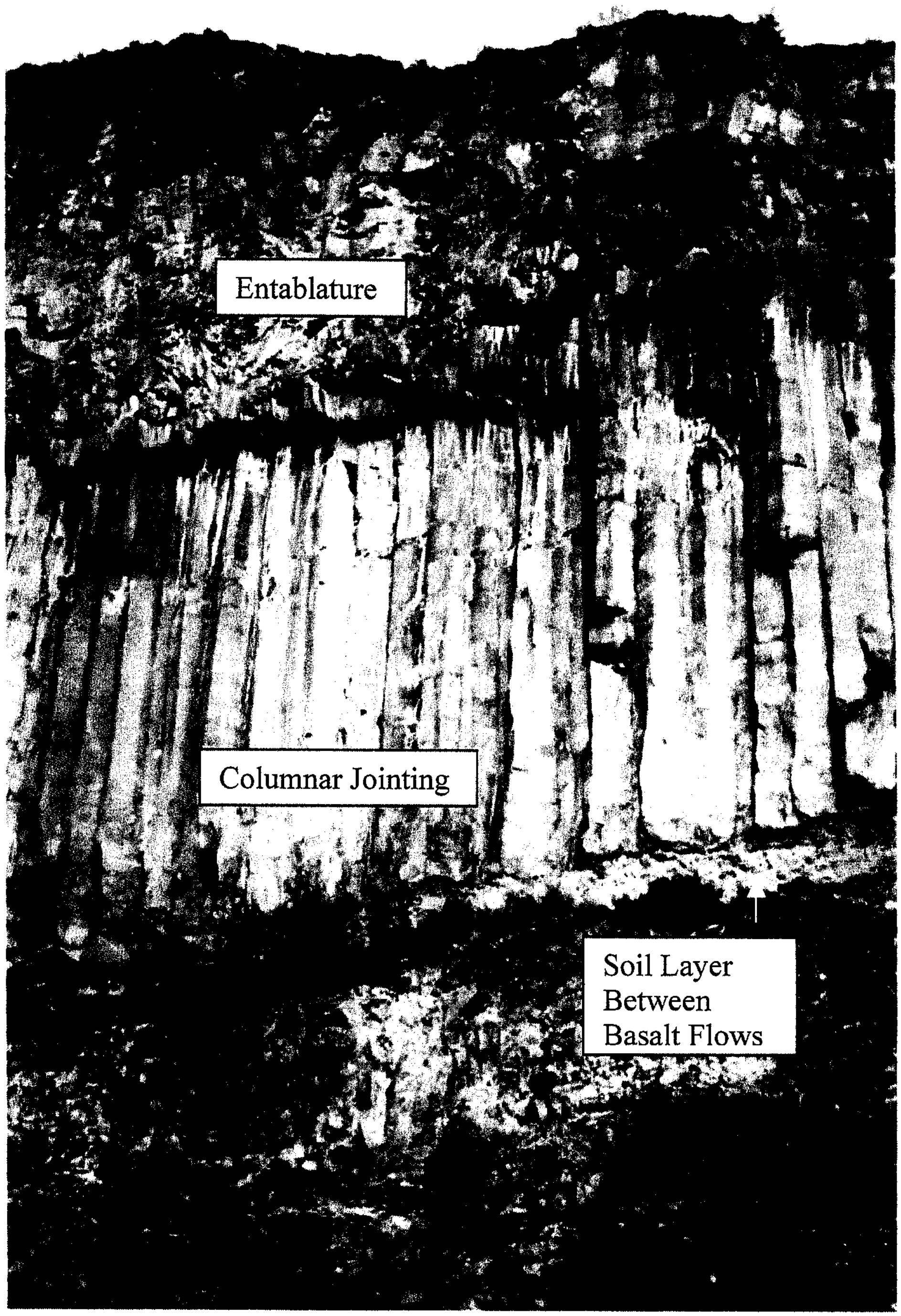


(Top) Picture 5A - Polystyrene Model Of Grand Coulee With Coulee Pieces In Place.



(Top) Picture 5B - Polystyrene Model Of Grand Coulee With Coulee Pieces Removed.

Picture 6 – Basalt Flow



Picture 6

Basalt's Entablature and Columnar Jointing

Picture 7 – Camas Prairie Model

Picture 7

Filling The Camas Prairie Model With Water Which Will Be Used To Create
A Mini-Megaflood On The Scabland Model Directly Below This Model
The Far Basin Is The Bitterroot Valley And The Near Basin Is The Camas Prairie

Picture 8 – Scabland Model

Picture 8

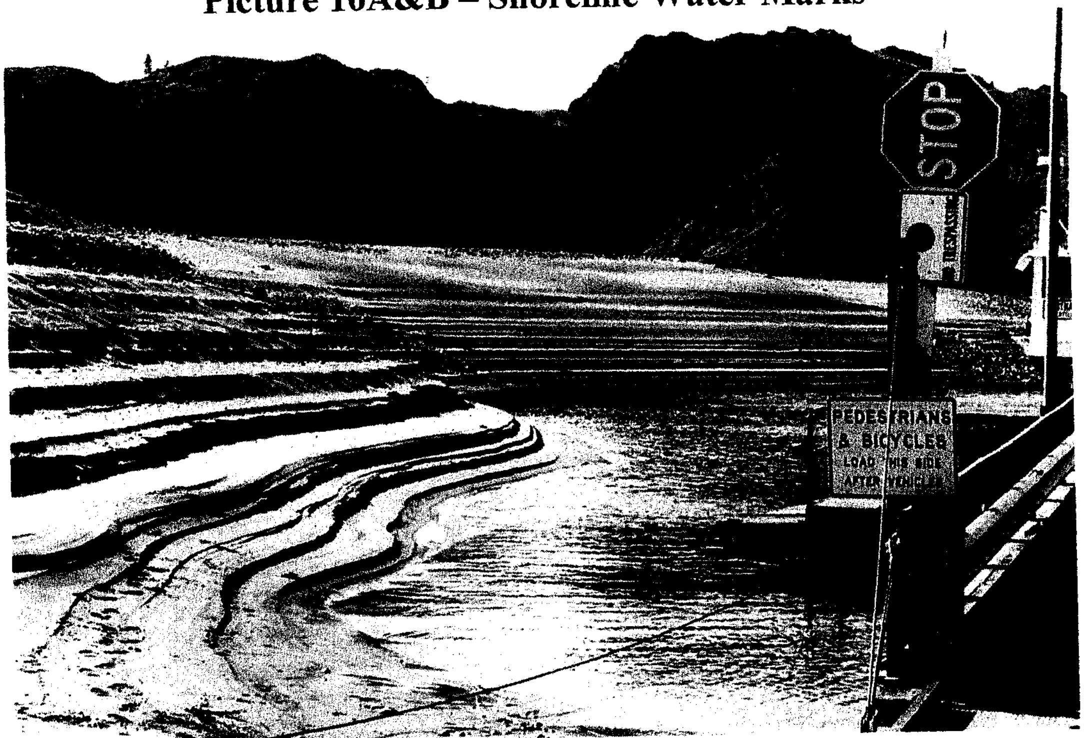
Scabland Model During Mini-Megaflood

Picture 9 – Undermining

Picture 9

Undermining – The Area Behind A Waterfall Is Eroded Away By Turbulent Water And Rocks. This Is The Process That Helped Form The Grand Coulee. This Picture Is Of One Of The Waterfalls That Are In The Sides Of The Grand Coulee Today. The Amount Of Water Going Over The Falls Is Very Low So Current Undermining Is Really Non-existent. However, At One Time The Falls Was Quite Active.

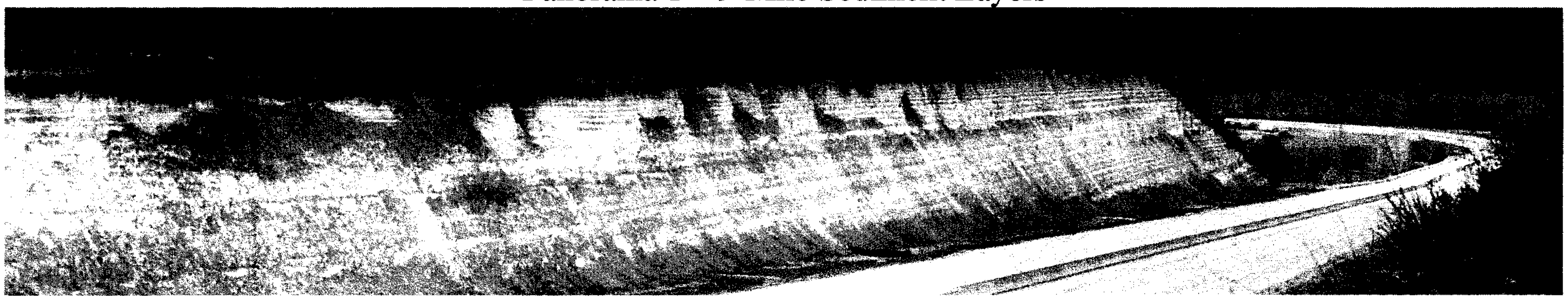
Picture 10A&B – Shoreline Water Marks



Picture 10A
Kelly Ferry Shoreline Water Marks During Low Water

Picture 10B
Keller Ferry Shoreline Water Marks During Low Water

Panorama 1 – 9-Mile Sediment Layers



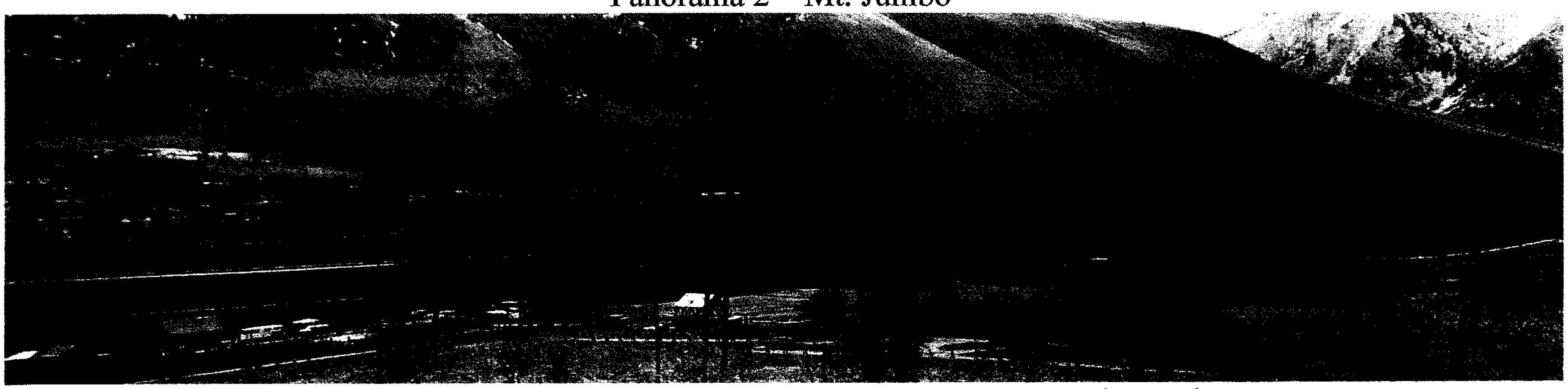
Red Layers Are Varve Layers Deposited In The Bottom Of Glacial Lake Missoula West ⟶

Light Layers Are River Deposits That Accumulated In The Bottom Of Glacial Lake Missoula When There Was No Lake

Glacial Lake Missoula Sediment Layers 1 Mile West Of The Nine Mile Road Exit On I-90 23 Miles West Of Missoula Montana

Viewer Is Facing Southwest From The North Bluff Above I-90

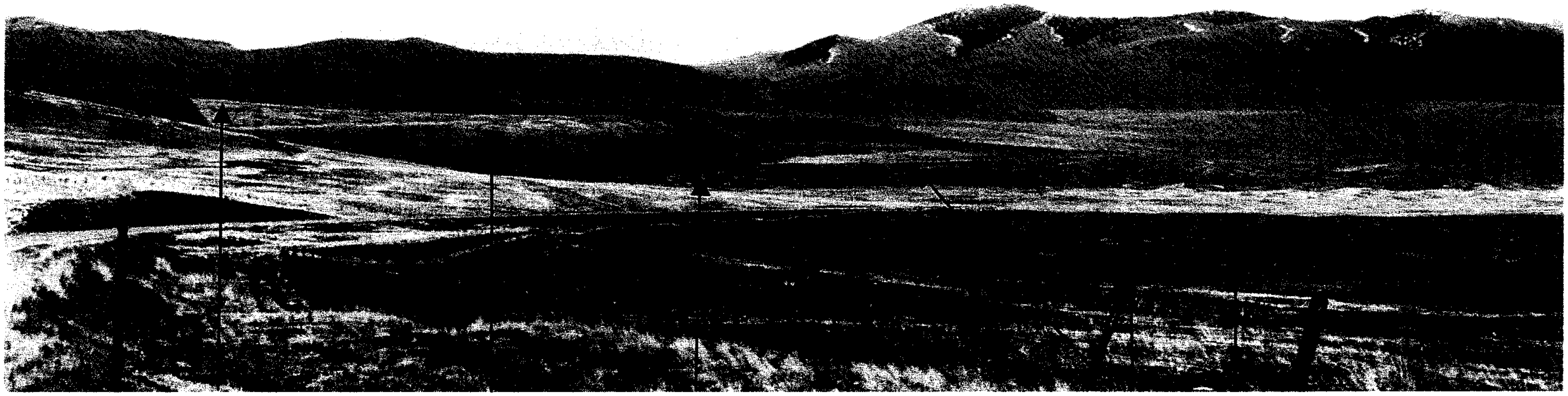
Panorama 2 – Mt. Jumbo



Water Line Marks Water Line Marks South ⟶

West Face Of Mt. Jumbo – Viewer Is Facing South East - Northwest Missoula Montana

Panorama 3A – Camas Prairie

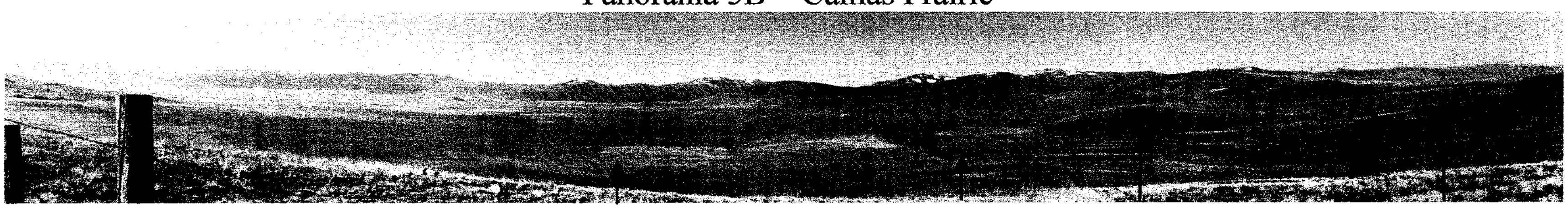


← North Willis Creek Pass Sediment Pile Two-Story House and Tree Giant Ripple Marks

Camas Prairie 100-Degree Panorama

Viewer is Facing East From The Northwest Rim Of The Camas Prairie Basin

Panorama 3B – Camas Prairie



Giant Ripple Marks Giant Ripple Marks Giant Sediment Pile Willis Creek Pass

North →

Camas Prairie 180-Degree Panorama

Viewer is Facing West From The East Rim Of The Camas Prairie Basin

Panorama 4 – Latah Creek Sediments

Sediment Layers From Glacial Lake Columbia And Glacial Lake Missoula South →

Latah Creek Sediments – View Facing East From Open Field Just North Of The Hatch Road Exit On Hwy 195 South Of Spokane Washington

Panorama 5 – North End Of Upper Grand Coulee

Steamboat Rock North Earthen Dam Canal Banks Lake West →

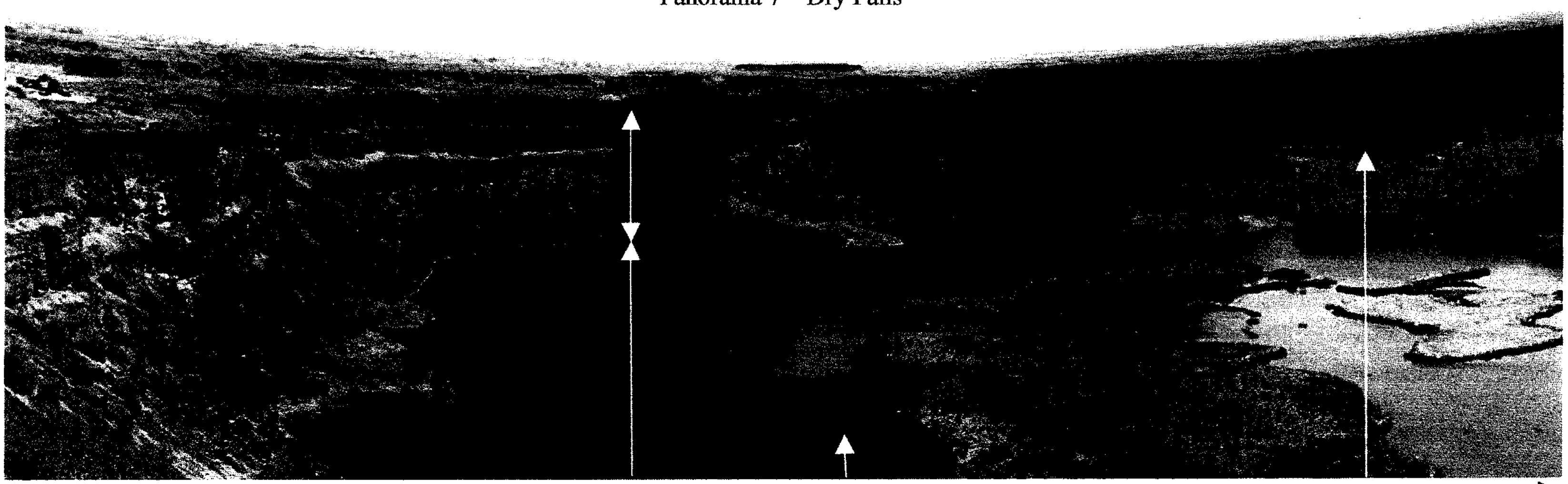
North End Of The Upper Grand Coulee – Viewer Is Facing South

Panorama 6 – Bank's Lake Turn Out

Banks Lake 800 Feet High Steamboat Rock Hwy 155

Viewer Is Facing North From Turn Out Marked "Banks Lake" In The Middle Of The Upper Grand Coulee East →

Panorama 7 – Dry Falls



400 Feet High Dry Falls Lake Green Lake East →

Dry Falls In The Extreme North End Of The Lower Grand Coulee - Viewer Facing North From The Dry Falls Interpretive Center Parking Area

Panorama 8 – Sun Lake State Park

Camping Swimming Park Lake Monocline Through Here West→

Sun Lake State Park

Upper End Of The Lower Grand Coulee – Viewer Is Facing South

Panorama 9 - Monocline

Monocline Monocline East→

Monocline In The Upper End Of The Lower Grand Coulee – Viewer In Sun Lake State Park Facing Northwest

VITA

Daniel B. Lewis was born in Hot Springs, South Dakota. He has spent a decade and a half teaching Earth Science to eighth graders and several years teaching Science Methods to perspective teachers in Spokane where he lives. At Eastern Washington University he earned a Bachelor of Arts degree in Education and a Master of Education from Gonzaga University. In 2008 he earned a Doctor of Philosophy at the University of Washington in Education.