Indigenous Knowledge and Geoscience on the Flathead Indian Reservation, Northwest Montana: Implications for Place-Based and Culturally Congruent Education

Adam N. Johnson,[1,a] Regina Sievert,[1] Michael Durglo, Sr.,[2,3] Vernon Finley,[4] Louis Adams,[5] and Michael H. Hofmann[6]

ABSTRACT

We investigated connections between the natural and the cultural history of the Flathead Indian Reservation through the integration of geoscience, traditional tribal knowledge, and oral narratives for the purpose of improving Earth Science education in the tribal community. The project served as an avenue for the incorporation of indigenous knowledge into science curricula by providing parallel perspectives for the same landscapes while considering compatibilities between Western science and Native knowledge. We developed educational resources through collaborations with local school communities, tribal elders, and cultural experts who approved the materials for general distribution. Participants identified multiple localities throughout the reservation that served as field sites critical to understanding geoscience concepts, tribal scientific knowledge, and oral histories. One such place (the Big Draw Valley west of Flathead Lake) figures prominently in both geoscience and indigenous accounts of the evolution of the land. Compatible perspectives of local landscape formation are indicated by similarities between the interconnected Earth Science and Native narratives. Indigenous knowledge reveals potential locations for additional scientific research that could prompt a reconsideration of current geoscience theories regarding the glacial history of the region. Preliminary research suggests that culturally congruent instruction using the Flathead Geoscience Education Project materials was effective in supporting increased American Indian student achievement in geosciences on the reservation. We believe that curricular materials similar to those produced during this project can also be developed for and successfully used in other tribal communities. © *2014 National Association of Geoscience Teachers*. [DOI: 10.5408/12-393.1]

Key words: Big Draw Valley, Flathead, glacial history, glacial outwash, indigenous, oral narratives, Pend d'Oreille, Kootenai, Montana, moraines, Salish, Rocky Mountains, Flathead Lake, Glacial Lake Missoula

> *"In the beginning, tribal elders tell us, Coyote prepared the world for the human beings who were yet to come. And from that time in the ancient past, beyond all memory and history, Indian people have inhabited the mountains and valleys of what is now western Montana. . . . The profound age of tribal inhabitance of the region is suggested by the numerous tribal legends that closely parallel geological descriptions of the end of the last ice age."*
>
> —Salish Kootenai College Tribal History Project (2008)

Received 11 December 2012; revised 13 October 2013 and 8 December 2013; accepted 2 January 2014; published online 28 May 2014.

[1]Indigenous Math and Science Institute, Salish Kootenai College, PO Box 70, Pablo, Montana 59855, USA
[2]Salish–Pend d'Oreille Elders Cultural Advisory Council, Confederated Salish and Kootenai Tribes (CSKT), PO Box 278, Pablo, Montana 59855, USA
[3]Tribal Preservation Department, PO Box 278, Pablo, Montana 59855, USA
[4]Kootenai Culture Committee, PO Box 278, Pablo, Montana 59855, USA
[5]Salish–Pend d'Oreille Culture Committee, 81 Blind Barnaby Street, PO Box 550, St. Ignatius, Montana 59865, USA
[6]Geosciences Department, The University of Montana, 32 Campus Drive, #1296, Missoula, Montana 59812-1296, USA
[a]Author to whom correspondence should be addressed. Electronic mail: haulpack@yahoo.com. Tel.: +56(9) 5650-3159

INTRODUCTION

Across the Northern Rocky Mountains, a range of geologic processes play major roles in shaping the land and have created memorable terrain variations. Knowledge of such landscapes, acquired over millennia by North American indigenous peoples, is passed on in oral narratives. In many indigenous traditions, the natural world possesses a sacred quality. Tribal narratives, which typically involve local and familiar landscapes, are indicative of the importance of place to many indigenous peoples, including those living in the Northern Rocky Mountains. The Rockies are known as Xʷc̓xʷc̓ut in the Salish language and Á·kxnʔis Naɬmuqɢin in the Kootenai language.[1] By comparison, modern geology is a young science that arguably started with the publication of James Hutton's *Theory of Earth* in 1788, and geoscientists have only recently begun to describe the Earth history of North America. Researchers have theorized about how compressional forces first folded and faulted the Northern Rocky Mountains before they were pulled apart by extensional forces. Geologists have developed a complex and detailed theory of Earth history extending back millions and even billions of years.

Both indigenous people and geoscientists hold Rocky Mountain landscapes in high regard. For North American

[1]The fonts for the Salish and Kootenai languages are refinements of the international phonetic alphabet (IPA) developed by the SPCC and KCC. For pronunciation of Salish terms, see SPCC and Elders Cultural Advisory Council (2005).

 © Nat. Assoc. Geosci. Teachers

Indians, many significant landscape features are at the center of ancient oral traditions, and tribal scientific knowledge provides information that has allowed the people to thrive for many generations. Geoscientists use the same places to observe, study, and interpret rocks, soils, sediments, and Earth processes. However, many typical geoscience curricula lack place-based content that is culturally relevant and that reinforces indigenous peoples' strong ties to the land. In addition, data show that the percentage of tribal students enrolled in Earth Science college-degree programs is small relative to their proportion in the overall population (Riggs, 2004).

This paper examines the connections between Native knowledge and modern geoscience theories for one locality in western Montana. The objectives of the project were to (1) illustrate the value of both Western scientific and traditional indigenous perspectives for understanding landscapes, geologic materials, and Earth processes; (2) promote consideration of compatibilities between Western science and Native knowledge; (3) explore examples of indigenous knowledge of landscape change; and (4) provide a resource for educators that can be used in geoscience instruction to present multiple perspectives on the landscapes of northwestern Montana.

THE FLATHEAD GEOSCIENCE EDUCATION PROJECT

The work discussed herein originated as part of the Flathead Geoscience Education Project (FGEP), which was funded by a grant from the National Science Foundation and administered by the Indigenous Math and Science Institute (IMSI) at Salish Kootenai College (SKC), the tribal college of the Confederated Salish and Kootenai Tribes (CSKT). The college strives to further the preservation of the cultures, languages, histories, and natural environments of the tribes. Consistent with this objective, the FGEP investigated connections between the natural and the cultural histories of the Flathead Indian Reservation through the study of relevant geoscience information and traditional tribal knowledge and oral histories.

The project's overarching and ongoing objective is to enhance geoscience education in local K–16 classrooms by promoting the presentation of Western scientific (geoscience) concepts in concert with tribal oral histories and traditional knowledge relevant to the aboriginal territories of the Salish, Pend d'Oreille, and Kootenai people. The project's collaborators seek to improve geoscience instruction, student academic achievement, and understanding of the land through the presentation of knowledge from both systems of thought. Components of successful geoscience education programs designed for indigenous peoples include (1) collaboration between geoscientists and local communities (e.g., community members, elders, and educators) and (2) inclusion of traditional Earth Science knowledge alongside Western scientific concepts in the curriculum (Riggs, 2004). We incorporated both of these key components into the project. The philosophy behind the FGEP is that the two bodies of knowledge taught together will improve students' engagement and learning by validating their cultural identities, boosting personal investment in education, and building on prior knowledge and experiences.

METHODS

FGEP staff members, consisting of geoscience and science education faculty and geoscientists, worked with multiple stakeholders in a series of meetings, interviews, and field trips over several years. These activities enabled the staff to build strong relationships with elders and tribal professionals, to obtain permission from cultural gatekeepers to conduct the work, to identify specific landscapes of both cultural and geologic significance to be examined, and to discuss the types of cultural knowledge that were appropriate for inclusion in the project's curriculum products. Collaborations were critical to the success of the project, which depended on acceptance and investment by the community and the tribal leadership.

Prior to launching the project, SKC and FGEP educators first visited the two committees of elders, the Salish–Pend d'Oreille Culture Committee (SPCC) and the Kootenai Elders Committee, to introduce the project and obtain their approval for implementation. Subsequently, we asked the two committees for volunteers to collaborate on the project, and three of the coauthors stepped forward (Durglo, Finley, and Adams, all of whom are tribal members). Additional participants included members of local institutions and organizations (listed in the acknowledgements). The traditional stories they shared have been passed down through generations and were provided in oral interviews during the project. In addition, a literature review supplemented the narratives provided by the participants. Multiple localities throughout the reservation were identified by the project partners as field sites critical to understanding local geoscience concepts, traditional knowledge, and oral histories.

Project participants (tribal elders, cultural experts, tribal high-school science faculty, and SKC geoscience faculty) were videotaped by KSKC Public Television from 2007 to 2010 on location at several field sites as they were discussing various narratives associated with the creation of reservation landscapes. In addition, elders were videotaped at the CSKT headquarters in Pablo, Montana. On the field trips, which included local high-school students and their science teacher, cultural experts and geoscience educators provided both traditional and geologic narratives. Traditional stories obtained during the field and office interviews were first transcribed from video footage and then summarized. Materials obtained from literature sources were either summarized or included unedited in the curriculum materials.

The culmination of the formal grant-funded project was a 2-d summer 2010 professional development workshop for 25 Flathead Indian Reservation teachers. Participants included nearly all of the reservation's middle- and high-school science teachers, as well as several elementary-school teachers. The workshop focused on training teachers on the use of the FGEP curriculum materials and included 1 d of classroom activities and discussions, and 1 d of field trips to the sites highlighted in the FGEP teacher guide as holding cultural and geologic significance. All participants received copies of the curricular materials. Although the formal funded project has ended, the FGEP partnership lives on in Montana's K–16 classrooms, on field trips, and within the Flathead Indian Reservation community.

Products derived from FGEP activities comprise a set of locally and culturally relevant curricular resources developed

for use in Flathead Indian Reservation K–12 science classrooms and for SKC (Johnson, 2011). These include a disc containing film footage of field trips with geoscientists, tribal consultants, and students, as well as tribal consultant interviews and traditional stories; aerial imagery that pinpoints the relevant sites on satellite images and includes pop-up boxes with local tribal knowledge, Western geoscience information, and photographs; maps of the geography and geology of the reservation; and a printed teacher reference guide (IMSI, 2011) that describes both the cultural and the geologic perspectives on the land and details of each of the reservation field-trip stops. These materials have been approved for distribution by the SPCC and the Kootenai Elders Committee (the designated cultural leaders for the CSKT), and the teacher reference guide (IMSI, 2011) is available online as supplemental material (at http://dx.doi.org/10.5408/12-393s1, http://dx.doi.org/10.5408/12-393s2, and http://dx.doi.org/10.5408/12-393s3). FGEP staff disseminated the materials throughout Montana, provided several professional development trainings on their use, and presented the results of the project at local and national meetings (Sievert, 2009, 2011, 2013; Johnson, 2010a, 2010b, 2011, 2012; Kelch, 2012). The meetings, interviews, field trips, writing, videography, and creation of the curriculum products occurred over the formal grant period of approximately 6 y. However, we believe that similar types of curricular resources could be developed and implemented in as little as 2 y.

In March 2013, the FGEP materials were used to conduct a 1-d educational session and a 1-d geoscience field trip for 96 students representing five classes (4th grade through high school) from two local schools. This educational program was completed with the assistance of a grant from the American Indian Science and Engineering Society (AISES). Ten SKC AISES student chapter members have used or helped teach the materials. The curriculum has also been introduced to approximately 15 students who participated in summer internships offered through the new SKC hydrology degree program. At least eight K–12 teachers in Flathead Indian Reservation schools are using various portions of the materials to support classroom instruction and field-trip planning. Several teachers who participated in a study by Sievert (2013) gave the materials and the use of culturally congruent instruction (CCI) high praise in terms of their impacts on student engagement and their positive influence in changing classroom practices, instructional atmospheres, and teacher relationships with students' families and other community members. The current SKC hydrology program chair has also indicated that the materials are useful and relevant to the core of the program. Coauthor Sievert held a series of training workshops at local tribal pupil instruction meetings and at Montana Indian Education Association conferences. Informal feedback suggests that attendees were enthusiastic about the materials.

PERSPECTIVES: GEOSCIENCE AND INDIGENOUS KNOWLEDGE

Geoscientists and indigenous people often approach an understanding of Earth's systems from disparate paths. Western scientists accumulate knowledge using methods that are typically standardized, methodical, and compartmentalized, and geoscientists often reduce geologic processes or phenomena to individual and discrete events or elements (Murray, 1997). In the geoscience paradigm, the natural sequence of events always moves forward, as recorded on the geologic timescale. Indigenous people often view and interact with the land in a way that differs from Western scientific study, according to Pend d'Oreille elder and co-author Michael Durglo, Sr. The Native perspective is holistic and, similar to the science of ecology, encompasses interacting landscapes, water, animals, plants, and people (Cajete, 1999). An example illustrating the differences in perspectives was offered by Salish elder and coauthor Louis Adams, who explained that animals existed on Earth before people and that the Creator placed animals here to assist and sustain humans when they eventually arrived. This perspective differs substantively from the typical Western mindset that places humans in dominion over all other creatures on Earth.

LESSONS FROM NATIVE SCIENCE

Indigenous people lived in North America long before formal geoscientific study began, and traditional stories about sacred landscapes illustrate the extensive Earth system knowledge they have long held. Native science has been defined as "a map of natural reality drawn from the experience of thousands of human generations" (Cajete, 1999). American Indian knowledge systems can be viewed as unique and ongoing long-term studies of thousands of years. Semken (2005) applied the term *ethnogeology* to describe "indigenous geological knowledge based on empirical observation." Traditional narratives reveal a long history of indigenous peoples' awareness of numerous geologic processes. This awareness is due in part to long tenures on the land. Many literature sources record indigenous knowledge and oral histories about, for example, volcanoes and volcanic landscapes, earthquakes, tsunamis, glacial features, rivers and streams, flooding, lakes, groundwater, and springs (e.g., Clark, 1953, 1966; Morton and Gawboy, 2000; McMillan and Hutchinson, 2002; Ludwin et al., 2005a, 2005b).

In some cases, the Western scientific (geologic) explanation of a feature or place confirms the ideas discussed in the indigenous tradition. Indigenous oral narratives have provided information about previously unknown geologic events, and they can be used to interpret the history of Earth or to develop testable hypotheses (e.g., Vitaliano, 1973; Ludwin et al., 2005b). The stories have therefore advanced the geosciences and provide useful information about current geologic hazards. In a similar manner, tribal stories from the Salish, Kootenai, and Pend d'Oreille people, who have inhabited northwestern Montana for thousands of years, reveal deep knowledge of the evolution of the land (e.g., McDonald, 1973; Miller and Harrison, 1974). Several researchers have described local sites that provide evidence of continuous human occupation since at least the end of the last glacial period (SPCC and Elders Cultural Advisory Council, 2005). In this paper, we highlight an example of such knowledge within a small valley in the northwestern portion of the Flathead Indian Reservation.

INDIGENOUS KNOWLEDGE, GEOSCIENCE, AND MYTH: ADVANTAGES OF MULTIPLE VIEWPOINTS

Oral narratives and traditional stories are sometimes regarded as myths, while the results and interpretations of scientific investigations are deemed to be the best approximations of true explanations for processes or phenomena (e.g., Vitaliano, 1973). Others argue, however, that because myths help explain the world and often contain truthful elements, the distinction between myth and science is arbitrary. We can think of geologic field studies and oral traditions as two different means to an understanding of the same place.

Many scientists and tribal representatives agree that a dual perspective is desirable. According to Semken and Morgan (1997), "The capacity to draw on two systems of scientific knowledge will better enable … students to hypothesize and think critically." As Carl Gawboy, an Ojibwe historian and retired Native American Studies professor, wrote, "In the past, we have taken Native American oral histories, and tried to place them in the context and confines of geological events and processes." An equally valid approach, he says, would be to show how American Indians might interpret a geologic story. The indigenous and Western scientific perspectives not only are compatible but also can mutually reinforce each other (Morton and Gawboy, 2000). Local support for the inclusion of multiple perspectives was provided by the CSKT in a vision statement for its Division of Fish, Wildlife, Recreation, and Conservation, which states that the tribe's future will integrate "the wisdom from our elders and ancestors—our traditional ways of knowing and understanding—with the best available science in a way that ensures our children and grandchildren will always enjoy abundant native fish and wildlife."

Additional testimony to the value of multiple perspectives is offered by coauthor Vernon Finley, a Kootenai language specialist, who discussed the importance of both Western scientific and traditional tribal knowledge during a field trip on the Flathead Indian Reservation in October 2007 (transcription below). He noted that because traditional indigenous narratives and scientific theories are explanations of similar events that were seen with different eyes, each narrator tells a different story, and knowing both stories is advantageous:

> *"One of the things that will help you the most, in science classes and in everything, is to know your traditional stories about [the topic]. Then when you hear it from the scientific viewpoint you'll see explanations of the same thing. If you understand both, that will put you ahead of the ones who only see it with the scientific eye … or a traditional Indian eye. And this will help you to draw some larger conclusions—some bigger views—about the whole thing, than if you had just one or the other."*

Students' ability to consider more than one concept of time will also help them to integrate what they learn in Earth Science courses. In the geosciences discipline, time moves inexorably forward from an initial beginning, and absolute dating has allowed scientists to develop hypotheses relating to the precise ages of materials and events. In contrast to the concept of a linear sequence of events, American Indian cultures tend to consider time in a more cyclical fashion, with no well-defined beginning or end. Although the sequences of events in tribal and geologic stories may not necessarily match, this difference becomes less important when we consider that the idea or definition of time varies according to the cultural background of the storyteller. Similarities in the storylines provide evidence supporting the notion that people lived in the western Montana area during the glacial period. Consequently, they likely witnessed major landscape alterations as the glacial period waned, alterations that are reflected in their oral histories.

FLATHEAD INDIAN RESERVATION: GEOGRAPHIC AND CULTURAL SETTING

Although the traditional homelands of the Salish, Pend d'Oreille, and Kootenai people include large portions of what is now the northwestern United States and southwestern Canada, many of the people now live on the Flathead Indian Reservation in northwestern Montana. The reservation, which encompasses approximately 1.2 million acres, is governed by the CSKT. Traditionally, Indians lived a subsistence lifestyle in direct connection with the land, and they used many localities as hunting and fishing grounds, bathing and drinking areas, travel corridors, and plant- and herb-gathering areas. Many of these places remain important cultural sites. The geographic focus of this paper is a small valley in northwestern Montana, which is associated with long geologic and cultural histories and figures prominently in both geoscience and indigenous narratives. The Big Draw Valley lies near the west side of Flathead Lake on the Flathead Indian Reservation (Fig. 1). The lake is known as Č łq'étkʷ (Salish) or Yawuʾnikʾ Á·kuq̓nuk (Kootenai).

The Selíš (Salish), Qłispé (Pend d'Oreille), and Ktunaxa (Kootenai) People[2]

The Salish people (also known as Sqélixʷ, or "flesh of the land") are the easternmost group within the language family of the same name. The Pend d'Oreille people are closely related to the Salish, and the cultures, oral literatures, languages, and homelands of the two groups are similar (Clark, 1966; SPCC, 2003). The Pend d'Oreille call themselves the Qłispé, a term that may refer to camas roots and has been transliterated as Kalispell. As described in the SKC Tribal History Project (2008:18), both the Salish and the Pend d'Oreille people have inhabited the western Montana region since an early period "beyond all memory and history." The Kootenai people call themselves Ktunaxa (KCC, 1997; SPCC, 2003). According to their histories, the Kootenai people (a tribe unrelated to the Salish and Pend d'Oreille) have lived in the Flathead Lake area since humans have been speaking languages. The people trace their roots back to the beginning of time. Physical evidence indicates the presence of Ktunaxa people in the area for at least the last 14,000 years (KCC, 1997). The band of Ktunaxa residing in the Elmo area is known as Ksanka (translated as

[2]Terms are written using forms of the IPA specific to the Salish and Kootenai languages.

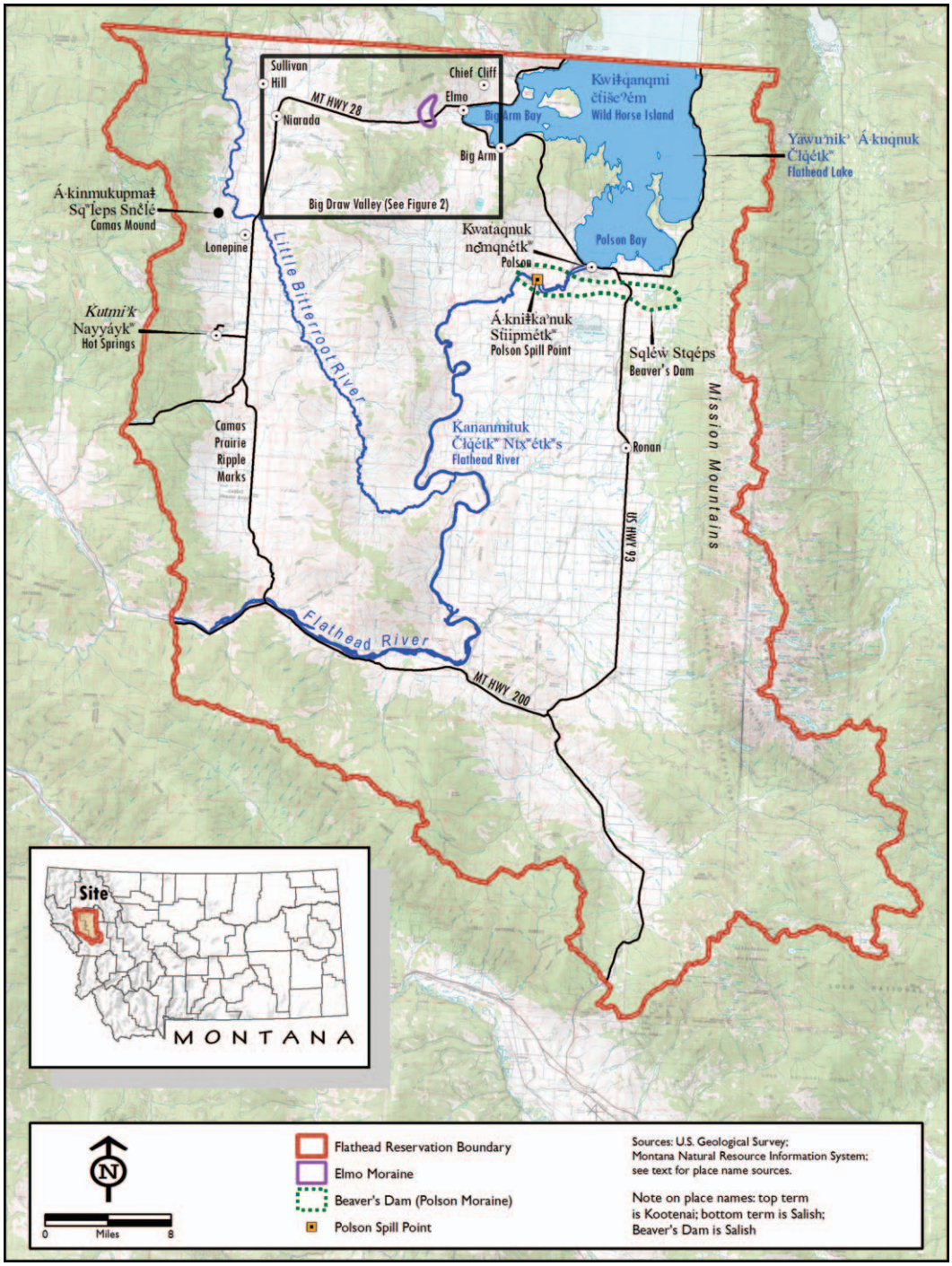

FIGURE 1: Physiographic setting of the Flathead Indian Reservation. Source: Topographic information is from the USGS, and geographic features (e.g., reservation boundary, roads, streams, and localities) are from the Montana NRIS. Modified with the assistance of Shane Fox.

Standing Arrow). The Kootenai language is distinct from that spoken by the Salish and Pend d'Oreille.

The SPCC (formerly the Flathead Culture Committee) and the Kootenai Culture Committee (KCC) were established in the 1970s by the CSKT to guide the perpetuation of local languages and cultures. Under the guidance of these committees, the people gather oral histories, develop cultural curricula, and provide consulting services to schools and agencies (SPCC, 2003). Advisory councils of tribal elders provide critical input to the committees, and the members serve as teachers, historians, and guardians of tribal knowledge. The purpose of the SPCC is to "preserve, protect, and perpetuate living culture and traditional ways of life of the Salish people." The mission of the KCC is to "protect, preserve, perpetuate, and enhance the language, culture, and traditional lifestyle of the Kootenai People." The

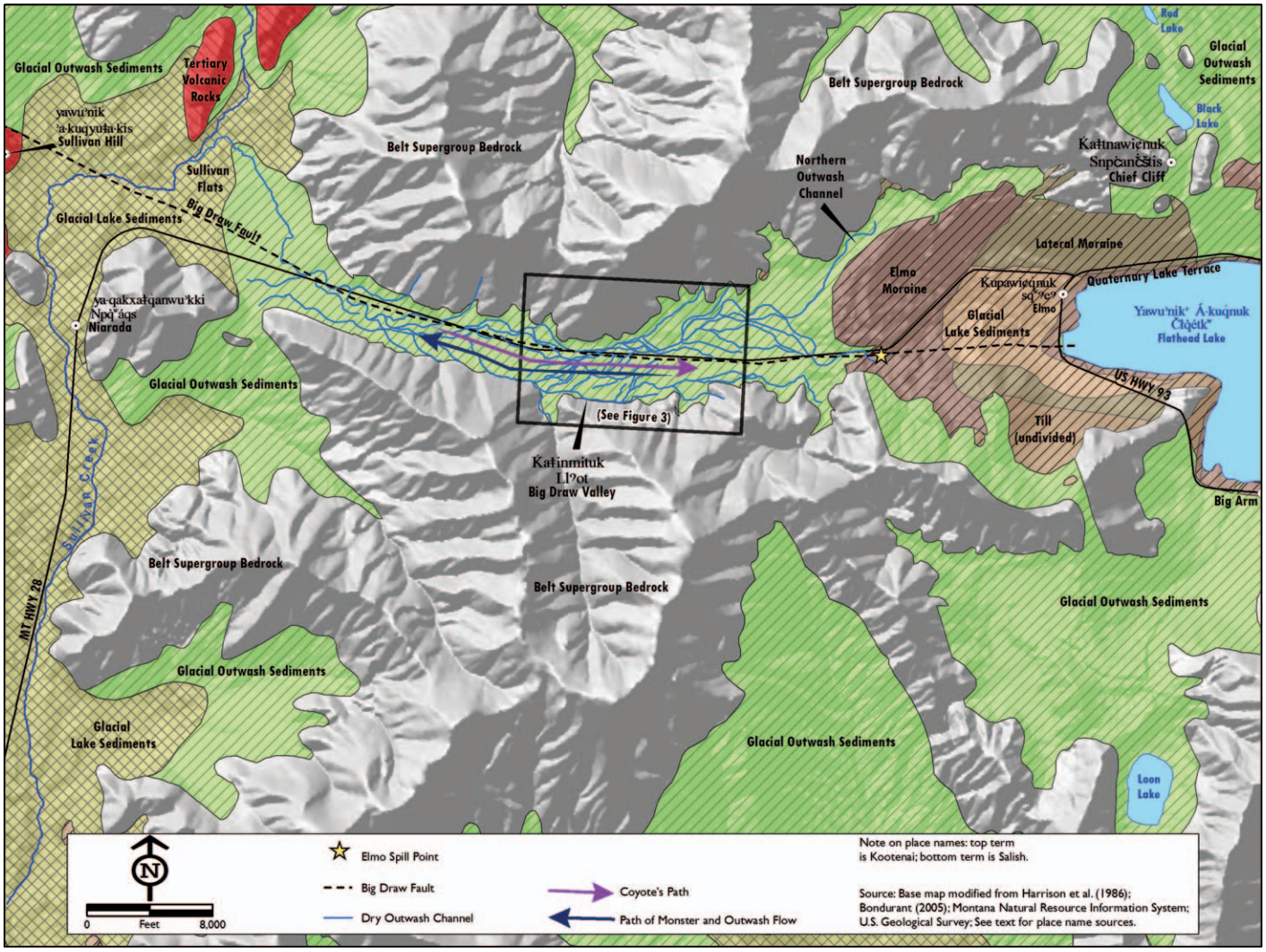

FIGURE 2: Ethnogeologic map of the Big Draw Valley. Sources of place names are provided in the text, and arrows depicting the paths of Coyote and the Monster were based on interpretations of the traditional narratives. A color version is available in the online version of the journal. Source: Topographic information is from the USGS, digital elevations and shading are from the Montana NRIS and geology is from Harrison et al. (1986) and Bondurant (2005). Modified with the assistance of Shane Fox.

CSKT also created the Tribal Preservation Office, which is charged with protecting tangible cultural resources both on the reservation and within the larger original aboriginal territories. All of these entities were partners in the FGEP, and coauthors Durglo, Finley, and Adams are active members of these organizations.

A NOTE ABOUT LOCAL PLACE NAMES

Much of the visible landscape of northwestern Montana is central to the culture, spirituality, oral histories, and traditional stories of the three tribal groups that inhabit the Flathead Indian Reservation. Oral traditions passed down through generations document the deep connections among people, natural features, and places (Miller and Harrison, 1974; FCC, 1979; KCC, 1997). Many indigenous terms and names describe places or their associated activities, such as hunting and gathering areas, fishing spots, and historical and sacred locations (Weatherford, 1991). Such names often provide insights into tribal ways of life and relationships with the land (SPCC and Elders Cultural Advisory Council, 2005). Indigenous languages have developed in part based on the types of landscapes where they are spoken (Cajete, 1999). The connections between indigenous people and places that developed over thousands of years have created a rich sense of place (Semken, 2005) within tribal communities. The phrase refers to both the intellectual meanings and the emotional attachments that are formed in connection with places (Semken, 2005, 2011).

We believe that the substantive inclusion of local knowledge of places (e.g., aboriginal names, oral traditions, and multilingual labels and legends) in the curriculum increases the relevance of science courses for Native students. In this paper, we present tribal place names in the text and in Figs. 1, 2, and 3. Words and place names in

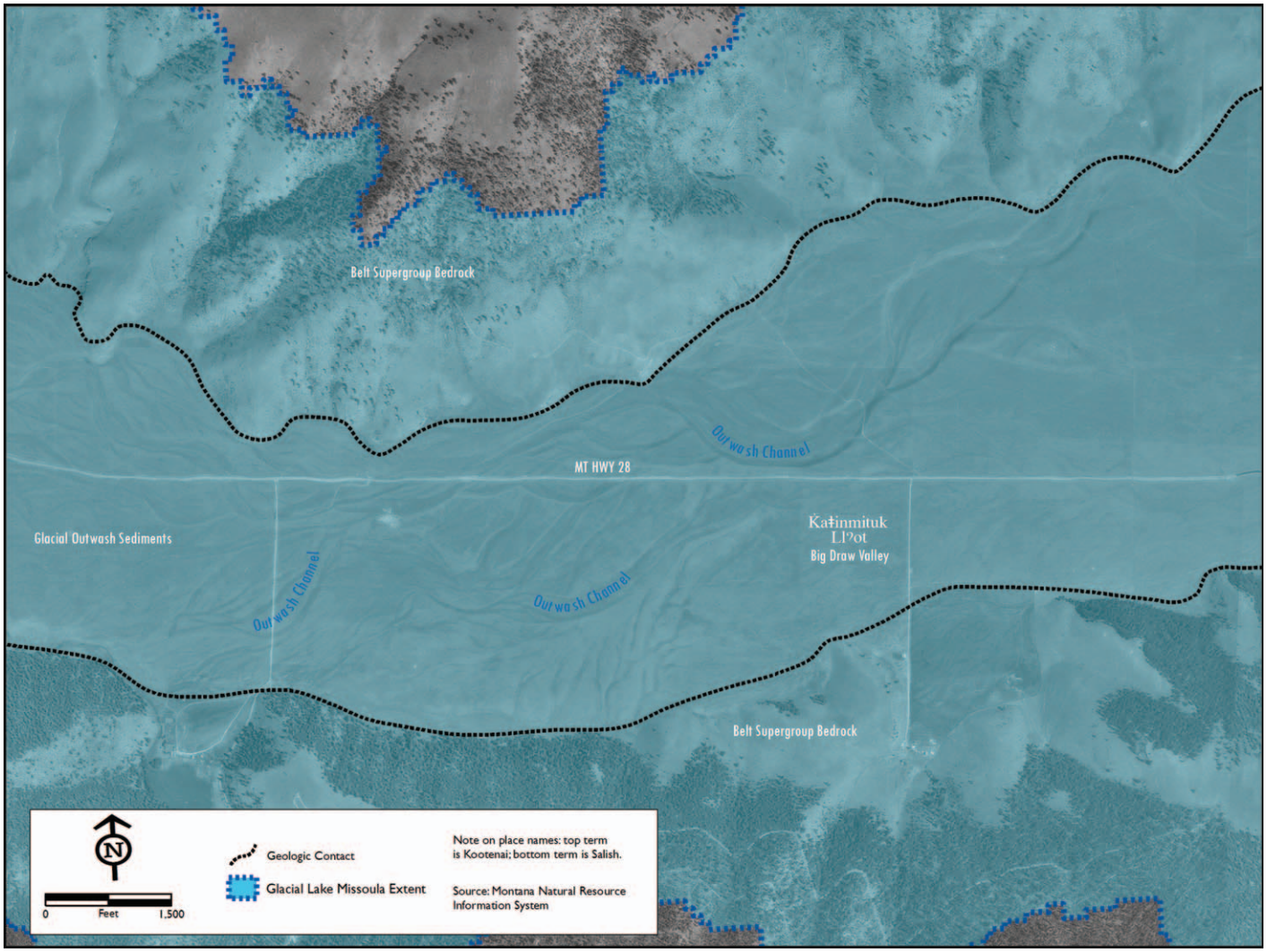

FIGURE 3: Aerial photograph from 1990 showing a portion of the Big Draw Valley. Abandoned river channels are clearly visible. Highway 28 runs from east to west across the middle of the view. Source: Montana Natural Resource Information System. Modified with the assistance of Shane Fox.

the indigenous languages were obtained from the following sources: Salish Culture Committee (SCC, 1996), KCC (1997), SPCC (2003), SPCC and Elders Cultural Advisory Council (2005), SKC and KCC (2010), SKC and SPCC (2010), Julie Cajune (SKC Tribal History Project and Center for American Indian Policy and Applied Research), Shandin Pete, and coauthors Durglo, Finley, and Adams.

THE BIG DRAW VALLEY: A LOCALITY THAT ENCOURAGES THE EXPLORATION OF MULTIPLE PERSPECTIVES ON THE FORMATION OF THE LAND

The following sections describe both the geoscientific and the traditional tribal perspectives of the history of Big Draw, a small valley located within the northwestern portion of the Flathead Indian Reservation (Figs. 1–4). Geologists have been working to unravel the Earth history of the Flathead Lake area for more than 100 years. For the Big Draw Valley, generations of storytellers have shared at least three local oral traditions describing the creation of the same landscape. A cross section through the valley resembles a V-shaped river catchment that has been partially filled with sediment. The Big Draw Valley is a gently sloping glacial outwash plain, an ancient stream channel system. From the hillsides, a sinuous network of interconnected dry stream channels is clearly visible on the valley floor (Figs. 3 and 4). According to geologists, the deep outwash deposits suggest the past discharge of large volumes of sediment-laden water (Smith, 1977), and glacial meltwaters created many well-preserved geomorphic features in the Elmo area (Fig. 3). The Salish term for Elmo is sqʷʔeʔ (translated as "corner of the lake"), and the Kootenai call the area Ḱupawiȼq̇nuk. The Hog Heaven Range north of the valley culminates in the imposing face of Chief Cliff (Figs. 1 and 2), which is known as Snpćančštis (Salish) or Ḱaƛtnawiȼnuk (Kootenai).

A hummocky, arc-shaped geomorphic feature known as the Elmo Moraine rises above the floor of the Big Draw

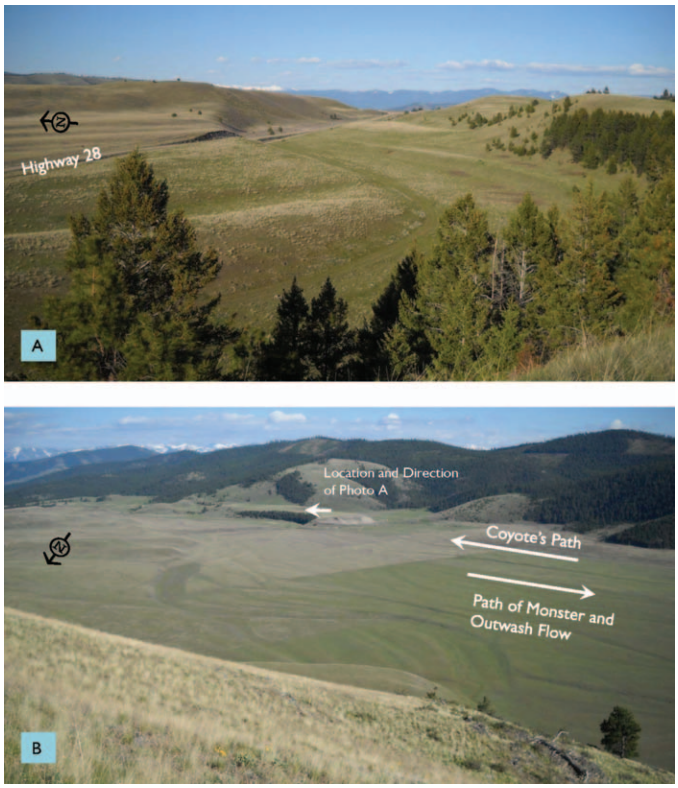

FIGURE 4: Oblique photographs of the Big Draw Valley, the Elmo Moraine, and glacial outwash channels. (A) Outwash channel (center right) that has eroded the Elmo Moraine (north of Highway 28) in view to the east toward Flathead Lake. Geologists believe this channel received flow from the Elmo Spill Point. (B) Braided network of outwash channels (center) downstream of the Elmo Moraine (far left). The arrow shows the approximate location and direction of photograph A. The Mission Mountains are visible in the background of both photographs.

Valley near its eastern extent. The moraine forms a drainage divide between the Flathead Lake Basin and the valley of the Little Bitterroot River (Fig. 1). The crest of the moraine lies approximately 180 m above the current elevation of Flathead Lake. Together with lateral moraines that occur along the margins of the valley (Fig. 2), the Elmo Moraine marks the westward extent of ice in the area during the most recent glacial period.

PREGLACIAL HISTORY

A brief review of local Earth history is key to understanding similarities between geoscience theories and indigenous knowledge relevant to the Flathead Indian Reservation. Beginning in the late Cretaceous period, plate tectonic forces vastly changed the western Montana landscape and created the Rocky Mountains (Constenius, 1996). Tectonic processes created faults and broad, gentle bedrock folds on the western side of the reservation, including beneath and alongside the Big Draw Valley. Later, starting in the Paleogene period (and still ongoing today), different tectonic processes created tensional (extension related) forces that pulled the crust apart along a series of faults that were largely superimposed on the older compressional faults (e.g., Constenius, 1996). A relatively large fault underlies the Big Draw Valley (Fig. 2) and, according to geologists, is likely responsible for its formation.

The small, dormant Hog Heaven volcanic field lies north and west of the valley near the northern Flathead Indian Reservation boundary. Sullivan Hill (yawuʾnik̓ ʾa·kuq̓yuɬa·k̓is in the Kootenai language), a relatively inconspicuous feature at the western end of the valley, is composed largely of light-colored ash and other volcanic material (Figs. 1 and 2; see also Lange and Zehner, 1992). This feature is an important place that is integral to one of the traditional stories presented below.

REGIONAL GLACIAL HISTORY AND GLACIAL LAKE MISSOULA

During the most recent glacial period, the Flathead lobe of the Cordilleran ice sheet advanced southward from Canada, covering the Flathead Lake Basin and the northern portion of the Flathead Indian Reservation (e.g., Alden, 1953; Smith, 2004; Hofmann et al., 2006). The Flathead lobe followed a two-pronged approach at the southwest end of Flathead Lake. The southern sublobe invaded Polson Bay, while the western sublobe was forced westward into Big Arm Bay (Alden, 1953; Smith, 1966). The corresponding southern and western limits of the most recent ice advance are marked by the Polson and Elmo terminal moraines, respectively (Fig. 1). The Polson Moraine, a prominent ridge south of the town with the same name, is oriented from east to west and extends from the Mission Mountains to a point west of Kerr Dam on the lower Flathead River, which is known as Cˇłq̓étkʷ Ntx̣ʷétkʷs (Salish) or K̓ananmituk (Kootenai). Bedrock glacial striations indicate that glacial ice moved westward toward the Big Draw Valley from the Flathead Lake Basin (Bondurant, 2005).

During the time of maximum glacial advance, one lobe of the Cordilleran ice sheet dammed the Clark Fork River in the Pend d'Oreille River Valley near the present-day Montana–Idaho border. Surface water levels in the valleys of the Clark Fork Basin rose as glacial meltwater backed up behind the dam of ice to create Glacial Lake Missoula (GLM; Pardee, 1910, 1942). Ancient shorelines visible along hillsides in many northwestern Montana valleys (including the Big Draw Valley at an elevation of 1,150 m; Fig. 3) provide the most obvious reminder of the lake's former existence.

GLM submerged the entire Big Draw and Little Bitterroot River valleys (Figs. 1 and 3; see also Alden, 1953), including the Hot Springs area, also called Nayyáykʷ (Salish) or K̓utmiʾk (Kootenai). GLM silts are found overlying outwash sediments at the western end of the Big Draw Valley in the Sullivan Flats area (Fig. 2; see also Harrison et al., 1986). At some point, the ice dam failed (e.g., Waitt, 1985), and the torrent of water that was released rushed down the Lower Flathead River and Clark Fork River drainages. The massive volume and rapid flow rate produced spectacular landscape features, such as the giant ripple marks in the Camas Prairie Basin on the western side of the Flathead Indian Reservation (Fig. 1).

GLACIAL TIMELINE

During the terminal glacial period, terminal and lateral moraines formed in the Big Draw area (Fig. 2), glacial meltwater deposited outwash gravels and eroded stream drainage channels (Figs. 3 and 4), and backmelting offset incoming ice (Smith, 1966). During the recessional glacial stage, a temporary lake, much smaller in scale than GLM and dammed only by the Elmo Moraine, formed upon retreat of the ice lobe, and the glacial meltwaters eventually cut a channel through the Elmo Moraine (Smith, 1977). Large portions of the Elmo Moraine were likely deposited under the waters of GLM when the Flathead lobe was at its farthest advance during the glacial maximum. At this location, the Flathead lobe terminated into GLM, which had inundated the Big Draw Valley at that time (Bondurant, 2005).

During the early retreat of the Flathead lobe, during which time GLM had already disappeared from the valleys of northwestern Montana, glacial meltwaters flowed along the northern part of the Big Draw Valley, cutting a stream channel along the ice margin (Fig. 2; see also Bondurant, 2005). As the Flathead lobe continued to retreat, a dam created by the moraine captured increasing quantities of meltwater, resulting in the formation of a temporary lake known as ancestral Glacial Lake Flathead (GLF). The shoreline of this water body was higher than that of the current lake but much lower than the maximum level of GLM. Ancestral GLF existed only for a relatively short period during the retreat of the ice lobe. According to Smith (1977), GLF began as two separate lakes, one in Big Arm Bay dammed by the Elmo Moraine and the other in Polson Bay dammed by the Polson Moraine (Fig. 1). The two lakes were initially separated by the retreating ice mass of the Flathead lobe, and they drained in different directions. Water from GLF at Elmo discharged to the Big Draw Valley, and the other lake drained near the southern end of Polson Bay. At its highest level, the Big Arm Bay portion of GLF rose to the level of the lowest elevation on the surface of the Elmo Moraine (near its southern end).

The lake's outflow then began to downcut through the moraine (Fig. 2). The resulting drainage water eroded the moraine at the spill point and flowed to the west, into the middle of the Big Draw Valley (Fig. 2; see also Bondurant, 2005). In this way, the Big Arm Bay portion of ancestral GLF began to drain. The drainage from the spill point (Fig. 2) formed a glacial outwash stream channel system that carried water westward through the Big Draw Valley, cross-cutting the older channel system to the north (Fig. 3). When the Flathead lobe had melted sufficiently during its retreat, the two lakes became connected. Presumably, the elevation of ancestral Lake Elmo was higher, and the meltwater flowing out at the Big Draw Valley ceased and changed direction and flowed out at Polson (the lake's only current outlet). The Salish language term for Polson is nčmqnétkʷ, which has been translated as "where the lake shore tapers down like the top of a tipi." The Kootenai use the term Kwataqnuk ("lake spilling over and down"), a reference to the place where the lake flows into the Flathead River. The Polson outlet (Fig. 1) continued to drain the lake until the modern lake level was established (Bondurant, 2005; Hofmann et al., 2006). The current elevations of the landforms involved are generally consistent with this hypothesis.

LOCAL TRADITIONAL STORIES

Many tribal stories from across northern North America relate to landscape features that were created and/or shaped by glacial ice, and some indigenous oral traditions are consistent with geologists' interpretations of regional glacial history. Oral histories indicate that members of tribes residing in western Montana witnessed cycles of glacial advance and retreat.

The authenticity of oral traditions is generally considered highest for those stories recorded in the Native languages. Less confidence should be given to stories that relied on interpreters, translations, or stories told in English and written down by others (SPCC and Elders Cultural Advisory Council, 2005). Some claim that oral traditions should not be written down. However, Pend d'Oreille elder John Stanislaw said that "it is good when things are written down…in that way it is possible that our language and our culture will not be forgotten" (SPCC and Elders Cultural Advisory Council, 2005:151). If we assume that the stories were first told when the events occurred (perhaps 12,000 years ago), and that the average human generation is 25 years, the narratives have been recounted for almost 500 generations.

For the narratives below, we have relied on the storytellers, as well as on published sources, and we have identified the source type (recording in the original language, recording in English, or a published source). Elders point out that stories and place names vary by storyteller and by family. In the following sections, we present three traditional indigenous stories that include descriptions of the formation of the Big Draw Valley. First, however, it is important to provide a few words of caution about problems that may arise when oral knowledge is converted into written words. Translation and transcription errors can alter the wording or meanings of the narratives. In addition, oral storytelling is typically accompanied by nonverbal communication, which cannot be accurately captured with text. According to Mihesuah (2005), the significance and meaning of indigenous oral traditions can be misinterpreted based on the personal values, cultural backgrounds, expectations, and personal biases of those listening to or writing about the stories. Therefore, interpretations may vary among individuals, and attribution of meaning to any particular story is challenging. Educators and others should refrain from interjecting personal interpretations as informed or accurate representations of the meanings of indigenous stories. Because the narratives have many layers of meaning, caution should also be exercised regarding use of the stories out of context. In this paper, we show that the narratives appear to exhibit correlations in some cases with geologic histories as determined by scientists, but we do not mean to imply that the narratives were necessarily developed to explain the geologic features or histories.

Narrative 1: Kootenai

Kootenai language specialist Finley related the following traditional story in English during an October 2007 FGEP field-trip stop near the crest of the Elmo Moraine (Fig. 2). The version below has been adapted from film footage, and a complete transcription of the story can be found in the *FGEP Teacher Reference Guide* (IMSI, 2011), which is available online as supplemental material at http://dx.doi.org/10.5408/12-393s1.

Hawk and Grouse were married and lived near the western shore of Flathead Lake. Grouse developed an amorous attachment to a monster in the lake, and Hawk became angered at his wife for her infidelity. When he discovered them, Hawk shot them both with arrows, killing Grouse. The monster, wounded in the stomach, dove deep down to the bottom of the lake. He was upset, and he started drinking the water in the lake. He drank until all the water in the lake was gone. The rivers, streams, and creeks draining into the lake also dried up. The thirsty people told Hawk he needed to get the water back, and so Hawk pursued the monster.

When the monster tried to escape from Hawk, he fled to the west, away from the lake (Fig. 2). Because his body was full of water, he dragged it along the ground, forming the narrow valley that is now called the Big Draw (Ḱaɬinmituk, or "big wide river" in the Kootenai language). The trail left by the monster allowed Hawk and the people to track him easily, and they followed him to the west end of the valley near Niarada, which is known as Npq̓ʷáqs (Salish) or ya·qakxaɬq̓anwuʾkki (Kootenai). They followed him to a ridge now called Sullivan Hill (yawuʾnik̓ ʾa·kuq̓yuɬa·k̓is; Fig. 2). Hawk caught up to the monster, saw that the arrow still protruded from his stomach, grabbed its shaft, and pulled it out. Water flowed out of the hole in the monster left by the arrow and flooded the area, but it rose above its original level, creating a giant flood. All the people ran for their lives and arrived at a place now called Baldy Mountain near the town of Hot Springs (Ḱutmiʾk in Kootenai). Hawk eventually saved them all by singing until the water finally returned to its current level. According to Mr. Finley, Sullivan Hill represents the monster's body.

A brief version of the same story provided in a recent publication by SKC and KCC (2010) indicates that the monster created the valley by splitting the mountains as it dragged its body through the Big Draw Valley. The flowing water produced a wide river in the valley.

Narrative 2: Salish, Pend d'Oreille, or Kootenai

In her 1966 book *Indian Legends from the Northern Rockies,* Ella Clark included an oral tradition relating to the origin of the Flathead River and the Elmo and Polson moraines. The original narrative, which was recounted near Flathead Lake by a local Indian man to Major Robert Hollister Chapman, is preserved in the National Anthropological Archives of the Smithsonian Institution. Chapman (1900) recorded the story during a horse trip near Flathead Lake. Neither Clark nor Chapman identified the tribal affiliation of the storyteller. It is also unknown whether the story was told in English to Chapman or translated through an interpreter and then transcribed. A summary of the narrative is provided below, and author comments are provided in brackets.

According to the narrator, a giant beaver lived in Flathead Lake prior to the arrival of Indians in the valley. He was so big that no man could kill him [beavers up to 1.2 m in height lived on the continent during the glacial period]. At that time, the outlet of the lake was near Big Arm [near Elmo] where there is now a "flat, long valley." The giant beaver built a dam across the river outlet, causing the lake level to rise. As the beaver got older and bigger, he built the dam higher, but soon the water began to run out at the south end of the lake [Polson area]. So the beaver built up a high dam at that point. It was strong in all but one place. Then the beaver was able to build the first dam higher, and he had more water in the lake in which to live. Some years later, a big snowfall was followed by a warm spring, producing a large amount of runoff that fed the lake. It was more water than the Indians had seen in many years. Increased pressure caused the dam at the south end of the lake to eventually give way, and a new Flathead River outlet formed. After that, the beaver did not build dams again. The storyteller indicated that both dams are still visible; the southern dam is broken where the river flows through, and the dam near Big Arm is unbroken but has been weathered and eroded.

At the end of the typed narrative, Chapman handwrote the phrase "Moraine gravels, dams, 200 feet [61 m] thick."

During an April 2008 FGEP field trip, Durglo told a Pend d'Oreille story that contains elements similar to the narrative recorded by Chapman. The story focused on a beaver that built a lodge in the middle of the lake at Wild Horse Island (Fig. 1). The island is known as čt̓išeʔém (Salish) or Kwiɬq̓anqmi (Kootenai). The beaver had four kits, and every one of them had Indian names. The beaver then built a dam because he wanted a bigger lake. The dam was located at Polson Hill (Fig. 1), which tribal people refer as Sqlé́w̓ Stq̓éps (Beaver's Dam). According to a geologic marker recently installed at a roadside pullout on top of the Polson Moraine (MDT, 2011), the term Sqlé́w̓ Stq̓éps relates to a Pend d'Oreille creation story about White Beaver. The story indicates that the Wolf Brothers killed White Beaver, destroyed his lodge, and breached the dam. Flathead Lake is the only remains of the water that flowed out.

Narrative 3: Pend D'Oreille

According to the Salish, Pend d'Oreille, and Kootenai people, Coyote and other animals lived on Earth before humans and prepared the world for the arrival of people. Tribal elders often represent the cultural perspective of the landscape through Coyote stories, which have been told for thousands of years. The Salish–Pend d'Oreille term for the animal is Snčl̓é, and the Kootenai people use the word Skinkuȼ. We ask that readers respect tribal cultures by restricting the oral retelling of Coyote stories to the winter months when snow is on the ground.

The third oral tradition explains the origin of the Elmo–Big Draw area from a Pend d'Oreille perspective. Elder John Peter Paul told a version of a Coyote story in a 2000 videotaped interview that is contained in the Oral History Archives of the SPCC. A narrative derived from that interview was published by the SPCC and Elders Cultural Advisory Council (2005:25–26). The story is believed to have been told in the Pend d'Oreille language and then translated by the SPCC. Paul indicated that Coyote baked camas at a low mound called Sqʷl̓eps Snčl̓é that was an important area for gathering camas (Fig. 1). Coyote was constructing a river channel leading toward Flathead Lake to allow the passage of salmon. In the process he created Big Draw, a valley

extending from the Lonepine–Niarada area toward sqʷʔeʔ (known in English as Elmo). According to the story, Coyote wanted to marry a woman living in a village near sqʷʔeʔ. In preparation to marry her, he dug some camas bulbs and started cooking them at Sqʷl̓eps Snčl̓é. Coyote became angered when the woman rejected him and did not finish the river passage, leaving a hill separating the Big Draw Valley from Elmo.

Durglo, the mapping history project leader at the CSKT Tribal Preservation Department, told a version of this story during a March 2007 interview videotaped for the FGEP. A transcription of the interview follows:

> *"At the Big Draw, Coyote was making a river for the salmon to come through. He went over there by Niarada (*Npq̓ʷáqs*) and he found some camas. He dug some camas and started baking it while he was digging that ditch. And a bunch of women came through there and he went crazy. So that's why he didn't finish his ditch. Today you can go over there by Niarada and you can see his baking pit there. That's a landform we've got a story on. Coyote gets in trouble once in a while over women."*

Durglo indicated that the Salish place name for the Big Draw Valley is llʔot and that its meaning can be translated as "going into a place." SCC (1996) indicates that the term is written as laót or llot and that its meaning is "a valley." The Kootenai term for the Big Draw Valley is K̓aɬinmituk, which means "big wide river."

SIMILARITIES BETWEEN INDIGENOUS NARRATIVES AND GEOLOGIC INTERPRETATIONS OF THE LANDSCAPE

A scientist interpreting Narrative 1 might conclude that, according to the local people, hydraulic forces were major factors contributing to the creation of the Big Draw Valley. The monster's body was so full of water from Flathead Lake and the surrounding watershed that it created an elongated depression ("splitting the mountains") while fleeing from Hawk. A geologist might point out that the original development of the valley could have been caused by displacement along the Big Draw Fault (Fig. 2). Geologists also believe, however, that glacial meltwaters played a major role in the development of the current landscape on the valley floor by leaving behind well-preserved stream channels. Thus, interesting parallels can be drawn between the traditional indigenous Narrative 1 and the Western scientific theories of the creation of the valley.

In addition, it is possible that the low Flathead Lake level resulting from the monster's drinking prior to the creation of the Big Draw Valley could be related to a period of major drought that likely caused lake levels to drop during the mid-Holocene, about 7600 cal y BP (Hofmann et al., 2006). Major tributaries of Flathead Lake were likely almost completely dried up for a significant period (Hofmann, 2005). Both of these scientific findings are in accordance with the tribal narrative about the monster drinking large portions of the lake water and causing nearby rivers and streams to go dry.

At Sullivan Hill (16 km west of the Elmo Moraine), Hawk pulled the arrow from the monster, thereby releasing all of the water stored in the monster's stomach (Figs. 1 and 2). Narrative 1 does not specify which direction the water flowed once it was released. Using the current landscape as a framework, the water could have flowed to the east toward Flathead Lake or to the south along the Little Bitterroot Valley (Fig. 1). Geologic evidence suggests that glacial outwash channels at the Elmo Moraine moved water to the west, away from the ice margin. Regardless of the exact flow path, a large volume of flowing water is an important component of both the traditional and the geoscience narratives.

The flood mentioned in Narrative 1 could be a reference to GLM. Hawk and the people rushed to the top of Baldy Mountain to escape the rising waters. The summit lies at an elevation of over 2,130 m above sea level, well above the highest GLM level of approximately 1,280 m. GLM inundated the Hot Springs area near Baldy Mountain. The narrative suggests that the flood or lake occurred after the initial release of water from the monster's stomach. This burst could be interpreted to have caused the fluvial channels seen on the valley floor. According to geologists, GLM filled and drained prior to the formation of the Big Draw outwash channels, which were carved by glaciofluvial meltwaters (Figs. 3 and 4). Although the geologic and the traditional narratives do not match in terms of the sequence of events, the similarities of the stories are striking.

M.J. Elrod speculated in 1903 that the Big Draw Valley was a possible temporary Pleistocene-age outlet of Flathead Lake. Under this scenario, a spill point was created when Flathead Lake overtopped the Elmo Moraine. Meinzer (1917), whose geologic map also depicts the moraine, postulated that the Flathead River flowed through the Big Draw Valley prior to the most recent glacial advance. Alden (1953) and Smith (1977) suggested that the Big Draw Valley may be an abandoned outlet of the Flathead Basin. The valley near Big Arm mentioned in Narrative 2 is almost certainly a reference to the Big Draw Valley, which some geologists believe was one of the outlets of ancestral GLF. According to the story recorded by Chapman (Narrative 2), water flowed out of the lake along the valley prior to Beaver's activities. This is consistent with the preglacial outflow of water through the Big Draw Valley as envisioned by Meinzer (1917). Beaver's first task of building a dam is consistent with the advance of glacial ice westward into the head of the Elmo Valley and the subsequent creation of the Elmo Moraine. According to geologists, the lake's flow was blocked by the moraine, which generally corresponds in size and location to the Beaver's first dam.

Narrative 2 then tells us that the water flowed out of the lake at its south end where the dam broke. This locality, known to geologists as the Polson spill point, may be the current site of Kerr Dam (Fig. 1). The place is known to the Kootenai as Á·kni‡k̓aʾnuk, or "narrow pass between cliffs," and to the Salish as Sčiipmétkʷ, or "falling waters" (Bigcrane and Smith, 1991; SKC Tribal History Project, 2008). Beaver then built a dam to prevent the lake water from exiting at this second point. The location of the Polson Moraine (Fig. 1) is similar to that of Beaver's southern dam through which the river eventually broke during the above-average water year. The high-runoff year could represent the postglacial warming period that resulted in glacial retreat and increased runoff. The size of Beaver's dam is similar to that of the Polson Moraine, which is larger than the corresponding feature at Elmo (Fig. 1).

Narrative 2 bears a resemblance to Smith's (1977) hypothesis explaining the final draining of ancestral GLF. According to Smith, during the initial deglaciation period, glacial meltwaters fed two ancestral lakes that drained in opposite directions due to the separating (diminishing) ice mass. The story indicates that the original outlet point was at Elmo. Sometime after Beaver dammed that outlet (the Elmo Moraine), the water began to drain at Polson. Beaver then built a giant dam across the Polson outlet, and at some point he increased the elevation of the first dam. According to Smith, the two outlets drained contemporaneously, while Narrative 2 suggests that the spill points drained in sequence.

Sediments collected more recently from the Flathead Lake Basin (Hofmann and Hendrix, 2010) provide evidence for a connected lake during the very latest stages of GLF, which supports Narrative 2. Beaver built a dam at Polson and then increased the height of the Elmo dam, which suggests he was building structures at the margins of a single water body (consistent with sedimentological evidence). Finally, the Polson spill point represented the final outflow point of the lake, as suggested by both the geologic and the indigenous narratives.

This part of the story that depicts the temporal relationship of the different dam constructions is particularly intriguing to geoscientists interested in the area. Although presently no conclusive scientific evidence exists, the story could potentially refer to multiple advances and retreats of the Flathead lobe during the last glacial maximum. The mention of a second dam building phase in the Beaver story might refer to such multiple advances and may convince geoscientists to reexamine the geologic record to find evidence for such a glacial resurge to the exact position of the original glacial location. Narrative 2 also raises the question of whether the Polson Moraine was only constructed during the latest ice advance, which is in temporal accordance with the improvement of the Elmo Moraine. A potentially older moraine in the Polson Bay area could have been removed by this latest ice advance. In summary, this part of the Narrative 2 seemingly refers to a particularly interesting aspect of glacial history in the basin and might help scientists better pinpoint the best locations to look for more definitive scientific evidence.

According to Narrative 3, Coyote created both the Big Draw Valley and the feature geologists call the Elmo Moraine (Figs. 1 and 2), in addition to the camas-baking mound. The story does not indicate whether water flowed in Coyote's channel, but it suggests that the hill blocked the flow of water from the Big Draw Valley to Flathead Lake. The geologic explanation is similar in that the moraine temporarily blocked the westward flow of water from the lake. Although the exact details may not match, hydrologic forces are principal components of both explanations for the creation of the unusual landforms. The SPCC and Elders Cultural Advisory Council (2005) noted that "The story of the Big Draw is yet another case of the Coyote stories reflecting how long the people have been here, in that they tell the story of the same places that geologists now say were key sites in the geology of the last ice age."

The eventual surface water flow direction that Coyote may have intended (from west to east) might differ from that described by scientific evidence. However, Narrative 3 should spark scientific interest about whether it depicts a part of the geologic history that is now covered by sediments deposited by more recent events. In this case, a geoscientist might look for evidence regarding whether the flow direction prior to the glacial maximum was toward a lake to the east that might have existed in the same position as Flathead Lake prior to the glacial maximum, as suggested by the Coyote story. Such a scenario is possible given the present-day surface elevations of Flathead Lake and the western end of the Big Draw Valley. In accordance with Narrative 3, the emplacement of the moraine ("big hill") during the time of maximum glacial advance (associated with large volumes of sediment and water) may have caused a flow reversal in the valley that resulted in the observed conditions.

Indigenous narratives originating in western Montana (e.g., those presented above) are consistent with massive local landscape transformations due to movements of great ice sheets and the erosive powers of glacial meltwaters. Hydrologic processes play critical roles in both the geoscientific and the traditional indigenous narratives regarding the formation of the Big Draw Valley on the Flathead Indian Reservation, and the traditional stories and Western geoscience theories exhibit intriguing similarities with regard to the content and timing of major events. Local indigenous knowledge may prompt a reconsideration of current geoscience theories regarding the glacial history of the valley. The oral traditions presented in this paper are consistent with other information suggesting that the Salish, Kootenai, and Pend d'Oreille people have a long history of experiences on the lands of western Montana and have lived here for many generations.

DISCUSSION AND CONCLUSIONS

The principal objective for developing the FGEP curriculum products was to provide culturally congruent geoscience materials that could be used in Flathead Indian Reservation K–12 and postsecondary schools to make science more relevant and engaging and to increase science achievement in American Indian students. Indeed, teachers across the K–16 spectrum report that they are using the FGEP materials and complementary culturally congruent methods of instruction in their reservation classrooms. For example, teachers are widely using the reference guide (IMSI, 2011) for background knowledge to inform their instruction. The field-trip stops from the guide are known to be in use by five educators (one high-school–level Earth Science teacher, three K–8 teachers, and one college instructor). In addition, at least four instructors are using the film footage to allow their students to watch elders telling creation stories, and four teachers have reported that their students use the aerial imagery exercises to view satellite images of culturally and geologically significant sites on the reservation. We anticipate that we are unaware of many other instructors using the FGEP materials. One 4th-grade teacher has developed a full unit on the geology of the reservation that substantively employs the FGEP products in each of its four lessons (Kelch, 2012). The unit is available online as supplemental material to this article (at http://dx.doi.org/10.5401/12-393s4).

Specific examples of FGEP materials used at the K–8 level were provided through data collection for a research project and include the following:

- *Tribal guest instructors and mentor–apprentice observational learning*—A local cultural expert visited a kindergarten classroom and employed the traditional and contemporary tribal uses of rocks and minerals as a context for teaching about the rock cycle. He demonstrated the use of rocks for grinding food and in tool making, and he showed students how minerals were sources of pigments that tribal people used in decoration and communication. As he taught, he reminded students about the processes by which rocks are made in the rock cycle and of the properties of different types of rocks that render them suitable for tool making and other uses. He also used the FGEP aerial imagery to discuss where specific rocks and minerals are found on the reservation. Students then engaged in a variety of activities to examine rock types and their properties, including using rocks to grind minerals for pigments that they then used to paint messages and objects.
- *Traditional stories, Native languages, and indigenous science knowledge*—In visits with 2nd-grade students both in the classroom and on field trips, tribal elders who were partners in the FGEP related traditional stories about the land, creation narratives, and family histories relevant to the local area. The elders incorporated Native languages in their dialogues, including the use of tribal names to identify places. Many discussions centered on the use of local sites by tribal people, for example, for day trips to gather important plants or as long-term camps because the topography and climate were favorable for subsistence lifestyles. On the field trips, students added to their science journals, generating diagrams of the land and annotating them with the local landscape knowledge they had gained. When elders were not able to come in person to visit with students, the video footage from the FGEP materials was used instead. Students were also asked to talk with their relatives, and many enthusiastically shared their family's stories about the local area with their classmates. According to the teacher, students became invested in their studies, often asking if they could work on science in their spare time, and became conversant in the use of Native language terms referring to specific landscapes, animals, plants, etc., that elders had taught them, as well as the geoscientific terms for the landforms and geologic processes.
- *Language and visual arts activities*—In the same 2nd-grade classroom discussed in the preceding example, students elaborated on what they learned on the field trips by examining aerial images of the reservation from the FGEP materials and discussing the processes that scientists believe formed the landscape and the types of rocks that compose local landforms. They then added their new knowledge to the annotated drawings of the landforms they had already created in their science journals. Students followed up by writing their own stories about the land surrounding their community and how it was formed. The stories were often analogous to the types of stories presented by the elders, frequently involved animal protagonists and antagonists, and included local place names and other Native language, as well as geoscientific terms for the landforms and processes in their stories. These same students then created three-dimensional clay models of the landscapes they had visited on field trips, labeling the landforms by their geologic types and with their Western and indigenous place names. They were assessed on their ability to discuss the land, using both indigenous and Western science knowledge, and to describe the geologic processes that scientists believe formed the local landscape.

At the postsecondary level, the *FGEP Teacher Reference Guide* is the foundation for an SKC course titled Geology of the Flathead Indian Reservation, which has been taught since 2011. Two introductory physical and environmental geology courses at the college also incorporate portions of the FGEP content. From 2009 to 2013, approximately 65 college students attended these three courses, which include field trips to selected localities highlighted in the project materials. According to the instructor, the FGEP also contributed significantly to the creation and design of the college's new hydrology program, which offers both 2- and 4-y degrees (A. Berthelote, pers. comm., 2013). These are believed to be the only geoscience-related degrees offered at a tribal college or university in the United States. Therefore, the FGEP materials are directly contributing to the education of an increasing number of American Indian geoscience graduates. Also at the postsecondary level, the FGEP materials were heavily used in the geoscience course designed and delivered by SKC's Big Sky Science Partnership, a National Science Foundation–sponsored math-and-science partnership program that focused on the professional development of over 100 teachers working on or near reservations across Montana. Currently, the FGEP materials are being used in the college's teacher preparation program as an example of high-quality, culturally congruent curriculum materials.

We have ample evidence that the FGEP materials are in wide use in local education endeavors on the Flathead Indian Reservation, but the question of their efficacy in supporting American Indian science achievement remains unanswered. In partial response to this question, a small, mixed-methods, quasiexperimental study was conducted by Sievert (2013). Four Flathead Indian Reservation classrooms with high American Indian student enrollment were involved in the study: one 2nd grade, one 5th grade (both treatment classrooms), and two kindergarten classrooms. The latter two were used as matched treatment and comparison classrooms. The three treatment classroom teachers modified their instruction to include substantive use of FGEP materials, along with various types of Culturally Congruent Instruction (CCI) methods, as deemed appropriate for their students' developmental levels. Data collected by the researcher included pre-, post-, and formative student assessments of students' content knowledge, teacher instructional logs, teacher interviews before and after instruction, and multiple observations of instruction in each classroom. Findings, both qualitative and quantitative, provide evidence of the positive effects of the FGEP and CCI on student learning. Postinstruction interviews with treatment teachers were overwhelmingly positive regarding students' increased engagement in their studies, their enthusiasm for the materials they were studying, and the

outcomes of assessments indicating their understanding of the content (e.g., in their stories and explanations of their models of landscapes and the processes that formed them). Classroom observations (utilizing a validated observation protocol that quantifies the nature of instruction), in concert with teacher postinstructional interviews and teachers' instructional logs, provided abundant evidence of the high instructional rigor in both treatment and comparison classrooms. This is an important finding considering that some teachers resist CCI on the basis that the time spent on it reduces the time for teaching core content. In the matched treatment and comparison kindergarten classrooms, students completed identical pre- and postassessments of their content knowledge regarding the rock cycle and properties of rocks. Paired t-tests of the students' test score gains indicated that, statistically, treatment students' average score gains were significantly higher than those of the comparison classroom ($N = 20, 17$; $p = 0.045$; $d = 0.67$). The power analysis on the results indicates a medium to high effect size.

Increasing numbers of studies, like the one by Sievert (2013) described above, are providing evidence of the efficacy of CCI for increasing educational achievement in ethnic minority students. Research suggests that the success of geoscience education programs in tribal communities depends on close relationships between scientists and community members and the inclusion of traditional Earth Science knowledge alongside Western scientific concepts in the curriculum (Riggs, 2004). We believe that interrelated indigenous and geoscience narratives describing specific places such as those above, developed through collaborative efforts, will increase the relevance of geoscience study and will improve teaching and learning on the Flathead Indian Reservation.

Additional research on place-based CCI is needed to further delineate the details of its use and effects. Future research questions may include the following: How do such methods best interface with other instructional practices? How do they influence curricular content? Which combinations of CCI practices are effective in specific contexts? How can teachers improve their cultural competence? How can the increased use of CCI be supported in the classroom? We are continuing our research on the nature and efficacy of CCI materials and methods (including the FGEP) in a study involving science students attending a tribal college. Additional studies with American Indian K–12 students are also a research priority.

Compiling culturally congruent resources requires significant time and effort and will be more difficult without dedicated funding sources. Identifying and building relationships with elders and other community members who can work with teachers to develop and implement curricula that enable the significant inclusion of cultural content and pedagogy is also challenging but well worth the effort. Gaining approval from cultural gatekeepers to use local tribal knowledge for classroom instruction and to visit cultural sites is also an important issue that must be addressed before developing a curriculum like the FGEP. The blocks of time required and transportation expenses incurred to conduct field trips with students can limit their use in K–12 educational settings. Even with these challenges, the increase in student engagement, the opportunities to build on students' existing knowledge and to validate their cultural identity, the potential to improve student achievement, and the significant involvement of the tribal community in education are all positive outcomes of CCI similar to those supported by the FGEP materials. Several instructors have successfully planned and executed field trips to sites outlined in IMSI (2011), which suggests that time limitations can be overcome.

The content, processes, and approaches presented herein were specifically prepared to help enhance local geoscience education in the Flathead Indian Reservation schools and at the Salish Kootenai College. Preliminary research provides evidence of the efficacy of the materials in supporting improved achievement at the local level. These results make the FGEP materials and those like them attractive additions to science curricula. We believe that the FGEP materials can serve as model CCI resources that could be adapted and employed for similar work in other ethnic contexts, particularly American Indian contexts. The FGEP place-based resources and approaches presented in this paper may not be directly relevant to other geographic areas, but geoscience educators should be able to develop similar curricula and implement instructional approaches in other settings. This paper is not intended to be a definitive statement on the topic of geoscience education in tribal communities. Instead, we hope that it will encourage ongoing discussions and generate ideas about how best to teach geosciences in Indian country and beyond.

Acknowledgments

The following individuals and organizations made invaluable contributions to the FGEP and its products (including this paper): members of the CSKT Culture Committees and Elders Cultural Advisory Councils; the CSKT Tribal Preservation Department; tribal cultural experts; SKC faculty, staff, and students; faculty and students from Two Eagle River School (CSKT); Flathead Indian Reservation elementary-, middle-, and high-school faculty; and KSKC Public Television. A full list of acknowledgements is provided in IMSI (2011). Shane Fox assisted with the figures. We thank one anonymous reviewer for helpful comments that improved this paper. Research for this paper was supported in part by funds from National Science Foundation Geoscience Award No. 0608106 (FGEP).

REFERENCES

Alden, W.C. 1953. Physiography and glacial geology of western Montana and adjacent areas. U.S. Geological Survey Professional Paper 231, 200p.

Bigcrane, R., and Smith, T. 1991. *The Place of the Falling Waters*. Pablo, MT: Salish Kootenai College Media Center [film].

Bondurant, A.K. 2005. Geologic mapping and sedimentologic analysis of quaternary deposits along the western shore of Flathead Lake, northwest Montana: Documenting the record of deglaciation [M.S. thesis]. Missoula: University of Montana, 69p.

Cajete, G. 1999. Native science: Natural laws of interdependence. Santa Fe, NM: Clear Light Publishers, 339p.

Chapman, R.H. 1900. Tahwah's geology or the legend of the big beaver. National Anthropological Archives, Manuscript 3777. Washington, DC: Smithsonian Institution.

Clark, E.E. 1953. Indian legends of the Pacific Northwest. Berkeley, CA: University of California Press, 225p.

Clark, E.E. 1966. Indian legends from the northern Rockies. Norman, OK: University of Oklahoma Press, 350p.

Constenius, K.N. 1996. Late Paleogene extensional collapse of the

Cordilleran foreland fold and thrust belt. *Geological Society of America Bulletin,* 108(1):20–39.

Elrod, M.J. 1903. The physiography of the Flathead Lake region. *In* Lectures at Flathead Lake. Bulletin of the University of Montana No. 16, Biological Series No. 5. p. 197–203.

Flathead Culture Committee (FCC). 1979. Stories from our Elders. St. Ignatius, MT: Flathead Culture Committee, 80p.

Harrison, J.E., Griggs, A.B., and Wells, J.D. 1986. Geologic and structure maps of the Wallace 1 × 2 degree quadrangle, Montana and Idaho. U.S. Geological Survey Miscellaneous Geologic Investigation 1509A, scale 1:250,000, 2 sheets.

Hofmann, M.H. 2005. Using sediments to infer the geologic history of northwestern Montana during and after the last glacial maximum: The record from Flathead Lake [Ph.D. thesis]. Missoula: University of Montana.

Hofmann, M.H., and Hendrix, M.S. 2010. Depositional processes and the inferred history of ice-margin retreat associated with the deglaciation of the Cordilleran ice sheet: The sedimentary record from Flathead Lake, northwest Montana, USA. *Sedimentary Geology,* 223:61–74.

Hofmann, M.H., Hendrix, M.S., Moore, J.N., Sperazza, M. 2006. Late Pleistocene and Holocene depositional history of sediments in Flathead Lake, Montana: Evidence from high-resolution seismic reflection interpretation. *Sedimentary Geology,* 184:111–131.

Hutton, J. 1788. Theory of the Earth; or an investigation of the laws observable in the composition, dissolution, and restoration of land upon the globe. *Transactions of the Royal Society of Edinburgh,* 1 (part 2):209–304.

Indigenous Math and Science Institute (IMSI). 2011. Flathead Geoscience Education Project teacher reference guide, 2nd ed. Pablo, MT: Salish Kootenai College, 64p.

Johnson, A.N. 2010a, The Flathead Geoscience Education Project: Collaborative Earth Science education in western Montana. Presented at the Engaging America's Talent: National Science Foundation Education Outreach Conference, Little Rock, AR, March 22, 2010.

Johnson, A.N. 2010b, Weaving Native science and Earth Science together on the Flathead Indian Reservation, western Montana. Poster for the 1st Annual Geoscience Alliance National Conference, Carlton, MN, September 16–18, 2010.

Johnson, A.N. 2011. Compatible indigenous and geoscientific knowledge, Flathead Indian Reservation, northwest Montana. *Geological Society of America Abstracts with Programs,* 43(5):24.

Johnson, A.N. 2012. Flathead Geoscience Education Project: A practical integration of people and place. Presented at the 2nd Annual Geoscience Alliance National Conference, Pablo, MT, March 17, 2012.

Kelch, R. 2012. Flathead Geoscience Elementary Curriculum Project. Presented at the Flathead Reservation Tribal Pupil Instruction Related Day, Polson, MT, September 2012.

Kootenai Culture Committee (KCC), Confederated Salish and Kootenai Tribes. 1997. Ktunaxa legends. Seattle, WA: University of Washington Press, 382p.

Lange, I.M., and Zehner, R.E. 1992. Geologic map of the Hog Heaven volcanic field, northwestern Montana. Montana Bureau of Mines and Geology Geologic Map 53, scale 1:50,000, 6p, 1 sheet.

Ludwin, R.S., Dennis, R., Carver, D., McMillan, A.D., Losey, R., Clague, J., Jonientz-Trisler, C., Bowechop, J., Wray, J., and James, K. 2005a. Dating the 1700 Cascadia earthquake: Great coastal earthquakes in Native stories. *Seismological Research Letters,* 76:140–148.

Ludwin, R.S., Thrush, C.P., James, K., Buerge, D., Jonientz-Trisler, C., Rasmussen, J., Troost, K., and de los Angeles, A. 2005b. Serpent spirit–power stories along the Seattle Fault. *Seismological Research Letters,* 76:426–431.

McDonald, W.H. 1973. Creation tales from the Salish. Billings, MT: Montana Indian Publication Fund, 32p.

McMillian, A.D., and Hutchinson, I. 2002. When the mountain dwarfs danced: Aboriginal traditions of paleoseismic events along the Cascadia subduction zone of western North America. *Ethnohistory,* 49(1):41–68.

Meinzer, O.E. 1917. Artesian water for irrigation in the Little Bitterroot Valley, Montana. U.S. Geological Survey Water Supply Paper 400-B, pp. 9–37.

Mihesuah, D.A. 2005. So you want to write about American Indians? A guide for writers, students, and scholars. Lincoln, NE: University of Nebraska Press, 164p.

Miller, H., and Harrison, E. 1974. Coyote tales of the Montana Salish. Bozeman, MT: Artcraft Printers, 80p.

Montana Department of Transportation (MDT), undated. The beaver's dam. Available at http://mathscience.mt.gov/files/RoadSignPDF/BeaversDam.pdf (accessed November 2011).

Morton, R., and Gawboy, C. 2000. Talking rocks: Geology and 10,000 years of Native American tradition in the Lake Superior region. Duluth, MN: Pfeifer-Hamilton Publishers, 213p.

Murray, J. 1997. Ethnogeology and its implications for the aboriginal geoscience curriculum. *Journal of Geoscience Education,* 45:117–121.

Pardee, J.T. 1910. The Glacial Lake Missoula, Montana. *Journal of Geology,* 18:376–386.

Pardee, J.T. 1942. Unusual currents in Glacial Lake Missoula. *Geological Society of America Bulletin,* 53:1569–1600.

Riggs, E.M. 2004. Field-based education and indigenous knowledge: Essential components of geoscience education in Native American communities. *Science Education,* 89:296–313.

Salish Culture Committee (SCC). 1996. Common names of the Flathead language, 3rd ed. St. Ignatius, MT: Salish Culture Committee, unpaginated.

Salish Kootenai College (SKC) and Kootenai Culture Committee (KCC), Confederated Salish and Kootenai Tribes (CSKT). 2010. Selected place names in the aboriginal territories of the Ksanka and Ktunaxa (Kootenai People). Pablo, MT: Salish Kootenai College. Indian Land Tenure Foundation, SKC Tribal History Project, and KCC, CSKT. Map layout and design by Michelle Mitchell.

Salish Kootenai College (SKC) and Salish–Pend d'Oreille Culture Committee (SPCC), Confederated Salish and Kootenai Tribes (CSKT). 2010. Selected Salish place names in the aboriginal territories of the Salish and Pend d'Oreille tribes of the Flathead Reservation. Pablo, MT: Salish Kootenai College. Indian Land Tenure Foundation, SKC Tribal History Project, and SPCC, CSKT. Map layout and design by Michelle Mitchell.

Salish Kootenai College (SKC) Tribal History Project. 2008. The lower Flathead River, Flathead Indian Reservation, Montana: A cultural, historical, and scientific resource. Pablo, MT: SKC Press, 106p.

Salish–Pend D'Oreille Culture Committee (SPCC). 2003. A brief history of the Salish and Pend D'Oreille tribes. St. Ignatius, MT: Confederated Salish and Kootenai Tribes, 70p.

Salish–Pend d'Oreille Culture Committee and Elders Cultural Advisory Council, Confederated Salish and Kootenai Tribes. 2005. The Salish people and the Lewis and Clark expedition. Lincoln, NE: University of Nebraska Press. 198p.

Semken, S.C. 2005. Sense of place and place-based introductory geoscience teaching for American Indian and Alaska Native undergraduates. *Journal of Geoscience Education,* 53:149–157.

Semken, S.C. 2011. Implications of sense of place for Earth-Science interpretation in parks. *Geological Society of America Abstracts with Programs,* 43(5):180.

Semken, S.C., and Morgan, F. 1997. Navajo pedagogy and Earth systems. *Journal of Geoscience Education,* 45:109–112.

Sievert, R. 2009. The Flathead Geoscience Education Project: Perspectives on the land—traditional Tribal and Western science. Presented at the Flathead Reservation Tribal Pupil Instruction Related Day, Polson, MT, September 2009.

Sievert, R. 2011. The Flathead Geoscience Education Project:

Perspectives on the land—traditional Tribal and Western science. Presented at the Montana Education Association Conference, Missoula, MT, October 2011.

Sievert, R. 2013. Supporting American Indian students' learning in the geosciences with culturally congruent instruction. Presented at the American Educational Research Association Annual Meeting, San Francisco, CA, May 1, 2013. American Educational Research Association Online Paper Repository. Available at http://www.aera.net.

Smith, D.G. 1966. Glacial and fluvial landforms adjacent to the Big Arm embayment, Flathead Lake, western Montana [M.A. thesis]. Missoula: University of Montana, 74p.

Smith, D.G. 1977. Glacial geology of the Big Arm region of Flathead Lake. *In* Glacial geology of Flathead Valley and catastrophic drainage of Glacial Lake Missoula. Field Guide No. 4, 30th Annual Meeting, Rocky Mountain Section, Geological Society of America. Missoula: University of Montana, 38p.

Smith, L.N. 2004. Late Pleistocene stratigraphy and implications for deglaciation and subglacial processes of the Flathead lobe of the Cordilleran ice sheet, Flathead Valley, Montana, USA. *Sedimentary Geology,* 165:295–332.

Vitaliano, D.B. 1973. Legends of the Earth: Their geologic origins. Bloomington, IN: Indiana University Press, 305p.

Waitt, R.B., Jr. 1985. Case for periodic, colossal jökulhlaups from Pleistocene Glacial Lake Missoula. *Geological Society of America Bulletin,* 96:1271–1286.

Weatherford, J.M. 1991. Native roots: How the Indians enriched America. New York: Fawcett Columbine, 310p.