Tool Stone Found At South Dakota Archaeological Sites

ARCHAEOLOGICAL RESEARCH CENTER

CULTURAL MATERIAL SERIES NO. 1

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RENEE M. BOEN, EDITOR

SOUTH DAKOTA
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Contents

Tables

Figures

ACKNOWLEDGEMENTS

This document, the first publication in the Cultural Material Series, presents information on raw stone materials (tool stone) found at archaeological sites in South Dakota. It relies heavily on other's descriptions and research, combined with the research of the authors and discussions with archaeologists at the Archaeological Research Center, particularly Roger Williams. Williams also prepared many of the examples that were photographed for the guide. The project spanned over a decade and was supported, in part, by the Archaeological Research Center and the Bureau of Reclamation, as well as by the major authors.

Other contributors include photographers Kate Sieverding, Lynn Griffin, Lisa Nesselbeck, and Boen; Jane Watts edited the geology section and illustrated fossils that are typically found in some of the materials, particularly the cherts; Katie Lamie and Griffin helped locate examples of stone tools made out of various materials; and everyone around us has tolerated this long-term, intermittent project over the years. Unless otherwise noted, all images appear courtesy of the Archaeological Research Center. Other images appear courtesy of the US Department of the Interior, Bureau of Reclamation, Dakotas Area Office (USDI BOR DKAO); US Department of Agriculture, Forest Service, Black Hills National Forest (USDA FS BKNF); Kent Boen (KB); Renee M. Boen (RMB); Matthew Busch (MB); Denise Hilde Lewis-Hilde Collection (DHL-HC) and David Williams (DW).

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INTRODUCTION

This guide describes raw stone materials, or tool stone, used to create stone implements, weapons, ornaments, and other objects found at archaeological sites in South Dakota. More specifically, it focuses on stone artifacts that were flint knapped or soft stone that was cut, abraded, or drilled. Raw stone materials described in this guide include cherts, chalcedonies, quartzites, silicified sediments, obsidian, catlinite, red pipestone, and quartz. Tool stone available to prehistoric cultures can be categorized as either local or non-local (exotic). Local materials are available to cultural groups during their seasonal rounds or planned trips to known procurement or quarry sites. Non-local materials are typically traded either directly or indirectly through neighboring cultural groups. There is no specific distance to a resource to label it local or non-local; that decision is usually left to the interpretation of the archaeologist.

The tool stone definitions in this guide incorporated the results of original research and descriptive identifications of the materials, as well as information derived from the existing literature. In the same vein, the authors visited several primary sources of stone material and collected lithologic examples to study; however, the lithic comparative collection at the Archaeological Research Center also includes many good examples of the various material types. The early foundation of this comparative collection is over 100 years old and continues to grow with contributions by archaeologists today.

The tool stone types described are from South Dakota and parts of Idaho, Minnesota, Nebraska, North Dakota, Montana, Oregon, and Wyoming. The result is a compilation of descriptors to serve students, novice archaeologists, and professional archaeologists by providing a general reference and overview. The study did not focus on every type of material available on the landscape. Instead, it reflects most tool stone types found thus far at archaeological sites within the boundaries of South Dakota. Certain tool stone types from neighboring states, such as Nehawka flint from

Nebraska, were not included in the guide because they are well-described elsewhere, are rarely found, or have not yet been properly identified in South Dakota archaeological sites.

Nomenclature was standardized to reflect the most well-known or frequently used terminology for the lithic material found in the archaeological literature. Although others have re-named some of these popular types to reflect geologic sources, it was decided to respect the first or most popular use in the historic references. Standardizing the nomenclature is needed if lithics across regions are to be consistently compared and identified at archaeological sites.

Descriptions include other names for the material; examples of quarries, if known; color range, including Munsell rock colors; cortex; grain; fracturing qualities; and characteristics that are thought to be diagnostic of each tool stone. Fracturing properties are described in relationship to the tool stone's conchoidal breakage patterns and rated as poor, fair, good, or excellent. However, these ratings are difficult to define except in a relative way. Deadwood Scolithus quartzite, which has many internal flaws and unpredictable fracture patterns, is a material unlikely to be selected for making a stone tool; it is the standard for a poor rating. The deep red colored Deadwood quartzite has large grains and an unpredictable fracturing pattern; it is the standard for a fair rating. Petrified wood, with variable quality and internal flaws, is more predictable regarding fracture properties than Deadwood quartzite; it is the standard for a good rating. Obsidian has excellent and predictable conchoidal fracturing properties; it is the standard for an excellent rating. Because of variability among samples from a single source, some of the tool stone fell between these four ratings.

Photographs provide a range of each material's characteristics. Source maps indicate general locations of lag deposits, a geological formation(s), or a known outcrop. Especially on the Plains, lithic materials are often secondary deposits from major geologic outcrops that are found as cobbles along stream beds or in outwash deposits. The exact locations of quarries are not shown on maps to protect the sites. Finally, references, other than those cited in the guide, are provided for those who want to do more in depth research.

A search of the Archaeological Research Center's site database identified 254 previously recorded sites identified as prehistoric quarries in South Dakota at the time of publication (Figure 1). The quarry site type, does not distinguish between actual quarrying activities on a site and exploiting a surface geologic outcrop. It is probably more accurate to state that these are lithic procurement sites. Following the introduction are Chapter 2-Geology, Chapter 3-Raw Material Definitions, Chapter 4-Raw Material Descriptions, References, Appendix A-Flint Hill and Spanish Diggings Quarries, and Appendix B-Suggested Readings.

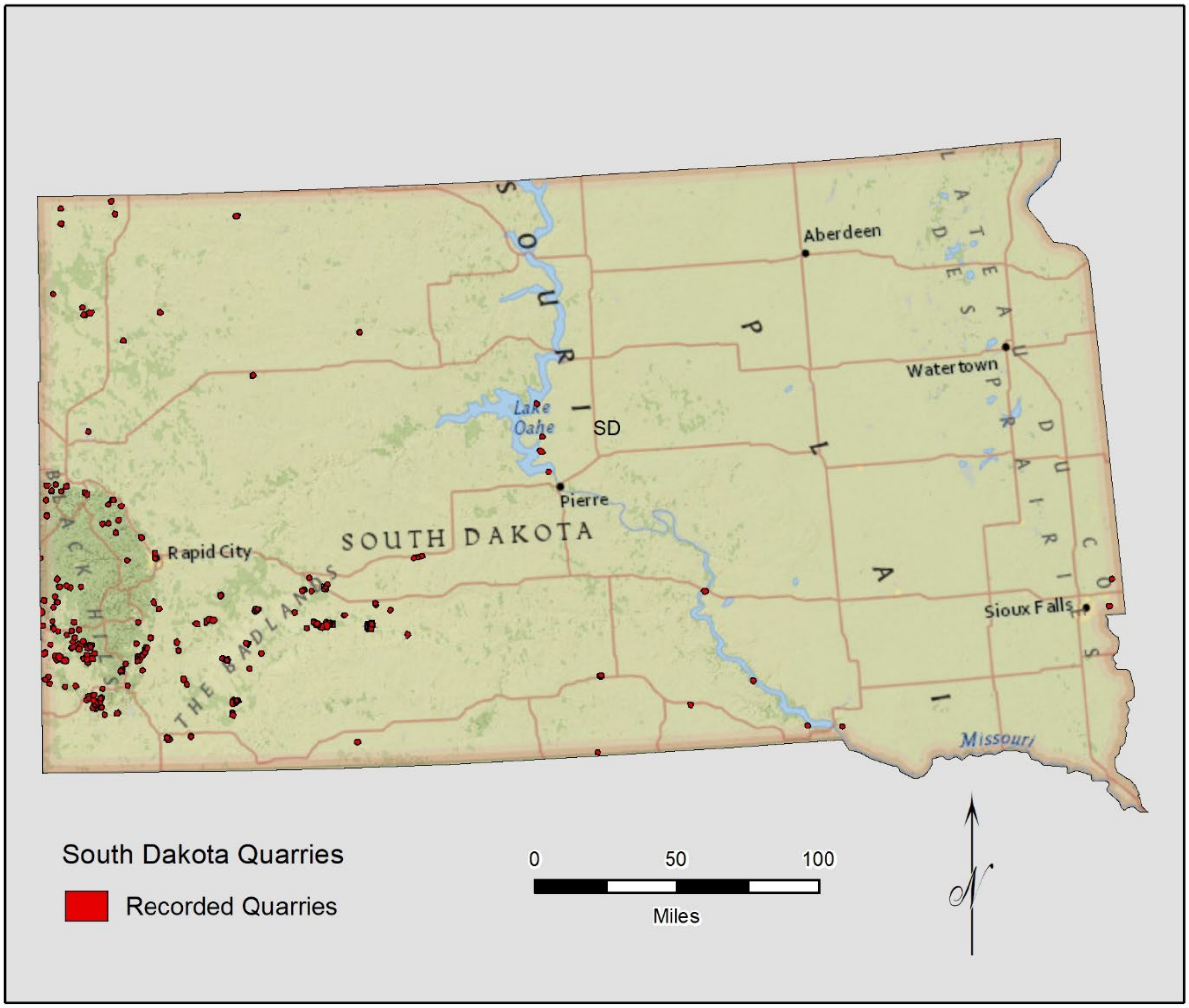


Figure 1. Generalized location of recorded prehistoric quarry and procurement sites in South Dakota, as of December 2020.

GEOLOGY

Tool stone chosen and used by prehistoric cultural groups in what is now South Dakota came from not only within the state, but from adjacent areas of Minnesota, North Dakota, Montana, Wyoming, and Nebraska, as well as Colorado, Idaho, and possibly Oregon (Figure 2). The description of the different geologic contexts for the tool stones discussed in this guide are presented from oldest to youngest. Tables summarize the geologic time frame and location of the materials, and maps support the geology descriptions.

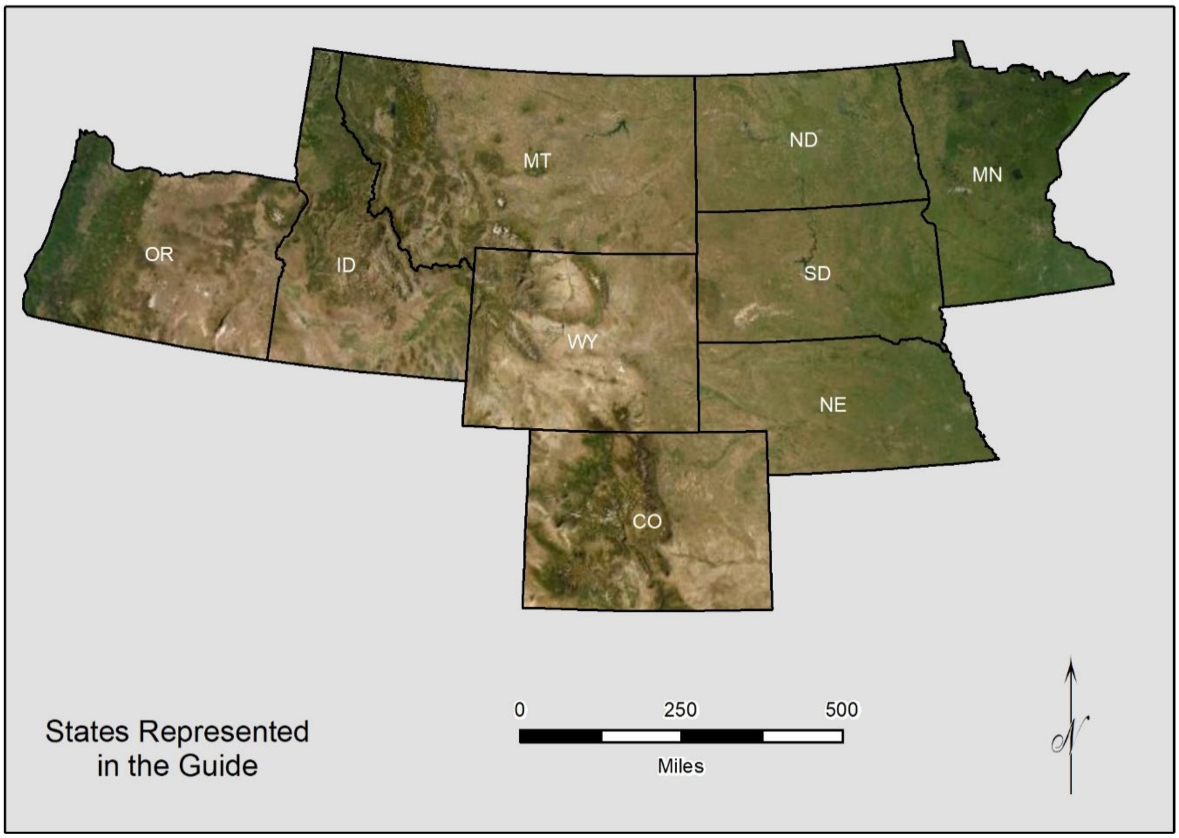


Figure 2. Tool stone from Colorado, Idaho, Minnesota, Montana, Nebraska, North Dakota, Oregon, South Dakota, and Wyoming are discussed in this guide.

As a prelude to the geology discussion, a brief introduction is provided regarding two major uplifts, the Black Hills Uplift in southwestern South Dakota and the Hartville Uplift in eastern Wyoming. Both uplifts include quartzite and chert tool stone found at archaeological sites in South Dakota. Geologically, they are closely related, and similar tool stone formations can be found between the two uplifts, although these formations frequently have different names.

BLACK HILLS UPLIFT

Spanning approximately 100 miles north to south and 80 miles east to west, the Black Hills are located in southwestern South Dakota, northeastern Wyoming, and extreme southeastern Montana. This feature is part of the Laramide Uplift that occurred about 48 million years ago (mya) in the early Tertiary or possibly late Cretaceous time (United States Geological Survey 2013:1). The Black Hills represent the easternmost outlier of the Rocky Mountain system and are likely structurally related to the isolated mountain ranges in central Montana and Wyoming (Gries 1996:217; Schwartz 1928:57). The uplift may have occurred as a result of the tectonic plates of the Pacific Ocean and the North American continent colliding. During the middle to late Cretaceous a vast shallow seaway covered most of the interior of the North American continent, leaving the future Black Hills location along the edge of that sea. Materials that settled out of the sea during these episodes, such as sands, silt, and calcium, provided the parent material for the layers of rock exposed on the surface today.

Encompassing all periods, except the Silurian, the Black Hills are made up of at least 30 formations, although some are only minimally represented (Figure 3). Erosional forces from 48 to 37 mya exposed the Cretaceous through Precambrian complex formations (1.7 to 2.5 billion years ago [bya]) (Schwartz 1928:57). The oldest metamorphic and igneous rocks of the Precambrian complex comprise the highest point, Black Elk (formerly Harney) Peak, at 7,242 feet above mean sea level, in the central core. These same rocks are represented in the area surrounding Black Elk Peak, referred to as the Needles. Moving out from the central core in concentric circles, the main formations are the Paha Sapa (Madison) limestone and the Minnelusa, the Opeche-Spearfish, the Lakota-Skull Creek, and the Newcastle-Niobrara. Post-depositional actions, such as heat, compression, and fluid movements within a formation, such as contact metamorphism, are spatially variable. This can result in variations in the composition of the formation and provide diagnostic characteristics that allow archaeologists to source a given tool stone material.

The Deadwood, Minnelusa, Lakota, and Fall River formations all contain quartzites that were used as tool stone by prehistoric inhabitants in the region. A quartzite is metamorphosed sandstone that is welded so firmly together that when stressed, it breaks across the grains instead of around them, as in loosely bonded sandstone. Mineral composition of quartzite is dominated by quartz, which makes up from 60 to 95 percent of the rock. Quartz is extremely durable and harder than steel. Quartzites are among the hardest and most resistant of common rock types due to the high quartz content and strong bonding. Quartzite presents in the same colors as sandstone, including browns, yellows, grays, reds, and whites (Heinrich 1956:206, Pough 1957:24 & 316). Although it would be useful if color could be used as an identifying characteristic of all stone, in most cases, color is determined by compounds, not trace elements, in the stone and there is typically no direct correlation between trace elements and color.

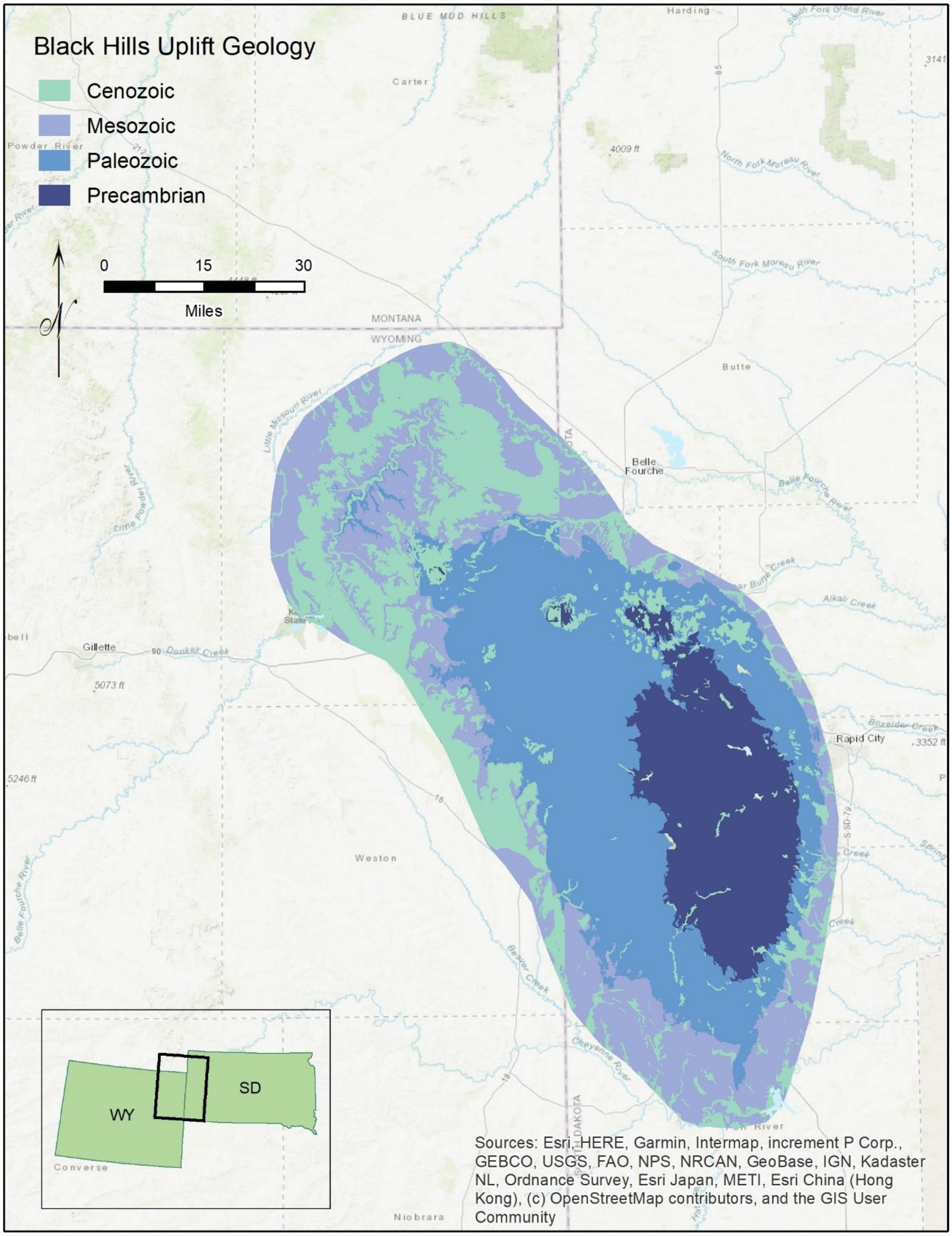


Figure 3. Black Hills Uplift stratigraphy units.

HARTVILLE UPLIFT

The Hartville Uplift (Figure 4), located in southeastern Wyoming, links the Laramie Range in Wyoming with the southern Black Hills in South Dakota. The Hartville Uplift is a Laramide anticlinal dome with a Precambrian core. Unlike the Black Hills, however, there is direct evidence of a pre-Laramide orogeny. There is extensive evidence of three, or possibly four, Proterozoic deformation events, a Trans-Hudson related uplift (~1.82 Gigaannum [Ga]), and an unnamed deformation/uplift (~2.1 Ga) (Sims et al. 1996:2). The core of the uplift is composed of Late Archean-aged granite called the Rawhide Butte Granite, Archean gneisses and the Precambrian-aged Whalen group. A set of Precambrian granite and diorite intrusions bisect the Whalen group. It is a complex structural area with many structures overprinting other structures, but the net result is a slightly rotated north-south trending uplifted mountainous region with a large central thrust fault called the Hartville fault. The Hartville Uplift is approximately 40 miles long and 24 miles wide with elevations ranging from 4,700 to 6,100 feet (Reher 1991:255).

Outward from the Precambrian core of igneous and metamorphic rocks there are outcroppings of Cambrian or Devonian aged quartzites (Deadwood quartzite), the Devonian or Mississippian aged Guernsey formation, followed by the Carboniferous (Mississippian/ Pennsylvanian) Hartville formation. This is overlain by the more familiar units of the Opeche Shale, Minnekahta Limestone, then the equivalent of the Black Hills' Spearfish formation (a Triassic gypsum and red-shale sequence), followed by the Chugwater formation. The Chugwater formation is also the local equivalent of the Black Hills' Spearfish formation. This is overlain by a basal Mesozoic era Jurassic sandstone sequence, then the Sundance formation, the Morrison formation and then the Cloverly formation. The Cloverly formation is the equivalent of the Cretaceous period Inyan Kara group. This is overlain by Cenozic era Tertiary claystone and sandstone (Denson and Botinelly 1949). Many of the geologic formations present in the Hartville Uplift have geologic equivalents in the Black Hills and similar depositional environments. The Hartville Uplift is well-known for its copper and hematitic and magnetic iron deposits. Mineral production began somewhere around 1880 and has continued sporadically through the present day (Sims et al. 1996:21).

Within the Hartville formation in Wyoming, both Hartville cherts and quartzites are tool stone materials known for their high knapping quality. They are referred to as Spanish Diggings cherts and quartzites. In the Black Hills, the equivalent formation includes tool stone materials called Paha Sapa chert (Mississippian), Minnelusa chert (Pennsylvanian), Spearfish chert (Permian) and a variety of Black Hills quartzites (Pennsylvanian/Permian). Some examples of quartzite quarries or quarry complexes include the Saul #1 (or Barbour), Saul #5, Dorsey, and Spanish Creek in the Hartville Uplift and Cabot Hill, Battle Mountain, and Flint Hill quarries in the Black Hills Uplift. A wide variety of quartzites are also found in several formations in the Bighorns, Pryor Mountains, Bear Lodge Mountains, and Laramie Range in Wyoming and in the Black Hills of South Dakota.

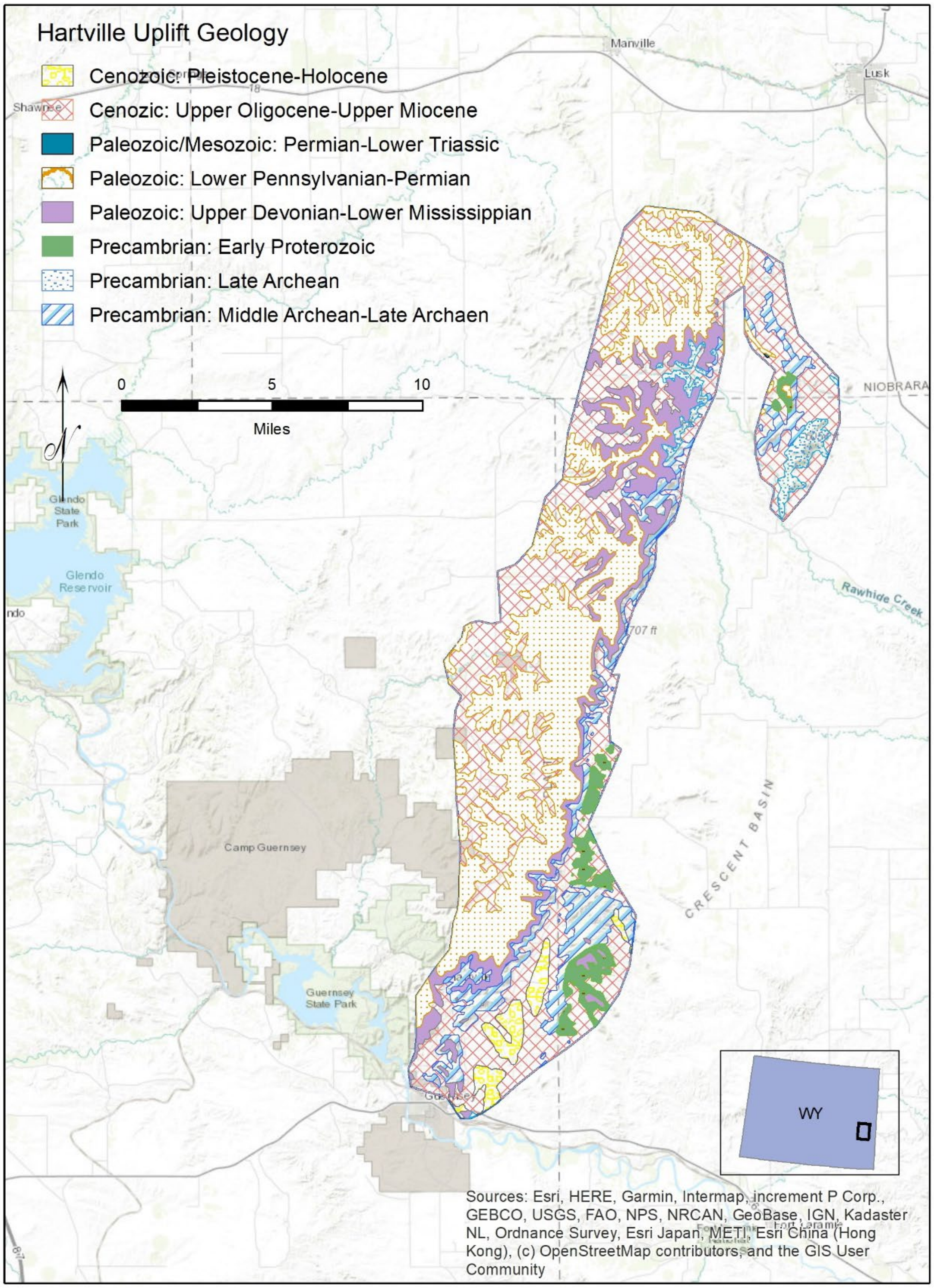


Figure 4. Hartville Uplift stratigraphy units.

PRECAMBRIAN ERA

The earth began to form about 4,660 mya. This early date through 541 (+/-1) mya is known as the Precambrian era. Four tool stone material types are associated with this era, including Sioux quartzite, catlinite, ferruginous chert, and quartz (Table 1 and Figure 5). In South Dakota, two major structural features from the Precambrian era are represented, one east and one west of the Missouri River. East of the Missouri River is a 135 mile east-west ridge, the Sioux formation, that stretches from southwestern Minnesota into southeastern South Dakota, and northwestern Iowa. In South Dakota, exposures are evident between Sioux Falls and Mitchell, at Dell Rapids, and in Alexandria. In Minnesota, outcrops can be seen around Pipestone, and in Iowa, at Gitchie Manitou State Preserve. Cobbles are also present in stream beds and the glacial drift of eastern South Dakota.

Table 1. Tool stone associated with the Precambrian era that are found at archaeological sites in South Dakota.

ERATHEM	UNIT	GENERAL LOCATION	GEOLOGIC DETAILS	TOOL STONE
PRECAMBRIAN	UNDIFFERENTIATED IGNEOUS AND METAMORPHIC ROCKS	BLACK HILLS UPLIFT	PRECAMBRIAN CORE	FERRUGINOUS CHERT
				QUARTZ
		EASTERN SOUTH DAKOTA, SOUTHWESTERN MINNESOTA, and NORTHWESTERN IOWA	SIOUX FORMATION	CATLINITE
				SIOUX QUARTZITE

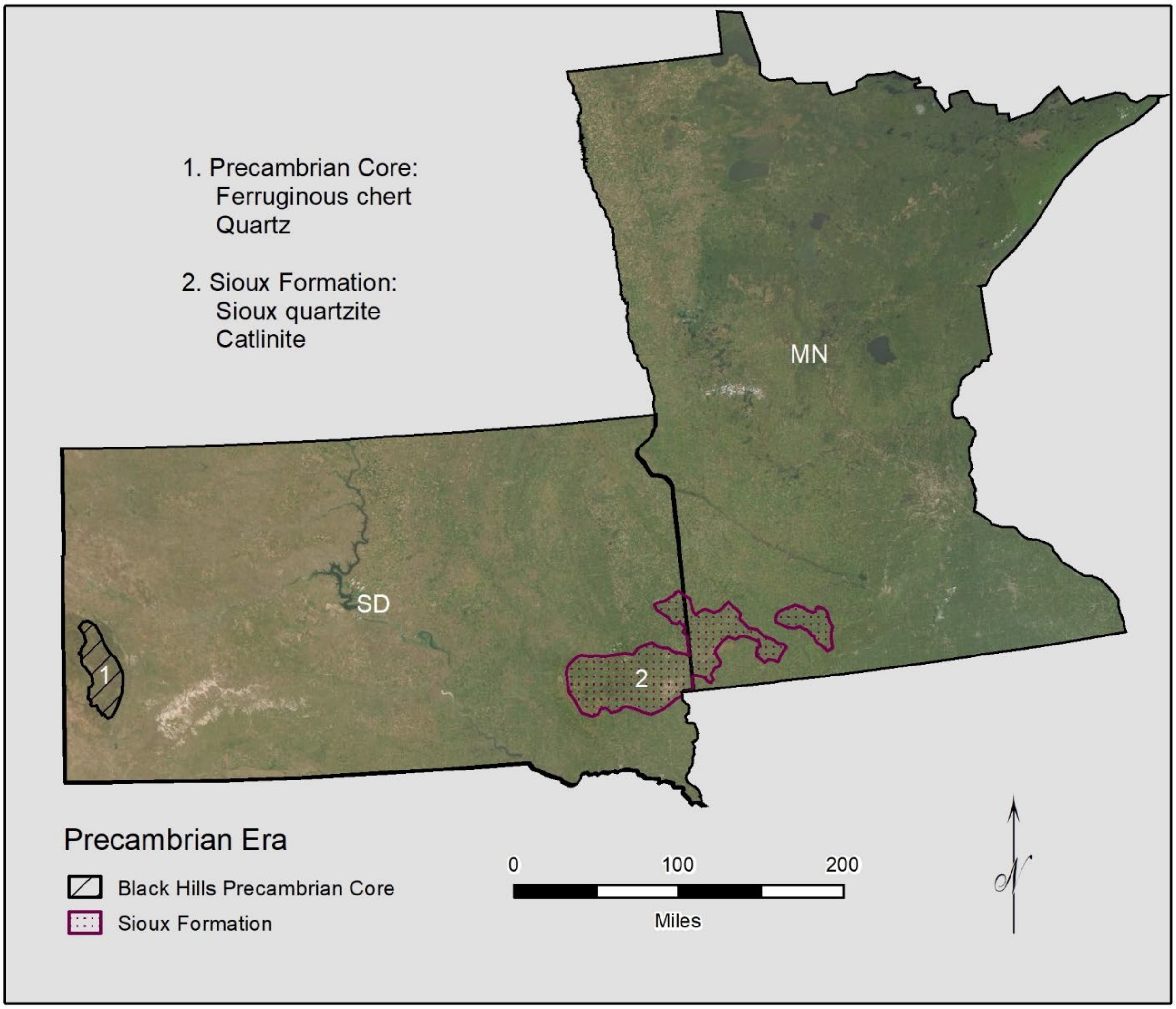


Figure 5. Generalized location of Precambrian era deposits in South Dakota and Minnesota. Tool stone locations for ferruginous chert and quartz are likely found in the Black Hills Uplift (1), and Sioux quartzite and catlinite are found in the Sioux formation (2).

Sioux quartzite, a major component of the Sioux formation, originated as a thick layer of sand laid down about 1.7 bya. Through time, it was firmly compressed, creating a highly resistant quartzite (Gries 1996:20) (Figures 6 and 7). Sioux quartzite has a distinctive pink color, caused by a layer of iron oxide that formed around every grain of sand. In modern times, it has been extensively mined for many uses, including building stone and road gravel. It appears to have limited use prehistorically because it is difficult to work by hand. However, examples of large chipped stone tools and two metates have been found in South Dakota. No prehistoric quarries or procurement sites of Sioux quartzite have been found or recorded in South Dakota.

Figure 6. Sioux quartzite outcrops in Falls Park, Sioux Falls, South Dakota. (Courtesy of KB.)

Figure 7. Closeup of Sioux quartzite outcrops in Falls Park, Sioux Falls, South Dakota. (Courtesy of KB.)

Catlinite is another tool stone material that occurs as seams of indurated, or hardened, clay in the Precambrian Sioux formation. The primary source of catlinite is at Pipestone Quarry, Pipestone County, in southwestern Minnesota (Figures 8 and 9). On August 25, 1937, Congress established Pipestone National Monument to protect the quarry. Managed by the National Park Service, the monument encompasses 238 acres around a series of prehistoric and historic quarry pits. Other small outcrops of catlinite have been identified at the eastern edge of the city of Jasper, Pipestone County, although there is no evidence that this location was ever quarried prehistorically. A lens of prehistorically quarried catlinite (39MH9) was also identified in 1976 along Split Rock Creek, Minnehaha County, South Dakota, by J. Steve Sigstad of the W.H. Over Museum.

The best-known quarries of catlinite recorded as cultural sites are found at the Pipestone National Monument in Minnesota, including sites such as 21PP9, 21PP10, and 21PP11. Unlike Sioux quartzite and its difficulty working it into a tool, catlinite was a popular material prehistorically and historically, and very easy to work.

Figure 8. Falls at Pipestone National Monument, Minnesota. (Courtesy of RB.)

Figure 9. Exposures of Sioux quartzite and catlinite at Pipestone National Monument, Minnesota. Note the spade that was used to extract slabs of catlinite out of the outcrop. (Courtesy of RB.)

Red pipestone has been found in gravels in terraces and riverbeds in northwestern Iowa and in outcrops and cores from south central Minnesota. Using x-ray powder diffraction, it has been determined that these materials were not the same as catlinite from Pipestone National Monument (Gunderson and Tiffany 1986), although it seems likely that they are related to the Sioux formation. Materials like catlinite, not associated with the Sioux formation, have been found outside of South Dakota. One is **red pipestone**, which outcrops in Barron County, Wisconsin and Scioto and Perry Counties, Ohio. Another is **red argillite**, which outcrops in Yavapai and Pima counties, Arizona. Transported or outwash deposits of red pipestone have also been found in Kansas. One specific example is a cobble collected along the north bank of the Kansas River six miles east of Manhattan, Kansas (Sigstad 1973). Though similar in appearance, none of these materials should be referred to as catlinite; a term that is reserved for the characteristic deep red to pink indurated clay associated with the Pipestone National Monument and outcrops in South Dakota.

West of the Missouri River, in the central Black Hills, the Precambrian era is represented as pillars of granite, gneiss, schist, and other materials (Figures 10-12). This spectacular area has place names such as the Needles Highway, Needles Eye, Cathedral Spires, and Little Devils Tower. The source of a clear to translucent **quartz** in the Black Hills is most likely the Precambrian pegmatitic granites. The massive quartz crystals, often several centimeters in size, are quite rare. Although not a common material used for stone tools, examples are found in archaeological sites in the Black Hills.

Quartz also appears in the glacial till of eastern South Dakota and should not be confused with Precambrian quartz. Though both quartz materials were used in the same ways, interpretations on the source of a given quartz sample should rely on the context in which it was found and proximity to either the Black Hills or the glaciated plains of eastern South Dakota.

The other South Dakota tool stone material related to the Precambrian central core of the Black Hills is **ferruginous chert** (Tratebas 1986). Ferruginous chert has two striking features: its homogeneity and its diagnostic dark reddish brown or tan color interspersed with bluish-white quartz inclusions, and the occasional vein of quartzite. The material is a metamorphic rock with relic bedding planes or flow lines visible. It may represent what geologists refer to as Lyddite, or Lydian stone, which is a variety of dense black chert (Whitten and Brooks 1975). No specific prehistoric quarry or procurement sites for Precambrian ferruginous chert have been found or recorded in the Black Hills.

Figure 10. Overview of the Precambrian core in the Black Hills Uplift showing granite outcrops, taken from Black Elk Peak. (Courtesy of RB.)

Figure 11. Precambrian core on Black Elk Peak in the Black Hills Uplift. (Courtesy of RB.)

Figure 12. The Needles in the Precambrian core of the Black Hills Uplift. (Courtesy of RB.)

PALEOZOIC ERA

The Paleozoic era, spanning 541 (+/-1) to 252 mya, is divided into seven periods. Cambrian is the oldest period, overlain by the Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian periods. During the middle of the Precambrian era, when the granites in the Black Hills were established, there were deposits of marine sands and clays in South Dakota. Erosion in the late Precambrian continued in the Cambrian period. Towards the end of this period, sand and shale were deposited over large areas of western South Dakota, which continued into the Ordovician period. This was followed by the deposition of limestone across much of the state late in the Ordovician period (Gries 1996:205). Tool stone material associated with this era includes Deadwood and Minnelusa quartzites; Swan River, Spanish Diggings, Mississippian, Paha Sapa, Minnelusa, and Spearfish cherts; and Teepee Canyon agates (Table 2 and Figure 13).

Table 2. Tool stone associated with the Paleozoic era that are found at archaeological sites in South Dakota.

ERATHEM	SYSTEM	GENERAL LOCATION	GEOLOGIC DETAILS	TOOL STONE
PALEOZOIC	PERMIAN	BLACK HILLS UPLIFT	SPEARFISH FORMATION	SPEARFISH CHERT
	PENNSYLVANIAN	BLACK HILLS UPLIFT	MINNELUSA FORMATION	MINNELUSA CHERT
				MINNELUSA QUARTZITE
				TEEPEE CANYON AGATES
	MISSISSIPPIAN	BLACK HILLS UPLIFT	MADISON (PAHA SAPA) LIMESTONE	PAHA SAPA CHERT
				MISSISSIPPIAN CHERT
		HARTVILLE UPLIFT	GUERNSEY FORMATION	SPANISH DIGGINGS CHERT
	DEVONIAN	CANADA AND NORTHERN PLAINS	SOURIS RIVER FORMATION	SWAN RIVER CHERT
	ORDOVICIAN	BLACK HILLS UPLIFT	DEADWOOD FORMATION	DEADWOOD QUARTZITE
	CAMBRIAN			

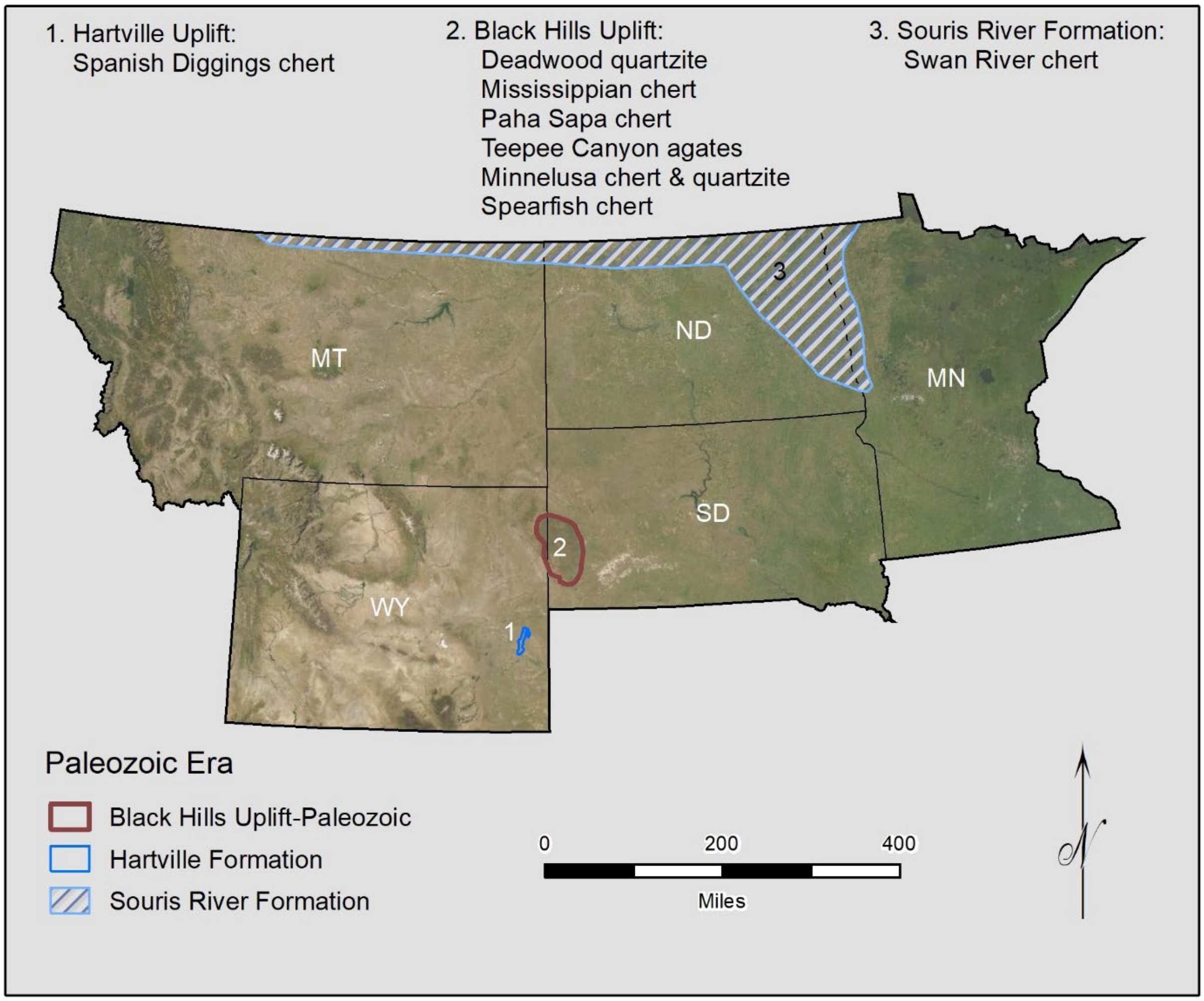


Figure 13. Generalized location of Paleozoic era deposits in Minnesota, Montana, North Dakota, South Dakota, and Wyoming, that contain tool stone found at South Dakota archaeological sites. Tool stone locations include a variety of cherts, quartzites and agates likely found in the Hartville Uplift (1), Black Hills Uplift (2), and glacial outwash deposits and till of the Souris River formation (3).

The Deadwood formation, spanning 485 to 445 mya, was deposited during the Upper Cambrian and Lower Ordovician period. The type section for the Cambrian-age Deadwood formation, where the **Deadwood quartzite** is found, is located along Highway 14A near the town of Deadwood. The Deadwood formation is the oldest sedimentary formation present in the Black Hills. It is composed of glauconitic sandstones, shale, limestone, and a basal flat-pebble conglomerate. The Deadwood formation is variable in thickness and can be up to 500 feet thick. The depositional environment of the Deadwood formation is unique; this formation was deposited during an atmospheric change and the grains and clasts have a different weathering pattern than younger formations. Grains, if not strongly metamorphosed, are well-rounded and deposits of frac sand are present in the formation.

At least two distinct types of quartzite are found in this formation. One is a coarse-grained quartzite ranging from dark red to orange. A conchoidal fracture creates a somewhat rough surface and breakage patterns when knapping, which are not as predictable as the Inyan Kara group quartzites from the Fall River and Lakota formations. A very different type of material, a fine-grained yellowish-gray and brown siliceous quartz sandstone with fossil Scolithus burrows, caps the Deadwood formation. Although this material has a smooth conchoidal fracture, the numerous burrow cavities present flaws throughout that make the material inconsistent for stone tool manufacturing.

The Devonian deposits of carbonates occur in the Williston Basin and continue north into Canada and south into South Dakota. **Swan River chert** is found in the Point Wilkins member of the Devonian Souris River formation in western Manitoba and Quaternary outwash deposits in central Canada and the Northern Plains. The Souris River formation exposure, where Swan River chert was identified by Grasby et al. (2002:275-281), is not a natural exposure, rather it occurs in the modern Mafeking quarry. Elongated or rounded chert nodules formed near the rind of vertical cone-shaped solution chimney features, that occur in the Souris River formation. Because the features are vertical, they may also be associated with bedrock other than the Devonian age rock (Grasby et al. 2002:275-281).

Swan River chert was probably more readily available prehistorically as outwash deposits associated with retreating glaciers than directly from an exposed outcrop. Swan River chert is distributed across western Manitoba, south-southeastern Saskatchewan, southeastern Alberta, northern Montana, eastern and northwestern North Dakota, western Minnesota, and eastern South Dakota. No prehistoric quarries or procurement sites have been found or recorded in South Dakota. However, it has been found in outwash deposits in the local glacial till at cultural site 39RO10, Roberts County, in northeastern South Dakota.

Next on the geological ladder is the Mississippian period, represented by limestones and erosion across most of South Dakota except the northwestern corner. These deposits extend west into Wyoming as well. The Paha Sapa formation, also referred to as the Madison Limestone or Guernsey formation, depending on locality, is Mississippian in age and ranges from 300 to upwards of 630 feet thick around the Black Hills. The formation is one of the most prominent in the Black Hills and consists of massive light gray to tan, weathering to black, medium crystalline limestone or dolomite. It is resistant and cliff-forming. The formation also exhibits karst topography in the form of solution features, such as breccias, vugs, sinkholes, and extensive cave systems, including Jewel Cave and Wind Cave. The Paha Sapa formation contains many invertebrate fossils, including brachiopods, bivalves, corals, crinoids, foraminifera, and graptolites, and was likely deposited in a carbonate shelf marine environment (Figures 14-16).

Present at the top of the formation is the Terra Rosa, an erosional feature consisting of red claystone that likely underwent significant erosion before the deposition of the overlying Minnelusa formation. The Paha Sapa formation is an important freshwater aquifer. A caramel colored chert with black dendritic inclusions has been found at archaeological sites in the Black Hills (e.g. 39LA138). This chert is similar to the **Spanish Diggings chert** from the Guernsey formation in the Hartville uplift, which is analogous to the Paha Sapa formation in South Dakota; however, the caramel colored chert has not been found in context and its exact origin is unknown. When found at sites or as cobbles in the Black Hills, it is often referred to as **Mississippian chert**, because it is usually near Mississippian age deposits. It has also been misidentified as Spanish Diggings chert because it is such a distinct material type and resembles the true Spanish Diggings chert found in Wyoming.

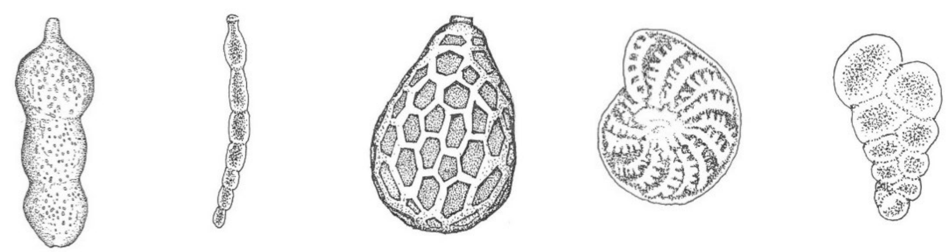


Figure 14. Examples of foraminifera that can be found in, and diagnostic of, some types of chert, such as Mississippian chert. Artistic representation, not to scale.

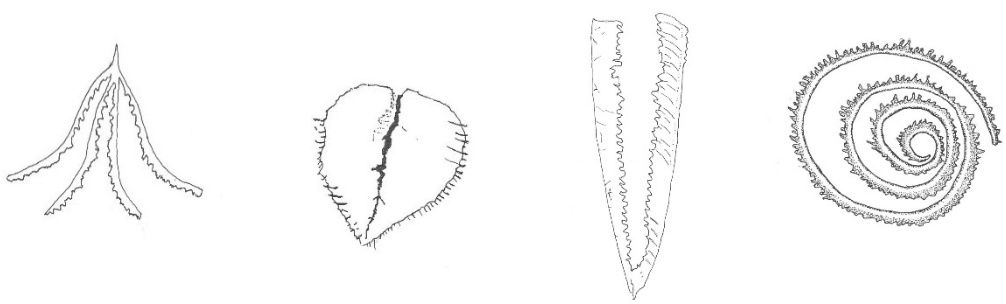


Figure 15. Examples of foraminifera and a graptolite (far right) that can be found in, and diagnostic of, some types of chert. Artistic representation, not to scale.

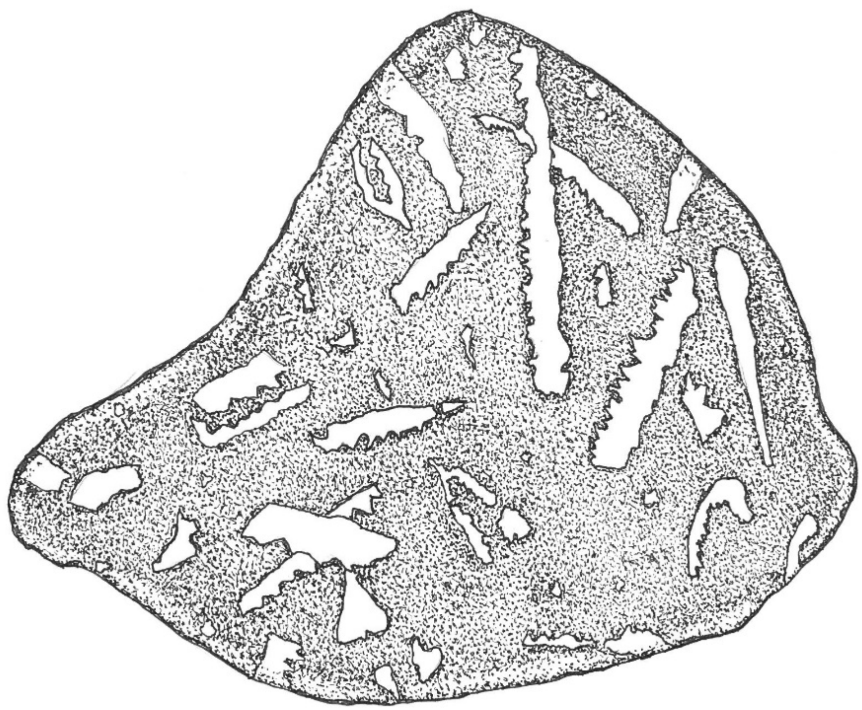


Figure 16. Artistic representation of a chert stone with foraminifera inclusions.

The Minnelusa formation was created during the Pennsylvanian, spanning 318.1 to 299 mya, and Permian periods, spanning 299 to 251 mya. The formation can be significantly variable in thickness, ranging from just less than 400 feet to over 1,000 feet in thickness. The formation consists mainly of red and yellow sandstone, including limestone and anhydrite in the upper third, a layer of interbedded sandstone, limestone, dolomite, shale, and anhydrite in the middle third, and a lower third comprised of red shale with interbedded limestone and sandstone (Gries 1996:209). The Minnelusa formation was deposited in aeolian, interdune, and sabkah environments. In Wyoming, the Minnelusa formation correlates with the Tensleep and Amsden formations, and in the Williston Basin of North Dakota, it correlates with the Amsden and Tyler formations. The basal sandstone member of the Minnelusa is called the Belle Sand; it is typically a loosely cemented, fine-grained white aeolian sandstone. The middle members of the Minnelusa are known as the Leos. There are typically four Leos with each featuring massive cross-bedded red to yellow sandstone beds. The upper sandstones of the Minnelusa are called the Converse or Tensleep sands, and two sandstone beds are typically present. The Converse sands are more loosely consolidated and often have a popcorn-like weathering texture. The Minnelusa formation and its equivalents in both Wyoming and North Dakota are oil trapping units and have been extensively explored for oil and gas deposits. **Minnelusa quartzite**, **Minnelusa cherts**, and **Teepee Canyon agates** are associated with the Minnelusa formation. Porcellanite may also be associated with the Tensleep formation in the Big Horn Mountains.

The Spearfish formation is Permian to Triassic in age and is easily recognized by its distinct red coloration. The Spearfish formation is exposed as a valley surrounding the Black Hills, referred to as the "red racetrack". It consists of, in order of increasing abundance, limestone, sandstone, claystone, siltstone, and white gypsum and can range from 250 feet to upwards of 700 feet in thickness. The limestone can be micritic or stromatolitic. The sandstone is composed of fine quartz grains and typically features laterally restricted massive beds or planar-laminated beds. The shale of the Spearfish formation can be either massive or fissile and is very organic-rich, with up to 23 percent organic material in some localities, and has been explored as a petroleum resource. The siltstone and claystone can be massive, planar-laminated, or rippled. The distinct white gypsum of the Spearfish formation can occur as massive, bedded, brecciated units. The gypsum concentration near the base of the Spearfish formation can be correlated to the Goose Egg formation recognized outside of South Dakota. The Spearfish formation itself can be correlated to the Chugwater formation recognized in Wyoming and the Williston Basin. The Spearfish formation has been interpreted as having been deposited in a marginal-marine sabkha environment. **Spearfish chert** is one of the few distinct types of cherts found in the Black Hills that is readily identifiable when found at a cultural site.

MESOZOIC ERA

The Mesozoic era, spanning 252 to 65 mya, is known as the age of the dinosaurs. It includes three periods: Triassic, Jurassic, and Cretaceous. This era started and ended with mass-extinctions. Tool stone is only represented in the Morrison, Lakota, and Fall River formations of the Black Hills Uplift and the Cloverly formation of the Hartville Uplift and includes Spanish Diggings, Morrison, Lakota, and Fall River quartzites and Morrison chert (Table 3 and Figure 17).

Table 3. Tool stone associated with the Mesozoic era found at archaeological sites in South Dakota.

ERATHEM	SYSTEM	GENERAL LOCATION	GEOLOGIC DETAILS	TOOL STONE
MESOZOIC	CRETACEOUS	BLACK HILLS UPLIFT	INYAN KARA GROUP-FALL RIVER FORMATION	FALL RIVER QUARTZITE
			INYAN KARA GROUP-LAKOTA FORMATION	LAKOTA QUARTZITE
		HARTVILLE UPLIFT	CLOVERLY FORMATION	SPANISH DIGGINGS QUARTZITE
	JURASSIC	BLACK HILLS UPLIFT	MORRISON FORMATION	MORRISON QUARTZITE
				MORRISON CHERT

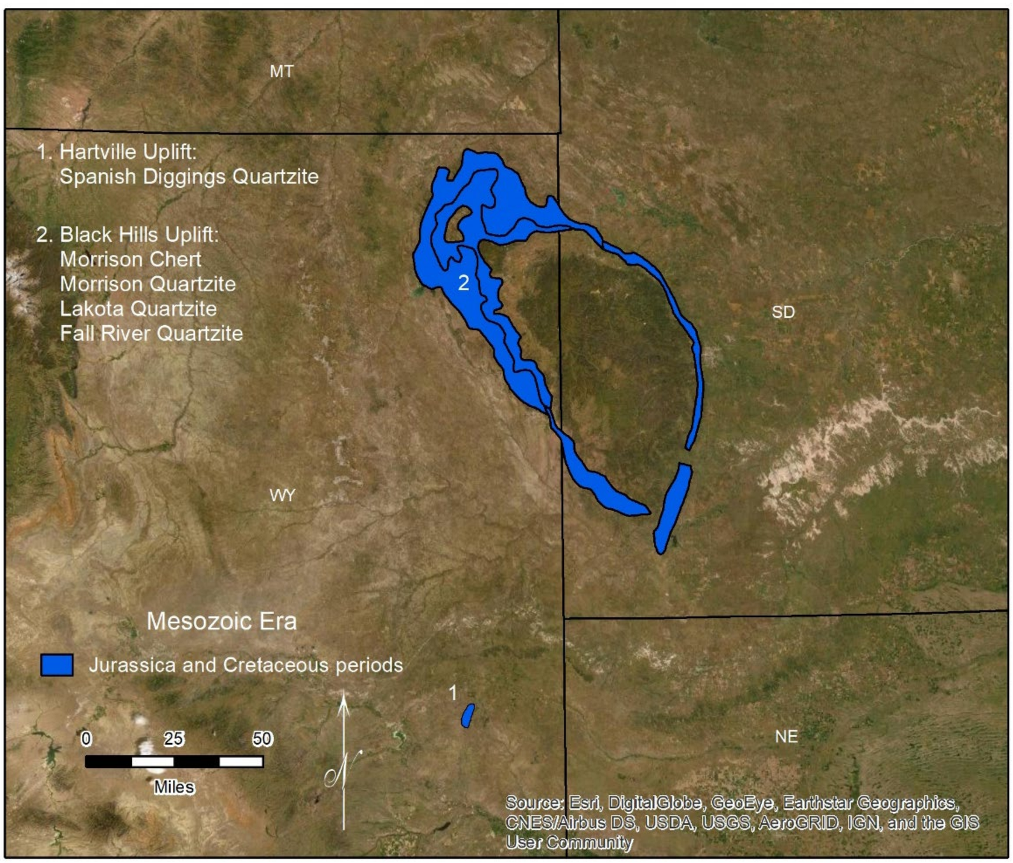


Figure 17. Generalized location of Mesozoic era deposits in South Dakota and Wyoming that contain tool stone found at South Dakota archaeological sites. Tool stone locations include a variety of cherts and quartzites found in the Hartville Uplift (1) and Black Hills Uplift (2).

The Morrison formation is Late Jurassic in age. It reaches a maximum thickness of 100 feet and consists of nonresistant, green to maroon variegated shales, siltstones, and claystones with thin interbeds of quartz sandstone. The formation contains dinosaur fossils and fossil trackways. It has been interpreted as having been deposited in a fluvial setting by freshwater streams, sheetwash, and volcanic ashfalls. It can be found in southwestern South Dakota, eastern Wyoming, and southeastern Montana. **Morrison chalcedony** quarry and procurement sites are numerous; for Black Hills quarry and procurement sites in South Dakota see Church (1990), and for Wyoming quarry and procurement sites see Craig (1983).

The Cloverly formation in the Hartville Uplift is the local equivalent of the Inyan Kara group, specifically the Fall River formation, in the Black Hills Uplift. The Cloverly formation is Early Cretaceous (Neocomian to Albian) in age (Finn 2010) and can be up to 80 feet thick (Reher 1991). It is a fluvially deposited sandstone unit with interbedded conglomerates, siltstones, and shales. The Cloverly formation was deposited in a floodplain and playa environment. The basal unit is the Pryor Conglomerate which contains abundant black chert. The Pryor Conglomerate is overlain by the Little Sheep member which is predominantly a bentonite-rich mudstone. The upper member is a clean channel-filled sandstone deposit which intersects variegated mudstones called the Himes (Moberly 1960). This is overlain by the Greybull member, a fine to medium gray sandstone depending on geographic location (Finn 2010).

Above the Cloverly in the southern Bighorn Basin, sandstone and siltstone beds have a distinctive rust color which is why they are called the Rusty Bed member; these units are sometimes included in the Cloverly and sometimes considered to be part of the Thermopolis formation, depending on geographic location. The Rusty Bed member is believed to correlate with the Fall River formation. Vertebrate fossils have been found in the Himes member of the Cloverly formation in Wyoming. The Cloverly formation is known to produce both mottled cherts and very fine-grained quartzites in a wide variety of hues (Reher 1991:251-284). The Spanish Diggings is comprised of a large number of quarries in the Hartville Uplift, numbers range from around ten to upwards of 60 quarries as listed by Reher (1991). The Hartville Uplift contains many different potential tool sources; however, there are two quartzite-bearing formations which stand out for quality, including the Cloverly formation and an unnamed Precambrian or Devonian-aged quartzite. When cross-referenced, historical maps, scientific references, and archaeological resources are often conflicting as to the locations of many of the quarries, perhaps because they are so numerous. However, there is a general agreement that the majority of these quarries are located in outcroppings of the Cloverly formation. Saul Quarry #1, also known as the Barbour quarry, and Saul Quarry #5 are located in the Cloverly formation.

The Fall River and Lakota formations in the Black Hills Uplift were initially grouped together into the Inyan Kara group (Figure 18) by W. Rubey in 1930 because the formations were so difficult to differentiate (Post 1967). Once out of geologic context, the materials from these formations are even more difficult to differentiate. Fall River sandstones generally have more tabular bedding and more ripple marks in comparison to the Lakota (Post 1967). Both members of the Inyan Kara group contain anomalous radioactivity on the southern, western, and northern flanks of the Black Hills. Economically viable deposits of uranium and related minerals, such as vanadium, have been mined from the sandstones of the Inyan Kara. However, uranium mineralization is generally concentrated in carbonate-cemented sandstone with sporadic pyrite (Robinson and Gott 1958), so it is unlikely that quartzite samples from the Inyan Kara will have anything other than trace uranium or vanadium mineralization.

Figure 18. Inyan Kara group along the Cheyenne River in the southern Back Hills Uplift. (Courtesy of RB.)

The Fall River formation is the upper member of the Inyan Kara group, deposited during the Albian period, spanning 113 to 100.5 mya, of the Lower Cretaceous. The formation is composed of interbedded sandstone, siltstone, and shale and was deposited in a marginal-marine sedimentary environment (Dahlstrom and Fox 2003). The formation ranges in thickness from 135 to 180 feet in the Black Hills area. The Fall River formation contains abrupt facies changes which make unit subdivision and correlation difficult. Sandstone stringers range from thin to massive (Figure 19). Ripple marks and worm burrows and tracks are abundant on bedding surfaces in the informal, thinly bedded sandstone lower unit (Post 1967). The informal middle unit is more massively bedded from a distance but upon close inspection there are scour-and-fill, cross-stratification, and slumping structures. The informal upper unit is silty, thinly bedded, slabby and contains ripple marks near the top of the sandstone bed (Post 1967). A regional transgressive disconformity separates the Fall River formation from the underlying Lakota formation (Dahlstrom and Fox 2003) and forms part of the Cretaceous hogback ridge on the outer ring of the Black Hills.

Figure 19. Sandstone associated with the Inyan Kara group along the Cheyenne River in the southern Black Hills Uplift. (Courtesy of RB.)

The Lakota formation is the lower member of the Inyan Kara group, deposited during the Lower Cretaceous period, spanning 121 to 135 mya, specifically the Neocomian series. The Lakota formation has three subdivisions: the Fuson, Minnewaste Limestone, and Chilson members and contains a wide variety of rock types including conglomerates, sandstones, shale, coal, and limestone (Dahlstrom and Fox 2003). The formation typically ranges in thickness from 100 to 550 feet in the Black Hills area. Fluvially-deposited sandstone units form the prominent ridges of the hogback. The Lakota formation has a predominantly sedimentary source (Dahlstrom and Fox 2003), meaning the grains composing the rock had been previously deposited in other sandstone units. Four formal fluvial units have been identified, two in the Chilson member and two in the Fuson member. These units are predominantly differentiated by architectural elements which are often macroscopic in nature; it is often difficult to discern from small samples how or where they fit in the fluvial architecture. Within the Lakota formation, as with most all sandstones in the Black Hills, there are localized areas of contact metamorphism due to Tertiary intrusions. There are also regional areas of differential cementation due to high-temperature fluid flow and mineralization. Because of the variable nature of the fluvial sediments present, fluid flow is anisotropic and resulting cementation is often patchy. The color, texture, and composition of the sandstone are often regionally variable, and the formation is generally classified based on facies and depositional texture. The Lakota formation correlates to the Cloverly formation in the Hartville Uplift in eastern Wyoming (Hahn and Jessen 2006).

Several well-known prehistoric tool stone quarries have been recorded in the Fall River, Lakota and Cloverly formations, including Flint Hill, Battle Mountain, and Cabot Hill quarries in South Dakota and Saul Quarry #1 (or Barbour Quarry), Saul Quarry #5, and Dorsey quarries (also broadly known as the Spanish Diggings complex) in eastern Wyoming. All these quartzites are typically well-sorted, well to moderately well-rounded, and fine to medium-grained with varying amounts of cement. They most often present a smooth conchoidal fracture; probably at least one of the reasons they were popular choices for tool stone. The color range is wide including grays, browns, yellows, and reds. Colors may be solid or banded. Although distinctions between the materials extracted from the Wyoming and South Dakota quarries have been noted (cf. Witzel and Hartley 1976), unknown source samples can be difficult to sort by quarry-type with any more than a relative degree of certainty. To do an effective sort, one needs a wide variety of comparison samples from all the sources and even then, the sort may not result in a reliable determination of the quarry.

CENOZOIC ERA

Several tool stone materials used in South Dakota were formed during the Cenozoic era, 65 mya to the present, and are found in South Dakota, North Dakota, Montana, Nebraska, Colorado, Wyoming, Idaho, and Oregon (Table 4 and Figure 20). Examples include Tongue River silica, porcellanite and non-vitreous natural glass, petrified wood, Knife River flint, Badlands plate chalcedony, White River group silicates, Short Pines and Bijou Hills quartzites, and obsidians.

Table 4. Tool stone associated with the Cenozoic era found at archaeological sites in South Dakota.

ERATHEM	SYSTEM	GENERAL LOCATION	GEOLOGIC DETAILS	TOOL STONE
CENOZOIC	QUARTERNARY and TERTIARY (?)	BEAR GULCH, IDAHO	PLEISTOCENE-HOLOCENE	BEAR GULCH OBSIDIAN
		YELLOWSTONE NATIONAL PARK, WYOMING	PLEISTOCENE: OBSIDIAN CREEK AND ROARING MOUNTAIN FORMATIONS (2ND and 3RD VOLCANIC CYCLES)	OBSIDIAN
	TERTIARY	SOUTH-CENTRAL SOUTH DAKOTA and NEBRASKA	PLIOCENE: OGLALLALA GROUP, BIJOU HILLS FACIES	BIJOU HILLS QUARTZITE
		LAKE and HARNEY COUNTIES, OREGON	MIOCENE-PLIOCENE: SIX MILE CREEK FORMATION (1ST VOLCANIC CYCLE)	OBSIDIAN
		EAST and WEST SHORT PINES in NORTHWESTERN SOUTH DAKOTA	OLIGOCENE-MIOCENE	SHORT PINES QUARTZITE
		COLORADO, MONTANA, WYOMING, NEBRASKA, and WESTERN SOUTH DAKOTA	EOCENE-OLIGOCENE: WHITE RIVER GROUP	WHITE RIVER GROUP SILICATES
		BADLANDS in SOUTHWESTERN SOUTH DAKOTA	EOCENE-OLIGOCENE: WHITE RIVER GROUP	BADLANDS PLATE CHALCEDONY
		DUNN and MERCER COUNTIES, NORTH DAKOTA	PALEOCENE-EOCENE: GOLDEN VALLEY FORMATION	KNIFE RIVER FLINT
		MONTANA, WYOMING, NORTH DAKOTA, and WESTERN SOUTH DAKOTA	PALEOCENE: FORT UNION GROUP	PETRIFIED WOOD
				PORCELLANITE
				NON-VITREOUS NATURAL GLASS
		MONTANA, WYOMING, WESTERN NORTH DAKOTA, and NORTHWESTERN SOUTH DAKOTA	PALEOCENE: CONTACT BETWEEN SLOPE FORMATION (AKA: LUDLOW FORMATION) and FORT UNION GROUP	TONGUE RIVER SILICA

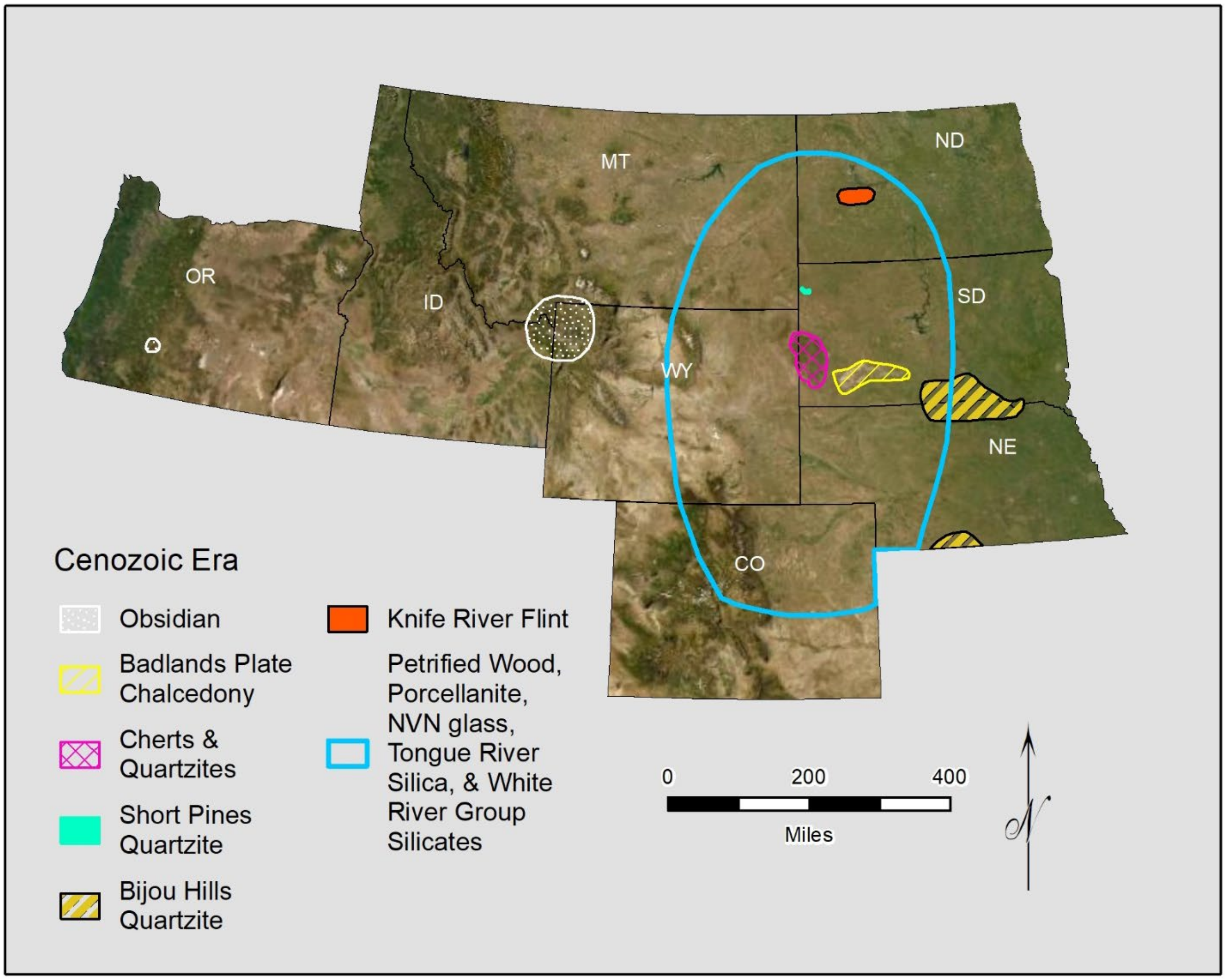


Figure 20. Tool stone associated with the Cenozoic era found at archaeological sites in South Dakota.

The earliest example is **Tongue River silica** (Figure 21), formed between the contact of the lower Slope formation and upper Bullion Creek formations, part of the Paleocene Fort Union group (Clayton et al. 1977). Sentinel Butte formation, just above the Bullion Creek formation in the Paleocene, contains major lignite beds. Where burned coal seams are present, **porcellanite** and **non-volcanic natural glass** forms in Montana, Wyoming, western North Dakota, and northwestern South Dakota. The topography in this region is made up of flat basins and erosion resistant mesa-like remnants capped with clinker. Porcellanite is easily accessible on these features (Fredlund 1976:207; Lageson and Spearing 1988:102).

Figure 21. Lag deposit of Tongue River silica found on the shoreline around Shadehill Reservoir in Perkins County, South Dakota. (Courtesy of USDI BOR DKAO.)

Petrified wood is found in the Tongue River member, the youngest member of the Fort Union formation that was deposited 66 to 56 mya during the Paleocene period. The Tongue River member ranges from not present to 425 feet thick. It consists of light-colored sandstones, siltstones, shales, and coals, with economically viable coal beds present towards the north in the Powder River and Williston Basins. The Tongue River member was deposited in a fluvial environment consisting of broad, meandering streams flowing across an alluvial floodplain. Sediment deposition occurred as vertical accretion and overbank deposits (levees and back swamps), channel-fill deposits, crevasse-splays, lateral accretion (point bar and channel bar deposits), and as channel lag deposits. Coal beds can be traced laterally for tens of kilometers and tend to grade into channel sands. They can also be found interbedded with shales.

Figure 22. Petrified wood found on the shoreline around Shadehill Reservoir in Perkins County, South Dakota. (Courtesy of USDI BOR DKAO.)

The sandstone of the Tongue River member can be classified as a feldspathic wacke, due to the high percentage of matrix supporting sub-rounded quartz, chert, calcite, and plagioclase grains. The sandstone tends to exhibit tabular or sheet geometries, and conglomerates can be found randomly distributed throughout sandstone beds. Outcrops or eroded cobbles occur along streams in Perkins, Harding, and Meade counties in western South Dakota, as well as other locations where the Tongue River member outcrops. Around the Bureau of Reclamation's Shadehill Reservoir in Perkins County, examples of petrified tree trunks and branches are exposed along the shoreline (Figure 22). North of Shadehill Reservoir, the town of Lemmon created the Petrified Wood Park and Museum with material collected from the local area to create spires, a small castle, and displays of large, petrified logs (Figure 23).

Figure 23. Petrified Wood Park in Lemmon, Perkins County, South Dakota. (Courtesy of USDI BOR DKAO.)

Knife River flint has never been observed in its original source but is believed to have formed in the hard siliceous bed in the upper member of the Eocene age Golden Valley formation, known as the Camels Butte member. This bed is only inches thick and consists of impure brown and gray siliceous rock. The Bear Den member lies below the Camels Butte member of the Golden Valley formation and consists of light to brightly colored kaolinitic strata. The Bear Den member can range from 5 to 65 feet thick and becomes more fine-grained and carbonaceous towards the top. The Camels Butte member reaches a maximum of 150 feet in thickness and consists of illitic to montmorillitic strata. These strata tend to be cross-bedded, predominantly sandy channel deposits or parallel-bedded overbank deposits. As a whole, the Golden Valley formation consists of scattered erosional remains that reach a maximum of 180 feet in thickness. It is primarily composed of claystone, mudstone, siltstone, micaceous sandstone, and scarce lignite and is interpreted as having been deposited in a fluvial environment. The uniform presence of mica in the sandstones is one of the diagnostic characteristics of the Golden Valley formation. Although commonly associated with alluvial slopewash and colluvial lag deposits from the Pleistocene age (Clayton et al. 1970), Knife River flint is rare or absent in glacial drift throughout South Dakota.

Knife River flint occurs in Dunn and Mercer counties along the Knife River in western North Dakota. It has been described as covering a broad area around the Lynch Knife River Flint Quarry that has been designated a National Register District: "…northwestern Dunn County west of the Killdeer Mountains…some 125 km to the south near White Butte in Slope County…north of Hazen in eastern Mercer County and from the eastern shoreline of Lake Sakakawea in McLean County near Riverdale" (Ahler and Christenson 1983:1-8). The White River group, including the lower Brule and upper Chadron formations, is formed from several Eocene to Oligocene sediments derived from Laramide uplifts to the west. Fine-grained, volcanic ash sediments that accumulated across the Northern Plains in the late Eocene to Early Miocene comprise much of the group. "The complex and variable diagenetic signature for the White River group can be attributed to shallow conditions, fluctuating groundwater table positions and groundwater fluxes, and the peculiarly volcanic ash-rich nature of the sediment" (Maher and Shuster 2012:168). The banding seen within the White River group is likely caused by paleosol development (Maher and Shuster 2012; Terry et al. 1988).

Vertical dikes formed in cracks when the Brule formation dried out after a rain event. These cracks can be several inches thick, and some were filled in with a sandy clay. Other cracks are veins of translucent, extremely fine-grained quartz. The thin gray plates are durable and known as **Badlands plate chalcedony**. The thicker dikes are known as **White River group silicates**, although technically, Badlands plate chalcedony is also part of the White River group silicates. These are often found in remnants of the White River group scattered across western South Dakota, including the Black Hills, northwestern Nebraska, and eastern Colorado and Wyoming. A wide range of colors have been observed, including pale orange, dark yellowish brown, and purples, depending on the local variations in surrounding rocks that have been incorporated into the material. Aside from these differences, the chalcedonies in the White River group are quite similar, regardless of their location of origin. Examples of identified quarries include the West Horse Creek Quarry (39SH37), Flattop Butte Quarry (5LO1), Flattop Mesa Quarry (5LO34), and Table Mountain Quarry in east-central Wyoming. A chalcedony and chert material have been found along French Creek in Custer County that are outwash deposits from the White River group (Figure 24).

Figure 24. Outwash deposits of White River group silicates can be found along stream beds outside the Black Hills. (Courtesy of RB.)

The White River group is overlain by the Arikaree group, which includes five formations and starts in the upper Oligocene and continues into the Miocene. The Arikaree group includes: "concretionary, cross-bedded, calcareous sandstones siltstones, concretionary, cross-bedded, calcareous sandstones, siltstones, silty claystones, tuffaceous beds, and carbonates, and caps several isolated buttes in southwestern North Dakota" (Hoganson et al. 2004).

Greenish gray **Short Pines quartzite** has been found out of context in both the East and West Short Pines in Harding County, South Dakota, but not yet discovered *in situ*. However, it is thought that it occurs in the Miocene-Oligocene geologic time frame.

Moving up the geologic time scale but west to Lake and Harney counties, Oregon, is **obsidian** which is associated with the Six Mile Creek formation in the Miocene and Pliocene periods (Robinson 1967). The Six Mile Creek formation, the uppermost unit of the Bozeman group, is composed of tuffaceous, ridge forming fanglomerate and shard-rich sandstone, stream silt, pond limestone, and the first cycle of air-laid rhyodacitic volcanic ash.

Crossing back east to the Great Plains along the Missouri River in south-central South Dakota, is the **Bijou Hills quartzite** (Figures 25-28). This material was formed in the Bijou facies of the Valentine and Ash Hollow formations of the Ogallala group during the upper Pliocene (Schoon 1957). The quartzitic sandstone was laid down as irregular layers in the Early Pliocene and likely cemented during the Late Pliocene. One of its strong characteristics is its distinctive green color, a result of glauconite trapped in volcanic ash deposits. It outcrops in Brule, Gregory, Tripp, and Charles Mix counties in southern South Dakota; Knox, Holt, Rock, Keya Paha, Brown, and Boyd counties in northern Nebraska; and throughout north-central to northwestern Kansas. The term Bijou Hills quartzite should be confined to only the material found in the Lower Ogallala formations. Although geologists in the 1950s tentatively identified small outcrops west of the Missouri River in Corson County, South Dakota, as Arikaree or Ogallala groups, these have since been identified as Upper Wisconsin outwash deposits. Green quartzites from these areas should not be called Bijou Hills quartzite, though they may be associated with the geologic formation producing the Short Pines quartzites. Bijou Hills quartzite has been recovered from cultural sites 39TP6 and 39TP7 in Tripp County, South Dakota.

Agnew's (1957:129) early research on Bijou Hills quartzite provides this description:

> Bijou quartzite or quarzitic sandstone is present irregularly at several stratigraphic positions within the lower Ogallala Valentine and Ash Hollow Formations. Although the original sediments are of Early Pliocene age, the cementing occurred probably during Late Pliocene time.
>
> The line of quartzite-capped buttes in southern South Dakota, which extends from Wood eastward to the Bijou Hills, is not the result of channel-filling of a pre-Ogallala stream; rather, it represents the south

escarpment of the valley of the post-Ogallala White River, cut into the Ogallala sediments that contain zones of Bijou quartzite facies.

Figure 25. Bijou Hills prehistoric quarry pit in the Iona Hills of Lyman County, South Dakota. (Courtesy of MB.)

Figure 26. Bijou Hills in southcentral South Dakota. (Courtesy of RB.)

Figure 27. Unknown modern mining activity (possibly glacial gravels or sand) in the Bijou Hills in southcentral South Dakota. (Courtesy of RB.)

Figure 28. Quarried landscaping block of Bijou Hills quartzite placed in Vermillion, Clay County, South Dakota. (Courtesy of MB.)

Wrapping up with the Quaternary period in Wyoming and Idaho are the second and third volcanic cycles that produced high quality **obsidians** during the Pleistocene and Holocene epochs. The most common source of prehistorically used and traded obsidian on the Northern Plains is from the Obsidian Creek and Roaring members of the Plateau Rhyolite unit, known as Obsidian Cliff in Yellowstone National Park, Wyoming. The Plateau Rhyolite unit includes the better-known Obsidian Cliff and the lesser-known Cougar Creek obsidians (MacDonald et al. 2019) (Figures 29-31). Two other sources in the northwestern United States, associated with the late Pleistocene and early Holocene, include Teton Pass south of Jackson Hole, Wyoming and the Bear Gulch, Idaho sample (called the FMY or 90 Group) at the Chicago Field Museum, cataloged at the museum as "Yellowstone". Neutron activation analysis in the 1960s did not support a Yellowstone origination of the FMY/90 Group sample, now identified as Bear Gulch, located southwest of Obsidian Cliff. Bear Gulch obsidian occurs in alluvial fan deposits that also date to the Pleistocene and Holocene age (Hughes and Nelson 1987:313). Hughes and Nelson (1987) suggest that the parent source exists to the north in the Centennial Mountains of Idaho.

Figure 29. Obsidian Cliff in Yellowstone National Park, Wyoming, 2020. (Courtesy of DW.)

Figure 30. Another view of Obsidian Cliff in Yellowstone National Park, Wyoming. (Courtesy of MB.)

Figure 31. Lava flow frozen in time, Obsidian Cliff in Yellowstone National Park, Wyoming. (Courtesy of MB.)

To round out the discussion of obsidian sources requires referencing the oldest Precambrian core of the central Black Hills. **Pitchstone**, a poor-quality material that does not represent true obsidian, was created in volcanic tubes found in internal fractures of the central Black Hills. Examples have been collected from the Tomahawk Country Club in Lawrence County, South Dakota, which may be 10 million years old (Raventon 2003). The authors of this guide are only aware of fragments of poor-quality pitchstone collected at the Tomahawk Country Club by the late State Archaeologist, Dr. Robert Alex, and added to the lithic comparative collections at the Archaeological Research Center. Finally, outwash from the Black Hills deposited in the Badlands, occasionally include cobbles of high-quality obsidian. Examples have been collected at cultural site 39PN746 and are stored at the Archaeological Research Center's repository on behalf of the US Department of Agriculture. To date, no examples of high-quality primary source obsidian have been found in context within the Black Hills.

RAW MATERIAL DEFINITIONS

Standard definitions for rocks and minerals discussed in this guide are quoted from Whitten and Brooks (1975), with additional information from Gunderson and Tiffany (2020), Merriam-Webster Dictionary (2020), and Hudson Institute of Minerology (2020).

Whitten and Brooks (1975):

Agates. Banded chalcedonic silica.

Argillite (Argillaceous rocks). A group of detrital sedimentary rocks, commonly clays, shales, mudstones, siltstones, and marls. In addition to the clay minerals, argillaceous rocks may contain colloidal material, very finely divided quartz, carbonate dust, finely divided carbon, and iron pyrites. The latter two minerals are characteristic of rocks formed under anaerobic conditions. Argillaceous rocks are almost always laid down in water, either fresh, brackish, or marine environments. Their minerology is to some extent controlled by their environment of deposition. General types include clay, shale, mudstone, siltstones, and marl.

Pipestone. Special types include ball or pipe clay.

Gunderson and Tiffany (2020):

Catlinite. A red clay associated with Sioux quartzite on the Northern Plains.

Whitten and Brooks (1975):

Chalcedony. A cryptocrystalline variety of silica, consisting essentially of fibrous or ultrafine quartz, some opal, together with water, which is either enclosed in the lattice or in the macrostructure of the mineral. It is possible that some of the quartz has oxygen ions replaced by hydroxyl ions. Chalcedony can be incredibly diverse in appearance with banded varieties such as agate, onyx, and sardonyx. Reddish or brownish varieties are called sard or carnelian, while green varieties are called prase or chrysoprase. Chalcedony is usually regarded as a low-temperature material, occurring mainly in sediments, low-temperature hydrothermal veins, and as an amygdale filling. Several varieties of chalcedony are used as semi-precious stones.

Jasper is a red chert-like variety of chalcedony.

Chert. Cryptocrystalline silica which may be of organic or inorganic origin. It occurs as bands or layers of nodules in sedimentary rocks. It can be a primary deposit, sometimes formed by the confluence of disseminated silica in a rock, or a secondary replacement material. Some cherts from geosynclinal deposits contain abundant radiolaria (Protozoa) and are sometimes called radiolarites; these probably represent deep-water accumulations.

Flint is the variety of chert occurring primarily in the Upper Cretaceous and as detrital pebbles in the Tertiary. It has a conchoidal fracture, as opposed to the flat fracture of chert. Lyddite (Lydian stone) is a dense black variety of chert, formerly used as a touchstone.

Touchstone: A hard, black, very fine-grained stone (basalt or chert, notably Lyddite) used for determining the fineness (i.e. the purity) of gold and silver. The method involves comparing the streak of a gold or silver object of unknown purity on the touchstone with the streak produced by gold or silver specimens of known fineness (touch needles).

Obsidian (Rhyolite). Fine-grained to glassy acid volcanic rocks. Mineralogically they are similar to granites and microgranites, although chemically they appear somewhat richer in silicon dioxide (SiO2). Occasionally quartz in rhyolites is replaced by the high-temperature beta-form, and very rarely by tridymite or cristobalite. Ferromagnesian minerals are less obvious than in the corresponding plutonic rocks. Rhyolites in the strict sense are divided into sodic and potassic forms, according to the type of feldspar present. Glassy rocks of the acid group are termed obsidian or pitchstone. Obsidian is a black, wholly glass rock and displays a conchoidal fracture; pitchstone is a glass rock which contains a much higher proportion of crystallites and displays a flatter fracture. It may be black, dark gray, red, or brown. Phenocrysts are often present.

Pitchstones are unusual in that they commonly occur as dykes as well as lava flows. Both obsidian and pitchstone may show the beginnings of devitrification by the formation of radiating masses of crystals called spherulites (hence 'spherulitic pitchstone'). Progressive devitrification of these glassy rocks produces felsites. If the initial process of devitrification gives rise to spherulites, a spherulitic rhyolite or variolate may result, which should be carefully distinguished from an amygdaloidal rhyolite. If the amygdales are filled with quartz, the materials will have a superficially similar appearance. Many rhyolites show well-marked flow textures and structures.

Non-volcanic Natural Glass.[1] The word glass is used in geology specifically for rocks or parts of rocks which do not consist of discrete crystalline units and are wholly without crystalline structure. Complete melting of sediments by thermal metamorphism is rare, but the natural silica glass, lechatelierite, has been recorded.

[1] In this case, non-volcanic natural glass is used to describe material formed in burning coal seams, creating a glass-like material that is non-volcanic in nature.

Petrified Wood (Fossil). An organic material buried by natural processes, and subsequently permanently preserved. With hard parts altered by petrification, the infilling of pore spaces in shells, cellular plant material, or bones, by one of several substances (e.g., silica, calcite, limonite, pyrite, etc.), or by replacement, either coarse or molecular, of the original skeletal material by either similar or different substances (e.g., calcareous shells may be replaced by crystalline calcite or by silica). Coarse replacement destroys fine detail while molecular replacement preserves it.

Merriam-Webster Dictionary (2020):

Porcellanite. A hard and dense siliceous rock having the appearance of unglazed porcelain on fresh fractures.

Hudson Institute of Minerology (2020):

Porcellanite. It is less tough, dense, and vitreous than chert. An indurated or baked clay or shale often found in the roof or floor of a burned-out coal seam.

Whitten and Brooks (1975):

Quartz. Common quartz (or low quartz) is stable up to 573 degrees Centigrade and is a common mineral in all kinds of rocks and mineral veins. Crystallographically, quartz is trigonal trapezohedral. When quartz crystals occur showing trapezohedral faces, a division can be made into left-handed and right-handed according to the position of the indicator faces. A characteristic feature of quartz is the absence of cleavage and the presence of a well-developed conchoidal fracture. Quartz serves as the standard for hardness 7 on Mohs scale.

Quartzite. The constituent grains re-crystallize and develop an interlocked mosaic texture, with little or no trace of cementation. Impurities in the original rock may give rise to metamorphic minerals, for example argillaceous impurity will yield chlorite or biotite while calcite may give wollastonite. Quartzites are usually thought of as thermally metamorphosed rocks, but regional metamorphism will produce an orientated fabric which distinguishes them from the thermally metamorphosed kinds. Under intense regional metamorphism, a quartz schist may develop.

Orthoquartzite: arenaceous rocks.

Metaquartzite: a metamorphosed arenaceous rock.

Silicates. Silicates are the most important group of compounds occurring in the crust of the Earth, and probably make up 95 percent of the crust (if one counts the silica group, SiO_2, as a silicate). They are classified according to their atomic structure. As listed in the table overleaf, the various structures may be regarded as being derived from a tetrahedral unit, SIO4, by linking them together with the elimination of an oxygen at each linkage.

RAW MATERIAL DESCRIPTIONS

The material descriptions are organized by chert, chalcedony, quartzite, and other (Table 5). Within each category the materials are sorted alphabetically by the name preferred by the authors.

Table 5. Order of tool stone descriptions.

MATERIAL TYPE	GENERAL LOCATION
CHERT	
Ferruginous	Black Hills Uplift
Minnelusa	Black Hills Uplift
Mississippian	Black Hills Uplift
Paha Sapa	Black Hills Uplift
Spanish Diggings	Hartville Uplift
Spearfish	Black Hills Uplift
Swan River	Northern Great Plains
CHALCEDONY	
Knife River Flint	Dunn and Mercer Counties, North Dakota
Morrison	Black Hills Uplift
Plate	Badlands, South Dakota
Petrified Wood	Western and Northwestern Great Plains
White River Group Silicates	Western and Northwestern Great Plains
QUARTZITES	
Battle Mountain	Black Hills Uplift
Bijou Hills	South Central South Dakota and North Central Nebraska
Deadwood	Black Hills Uplift
Flint Hill	Black Hills Uplift
Lakota	Black Hills Uplift
Minnelusa	Black Hills Uplift
Morrison	Black Hills Uplift
Short Pines	Northwestern South Dakota
Sioux	Southeastern South Dakota and Southwestern Minnesota
Spanish Diggings	Hartville Uplift
Tongue River Silica	Western and Northwestern Great Plains
OTHER	
Catlinite and Red Pipestone	Southeastern South Dakota and Southwestern Minnesota
Obsidian	Wyoming, Montana, Idaho, and Oregon; low quality material in Western South Dakota
Porcellanite and Non-volcanic Natural Glass	Western and Northwestern Great Plains
Precambrian Quartz	Black Hills Uplift

FERRUGINOUS CHERT

OTHER NAMES: Precambrian chert

MUNSELL COLORS: Very dusky red 10R 2/2; Grayish brown 5YR 3/2; Dark reddish brown 10R 3/4

Quarries	None identified	**Diagnostics**	Deep reddish-brown color and bluish white veins
Cortex	Moderately rough texture with a pitted appearance. Few examples with cortex have been found, thus this is a preliminary description.	**Fracture Quality**	Good except where the quartz inclusions occur, then breakage occurs around the inclusions, creating a low-profile, ripple-like surface
Grain	Very fine to medium	**Color**	Dark reddish brown and tans, only the reddish-brown material was available for checking against a color chart

Ferruginous chert is a dark reddish brown or tan metamorphic rock with visible relic bedding planes or flow lines (Figures 32 and 33). It may be banded and interspersed with bluish-white quartz inclusions or, occasionally, a vein of quartz may be present (Figure 34). The cortex may present as a rough texture (Figure 35). The striking feature of this material is its consistent color and homogeneity. Typically, it has low to moderate reflectivity. Samples that are highly reflective may have been heat treated. Samples were examined from Black Hills sites 39PN107 (Accession 86-122), 39PN219 (Accession 88-0109), and 39PN270 (Accession 78-0281). Other examples have also been identified in excavated collections from 39PN90 (Accession 77-296) and 39PN96 (Accession 86-113), among other sites. Some flakes selected for photography exhibit nibbling or fine retouch along the edges (Figure 36). Ferruginous chert is thought to originate in the Precambrian central core of the Black Hills (Tratebas 1986), although the material has never been found *in situ* (Figure 37).

Figure 32. Ferruginous chert flakes. (Artifacts were photographed courtesy of the USDA FS BKNF.)

Figure 33. Modified ferruginous chert flake; note the flow banding. (39PN219, Accession 88-0109, Catalog #0001-12) (Artifact was photographed courtesy of the USDA FS BKNF.)

Figure 34. Ferruginous chert flake; note the quartz vein. (39PN107, Accession 86-0122, Catalog #0001-2) (Artifact was photographed courtesy of the USDA FS BKNF.)

Figure 35. Modified ferruginous chert flake; note the rough cortex. (39PN219, Accession 88-0109, Catalog #12) (Artifact was photographed courtesy of the USDA FS BKNF.)

Figure 36. Modified ferruginous chert flake. Edges exhibit nibbling and a small worked concave area (spokeshave). Note the breakage around quartz inclusions, giving it a rough texture. (39PN107, Accession 86-0122, Catalog #0001-3). (Artifact was photographed courtesy of the USDA FS BKNF.)

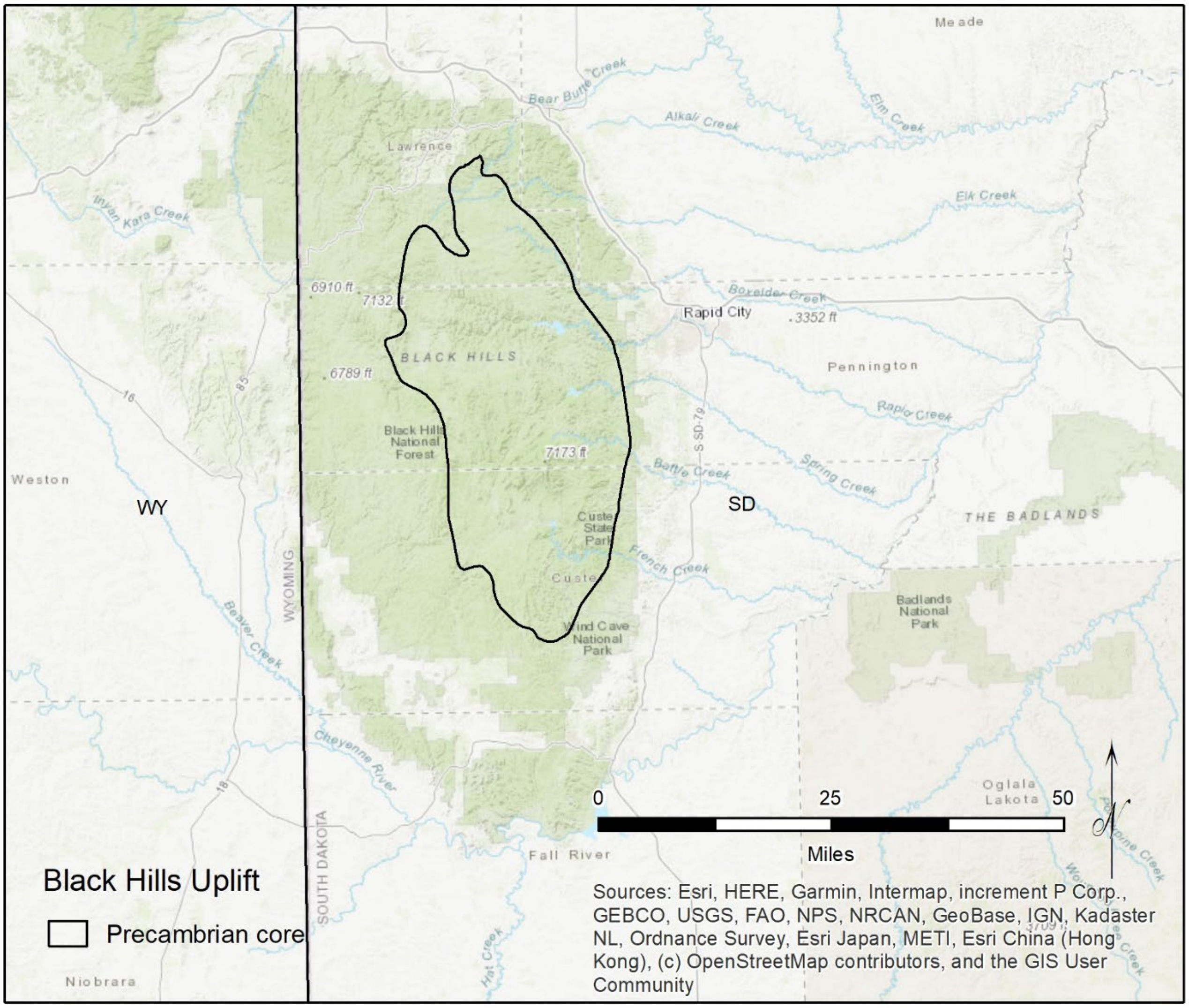


Figure 37. Ferruginous chert is thought to originate in the Precambrian core of the Black Hills Uplift.

MINNELUSA CHERT

OTHER NAMES: Black Hills chert

MUNSELL COLORS: *Minnelusa chert*: Light gray N7; Medium gray N5:
Moderate reddish orange 10R 6/6; Pale red 5R 6/2; Moderate red 5R 5/4; Grayish red 5R 4/2;
Very pale orange 10YR 8/2; Grayish orange pink 5YR 7/2; Light olive gray 5Y 6/1; Brownish gray 5YR 4/1;
Tepee Canyon Agate: Dark yellowish brown 10YR 4/2; Pale brown 5YR 5/2

Quarries	39LA138, 39LA259-Mega-Quarry, 39LA259, and 39LA345, Lawrence County; and 39MD29, Meade County; South Dakota	**Diagnostics**	Banding tends to be much wider than what appears in the Paha Sapa cherts
Cortex	White to gray, rough, dull luster	**Fracture Quality**	Good
Grain	Fine, banded, mottled, solid with veins or quartz inclusions	**Color**	Gray, red, orange, green, brown, yellow

Minnelusa cherts are highly variable, can be banded, mottled or solid with veinlets or quartz inclusions, and can be almost any color (Figure 38-40). Some have a jasper-like or Knife River flint-like appearance and will spark. Thus, they are not only cherts but flint stones as well. It may be that this was one reason this material was collected by prehistoric groups. Banding tends to be much wider than what appears in the Paha Sapa cherts. Overall, its conchoidal fracturing quality appears to be better than the Paha Sapa cherts although the veinlets and quartz inclusions interfere with its usefulness as a stone tool material. Tratebas (1986) notes that quartzite can occur in the same nodule with chert in the Minnelusa formation. Minnelusa cherts occur as nodules, concretions, or sometimes as layered deposits; color, luster, and knapping quality vary widely among samples from the Black Hills area.

Among the materials from the Minnelusa formation are the Tepee Canyon agates. Although the rock collector's variety of agates occur in the area west of Custer, other agates occur outside of this area as nodules that contain a chert or jasper in a yellowish-brown color between the rind and the central core (Figures 41-43). Teepee Canyon agates have a dull luster and good conchoidal fracturing quality. The central core of the nodule is in the very pale orange color range and is not of knapping quality (Figure 44). Minnelusa chert occurs in the Pennsylvanian age Minnelusa formation of the Black Hills Uplift (Figure 45).

Figure 38. Minnelusa chert from near site 39LA259 in Lawrence County, South Dakota.

Figure 39. Minnelusa chert from near site 39LA259 in Lawrence County, South Dakota.

Figure 40. Minnelusa chert from near site 39LA259 in Lawrence County, South Dakota.

Figure 41. Teepee Canyon chert.

Figure 42. Closeup of Teepee Canyon chert.

Figure 43. Teepee Canyon chert.

Figure 44. Teepee Canyon chert interior.

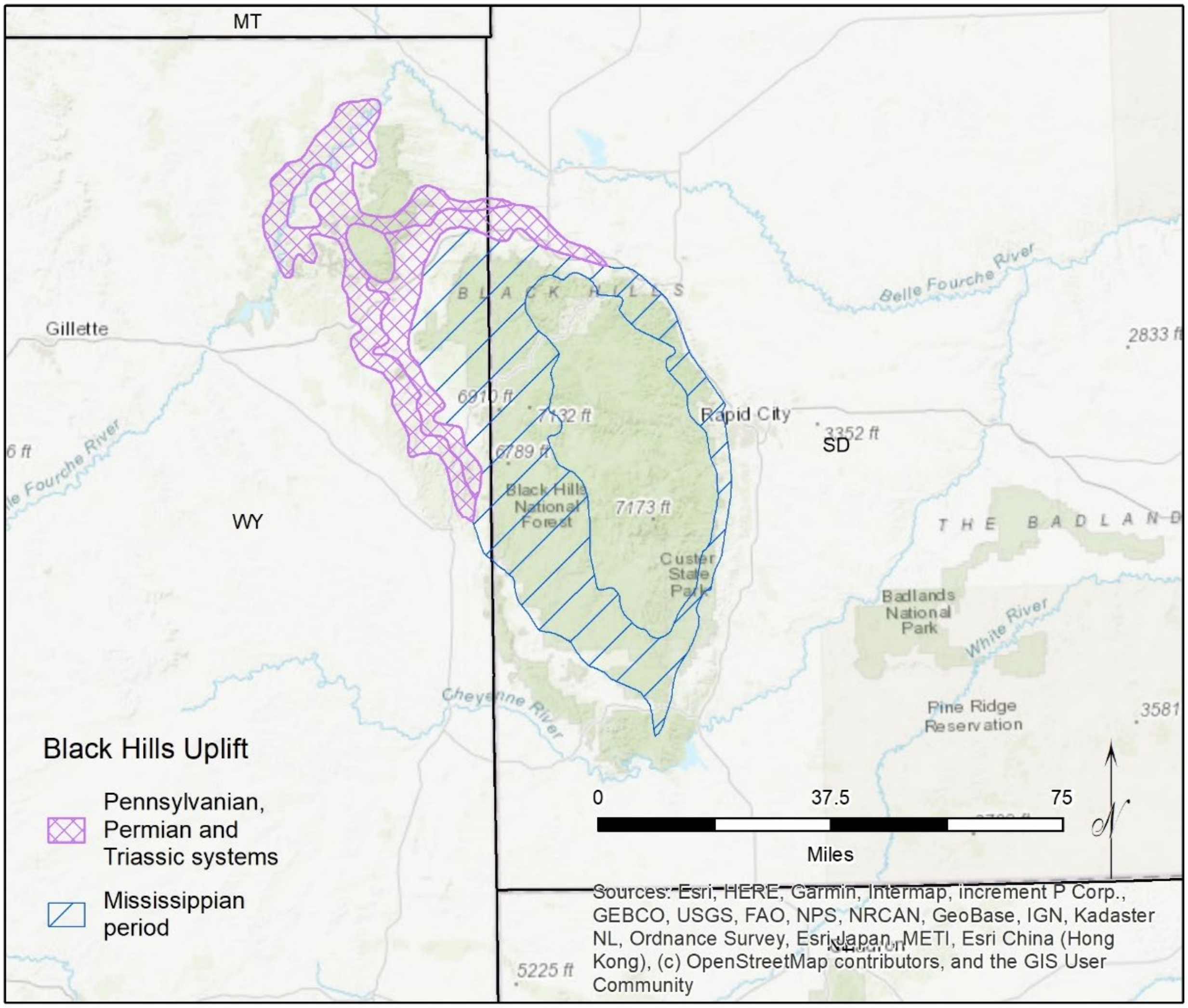


Figure 45. Generalized geology map showing the Mississippian, Pennsylvanian, Permian, and Triassic age layers in the Black Hills Uplift. Minnelusa chert and Teepee Canyon agates originate in the Permian age geologic deposits. However, because this geology map is generalized, the Permian age deposits located within the Mississippian period deposits are not represented on the map.

MISSISSIPPIAN CHERT

OTHER NAMES: None

MUNSELL COLORS: Dark yellowish orange 10YR 6/6; Grayish red 5R 4/2; Dark gray N3; Dark reddish brown 10R 3/4

Quarries	None identified	**Diagnostics**	Distinctive caramel and red color and the black dendritic inclusions
Cortex	White to gray, rough, dull luster, cobbles can be pitted and tumbled smooth	**Fracture Quality**	Good
Grain	Fine	**Color**	Caramels and reds

Mississippian chert is a caramel to red colored chert with black dendritic inclusions (Figures 46-48). The dendrites are believed to develop in limestone bedding planes when a solution containing manganese spreads out as liquid tendrils. The dendrites form quickly when the liquid dries, creating the tendrils with the limited amount of manganese available, instead of a sheet deposit. In its final form, the fractal patterns of the fast mineral growth are preserved (Cordua 2020). Although examples of cobbles have been found in various locations in the Black Hills (Figure 49), the material has never been found *in situ*. However, it is thought to be associated with the Mississippian age limestones in the Black Hills Uplift (Figure 50).

Figure 46. Mississippian chert flake. (39CU750, Accession 86-0208, Catalog #01-12) (Artifact was photographed courtesy of the USDA FS BKNF.)

Figure 47. Mississippian chert endscraper. (39CU12, Accession 86-0039, Catalog #0001-6) (Artifact was photographed courtesy of the USDA FS BKNF.)

Figure 48. Mississippian chert from Pennington County, South Dakota. Cortex is shown on the left example.

Figure 49. Mississippian chert cobble from Fall River County, South Dakota.

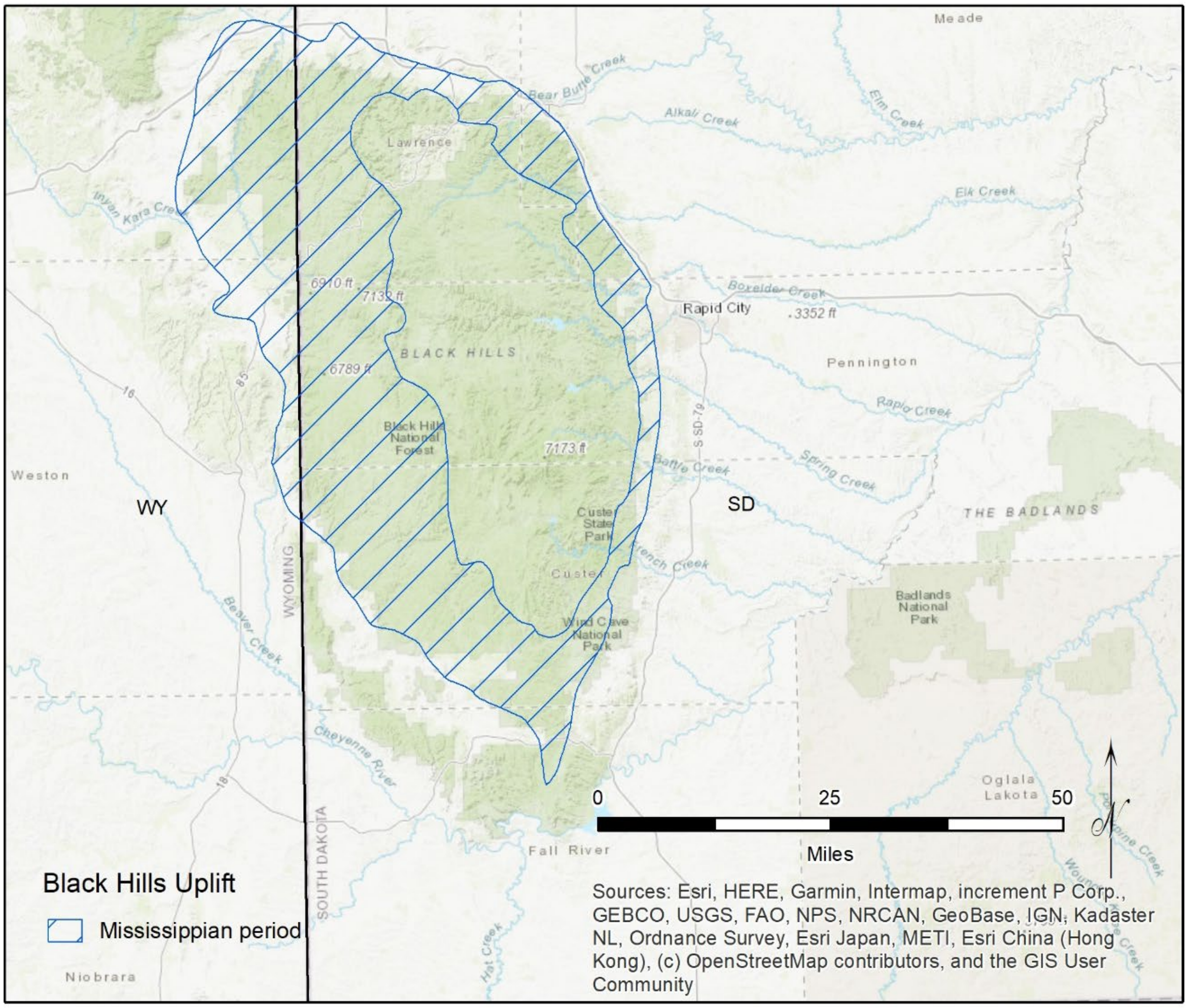


Figure 50. *In situ* deposits of Mississippian chert have not been found in the Black Hills, however, they are thought to originate in the Mississippian age deposits of the Black Hills Uplift.

PAHA SAPA CHERT

OTHER NAMES: Black Hills chert

MUNSELL COLORS: Dark yellowish orange 10YR 6/6; Pale yellowish brown 10YR 6/2; Very pale orange 10YR 8/2; Moderate yellowish brown 10YR 5/4; Moderate reddish brown 10R 4/6; Light brown 5YR 6/6; Moderate brown 5YR 3/4; Grayish brown 5YR 3/2; Dusky yellow 5Y 6/4; Moderate olive brown 5Y 4/4; Medium dark gray N4

Quarries	Many, including 39LA139, Lawrence County, South Dakota	**Diagnostics**	Vugs, oolites, dendrites
Cortex	Yellow, brown, red, white, gray, coarse, waxy, dull	**Fracture Quality**	Poor to good
Grain	Very fine to medium	**Color**	Wide range of colors, including light gray to tan, red, and orange, weathers to black

Paha Sapa cherts have a very fine-grained texture and exhibit micro-fracturing. They have a tan opaque crystal structure and can exhibit magnetitic or hematite-related black feathery or dendritic inclusions. Weathered surfaces are pock-marked, have a clay like appearance, and may present a white patina. Paha Sapa chert has a wide range of colors that may be solid or semi-translucent, have narrow banding, and oolitic or dendritic inclusions. Samples photographed are from site 39LA138 (Figures 51-57). The Mississippian age Paha Sapa limestone is a prominent formation in the Black Hills Uplift and consists of a light gray to tan limestone or dolomite. Two National Parks, Jewel Cave and Wind Cave, were established around some of the most prominent cave systems in this formation (Gries and Martin 1985:269). The Paha Sapa chert occurs in beds or lenses in the Paha Sapa limestones of the Black Hills Uplift (Figure 58).

Figure 51. Paha Sapa chert from near site 39LA138, Lawrence County, South Dakota

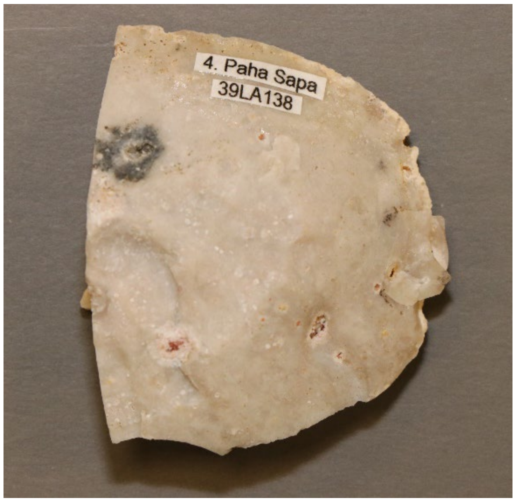


Figure 52. Vugs and oolitic inclusions in Paha Sapa chert.

Figure 53. Example of cortex on Paha Sapa chert.

Figure 54. Oolitic inclusions in Paha Sapa chert.

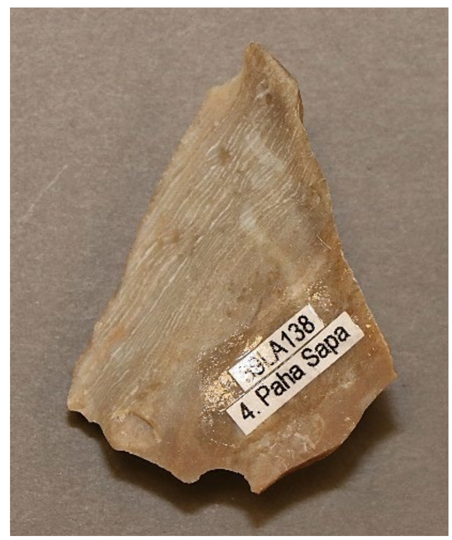


Figure 55. Narrow banding in Paha Sapa chert.

Figure 56. Paha Sapa chert sidescraper and perforator. (39CU12, Accession 86-0039, Catalog #0001-31) (Artifact was photographed courtesy of the USDA FS BKNF.)

Figure 57. Paha Sapa chert graver and retouched flake. (39CU12, Accession 86-0039, Catalog #0001-13) (Artifact was photographed courtesy of the USDA FS BKNF.)

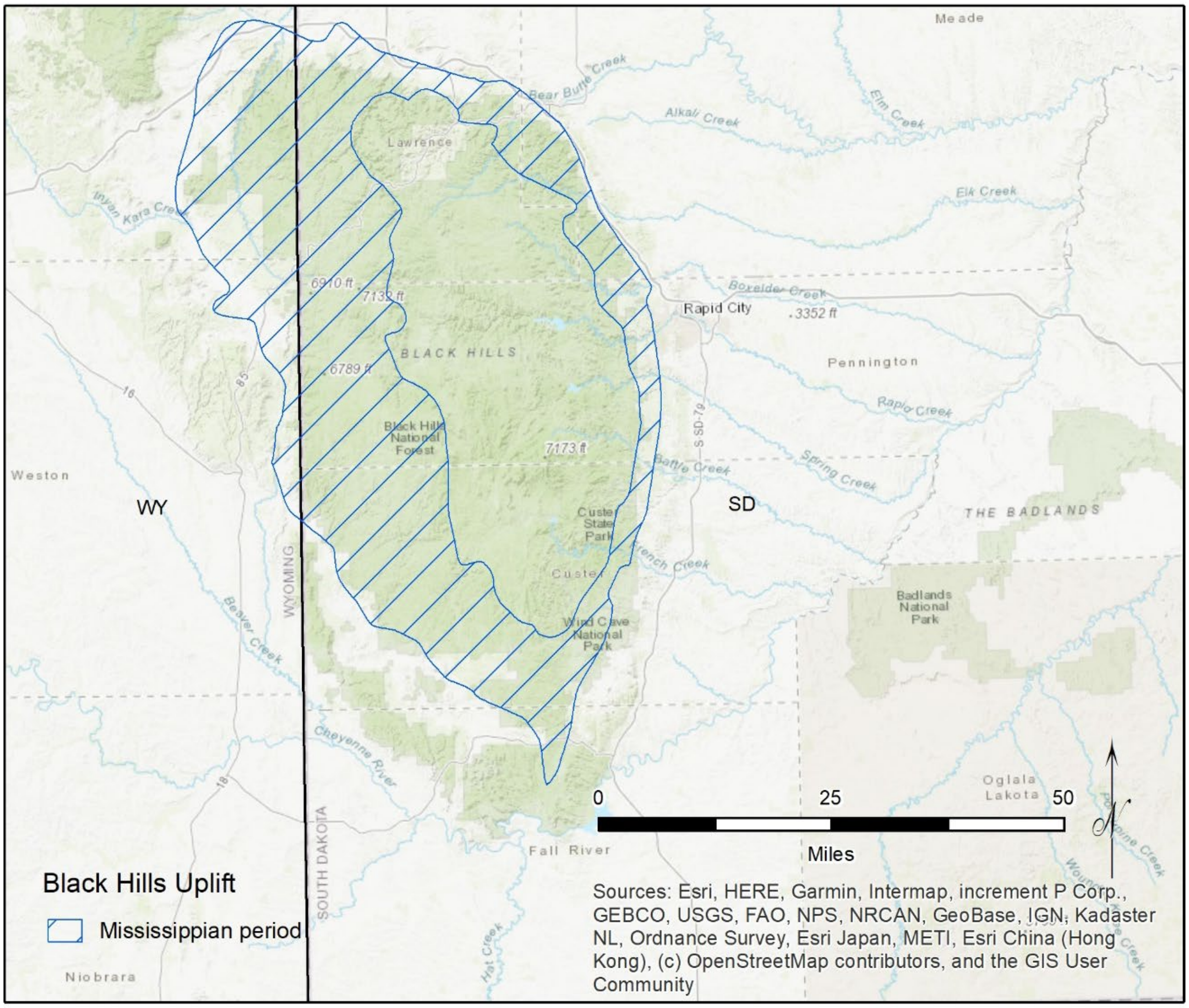


Figure 58. Paha Sapa chert originates in the Mississippian age deposits in the Black Hills Uplift.

SPANISH DIGGINGS CHERT

OTHER NAMES: None

MUNSELL COLORS: Olive black 5Y 2/1; Light olive gray 10YR 5/4; Brownish black 5YR 2/1; Moderate brown 5YR 4/4; Dark yellowish brown 10YR4/2; Moderate yellowish brown 10YR 5/4; Dark yellowish orange 10YR 6/6; Grayish orange 10YR 7/4

Quarries	Saul Quarry #9, Platte County, Wyoming	**Diagnostics**	Distinctive caramel color with black dendritic inclusions
Cortex	White, yellow, gray, waxy	**Fracture Quality**	Good
Grain	Fine	**Color**	Yellowish orange, red, brown, black inclusions

Spanish Diggings chert is a very fine-grained material that exhibits micro-fracturing. It has a tan opaque crystal structure with a weathered white patina on surface exposures. The material is noted for its hematitic or magnetitic black feathery or dendritic inclusions against a caramel-colored background (Figures 59-64). It occurs in the Guernsey formation on the western side of the Hartville Uplift in Wyoming and correlates to the Paha Sapa formation in the Black Hills Uplift (Figure 64).

Figure 59. Spanish Diggings chert, Saul Quarry #9, Platte County, Wyoming.

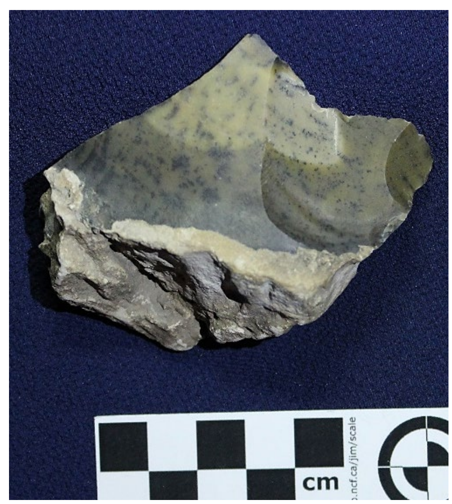


Figure 60. Spanish Diggings chert flake, Niobrara County, Wyoming, on the west side of the Hartville Uplift.

Figure 61. Spanish Diggings chert endscraper, Niobrara County, Wyoming, on the west side of the Hartville Uplift.

Figure 62. Spanish Diggings chert projectile point, possibly from Niobrara County, Wyoming.

Figure 63. Spanish Diggings chert blank or preform, Niobrara County, Wyoming, on the west side of the Hartville Uplift.

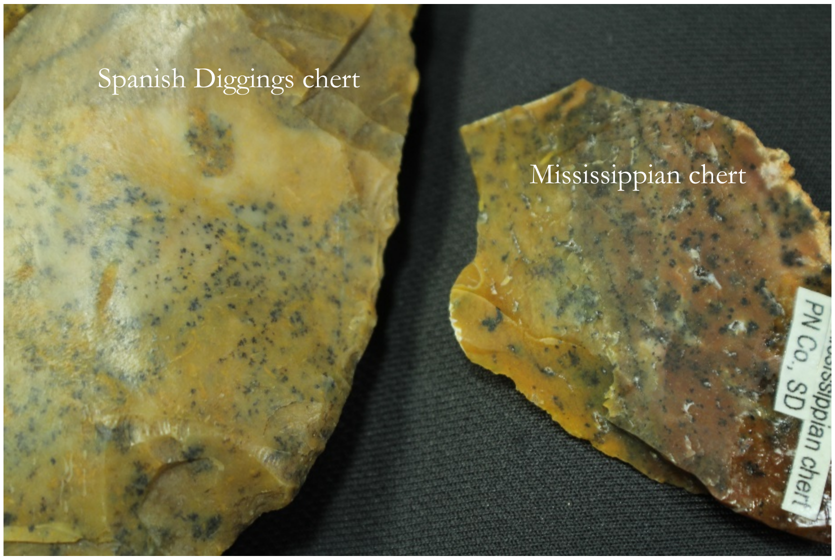


Figure 64. Comparing Spanish Diggings chert from Wyoming on the left and Mississippian chert from South Dakota on the right.

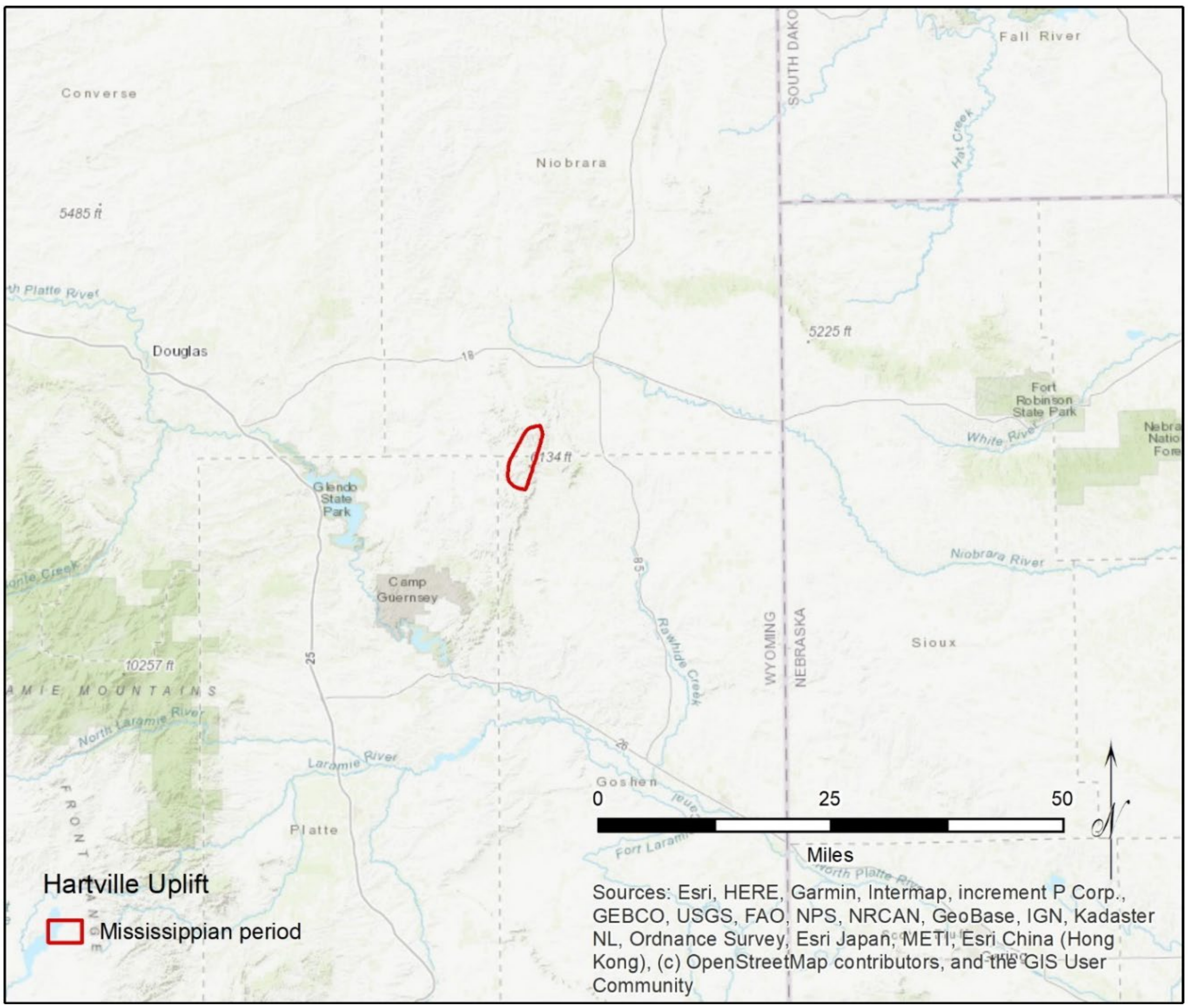


Figure 65. Spanish Diggings chert occurs in the Guernsey formation in the Hartville Uplift, eastern Wyoming.

SPEARFISH CHERT

OTHER NAMES: Black Hills chert, Gypsum Springs chert, Fine purple chert

MUNSELL COLORS: *Type 1*: Light gray N7; Medium light gray N6; Medium gray N5; Grayish purple 5P 4/2; Grayish red purple 5RP 4/2; Pale red purple 5RP 6/2; Pale blue 5PB 7/2; *Type 2*: Grayish red 5R 4/2; Pale red 5R 6/2

Quarries	39CU231 (Type 1) and 39CU1145 (Type 2), Custer County, South Dakota	**Diagnostics**	Type 1 – excellent conchoidal fracturing, red to purple in color, spherical to elliptical nodules Type 2 – white bedding, rough conchoidal fracturing, irregular nodules, rectangular-shaped pits
Cortex	White to off-white or yellow, coarse, can be thick or thin	**Fracture Quality**	Type 1 – Excellent Type 2 – Good
Grain	Very fine to medium	**Color**	Red, maroon, purple, yellow, buff, tan, with white bedding

Although other Black Hills cherts have a wide range of colors and exhibit various flaking qualities, Spearfish chert is distinct and exhibits a consistent fracturing quality between the two source locations (39CU231 and 39CU1145) found in the Spearfish formation. The material has been divided into Types 1 and 2 (Williams 1992) (Figure 66). Both types are a microcrystalline chert that formed in gypsum beds. The gypsum contains feldspar which has a rectangular cleavage. When exposed to the atmosphere, the feldspar weathers quickly to clay which then weathers out, leaving behind a telltale rectangular pit. These rectangular-shaped weathered pits are diagnostic of this material and can be found in Types 1 and 2, however, they may not be present in every example. Both types also exhibit vugs infilled with calcite crystals that sometimes have a chalk-like appearance. Spearfish chert is one of the few identifiable cherts in the Black Hills, when found in an archaeological context. Traits specific to each type are described below.

Type 1 consists of large regular, spherical to elliptical shaped nodules found in massive gypsum beds (Figures 67 and 68). The nodules tend to be mottled red to purple and white with lenticular bedding. Knapping quality is excellent, producing a clean conchoidal fracture. The cortex often exhibits spalls that resemble pot lid fractures seen on heat-treated stones. These are the result of weathering and should not be confused with heat treatment.

Type 2 consists of irregular nodules, smaller than the Type 1, found in the lenticular or slabby limestone above the massive gypsum beds (Figure 69). Colors include maroon, red, yellow, buff, and tan; the weathered surface is somewhat lighter than the interior. The knapping quality of Type 2, which produces a rough conchoidal fracture, is usually inferior to Type 1, but is still considered good.

Spearfish chert is found in the Spearfish formation (Permian to Triassic), which encircles the Black Hills (Figure 70). The Spearfish formation consists of red shale and siltstone, and white gypsum and minor limestone. Samples of Spearfish chert have been collected from two locations in southwestern Custer County, sites 39CU231 and 39CU1145. At 39CU231, the chert outcrop occurs from 3 meters to 5 meters below the limestone rimrock overlooking Tepee Canyon Creek. The other outcrop sampled is on a low ridge within the site boundary of 39CU1145, southwest of Gillette Canyon. It is located near the South Dakota-Wyoming border on the northeastern toe-slope of the Elk Mountains, below the Elk Mountain Lookout tower. This low ridge is capped with gypsum of the Spearfish formation and the chert-bearing stratum occurs below the crest in the central portion of the archaeological site. The chert is exposed on the surface at the northwestern end of the ridge.

Figure 66. Spearfish chert from Custer County in the Black Hills Uplift, South Dakota.

Figure 67. Gypsum rind on a Type 1 Spearfish chert from Custer County in the Black Hills Uplift, South Dakota.

Figure 68. Interior of a Type 1 Spearfish chert from Custer County in the Black Hills Uplift, South Dakota.

Figure 69. Type 2 Spearfish chert from Custer County in the Black Hills Uplift, South Dakota. Note the diagnostic rectangular vugs (red arrows) in the close-up of the reverse side of this sample.

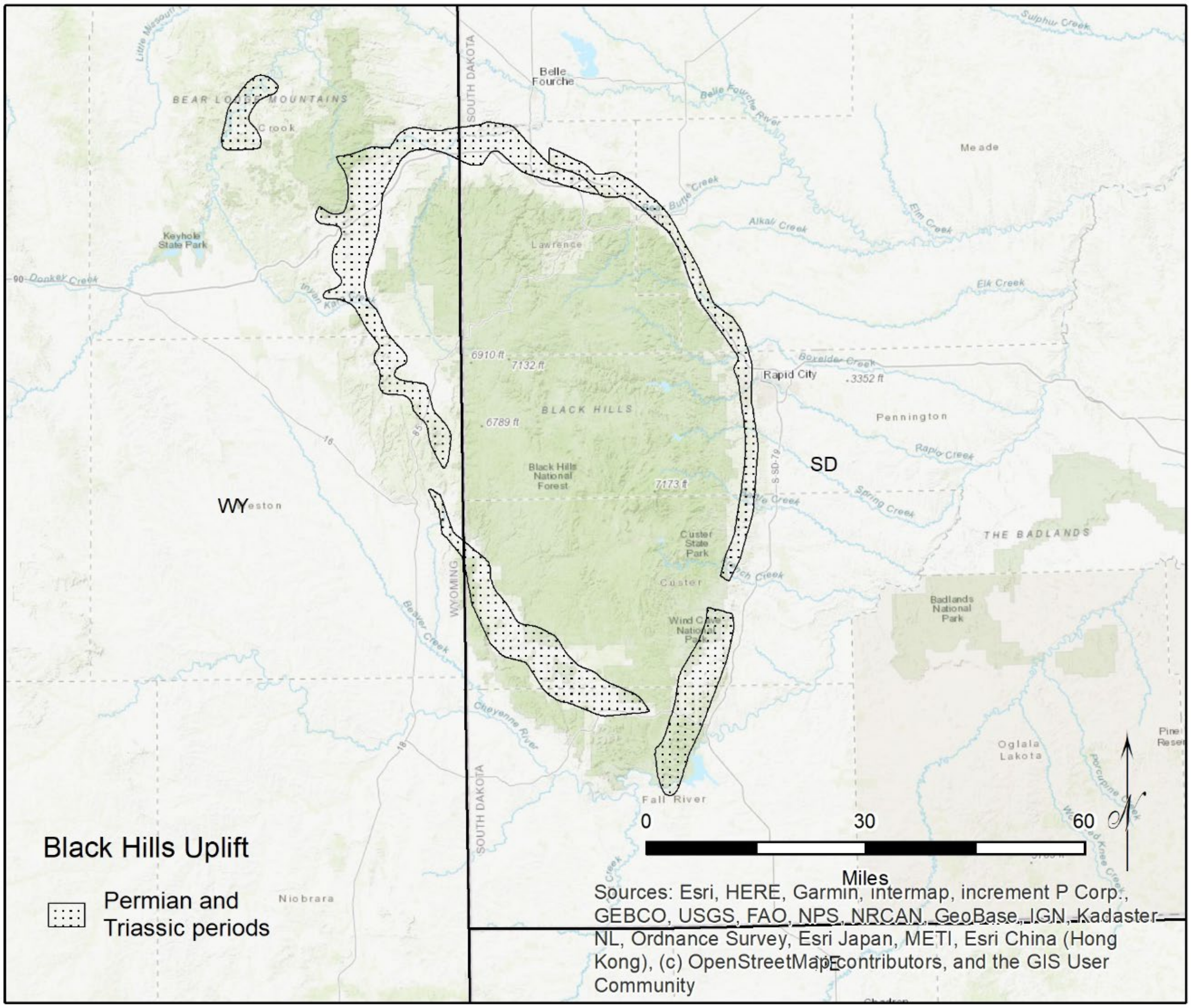


Figure 70. Geology map showing the Permian and Triassic age layers in the Black Hills Uplift, South Dakota and Wyoming. Spearfish chert originates in Spearfish formation within these deposits.

SWAN RIVER CHERT

OTHER NAMES: None

MUNSELL COLORS: Medium gray N5; Medium light gray N6; Pale yellowish orange 10YR 8/6; Very pale orange 10YR 8/2; Pale yellowish brown 10YR 6/2; Pale olive 10Y 6/2; Moderate orange pink 5YR 8/4; Grayish orange pink 5YR 7/2; Light olive gray 5Y 5/2; Light red 5R 6/6; Pale red 5R 6/2; Moderate red 5R 4/6; Moderate reddish 10R 4/6

Quarries	Southern Canada; northwestern North Dakota; western Minnesota; outwash deposits in local till in northeastern South Dakota, such as around 39RO10, Roberts County, South Dakota	**Diagnostics**	True chert with no grains visible; vugs filled with muscovite which gives a "sugary" appearance; inclusions within vugs weather to a dark clay
Cortex	Pink, gray, brown, white, yellow, coarse	**Fracture Quality**	Fair; inconsistent trending towards coarse
Grain	Medium to coarse	**Color**	White, tan, gray, pink, red, brown, orange, yellow

Swan River chert is a true chert; no grains are visible. It consists of 99 percent quartz and may feature vugs filled with muscovite (Figures 71 and 72). With atmospheric exposure, the muscovite (or mica) weathers to a clay, radically changing the appearance to a dull gray or black color; this may be a diagnostic trait of Swan River chert (Figure 73). The clay can then completely weather out of the sample, creating vugs (Figure 74). On a clean break, the muscovite gives it a glittery, or sugary appearance, and a rough surface, that may result in a misidentification as quartzite (Figures 75 and 76). This sugary looking interior texture and a cortex, likened to an orange peel or curdled milk, can be diagnostic of the material.

Swan River chert is a distinctive material that can vary widely within a single specimen. For example, it can have an inconsistent to mottled coloration with white, tan, gray, pink, red, brown, orange, and yellow in a single cobble (Figure 77). Translucency can also vary in a single cobble from clear, to translucent, to opaque (Bakken 1985). Due to the irregularities of the material, conchoidal fracturing is inconsistent, trending towards rough, and is considered fair. Although it is not typically a high-quality knapping material, it is quite abundant in the glacial till and was widely used in areas with few local lithic resources. The knapping quality improves with heat treatment, which causes the luster to turn waxy (Low 1966). Most, if not all, Swan River chert found at archaeological sites in South Dakota and surrounding areas on the Northern Plains probably originated from glacial outwash cobbles. Because the raw material *in situ* is found in vertical features, it may be associated with bedrock other than the Devonian age material (Grasby et al. 2002). Swan River chert was probably more readily available prehistorically as outwash deposits associated with retreating glaciers than directly from an exposed outcrop (Figure 78).

Figure 71. Variety of Swan River chert samples, no grains visible.

Figure 72. Variety of colors found in Swan River chert.

Figure 73. Vugs filled with muscovite, which has weathered to a dark clay in Swan River chert.

Figure 74. Muscovite weathered out of Swan River chert, leaving behind vugs.

Figure 75. Close-up of muscovite's glittery appearance in vugs, that may result in misidentifying Swan River chert as a quartzite.

Figure 76. Another example of a flake of Swan River chert that be mistaken for a quartzite due to the rough breakage surface.

Figure 77. Swan River chert can exhibit a wide variety of colors in one sample.

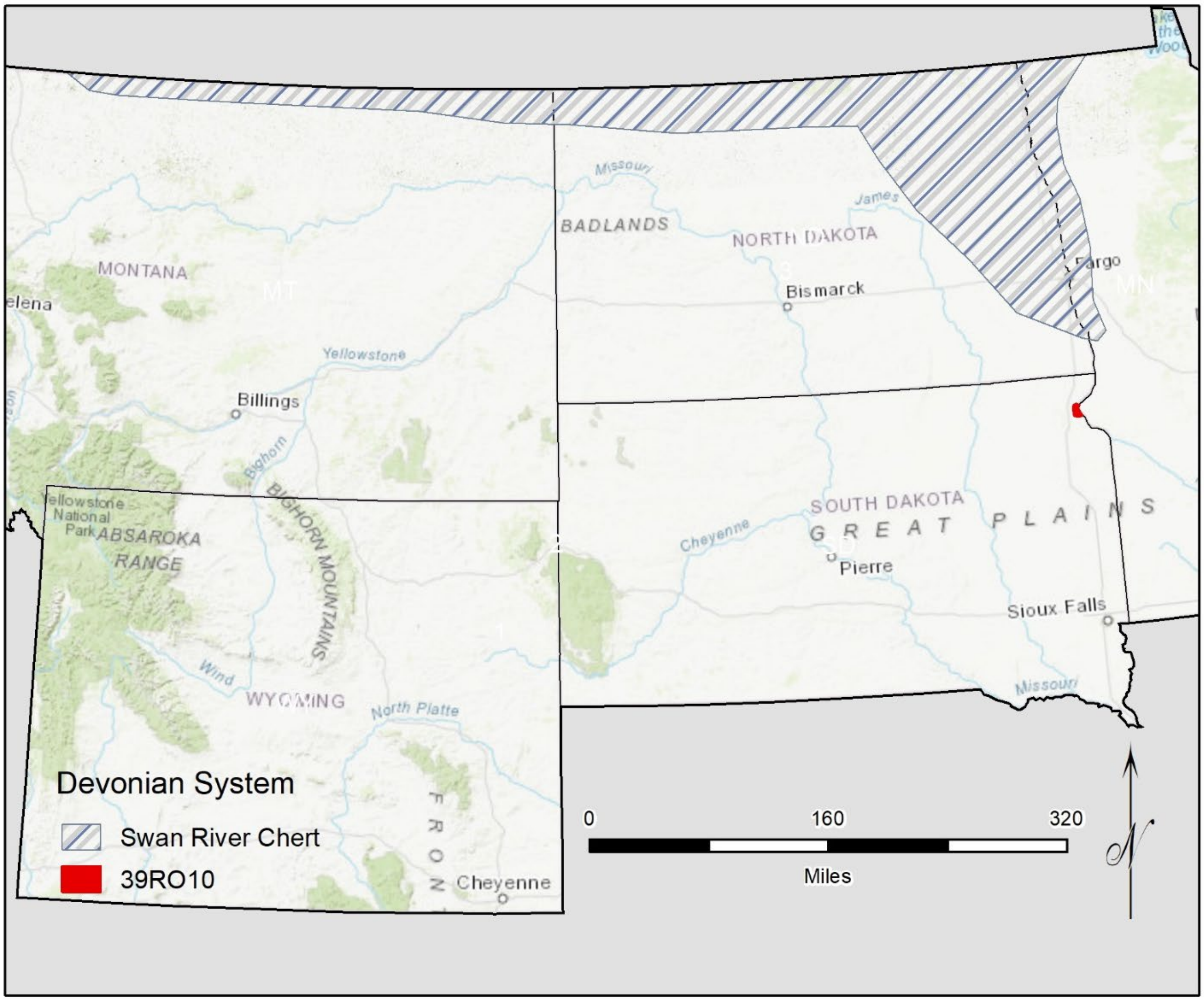


Figure 78. Swan River chert expanse across the Northern Great Plains.

KNIFE RIVER FLINT

OTHER NAMES: None

MUNSELL COLORS: Grayish brown 5YR 3/2; Dusky yellowish brown 10YR 2/2; Moderate yellowish brown 10YR 5/4; Moderate brown 5YR 3/4

Quarries	Lynch Quarry, Dunn and Mercer counties, along the Knife River, North Dakota	**Diagnostics**	Uniform, non-pourous dark brown flint; excellent conchoidal fracturing; fresh surfaces have a dull luster; weathered surfaces waxy luster
Cortex	Very dark brown, opaque, off-white, white, smooth; rusty orange staining also observed	**Fracture Quality**	Excellent
Grain	Very fine to fine	**Color**	Brown, yellowish brown, grayish brown

Knife River flint, a material with varying degrees of impurities, is microcrystalline with some minor bedding, especially on weathered surfaces. It was deposited in lenses when the organic matter of a peat deposit was replaced by silica approximately 30 to 60 mya, resulting in a dark brown chalcedony (Figure 79). A waxy luster occurs on weathered surfaces of Knife River flint (Figure 80), while a dull luster is present on fresh fractures (Figure 81). A weathered rind, or patina, causes the translucent dark brown color to change to a very dark brown, opaque white, or off-white color. The white rind is the result of silica dissolution, or desilicification (VanNest 1985). In some cases, the white patina has a bluish hue (Figure 82). A yellow to rusty-orange iron staining has also been observed on the rind. Despite examples with mottling, the material maintains a smooth texture with a sheen not seen in the brown chalcedonies in the Black Hills or the White River group silicates.

It is an extremely common material found in archaeological sites in South Dakota, especially in the northern portions of the state. It should not be confused with petrified wood, the brown chalcedonies of the White River group silicates, or Morrison chalcedony that originates in the Morrison formation (Figure 83). The irregular lenses and layers observed in Knife River flint are detrital peat fragments that can sometimes lead to the misidentification of the material as petrified wood; however, petrified wood has uniform parallel bands from tree growth. Careful examination with backlighting should help with proper identification between these two materials. To help distinguish Knife River flint from White River group brown chalcedonies, it should be noted that Knife River flint has fewer inclusions. Inclusions in the White River group brown chalcedonies results in less consistent conchoidal fracturing than Knife River flint. Another limiting factor for the White River group brown chalcedonies is the challenge to find sizable, high quality, samples that could be used to imitate the large, well-crafted Knife River flint bifaces and projectile points found at archaeological sites. Morrison chalcedony occurs as browns or grays, but can also exhibit marbling, banding, and mottling. The conchoidal fracturing of this material ranges from poor to fair to good; not nearly the excellent fracturing quality of Knife River flint.

Knife River flint has been used as an archaeological lithic source for at least 10,000 years, confirming its high quality and consistent response to flintknapping. Many examples of finely worked projectile points, endscrapers, bifaces, and other well-made tools exist on the Northern Plains and beyond, through long-distance trading. One example is a Paleoindian Angostura projectile point (39CL7), made from Knife River flint, found in a field near the Vermillion River in Clay County in 1973 (Figure 84a). Other examples include a Middle Archaic lanceolate point with a constricted base and several bifaces or point preforms, made from Knife River flint, excavated at a site (39LK7) on the south side of Lake Madison in the early 1980s (Figures 84b and 84c). Much of the Knife River flint found at archaeological sites was probably quarried from secondary sources in the Knife River Valley in Dunn and Mercer counties, North Dakota. It occurs in the Paleocene to Eocene Golden Valley formation which includes the upper Camels Butte member and lower Bear Den member (Figure 85). The Golden Valley formation overlays the Sentinel Butte formation (Paleocene), which contains major lignite beds.

Figure 79. Knife River Flint interiors and cortex.

Figure 80. Example of a waxy weathered surface on Knife River Flint.

Figure 81. Example of a dull fresh fracture on Knife River Flint.

Figure 82. Two bifaces made from Knife River flint. The left biface shows the white patina that is the result of silica dissolution.

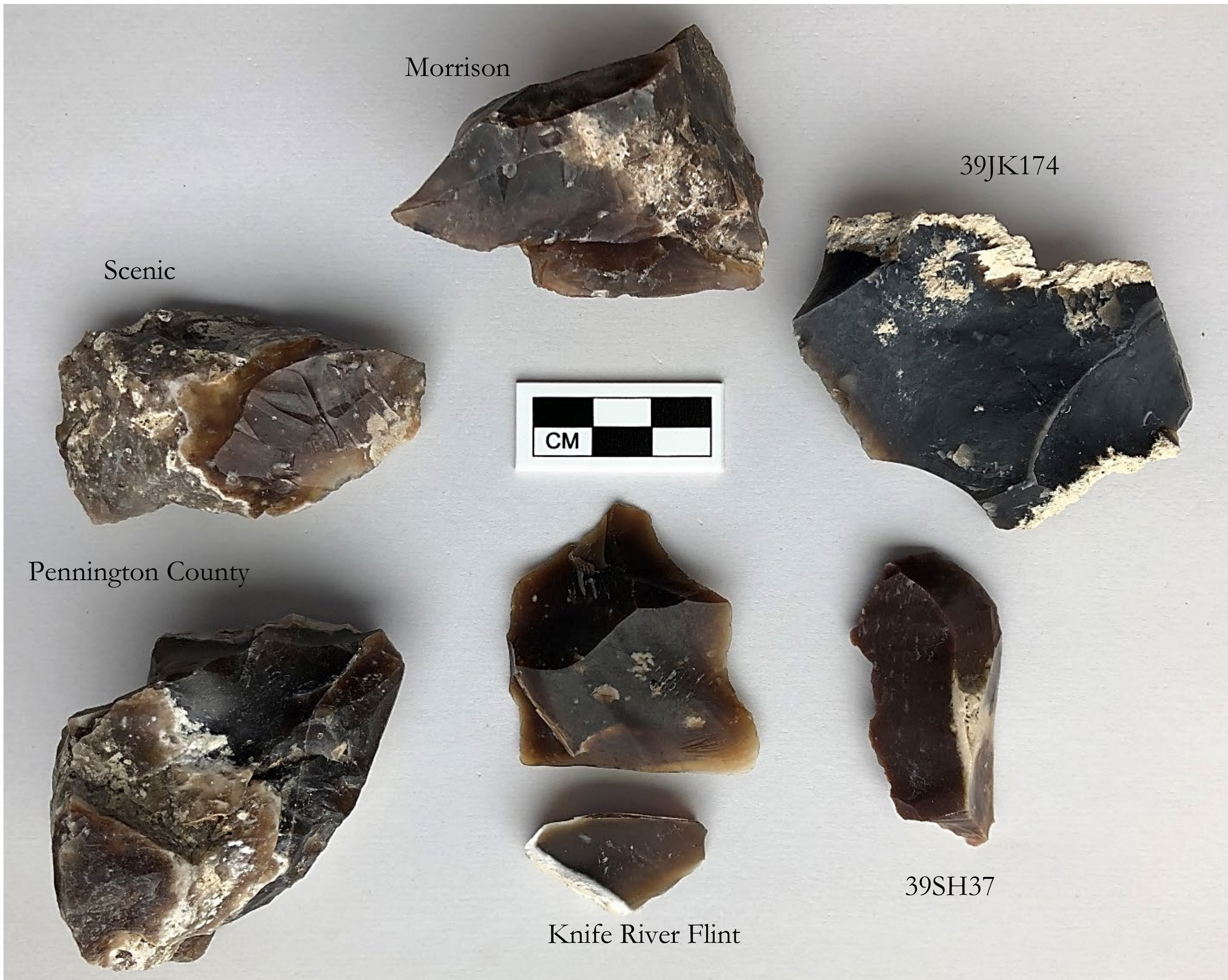


Figure 83. Comparing examples of brown chalcedonies. White River group silicates from Pennington County, near the town of Scenic, from 39JK174 in Jackson County, and from 39SH37 in Oglala Lakota (previously Shannon) County, South Dakota; Morrison formation chalcedony from Crook County, Wyoming; and Knife River Flint from Dunn and Mercer counties, North Dakota. Below, comparing fracturing qualities.

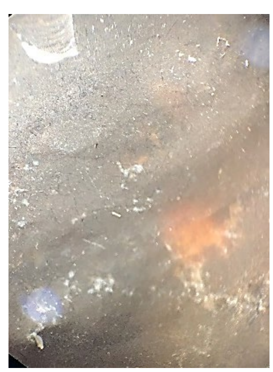
Fracturing Qualities

Knife River Flint

Excellent

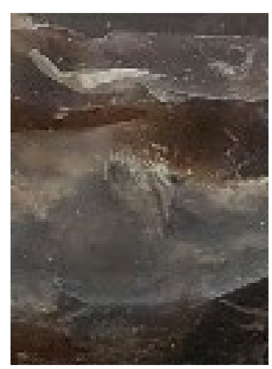
Petrified Wood

Good



39JK174

Fair to Good



Morrison Chalcedony

Poor to Fair to Good

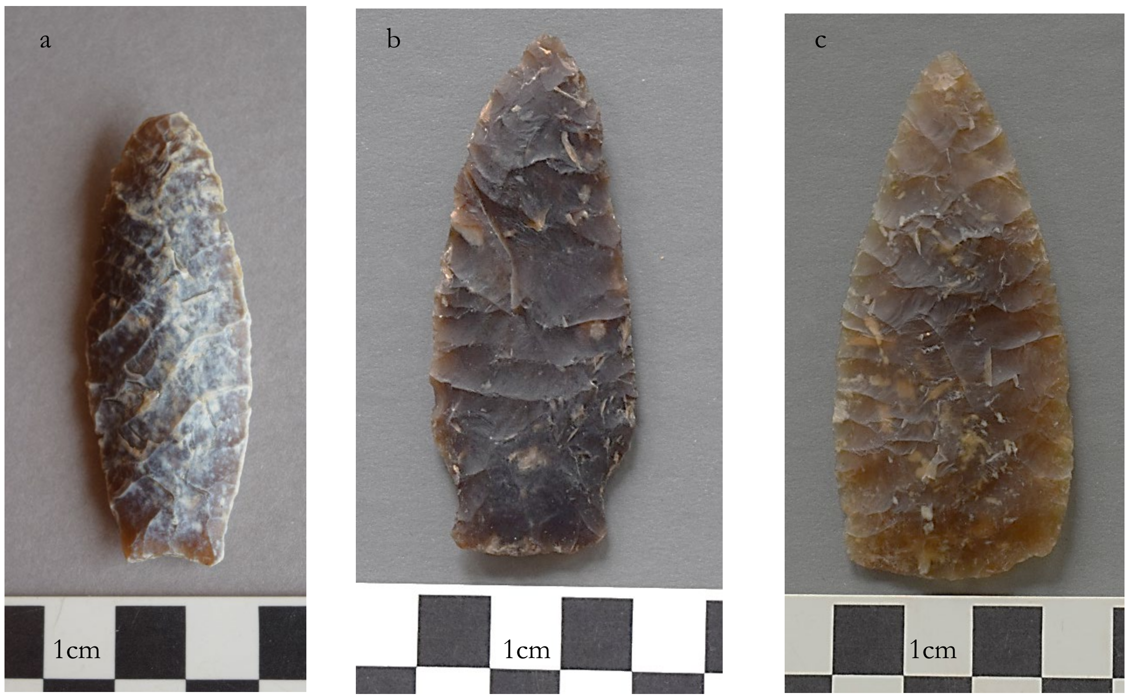


Figure 84. Knife River flint tools from southeastern South Dakota. a) Paleoindian Angostura projectile point, 39CL7; b) Middle Archaic lanceolate projectile point with a constricted base and c) a biface or point preform, both from 39LK7. (a: Artifact was photographed courtesy of owner. b and c: Artifacts photographed courtesy of DHL-HC.)

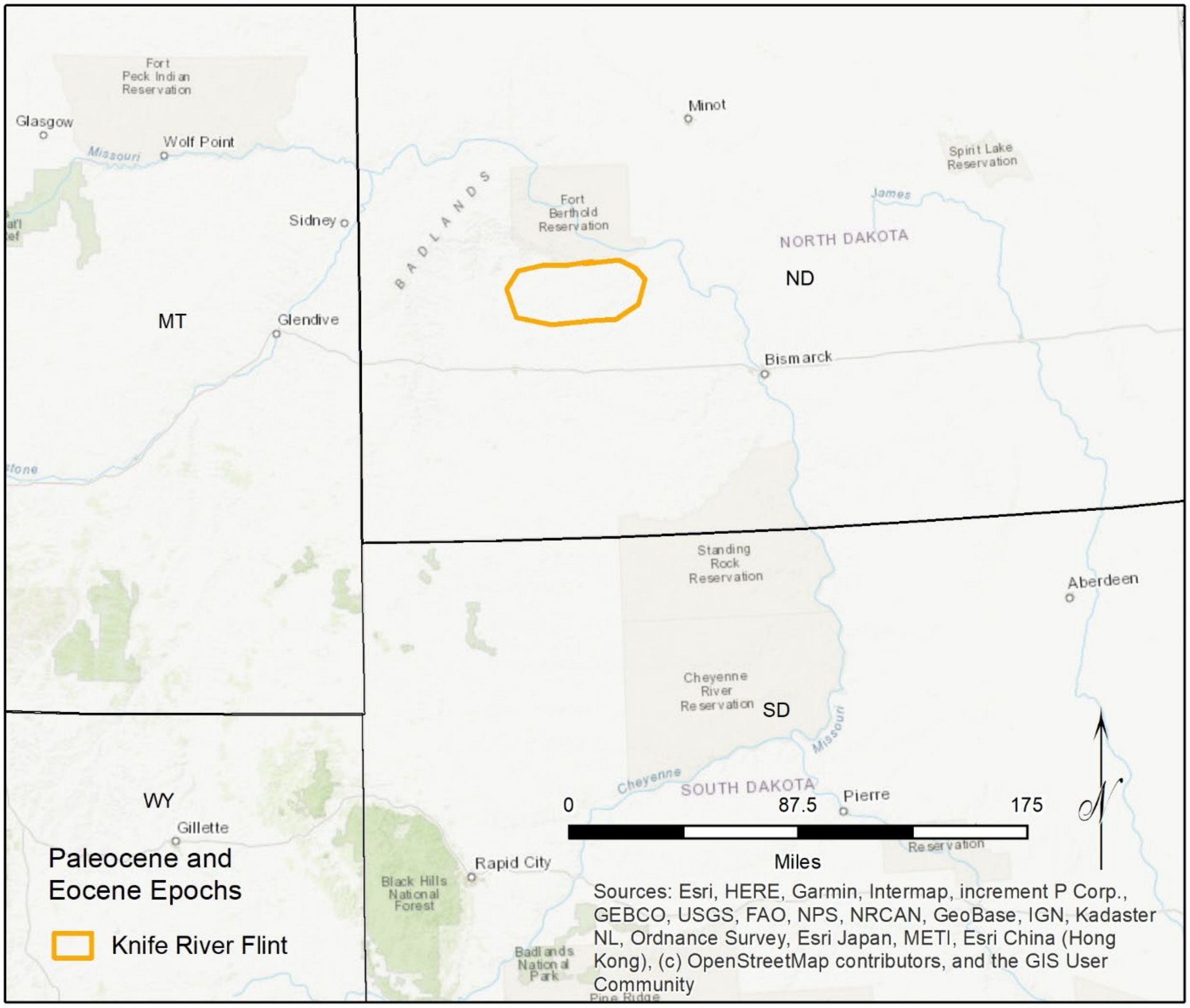


Figure 85. Knife River flint is associated with Paleocene and Eocene deposits in Dunn and Mercer counties, North Dakota.

MORRISON CHALCEDONY

OTHER NAMES: Black Hills chalcedony

MUNSELL COLORS: Grayish brown 5YR 3/2; Light brown 5YR 5/6; Dark yellowish brown 10YR 4/2

Quarries	Crook County, Wyoming	**Diagnostics**	Marbling, banding, and mottling; cortex can be used to differentiate from Knife River flint; translucent; dull to vitreous luster
Cortex	Rough texture of mixed cryptocrystalline material and rind in browns and oranges	**Fracture Quality**	Poor to good
Grain	Very fine to coarse	**Color**	Brown, gray, yellowish brown

Morrison chalcedony occurs as nodules or in tabular form in browns and grays; marbling, banding, and mottling can occur. Surfaces with conchoidal breaks tend to have a sugary appearance. It is cryptocrystalline, translucent, and varies from dull to vitreous in luster (Church 1996: 135-164) (Figure 86). The photographed samples are from Crook County, Wyoming in the Bear Lodge Mountains (Figure 87). The interior inclusions and color resemble samples from the Knife River flint quarry, although the cortex does not. The Morrison cortex has a rough texture of mixed cryptocrystalline material and rind in browns and oranges. It does not appear that the Morrison chalcedony forms the type of white rind that is seen on weathered Knife River flint. The processes forming the two materials are also different (see Knife River flint). Church (1996:135-164) used X-ray fluorescence to identify the elements of Morrison chalcedony, which includes "silica (31.85 percent), manganese (22.60 percent), cobalt (21.80 percent), and iron (10.62 percent)." This provides a baseline for distinguishing between Morrison chalcedony and other similar materials, such as Knife River flint. Morrison chalcedony originates in the Upper Jurassic age Morrison formation (Figure 88).

Figure 86. Morrison chalcedony from the Bear Lodge Mountains, Wyoming.

Figure 87. Morrison chalcedony from the Bear Lodge Mountains, Wyoming.

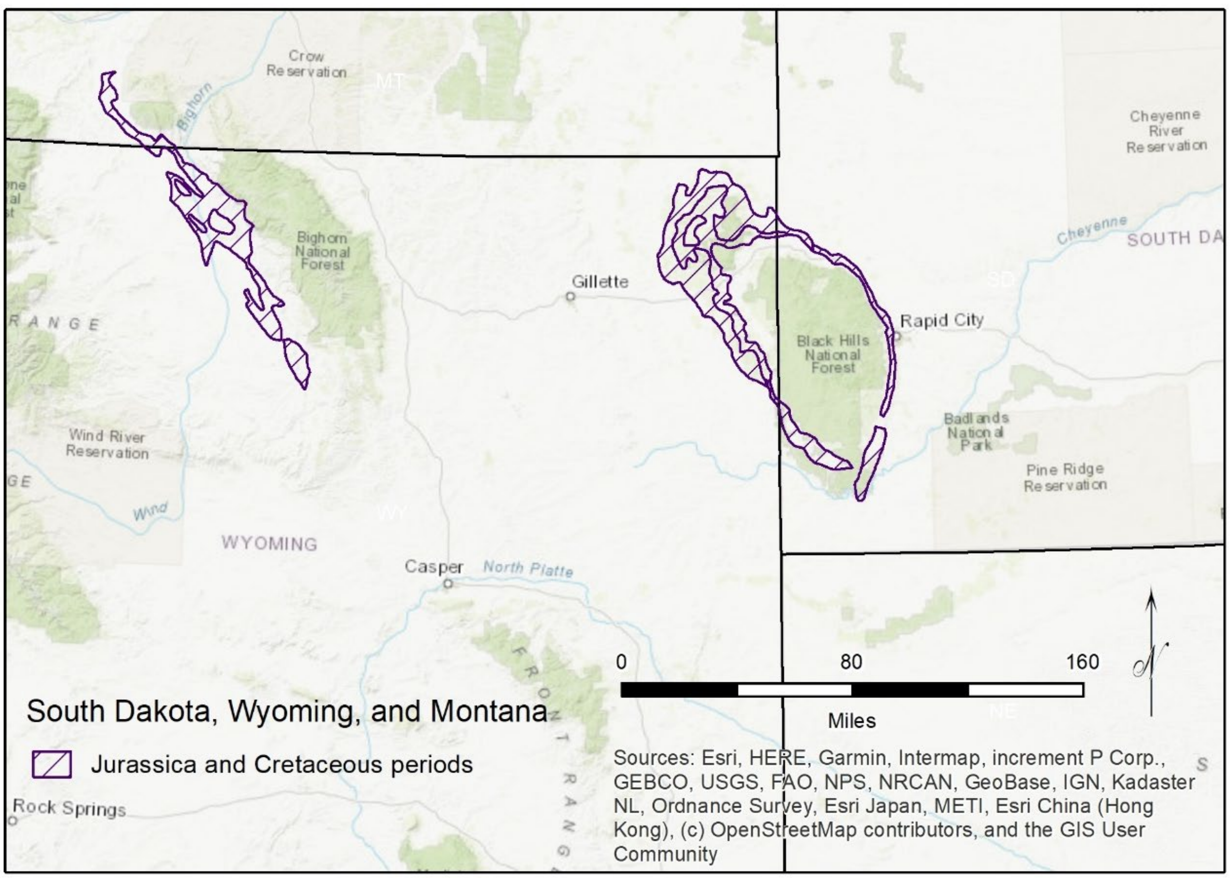


Figure 88. Generalized geology map showing the Jurassic and Cretaceous age layers in the Black Hills Uplift and central Wyoming and Montana. Morrison chalcedony originates in Jurassic period deposits.

PLATE CHALCEDONY

OTHER NAMES: Badlands chalcedony

MUNSELL COLORS: Very light gray N8; Light gray N7; Medium light gray N6

Quarries	White River Badlands, southwestern South Dakota	**Diagnostics**	Slabby; generally, 0.25-inch-thick found around southern South Dakota and northwestern Nebraska; only the edges tend to be worked
Cortex	Shades of white to gray, rough or bubbly	**Fracture Quality**	Fair to good
Grain	Fine to medium	**Color**	Clear, milky, white, gray

Plate chalcedony is a cryptocrystalline silica that forms when an aqueous solution is deposited in fissures of rock. It is a slow process that results in typically thin, elongated, and vertical veins of hard, bluish-gray chalcedony. These veins of chalcedony are much harder than the surrounding clay. As the clay erodes, the platy chalcedony is no longer supported and breaks away in angular pieces (O'Harra 1920). The cortex may present as a white or gray rough or bubbly surface (Figure 89). These thin plates need only be worked unifacially or bifacially along the margins to create a functional knife (Figures 90-92), which is the most common tool made from Plate chalcedony. These tools are traditionally known as Badlands chalcedony knives. The occasional projectile point has also been found at archaeological sites. Plate chalcedony is found in the Badlands of southwestern South Dakota; Oglala Lakota, Pennington, Jackson, Meade, and Custer counties in southern South Dakota; outcrops in Ziebach County; and other locations where there are eroded remnants of the Oligocene Brule formation (Figure 93). However, the examples associated with the eroded remnants of this formation are, oftentimes, quite small and weathered; as a result, they have a low knapping value.

Figure 89. Bubbly cortex on Plate chalcedony.

Figure 90. Badlands chalcedony knife bifacially modified on two edges and the distal end. The center of the face presents a natural rough surface.

Figure 91. Badlands chalcedony knife bifacially modified on one edge while the face presents a natural rough surface.

Figure 92. Profile of the Badlands chalcedony knife shown in Figure 91.

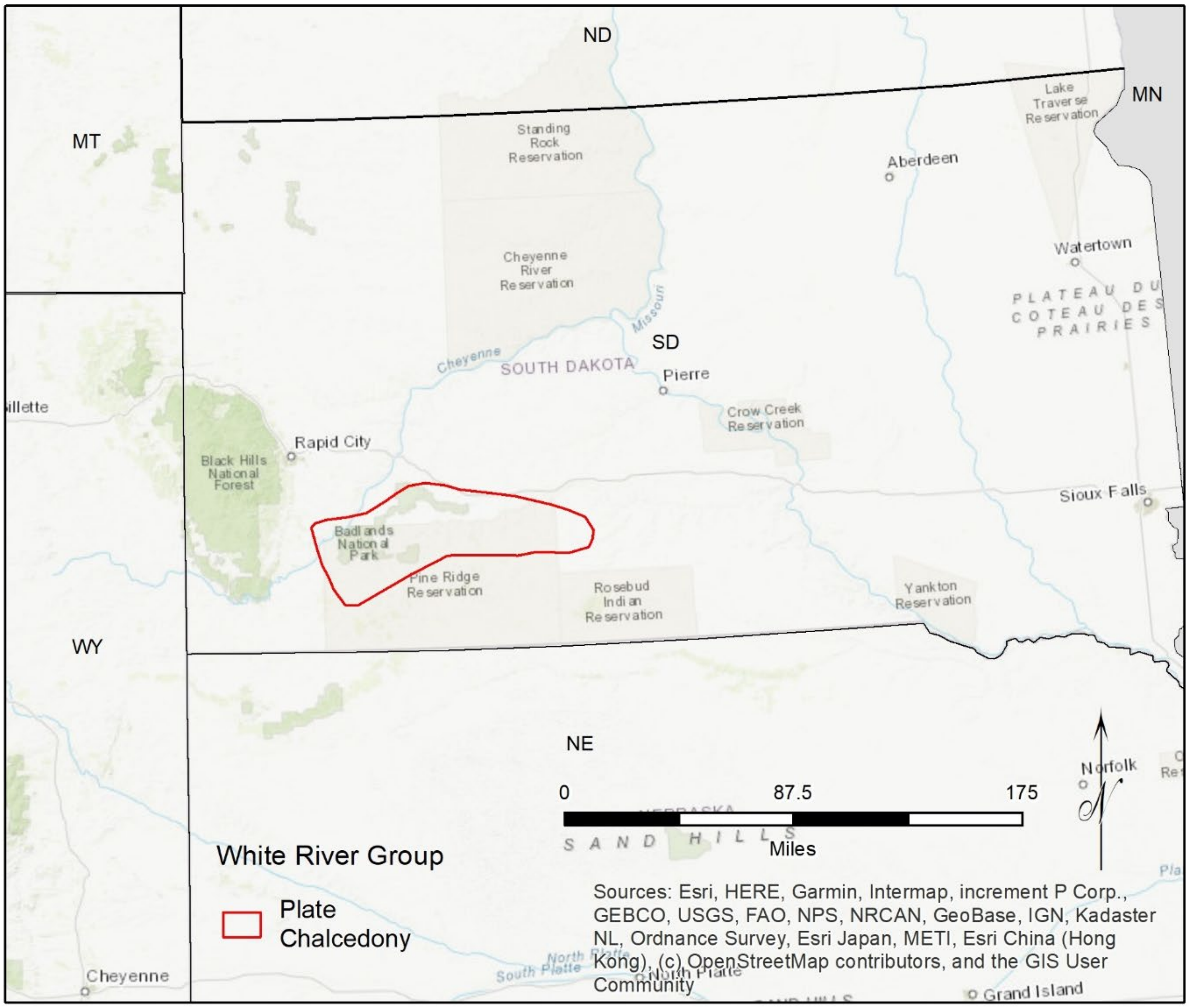


Figure 93. Plate chalcedony can occur anywhere that remnants of the White River group occur, although it is frequently found in the Badlands of southwestern South Dakota.

PETRIFIED WOOD

OTHER NAMES: Fossilized wood; Silicified wood

MUNSELL COLORS: *Interior*: Dusky yellowish brown 10YR 2/2; Dark yellowish brown 10YR 4/2; Moderate yellowish brown 10YR 5/4; Dark yellowish orange 10YR 6/6; Medium light gray N6; Dark gray N3; Brownish gray 5YR 4/1; *Cortex*: Very pale orange 10YR 8/2; Grayish orange 10YR 7/4

Quarries	Outcrops or eroded cobbles are found along streams in Perkins, Harding, and Meade Counties, as well as many other locations across western South Dakota	**Diagnostics**	Parallel lines (wood grain) can be seen when held up to the light; translucent to nearly opaque, conchoidal fracturing is not as smooth as Knife River flint
Cortex	White to yellowish-white, smooth, patina	**Fracture Quality**	Good
Grain	Fine to medium	**Color**	Reds, browns, yellows, grays

Petrified wood is fossilized when its organic structure is replaced with a mineral such as silica or quartz (Figure 94). Fossilized wood is typically part of the redwood family (Gries 1996). It retains much of the original structure and features of the wood causing a platy structure and its strongest identifying feature, parallel lines that can best be seen if held up to the light (Figures 95 and 96). It is often a translucent to nearly opaque material, depending on the thickness of the sample. Colors vary and are determined by the elements present in the replacement material. Iron oxides yield reds, browns, and yellows; manganese oxides yield yellows and browns. A variety of other colors are possible as well. In western South Dakota the yellows, browns, and grays are most common. Petrified wood may be misidentified as a White River group brown chalcedony or Knife River flint, both of which may exhibit banding or striations resembling wood structure. However, neither petrified wood nor White River group chalcedonies exhibit the fine conchoidal fracturing and high luster seen in Knife River flint. Petrified wood is associated with the Tongue River member, the youngest member of the Paleocene Fort Union formation in North Dakota and South Dakota (Figure 97).

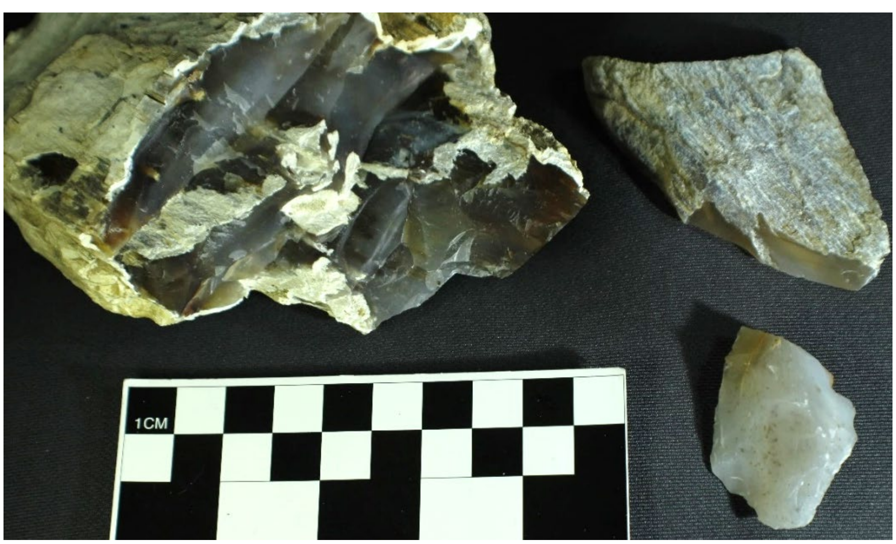


Figure 94. Petrified wood from Perkins County, South Dakota.

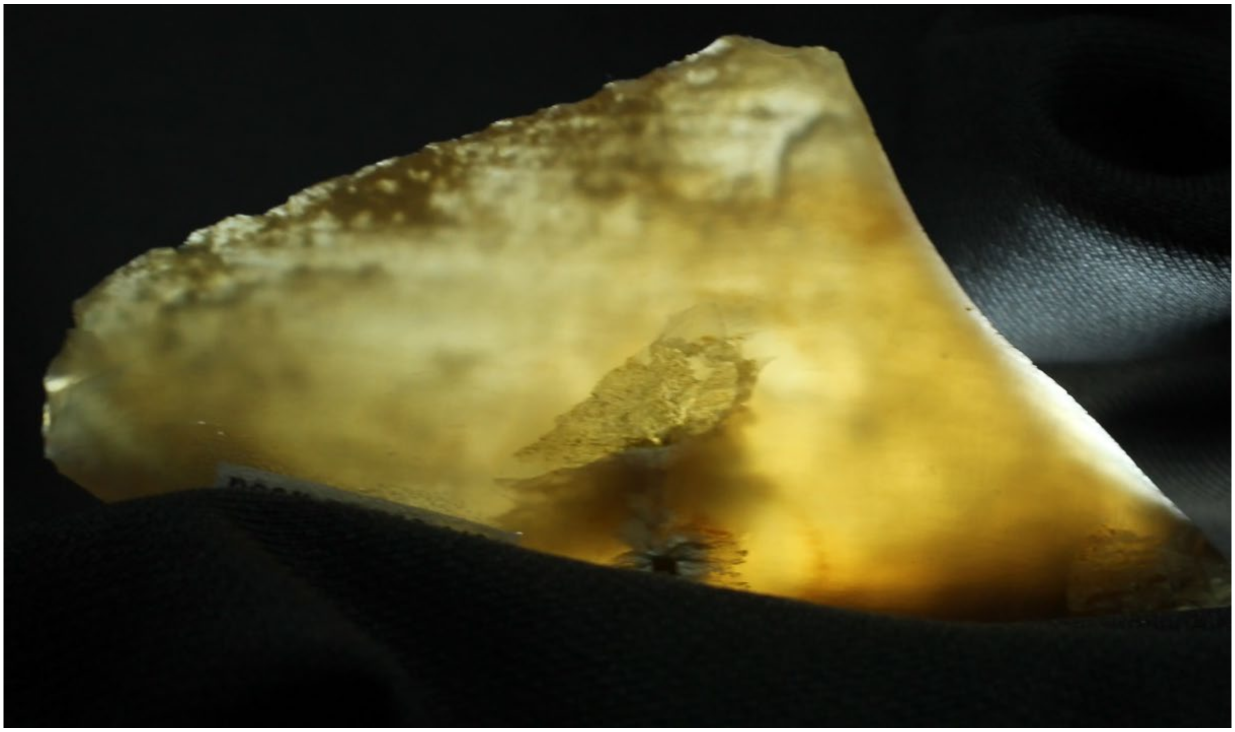


Figure 95. The platy structure of petrified wood, one of its diagnostic characteristics, is emphasized by backlighting.

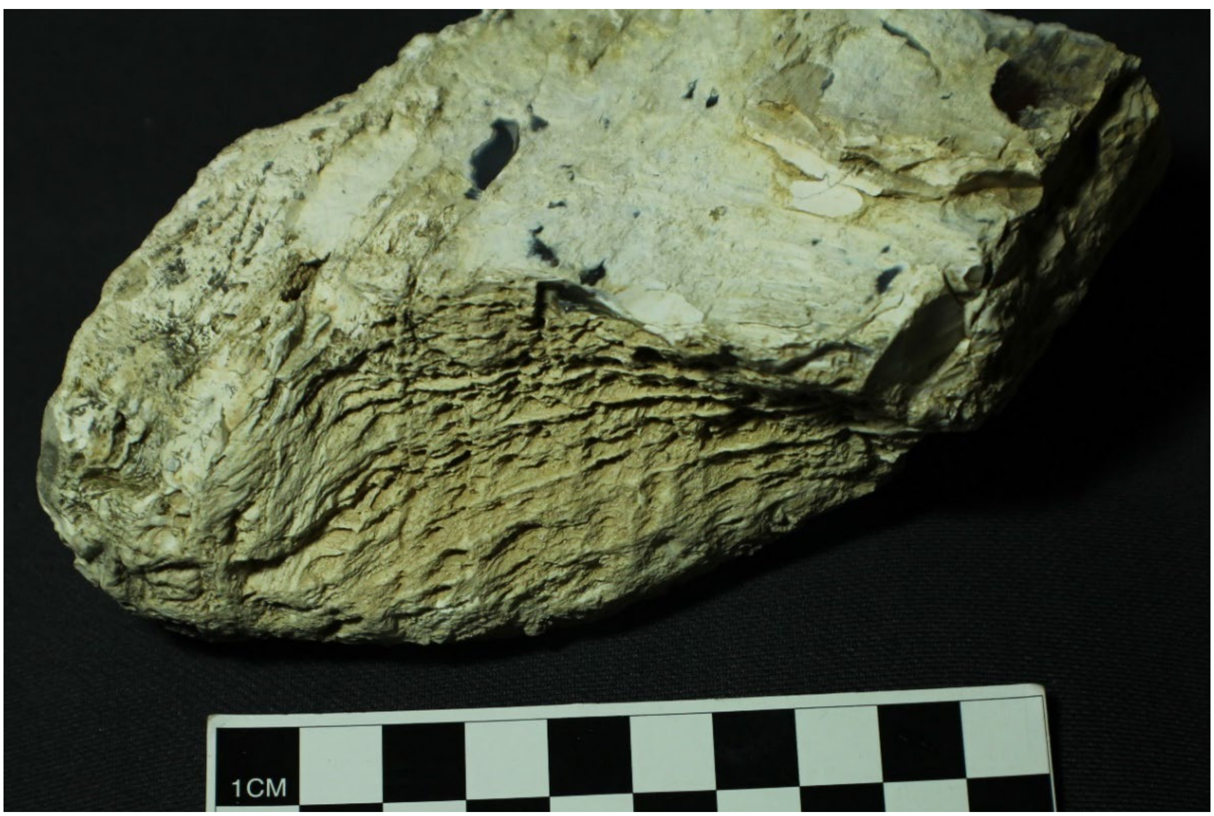


Figure 96. Structural characteristics of the wood were preserved in this petrified wood sample when the cells were replaced during mineralization.

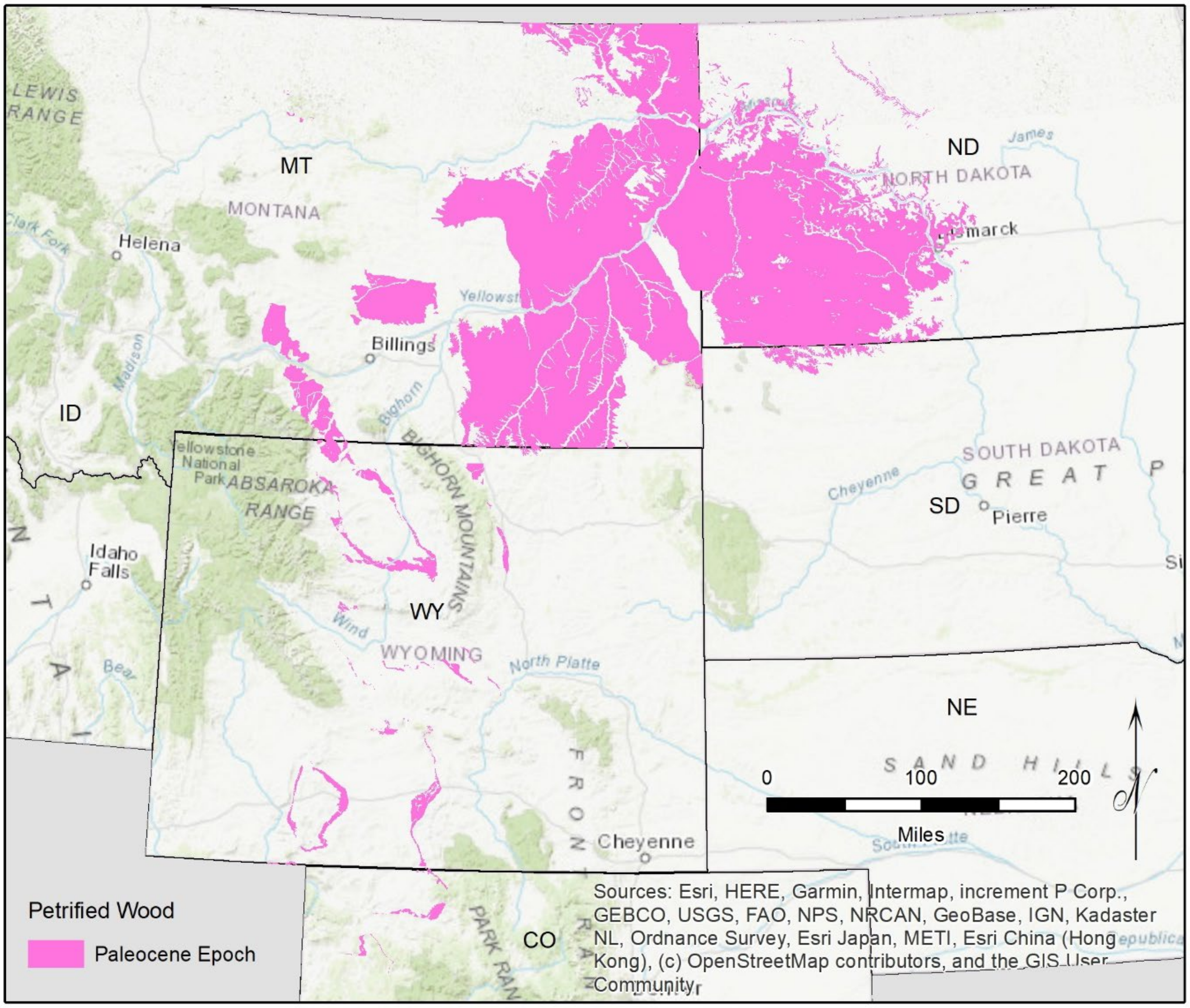


Figure 97. Petrified wood is associated with the Paleocene epoch which includes the Fort Union group. The material can be found associated directly with outcrops or as eroded cobbles along streams far from its original source.

WHITE RIVER GROUP SILICATES

OTHER NAMES: Scenic chalcedony, West Horse Creek chert, Flattop chalcedony, and Table Mountain chalcedony

MUNSELL COLORS: Medium light gray N6; Medium gray N5; Medium dark gray N4; Dark gray N3; Light gray N7; Pale brown 5YR 5/2; Very pale orange 10YR 8/2; Dark yellowish brown 10YR 4/2; Moderate yellowish brown 10YR 5/4; Grayish red 5R 4/2; Pale red 5R 6/2; Grayish orange pink 10R 8/2; Grayish orange 10YR 7/4; Moderate reddish brown 10R 4/6; Very pale orange 10YR 8/2; Pale red 10R 6/2; Grayish blue 5PB 5/2; Pale blue 5PB 7/2; Moderate brown 5YR 4/4; Olive gray 5Y 4/1; Pale red purple 5RP 6/2

Quarries	39SH37-West Horse Creek, Oglala Lakota County, South Dakota; 5LO1-Flattop Butte and 5LO34-Flattop Mesa, Logan County, Colorado	**Diagnostics**	Often multi-colored with varying hues or shades; difficult to distinguish specific source if not found in context or close to its primary source
Cortex	Most often white and smooth	**Fracture Quality**	Good
Grain	Amorphous to coarse	**Color**	Brown, gray, purple, white, tan, yellow, sometimes all within a single sample

The White River group silicates, often used as a catchall for unknown silicates, encompass a variety of chalcedonies that originate from the same geologic unit, the White River formation (Figure 99). They represent crack deposition or vertical orientation, created when silica-rich fluids percolated through breaks in the rock, forming lenses in the formation. Therefore, the White River group silicates all have the same basic composition (Figures 98-101). Fox Ridge and French Creek samples also include an opaque to translucent variety; the thickness and quality of the materials vary. All varieties exhibit a white chalk-like weathering patina and are interbedded with the White River clays. When massive, the material has a clean conchoidal break; only these massive samples would be good for tool stone. The darker, more massive, fine-grained depositions are the White River group silicates, which grade from a lower quality Badlands chalcedony with crystal depostion to crack infilling agate-like deposition. The color differences among the outcrops reflect local mineral variations in surrounding rocks that are dissolved and incorporated into the material. Material quality depends on the thickness and purity of the deposit. The translucent brown chalcedonies in the group can closely resemble Knife River flint, and assumptions should not be made regarding the identification between these two materials without a close examination. Artifacts found in an archaeological context, either from the same site or multiple sites, may be visually identical yet made from chalcedonies acquired at different quarries. As a result, it is extremely challenging to source beyond the general reference of White River group silicates if they are not found close to a primary source. Even then, there is no certainty that the material originated from that location. Elemental analysis, such as X-ray fluorescence, could help differentiate between sources.

The White River group was formed from several Eocene to Oligocene sediments derived from Laramide uplifts to the west. Fine-grained volcanic ash sediments that accumulated across the Northern Plains in the late Eocene to Early Miocene comprise much of the group. The banding seen within the White River group is likely caused by paleosol development (Maher and Shuster 2012; Terry et al. 1988) (Figure 102). "The complex and variable diagenetic signature for the White River group can be attributed to shallow conditions, fluctuating groundwater table positions and groundwater fluxes, and the peculiarly volcanic ash-rich nature of the sediment" (Maher and Shuster 2012). Isolated remnants of the White River formation can be found in western South Dakota, Montana, Wyoming, North Dakota, Colorado, and Nebraska.

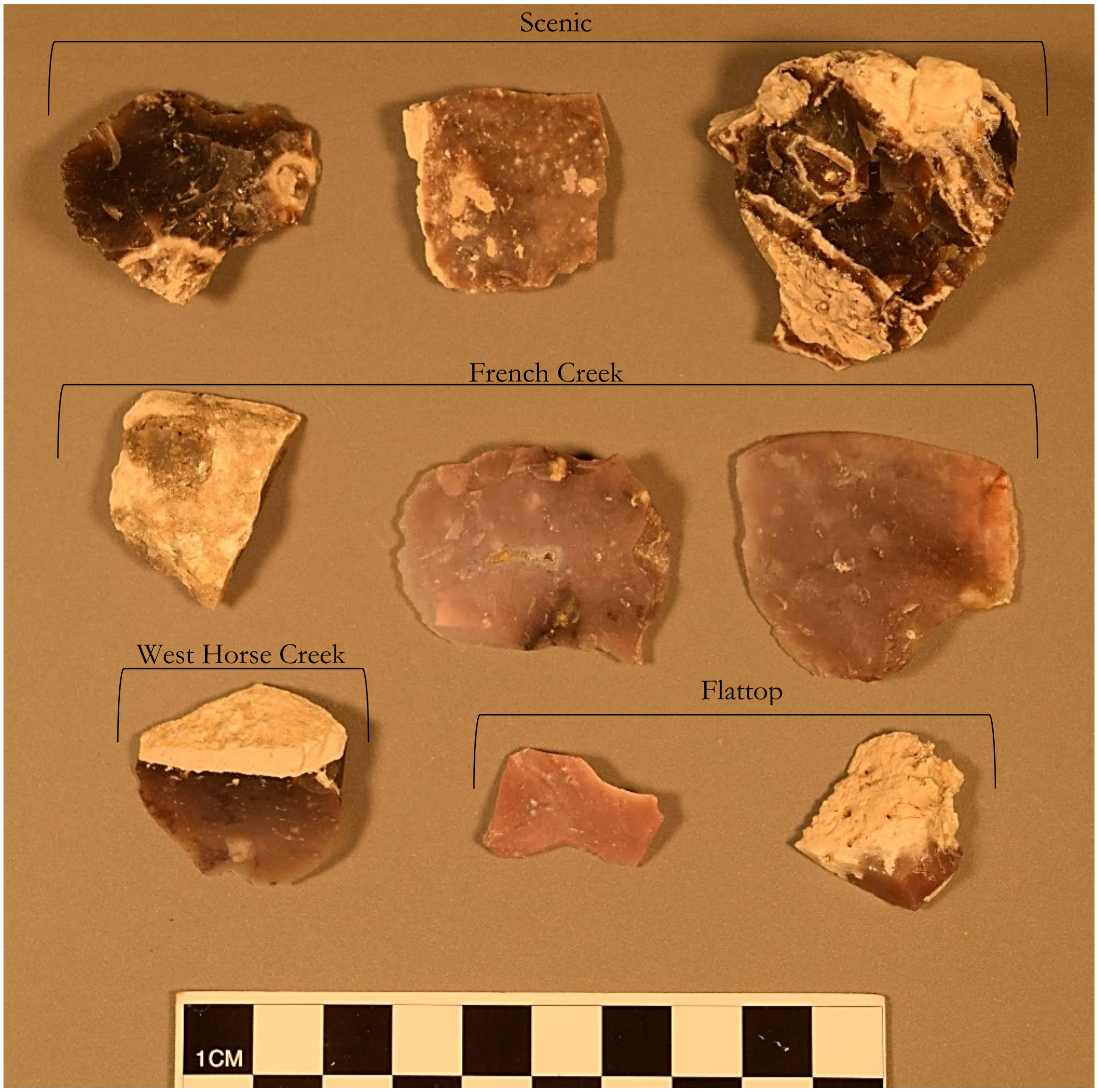


Figure 98. Examples of White River group silicates from various source locations.

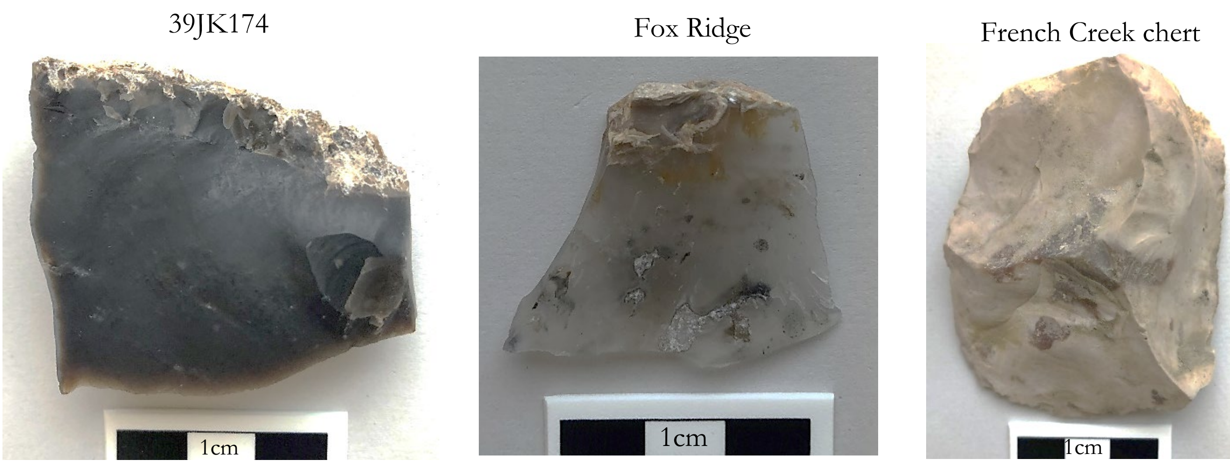


Figure 99. Additional examples of White River group silicates from various source locations.

Figure 100. Scenic chalcedony, one of the White River group silicates. Note the brown coloration that could be mistaken for Knife River flint.

Figure 101. Scenic chalcedony, one of the White River group silicates. Reverse side of sample pictured in Figure 100; note the narrow banding.

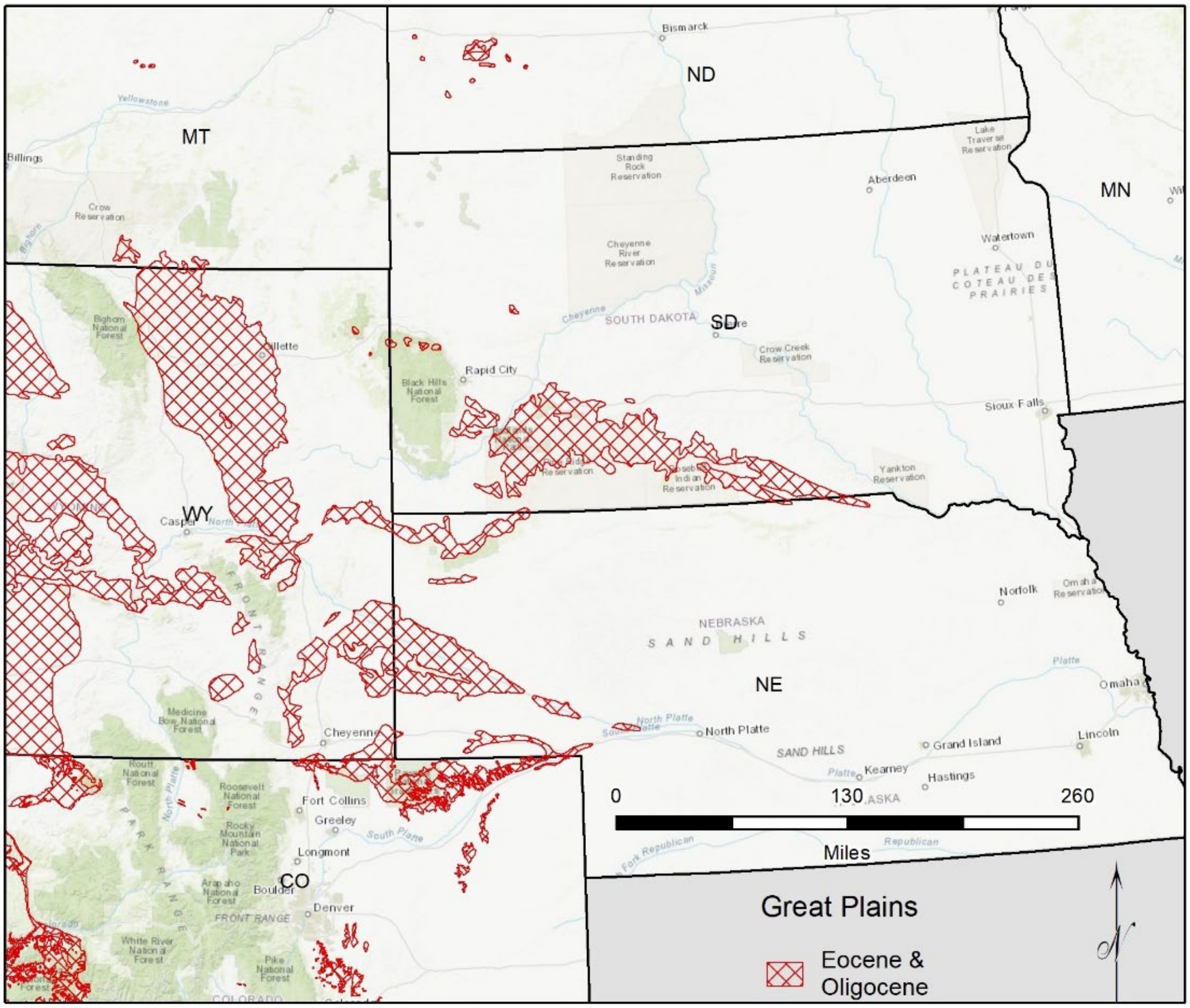


Figure 102. White River group silicates originate in the Eocene and Oligocene deposits on the Great Plains.

BATTLE MOUNTAIN QUARTZITE

OTHER NAMES: Black Hills quartzite, Fall River formation quartzite

MUNSELL COLORS: White N9; Very light gray N8; Light gray N7; Medium light gray N6; Medium dark gray N4; Dark gray N3; Grayish grown 5YR 3/2; Moderate brown 5YR 3/4; Moderate brown 5YR 4/4; Light olive gray 5Y 6/1; Dark yellowish brown 10YR 4/2; Moderate yellowish brown 10YR 5/4; Very dark red 5R 2/6; Dusky red 5R 3/4; Grayish red 5R 4/2; Moderate red 5R 5/4; Very dusky red 10R 2/2; Dark reddish brown 10R 3/4; Pale red 10R 6/2; Light olive gray 5Y 6/1

Quarries	39FA55-Battle Mountain, Fall River County, South Dakota	**Diagnostics**	Large-grained weathered cortex
Cortex	Large, angular quartz grains that are chalky white, tan, brown, or red; overall a generally weathered surface	**Fracture Quality**	Good to excellent
Grain	Fine	**Color**	Whites, grays, browns, deep reds; ocassionally mottled reds and whites; variable widths of banding on some examples

Battle Mountain quarry samples are a fine-grained quartzite (Figures 103-107). They exhibit sub-rounded to sub-angular, spherical, well-sorted, 0.125 to 0.25-millimeter diameter quartz and lithic fragments. The silica matrix is variable in color with occasional powdery iron inclusions. Minimal evidence of compression is present; grain edges are rounded and well-silicified. The rock is poorly compacted and composed of approximately 65 percent clear quartz grains, 25 percent tan quartz grains, and 10 percent dark lithic fragments. Angularity, sorting, and grain size distribution appears to be influenced by bedding patterns in the parent rock. Overall, color of the rock is influenced by the matrix and color changes in a single sample can be nonexistent, gradual, or abrupt. Although it was once thought that the deep red color was diagnostic of Battle Mountain quartzite, the color range is quite broad. Conchoidal fracturing, considered good to excellent, presents as a smooth surface with breakage occurring across the grains. The quarry is an extensive outcrop of variable qualities of quartzite with features such as small mining pits, an adit, and massive amounts of rejected materials (Figures 108-111). The quarry lies within the Inyan Kara group in the southeastern portion of the Black Hills Uplift in Fall River County, South Dakota (Figure 112). Unfortunately, the quarry site has been negatively impacted by radio towers and attracts local collectors.

Figure 103. Battle Mountain quartzite.

Figure 104. Battle Mountain quartzite.

Figure 105. Closeup of grains and gradual color change in Battle Mountain quartzite.

Figure 106. Battle Mountain quartzite with quartz inclusion.

Figure 107. Closeup of grains in Battle Mountain quartzite.

Figure 108. The Battle Mountain quarry, 39FA55, in Fall River County, South Dakota.

Figure 109. Prehistoric quarry pit at the Battle Mountain quarry, 39FA55, in Fall River County, South Dakota.

Figure 110. Excess quarrying material on the slope at the Battle Mountain quarry, 39FA55, in Fall River County, South Dakota.

Figure 111. A prehistoric quarry adit at the Battle Mountain quarry, 39FA55, in Fall River County, South Dakota.

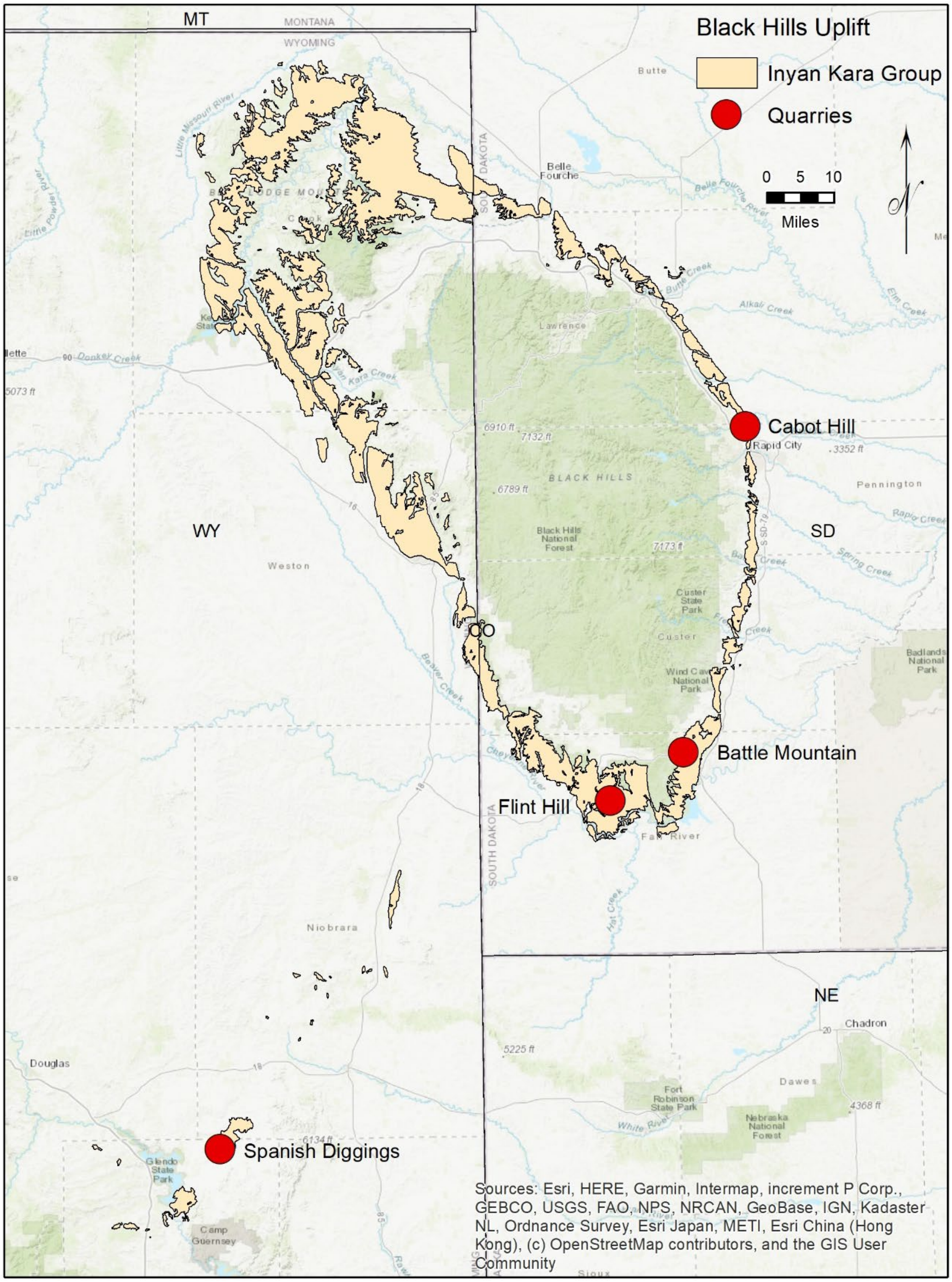


Figure 112. A series of quartzite quarries in the Black Hills and Hartville Uplifts in southwestern South Dakota and eastern Wyoming.

BIJOU HILLS QUARTZITE

OTHER NAMES: Bijou Hills silicified sediment, Ogallala orthoquartzite, green quartzite, Bloomington quartzite

MUNSELL COLORS: *Weathered surfaces*: Yellow gray 5Y 7/2; Pale olive 10Y 6/2; Pinkish gray 5YR 8/1. *Fresh surfaces*: Pale olive 10Y 6/2; Grayish red 10R 4/2

Quarries	Outcrops in southern South Dakota, northern Nebraska, and northwestern Kansas	**Diagnostics**	Overall greenish color; rough to moderate conchoidal fracture; abundance and variety of feldspar making for a chalk-like exterior; mature and well-sorted
Cortex	Pitted (semi-rectangular) and chalk-like; green	**Fracture Quality**	Good
Grain	Medium to coarse	**Color**	Gray, olive, yellow gray, pinkish gray, grayish red

Bijou Hills quartzite has a variable parent material from arkosic to quartzitic sandstones (Figure 113-114). If it has more feldspar it is arkose, if it is more quartz then it is quartzitic. The glauconite and chlorite gives the material its green coloration, a distinctive characteristic of this material; however, the coloration of individual grains can be translucent to gray to black to pink. Another explanation for the distinctive greenish color may be that an ash bed deposited above the Ogallala quartzite was soon below the water table, during which time ferrous iron could have been adsorbed by the silica gel created under these conditions. The gel would have leached into the quartzitic sediment lentils, creating the greenish color and opal and chalcedony cement (Frye and Swineford 1946). It is a well-sorted sandstone, with variable rounding, contact metamorphism, and fluid-based quartzite. One can easily pick out individual grains without the aid of a microscope or hand lens. These would not be easily visible in a more highly metamorphosed rock. Other silicified sediments do not contain feldspar; the abundance and kinds of feldspars are also diagnostic features of this material (Porter 1962). The feldspars give it a chalk-like appearance and when they weather out, a pitted surface comprised of semi-rectangular pits. Bijou Hills quartzite is a well-sorted, mature stone; grain size exhibits a bimodal distribution. The term Bijou Hills quartzite should be confined to the material found in the Lower Ogallala formations only (Figure 115).

Bijou Hills quartzite is frequently found in Initial and Extended Middle Missouri and sites in eastern South Dakota. Although Bijou Hills quartzite projectile points and other small chipped stone tools have been found in South Dakota, large, lanceolate biface knives over 15 centimeters in length are the more common tools made from this material. Bijou Hills quartzite is also commonly found in archaeological sites in northern Nebraska, some of these sites may have been occupied by the Ponca tribe. Ethnographic accounts mention a blue stone favored by the Ponca:

> Arrowpoints [sic], lance heads, and knives were made of(?) flint quarried approximately 2 miles south of the present Butte, Nebr. Another Ponca quarry located

"east of Pike's Peak" is mentioned by PLC [Peter Le Claire, the informant] in his "History" (p. 20). Leonard Smith mentioned a type of blue stone that was called *Móhį-dù* (Blue-knife) by the Ponca because they so often used it for making knives and other flint implements, but he did not know the location of the quarry. (Howard 1965)

Excavations at Ponca villages in northern Nebraska also mention this account and describe projectile points, drills, and knives made of Bijou Hills quartzite that were recovered by archaeologists (Wood 1965). According to Gary Robinette, Ponca Tribe, (personal communication, 2009), the Ponca words for blue and green are similar, blue is *t-du-h*, and green is *p-bayshee-h t-du-h*. It is possible that the reference is to a Green-knife, or Bijou Hills quartzite. Butte, Nebraska is located within the Bijou Hills formation.

Figure 113. Bijou Hills quartzite artifacts: a) flake, b) flake, c) biface, and d) quarry blank.

Figure 114. Closeup of the grains in a fresh break of Bijou Hills quartzite.

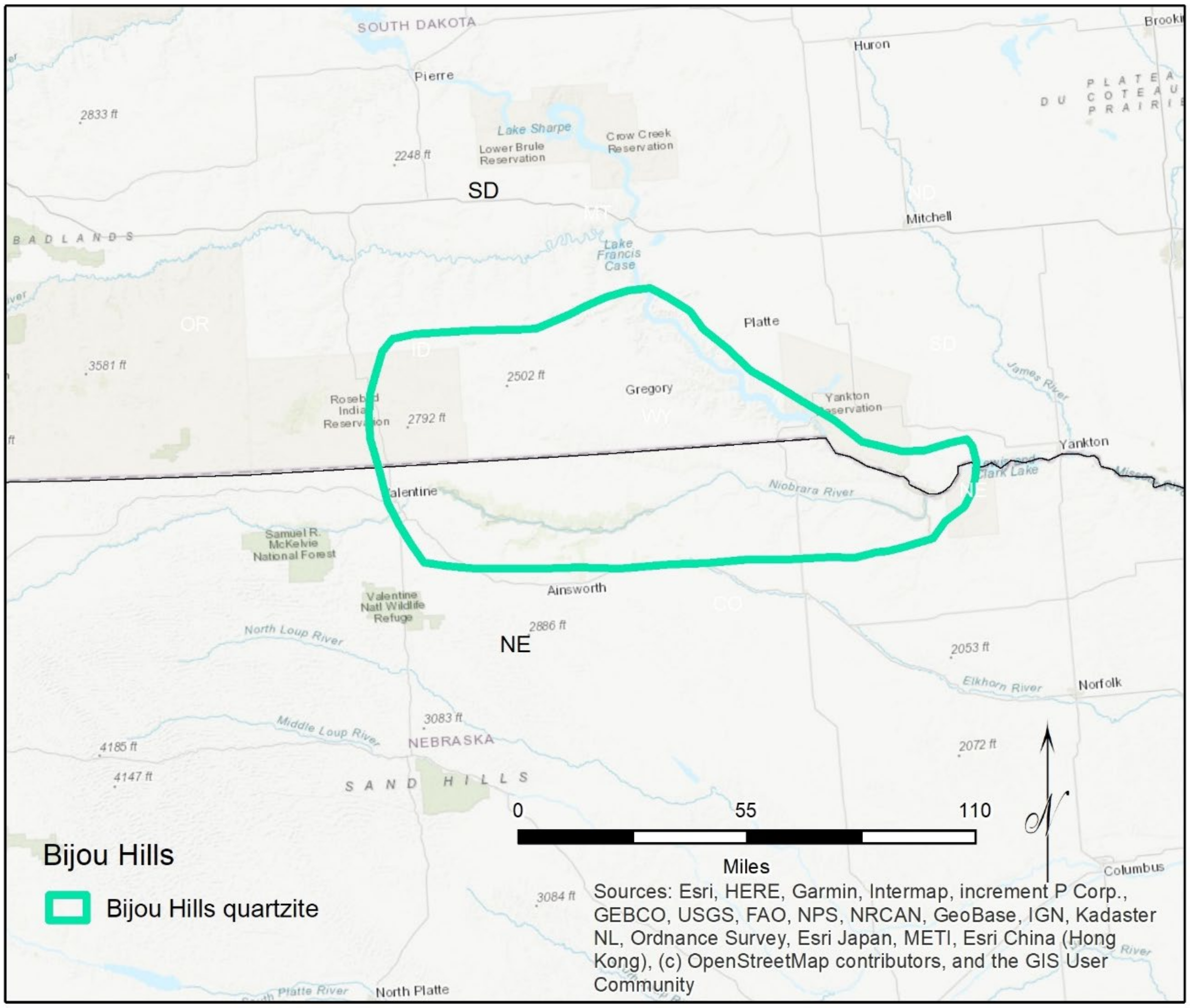


Figure 115. Bijou Hills quartzite originates in the Bijou facies in southern South Dakota and northern Nebraska. The formation also outcrops in southern Nebraska and northern Kansas.

DEADWOOD QUARTZITE

OTHER NAMES: Black Hills quartzite, Deadwood formation quartzite

MUNSELL COLORS: Light gray N7; Grayish brown 5YR 3/2; Dusky brown 5YR 2/2; Grayish orange pink 5YR 4/4; Dusky yellowing brown 10YR 2/2; Dark yellowish brown 10YR 4/2; Dark yellowish orange 10YR 6/6; Blackish red 5R 2/2; Grayish red 5R4/2; Very dusky red 10R 2/2

Quarries	39MD79-Meadow Creek, a possible quarry in Meade County, South Dakota	**Diagnostics**	39MD79 represents coarse-grained dark reds to brown with rough surface and unpredictable breakage, Crook County samples exhibit fine-grained yellowish gray to brown silceous quartz sandstone with fossil Scolithus burrow cavaties (makes for a smooth conchoidal fracture but uneven texture and unpredictable breaking pattern)
Cortex	White, yellow, red, coarse	**Fracture Quality**	Fair; rough surface and somewhat unpredictable breakage patterns
Grain	Fine to coarse	**Color**	Dark red to orange (coarse-grained), yellowish gray to brown (fine-grained)

The type section of the Cambrian age Deadwood formation is located along Highway 14A near the town of Deadwood. At least two distinct types of quartzite are found in this formation. One type is a coarse-grained quartzite ranging from dark red to orange (Figure 116). A conchoidal fracture creates a somewhat rough surface and breakage patterns are not as predictable as the Inyan Kara group quartzites. The second type of quartzite in this formation, which caps the Deadwood formation, is very different; it is a fine-grained yellowish gray or brown siliceous quartz sandstone with fossil <u>Scolithus</u> burrows (Figure 117). Although this material has a smooth conchoidal fracture, the numerous burrow cavities present flaws throughout that would be difficult to work around for stone tool manufacturing. The dark red to orange coarse-grained variety of quartzite is one of the few quartzites found at archaeological sites in the Black Hills and surrounding areas that can be identified with any degree of accuracy.

Meadow Creek quarry samples are a medium monocrystalline quartzite with hematitic and glauconitic inclusions (Figures 118 and 119). They exhibit angular, well-sorted grains of 0.25 to 0.5 millimeters in diameter and are composed of clear, smoky, and purple-toned single-grained quartz crystals with veining of up to 0.5 millimeter of hematite and 0.25-millimeter pockets of glauconite. The rock is highly metamorphosed and individual grains have been fully recrystallized. It is also well-bonded and silicified except for the glauconite and hematite. The rock is well-compacted and composed of approximately 10 percent smoky quartz, 20 percent clear quartz, 50 percent purple quartz, 15 percent hematite, and 5 percent glauconite. Overall, the color of the rock is influenced by the grains. Breakage patterns are somewhat unpredictable and conchoidal fracturing will present as a somewhat rough surface. Site 39MD79 is located in the northeastern portion of the Black Hills (Figures 120 and 121).

Figure 116. Deadwood quartzite from near site 39MD79, Meade County, South Dakota.

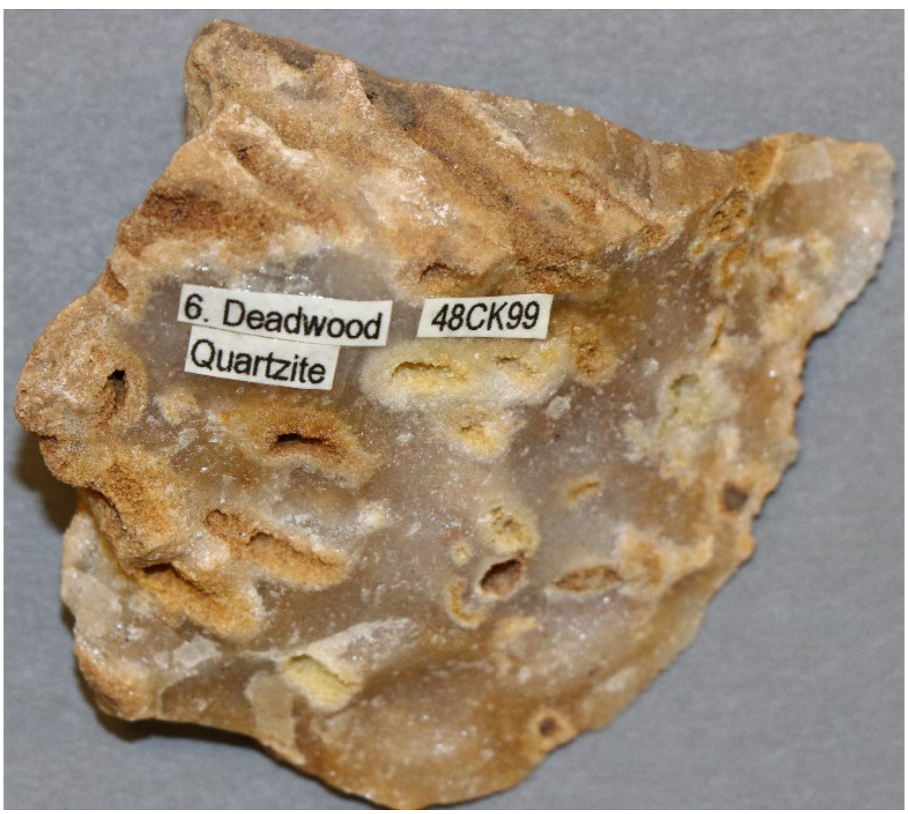


Figure 117. Deadwood quartzite with fossil Scolithus burrows from 48CK99, Crook County, Wyoming.

Figure 118. Deadwood quartzite from near 39MD79.


Figure 119. Closeup of the grains in Deadwood quartzite from near 39MD79.

Figure 120. The quartzite outcrop at possible quarry site 39MD79, Meadow Creek, in Meade County, South Dakota. (Courtesy of USDA FS BKNF.)

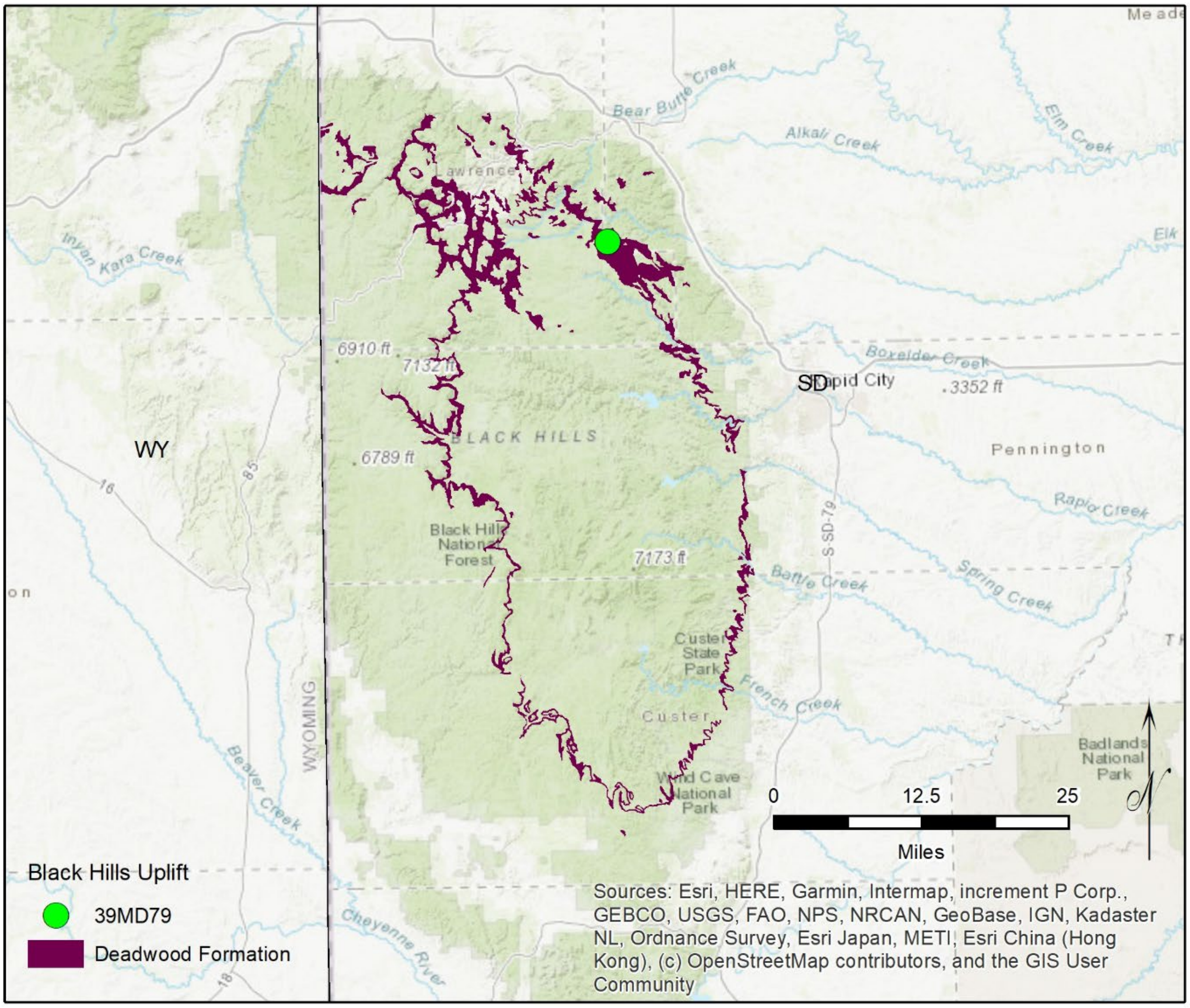


Figure 121. Deadwood quartzite occurs in the Deadwood formation in the Black Hills Uplift of western South Dakota. Samples have been collected at the Meadow Creek quarry site 39MD79, Meade County, South Dakota, as well as Crook County, Wyoming.

FLINT HILL QUARTZITE

OTHER NAMES: Black Hills quartzite, Fall River formation quartzite

MUNSELL COLORS: Light gray N7; Dark gray N3; Grayish purple 5P 4/2; Brownish gray 5YR 4/1; Grayish orange pink 5YR 5/2; Moderate brown 5YR 4/4; Light olive gray 5Y 6/1;
Dusky yellowish brown 10YR 4/2; Dark yellowish brown 10YR 4/2; Pale yellowish brown 10YR 6/2;
Blackish red 5R 2/2; Grayish red 5R 4/2; Pale red 5R 6/2; Light olive gray 5Y 5/2; Yellowish gray 5Y 7/2

Quarries	39FA49-Flint Hill, Fall River County, South Dakota	**Diagnostics**	Highly silicified; variable colored cement; fracturing breaks across the grains
Cortex	Medium to large quartz grains that are angluar to sub-angular with a weathered surface	**Fracture Quality**	Good to excellent
Grain	Angular, sub-rounded, spherical, well-sorted	**Color**	Grays, browns, reds

Flint Hill quarry samples are a fine-crystalline quartzite (Figures 122 and 123). They exhibit angular to sub-rounded, spherical, well-sorted grains of 0.125 to 0.25-millimeter diameter composed of variable colored silica matrix. The rock is highly silicified and well-bonded. The rock is well-compacted and composed of approximately 95 percent semi-transparent to clear quartz crystals and 5 percent dark lithic fragments which can be larger in diameter, up to 0.5 millimeters, with minor inclusions of hematite. Overall, the color of the rock is influenced by the matrix. Conchoidal fracturing presents as a smooth surface with breakage occurring across the grains.

Located in the southern Black Hills (Figures 124 and 125), the quarry covers several acres and includes many prehistoric mining features such as large surface pits, exploited outcrop exposures on the upper portion of the slope, stone processing and workshop areas, and an occupation area with stone circles. It is the most extensive and significant prehistoric quarry known in South Dakota (see Figure 112).

Figure 122. Modified edge on a large Flint Hill quartzite flake.

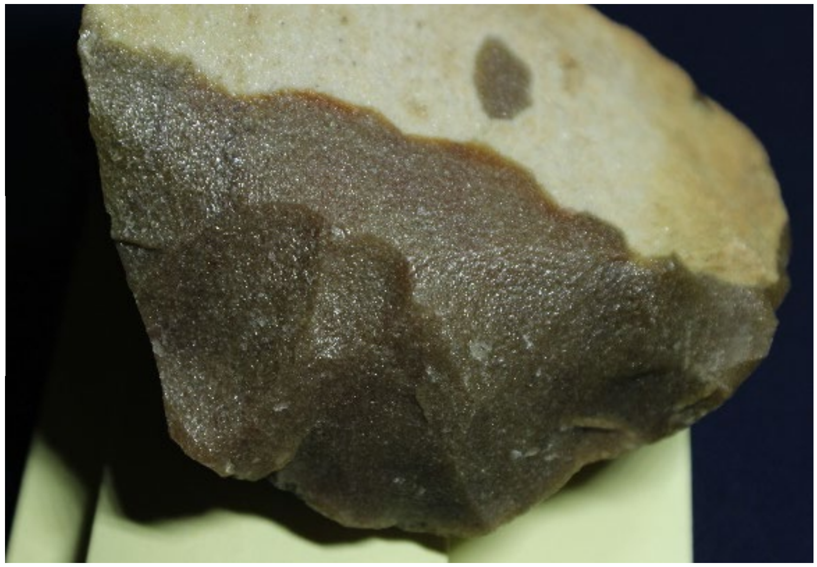


Figure 123. Flint Hill quartzite.

Figure 124. Flint Hill quarry, 39FA49, Fall River County, South Dakota.

Figure 125. Prehistoric quarry pits at Flint Hill quarry, 39FA49, Fall River County, South Dakota.

LAKOTA QUARTZITE

OTHER NAMES: Black Hills quartzite, Lakota formation quartzite

MUNSELL COLORS: Grayish purple 5P 4/2; Pale purple 5P 6/2; Very dusky red purple 5RP 2/2; Grayish red purple 5RP 4/2; Pale red purple 5RP 6/2; Grayish orange pink 5YR 5/2; Light olive gray 5YR 6/1; Pale yellowish brown 10YR 6/2; Blackish red 5R 2/2; Dusky red 5R 3/4; Grayish red 5R 4/2; Pale red 5R 6/2; Grayish red 10R 4/2; Yellowish gray 5Y 7/2; Yellowish gray 5Y 8/1

Quarries	39PN658-Cabot Hill and natural outcrops on Cowboy Hill (near "M" Hill), Pennington County, South Dakota	**Diagnostics**	Well-sorted quartz; fine-grained material typically breaks across grain boundaries
Cortex	Yellow, red, gray, white sugar-like texture	**Fracture Quality**	Good
Grain	Fine to medium	**Color**	Grays, browns, reds, yellows, purples; colors may be solid or banded

Quartzite samples were collected from an outcrop on the east slope of Cowboy Hill in Rapid City, South Dakota, south of Interstate 90 (Figures 126-128). The samples are a fine-grained quartzite that exhibit variable rounding, high sphericity, grain-colored, and 0.125 to 0.25-millimeter diameter quartz grains and lithic fragments. The matrix color is consistently white. Minimal evidence of compaction is present as the edges of the grains are clearly visible. The rock is composed of approximately 90 percent quartz grains of variable types, including rose quartz, and 10 percent variable-colored lithic fragments. Angularity, sorting, compaction, and grain size distribution appears to be influenced by bedding patterns in the parent rock. Overall, color of the rock is influenced by the grains. The rock compaction is variable, some areas are well-compacted, and others are not. Conchoidal fracturing presents as a smooth surface with breakage occurring across the grains. The general location where these samples were collected is shown in Figure 112.

Figure 126. Lakota quartzite from the Rapid City area in the Black Hills Uplift of western South Dakota.

Figure 127. Lakota quartzite from Cowboy Hill in the Black Hills Uplift of western South Dakota.

Figure 128. Lakota quartzite outcrop on Cowboy Hill in Pennington County, South Dakota.

MINNELUSA QUARTZITE

OTHER NAMES: Black Hills quartzite, Minnelusa formation quartzite

MUNSELL COLORS: Grayish orange pink 5YR 7/2; Moderate yellowish brown 10YR 5/4; Pale reddish brown 10R 5/4; Dark reddish brown 10R 3/4; Blackish red 5R 2/2; Dusky red 5R 3/4; Grayish red 5R 4/2; Moderate red 5R 5/4; Pale red 5R 6/2; Moderate pink 5R 7/4; Very dusky red 10R 2/2; Dark reddish brown 10R 3/4; Grayish red 10R 4/2; Moderate reddish brown 10R 4/6; Pale reddish brown 10R 5/4

Quarries	39CU484-Jewel Cave, Custer County, South Dakota	**Diagnostics**	Well-sorted quartz crystals; black spots caused by mineral staining; smooth conchoidal fracturing
Cortex	Yellow, red, tan, sugar-like texture	**Fracture Quality**	Good to excellent
Grain	Fine to medium	**Color**	Red, yellow, reddish brown, pink, yellowish brown, grayish

Minnelusa quartzite is fine to medium-grained and produces a smooth conchoidal fracture (Figures 129 and 130). Colors range from pinks to browns to reds. The photographed lithologic samples were collected from near a quarry site, 39CU484, in Custer County, South Dakota (Figures 131 and 132). The material occurs in the Pennsylvanian-Permian age Minnelusa formation that encircles the Black Hills with broad exposures on the western flank. The formation consists mainly of red and yellow sandstones in the upper half and dolomites in the lower half (Gries 1996). In the Hartville Uplift of Wyoming, the Minnelusa formation correlates with the Fairpoint, Reclamation, Roundtop, Hayden, Wendover-Meek, Broom Creek, and Cassa members (Gries and Martin 1985:270).

Jewel Cave quarry samples are a very fine crystalline quartzite. They exhibit angular, spherical, well-sorted, 0.125millimeter diameter quartz crystals with minor lithic fragments. Matrix color is variable and includes blackish-dusky reds to light red. Some spots of black mineral staining are present in the matrix. The rock is very well-compacted and composed of over 95 percent clear quartz crystals and less than 5 percent black lithic fragments. Some bedding is present in the rock samples; however,

Figure 129. Minnelusa quartzite with cortex and lichen.

grain size and sorting appear to be uninfluenced by the bedding pattern. Edge solution had taken place; therefore, the edges of the grains were not visible. Overall color of the rock is influenced by the matrix.

Figure 130. Minnelusa quartzite interiors and cortex.

Figure 131. The Jewel Cave quarry site, 39CU484, in Custer County, South Dakota. (Courtesy of the USDA FS BKNF.)

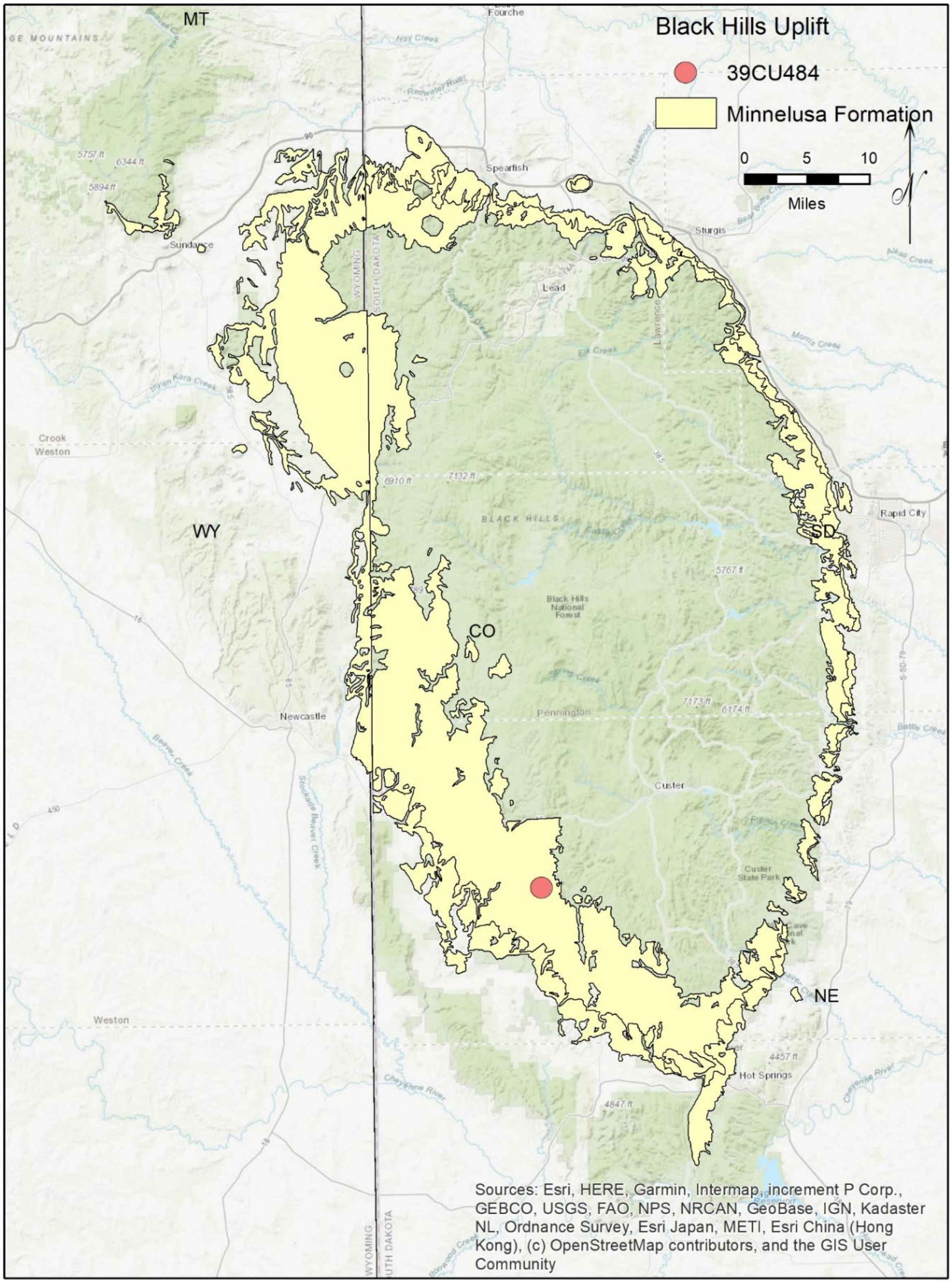


Figure 132. Minnelusa quartzite occurs in the Minnelusa formation in the Black Hills Uplift of western South Dakota and northeastern Wyoming. Samples have been collected from Jewel Cave quarry site, 39CU484.

MORRISON QUARTZITE

OTHER NAMES: Black Hills quartzite[2], Morrison formation quartzite, Morrison silicified siltstone, Morrison silicified sediment

MUNSELL COLORS: Pale yellowish brown 10YR 6/2; Grayish orange 10YR 7/4; Medium light gray N6; Very light gray N8

Quarries	None identified	**Diagnostics**	Small black inclusions or a gray to brown mottled appearance; sub-rounded to rounded quartz grains
Cortex	White to yellow sugar-like texture	**Fracture Quality**	Good
Grain	Fine to medium	**Color**	White, tan, gray

Morrison quartzite is composed predominantly of sub-rounded to rounded quartz grains that range from 95 to 100 percent white to translucent and a 0 to 5 percent copper and iron sulfate (possibly pyrrhotite or pyrite with a metallic sheen) (Figures 133 and 134). Grains which have weathered into the matrix cause a gray-black halo surrounding the weathered sulfate grains, giving it a black spotted appearance. Overall, it is a fine to medium-grained quartzite with white to tan to gray silica matrix with a good conchoidal fracturing quality. The exterior weathers to a somewhat darker patina. Colors occur in many shades and can be mottled or banded. Craig (1983:40-41) provides a succinct description of the source of this material:

> Thin bands of Morrison Formation are exposed on the south, east and west sides of the Black Hills, however, the formation is much more extensive in the northwestern part of the Black Hills in Wyoming from Newcastle north. Tratebas (1978:135) reports that sources of the Morrison Silicified Siltstone have been located only in the southwestern and northern ends of the Black Hills. The light blue silicified siltstone seems to be more common in the Black Hills than in the other source areas. The fine grained light blue quartzite with black, grain-sized inclusions is also found there.

No Morrison silicified siltstone, quartzites, or cherts have been identified in the Hartville uplift. While it is possible the material does exist there, based on present knowledge, the Hartville Uplift will be eliminated as a possible source of this material. Exposures of Morrison formation are limited in the Laramie Range with a distribution similar to the Pennsylvanian Age Hartville formation (Figure 135). Morrison silicified siltstone is known to occur, though not in great quantity.

[2] If found at an archaeological site in the Black Hills or on the fringe of the Black Hills, it would likely be from the Black Hills Uplift, as opposed to the Laramie Range. Therefore, it could be called Black Hills quartzite if the exact formation of origin is in question.

Figure 133. Morrison quartzite showing interior and cortex variations.

Figure 134. Fine-grained examples of Morrison quartzite.

Figure 135. Morrison quartzite occurs in the Morrison formation in the Black Hills Uplift of western South Dakota and northeastern Wyoming.

SHORT PINES QUARTZITE

OTHER NAMES: None

MUNSELL COLORS: Pale olive 10Y 6/2; Light olive gray 5Y 5/2; Light olive gray 5Y 6/1

Quarries	None identified	**Diagnostics**	Grayish-greenish color, immature material, poorly sorted
Cortex	Tan, coarse	**Fracture Quality**	Poor to fair
Grain	Fine to medium	**Color**	Gray, light gray, olive

Short Pines quartzite is a recent addition to lithic sources in South Dakota and is not well-researched. Based on the small sample size currently collected, it is an immature material, poorly sorted, with mostly clear, sub-angular to sub-rounded milky-colored quartz grains, tourmaline, and pink and orange feldspar (Figures 136 and 137). It contains 5 to 8 percent rock fragments (about twice that found in Bijou Hills quartzite) and maintains some euhedral shape with angular fractures. There is little silica cement visible between the tightly set grains. The druzy quartz surface layer, crystallized minute quartz crystals, gives it a sugary appearance (Roger Williams and Dave Nonnast, personal communication, 2008). It exhibits an overall greenish color, probably due to glauconite and chlorite particles, similar to Bijou Hills quartzite.

A biface from the East Short Pines Tongue River silica quarry site (39HN298, Accession 87-69, catalog #107) is made from a coarse grayish green quartzite (Figure 138). Both faces of the tool are weathered. After examining the biface, Dr. Stan Ahler and Dr. Robert Alex agreed that it was similar to Bijou Hills quartzite and referred to it as "Bijou Hills-like" quartzite (Keyser and Fagan 1987). In 2008, the biface was compared to the lithic sample from the East Short Pines. The biface material is like Short Pines quartzite in that it is immature, although the amount of cement between grains is less than that in the East Short Pines samples. Overall, it is comparatively much more like Short Pines quartzite than the more mature Bijou Hills quartzite samples. Thus, based on new information, it is quite possible that the biface material is from a local source, not, as originally suggested by Keyser and Fagan, a non-local source.

Macroscopically, if Short Pines quartzite was found out of geologic context at an archaeological site, it could easily be misidentified as Bijou Hills quartzite (Figure 139). Another point to make is that, in the 1950s, geologists tentatively identified a few small outcrops west of the Missouri River in Corson County, South Dakota, as a possible Bijou Hills formation. Based on these tentative outcrop identifications, Ahler (1977) suggested that the green quartzite material used for tools and debitage at sites along the Missouri River in northern South Dakota may have been procured at these locations. No information has been found indicating that archaeologists found the source of the green quartzite in these areas noted by geologists. Geologists have since reclassified these outcrops as Quaternary outwash deposits (Martin et al. 2004). Further research is necessary to determine if the green quartzite found at Missouri River sites is Short Pines quartzite, Bijou Hills quartzite, green quartzite found in outwash deposits along or near the Missouri River Valley Trench, or from another unidentified source. It is recommended that the term Bijou Hills quartzite be reserved for materials derived directly from the Bijou facies in the Valentine and Ash Hollow formations, as suggested by Agnew (1957). The Short Pines quartzite is probably coming out of a formation within the East and West Short Pines in northwestern South Dakota (Figure 140).

Figure 136. East Short Pines quartzite.

Figure 137. Closeup of East Short Pines quartzite shown in Figure 136.

Figure 138. Closeup of the edge of a quartzite biface from site 39HN298, that may be made from Short Pines quartzite.

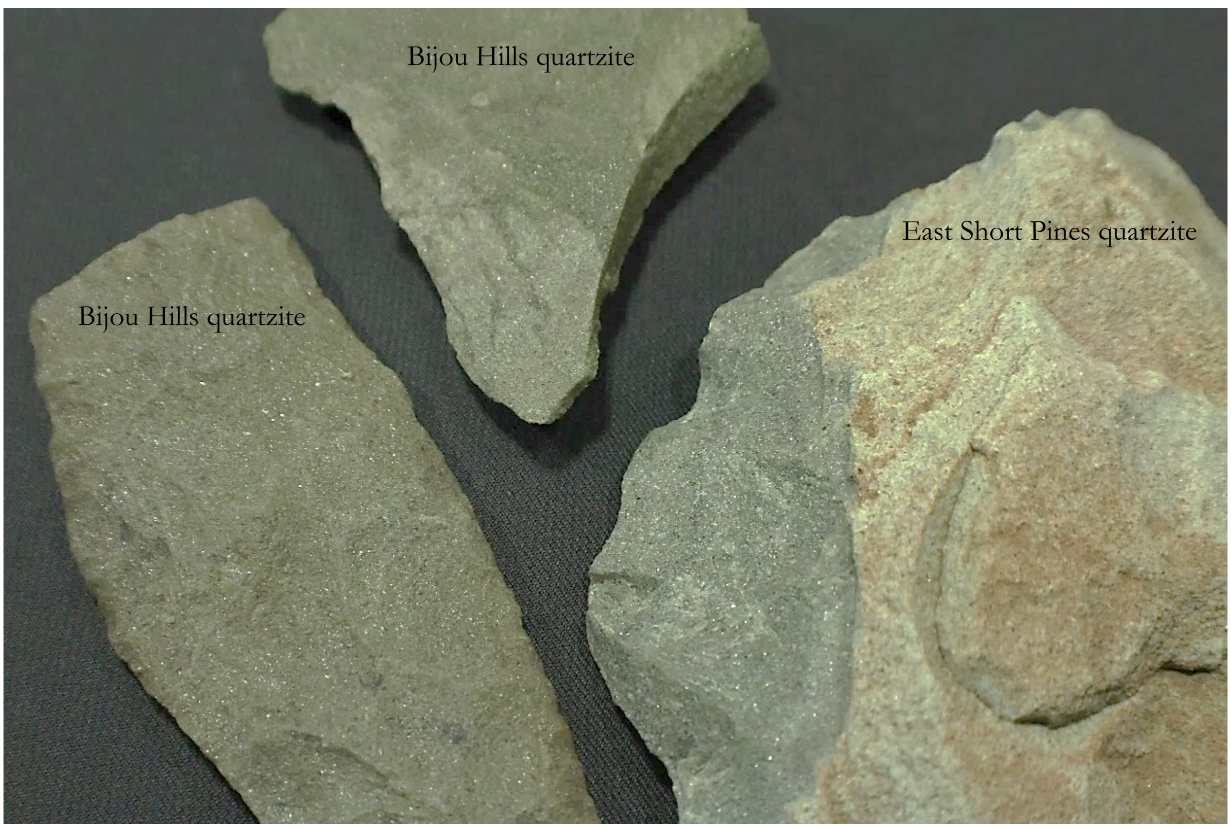


Figure 139. Comparing examples of Bijou Hills and East Short Pines quartzite.

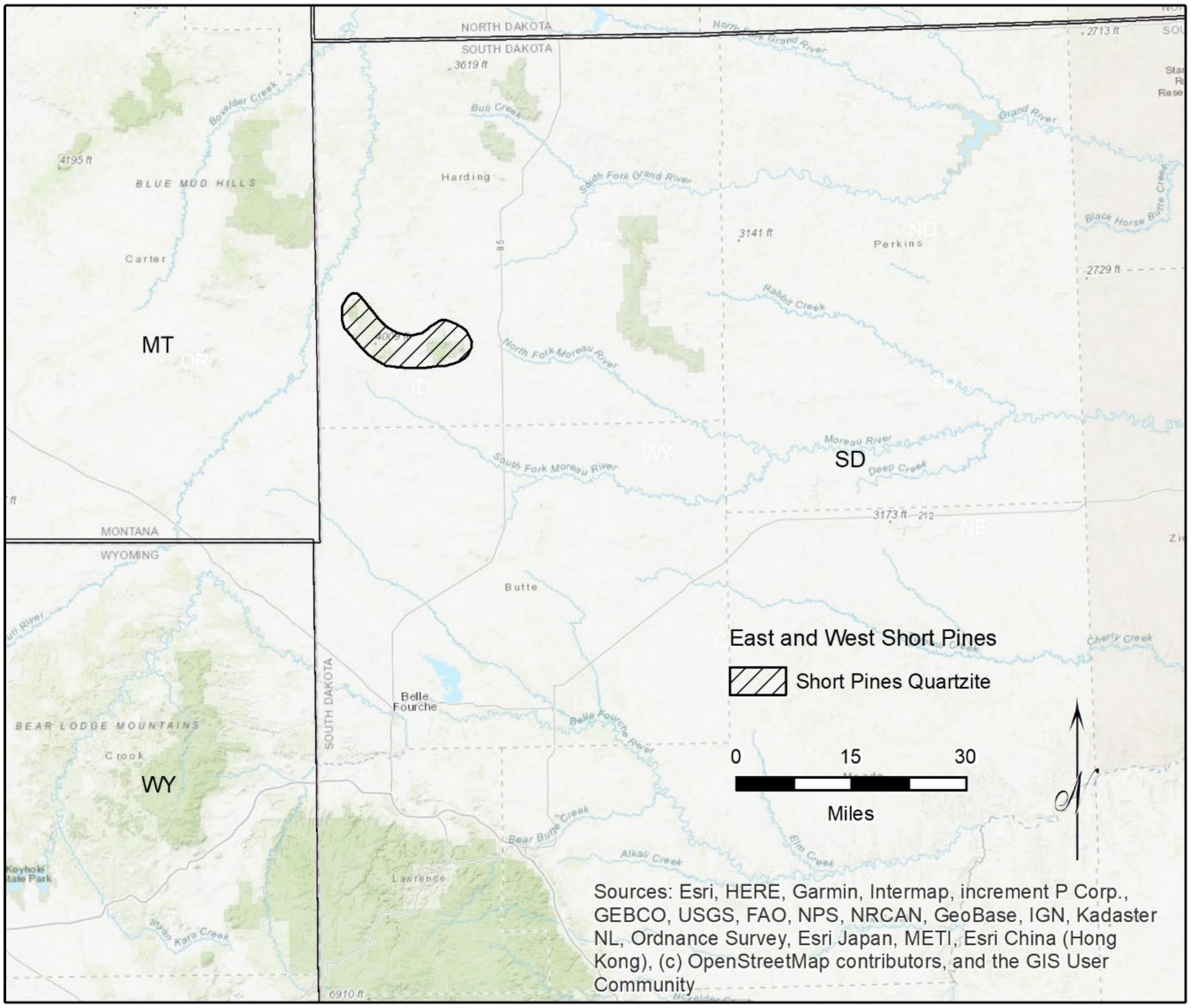


Figure 140. The East and West Short Pines in northwestern South Dakota, where it is thought that the Short Pines quartzite originates.

SIOUX QUARTZITE

OTHER NAMES: None

MUNSELL COLORS: Grayish red 5R 4/2; Pale red 5R 6/2;
Pale red 10R 6/2; Grayish orange pink 5R 7/2

Quarries	None identified	**Diagnostics**	Pink color (with or without banding); poor conchoidal fracturing
Cortex	Red, pink, yellow, gray, sugar-like texture	**Fracture Quality**	Poor to fair
Grain	Coarse	**Color**	Pink, pale red, grayish red

Sioux quartzite is a sandstone tightly cemented with quartz that exhibits a pink color, created by an iron oxide layer tightly encased around the sandstone grains (Figures 141 and 142). Banding may also be present in a sample. It is interbedded with layers of shale or clay that vary from 1 inch to 30 feet thick. Where compacted, this clay becomes indurated and is known as catlinite. Because this is a coarse quartzite with poor to fair knapping quality, it was infrequently used for prehistoric projectile points. It was typically used to make hand-held choppers or large bifaces, rather than knapped into small, chipped stone tools. There is one example of a large metate made of Sioux quartzite from probably southeastern South Dakota (Figure 143a); exact provenience is unknown. Another example was plowed up at site 39LK15, on the shore of Lake Madison, in Lake County, South Dakota (Figure 143b). Sioux quartzite is found in the Sioux formation (Figure 144).

Figure 141. Sioux quartzite from Pipestone County, Minnesota, showing banding.

Figure 142. Sioux quartzite. Example on the left is shown in Figure 141.

Figure 143. Two Sioux quartzite metates; a) probably from the southeastern portion of South Dakota and b) from 39LK15, Lake County, South Dakota. (Artifact "b" was photographed courtesy of DHL-HC.)

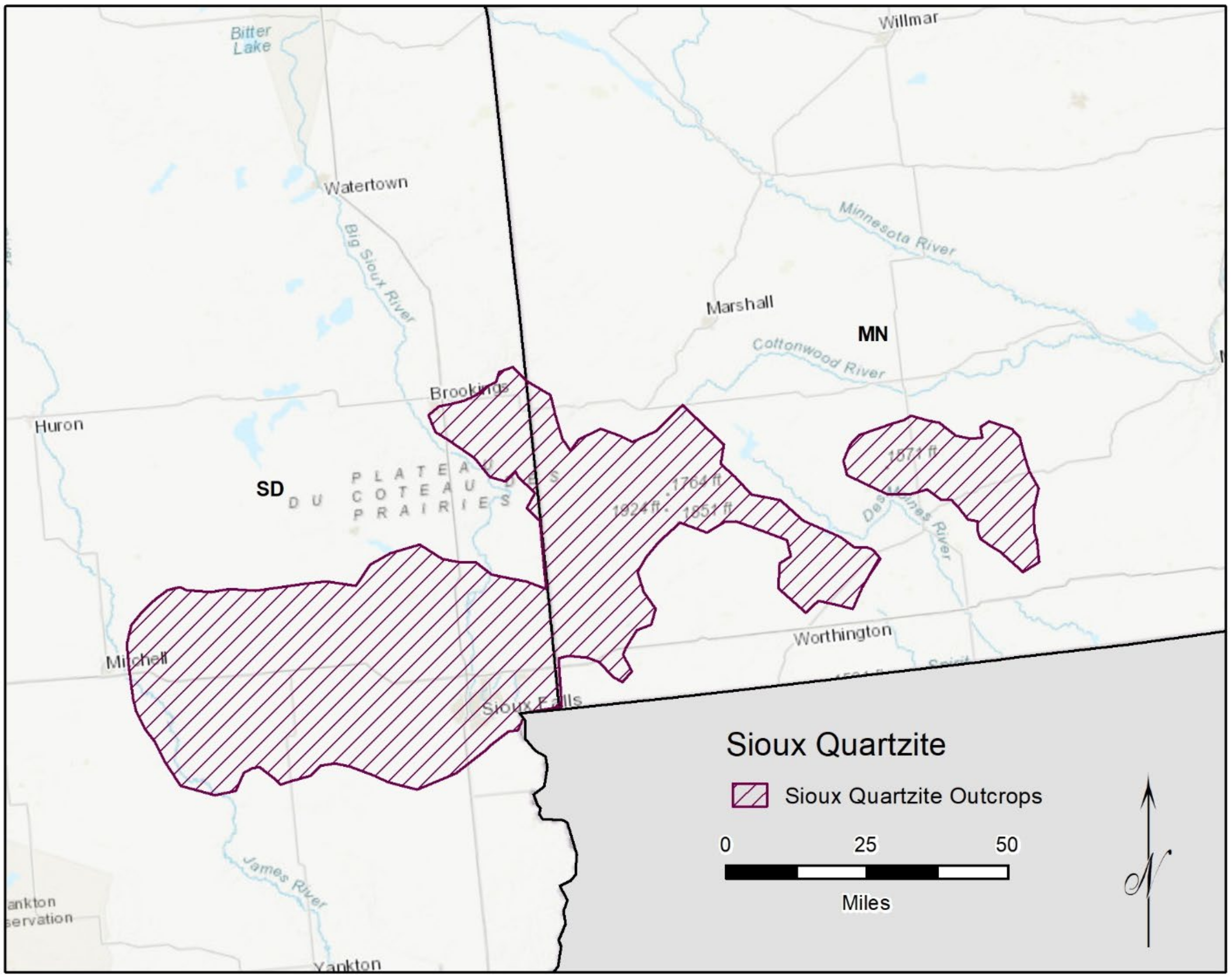


Figure 144. Sioux quartzite originates in the Sioux formation in southwestern Minnesota and southeastern South Dakota. The formation extends into Iowa as well.

SPANISH DIGGINGS QUARTZITE

OTHER NAMES: Hartville Uplift quartzite

MUNSELL COLORS: *Saul Quarry #1*: Grayish purple 5P 4/2; Grayish red purple 5RP 4/2; Pale red purple 5RP 6/2; Brownish gray 5YR 4/1; Grayish orange pink 5YR 5/2; Grayish orange pink 5YR 7/2; Pale yellowish brown 10YR 6/2; Pale red 10R 6/2
Saul Quarry #5: Light gray N7; Medium dark gray N4; Grayish brown 5YR 3/2; Moderate brown 5YR 3/4; Grayish orange pink 5YR 5/2; Light brown 5YR 5/6; Moderate yellowish brown 10YR 5/4; Very pale orange 10YR 6/2; Light olive gray 5Y 5/2

Quarries	Saul Quarry #1 (Barbour quarry) and Saul Quarry #5, Platte County, Wyoming	**Diagnostics**	Unknown source samples can be difficult to distinguish from other Black Hills quartzites with any more than a relative degree of certainty
Cortex	Variable color; sugar like texture; caliche-like weathering byproduct	**Fracture Quality**	Good to excellent
Grain	Medium, recrystalization; well-sorted, spherical, sub-rounded quartz; lithic fragments present	**Color**	Gray, brown, red, yellow; colors may be solid or banded

Figure 145. Saul quarry #1 quartzite.

Figure 146. Saul quarry #5 quartzite.

The Saul Quarry #1 and Saul Quarry #5 samples of Spanish Diggings quartzite from Platte County, Wyoming (see Figure 112) were examined separately but described together because of their strong similarity (Figures 145-149). The Saul quarry materials are a fine to medium-grained crystalline quartzite. They exhibit well-sorted, spherical, and sub-rounded quartz grains and lithic fragments. Composition is variable, but typically is more than 75 percent quartz of assorted coloration and less than 25 percent lithic fragments. Material can be variable in grain size and recrystallization; however, it is typically consistent within a given lithic sample. Grain size ranges from 0.125 to 0.5 millimeters with the reddish purple, more recrystallized material dominating the larger grain sizes. The larger grain sizes do not break across the grain boundaries, whereas, the smaller, more fine-grained material, which is less recrystallized, breaks cleanly across grain boundaries and produces a smoother conchoidal fracture. Several patinas were present in the samples, but of note was a malachite green, caliche-like weathering byproduct on one, that may have been influenced by the presence of copper. Clast size, color, compaction, and composition are highly variable between lithic samples as is matrix color. Saul Quarry #1 includes large mining pits in the Hartville Uplift in eastern Wyoming (Figure 150).

Figure 147. Spanish Diggings quartzite quarry blanks and debitage from the Hartville Uplift in eastern Wyoming.

Figure 148. Spanish Diggings quartzites from the Hartville Uplift in eastern Wyoming.


Figure 149. Banding in Spanish Diggings quartzite from the Hartville Uplift in eastern Wyoming.

Figure 150. Saul Quarry #1 in Platte County, Wyoming. (Courtesy of the WY SHPO.)

TONGUE RIVER SILICA

OTHER NAMES: Tongue River silicified sediment, Tongue River silicified sandstone

MUNSELL COLORS: Medium dark gray N4 or N5; Very light gray N8;
Pale yellowish brown 10YR 6/2; Dark reddish brown 10R 3/4; Pale reddish brown 10R 5/4;
Moderate reddish brown 10R 4/6; Light olive gray 5Y 6/1; Olive gray 5Y 4/1

Quarries	39HN298-ESP Quarry, Harding County, South Dakota; and outwash deposits across the Northern and Northwestern Great Plains	**Diagnostics Color**	Vugs and hollow fossil plant root or stem impressions which can create rough and inconsistent breakage; challenging to knap, but improves with heat treatment; heat treatment can result in a color change which should not be confused with a naturally occurring red exterior patina
Cortex	Tan to red patina	**Fracture Quality**	Fair to good
Grain	Variable; degree of metamorphism between grains varies	**Color**	Tan and gray (typically in the smooth variety) and yellowish brown, red, and purple (typically in the coarse variety)

Tongue River silica is a quartzite with a clay fracture fill and variable grain size associated with bedding (Figures 151 and 152). Colors can be gray to light tan to reddish hues, with a tan to reddish to purple weathering patina. The patina exhibits some clay formation on weathered surfaces and the reddish to purple staining is caused by hematitic or magnesium oxide staining. The tan matrix includes clear or translucent to tan or black grains. Individual grain boundaries are indistinct due to metamorphism; it is so highly metamorphosed that grain boundaries are pushed together and the degree of metamorphism from grain to grain varies. The original bedding is visible in some samples but not in others. The texture is related to the bedding and fracture infilling. This directly impacts the quality of the conchoidal fracturing, which can be quite irregular. Thus, the material has an inconsistent quality. A distinguishing characteristic is the presence of hollow fossil plant roots or stem impressions that have a random orientation.

Ahler (1977) recognized two varieties, including a smooth gray material and a coarse yellow and red material. Both varieties occur in the same geologic context. The smooth gray variety is opaque, often mottled, has a dull luster, moderate to well-defined conchoidal fracturing, and few plant fossil inclusions. It seems to occur less frequently than the coarse variety. The coarse yellow and red variety has a sub-conchoidal fracture, coarser texture than the smooth gray variety, and a color range of yellowish brown to dull red. Many hollow fossil plant roots and stems occur in this variety. It seems to be much more common than the smooth gray variety.

Tongue River silica was used extensively from the Paleoindian period forward. It is an extremely hard material that is difficult to knap. Predicting breakage patterns is challenging due to the fossil inclusions. Heat treating improves its knapping quality and may cause a color change from yellow to red. Assumptions of heat treatment should not be made based on the red color. Cobbles or smaller pieces of this material can be angular, as a result of natural freeze-thaw cycles on the Northern Plains. These may be misinterpreted as "fire-cracked rock" without direct evidence of hearths or hearth remnants. Archaeologists need to take this factor into consideration when they discover this angular material in or near a site.

Although there are examples of projectile points and scrapers made from this material, its qualities make it a poor choice for small scraping and penetrating tools. It serves better as a large cutting tool (see Ahler 1977). In Ahler's (1977) study, he concludes that both Middle Missouri and Coalescent Tradition populations made use of Tongue River silica available in local gravels. Several examples of stone tools made from Tongue River silica have also been found at sites on the Couteau des Prairies in eastern South Dakota.

In northwestern South Dakota (Figure 153) lag deposits of Tongue River silica occur naturally at the end of finger ridges where erosion depletes the soil, leaving small piles of the material exposed. In many cases, these natural exposures have been misinterpreted as cairns constructed by prehistoric or historic groups. One such natural exposure was recorded in Perkins County at site 39PE145 and tested by archaeologists (Laundry 2014). There were no cultural materials associated with the rocks and the profile exhibited no evidence that it was of human origin; it was defined as a natural deposit. Random exposures of this material have also been mistakenly identified as tipi rings in the same region. Subsurface testing is recommended to verify whether the stones represent a habitation or are a natural occurrence on the landscape.

Figure 151. Tongue River silica endscrapers. Tongue River silica is among the hardest stone materials that were used for chipped stone tools.

Figure 152. Tongue River silica, from northwestern South Dakota, with fossil inclusions.

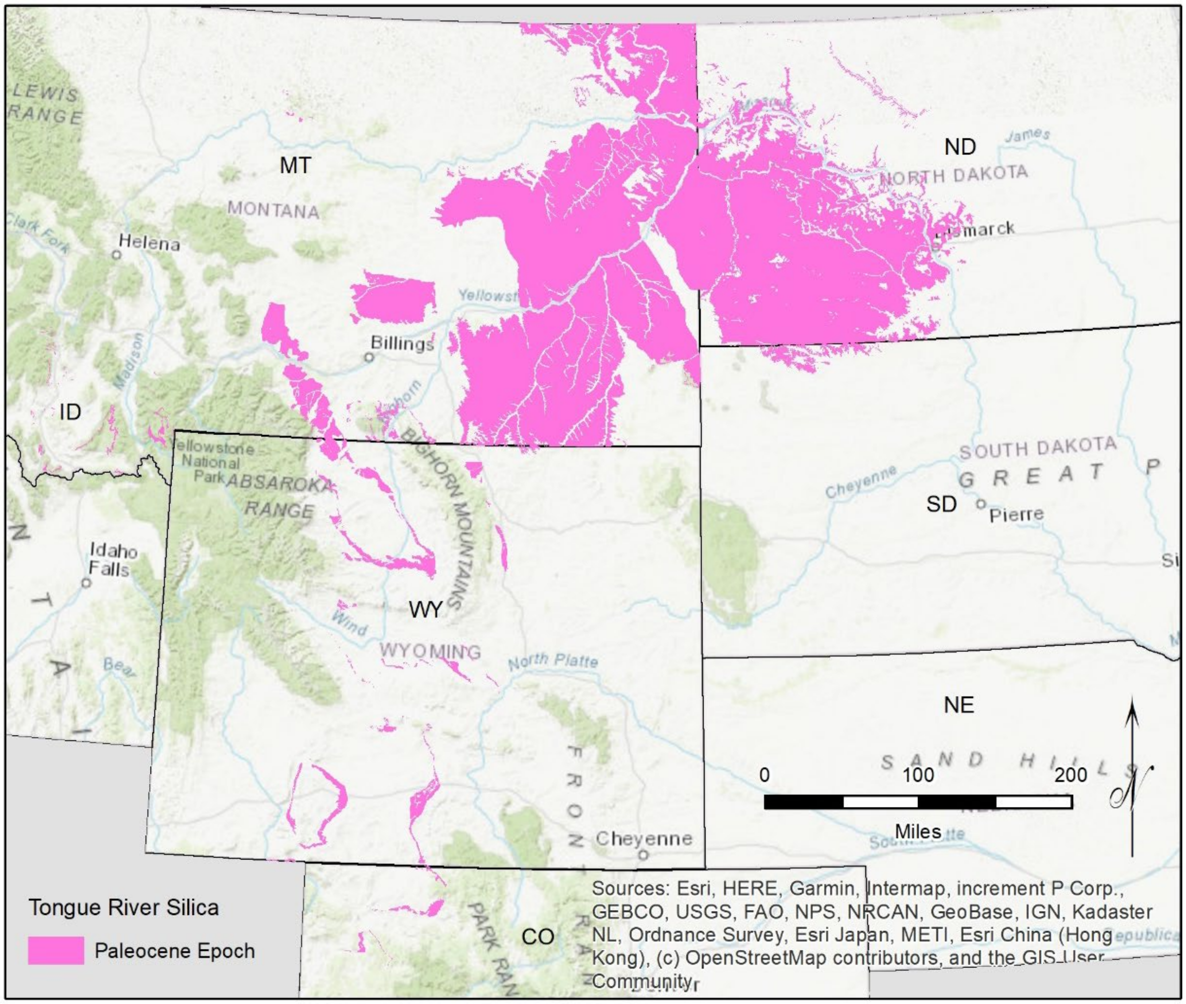


Figure 153. Tongue River silica is associated with the Tongue River formation and is also found across the Northwestern Great Plains as outwash deposits.

CATLINITE AND RED PIPESTONE

OTHER NAMES: None

MUNSELL COLORS: Moderate red 5R 4/6; Grayish red 5R 4/2; Moderate pink 5R 7/4; Moderate orange pink 10R 7/4

Quarries	*Catlinite*: 21PP9, 21PP10, and 21PP11, Pipestone National Monument, Pipestone County, Minnesota *Red pipestone*: Barron County, Wisconson; Scioto and Perry Counties, Ohio; Yavapai and Pima Counties, Arizona	**Diagnostics**	Soft claystone that exhibits a powdery residue when scratched; weathers easily in wet conditions; dull waxy luster; iron oxide inclusions
Cortex	Clay-like; pock-marked rind	**Fracture Quality**	Not knapped, but rather cut or otherwise worked
Grain	Fine	**Color**	Pink, red, purple

Catlinite and red pipestone are highly metamorphosed, micro-laminated, indurated clays that form as seams in local formations, depending on the location, such as the Sioux formation in South Dakota, Minnesota, and into Iowa (Figures 154-158). It has a dull waxy appearance, fine-grained conchoidal fracture, soft (with a hardness around 2), and has a powdery residue once scratched. Colors can include pinks to reds to purple tones with iron oxide inclusions. Tints can be so broken up that they give the appearance of mottling. Weathered surfaces have a clay-like, pockmarked rind that may have a white color. Because this claystone is so soft, it weathers readily when wet and can be easily worked using hand tools. Prehistorically, water was probably used in the processing of the material. Catlinite was originally named for George Catlin, an early Plains artist. Catlin documented his 1837 visit to the Pipestone quarry.

After an extensive study of indurated red clays from several geographical and geological locations listed in the above table, Sigstad (1973) reserved the term catlinite for the chemically distinct materials quarried at Pipestone, Minnesota and those found in Minnehaha County, South Dakota. Sigstad (1973) indicated that the term should also be applied to any other indurated clays with the same chemical make-up, regardless of the geological stratum from which they derived. He preferred the term red pipestone for all other similarly hardened red clays, which were typically associated with quartzite deposits, such as the Baraboo quartzite in Wisconsin.

Catlinite was used for pipes, pendants, beads, tobacco cutting boards, plaques, rings, and ornamental, sacred, and ceremonial items. It is not knapped, rather it is cut, carved, smoothed, drilled, or incised to form an object. Its use for pipes continues today, by Native Americans who have exclusive rights to quarrying at the Pipestone National Monument.

Red pipestone outcrops in Barron County, Wisconsin and Scioto and Perry counties, Ohio. Transported or outwash deposits of red pipestone have also been found in Kansas. One specific example is a cobble collected along the north bank of the Kansas River, six miles east of Manhattan, Kansas (Sigstad 1973). A red argillite (non-catlinite) outcrops in Yavapai and Pima counties, Arizona.

Figure 154. Variations of the interior and cortex of catlinite.


Figure 155. Mottling, inclusions, and color variations in catlinite.

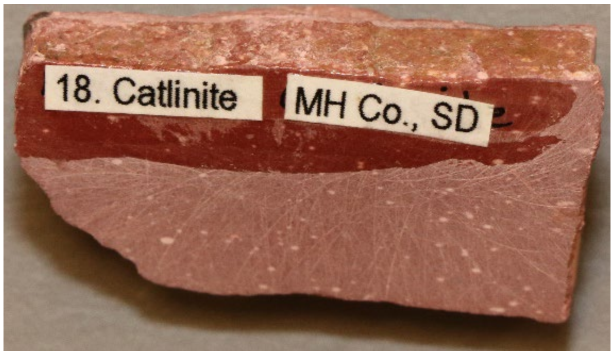


Figure 156. Catlinite from Minnehaha County, South Dakota.

Figure 157. Red pipestone from Wisconsin.

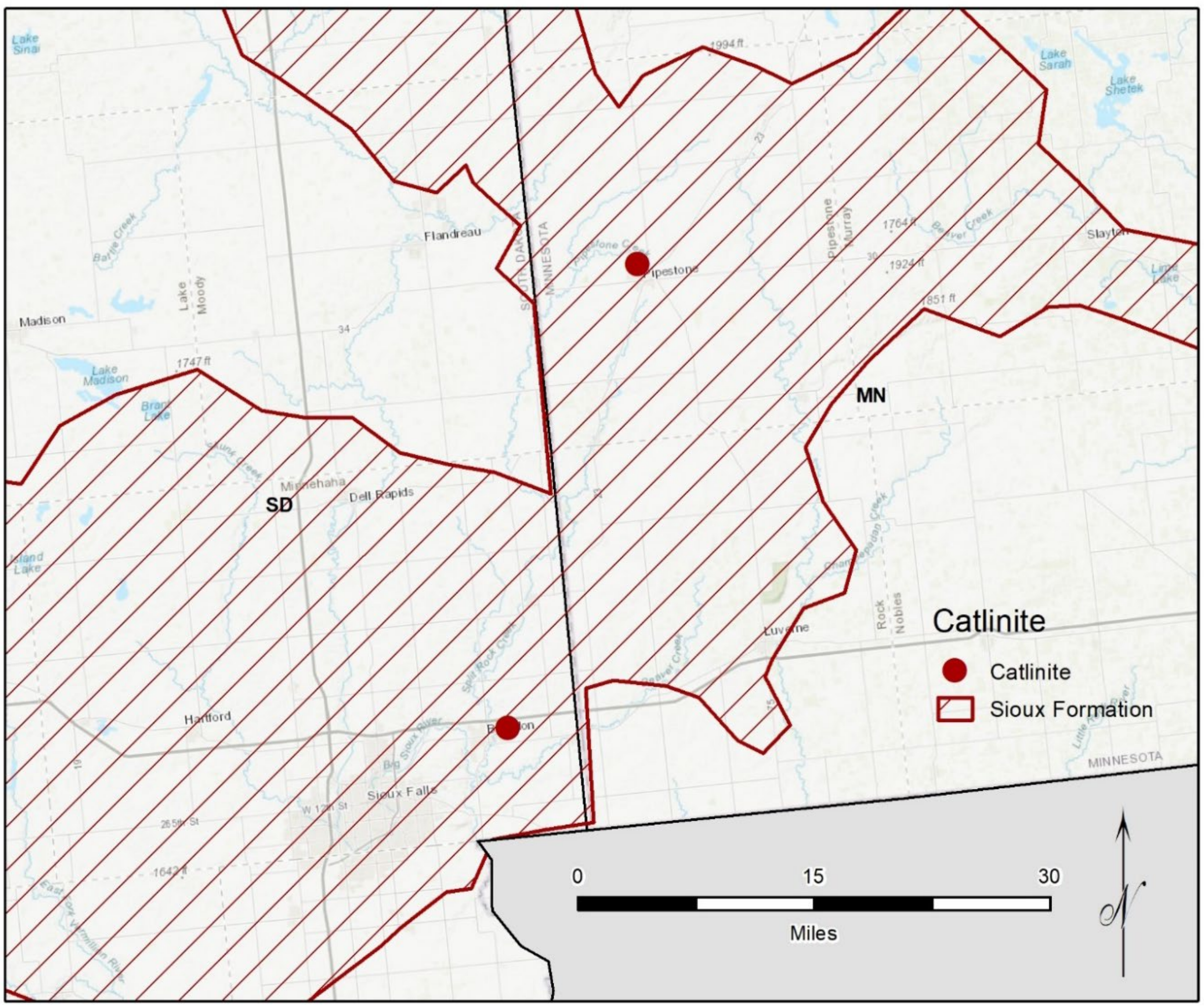


Figure 158. Catlinite originates in the Sioux formation in southwestern Minnesota and southeastern South Dakota. The formation extends into Iowa as well.

OBSIDIAN

OTHER NAMES: Black glass, Volcanic glass

MUNSELL COLORS: Black N1; Grayish black N2; Dark gray N3; Greenish black 5GY 2/1; Olive black 5Y 2/1; Moderate reddish brown 10R 4/6; Moderate brown 5YR 3/4

Quarries	Obsidian Cliff, Cougar Creek, and Teton Pass south of Jackson Hole, Wyoming; Bear Gulch, Idaho; Newberry Crater National Monument and Lake and Harney counties, Oregon; Outwash deposits in the Badlands at 39PN746, Pennington County, South Dakota	**Diagnostics**	Bright vitreous luster; razor-sharp when flaked; thin edges can be transparent; typically thought to be the highest quality tool stone because of its fine conchoidal fracturing
Cortex	White to gray, rough	**Fracture Quality**	Excellent
Grain	Extremely fine and glass-like	**Color**	Black, yellow, red, brown, reddish brown

Obsidian is a natural volcanic glass with a vitreous luster and excellent conchoidal fracturing properties (Figures 159-160). It can exhibit translucent to opaque flow banding, a solid color, or a range of colors in a single sample. Its color is due to small amounts of impurities such as iron or magnesium, which gives it a black, reddish brown, or dark green color. The reddish brown examples are often referred to as mahogany obsidian.

Obsidian is high in silica and low in water and carbon dioxide. It is likely that the low water content prevented the formation of crystals when the lava cooled. In composition, it represents the uncrystallized equivalent of rhyolite and granite. It is known for its glass-like quality which gives it a good to excellent conchoidal fracture and can be worked into a tool with a sharp edge that rivals a surgeon's knife. Obsidian Cliff in Yellowstone National Park, northwestern Wyoming, is the most common source for obsidian materials found at archaeological sites on the Northern Plains.

Two other sources in the northwestern United States include Teton Pass south of Jackson Hole, Wyoming, and a Bear Gulch, Idaho source, called the FMY or 90 Group, at the Chicago Field Museum, which has been cataloged at the museum as "Yellowstone". Neutron activation analysis in the 1960s did not support a Yellowstone origination of the FMY/90 Group sample, now identified as Bear Gulch, located southwest of Obsidian Cliff. Bear Gulch obsidian occurs in alluvial fan deposits that date to the Pleistocene and Holocene age (Hughes and Nelson 1987:313). Hughes and Nelson (1987) suggest that the parent source exists to the north in the Centennial Mountains of northern Idaho.

Pitchstone, a volcanic glass with a pitchstone appearance, has been found in the Black Hills at the Tomahawk Country Club west of Rapid City, South Dakota (Figure 161). Pitchstone is like obsidian but coarser and has more variable composition. The Tomahawk examples were created in volcanic tubes and are riddled with internal fractures. None of the samples available are a high enough quality to knap. Based on the trace elements, Hughes (2006:3) identified the Tomahawk samples as compositionally more like glassy basalt than true obsidian.

The obsidian samples collected in the Badlands southeast of Wall, South Dakota, at site 39PN746, vary greatly in quality with respect to flintknapping (Figure 162). However, some cobble sized samples are of a high enough quality to have been used prehistorically for toolmaking. The source, described as "a bedded deposit of secondarily derived, waterworn and transported cobbles and boulders" (Nowak 1982:16.11), is thought to represent materials that eroded out of the Black Hills. The material is a brownish black obsidian with many impurities (including vugs), which results in a weak conchoidal fracturing quality. Some of the larger cobbles are an overall higher quality.

Both the Tomahawk Golf Course and 39PN746 samples were analyzed by Geochemical Research Laboratory in 2006 (Hughes 2006). The quantitative energy dispersive X-ray fluorescence data from these samples did not match any known geologic obsidian sources on the northern Great Plains. Thus, the unique composition of the samples from these sources should be useful comparisons in future tests on obsidian found at archaeological sites or at other sources that may be identified in the Black Hills and Badlands region.

Obsidian is generally a high quality material for stone tools although quality can vary. It was widely traded as early as the Late Archaic period and found during later periods as far southeast as Arkansas. On the Northern Plains, obsidian has held the interest of the archaeological community due to its high quality, widespread albeit thin distribution from the various geologic sources in the northwestern United States (Figure 163), and its place in the trade network among tribal cultures over the millennia. As additional prehistorically mined sources are chemically identified, the results will prove interesting in future interpretations of the archaeological record.

Figure 159. Mahogany, snowflake, black, and reddish-brown obsidian (left to right) from the northwestern United States. Obsidian, known for its high-quality fracturing characteristics, can be worked into a tool with a razor-sharp edge that rivals a surgeon's knife.

Figure 160. Obsidian often has a translucent quality.

Figure 161. Pitchstone, from Tomahawk Country Club in the Black Hills Uplift, has a low conchoidal fracturing quality.

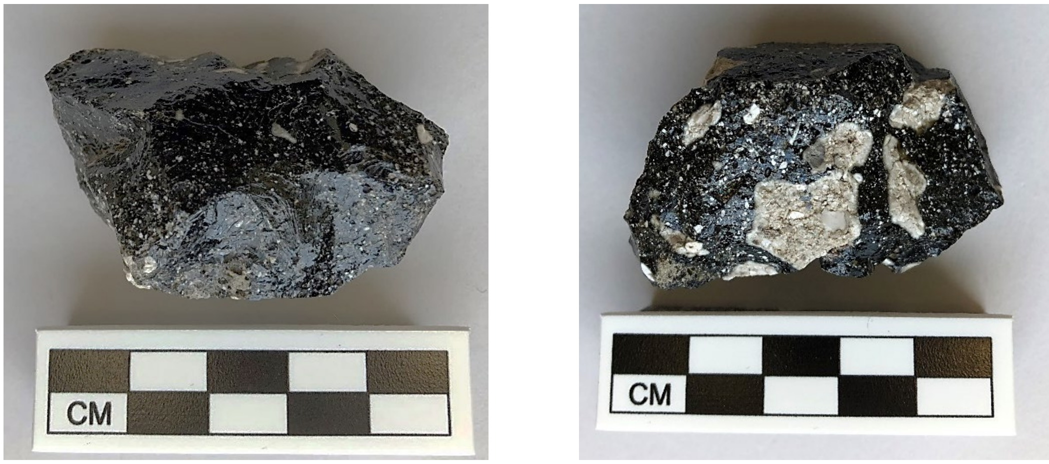


Figure 162. Two views of a fragment of reworked obsidian from Jackson County, South Dakota. It occurs as outwash deposits from the Black Hills Uplift.

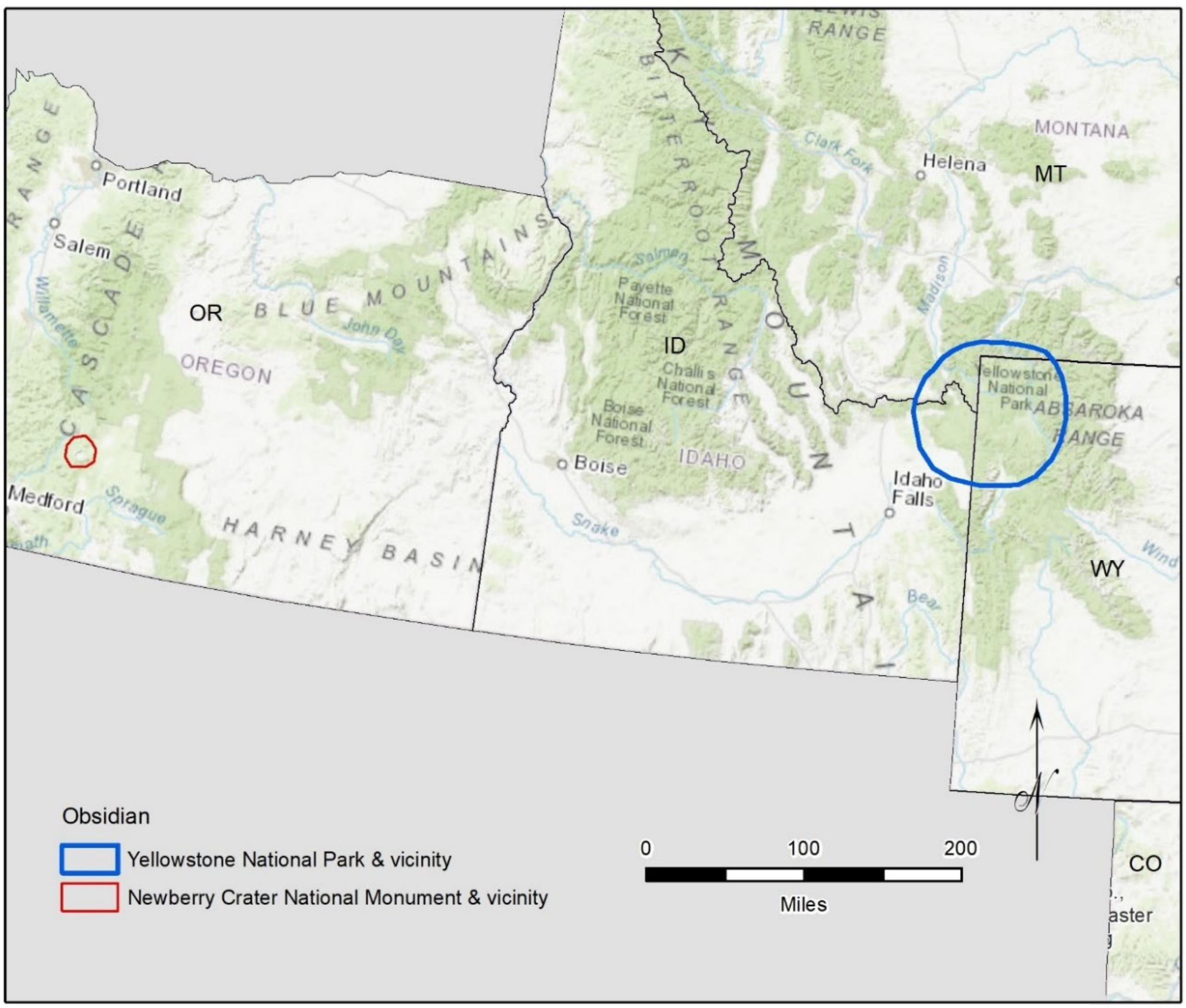


Figure 163. General location of obsidian sources in Oregon, Idaho, Montana, and Wyoming.

PORCELLANITE & NON-VOLCANIC NATURAL GLASS

OTHER NAMES: Fused glass, Clinker, Metamorphosed siltstone, Power River chert, Baked shale, Fired brick

MUNSELL COLORS: Black N1 to Medium light gray N6; Greenish black 5GY 2/1; Pale reddish brown 10R 5/4; Moderate reddish brown 10R 4/6; Grayish olive 10Y 4/2; Light brown 5YR 5/6; Moderate brown 5YR 4/4; Grayish brown 5YR 3/2; Dusky brown 5YR 2/2; Moderate yellow 5Y 7/6; Light olive brown 5Y 5/6; Olive gray 5Y 3/2; Light bluish gray 5B 7/1

Quarries	Along the Tongue River between Acme, Wyoming and Decker, Montana; western North Dakota and northwestern South Dakota, where burned coal seams are present	**Diagnostics**	Dull to waxy luster (non-vitreous); high sheen and glassy appearance (vitreous); uniform texture; opaque; color variation within a single sample because of bedding or fracturing
Cortex	Smooth; matte; dull to waxy; variety of colors	**Fracture Quality**	Fair to good
Grain	Fine and uniform	**Color**	Red and gray are common but yellow, black, brown, pink, and purple also occur

Porcellanite (also known as clinker), non-volcanic natural glass, and scoria are all formed in association with near-surface coal seam fires (Figures 164-170). On the Northern Great Plains, the seams can be found Montana, Wyoming, western North Dakota, northwestern South Dakota, and on talus slopes along the Tongue River. The topography in this region is made up of flat basins and erosion resistant mesa-like remnants capped with porcellanite (Heffern et al. 1983). Porcellanite is easily accessible on these features and can be seen along Interstate 90 just west of Spearfish, South Dakota (Fredlund 1976; Lageson and Spearing 1988).

Non-vitreous porcellanite is heat metamorphosed clay, quite uniform, and finely textured (American Geological Institute 1962). Although the term clinker has been used for this material, porcellanite is preferred because it has been more widely used, recognized, and accepted in the archaeological literature. This heat metamorphosed clay is quite uniform and fine-textured. Luster depends on the degree of metamorphism. The non-vitreous variety is opaque and exhibits a dull earthy to waxy luster. The vitreous variety has a high sheen caused by a higher degree of metamorphism. Red and gray are the most common colors for both types, however, a wide variety of colors can be found, including yellow, black, brown, pink, red, and purple. Discolorations in the material are linked to the bedding or fracturing. The non-vitreous porcellanite is more common and has a higher flintknapping quality than vitreous porcellanite. Both non-vitreous and vitreous porcellanite are inferior to cherts, chalcedonies, and jaspers when it comes to flintknapping, making them unlikely trade items.

Non-volcanic natural glass (NVN glass) undergoes a greater degree of compaction than porcellanite, leading to minor inclusions, vugs, and its vitreous nature. It is less common than porcellanite and tends to be opaque with small black dendritic inclusions. NVN glass is a fused glass that formed as nodules and though it can resemble obsidian, it has many tiny internal gas bubbles. It is neither volcanic nor true obsidian. Black and green are the most common colors of NVN glass, although it also occurs as red, yellow, and gray with minor inclusions and vugs. It has no physical resemblance to, and is not as abundant as, porcellanite. It is inferior to porcellanite for tool making.

Scoria forms in this same environment, although nearer to the surface and with a much higher degree of moisture and gas. Scoria is porous, light, buoyant, and has dull colors such as reds and grays. Without the moisture and gas, clinker will develop, which is found deeper than scoria but is also dull colored.

Carbone (1972:18) found several porcellanite procurement sites situated intermittently along the Tongue River between Acme in northeastern Wyoming and Decker in southeastern Montana, which he refers to as Area II (Acme-Decker). He also mentions two quarries where the material was mined in this area and notes the higher quality of the quarried material when compared to the material exposed on the surface. In order to protect the sites, he did not give the specific locations of these quarries. An effort by the authors to pinpoint these procurement sites has, thus far, been unsuccessful. However, it can be said that porcellanite is common in the Powder River Basin and is more densely scattered into Montana (Figure 171).

Figure 164. Banding in porcellanite from Wyoming.

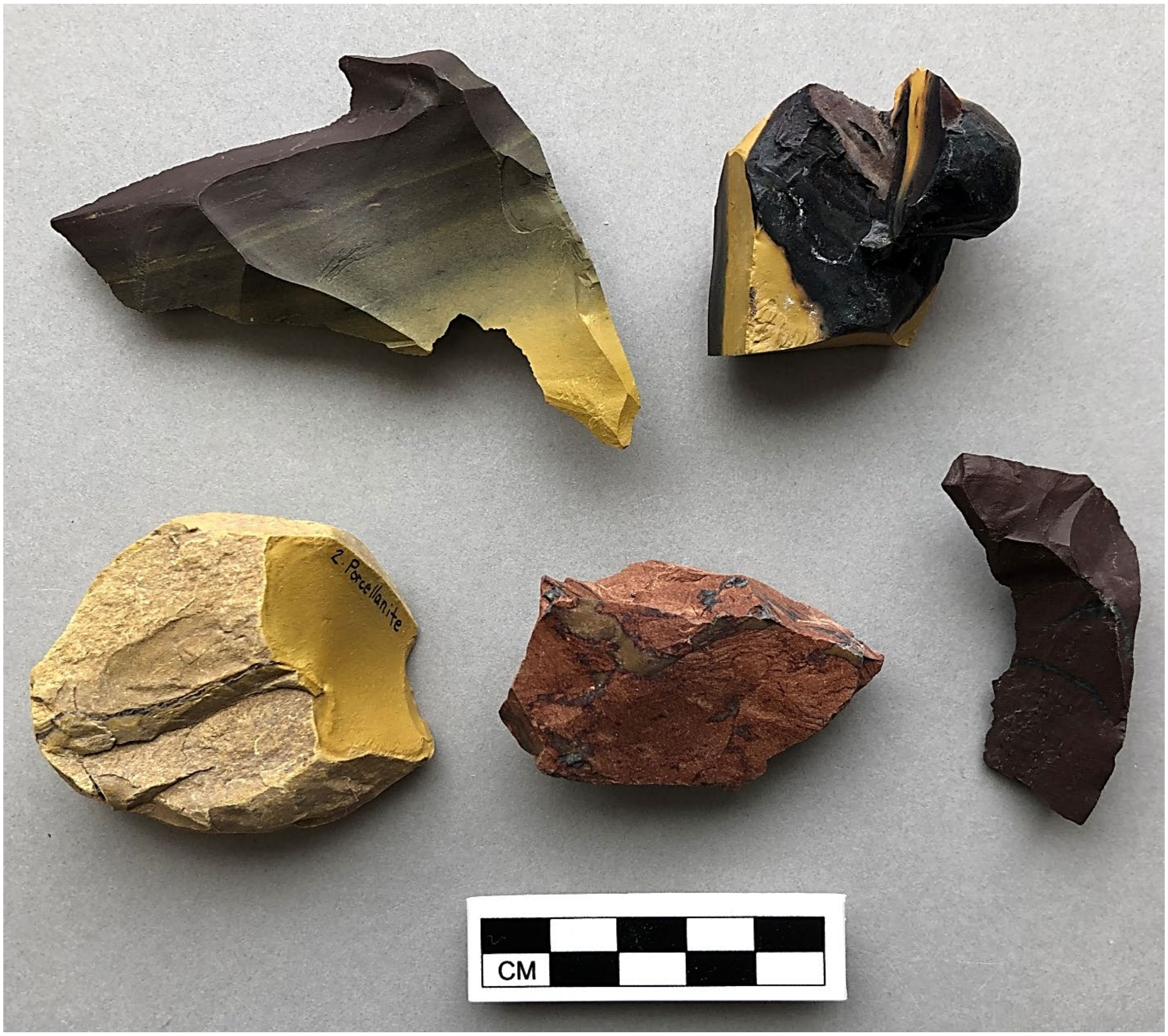


Figure 165. Black, yellow, orange-red, and deep red colors, banding, and cortex examples of porcellanite from Wyoming.

Figure 166. An example of a waxy luster on mottled porcellanite.

Figure 167. A biface made from porcellanite.

Figure 168. A reddish orange example of porcellanite.

Figure 169. Vitreous, waxy, and dull earthy luster examples found in porcellanite. Left to right: vitreous chunk, vitreous flake, waxy flake, and dull earthy flake.

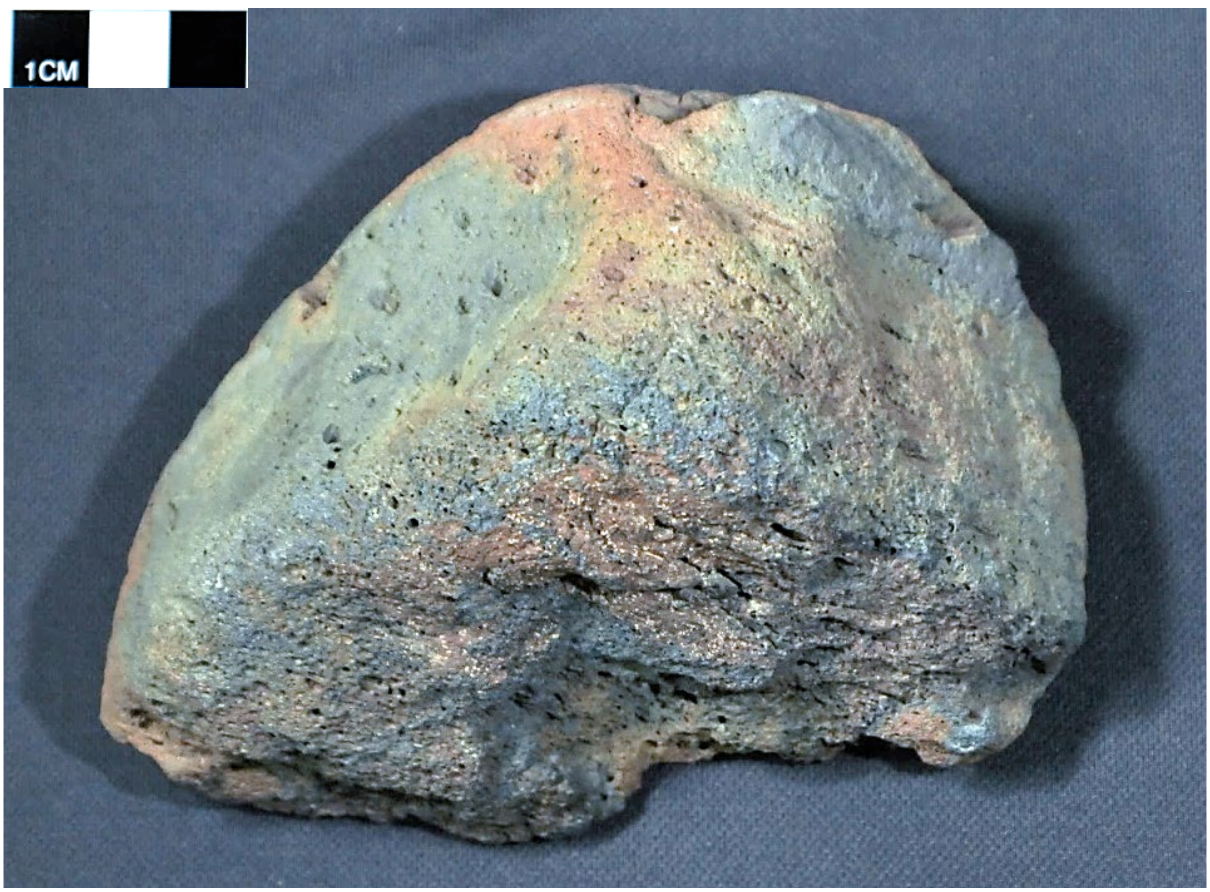


Figure 170. Scoria forms near the surface of a vent and has a higher moisture and gas content, resulting in a lighter, pitted material.

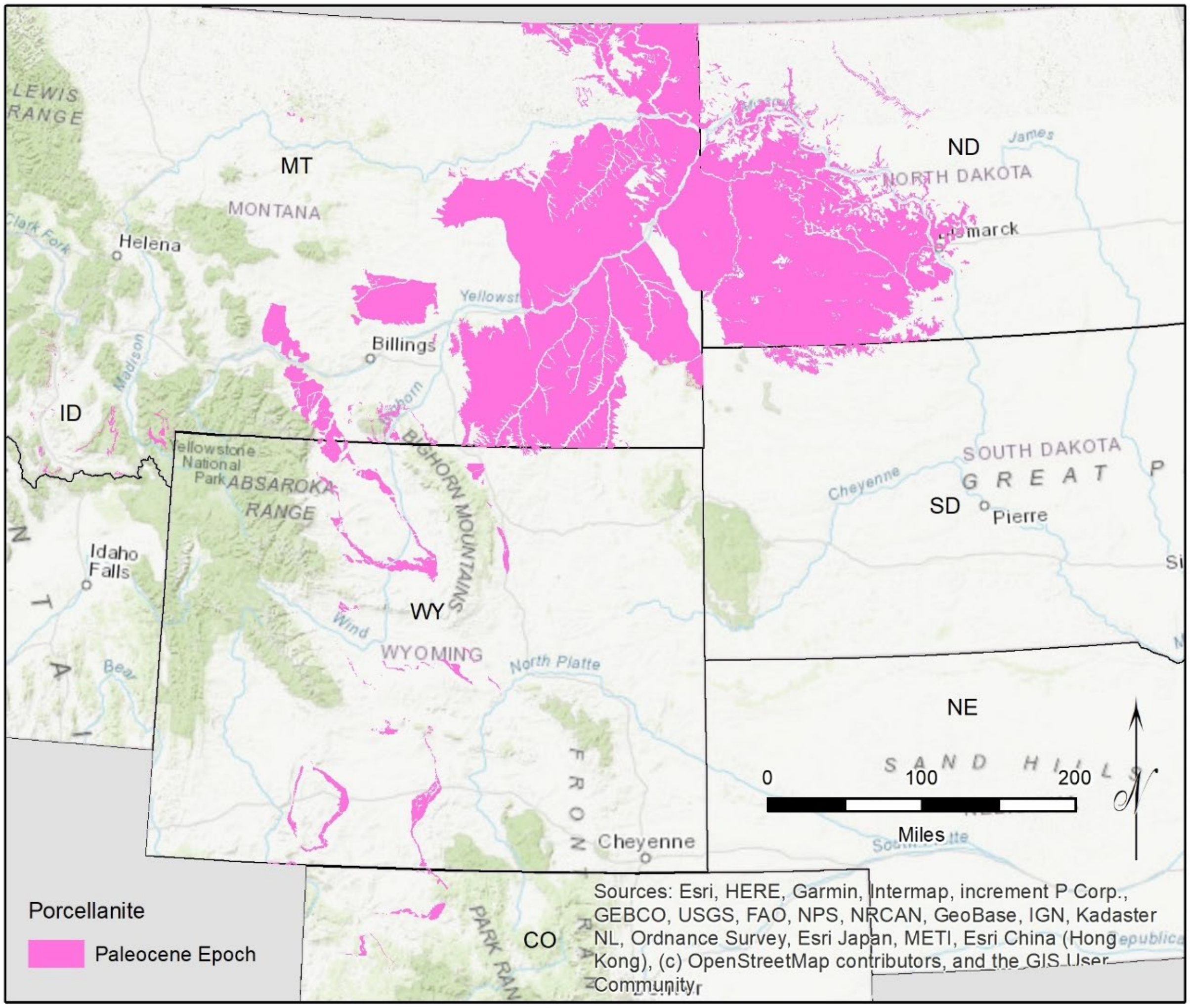


Figure 171. Porcellanite forms in the Paleocene Tongue River member of the Fort Union group on the Northwestern Great Plains, where burned coal seams are present.

PRECAMBRIAN QUARTZ

OTHER NAMES: None

MUNSELL COLORS: White N1; Pinkish gray 5YR 8/1; Pale pink 5RP 8/2; Grayish pink 5R 8/2

Quarries	None identified	**Diagnostics**	Clear, smoky, or pale pink glass-like appearance
Cortex	Clear, white, yellow, smooth	**Fracture Quality**	Poor to fair; rough and unpredictable
Grain	Fine to coarse	**Color**	Clear, white, pinkish gray, pale pink

Quartz, which is commonly found as a part of many kinds of rocks, is the mineral form of silica (Figures 172-175). The most likely source of massive quartz crystals several centimeters in size is in the pegmatitic granites of the Precambrian core of the Black Hills Uplift (Figure 176). The crystals can have the appearance of colorless clear broken glass, milky white, rose, or smoky, although the typical varieties are clear and milky white. Quartz often fractures in unpredictable ways; knapping quality is considered poor to fair. Nevertheless, flakes, check cores, and the occasional tool or projectile point of quartz can be found at Black Hills archaeological sites. Reher and Frison (1991) provide a good overview of the prehistoric use of quartz and its knapping qualities. However, no specific prehistoric quarry or procurement sites for Precambrian quartz have been found or recorded in the Black Hills. Quartz may have been collected when observed and used for an expedient tool or tested for its knapping quality.

Figure 172. Precambrian quartz flake from Custer County, South Dakota. (39CU730, Accession 86-0208, Catalog #01-17)

Figure 173. Precambrian quartz flake from Custer County, South Dakota. (39CU12, Accession 86-0039, Catalog #0001-223) (Artifact was photographed courtesy of the USDA FS BKNF.)

Figure 174. Translucent colorless and rose-colored Precambrian quartz.

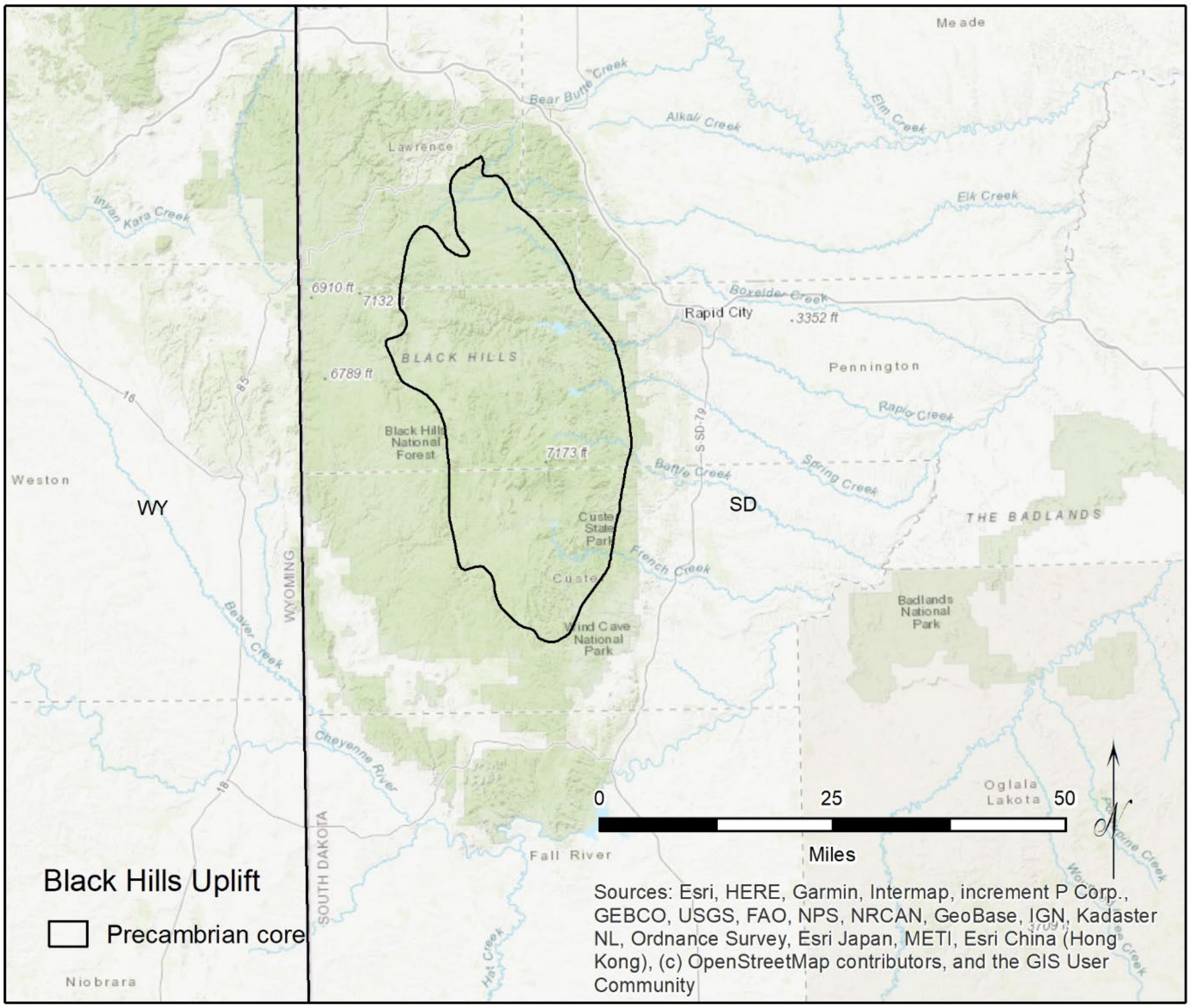


Figure 175. Precambrian quartz originates in the core of the Black Hills.

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APPENDIX A

FLINT HILL
AND
SPANISH DIGGINGS QUARRIES

Renee M. Boen, State Archaeologist
South Dakota Archaeological Research Center
and
Heidi Sieverding, Research Scientist
South Dakota School of Mines and Technology

2021

INTRODUCTION

The Black Hills Uplift in southwestern South Dakota and the Hartville Uplift in northeastern Wyoming contain significant, high quality tool stone used by prehistoric groups. Cherts, chalcedonies, silicified sediments, and quartzites are among the materials available in outcrops and as secondary outwash or lag deposits. Many examples of lithic studies geared towards identifying specific macroscopic and microscopic markers for the tool stone at known quarries and exposed outcrops have been undertaken in the region (e.g. Ahler 1975; Boen et al. 2015; Church 1990; Craig 1983; Lee 1925; Tratebas, et al. 1978). Determining the source of tool stone material recovered from an archaeological site can be used to predict the mobility of cultural groups, comprehend a group's interaction within a region, and lead to a better understanding of the group's land use. Identifying quarries used by a group can also help determine if the tool stone was acquired by direct collection or indirectly through trade. The original study (Boen et al. 2015) focused on developing a detailed composite signature for seven quartzite prehistoric quarries or possible quarries in the Black Hills and Hartville Uplifts. However, this chapter focuses on only two of the seven, Flint Hill quarry (39FA49) in the Black Hills and the Spanish Diggings quarry (Saul Quarry 1 and Saul Quarry 5) in the Hartville Uplift. Non-destructive X-ray fluorescence (XRF) testing applied to samples from both quarries, coupled with renewed microscopic and macroscopic examination, was used to enhance the identity markers of the two quarries.

Because the testing is non-destructive, two projectile points from the Ray Long site (39FA65) in Fall River County, South Dakota were also subjected to XRF testing and compared to results from Flint Hill, Spanish Diggings, and five other quarries or possible quarries in the Black Hills Uplift. The Ray Long site is the type-site for the Paleoindian period Angostura complex which has a regional distribution of Utah, Colorado, southeastern Idaho, Wyoming, southwestern South Dakota, and western Nebraska (Pitbaldo 2007; Buhta, et al. 2013). Pitbaldo (2003:233) noted that tool stone used by Angostura complex groups were often from local sources within approximately 70 kilometers of the site.

Three questions were posed for this study. First, does each quarry have a unique XRF signature and physical description, even though they are in the same geologic formation? Second, can the two quartzite projectile points from the Ray Long site be matched to a specific quarry or more generally, to a geologic formation included in the study? If so, is the tool stone used for both points from the same quarry or formation or not?

BACKGROUND

Some stone materials are better candidates for XRF analysis than others. For example, obsidian is a good candidate for XRF analysis because it typically has a homogenous composition. Discrete obsidian sources represent a single episode of magma deposition and different underlying geology resulting in a unique chemical signature (Speakman 2009:3; Kunselman and Husted 1996:27). As one of the highest quality tool stones available to prehistoric groups, it was traded over great distances from the various sources. It has been found hundreds of miles from its source in cultural settings; providing a hint at the trade routes used by early groups. Sources in Russia and Alaska have also been studied with the intention of testing the migration theory of early groups crossing the Bering land bridge from west to east. For these reasons identifying the signatures for obsidian sources has received a great deal of attention from archaeologists.

Cherts and chalcedonies, on the other hand, may be less than ideal candidates for XRF analysis because they typically have a heterogeneous chemical composition. Other means for identifying cherts and chalcedonies might be more reliable, for example, identifying fossils present, banding, mineralogy (Foradas 2003), cortext, and the use of long or short-wave ultraviolet light. Neutron activation analysis has also had some success for sourcing cherts and chalcedonies in the Upper Midwest by the University of Michigan Museum of Anthropology Neutron Activation Analysis Project (Luedtke 1978). This study also showed that artifacts from a buried environment may exhibit some degree of change in their chemical properties.

METHOD OF STUDY

The scope of this project is to establish a signature for seven quarries in four geologic formations of the Black Hills and Hartville Uplifts in South Dakota and Wyoming (Table 1 and Figure 1). The quarry samples and two quartzite Angostura projectile points (catalog numbers 12-0046-48 and 12-0046-50) from the Ray Long site were examined macroscopically, Munsell colors were identified, and observations were recorded. The samples and projectile points were also examined using a binocular microscope and described using standard geologic terminology. The XRF data from the samples and projectile points were processed and signatures for each quarry and artifact were defined. The compilation of quarry data was then compared to the data related to the Angostura projectile points. To simplify the reference to the projectile points in this study, catalog numbers 12-0046-48 and 12-0046-50 will be referred to as P48 and P50, respectively.

Table 1. Summary of quartzite quarry samples and projectile points used in the XRF study.

Site	Type	No. of samples	County	State	Formation	Collector	Year Collected
Flint Hill (39FA49)	quarry	11	Fall River	SD	Fall River	R. Boen	2011
Saul Quarry #1	quarry	3	Platte	WY	Cloverly	S. Ahler	1975
Saul Quarry #5	quarry	1	Platte	WY	Cloverly	S. Ahler	1975
Ray Long (39FA65)	occupation	2	Fall River	SD	Unknown	Augustana College	1985

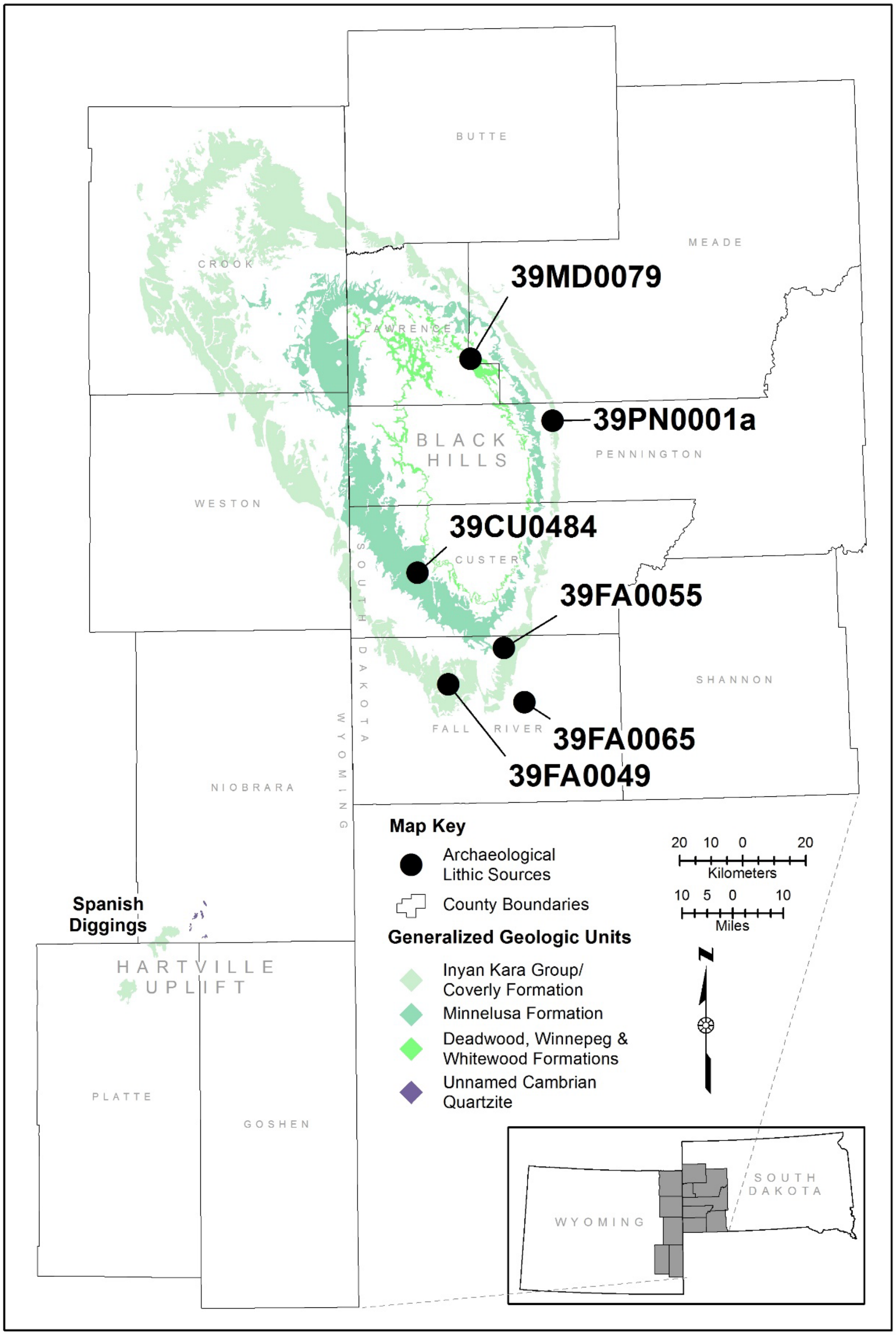

Figure 1. Location of the Ray Long site (39FA65) and the quarries included in this study.

In 1975, Dr. Stan Ahler collected raw material samples from two Platte County, Wyoming quarries, Saul Quarry #1 and Saul Quarry #5 (Ahler 1975). In 2011, Boen collected raw material from Flint Hill. These collections were sampled and used in this study. The two Angostura projectile points were collected by Dr. L. Adrien Hannus, Augustana College, from the surface of the Ray Long site in 1985. It should be noted that although quarry site numbers and names are used in this report, none of the quarry samples represent cultural materials. Samples were collected directly from the geologic formations; using the site number is a convenient way to track source locations for the comparative collection.

QUARRY SAMPLES[3]

The study included samples from two quarries, Flint Hill quarry in the Black Hills Uplift in South Dakota and Spanish Diggings quarry in the Hartville Uplift in Wyoming. Slight macroscopic differences were noted between Flint Hill and Spanish Diggings quartzites by Witzel and Hartley (1976:15). Flint Hill has fewer but relatively larger reflective surfaces and a rougher conchoidal fracture surface than Spanish Diggings samples, though these distinctions are difficult to ascertain when the sample base is expanded to include more quarries (Boen et al. 2015). Witzel and Hartley's (1976:14) Spanish Diggings quarry samples correspond to the location for Saul Quarry #5 (Ahler 1975) and the Barbour quarry (Saul Quarry #1) described by Reher (1991). Color was of little use when attempting to link a sample to a source.

Microscopic differences between the quarry samples are subtle with a few distinguishing characteristics noted for each. The details are presented below using standard geologic terminology. Some of the grains in the Saul Quarry samples reached 0.5 mm. Samples from both Saul Quarry #1 and #5 were notable for the high percentage of lithics present in the samples (25 percent); greater than in any other sample examined. Thus, microscopic differences between the two quarries are present. These can provide a foundation for differentiating materials recovered from an archaeological context. Other test results, such as the XRF data, have the potential to offer another means of identifying unique markers or properties to distinguish between quarries. The results of the macroscopic and microscopic examination of the samples is presented below.

FLINT HILL QUARRY (39FA49)

Site Description. The non-cultural samples collected at the Flint Hill quarry in Fall River County, South Dakota are from the Fall River formation (Figure 2). The site includes numerous quarry pits and tailings, exposed outcrops quarried on the slopes, stone circles, and workshop areas on a high broad ridge surrounded by steep slopes and canyons in the southern Black Hills. In the 1920s, W. H. Over, curator and later director of the Dakota Museum in Vermillion, South Dakota (now the W.H. Over Museum), and H.E. Lee, a self-taught archaeologist in the Black Hills, both visited the site on a number of occasions. These early twentieth century collections are curated at the South Dakota Archaeological

[3] See Chapter 2, Geology, of the Lithics Guide for information related to the geology of the Flint Hill and Saul quarries.

Research Center (Center). Another early collection was made by area rancher, Neal Conboy. Conboy's collection was examined by archaeologists from the Smithsonian Institution during the River Basin Survey Project at nearby Angostura Reservoir (Hughes 1949). It was reported that Conboy's collections included a wide variety of projectile points resembling other types known from the surrounding area. A Late Archaic point was identified in one of their photographs of this collection. No projectile points have been found in the Flint Hill collections stored at the Center. Although direct evidence is lacking, this site may have been mined for its high quality quartzites by prehistoric groups for thousands of years.

Figure 2. The Flint Hill quarry in Fall River County, South Dakota.

Several archaeologists have visited Flint Hill since those early years. One of those investigators, Dr. Stan Ahler, made an extensive collection from the site (Ahler 1975; Ahler 1977). Ahler dispersed his collections from the quarry to the Center, the Illinois State Museum, the Midwest Archeological Center, and the University of North Dakota-Grand Forks. A recent investigation for a transmission line project resulted in the most intense mapping and recording ever done at the Flint Hill Quarry (Shaver and Smith 2013). However, no artifacts were collected during this project.

Sample Description. Flint Hill quarry samples are a fine crystalline quartzite. They exhibit angular to sub-rounded, spherical, well-sorted grains of 0.125 to 0.25 mm diameter composed of variable colored silica matrix. The rock is highly silicified and well-bonded with variable colored cement. The rock is well-compacted and composed of approximately 95 percent semi-transparent to clear quartz crystals and 5 percent dark lithic fragments which can be larger in diameter, up to 0.5 mm, with minor inclusions of hematite. The overall color of the rock is influenced by the matrix. Conchoidal fracturing presents as a smooth surface with breakage occurring across the grains.

SAUL QUARRY #1 AND SAUL QUARRY #5

The non-cultural quarry samples from Saul Quarry #1 and #5 are located approximately one-half mile apart in Platte County, Wyoming in the Cloverly formation (Figure 3). Saul Quarry #1 (Saul 1969) is also known as the Barbour quarry (Reher 1991:264 and 266). Saul Quarry #1 (Saul 1969) consists of approximately 200 quarry pits, rubble piles, and stone circles located south of the quarry area. Flaking debris is scattered between the quarry and the stone circles. The quartzite material at this location was buff, grey, light purple, and lavender (Ahler 1975:5).

Figure 3. Saul Quarry #1 in Platte County, Wyoming. Photo courtesy of the Wyoming State Historic Preservation Office.

Saul Quarry #5 (Saul 1969) is located southwest of Saul Quarry #1. There are many quarry features in this area and without a field check, it is not possible to link this location to other named quarries described in the extensive literature on the Spanish Diggings complex. It seems best not to speculate. The legal location used in Ahler's (1975:26) manuscript corresponds to the samples used in this study. This quarry consists of a single pit on a dome-shaped hilltop and two stone circles. It contained mainly a yellow quartzite and a large amount of flaking debris (Ahler 1975:5).

Sample Description. The Saul Quarry #1 and Saul Quarry #5 samples from Platte County, Wyoming were examined separately but described together because of their strong similarity. The Saul quarry materials are a fine-grained to medium crystalline quartzite. They exhibit well-sorted, spherical, and sub-rounded quartz grains and lithic fragments. Composition is variable, but typically is approximately more than75 percent quartz of assorted coloration and less than25 percent lithic fragments. Material can be variable in grain size and recrystallization; however, it is typically consistent within a given lithic sample. Grain size ranges from 0.125 to 0.5 mm with the reddish/purple, more recrystallized material dominating the larger grain sizes. The larger grain sizes do not break across the grain boundaries. The smaller, more fine-grained material (which is less recrystallized) breaks cleanly across grain boundaries and produces a smoother conchoidal fracture. Several patinas were present, but of note, a malachite green caliche-like weathering byproduct was present on one of the lithic samples. Clast size, color, compaction, and composition are highly variable between lithic samples as is matrix color.

RAY LONG SITE (39FA65)

The Ray Long site is a multi-component prehistoric occupation site that dates to the Paleoindian and Middle Plains Archaic periods, and possibly before and after those time periods. Based on the recovery of obliquely flaked lanceolate points during the 1940s and 1950s, it is the type-site for Angostura projectile points and the Angostura complex. The site is situated on the right bank of the now inundated Horsehead Creek in southwestern South Dakota just outside the Black Hills (Figure 11). Horsehead Creek originally flowed northwest from the site to its confluence with the much larger Cheyenne River. The location provides access to a wide variety of natural resources associated with the plains and foothills of the Black Hills, and the Black Hills Uplift.

Among those resources are an abundance of tool stone outcrops and secondary deposits within a few miles of the site. Compared to the surrounding plains, a wide variety of primary sources of quartzites and cherts are available within the Black Hills Uplift. Although many of these stone types have eroded out onto the foothills and plains surrounding the Black Hills, secondary sources would not have provided the same quality, quantity, or size of material available at the outcrop. Outlying sources of cherts and chalcedonies in remnants of the White River group in South Dakota, Wyoming, and Nebraska would also have been available to groups living at the Ray Long site.

Projectile Point Catalog #12-0046-48 (P48). Projectile point P48 is made from a fine-grained quartzite that exhibits sub-rounded to sub-angular, spherical, 0.125 to 0.25 mm diameter quartz grains and lithic fragments (Figure 12). The matrix color is transparent to milky white. It has a normal compaction, with a composition of less than 85 percent assorted quartz grains ranging from yellow, light orange, tan, opaque white, to clear, with more than 15 percent lithic fragments of assorted colors including black and dark vivid red and sporadic vivid blue crystals. There is a distinct color change in the grains and a reduction of black lithic fragments at the base of the point. In addition, there is a distinct malachite green surface patina or caliche of some form on several locations towards the tip of the point. Overall color of the rock is influenced by the grains. This material produces a smooth conchoidal fracture.

On the base, varying from 12.45 to 17.18 mm on one face and 15.54 to 16.29 mm on the opposite face, as measured upward from the base towards the midsection, are remnants of a red stain believed to represent ochre. The ochre is visible with the naked eye as a definite darker color on the base compared to the midsection, which appears to be lithic bedding. Under magnification, the ochre is an irregular red surficial smudging that is more concentrated and darker where it was trapped in tiny depressions on the surface. Additional testing is needed, but the distribution of the red staining has an unnatural appearance. When first applied, red ochre would likely appear as a dark red pigment that would have worn off over time. The ochre would have been intentionally rubbed onto the base of this point; the placement is too precise to suggest unintentional contact with an ochre source whether from the soil, someone's hands, or some other means. Or, if the entire point was once covered, there is no evidence above the base at this time. Red ochre is a natural earth pigment made of hydrated iron oxide (hematite) that has been used throughout prehistory by many cultures, often in the context of rituals related to belief systems. It is one of the most common earth pigments. In XRF testing, the ochre would have read as iron.

Projectile Point Catalog #12-0046-50 (P50). Projectile point P50 is made of a fine-grained quartzite that exhibits well-rounded to sub-rounded, well-sorted, well-cemented, 0.125 to 0.25 mm diameter quartz grains and lithic fragments (Figure 13). This material is poorly compacted but well-cemented within a clear silica matrix. This rock is composed of approximately 75 percent transparent, well-rounded quartz with more than 20 percent sub-rounded lithic fragments and less than 5 percent metallic fragments, possibly pyrrhotite or chalcopyrite. The metallic glints and sheen associated with these small inclusions are visible to the naked eye. The color and variability of the lithic fragments dominate the color and texture of this rock. The majority of the rock is composed of clear transparent quartz with black mineralization, but fragments also include red textured fragments and brown, black, tan, pink, red, and mixed earth tone clasts. Overall color of the rock is influenced by the grain color not by the matrix. Bedding is visible, parallel to the projectile, and does not influence the texture or durability of the material. This material produces a smooth conchoidal fracture across grain boundaries.

RESULTS

DISCUSSION

The interpretation of this data is considered preliminary and changes should be expected as more samples are examined using XRF or other geochemical testing (Table 2). Nevertheless, some initial patterns have begun to emerge. Saul Quarry #1 has the lowest correlation to either of the projectile points from the Ray Long site. Flint Hill and Saul Quarry #5 have the highest correlation to the projectile points from the Ray Long site.

Table 2. XRF correlation between the Ray Long site projectile points and the quarries.

FORMATION: QUARRY	P48 CORRELATION (%)	P50 CORRELATION (%)
Deadwood: Meadow Creek (39MD79)	46.3	44.97
Minnelusa: Jewel Cave (39CU484)	97.07	**95.69**
Lakota: Cowboy Hill (39PN1)	94.26	92.49
Fall River: Flint Hill (39FA49)	97.28	94.36
Fall River: Battle Mountain (39FA55)	75.44	71.1
Cloverly: Saul Quarry #1	56.2	74.86
Cloverly: Saul Quarry #5	**98.23**	94.95

Saul Quarry #1 is situated in the Cloverly formation in eastern Wyoming approximately 145 kilometers (90 miles) southwest of the Ray Long site. Although quite similar macroscopically and microscopically to Saul Quarry #5, their XRF signatures were quite different. At this time, it is unknown whether this represents a sampling bias or not, considering that only one sample was tested from Saul Quarry #1 and three from Saul Quarry #5. Trace elements strontium, titanium, and arsenic are all present in the single sample from Saul Quarry #1. Colors include purples, browns, yellowish browns, and reds. Ray Long site projectile points P48 and P50 have a weak correlation to Saul Quarry #1 with P48 at 56.2 percent and P50 at 74.86 percent.

The Flint Hill quarry is situated in the Fall River formation of the southern Black Hills approximately 24 kilometers (15 miles) northwest of the Ray Long site. Microscopically, this fine-crystalline quartzite contains about 5 percent lithics and hematic inclusions are not present in the samples from Jewel Cave quarry. Colors, which are influenced by the matrix, are also more variable than the Jewel Cave samples, including grays, purples, browns, yellowish browns, pinks, reds, and yellows. Ray Long site projectile points P48 and P50 both have a strong correlation to the Flint Hill quarry with P48 at 97.28 percent and P50 at 94.36 percent.

Saul Quarry #5 is situated in the Cloverly formation of eastern Wyoming approximately 145 kilometers (90 miles) southwest of the Ray Long site. Although quite similar macroscopically and microscopically to Saul Quarry #1, their XRF signatures were quite different. At this time, it is unknown whether this represents a sampling bias or not, considering that only one sample was tested from Saul Quarry #1 and three from Saul Quarry #5. Trace elements strontium, titanium, and arsenic are present in all three samples from Saul Quarry #5. Colors include grays, browns, yellowish browns, and pale orange. A striking feature of these samples was the high percentage of lithics (25 percent) in the samples. In addition, a malachite green caliche-like weathering byproduct was present on one of the lithic samples. A small representation of this same type of weathering byproduct was present on P48. Ray Long site projectile point P48 has its strongest correlation, at 98.23 percent, and P50 has its second strongest correlation, at 94.95 percent, to Saul Quarry #5.

CONCLUSIONS

First, do the quartzite quarries each have a unique XRF signature and physical description compared to the other quartzite quarries, whether from the same geologic formation or not? Yes and no. With regards to the XRF results, the elements iron, strontium, titanium, and arsenic represent the greatest variation in readings between all the samples, with iron being the greatest. Four quarries had very distinctly different XRF signatures: Meadow Creek, Battle Mountain, Cowboy Hill, and Saul Quarry #1. Meadow Creek quarry is in the Deadwood formation; Cowboy Hill quarry is in the Lakota formation; Battle Mountain quarry is in the Fall River formation within the Inyan Kara group; and Saul Quarry #1 is in the Cloverly formation within the Inyan Kara group. Battle Mountain and Saul Quarry #1 are from correlative geologic groups but their signatures are not a close match.

Microscopically, these samples also present distinct differences. Meadow Creek samples were medium-grained, Battle Mountain and Cowboy Hill samples were fine-grained, and Saul Quarry #1 was fine to medium-grained (based on a macroscopic and microscopic examination of additional samples from Ahler's collection, as well as one sample tested using XRF). Meadow Creek is well-compacted, and samples contained hematitic and glauconititc inclusions, which the others do not have. Cowboy Hill has minimal compaction and Battle Mountain is poorly compacted. Color in Meadow Creek and Cowboy Hill samples were influenced by the grain color while Battle Mountain and Saul Quarry #1 samples were influenced by the matrix color. Lithic fragments were present in the Battle Mountain, Cowboy Hill, and Saul Quarry #1 samples, but not Meadow Creek.

The Jewel Cave quarry in the Minnelusa formation and Flint Hill quarry in the Fall River formation have closely related XRF signatures. These two quarries are from different geologic formations, yet they are quite similar elementally. Interestingly, Flint Hill materials do not closely match the Battle Mountain materials although they are both in the Fall River formation. Microscopically, samples from the Jewel Cave quarry and the Flint Hill quarry were similar but not the same. Differences include minor inclusions of hematite unique to Flint Hill some bedding present in Jewel Cave that was note observed in the Flint Hill samples. Besides these differences, the physical descriptions of each are quite similar. Although color has not been a reliable indicator of source identification, each material exhibits a range of browns, yellowish browns, reds, and pinks with Flint Hill also displaying grays, purples, and yellows.

The XRF signature of Saul Quarry #5 in the Cloverly formation, except for the presence of titanium and arsenic in all its samples, was similar to the Jewell Cave and Flint Hill quarries. Only one sample from Flint Hill contained arsenic. Microscopically, Saul Quarry #5 contained a higher percentage of lithic fragments (25 percent) than either Jewel Cave (5 percent) or Flint Hill (5 percent). Grain sizes in the Saul Quarry #5 samples had a greater variation (0.125 to 0.5 mm) than either Flint Hill (0.125 to 0.25 mm) or Jewel Cave (0.125 mm). Angular, sub-rounded, and spherical grains were present in the Flint Hill and Jewel Cave samples, but only spherical and sub-rounded grains were present in the Saul Quarry #5 samples. Black mineral staining was only present in the Jewel Cave samples.

Thus, the results are mixed. In the region surrounding the Black Hills and Hartville Uplifts on the Northern Plains, identifying the quarry or geological formation of a quartzite artifact, relying only on macroscopic properties of the artifact and quarry samples, will be unlikely to produce reliable, testable results. If microscopic analysis is added to this examination, the results would likely improve dramatically, however, to what degree is unknown. Taking analysis to yet another level, using XRF, would likely improve results.

Additional testing would be needed to improve the XRF signatures of the quarries included in this study. If XRF is unavailable, researchers may find it more useful to utilized a “Black Hills quartzite” type that includes at least Cowboy Hill, Flint Hill, Battle Mountain, Jewel Cave, and other quarries located in the same formations. If this level of identification is used, one that crosses formation boundaries and encompasses a large geographic area, it would prove most useful in regional studies as opposed to local prehistoric mobility studies. However, the Deadwood formation quartzites would likely hold their own as a specific type based on physical characteristics alone. However, without further tests of Deadwood formation quarries, it is unclear whether the Meadow Creek quarry stands out as its own type source at this time.

PROJECTILE POINT TEST RESULTS

Second, can two quartzite projectile points from the Ray Long site, located in the southwestern foothills of the Black Hills, be matched to a specific quarry or geologic formation included in the study? If so, are they from the same tool stone source? Yes, though qualifiers persist. Based on both macro and microscopic examinations and XRF testing, there is no clear match between P48 and P50 to the Meadow Creek, Battle Mountain, Saul Quarry #1, or Cowboy Hill quarries. These quarries can likely be dismissed as possible sources for the quartzites used to produce either projectile pint. On the other hand, P48 and P50 had strong XRF matches to Jewel Cave (P48 at 97.97 percent and P50 at 95.59 percent), Flint Hill (P48 at 97.28 percent and, P50 at 94.36 percent), and Saul Quarry #5 (P48 at 98.23 percent and P50 at 94.95 percent). Microscopically, the most distinctive characteristics of these two projectile points was the strong presence of lithic fragments (P48 was more than15 percent and P50 contained more than 20 percent), lack of angular grains, and colors influenced by the grains rather than the matrix. The characteristics more closely fit the description of Saul Quarry #5 than either Flint Hill or Jewel Cave samples, regardless of the slightly stronger affiliation of P50 to Jewel Cave quarry. The microscopic comparison is stronger to Saul Quarry #5 in this case.

Taking a more comprehensive view, Saul Quarry #5 is situated in a large expanse of quarrying activities within the Cloverly formation; a geologically complex formation. The limited number of samples used in this study, only three from Saul Quarry #5, suggests that more XRF testing needs to be done to determine if specific quarries have distinct XRF signatures within the formation. At this time, the conservative interpretation suggests a higher probability that the quartzite source for both P48 and P50 lies in the Spanish Diggings quarry complex in the Cloverly formation of the Harville Uplift in eastern Wyoming.

If these results are accepted, researchers may postulate whether this tool stone material was obtained by direct or indirect acquisition. If direct acquisition, was it collected by a group during migration out of the southern Rocky Mountains, or was it collected by a group that made a special trip to the quarry to obtain this high-quality stone for a hunt? If indirect acquisition, who were they trading with, related groups of the Angostura Complex or another group? Did they trade other goods as well? These are all important areas of research that should be explored.

There is also the question of how other quartzite quarries in the region compare to these, such as Parker Peak quarry (39FA762) only a few miles west of Flint Hill in the Fall River formation. Will its signature be like Flint Hill or as different as that for Battle Mountain? What other types of testing, such as mass spectrometry or petrographic thin sections, may be needed to create a useful composite picture of a quarry? Another consideration for future studies includes looking outside the Black Hills to create signatures for quartzite quarries in other major source areas, such as the Big Horn Mountains in Wyoming. Whether these will have signatures distinct from the correlative formations in the Black Hills is unknown but would be important to determine.

Finally, the defining characteristics of the material from tool stone quarries need to be gathered from various levels of examination and testing to create a strong composite picture of the quarry stone. Microscopic examination, XRF testing, petrographic thin sections, mass spectrometry, and other means will change and strengthen the initial research presented in this study. Until such studies are done, determining a quarry or formation source for tool stone found in an archaeological context, or at least quartzite tool stone, should consider only general identifications to a source area.

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APPENDIX B

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