The Ancient Environment of the Beartooth Butte Formation (Devonian) in Wyoming and Montana: Combining Paleontological Inquiry With Federal Management Needs

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Abstract—The Beartooth Butte Formation is found in many mountain ranges throughout central Montana and northern Wyoming. This study combines a variety of geologic data to provide a clearer understanding of the fossil fauna and environmental setting of this rock unit.

Results show not all exposures of this unit are fossil-bearing and where present, faunal data vary significantly from locality to locality. Also, not all exposures of the Beartooth Butte Formation are the same age. Lastly, isotopic data show a consistent pattern of ancient salinity for this rock unit through time, suggesting a constant environmental setting for approximately 20 million years.

A casual observation of science stories across all media reveals that the public is fascinated with fossils, particularly dinosaurs (Springer 1997). These stories have served an overall purpose of raising public awareness of ancient life and ancient ecosystems. Given this latest round of enthusiastic public interest in paleontology, and the problems associated with increasing multiple-use demands on federally managed lands, it is increasingly important to document the occurrences of fossils. In addition to the public interest in fossils as an educational experience, the recent auction of a *Tyrannosaurus* (dinosaur) skeleton at a selling price in excess of eight million dollars has demonstrated that some fossils now have proven monetary value.

Federally managed lands contain some of the most important fossil-bearing rock units in the world, although historically much of the documentation and evaluation of these important units has been inconsistent, with little attention devoted to management needs. In addition to the now-established monetary value for some specimens, these fossils have proven scientific and educational worth.

Rocks of Devonian age (approximately 360-410 million years ago) have gained in scientific importance in recent years as new fossil finds around the world began to provide insight into issues of biodiversity and how vertebrate life moved onto land. The increased global interest in the Devonian Period initiated this investigation into the Devonian-aged Beartooth Butte Formation.

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The Lower Devonian Beartooth Butte Formation was discovered in northern Wyoming in the 1930s and has since been a source of vertebrate remains (Bryant 1932, 1933, 1934, 1935; Dorf 1934a). This formation was the focus of stratigraphic and paleontologic work again in the 1950s and 1960s (Denison 1966, 1968, 1970); through the course of these efforts all exposures of this rock unit had been interpreted to be the same age. Despite the geographic extent of this formation ranging from central Montana to northeastern Wyoming (Sandberg 1961), virtually all of the paleontological data collected for this rock unit are from two sites: the Beartooth Butte site or the Cottonwood Canyon site. One exception is the preliminary work at a third locality, the Half Moon Canyon site in central Montana (Fiorillo 1998). Subsequent to these early reports, additional work by others, again from only the two well-established sites, has shown that this rock unit continues to have great paleontological potential (Elliot and Ilyes 1996; Elliot and Johnson 1997).

The purpose of this report is to review the available data from these localities and two additional localities (fig. 1). More specifically, this report highlights the complex depositional history of the Lower Devonian Beartooth Butte Formation and its paleontological importance. These sites were chosen based on the presence or absence of fossil remains and the accessibility of the localities. Most of these sites are located near the boundaries of wilderness areas, or areas under study as wilderness. Lastly, this survey is being conducted to assess the paleontological importance of the rock unit and to provide federal land managers of specific forests information needed to develop a viable management plan.

Why Are Fossils Important to Management?

> "A knowledge and understanding of fossils played a crucial role in the recognition of the immense age of the Earth and in the development of evolutionary theory. In these ways paleontology has influenced fundamentally our conception of the natural world and of our own human place within it" (Rudwick 1976).

> "A century after the founding of the Republic, the United States was a leader in the scientific exploration of time..." (Lanham 1972).

For earth scientists as a whole, Zen (1993) and Moores (1996) issued a "call to arms" — a request for earth scientists

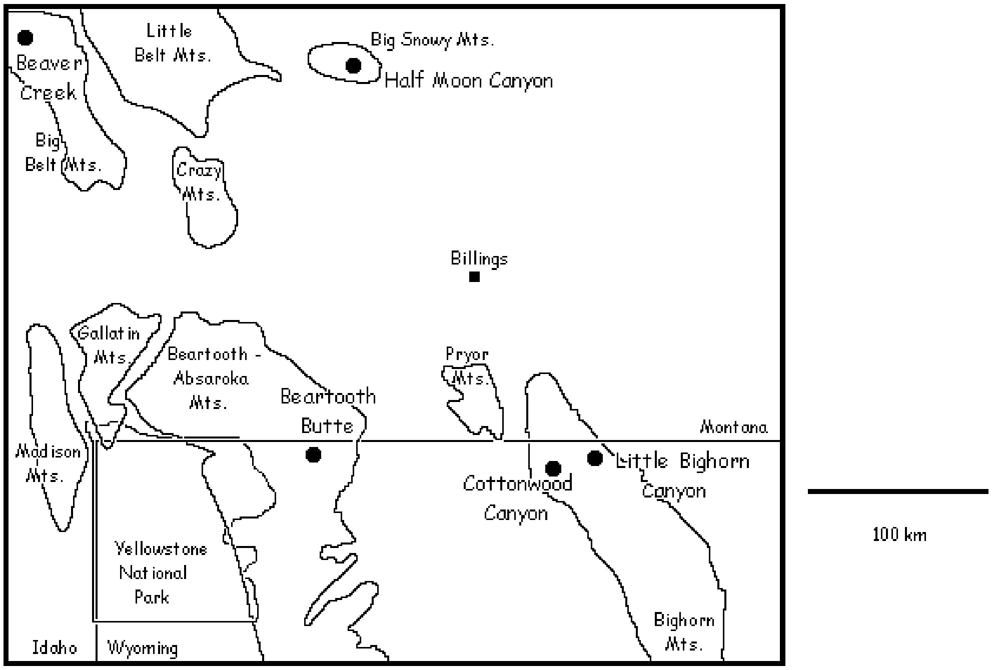

Figure 1—Map of region showing localities mentioned in this report.

to make geoscience data meaningful to the general public. Perhaps no other subdiscipline of the earth sciences can make the singular claim of already having the attention and enthusiasm of the general public, as can paleontology. Public fascination in fossils is historical, at least dating back to the earliest public displays of dinosaurs in the mid and late 19^{th} century. In fact, based on the abundance of fossil bones discovered in the second half of the last century in the western United States, one can effectively argue that vertebrate paleontology was the means by which a young United States made its debut in the global scientific community. That this fascination with paleontology continues today is clear from the vast number of stories in the news regarding fossils. Similarly, college-level dinosaur courses are one of the two most popular earth science courses offered according to one survey (Lessem 1994), the other course being an offering on the geology of the national parks.

A potential problem is developing for federal land and resource managers concerned with the valuable paleontological resources under their care: Who should be allowed access to these resources? This development stems, in part, from increased public use of federal lands. It also is derived from the increasing tendency by some nonscientists to view fossils as commercial commodities. This tendency is evident in the recent announcements of scientifically significant fossils that are now available in auctions at substantial prices (Alvarez 1996; Browne 1996).

Increased attention to fossils by federal land and resource managers is not only timely – it is imperative given the following: the broad range of public interest in fossils, the passionate advocacy of opposed special interest groups, the appeal that such controversy has among the media (Ritter 1996), and the economic and legal impacts of an expanded array of special uses of fossil resources across the federal estate. Two previously proposed pieces of legislation, Senate Bill 3107 in the 102^{nd} Congress (the Baucus Bill) and House Bill 2943 in the 104^{th} Congress (the Johnson Bill), illustrate the controversy surrounding access to publicly owned fossils on federally managed lands. Despite their titles, the Vertebrate Paleontological Resources Protection Act and the Paleontology Preservation Act of 1996, respectively, these two bills represent diametrically opposed constituencies. These constituencies are, respectively, those who collect fossils for scientific and educational purposes versus those who collect fossils for monetary profit. Given the economic and legislative issues at stake, a greater awareness of fossil resources on public lands is now mandatory.

The nature of fossil resources as an educational resource makes it reasonable to develop a broad-based, flexible management plan that involves the careful identification and implementation of proper conservation of these resources. This management plan should be capable of implementation across the jurisdictional boundaries of several federal agencies. Such a plan will help satiate the public's well-developed and growing curiosity about life in the past.

The USDA Forest Service has begun an assessment of fossil resources in certain forest units with a field-level assessment on the Shoshone, Bighorn, Lewis and Clark, Helena and Gallatin National Forests, via an inter-regional partnership with the Dallas Museum of Natural History. This project, which focuses on paleontological resources, emphasizes the point that important management issues may include resources not traditionally recognized within individual federally managed land units. The common general public use of fossil resources indicates that a similar management plan can be adopted by several federal management agencies.

Geologic Background

The Beartooth Butte Formation was originally described by Dorf (1934a). While exploring the Beartooth Plateau, he noticed a reddish channel fill between the Ordovician Bighorn Dolomite and the overlying Upper Devonian Jefferson Limestone (fig. 2). Dorf, a paleobotanist, described the fossil plant material from the formation, all of which he attributed to being terrestrial (Dorf 1934b). Later work in Cottonwood Canyon of the Bighorn Mountains revealed the first evidence that this unit was more widespread than previously thought (Blackstone and McGrew 1954). Subsequent work by Sandberg (1961) demonstrated the widespread nature of the formation, though the geographic extension of the boundaries was in part based on the position of these channel-fill deposits in relation to the underlying Ordovician Bighorn Dolomite.

Bryant (1932, 1933, 1934, 1935) described in detail the original collections made of the fossil fish remains from the Beartooth Butte type section. Subsequent work by others, most notably Denison (1966, 1968, 1970) and Elliot and colleagues (Elliot and Ilyes 1996; Elliot and Johnson 1997), have demonstrated a diverse fauna for this rock unit.

The Beartooth Butte Formation has traditionally been considered to be Lower Devonian and, more specifically, Pragian in age (Johnson and others 1989). However, subsequent work by Elliot and Ilyes (1996), and Elliot and Johnson (1997) on the vertebrate material, and spore assemblages by Tanner (1983) strongly suggests that the Beartooth Butte locality and the Cottonwood Canyon locality are of two different ages. The former locality is Emsian in age, while the latter is still considered dominantly Pragian in age.

Dorf (1934a) originally considered the depositional setting for this rock unit to be an estuarine channel fill, an interpretation that remains favored by subsequent workers (Johnson and others 1988; Sandberg 1961). The data collected from these two sites, historically, are the basis for our understanding of the formation as a whole.

Rock Unit	Age
Jefferson Limestone	Upper Devonian
Beartooth Butte Formation	Lower Devonian
Bighorn Dolomite	Ordovician

Figure 2—Generalized stratigraphic column for rocks mentioned in this report. Typically the Beartooth Butte Formation is above the Ordovician Bighorn Dolomite and below the Upper Devonian Jefferson Limestone. In some areas, the Beartooth Butte Formation is located below the Devonian Maywood Formation (not shown), which underlies the Jefferson Limestone.

Locality Geologic Section Summaries

Summaries of the fossil fish-bearing localities (fig. 1) that were examined in this study are based on the literature, direct observations in the field or through lab tests and data obtained from museum collections.

Beartooth Butte Locality

The maximum thickness of the Beartooth Butte Formation at Beartooth Butte is approximately 50 meters (Dorf 1934a). The lithology is dominantly a thinly bedded red to pinkish red to reddish maroon fine-grained limestone, or micrite. Secondarily this limestone can be yellow to yellowish gray. There is a coarse basal conglomerate for this rock unit (Dorf 1934a) and there are several lenses of conglomeratic limestone (limestone containing limestone lithic clasts) throughout the upper part of the section. Dorf (1934a) reported fish remains from all lithologies present at this site, except for the basal conglomerate and plant material from the section approximately one-quarter to two-thirds from the base of the formation.

Cottonwood Canyon Locality

The thickness of the Beartooth Butte Formation on the south wall of Cottonwood Canyon is approximately 50 meters (Sandberg 1967). Based on vertebrate biostratigraphy, Elliott and Ilyes (1996) propose that this section of the Beartooth Butte Formation is slightly older than the type section at Beartooth Butte. The rocks in the Cottonwood Canyons section are dominantly red to reddish gray, gray to yellowish gray micrites. Pebble conglomerate lenses are present but are a minor component of the section. Fossil plants occur as mats in discrete layers within gray micrites. Fossil fish dominantly occur as isolated elements (see table 2).

Half Moon Canyon Locality

The Beartooth Butte Formation, which is approximately 20 m thick, crops out on the east wall near the head of Half Moon Canyon, and is comprised of several distinct subunits (Fiorillo 1998). Capping the reddish Beartooth Butte Formation are more continuous exposures of massive gray to grayish white micritic limestone, the Upper Devonian Jefferson Formation.

Based on the presence of several different lithologies, as well as the presence of several different types of sedimentary structures, the Half Moon Canyon section of the Beartooth Butte Formation represents a complex depositional history for this sedimentary interval. By the presence of mudcracks and possible raindrop impressions, this history includes periods of subaerial exposure. Further, there are several bone-bearing horizons in this section.

Little Bighorn Canyon Locality

Sandberg (1967) determined that the Beartooth Butte Formation at this locality was less than three meters thick. The formation is a yellowish gray, fine-grained limestone or micrite.

Beaver Creek Locality

Following information from Sandberg (field notes), I was able to relocate the position of this locality (with D. Elliott/ Northern Arizona University), which is present as a relatively small outcrop visible below the base of the Maywood Formation. Sandberg reported the thickness of the formation at this locality as approximately 6.5 meters. Lithologically, this outcrop is dominantly a red to reddish gray, fine-grained limestone or micrite, with numerous yellow interbeds. There are laterally inconsistent conglomeratic lenses that are greenish in color. The middle part of this section contains simple, tubular trace fossils that are only millimeters in diameter and oriented nearly vertically.

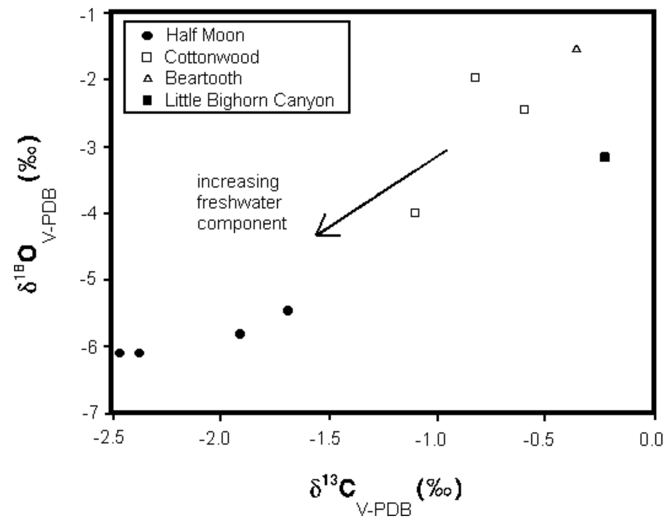

Figure 3—Plot of stable oxygen and carbon isotope data from the Half Moon Canyon, Cottonwood Canyon, Beartooth Butte, and Little Bighorn Canyon localities discussed in this report.

Stable Isotope Data

Figure 3 is a plot of the stable carbon and oxygen readings obtained from the matrix surrounding the fossils. These isotopes provide a qualitative measure of the paleosalinity in which these rocks were deposited. Values of 0 or greater indicate normal marine salinities or hypersaline conditions (Faure 1986). The data in figure 3 indicate that these rocks were deposited in an environment with a freshwater component.

Vertebrate Paleontology

Table 1 is a faunal list for the sites mentioned in this report. Historically, based largely on the work of Denison (see references), the major repository for fossils from this formation has been the Field Museum of Natural History. The specimens collected by the author during this study are housed at the Dallas Museum of Natural History. The discussion for the Little Bighorn Canyon locality is based on the literature (Sandberg 1967) and the collection of material at the University of Wyoming.

The most common fish found at these localities belong to the heterostracans, that group of primitive jawless, fossil fish that have all gills open to the outside of the skeleton by a single gill opening on each side of the body (Maisey 1996). These fish tend to be no more than several centimeters in length. The second most common fish remains found at these localities belong to placoderms, jawed and armored fishes that lived only in the Devonian. These two broad taxa represent the vast majority of fishes found at these localities.

Little Bighorn Locality

The specimens housed at the University of Wyoming are mostly broken bone plates identifiable as placoderm indeterminate. Further, these plates seem to be confined to well-defined layers within the rock unit. Given the highly fragmented nature of the material in this collection, identification of many of the plates is not possible. However, two median dorsal plates are present, suggesting that the minimum number of individuals in this assemblage is two.

Beaver Creek Locality

Although remains identified as fossil fish have been reported from the Beaver Creek locality (Sandberg 1961) none were found by the author. The fish remains collected by Sandberg have been identified as *Aethaspis* and arthrodire indeterminate (written communication from Whittemore to Sandberg 1961). Given that the current location of the fish remains collected by Sandberg is unknown, I have chosen the most conservative approach to their taxonomic identification, and they are referred to in table 1 as arthrodire indeterminate.

The fossil fish yield at the Half Moon Canyon locality is low compared to the better-studied localities at Beartooth Butte and Cottonwood Canyon. However, preliminary results suggest that this site is significantly younger than the two other sites. These results are the recovery of material attributable to an antiarch placoderm and somewhat advanced osteolepid fish material (Elliott, personal communication 1998). Both of these finds suggest a Middle Devonian rather than an Early Devonian age for this outcrop. If this determination bears up with further study, the Half Moon Canyon fauna potentially offers insight into a little-known interval of time in North America.

Taphonomy

In addition to the taxonomic identity of the animals present at a fossil locality, how those animals are preserved is a source of additional insight on the paleoecology of a particular site. Data presented here offer information

Table 1—List of fossil fishes from the Beartooth Butte Formation. Genera are listed with the first letter upper case. Listed beneath each genus are the corresponding species. Data for the Beartooth Butte and Cottonwood Canyon localities are from Elliott and Ilyes (1996). Data for the Beaver Creek locality are from Sandberg (1961).

Taxon	Beartooth Butte	Cottonwood Canyon	Half Moon Canyon	Beaver Creek	Little Bighorn Canyon
Cephalaspis					
wyomingensis	X				
Oreaspis					
ampla	X				
Protaspis					
bucheri	X				
mcgrewi		X			
dorfi	X				
brevispina		X			
Cyrtaspidichthys					
ovata	X				
sculpta	X				
Cosmaspis					
transversa		X			
Lampraspis					
tuberculata		X			
Caridpeltis					
wallacii	X				
richardoni		X			
bryanti		X			
Allocryptaspis					
flabelliformis	X				
ellipticus	X				
Bryantolepis					
brachycephala	X				
cristata	X				
Anarthraspis					
chamberlini	X				
montana	X				
Onchus sp.	X				
Uranolophus					
wyomingensis	X	X			
antiarch indeter.			X		
arthrodire indeter.				X	
placoderm indeter.					X

regarding the processes responsible for formation of the fossil assemblage. The study of how fossil assemblages form is taphonomy (Efremov 1940). For example, if skeletons are preserved intact, little post-mortem alteration to the assemblage is inferred. In contrast, if the assemblage of material consists of isolated skeletal elements, a high degree of post-mortem alteration is likely. In addition to currents, in marine or aquatic environments, skeletal disarticulation can occur through a variety of means such as disintegration of a floating carcass (Elder 1985; Schafer 1972), and scavenging by carnivorous gastropods (Long and Langer 1995) or other carnivores (Schafer 1972). Therefore, one of the basic parameters used to define a fossil assemblage (Fiorillo 1991) is an examination of the completeness of the skeletons at a site. Table 2 is a summary of skeletal completeness for the sites examined, while figure 4 illustrates the various categories used in table 2. Table 3 shows the frequency of isolated elements and associated elements for two broad taxonomic groups, the heterostracan and the placoderms, at the Beartooth Butte locality.

Discussion and Summary

The depositional environment for the Beartooth Butte Formation has been interpreted as an estuarine and fluvial channel-fill (Sandberg 1961). The isotopic data presented here suggest that the localities examined in this report are more freshwater than near-shore marine.

Stable carbon and oxygen isotope data from these localities indicate a variable freshwater component during deposition. The Half Moon Canyon samples may indicate that this exposure was deposited under more fresh water conditions than either the type section at Beartooth Butte, or at the section in Cottonwood Canyon (Poulson written communication, 1998) though this difference is not easily quantifiable (fig. 3). Alternatively, the Half Moon Canyon locality may have been deposited at higher temperatures than the other localities, or perhaps even some combination of higher temperatures and fresher waters (Poulson written communication, 1998).

Trace fossils, specifically burrow structures, are present at all of the fish-bearing localities that were examined in the

Table 2—Frequency of specimens according to degrees of skeletal articulation. Isolated elements refers to individual skeletal elements, while associated skeletons refers to the occurrence of at least two elements attributable to the same individual. Partially articulated skeletons are those specimens where some elements are still articulated, and articulated skeletons are essentially intact specimens. Data based on specimens housed at the Field Museum of Natural History, the Dallas Museum of Natural History, the University of Wyoming, observations in the field. This table only includes the remains identifiable as heterostracans or placoderm, as these are the most common types of fish found in the Beartooth Butte Formation. No specimens have been found by the author, for the Beaver Creek locality either at the site or in museum collections (see Sandberg, 1961), so this locality is omitted from this table.

	Beartooth Butte	Cottonwood Canyon	Half Moon Canyon	Little Bighorn Canyon
Isolated elements	220	95	9	0
Associated skeletons	34	2	0	2
Partially articulated skeletons	3	1	0	0
Articulated skeletons	1	3	0	0

field. The study of trace fossils has a rich terminology (see Bromley 1996, for a summary), and it is beyond the scope of this paper to discuss the details of the fossil traces found at the various localities. Rather, it is appropriate to point out here that the overall morphology of the burrows at each of the sites is similar, thereby suggesting similar depositional environments at each locality. Given the different fossil fish faunas at the various localities, and particularly the probability that the Half Moon Canyon locality is significantly younger than previously realized, these traces suggest a stability to this overall depositional environment that may have extended for 20 million years.

The taphonomy of these assemblages clearly shows a preference for fossil fish material to be preserved as isolated or associated skeletal material. Articulated fossil material is exceedingly rare. Interestingly, examination of table 3 shows a greater likelihood for placoderm material to be preserved as associated material compared with elements for heterostracan skeletons. This trend is not unexpected given the more robust nature of placoderm skeletal material, despite being of the same general size as heterostracan material. Given the differences in bone density between these two types of fishes, these different patterns of preservation indicate that currents were most likely the cause of skeletal disarticulation. In other words, these data suggest that this formation preserves material that experienced skeletal disarticulation due to winnowing by currents of moderate strength, sufficient to scatter the thin bones of the skeletons of heterostracan fishes but not strong enough strength to similarly scatter the bones of all the placoderms.

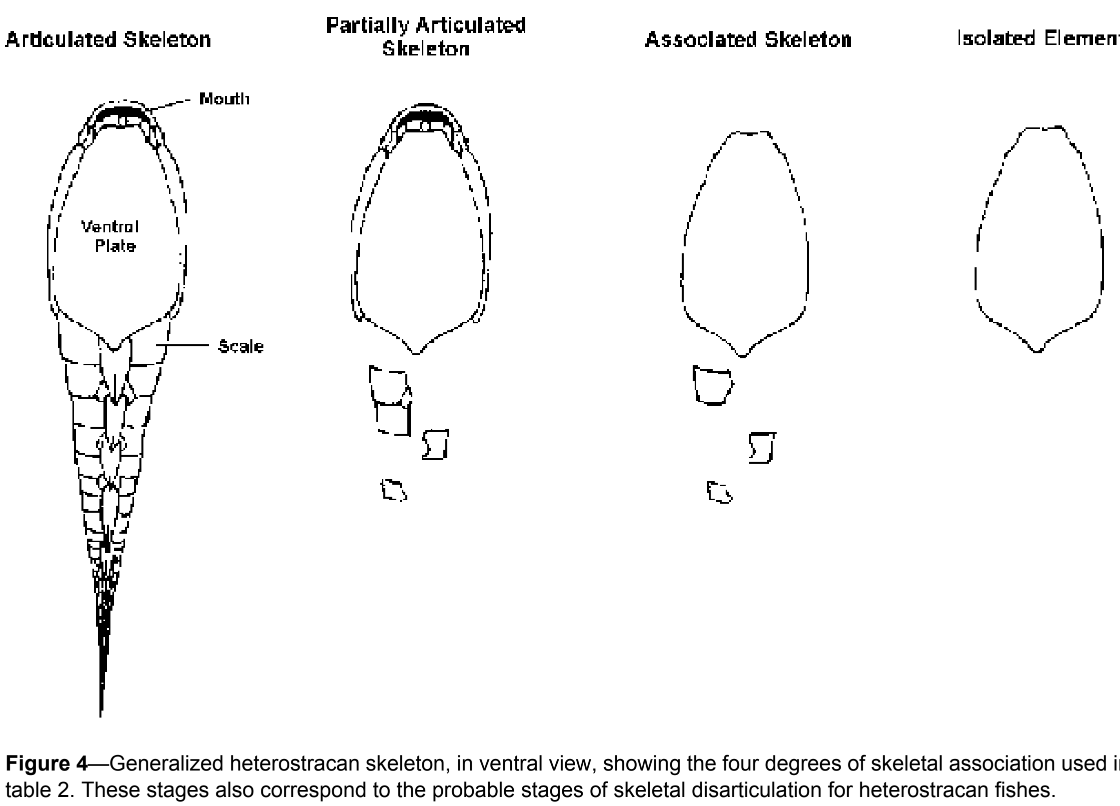

Figure 4—Generalized heterostracan skeleton, in ventral view, showing the four degrees of skeletal association used in table 2. These stages also correspond to the probable stages of skeletal disarticulation for heterostracan fishes.

Table 3—Frequency of isolated elements and associated elements for two broad taxonomic groups, the heterostracans and the placoderms, at the Beartooth Butte locality. These data were collected along a transect made along the outcrop and do not include all of the specimens listed in table 2. Notice the tendency for the bones of placoderms to stay together compared to those of heterostracans.

	Heterostraci	Placoderm
Isolated elements	67	30
Associated elements	3	31

In summary, the geologic and paleontologic data support the model that the Beartooth Butte Formation was deposited in an environment with a well-developed freshwater component. The environment probably remained stable for several million years, although the fish faunas changed during this interval. Bones accumulated in an environment that experienced moderate current flow, that disarticulated and, for some types of fish, disassociated skeletal elements.

Management Recommendations

Given the paucity of vertebrate fossil remains at the Beaver Creek locality, no special management issues need be considered here.

The abundance of fossil material at the Little Bighorn locality, based on the material already collected by the University of Wyoming, suggests that this site is worthy of more detailed scientific excavation. The inferred remote nature of the locality suggests that there are no additional management issues to be addressed at this time.

From a management perspective, the Half Moon Canyon locality is probably the most sensitive with respect to new scientific information, given the preliminary fauna recovered from this locality. However, this site is geographically remote, with difficult access. With the present state of development in the region, the site, despite its great paleontological potential, is low risk.

The Cottonwood Canyon locality has a high density of bone material and has produced large numbers of specimens. There are two components to this locality, the more commonly collected south wall locality and an apparent exposure of the rock unit on the north wall of the canyon. The north wall is nearly vertical and as such is very difficult to access. The south wall is also difficult to access, but it can be done with a great deal of effort. Unlike the other localities discussed in this report, the two components of this locality are currently on land managed by the Bureau of Land Management. No extension of this unit was found on land managed by the USDA Forest Service in this canyon. The Cottonwood Canyon localities are within a short drive of a small town (Lovell), with good road access. Therefore, though this locality is relatively close to a population center, the difficult access to reach the outcrop is a natural protective measure.

The Beartooth Butte Formation at Beartooth Butte is well-studied and abundantly fossiliferous, thereby making this locality the best known of all sites in this formation. The proximity of this locality to the existing fire tower at Clay Butte make it financially feasible to add interpretive text about the paleontology of this rock unit to the already existing interpretive displays about fire monitoring.

In summary, with respect to management issues, the geology and taphonomy of these sites indicates similar environments of deposition at all localities. However, the sites have different levels of scientific importance due to the faunal composition. Given the apparent new age considerations for the Half Moon Canyon locality, this site is the most sensitive with respect to paleontology. The Beartooth Butte locality, because of its accessibility, provides the best opportunity for a public interpretive facility.

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