The Taphonomy of Small Rodent Fossils in the Meade Basin (Kansas)

By

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Under the supervision of Andrew Haveles

ABSTRACT

The Meade Basin of Kansas contains a series of Pliocene to Pleistocene aged sand and ancient soil deposits, along with associated vertebrate fossil assemblages that record small mammal community turnover during the last four million years. The Meade Basin diversity record is a culmination of taxonomic presence and absence data but does not systematically consider the relationships among the environment, sediment and fossil assemblages. The study of taphonomy is a branch of paleontology that studies an organism from the time of its death until it is discovered. This can help our interpretation by assessing the potential biases in vertebrate fossil assemblages that may influence our interpretation of the diversity record, such as, fossil assemblages that accumulated in different depositional environments. I utilized standardized sampling in three representative faunas (Cudahy, Borchers and Ripley) to investigate how fossil abundances, distributions and preservation were affected by the hypothesized environmental conditions. By combining the taphonomic analyses with sedimentology, I determined that these faunas and their diversity could not be directly compared and that they experienced slightly different taphonomic processes based on the inherited biases present.

ACKNOWLEDGMENTS

I would like to thank my advisor, Andrew Haveles for all of the guidance and support throughout this research project. I would also like to thank Julie K. Bartley, Laura Triplett, Rory McFadden and my peers for their support and feedback and input.

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INTRODUCTION

The fossil record enables the study of faunal change on evolutionary timescales through a range of climate and environmental conditions not found in the modern record (Barnosky et al. 2003; Blois and Hadly 2009; Dietl and Flessa 2011). Researchers today are trying to find the answer as to how the fossil communities of the Meade Basin moved throughout time. The two hypotheses that they are looking at are the Red Queen and Court Jester hypotheses. The Red Queen shows that communities move due to biotic factors, or evolutionary pressures around them. The Court Jester is the opposite and shows that communities move due to abiotic factors, which are the physical environment changing around them. However, the fossil record is not complete due to differing preservational biases that result from the range of depositional environments, therefore we must consider which biases are present before comparing taxonomic diversity records. We identify the potential biases in the fossil record by using taphonomy. Taphonomy is a branch of paleontology that studies an organism from the time of its death until it is discovered. The study of taphonomy can reduce the noise introduced by preservation processes and enhance the paleoecological signal by providing information about the environment that the organisms lived in and their relationships with it (Brett and Baird 1986).

Taphonomic processes can introduce biases in fossil deposits that are based on morphology (e.g., favoring the preservation of larger individuals over smaller ones; Brown et al. 2013). These biases can influence the composition of a fossil assemblage and thus confound patterns of taxonomic or ecological diversity in space and time (Wing et al. 1992). We can account for these biases by examining fossil weathering patterns, size classes, and the distribution of fossil elements. These taxonomic and fossil characteristics can be combined with sedimentary attributes to form identifiable combinations known as taphofacies. Different approaches have been adopted to characterize the taphonomy of vertebrate assemblages. Some have focused on specimen features such as size, shape, and taxonomic identity to compare the preservation of fossils across and within lithologies (e.g., Blob and Fiorillo 1996; Wilson 2008). Others have focused on the analysis of fossils and their sedimentological context in the field to contrast vertebrate microfossil assemblages across depositional environments (e.g., Rogers and Brady 2010). These two approaches can be integrated to determine the taphonomic history of mammalian fossil assemblages (e.g., Badgley 1986). The two different approaches would be able to better tell us about the depositional environment, weathering processes, abundance records and much more.

PREVIOUS WORK

Between 1936 and his death in 1973, Claude W. Hubbard, along with his students from the University of Michigan, amassed multiple collections of vertebrate microfossils from the Meade Basin of Kansas that were upwards of five million years old. Hubbard worked specifically on the localities of Borchers and Cudahy, along with many others. They then identified numerous late Pliocene to Pleistocene small mammalian localities (Martin et al., 2003).

From 1973 to present, many other field crews from Murray State University, University of Michigan, University of Minnesota and the University of Kansas have investigated other areas of the Meade Basin to further the research started by Hubbard. These expeditions discovered many new localities that were then investigated to build a more complete spatial and temporal record of diversity. New species of small rodents have also been identified within those localities. All of the work that was completed by Hubbard, students, researchers and other scientists has contributed to creating presence and absence records of the fauna that lived on the landscape (Figure 1). Small mammal appearance data were produced by identifying the molars of multiple species of rodents like pocket gophers, ground squirrels and mice, and analyzing when various lineages went extinct, immigrated or emigrated. The resulting diversity record allowed researchers to determine that during climatic events, the warm temperate rodents survived deglaciation while the colder temperate rodents would have gone extinct and vice versa (Martin et al. 2003). The presence and absence data (Figure 1) were used to calculate community turnover rates which revealed numerous species immigrations and extinctions (Martin et al., 2003)(Figure 2). Ongoing research is testing whether rodent community turnover events are related to abiotic factors like volcanic events and climate fluctuations, or biotic factors like expanding C_4 food resources and inter-specific relations, or some combinations of all these factors (van Valen 1973). The geologic time interval of the Meade Basin is also important in learning about these factors. The Pliocene epoch began around five million years ago and at this time the Arctic ice sheets were beginning to form and started the new Ice Age. The lowered sea level allowed the Bering land bridge between North Amercia and Asia to come into form, which created an accessible way for different species to move from between the continents. During the two million years of the Pleistocene epoch there were multiple glacial and interglacial times that would affect the animals living on the landscape and potentially cause community turnover rates to change (American Museum of Natural History).

Rodentia	SR	F C	RipB	Rap1C	WnsB	Hor	R3	DP	Ss	Bor	SH	ArA	Na72	Cud	B S	CQ	Jin	GolB	Jon	Rob	Mod
Sciuridae																					
Spermophilus rexroadensis		x					x														
Spermophilus howelli		x					x														
Spermophilus meadensis										x	x										
Spermophilus tridecemlineatus												cf	x	cf	cf	x		o	x	x	x
Spermophilus cragini										x											
Spermophilus franklini										cf	o	o	cf	cf					x		K
Spermophilus richardsoni										cf				x	x			o	x	x	
Spermophilus spilosoma																					x
Spermophilus sp.	x		x	o	x	x		x	x								x				
Spermophilus sp.	o		o	o	o	o		o	o							o	o				
Cynomys ludovicianus /sappaensis													cf								
Cynomys l. /spenceri															x						
Cynomys l. /ludovicianus																	cf	o	x	x	x
Cynomys niobrarius																x					
Cynomys sp.														cf							
Paenemarmota barbouri /sawrockensis	x																				
Paenemarmota b. /barbouri		x	o	x																	

Figure 1: Presence/Absence record example from the Meade Basin of Kansas (Martin 2008).

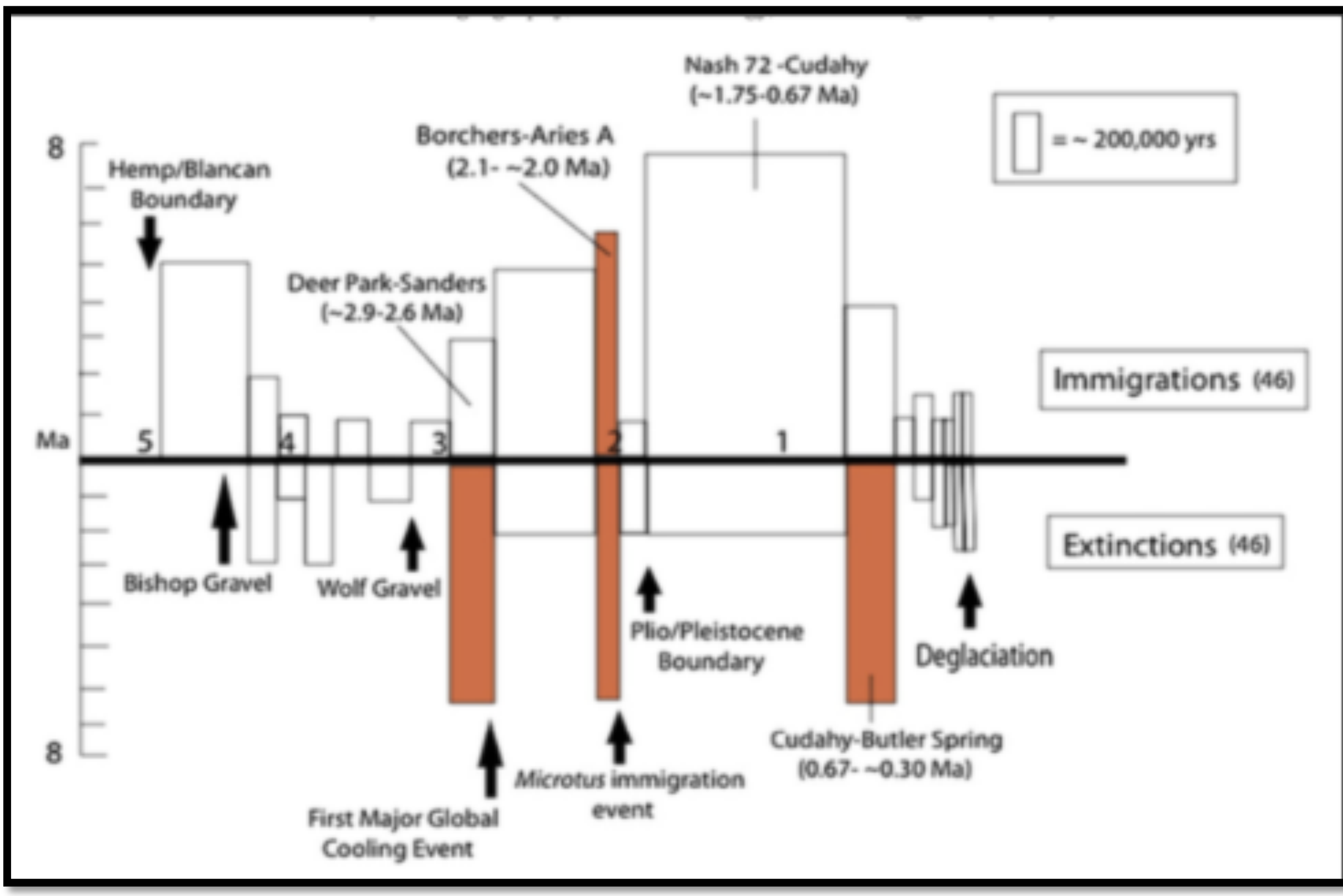

Figure 2: Community turnover rates in the Meade Basin (Marin 2008).

The taxonomic records of the Meade Basin are mainly described by appearance data alone but identifying the distribution of individuals among the identified taxa is very important for further research. Furthermore, the Meade Basin faunas may have experienced different taphonomic processes that can result in different taphonomic biases, which subsequently affect our interpretation of the fossil diversity record. These biases can inform us of the depositional, weathering and preservation patterns and it can reveal different biases that cause the fossil record to change over time. Therefore, it is important to study the taphonomy of the Meade Basin fossil record, so we can identify whether or not the different faunas can be directly compared. Here, I conducted a taphonomic analysis by investigating how fossil abundances, distributions and preservation were affected by the hypothesized environmental conditions.

GEOLOGIC SETTING

The geologic setting of my area of research, is located in the Meade Basin, found in southwestern Kansas. The Meade Basin lies within Meade County and includes the city of Meade. The Meade Basin is approximately 48 kilometers long and extends from northern Meade County to the panhandle of Oklahoma (Martin et al. 2008). This area of the United States can be defined as a semi-arid climate. The central plains see pacific and polar airs, that collide with the wet maritime tropical airs, which then creates desert and wet environments. The central plains area shows annual temperature changes and experiences drought and flood conditions. The rainfall average ranges from 40 cm in the dryer parts of the state and up to 100 cm of rain in the central, wetter areas of the state. This rainfall is received mainly from April to September (Goodin et al., 2004).

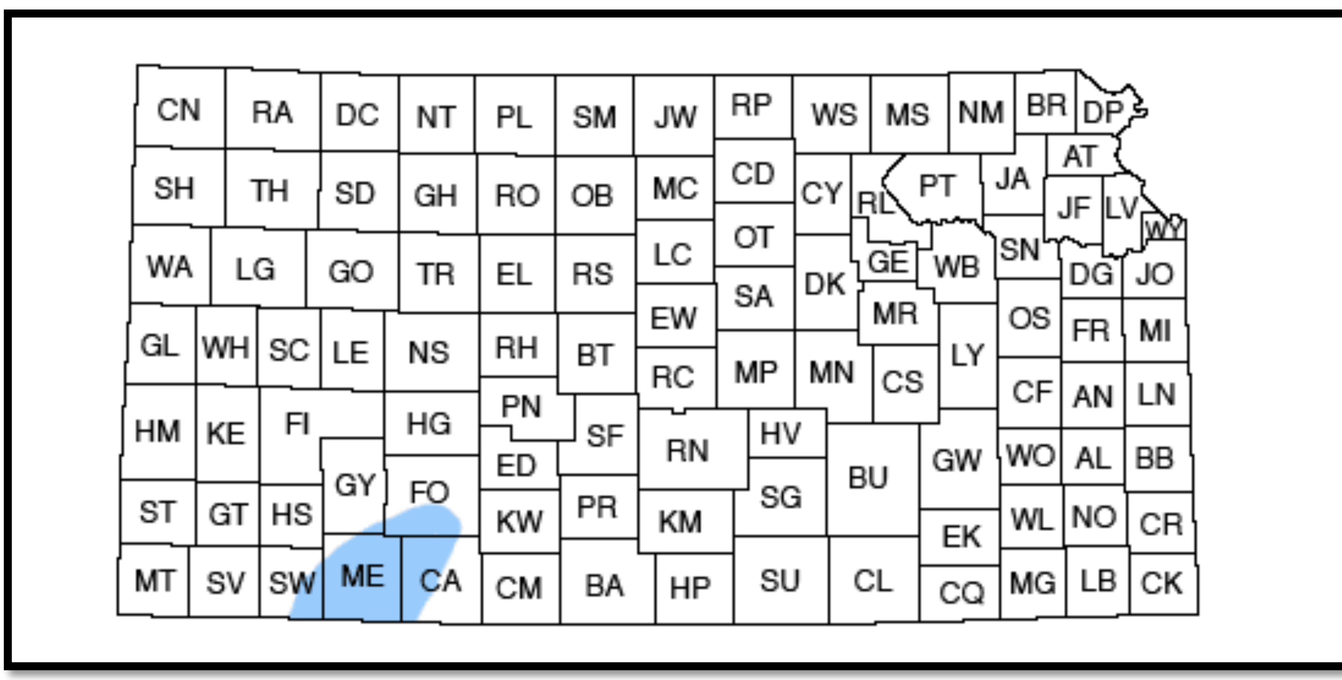

Figure 3: A map of Kansas that highlights the Meade Basin in blue (Goodin et al.,2004).

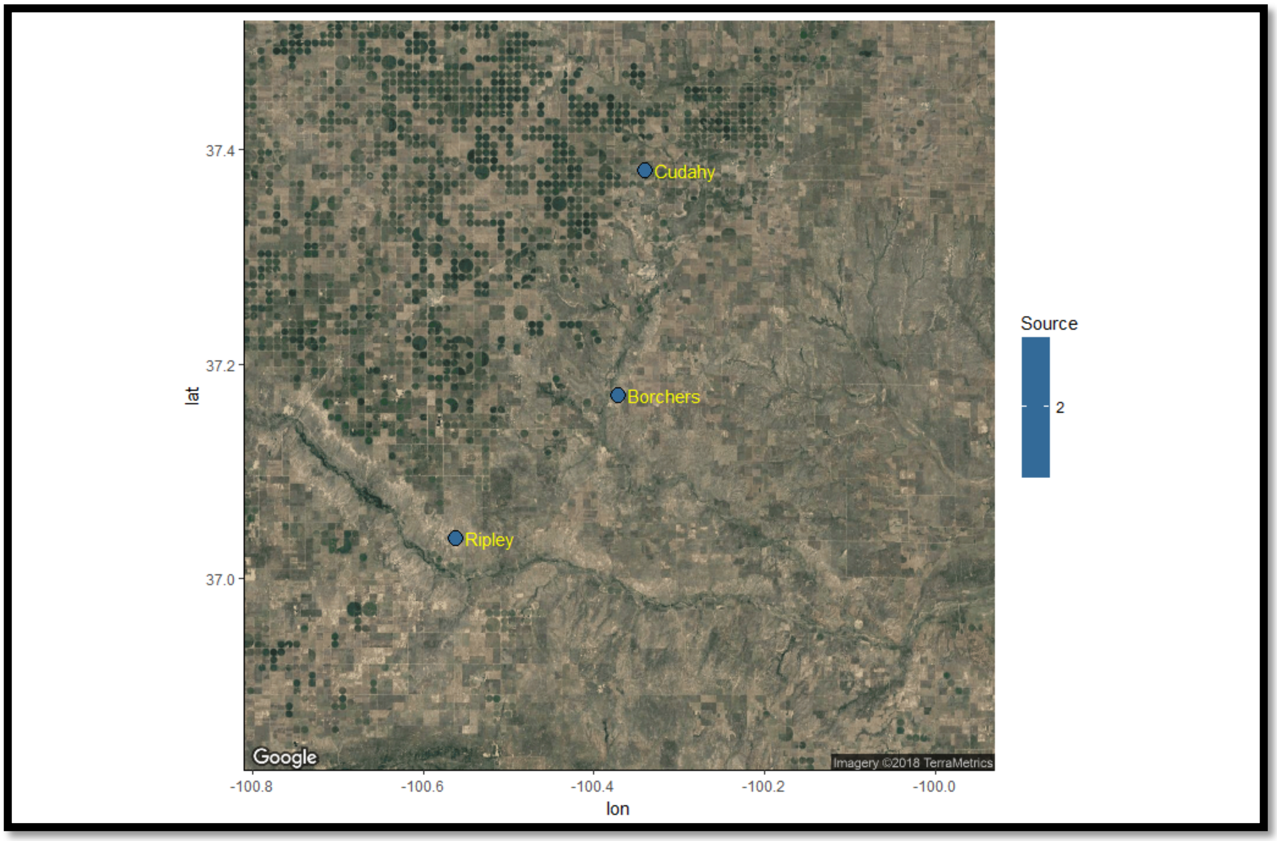

Figure 4: A Google image of the localities of interest.

The climate of the Meade Basin can affect the diversity record and create different biases. Areas that have more rainfall may see a more fossiliferous area due to the quick sedimentation that would preserve materials better. If the area is dry, you may have a larger chance of less preservation because the fossil material may be exposed to weathering more often and may be completely erased from the fossil record. The climate here has allowed for an abundant amount of fossil material to be preserved, and it creates a good area for research. This study focuses on three specific localities, Borchers, Cudahy and Ripley. Borchers and Ripley lie south of the city of Meade while Cudahy is to the North (Figure 4).

The Meade Basin contains many layers of sediment that were deposited in the late Pliocene epoch, approximately 4.17 Ma, to the early Pleistocene epoch around 0.7 Ma (Figure 6). These layers of sediment are now called paleosols because they have become ancient horizons of soil. The Meade Basin consists of multiple formations including the Laverne, Ogallala, Meade and Kingsdown. The localities of investigation are within the Laverne formation. The localities paleoenvironment and surrounding areas were formed by multiple alluvial sequences that caused channel trenching during the Holocene. Erosion then continued and alluvial sedimentation occurred afterwards, forming rich soils. Those soils developed in a time of higher moisture, creating calcium carbonate layers, trapping pollen, mollusks and vertebrate faunas. With a shift in the Earth's climate, it created a dryer time that allowed for more channel trenching, creating the riparian and prairie environments (Hall, 1990, Frye, 1944).

The layer in which the locality of Ripley lies, was deposited around 4.17 Ma and lies just above the Bishop gravel and underneath a calcium carbonate layer. This locality is made up of small to fine grained sandstones and siltstones that are brownish in color (Honey et. al., 2005). Some mollusks and burrowing insect burrows were also found in the sediments. The locality of Borchers lies in a layer that was deposited around 2.10 Ma. Borchers lies under an ash layer named Huckleberry Ridge ash (Martin, 2003, Marcolini, 2008). This ash layer was deposited by a super volcano that erupted in Yellowstone, Wyoming. The layer in which Borchers sits consists of fine to large grained gravel, mixed with some sandstones. The layer in which the locality of Cudahy sits, was deposited around 0.7 Ma. Cudahy sits just below of the Lava Creek ash layer that was also deposited by a super volcano in Yellowstone (Oard, 2014). Cudahy's deposition consists mainly of fine grained sand and few larger clastics. This locality produces a large amount of bivalve and mollusk material, giving the impression of a fluvial environment. The sediments can be seen in sample cups in (Figure 5).

Figure 5: Un-sieved sediment from each locality in the sample cups. The cup on the left is Borchers, middle is Ripley and the right most is Cudahy.

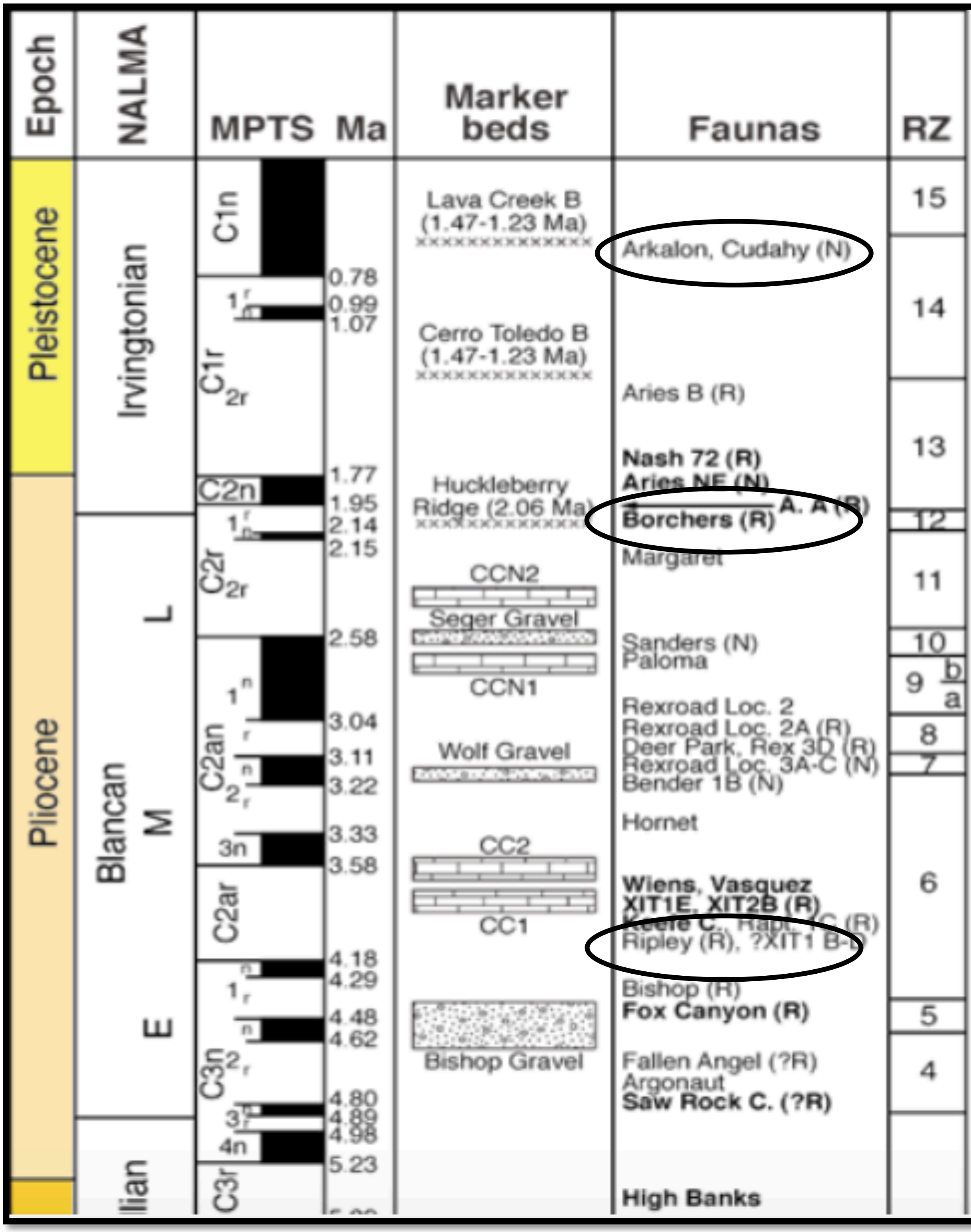

Figure 6: Stratigraphic placement of Ripley, Borchers and Cudahy (Martin 2008).

METHODS

During 2016, a field crew from the University of Minnesota collected bulk samples of paleosol from the known localities of Borchers, Ripley and Cudahy. The paleosol was then put through a stacked sieve, that separated the sediment into two different sieve sizes (2 mm and 50µm). The bulk samples were sieved by ~100g subsamples, that were place in the largest sieve and then slowly and repeatedly dunked in water for approximately 24 hrs. This helped reduce the amount of fossil breakage and maximize the fossil specimen recovery yields. Each of the two different sieve sizes were weighed before and after separating the material into the sample cups for further research.

Once I receive the samples, the remaining material was sorted underneath a microscope, using a fine tipped paintbrush and tweezer, into fossils, sand, debris, insect burrows and shelly material. Each cup of fossils was then further sorted and counted to determine the number of individual specimens (NISP), minimum number of individuals (MNI) and individual element counts of any identifiable bones.

Standardized sampling is a very useful tool as it will allow me to create a quantitative metric of effort. This is important because it helps give the Meade Basin diversity record a more accurate representation of the abundances there since the exact amount of initial sampling was never recorded. Standardized sampling will be used in this study to normalize the abundance data. The average weight per kilogram for each element group was calculated by dividing the number of bone elements by the amount of material sieved. By doing this, it was able to produce a more accurate representation of how fossiliferous each locality actually is by taking into account sampling effort.

To determine which taphonomic processed may have affected each fossil assemblage, I assigned a taphofacies to each locality. Taphofacies are layers of sediment and fossil material that share the same characteristics. Taphofacies consider the various modes of preservation, burial process and sedimentological processes that may influence which fossils are preserved. Isofacies are layers of sediment and fossil material that share the same characteristics and therefore contain the same biases. Therefore, if Ripley, Borchers and Cudahy are isofacies then we can directly compare diversity records. Alternatively, if these faunas are not isofacies, we must consider the different taphonomic biases when comparing diversity records.

RESULTS

The taphofacies assigned to the three localities confirmed that they were all different by the limited amount of sediments and other shelly material present, the difference in preservation of the fossils and how that affected the overall abundances of the localities. Ripley contained medium to fine grained sediments, some insect borrows and shells with very well-preserved fossils. Borchers contained large to fine grained sediments with debris from plant life and the same preservation as Ripley. Cudahy showed the most significant change with almost no sediment in the samples, except for some siliciclastic sediments which are carbonate material and shells (Figure 5). The concentration fossil material in Cudahy was very minimal and extremely weathered when found.

The NISP includes any identifiable or unidentifiable fragments and produced a grand total of 4,722 fossils when combining all three faunas (Rogers & Brady 2010). I individually counted the fossils to put the elements into their respective element groups (ex. Femora, humerus, teeth) for collecting the sample weights. The most common bone elements that were identified were 20 femora, 19 humeri and 191 teeth (Figures 11-13). 17 other elements were sparsely found and included scapulas, mandibles, radius/ulna, pelvic bones and vertebrae (Table 1). An item that showed up very frequently, with a total of 58, were bone pebbles (Figure 14), or bones that have experienced a large amount of weathering so that they have lost shape and are not identifiable anymore. These identifiable elements only provided a small amount of the total fossil material that was found, compared to the unidentifiable elements who created a total of 4,417.

With the abundances available, I was able to compare each locality to the others. (Figure 8) shows the total abundances for all three of the localities. Observing this, Ripley had the greatest raw abundance, Borchers second and Cudahy had the least. The NISP as a raw number did not accurately allow the viewing of the difference in the number of elements in either of the three localities different sieve sizes because the original amount of sieving effort was never recorded. To be able to understand the quantitative measurements that were collected, I standardized the selected samples to have a metric of sampling effort. Standardized sampling was also used to collect abundance data from the weight of the sediment and fossils. When graphing the NISP compared to their relative weight (Figure10), the sediments that were contained in each sample proved to have a bias towards each other. The 50µm sieve size showed to have a greater proportion of NISP, where the 2mm sieve size saw a greater weight proportion. This creates a large bias in the material that was produced because it shows that the fossils were being moved and separated differently in the fluvial environments and they were also being preserved in different ways.

DISCUSSION

The difference in taphonomic biases can greatly influence the way we look at the depositional environments and fossils within them. There was very little sediment available, only what was remaining post-sieving, but they were all visibly different in composition, size and faunal content. These can be biases that are created of different kinds of weathering, different types of preservation and they could affect overall abundances. Since the different localities were found to be separate taphofacies, I was able to look at how these different facies have preserved the fossils.

The NISP showed the total number of elements for each locality. After standardizing this number for sampling effort, it provided comparable numbers of elements in each locality (Figure 7). The standardization is done to show a quantitative metric of effort because no record was kept as to how much effort was put into the original sampling of the localities, therefore localities with more taxa may be a result of greater sampling effort. Subsequently, any changes in diversity may be the result of changing depositional environments and their corresponding taphonomic biases. The percent of raw element data (Figure 7) showed that overall, the 50 μm sieve size contained more fossils than the 2 mm. The data from the abundance counts also shows that the 50 μm sieve size was much greater than the 2mm (Figure 9).

Rogers & Brady (2010) explained the difference between grain size and their fluvial environments and by showing the proportion of NISP to weight in different grain sizes. They then determined that when their figures were skewed left, the NISP was greater than weight and skewed right when weight was greater than NISP. Rogers & Brady (2010) determined that the dkewed data belonged to channel hosted environments while the right skewed data belonged to lake or pond environments. This helped to give me a part of my interpretation of the fluvial environment.

Previous research describing the depositional environments indicated that the three faunas were in a complex terrestrial environment that included a fluvial system with small mammals living within the riparian habitats (Martin et. al., 2003). An example of this could be a stream that has a very small floodplain and has uplands very close to it. The zone would usually consist of many trees and other fauna along the stream's banks. The results presented below support the riparian zone interpretation as a possible fluvial backwater system. When thinking of a hydraulic environment, backwaters are a zone where flow decelerates between normal river flow and the upstream. This area usually renders the backwater highly depositional (Lamb et. al. 2012). The NISP vs Weight figure overall shows that the NISP is more significant in the 50µm sieve and the weight is more prominent in the 2mm sieve. With an interpretation of fluvial backwaters, this would make coincide because the fluvial environment could be slow enough to capture those small fossils when they are in suspension while there may not have been enough energy to carry the larger material onto the floodplains. With the low to medium velocity of the water, you would expect to see the heavier 2mm pieces being preserved. The 50µm could have been better preserved because of low velocity of waters flowing through those areas. This would allow the suspended loads of smaller material to be dropped faster and sooner than usual.

It appeared overall that the best-preserved items in both sieve sizes were femora, humeri and teeth. When looking at bonebeds of hydraulic derivation there should always be physical evidence of fluvial transport. This would include size sorting and rounding of bone materials (Rogers and Brady 2010). Bone pebbles were a very common element and are interpreted to be a part of a higher velocity environment (Figure 14). Most of the bone pebbles were found in Borchers and could indicate that at times there could have been frequent flooding and when happening intermittently, would continue to wear down the fossil over time through constant movement in the water while being weathered by the surrounding sediments and material around them.

The locality of Ripley was deposited around 4.17 Ma and had a mixture of coarse to fine grained sediments with shelly material. The fossil material found here is angular to sub angular. Ripley contained the greatest abundance of bone pebbles, which indicates that you must have a faster hydraulic energy environment. When sediment is carried out of a floodplain, the heavier bedload will be dropped immediately as the flood loses its initial velocity. This causes the materials dropped to be abraded during transport. Ripley also contained a small amount of shelly material and burrows of soil modifying organisms. This locality shows moderate physical weathering and an intermediate speed of sedimentation. It is interpreted that this member was deposited on the floodplain, very close to a body of water.

Borchers which was deposited around 2.10 Ma and shows an abundant amount of rootlets and grassy debris which are most likely modern day material that was collected in sampling. The preservation of Borchers is quite superior to the other two localities. This could mean that there are higher rates of sedimentation happening in this area, causing the preservation potential to be very high and abundances to rise. Much of the material found here was very small and mainly of the 50µm sieve size. This could be a bias as smaller materials like sand, silts and clays are able to be carried farther out onto the floodplain because it is a lighter material. That material is then left as the waters recede and the channel bank becomes dry again (Nichols 2013). The placement of this locality would lie in the middle of the floodplain.

The taxa was very abundant here, most likely due to the increased faunal content and the close proximity to the water.

The locality of Cudahy was deposited around 0.7 Ma. It showed almost no sediment but included shells and some carbonate material. Cudahy shows the least amount of fossil material between all elements and localities. The fossils are very worn and pitted and the weathering pattern has made them quite angular and broken. There appears to be a low rate of sedimentation which would decrease the abundance preservation potential. Low rates of sedimentation allow fossils to be left in the open air longer, subjecting it to chemical weathering by rain and physical weathering by abrasion, trampling and therefore, the fossils are more likely to be broken before burial. This locality was placed on the upper floodplain, very close to the uplands. This area would have seen frequent and/or prolonged flooding but would have had most of the small material in the suspended load within the water. This would allow the materials to be dropped later than the heavier material which would have disappeared right away. This may explain the amount of shelly material, as the shells are extremely light weight, they would have become part of the suspended load and then been congregated at the top of the floodplain as the waters receded. Although, the amount of fossil material left behind could have been due to the elevation of the taxa at that time, so when they were deposited, they are biased to have a much lesser chance of being preserved since there was not as much water and very low sedimentation rates. This locality was interpreted to be deposited on the upper floodplain, near the uplands. Overall, over time, it appears that the rodent communities were moving away from the body of water that they inhabited.

The Meade Basin diversity record is very complete in the presence and absence records but was not complete in the abundance category. My research allowed us to see that the three localities studied are different in abundances and their preservational properties. I can conclude here that different taphofacies do create a bias in the way that the fossil record is preserved.

To find a more complete abundance record for the Meade Basin, many more samples would need to be studied. To find a complete abundance record for the three localities studied, they deserve to have a larger chance of finding material than what this research allotted for. I also believe that many more localities need to be studied. The localities studied only represent a very small portion of the Meade Basin diversity record, so much more research would need to be done to confirm the most abundant areas. By completing more research, the full abundances will be found and then research can be done on the teeth to determine which taxa it is. This will eventually be able to lead researchers to come to their conclusion of the bigger picture as to whether the taxas are moving due to environmental or biological factors.

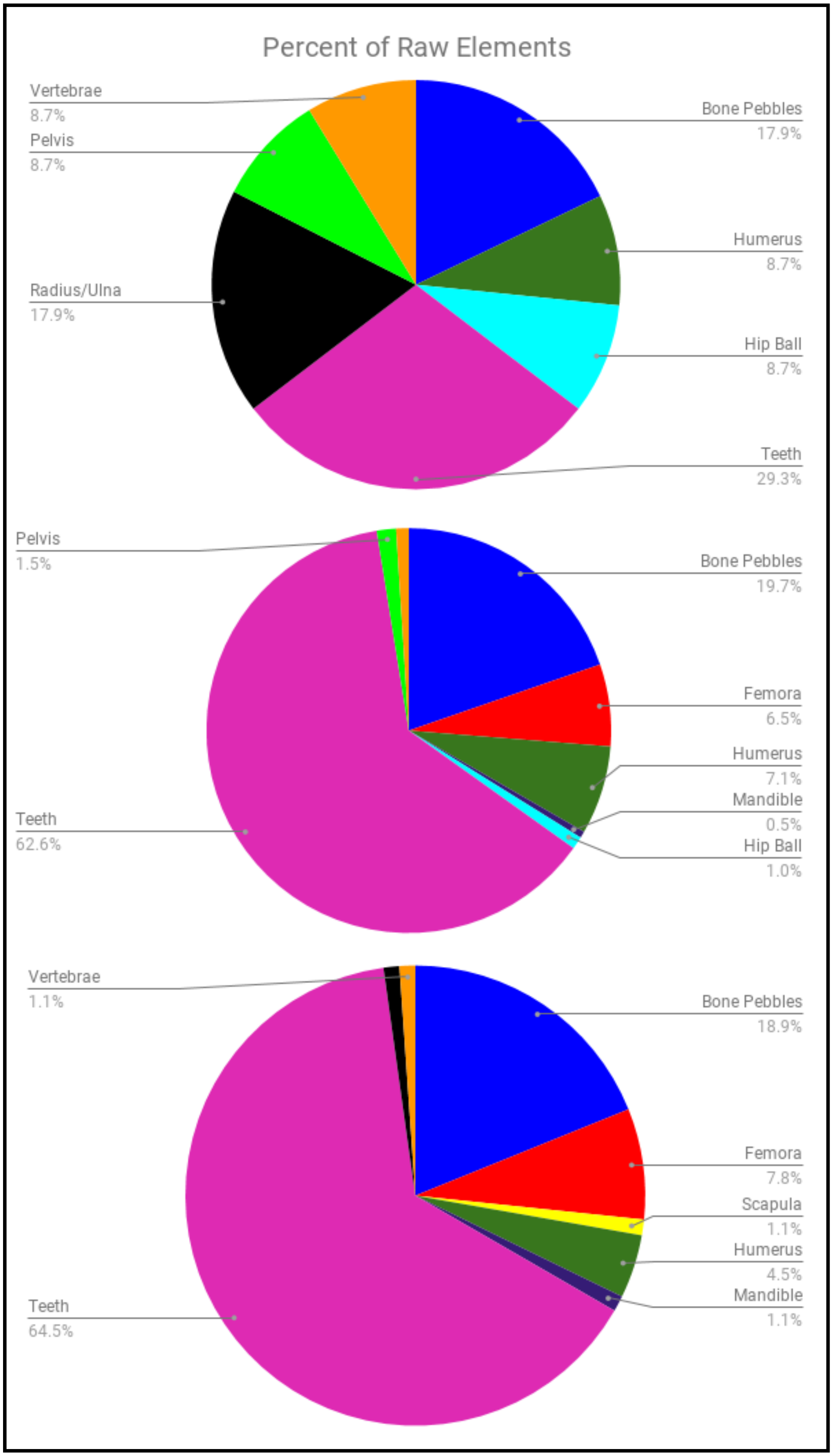

Figure 7. The percent of raw elements found in the 94 sample cups sieved. These graphs are stratigraphic with Cudahy at the top, Borchers and Ripley at the bottom.

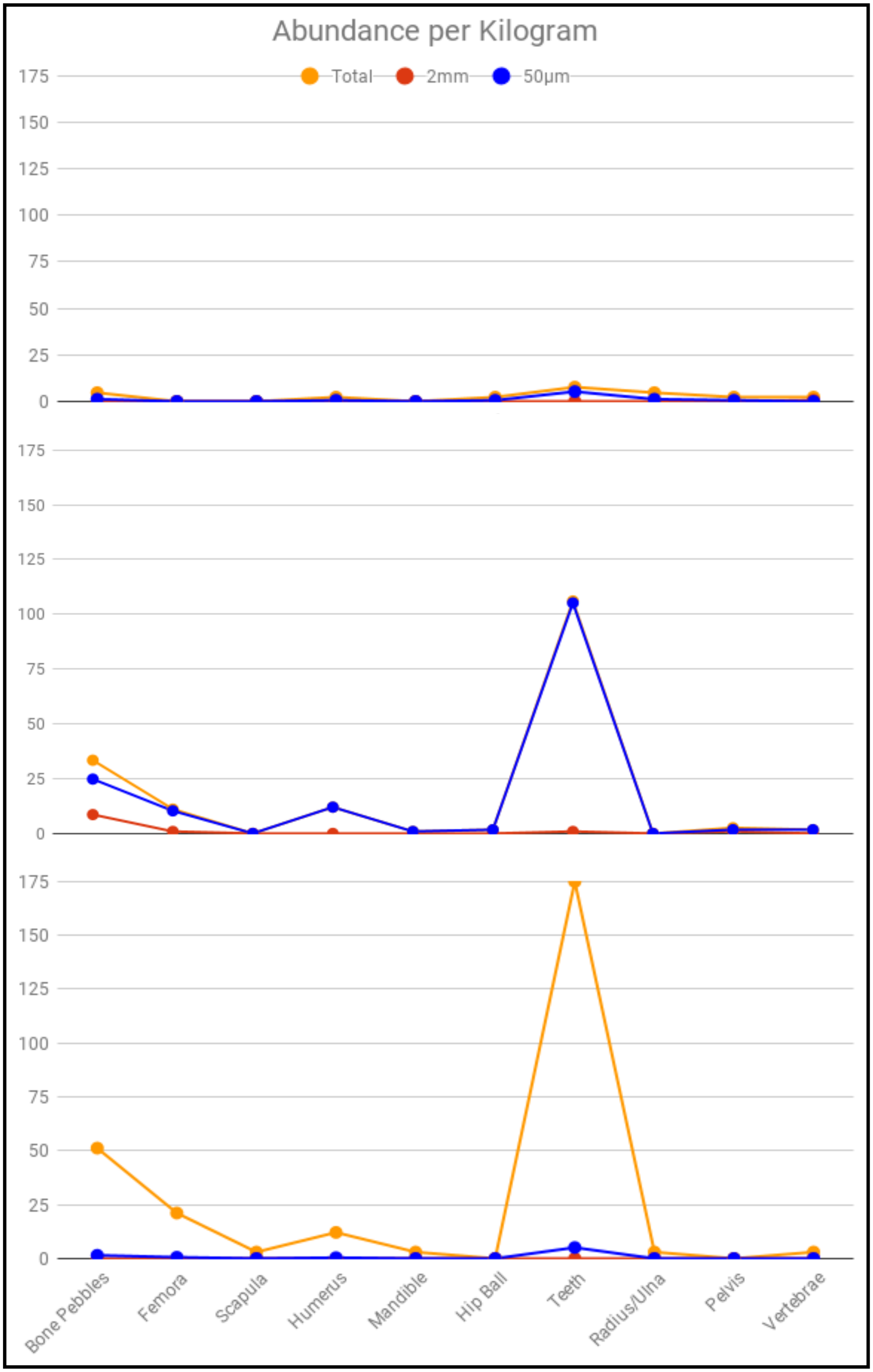

Figure 8: The identifiable element abundances per kilogram of the three stratigraphic units, Cudahy, Borchers and Ripley.

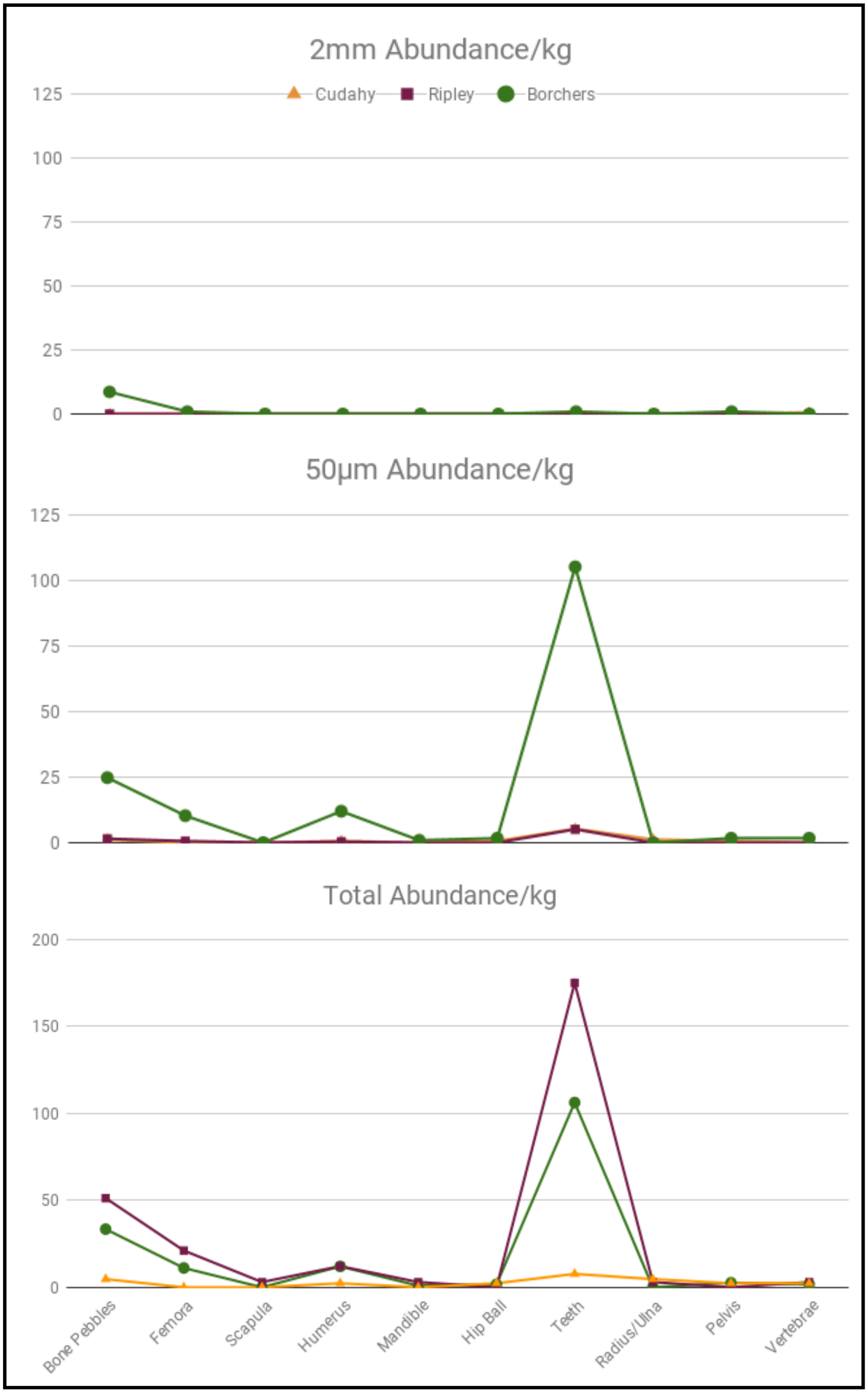

Figure 9: 2mm, 50µm and total abundances per kilogram of the identifiable elements in each locality.

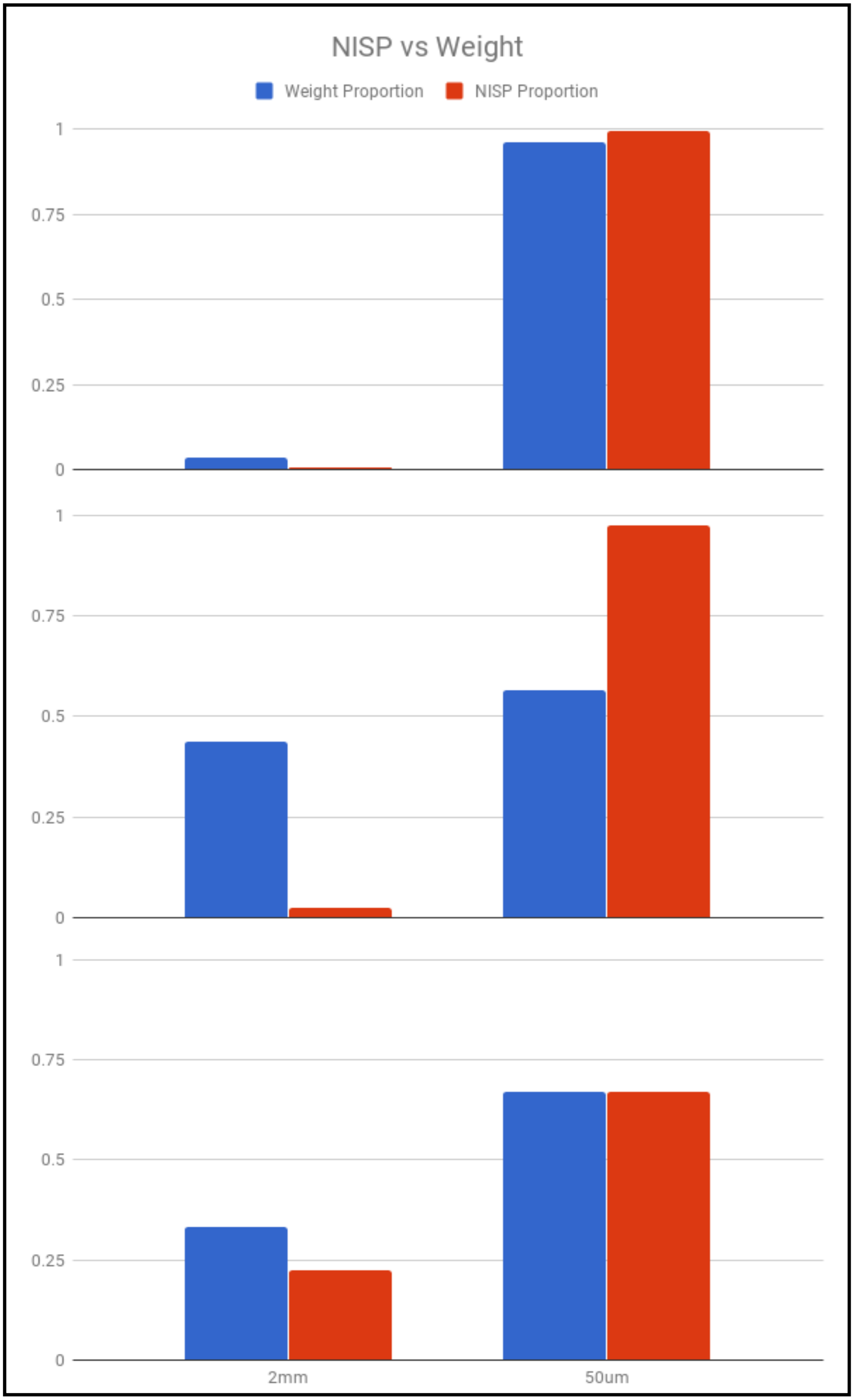

Figure 10: NISP vs Weight proportions stratigraphically of the three localities of interest.

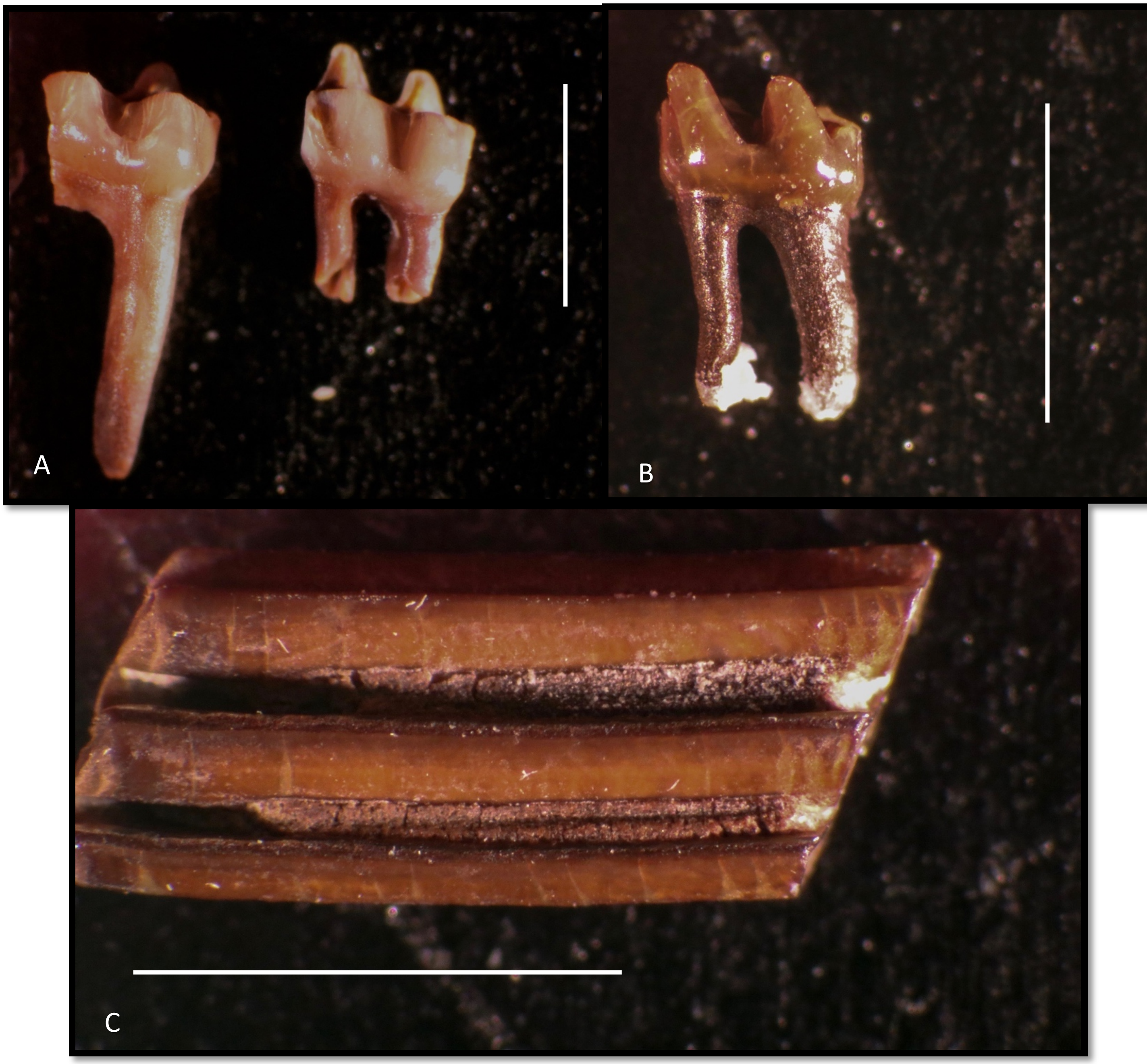

Figure 11: A. Two molars from the locality of Ripley. B. A molar from the locality of Borchers. Notice the preservation between the two. C. An incisor from the locality of Cudahy. Each white line indicates 3mm of length. All three specimens were found in the 50µm sieve size.

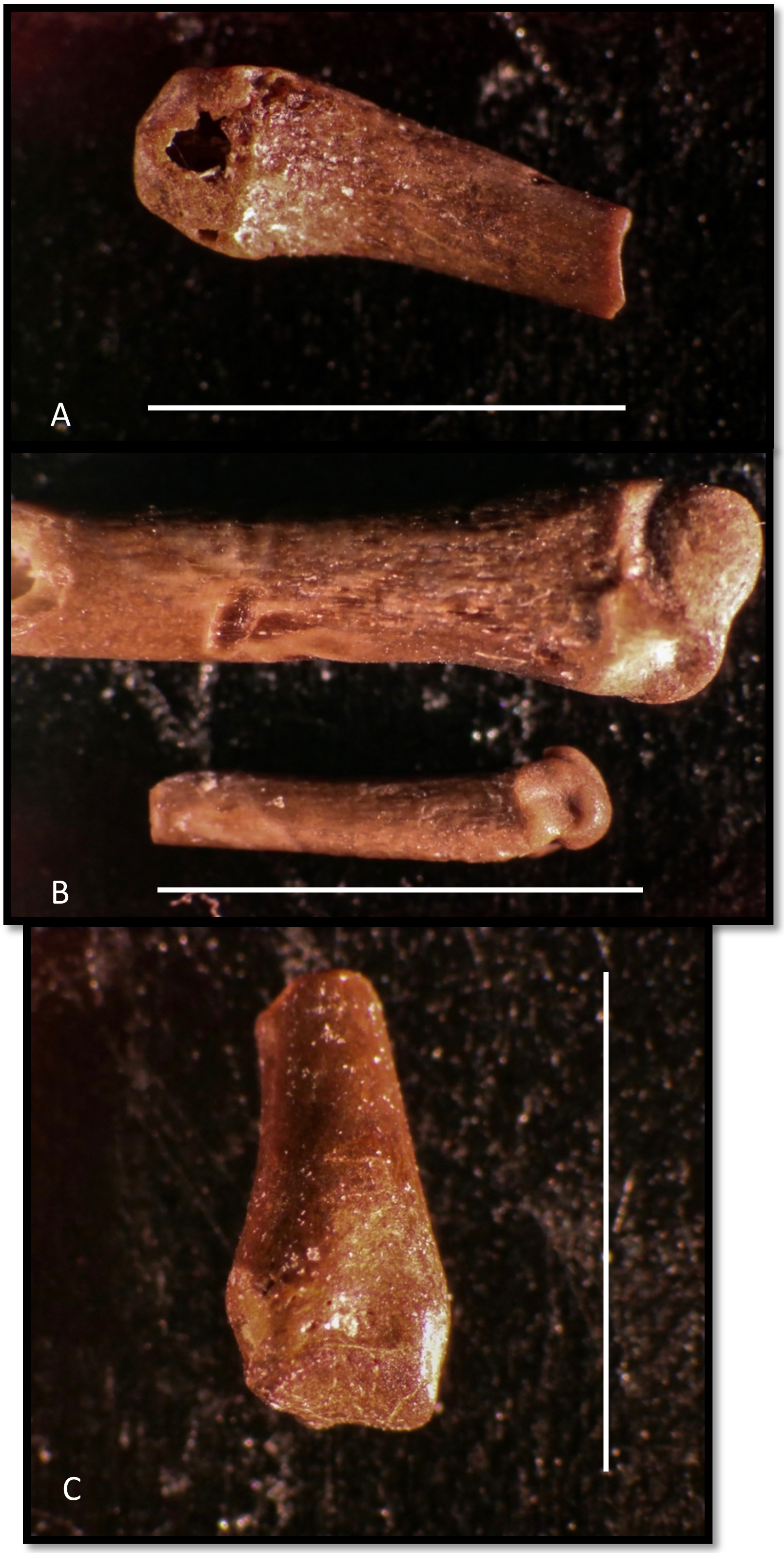

Figure 12: Images of femora from the samples collected. A. A femur from Ripley. B. A femur from Borchers. C. A femur from Ripley. All specimens were found in the 50µm sieve size. Each white line indicates 5mm.

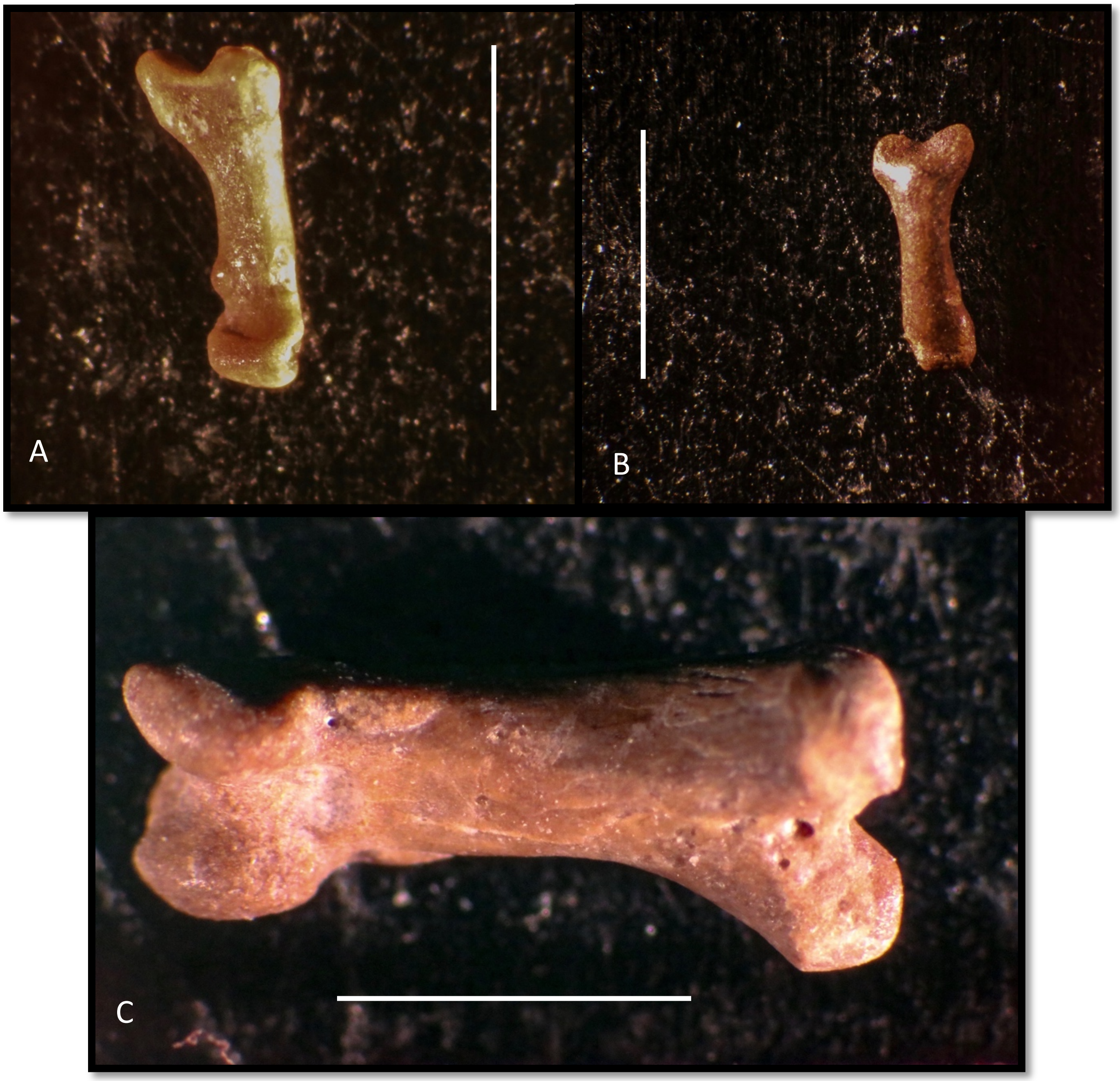

Figure 13: A. A humerus from the locality of Ripley. B. A humerus from the locality of Ripley. C. A humerus from the locality of Borchers. Each white line indicates 3mm. All specimens come from the 50μm sieve size.

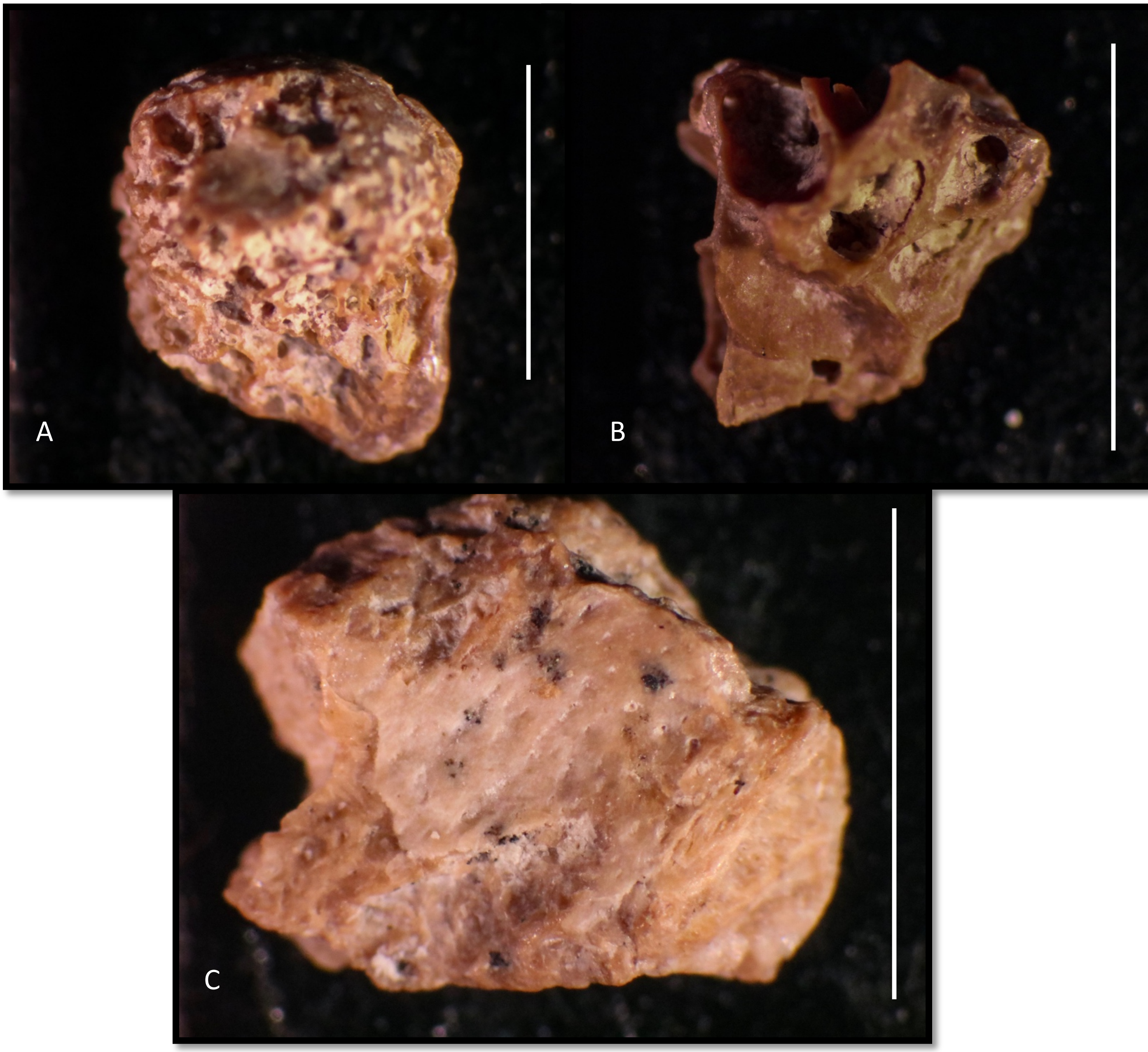

Figure 14: A,B and C are all bone pebbles from the locality of Borchers. Each white line indicates 4mm.

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APPENDIX

Table 1: Raw element group and abundance data.

Locality	Sieve Size	Bone Pebbles	Femora	Scapula	Humerus	Mandible	Hip Ball	Teeth	Radius/Ulna	Pelvis	Vertebrae	Unidentifiable
Borchers	50um	29	12	0	14	1	2	123	0	2	2	2914
Borchers	2mm	10	1	0	0	0	0	1	0	1	0	67
Borchers	Element Total	39	13	0	14	1	2	124	0	3	2	2981
Total material sieved(kg)	1.16915											
Abundance/kg	Total	33.4	11.1	0	12.0	0.9	1.7	106.1	0	2.6	1.7	2549.7
Abundance/kg	2mm	8.6	0.9	0.0	0.0	0.0	0.0	0.9	0.0	0.9	0.0	57.3
Abundance/kg	50um	24.8	10.3	0	12.0	0.9	1.7	105.2	0	1.7	1.7	2492.4
Ripley	50um	17	7	1	4	1	0	57	1	0	1	930
Ripley	2mm	0	0	0	0	0	0	1	0	0	0	292
Ripley	Element Total	17	7	1	4	1	0	58	1	0	1	1222
Total material sieved(kg)	0.33172											
Abundance/kg	Total	51.2	21.1	3.0	12.1	3.0	0.0	174.8	3.0	0.0	3.0	3683.8
Abundance/kg	2mm	0	0	0	0	0	0	3	0	0	0	880.3
Abundance/kg	50um	51.2	21.1	3	12.1	3	0	171.8	3	0	3	2803.6
Cudahy	50um	2	0	0	1	0	1	9	2	1	0	214
Cudahy	2mm	0	0	0	0	0	0	0	0	0	1	0
Cudahy	Element Total	2	0	0	1	0	1	9	2	1	1	214
Total material sieved(kg)	0.42904											
Abundance/kg	Total	4.7	0	0	2.3	0	2.3	21.0	4.7	2.3	2.3	498.8
Abundance/kg	2mm	0	0	0	0	0	0	0	0	0	2.3	0
Abundance/kg	50um	4.7	0	0	2.3	0	2.3	21.0	4.7	2.3	0	498.8

Table 2: Raw weight data for calculating the NISP vs Weight graphs.

Borchers	NISP	Weight (g)		Borchers	Weight Proportion	NISP Proportion
2	80	3.17685		2mm	0.4367530545	0.02516514627
50	3099	4.09694		50um	0.5632469455	0.9748348537
Total	3179	7.27379				
Ripley	NISP	Weight (g)				
2mm	293	0.50223		Ripley	Weight Proportion	NISP Proportion
50um	1019	1.01297		2mm	0.3314611932	0.2233231707
Total	1312	1.5152		50um	0.6685388068	0.6685388068
Cudahy	NISP	Weight (g)				
2	1	0.00404		Cudahy	Weight Proportion	NISP Proportion
50	230	0.107		2mm	0.0363832853	0.004329004329
Total	231	0.11104		50um	0.9636167147	0.9956709957