

## Chapter 4

### *Paleoenvironmental significance of a full-glacial biota from the Latch*

#### *Valley, Trempealeau County, Wisconsin*

#### **ABSTRACT**

Gastropods are valuable, yet underutilized fossil proxies in the Driftless Area of the Upper Mississippi Valley (UMV) region. Colluvial and alluvial sediments from two sites (Hwy-JJ and Kulas Quarry) within the Latch Valley, Trempealeau Co., Wisconsin, contain abundant terrestrial gastropod fossils and vertebrate remains. Identifiable dental elements from small rodents include those of *Dicrostonyx* sp. a tundra-dwelling lemming. The gastropod fauna is complex, and includes taxa with modern boreal-cordilleran affinities such as *Discus shimaki*, *Columella columella alticola*, and *Vertigo modesta*, which are not found in the region today. Other gastropods include species that prefer open, xeric habitats, and those that inhabit deciduous forests such as *Hendersonia occulta*. *H. occulta* is a locally endangered snail that inhabits the UMV today. Succineid gastropod shells yielded radiocarbon ages between 16,100 and 18,000 RCYBP and indicate the fauna is full-glacial in age. The differences in species richness observed between sites and samples can be largely attributed to the total number of shells within each sample. Samples with high numbers of shells per kilogram of matrix were the richest, while samples with few shells yielded few species. The rank order of abundance was nearly identical for all samples; the primary differences were between upland and floodplain samples, the former yielded a greater abundance of *Pupilla muscorum*, while the latter contained a larger number of rare species. This similarity in gastropod composition suggests a community that was largely unchanged throughout this time interval. The gastropod fauna from the Latch Valley is the northernmost full-glacial fauna in the UMV, located less than 100 km from the terminal moraine of the Chippewa Lobe of the Laurentide Ice Sheet. The age range of this deposit appears to coincide with a minor retreat of the Chippewa Lobe between the Stanley and Late Chippewa advances. These results generally agree with the ecological interpretations from other regional fossil localities of a tundra-like environment, however the presence of *H. occulta* at this site suggests the presence of minor amounts of deciduous vegetation, perhaps within topographically controlled microhabitats. It is likely that the Driftless Area of the UMV served as an important refuge for temperate species during the full-glacial period, much as it serves as an important refuge for northern species today.

## 4.1 INTRODUCTION

Reconstructing full-glacial (ca. 24,000 to 18,000 cal yr BP) environments near the Laurentide Ice Sheet is challenging. There are no surviving mid-latitude continental glaciers to serve as analogs, and much of the proxy evidence is ambiguous or contradictory. Geomorphic features indicate widespread permafrost, while fossil proxies consist of both tundra and boreal-hardwood forest taxa. The late Pleistocene sediments exposed within the Latch Valley, Trempealeau County, Wisconsin (Figure 4.1) contain abundant terrestrial gastropod remains. These fossils represent an unprecedented opportunity to examine full-glacial biotic communities preserved less than 100 km from the Chippewa Moraine, a major terminal moraine in north-central Wisconsin.

Gastropod fossils are valuable paleoecological proxies, particularly in the Driftless Area of the Upper Mississippi Valley (UMV). Their shells survive in a wide range of sediments that do not easily preserve other fossils such as pollen. Their shells can be radiocarbon dated, which provides an age of the fauna itself, not the surrounding sediment. Their limited range of movement makes them valuable indicators of local climate (e.g. Simmons, 1996; Rossignol et al., 2004). In addition, the small tributary drainage basins in the Driftless Area reduce the likelihood of long-distance transport of remains. Thus, uncertainties regarding provenance or differential destruction of gastropod remains as a result of sediment transport are unlikely complicating factors for these fossils (e.g. La Rocque, 1970; Miller and Bajc, 1990; Goodfriend, 1992).

The goal of this study is to use terrestrial gastropod fossils from two sites, Hwy-JJ and Kulas Quarry, within the Latch Valley to characterize the local full-glacial paleoenvironment. These gastropod assemblages contain an abundant and relatively

diverse fauna that provides valuable information regarding environmental conditions.

The differences and similarities between samples from these two sites in terms of their depositional setting and preserved shells will provide a context from which to draw environmental interpretations. Fossiliferous sediments within the Latch Valley offer a glimpse of an extreme landscape: the northernmost full-glacial fossil locality in the Midwest, less than 100 km from the maximum extent of the Laurentide Ice Sheet (Kuchta et al., 2007b).

## **4.2 BACKGROUND**

### *4.2.1 Study Location*

The Latch Valley basin in southwestern Trempealeau County, Wisconsin, contains a small, unnamed tributary creek of the Trempealeau River (Figure 4.2). This ca. 10 km<sup>2</sup> basin is located 10 km north of the Mississippi River in the Driftless Area of western Wisconsin (Mickelson et al., 1983; Syverson and Colgan, 2004). The basin's topography is similar to that of the Driftless Area in general, with deep, steeply sloping river valleys incised into Paleozoic bedrock.

Kulas Quarry and Hwy-JJ represent two distinct depositional environments. Hwy-JJ (Figure 4.3) is a 3m tall exposure of colluvial silt along the lower footslopes of the Latch Valley. The exposure at Hwy-JJ lies several meters above the top of Kulas Quarry; the concave-up surface can be traced downslope to the late Pleistocene terrace surface forming the top of the Kulas Quarry exposure. Kulas Quarry is a 21-meter wide, 7-meter tall exposure of alluvial valley fill (Figure 4.4).

#### *4.2.2 Regional Geology*

The Driftless Area is so named, because it lacks evidence of glacial modification; it likely remained ice-free throughout most or all of the Pleistocene (Chamberlin and Salisbury, 1885; Syverson and Colgan, 2004). The presence of heavily weathered tills to the North in Dunn and Pepin Counties suggests part of this region may have been covered during much earlier Pleistocene glacial advances (Syverson and Colgan, 2004). However, ice did not extend into Trempealeau County during the last full glacial period (ca. 24,000-18,000 cal yr BP; Figure 4.1).

The last advance of the Chippewa Lobe of the Laurentide Ice Sheet is generally poorly constrained, but is marked by several terminal moraines. The Stanley moraine is the oldest, and represents the southernmost extent of the Chippewa Lobe into Chippewa County (Syverson, 2007). To the west, geomorphic features from the Late Chippewa Phase obscure it. Syverson (2007) suggested that the Stanley moraine was formed approximately 24,000 cal yr BP, whereas the Late Chippewa Phase occurred between 18,000 and 15,000 cal yr BP.

The unconsolidated late Pleistocene sediments that overlie the bedrock within the Latch Valley Creek basin are similar to others found elsewhere in the Driftless Area. Throughout the region, loess creates a thin mantle on the gently sloping ridgetops, while the steep hillslopes are often covered with colluvium that grades into alluvial valley fill. These processes appear to have been much more active during the last glacial maximum (Mason and Knox, 1997).

Thick colluvium covers many of the steep valley sides throughout the Driftless Area, indicating active mass wasting along slopes. Based on radiocarbon and

stratigraphic analysis, colluvial deposition was most active from 25,000 to 14,000 cal. yr BP as a result of climatically induced mass wasting, probably dominated by solifluction (Mason, 1995; Mason and Knox, 1997). This colluvium consists of reworked eolian silt and clay and often contains large clasts of weathered bedrock. Along the lower footslopes in the Driftless Area, colluvial deposits often interfinger with alluvial sediments within the river valleys (Mason, 1995; Mason and Knox, 1997; Bettis et al., 2008).

Alluvial aggradation within the Upper Mississippi Valley began by 25,000 cal. yr BP and ended before 13,000 cal. yr BP (Flock, 1983; Knox, 1996). Much of the alluvial sediment is thought to be glaciofluvially derived (Flock, 1983; Knox, 1996). However, in river valleys not directly affected by glacial melt water, much of the valley fill consists of weathered bedrock and reworked silt and clay (Mason, 1995; see also Chapter 2).

Along the Upper Mississippi River Valley, the highest terrace surface not covered by loess is referred to as the Savanna Terrace (Flock, 1983; Knox, 1996). Terraces in tributaries of the Mississippi River are generally correlative with this surface (Mason, 1994; Knox, 1996). At the confluence of the Trempealeau and Mississippi Rivers, the Savanna Terrace is approximately 720 feet above sea level, whereas the highest terrace surface present in the Latch Valley is approximately 740 feet above sea level. Remnant terraces can be traced from the Latch Valley along the Trempealeau River downstream to the Savanna Terrace. Therefore, I consider the high terrace surface in the Latch Valley Creek basin as part of the Savanna Terrace.

Gently south-southwest dipping Cambrian and Ordovician bedrock underlies the entire basin (Runkel, 1994). The Cambrian section consists of orange, coarse sandstone

arenite of the upper Wonewoc Formation (Ironton Member), exposed along the mouth of the Latch Valley (Figure 4.2). At the mouth of the Latch Valley, the late Pleistocene sediments directly overlie the Wonewoc Formation and contain abundant weathered bedrock clasts. The Wonewoc is overlain by silty, glauconitic sandstone and shale of the Tunnel City (=Lone Rock) Formation; a large, ten-meter exposure lies approximately 800 m southeast of the field area, along Kulas Road. The remaining Cambrian section (Trempealeau Group) lies covered. At the head of the valley, however, Ordovician dolomite of the Oneota Formation (Prairie du Chein Group) crops out as a resistant bluff former.

#### *4.2.3 Paleoenvironmental Background*

Geomorphic evidence for the full-glacial climate in the Driftless Area includes periglacial features such as ice-wedge casts and patterned ground (Clayton et al., 2001). Permafrost development requires a mean annual temperature of several degrees below freezing and is generally associated with the absence of covered, forest habitats (Washburn, 1980; Pewe, 1983). Cryoturbated soils, talus slopes, rock glaciers, and colluvial stratigraphy show the influence of permafrost on the southwestern Wisconsin landscape from about 30,000 until about 16,000 cal yr BP (Mason and Knox, 1997; Clayton et al., 2001).

The porous, calcareous sediments within the Driftless Area often lack organic material such as pollen and plant macrofossils; although they can be preserved where the water table was high enough to prevent their degradation (e.g. Birks, 1976). Other important regional fossil localities include Conklin Quarry (Baker et al., 1986) and

Elkader (Woodman et al., 1996) in Iowa, and Jore-1 in Minnesota (Baker et al., 1999; Figure 4.1). These sites contain remains of tundra and subalpine vegetation such as *Dryas integrifolia* and *Salix* sp. (Baker et al., 1986; Baker et al., 1999). Elkader and Conklin Quarry contained a diverse assemblage of rodents, beetles, and gastropods with Cordilleran and Boreal/Arctic distributions (Baker et al., 1986; Woodman et al., 1996).

## 4.3 METHODS

### 4.3.1 Field Methods

The locations discussed in this chapter were discovered during a field survey in 2006. Sites were located by driving systematically along highways while looking for exposures of late Pleistocene sediments that contained abundant gastropod fossils. I selected the Latch Valley Creek basin for more detailed analysis because of the close association of different sedimentary facies, size of exposures, and abundance of gastropod fossils.

At each site, I described a generalized stratigraphic column to illustrate the vertical relationships between associated sedimentary facies. In addition, I took photographs to show the horizontal facies relationships and associations of prominent sedimentary structures. Some photographs were assembled into composite photographs using the “photomerge” function in Adobe Photoshop ®.

I followed facies designations as discussed by Miall (1977). These designations have been utilized for much older lithofacies, but can also be applied to Quaternary sediments (e.g. Mason, 1995). My strategy was to differentiate between sand-dominated and silt-dominated sediments, as these were relatively easy to distinguish in the field.

Sample locations and important sedimentological relationships are noted on the site photographs. Samples were limited to 30-cm intervals of individual facies and consisted of at least one 4-Liter plastic bag worth of material. I focused my sampling effort upon horizons that contained abundant gastropod fossils.

#### *4.3.2 Radiocarbon Analysis*

I obtained radiocarbon dates from succineid gastropod shells. Two samples were analyzed by Beta Analytic, Inc (BETA) and an additional five samples were analyzed at Arizona AMS lab (AA; Rech et al., in prep). Succineid gastropods are abundant in many late Pleistocene deposits, and are often the only organic material available for radiocarbon dating (Pigati et al., 2004). There are two primary sources of error in radiocarbon dates obtained from gastropod shells. The first is recrystallization of aragonite to calcite, which can yield younger-than-actual ages. This error can be avoided by using shells without visibly recrystallized, “chalky” shell material and by pre-etching the sample in acid before analysis (Goodfriend and Stipp, 1983; Goodfriend and Hood, 1983). The second problem is harder to detect and occurs when the snail ingests  $^{14}\text{C}$ -depleted carbonate, which can yield anomalously old radiocarbon ages (Goodfriend and Hood, 1983; Goodfriend and Stipp, 1983, Pigati et al., 2004). Succineid gastropods do not appear to ingest these “old” carbonates (Pigati et al., 2004; J. Rech and J. Nekola personal communication, 2007). Radiocarbon ages were converted to calendar years using the “CalPal” online calibration software (Danzeglocke et al., 2009).

#### *4.3.3 Lab Methods*



I followed the standard processing and shell extraction methods described by La Rocque (1970), Frest and Dickson (1986), and Nekola (2004). Each sample was dried and weighed, then soaked in water and washed through a standard series of ATSM sieves (smallest mesh = 0.425mm) and then all identifiable shells and fragments were picked from the remaining residuum. Shells were identified to species (or subspecies) using Pilsbry (1948), Burch (1962), Barthel and Nekola (2000), and reference collections from the University of Iowa Natural History Museum. Jeffrey Nekola of the University of New Mexico verified specimen identification, and nomenclature follows Hubricht (1985) with additions by Nekola (2004). Richard Slaughter (UW Geology Museum) identified the rodent material. All specimens are catalogued and repositied at the University of Wisconsin Geology Museum under the catalog number UW1987.

The total number of individuals reported from a sample is the sum of whole shells and the most abundant portion of broken fragments, which represents a minimum number of individuals (MNI). Succineid shells smaller than 2 mm and juvenile shells and fragments lacking diagnostic characters were not counted. Rather than using a mathematical transformation, I determined that establishing a cutoff point of 1000 individuals for any species within a sample provided a reasonable compromise between determining the relative species' frequency and problems associated with over-counting juveniles and broken shells.

#### *4.3.4 Statistical Methods*

To evaluate whether or not samples from Kulas Quarry and Hwy-JJ represent distinct groups, I performed Multi-Response Permutation Procedure (MRPP) tests using

the PC-ORD 5.0 software package (McCune and Mefford, 2006). MRPP is a non-parametric procedure that tests the null-hypothesis that no difference exists between two or more groups of sample units. MRPP has distinct advantages over other multivariate methods such as Hotelling's  $T^2$  and Discriminant Analysis in that it does not require assumptions of the data such as multivariate normality or homogeneity of variance (Mielke et al., 1981; McCune and Grace, 2002). This test is commonly used in ecological analyses and has tremendous potential in geological investigations (e.g. Orlowski et al., 1993; Bonuso and Bottjer, 2006).

MRPP compares the observed, average within-group distances of a data set (observed delta) to an expected value, the average distances for all possible partitions of the data set (expected delta). For example, if two a-priori groups within a data set are very different, the average of the within-group dissimilarities will be less than the average of the dissimilarities between randomly assigned groups of the entire data set (Mielke et al., 1981; McCune and Grace, 2002). The reported p-value represents the proportion of the expected-delta that is less than the observed-delta. In addition, MRPP reports a "chance-corrected agreement statistic"  $A$  [ $A=1-(\text{obs-delta}/\text{exp-delta})$ ], which describes within-group homogeneity compared to the random expectation (McCune and Grace, 2002). If all items are identical within groups, the observed minus expected delta is zero, and  $A=1$ . If homogeneity within groups equals the expectation by chance,  $A=0$ . If within-group agreement is less than that expected by chance,  $A<0$ . For ecological data sets, values of  $A$  are often less than 0.1 (McCune and Grace, 2002).

I performed seven MRPPs using the Euclidean distance measure on the Latch Valley terrestrial gastropod data. Because species frequency can be autocorrelative (an

increase in one species' frequency necessitates the decrease in another) and is likely dependent on depositional factors (e.g. hydrodynamic sorting), I performed MRPP on the presence/absence data matrix. To meet the assumptions of independence, only samples obtained from discrete stratigraphic horizons containing at least five taxa were included. In addition, one species, *Discus whitneyi*, was represented by a single shell (out of nearly 10,000 counted) and was omitted from the analysis to avoid over-estimating the differences between samples.

The first set of comparisons tested for difference in species frequency in samples from separate facies (tabular, trough cross-bedded sands, and silt). The second test looked for differences between different stratigraphic age groups (lower Kulas, upper Kulas, Hwy-JJ). I also performed a test on the samples grouped by site (Kulas Quarry, Hwy-JJ).

## 4.4 RESULTS AND DISCUSSION

### 4.4.1 Data Summary

The data consist of a total of 29 samples, 21 from Kulas Quarry and 8 from Hwy-JJ, which yielded a total of 9,682 individuals from 10 terrestrial gastropod taxa with largely Cordilleran-Boreal habitat preferences (Tables 4.1, 4.2). Kulas Quarry samples were collected from planar-bedded sands (Sp; n=8), trough cross-bedded sands (St; n=11) and laminated/convolute silt (Fl, Fc; n=2). All 8 Hwy-JJ samples were laminated, colluvial silt. Three samples from Hwy-JJ (JJ06, 07, 08) were bulk samples not confined to one horizon.

Radiocarbon results obtained from these sites are in stratigraphic order, and multiple dates from individual horizons generally overlapped within one-sigma. These

radiocarbon results indicate that both Kulas Quarry and Hwy-JJ are “full-glacial” in age, but younger than the Jore-1 or Elkader faunas (Table 4.3; Figures 4.3, 4.4).

#### 4.4.2 Site and sample group comparison

Richness correlated strongly with the total Shells/kg matrix for all samples (Spearman  $\rho=0.838$ ,  $p<<0.001$ ; Figure 4.5). Sample size (Sample Weight) also correlated with both Richness ( $\rho=0.575$ ,  $p=0.001$ ; Figure 4.6A) and Shells/kg matrix ( $\rho=0.433$ ,  $p=0.0199$ ; Figure 4.6B). However, this correlation was likely due to sampling bias: samples from horizons without visible shells were collected to obtain more complete coverage, but were generally smaller than samples from the most fossiliferous horizons. Excluding samples with five or fewer shells reduced the correlation of sample size to Richness and Shells/kg ( $\rho=0.412$ ,  $p=0.033$ ;  $\rho=0.232$ ,  $p=0.25$  respectively).

Colluvial silt samples from Hwy-JJ showed the little variation in gastropod richness and abundance with stratigraphic position (Figure 4.7A). At Kulas Quarry, both richness and abundance generally increased with stratigraphic position (=relative age; Figure 4.7B). The increase in richness at Kulas Quarry was likely due to changes in sedimentation rather than temporal variation. Trough cross-bedded facies were generally the richest in terms of gastropod species diversity and yielded the most abundant collections (Shells/kg of matrix). Richness and abundance within samples of tabular cross-bedded sands were the most variable, containing as few as two and as many as nine species, while the silt samples from Kulas Quarry contained only one species (*Catinella* cf. *gelida*).

The six most abundant species (*Catinella* cf. *gelida*, *Columella columella alticola*, *Discus shimeki*, *Vertigo modesta modesta*, and *Vertigo oughtoni*) were found at both sites (Table 4.1; Figure 4.8). Shells of *Catinella* cf. *gelida* were most abundant, and accounted for more than 56% of all shells counted. *Columella alticola*, *Vertigo modesta modesta*, *Discus shimeki*, slug plates, and *Pupilla muscorum* accounted for another 41%. *Pupilla muscorum* accounted for nearly 18% of the total shells in samples from Hwy-JJ, but only 3% at Kulas Quarry. *Vertigo oughtoni* was present, but rare, in most samples from Kulas Quarry, but it was found in only two samples from Hwy-JJ. Samples from Kulas Quarry included rare shells from species such as *Hendersonia occulta*, *Vertigo modesta parietalis* and *Discus whitneyi*; these taxa were not found in samples from Hwy-JJ (Table 4.1). In addition, aquatic taxa *Fossaria* sp. and *Helisoma* sp. were found in the upper beds at Kulas Quarry, but not in lower Kulas Quarry or any Hwy-JJ samples.

The rank abundance of taxa from Hwy-JJ was very similar to all sample groups from Kulas Quarry (Figure 4.8). The rank correlation of samples from Hwy-JJ was strongest with the pooled Kulas Quarry, Kulas Quarry upper bed, and Kulas Quarry “St” facies sample groups, but slightly lower for samples from the Kulas Quarry lower bed and Kulas Quarry “Sp” facies groups. The rank abundance of taxa within Kulas Quarry sub-groups were almost identical, with only small differences in the frequencies of individual taxa, including the presence of a single shell of *Discus whitneyi* (Figure 4.8).

Vertebrate remains consisted of heavily degraded, disarticulated mammalian dental and postcranial elements and occasional fish scales (Table 4.4). The most common identifiable elements were molars of *Dicrostonyx* sp. (collared lemming), a tundra-

obligate rodent. Molars from *Microtus* sp. that resembled both *M. miurus* and *M.*

*xanthognathus* were found, but these were too degraded to confidently assign to species.

In general, the fauna from these sites are characteristic of tundra and boreal forest habitats. The small rodents and the terrestrial gastropods no longer inhabit the UMV; they have Cordilleran-Boreal and Tundra modern distributions (Table 4.2; Figure 4.9A, 4.9B). *Dicrostonyx* sp. is found exclusively on the North American tundra, while the gastropods are more complex, with Cordilleran-Boreal and Eastern Deciduous Forest taxa. The low abundance of aquatic gastropods suggests a significant terrestrial sediment input. The fish scales and aquatic gastropods that were found, however, do suggest the presence of small pools and running water during warmer seasons. The aquatic gastropods may have been preferentially removed, swept away by channel streams.

*Catinella* cf. *gelida* and *H. occulta* both occur as relict populations in the Paleozoic Plateau region of the UMV, although Nekola (pers. comm. 2007) reported that the shell morphology of tundra populations of *Oxyloma groenlandica* is identical to that of fossil *C. gelida* and previous identifications of *C. gelida* in the Midwest (e.g. Frest, 1984; Baker et al., 1986) may be incorrect. However, accurate identification of succineids requires examination of soft tissues (i.e. genitalia). For consistency, I have chosen to follow the identification of earlier studies (e.g. Woodman et al., 1996) for this taxon, based on the overall size and aperture of the shell.

The recognition of *H. occulta* at Kulas Quarry is noteworthy because it was previously reported absent (Kuchta et al., 2007a). However, additional sampling and subsequent analysis of small fragments revealed its presence throughout the Kulas Quarry section. The co-occurrence of these taxa appears to constitute a non-analog fauna

(e.g. Graham and Mead, 1987), as they do not inhabit the same geographic ranges today (Figure 4.9A). Although not as diverse, the Latch Valley fauna is similar to that reported from Elkader in Iowa, which was interpreted as a sub-arctic climate with topographically controlled microhabitats that supported isolated patches of deciduous forest vegetation (Woodman et al., 1996). This deciduous vegetation was probably not very large; Baker et al. (1999) reported birch and willow macrofossils from a full-glacial site in southeastern Minnesota, both of these trees have cold-adapted dwarf forms. Alternately, fragments of *H. occulta* may be reworked from older sediments, suggesting that this species had been extirpated during the last full-glacial period and has since re-established its range. Because of the poor preservation and its occurrence throughout the Kulas Quarry section (to a depth of more than 5 m), it is unlikely that these shells burrowed into the deposit after deposition.

#### 4.4.3 MRPP

MRPP results indicate that the distances between sample groups were greatest between Kulas Quarry samples and those from Hwy-JJ (Table 4.5). The distances between samples from Hwy-JJ and *a priori* sample groups from Kulas Quarry (all, upper/lower beds, St/Sp facies) were significant at  $\alpha=0.05$ . Distances between Kulas Quarry sample groups (Sp vs. St facies and lower vs. upper bed) were not significant at  $\alpha=0.10$ . In addition, the within-group heterogeneity for Kulas Quarry samples grouped by facies was greater than the random expectation ( $A = -0.0101$ ; Table 4.5).

MRPP appears to be a useful tool in comparing fossil assemblages, especially as many paleoecological data sets do not meet assumptions of parametric tests. In this

analysis, the measured distances between groups based on presence-absence were significant when comparing alluvial samples from Kulas Quarry to the colluvial silt samples from Hwy-JJ, but the samples from within Kulas Quarry were not significantly different, regardless of the grouping criterion (Table 4.5). The difference between Kulas Quarry and Hwy-JJ may be due to the presence of rare taxa in Kulas Quarry samples compared to those from Hwy-JJ. Presence absence data tend to increase the influence of rare species and de-emphasize the effect of common species compared to frequency-based measures (e.g. Hill, 1973). Thus, the rare species present in most samples from Kulas Quarry (but absent at Hwy-JJ) were much more likely to affect the multivariate distances between the two sites than changes in the abundance of species between sites. For example, *Hendersonia occulta* represented less than 1% of the total shells counted and was not found at Hwy-JJ, but was present as at least one individual in most samples from Kulas Quarry. *Pupilla muscorum*, however, is much more abundant in samples from Hwy-JJ, but it is present at both sites (Table 4.1; Figure 4.8).

## 4.5 CONCLUSIONS

In general, the Latch Valley fauna suggests the presence of a tundra and boreal forest habitat in west-central Wisconsin between 21,700 and 19,200 cal yr BP. The terrestrial gastropod fauna from these study sites is somewhat less rich than other full-glacial gastropod sites, but still contains species with wide-ranging habitat preferences from open, xeric to shaded, mesic environments – including species that appear to feed exclusively on deciduous leaf litter (e.g. *Hendersonia occulta*; van der Schalie, 1939). These findings agree with the interpretations by other such as Baker et al. (1986) and



Woodman et al. (1996) who interpreted a dominantly tundra-forest habitat with topographically controlled microhabitats that supported the presence of deciduous vegetation in northeast Iowa during the last full-glacial period.

While samples from Kulas Quarry were different compared to samples from Hwy-JJ, there did not appear to be any monotonic change in the composition of the gastropod fauna within the Latch Valley. Differences in the observed species composition within samples appear to be a result of sample size, and depositional environment (e.g. large samples vs. small, colluvial hillslopes vs. trough cross-bedded facies). The similarity of all sample groups within Kulas Quarry suggests little or no change in the gastropod community at the time of deposition. In addition, there may have been some difference in the gastropod species assemblage located along hillslopes as compared to the floodplain. The high abundance of *Pupilla muscorum* in samples from Hwy-JJ suggests upslope conditions may have been drier and more open compared to lower elevations. It is possible that the large-scale climatic changes following the last glacial maximum did not result in observable changes to the full-glacial gastropod species assemblage until after 19,000 cal yr BP. Compared to the Elkader gastropod fauna, the Latch Valley fauna is about 2,000 years younger, but less diverse (Table 4.1; Woodman et al., 1996). It is possible that the fauna described here is also transitional, with gastropods migrating into a previously inhospitable periglacial climate.

*Vertigo oughtoni* is often described as a tundra-obligate species and can be found in muskeg and open, mesic bogs in Nunavut, northern Ontario, Manitoba, Newfoundland, and Baffin Island in Canada (Pilsbry, 1948; Oughton, 1948; Johnson, 1965; Waldén, 1966; Figure 4.9A). As a late Pleistocene fossil, it is often found at sites close to the ice

margin (Frest and Dickson, 1986). In eastern Iowa, it is present at both Conklin Quarry and Elkader (Baker et al., 1986; Woodman et al., 1996). It is also a common fossil from full-glacial sites in southwestern Ohio, along sites near the limit of late Wisconsin ice (LaRocque and Forsythe, 1967; Dell, 1991). While the presence of *V. oughtoni* is considered to indicate tundra, the presence of boreal forest gastropods in greater numbers within the same deposits implies a more complex correlation between a gastropod's modern and fossil ranges. Given the constricted, full-glacial climatic gradient that was present in the Upper Mississippi Valley (e.g. Schwert et al., 1997), competitive exclusion or other intraspecific interactions may have forced snails to occupy different habitats during the late Pleistocene.

Fragmentary remains of *Hendersonia occulta* were recorded from the majority of the samples collected from Kulas Quarry. This species is considered endangered within the state of Wisconsin today. It is found in the UMRV region, the Niagaran Escarpment of eastern Wisconsin and Michigan's Upper Peninsula, and the west central Appalachians (Van Der Schalie, 1939; Hubricht, 1985). *Hendersonia occulta* is a calciphile that requires moist, well-shaded habitats with sufficient leaf litter (Van Der Schalie, 1939; Pilsbry, 1948; Nekola, 2003). As a Pleistocene fossil, *H. occulta* occurs from western as Nebraska through eastern Ohio and southward along the Lower Mississippi River Valley to the Gulf of Mexico (Leonard, 1952; Hubricht, 1985).

Together, Kulas Quarry and Hwy-JJ represent the northernmost full-glacial fauna in the Midwest. The gastropod fauna (in particular, *Hendersonia occulta* and *Discus whitneyi*) suggests the presence of, at minimum, isolated deciduous vegetation in the northern Driftless Area soon after the last Glacial Maximum. Several species such as

*Discus shimeki*, *Columella columella alticola*, and *Vertigo modesta modesta* have mixed habitat preferences and are often found living within the leaf litter along forest edges (Pilsbry, 1948; Leonard, 1952). In eastern Iowa, Baker et al. (1986) and Woodman et al. (1996) interpreted the abundance of these taxa as indicative of coniferous-hardwood vegetation in the region during the full-glacial period.

The consistency of the gastropod fauna suggests the gastropod community was relatively stable and that a non-analog, mollusk fauna was established before 21,700 cal yr BP and remained unchanged through 19,200 cal yr BP. The dates reported for the Latch Valley fauna fit between the estimated dates for the glacial advances during the Stanley and Late Chippewa phases. It may be that the deposition at Kulas Quarry is connected to these glacial phases. However, a more detailed chronology would be needed. Alternately, the apparent stability of the gastropod fossil assemblage may indicate that the conditions necessary for the last advance of the Chippewa Lobe did not significantly impact the gastropod community. In addition, the remains of *Hendersonia occulta* at Kulas Quarry indicate that this species has been in the Driftless Area since the full-glacial period. Alternately, this species inhabited the region during the relatively warmer pre-glacial environment, and re-established itself in the UMV after the full-glacial period. It is interesting to note that living records of this species do not exist for Trempealeau County. This report expands the known Pleistocene range for this state-endangered species, and has implications for future conservation efforts.

Collectively, the gastropods preserved within the Latch Valley suggest cold tundra and tundra-forest environments similar to the tundra-forest boundary in Canada today characterized western Wisconsin at the end of the full-glacial period. The

deciduous forest elements were likely small, scrub-like plants similar to those found in subalpine Krummholz today (e.g. Baker et al., 1986). The presence of temperate species in close proximity to the glacial margin during the end of the full-glacial period suggests the Driftless Area served as a refuge for temperate species then, much as it currently harbors many northern species today.

#### **4.6 ACKNOWLEDGEMENTS**

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Table 4.1. Frequency and occurrence of gastropods within samples from Kulas Quarry and Hwy-JJ.

Kulas Quarry

Facies	Sample	Sample Wt (g)	Fossaria sp.	Helicoma sp.	Catinella cf. gelida	Columella columella alticola	Pupilla muscorum	Vertigo modesta modesta	Vertigo modesta parietalis	Vertigo alpestris ougtoni	Discus whitneyi	Discus shimeki	Hendersonia occulta	slug plates	Total Shells <sup>b</sup>	Richness	Shells/kg <sup>b</sup>	Stratigraphic Rank	
Fl	KQ21	2731.5				100.0										1	1	0.37	21
Sp	KQ20	3564.7	+	+		56.5	14.2	3.3	11.1	0.2	2.9		11.0	0.7	0.1	1771	9	520.94	20
St	KQ19	4582.2	+			59.1	11.5	1.9	15.2	0.3	8.3		2.9	0.5	0.3	374	9	82.71	19
St	KQ18	4646.5	+			72.4	4.8	0.3	11.8	0.3	0.8		4.0	16.3	0.5	526	9	117.08	18
St	KQ17	9039.4	+	+		65.3	5.8	0.6	7.1		1.9		4.5	14.3	0.2	467	8	52.77	17
St	KQ16	5031.1				75.1	5.2	0.3	9.0		0.6		2.9	6.4	0.6	346	8	68.77	16
St	KQ15	8623.1	+			50.5	18.6	3.7	12.0	0.2	1.7	0.03	10.9	2.2	0.1	3959	10	472.92	15
St	KQ14	5124.3	+			50.1	14.1	4.1	7.6		3.0		13.8	7.3		369	7	74.35	14
St	KQ13	4216.4	+			73.4	5.2	1.6	7.1		2.0		9.1	1.6		252	7	60.24	13
St	KQ12	4902.1				62.6	3.0		12.1		3.0		13.1	3.0	3.0	99	7	20.20	12
Fc	KQ11	1800				100.0										5	1	2.78	11
St	KQ10	5382.6	+			67.3	5.0		3.0				8.9	12.9	3.0	101	6	19.14	10
St	KQ09	4739.6				54.4	13.9	3.9	12.6		2.6		9.4	2.9	0.3	309	8	65.20	9
St	KQ08	4501.1				64.7	12.1	2.4	6.8		3.4		5.8	4.3	0.5	207	8	45.99	8
Sp	KQ07	4250.1				50.0	14.3	8.2	10.2	1.0	3.1		8.2	4.1	1.0	98	9	23.06	7
Sp	KQ06	4567.9				62.3	6.6	2.8	7.5		1.9		15.1	1.9	1.9	106	8	23.21	6
Sp	KQ05	4000				38.5	19.2	7.7	3.8		3.8		26.9			26	6	6.50	5
Sp	KQ04	3728.2				64.3	14.3						7.1	14.3		14	4	3.76	4
Sp	KQ03	8457.3				57.8	8.9	8.9	13.3				4.4	2.2	4.4	45	7	5.32	3
Sp	KQ02	2260							25.0					75.0		4	2	1.77	2
Sp	KQ01	1730				61.5		30.8	7.7							13	3	7.51	1
Hwy-JJ																			
Fl	JJ05	3870 <sup>a</sup>				54.1	9.9	4.5	10.8		13.5		1.8	5.4		111	7	28.68	5
Fl	JJ04	4126.7				66.7	2.7	2.7	21.3				4.0	2.7		75	6	18.17	4
Fl	JJ03	3200.1				54.3	4.3	35.7	1.4				4.3			70	5	21.87	3
Fl	JJ02	4170.9				78.6	2.4	4.8	11.9					2.4		42	5	10.07	2
Fl	JJ01	2653.1				38.1	7.1	28.6	4.8				14.3	7.1		42	6	15.83	1
Fl	JJ06	5700 <sup>a</sup>				44.4	5.6	22.2	9.3		13.0		1.9	3.7		54	7	9.47	bulk
Fl	JJ07	4683.4				34.7	16.9	28.0	7.6				5.1	7.6		118	6	25.20	bulk
Fl	JJ08	5015.1				48.7	3.8	16.7	9.0				10.3	11.5		78	6	15.55	bulk

Notes: <sup>a</sup>Sample weight estimated by sample volume; "Total Shells" does not include aquatic taxa, however "Shells/kg" does, "Stratigraphic Rank" represents relative position where 1= stratigraphically oldest. Results for Eastern Deciduous Forest-type taxa are shaded.

Table 4.2. Radiocarbon results from Latch Valley exposures (locations indicated in Figures 4.3 and 4.3).

<b>Site</b>	<b>Lab#</b>	<b><math>^{14}\text{C}</math> Age</b>	<b>Cal Age</b>	<b>Depth (m)</b>
Kulas Quarry	Beta-223641	16,670 $\pm$ 60	19,929 $\pm$ 295	2.75
Kulas Quarry**	AA-83090	16,840 $\pm$ 120	20,059 $\pm$ 296	2.75
Kulas Quarry**	AA-83091	17,180 $\pm$ 130	20,617 $\pm$ 330	2.75
Kulas Quarry**	AA-83092	16,890 $\pm$ 120	20,122 $\pm$ 288	2.75
Kulas Quarry	Beta-223642	17,550 $\pm$ 70	20,961 $\pm$ 314	4.5
Kulas Quarry**	AA-82558	17,990 $\pm$ 200	21,673 $\pm$ 448	4.5
Hwy-JJ	Beta-243248	16,120 $\pm$ 60	19,236 $\pm$ 236	2

Notes: "**Depth (m)**" indicates depth below top of section where  $^{14}\text{C}$  date obtained; all dates obtained via AMS  $^{14}\text{C}$  analysis of gastropod shell carbonate unless noted; site locations shown in Figure 1; radiocarbon calibration via calpal online (Danzeglocke et al. 2007); \*\*dates from Rech et al. (in prep).

Table 4.3. Generalized ecological preferences for common taxa from Latch Valley fauna. Data from Pilsbry (1948), Leonard (1952), and J. Nekola (pers. comm. 2007).

<b>Taxon</b>	<b>Province</b>	<b>Ecology</b>
<i>Columella columella alticola</i>	C-B	Very cold, moist, willow scrub, high elevations often above 2000m elevation.
<i>Pupilla muscorum</i>	C-B	Dry, open cold, catholic sp.
<i>Vertigo modesta modesta</i>	C-B	Willow-birch thickets, cold, moist
<i>Discus shimeki</i>	C	Cold, montane forest above 2000m elevation
<i>Discus whitneyi</i>	W (EDF)	Cold, moist to dry, open to forest habitats; warmer habitats than <i>D. shimeki</i> .
<i>Catinella cf. gelida</i>	MW	Common late Pleistocene fossil throughout Midwest, relict in UMW (Frest, 1987).
<i>Hendersonia occulta</i>	EDF (MW)	Paleozoic Plateau, Niagaran Escarpment, Valley and Ridge Appalachians, limestone cliffs, talus, deciduous forest. Generally associated with areas subject to seasonal flooding (Leonard, 1952).
<i>Vertigo alpestris oughtoni</i>	N	Moist tundra

Notes: C-B = Cordilleran-Boreal distribution, C = Cordilleran, W = widespread, EDF = Eastern Deciduous Forest, MW = Midwest Biome (Frest and Fay, 1980).

Table 4.4. Vertebrate remains found within Kulas Quarry samples. MNI = Minimum Number of Individuals.

Sample	Fish Scales	Mammal	Identified Elements	MNI
KQ20	x	indet. fragments		
KQ19	x	indet. fragments		
KQ18	x	indet. fragments		
KQ17	x	<i>Dicrostonyx</i> sp.	M1/M2*, Lm2	1
KQ16	x	<i>Dicrostonyx</i> sp.	Lm2	1
		indet. rodent incisor	R upper	
KQ15	x	<i>Dicrostonyx</i> sp.	Rm1, 2 Lm1, Lm2, M1/M2*	2
		indet. Sciurid (aff. <i>Tamias striatus</i> )	cheek tooth root*	1
		indet. rodent incisors	R upper, L upper, L lower	
KQ14	x	<i>Microtus</i> sp.	Lm2	1
		indet. rodent incisor	R lower	
KQ13	x	indet. fragments		
KQ09	x	<i>Dicrostonyx</i> sp.	Lm1	1
KQ08	x	<i>Microtus</i> sp.	LM2, Lm2, 2 RM1	2
KQ07	x	indet. fragments		
KQ06	x	<i>Dicrostonyx</i> sp.	RM1, Lm1*	1
		<i>Microtus</i> sp.	RM1, LM2, Lm2	1
KQ05	x	indet. fragments		
KQ03	x			

\*=tooth fragment, R=right, L=left, M=upper, m=lower



Table 4.5. MRPP results for *a priori* sample group comparisons. P values significant at  $\alpha=0.05$  are in bold.

<b>Group Comparisons</b>	<b>T</b>	<b>A</b>	<b><i>p-value</i></b>
KQ <sub>all</sub> vs. JJ	-4.715	0.1114	<b>0.0017</b>
KQ <sub>u</sub> vs KQ <sub>l</sub>	-1.117	0.0331	0.1274
KQ <sub>l</sub> vs JJ	-2.627	0.0796	<b>0.0223</b>
KQ <sub>u</sub> vs JJ	-5.325	0.2574	<b>0.0009</b>
KQ <sub>t</sub> vs KQ <sub>p</sub>	0.342	-0.0101	0.5506
KQ <sub>p</sub> vs JJ	-2.301	0.0798	<b>0.0306</b>
KQ <sub>t</sub> vs JJ	-5.366	0.2116	<b>0.0005</b>

Notes: A = average between-group differences, A=0 when all items identical within groups, A<0 if measured within-group distance greater than that expected by chance.

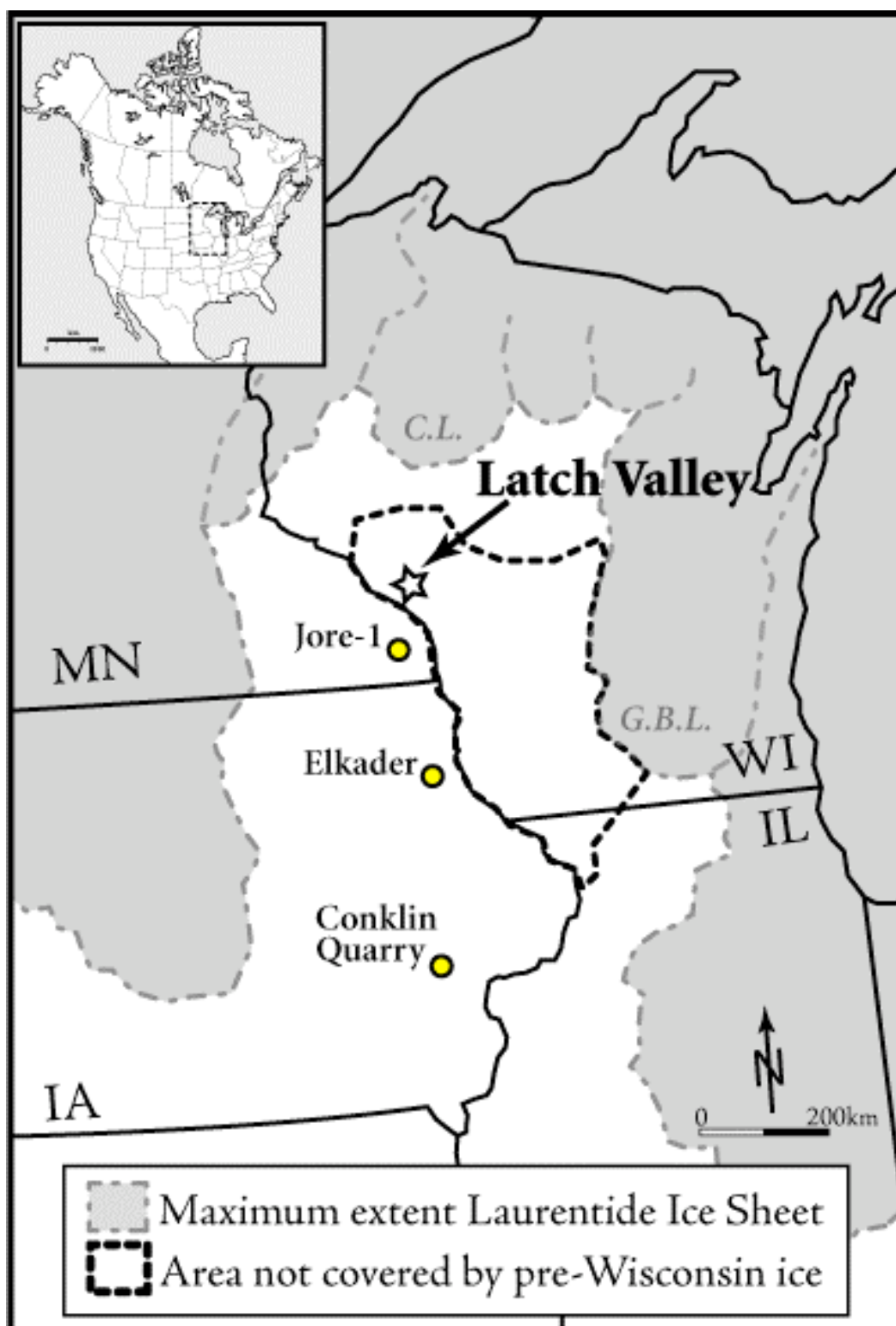


Figure 4.1. Map of study area and locations discussed in text. C.L. = Chippewa Lobe, G.B.L. = Green Bay Lobe. Ice extent based on Mickelson et al. (1984) and Syverson and Colgan (2004).

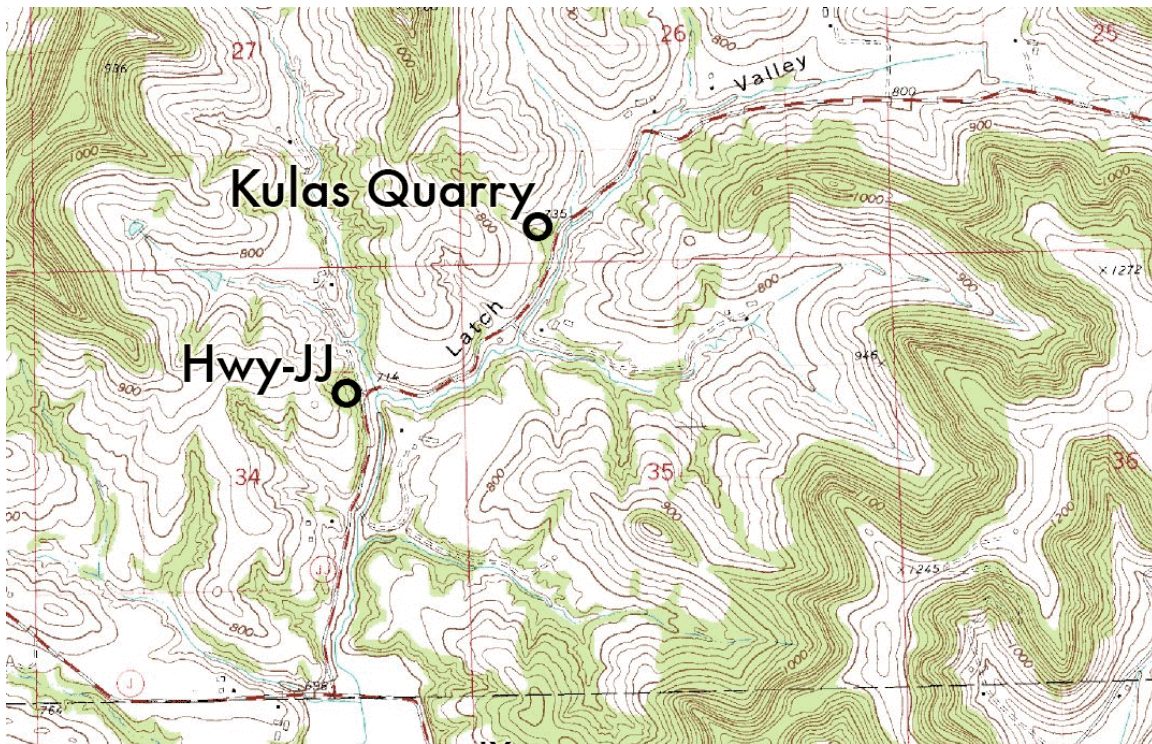


Figure 4.2. USGS topographic map of Latch Valley. Scale is approximately 1:25,000.



Figure 4.3. Hwy-JJ outcrop with gastropod shell radiocarbon date (BETA-243248) from material about 2 m below top of exposure.



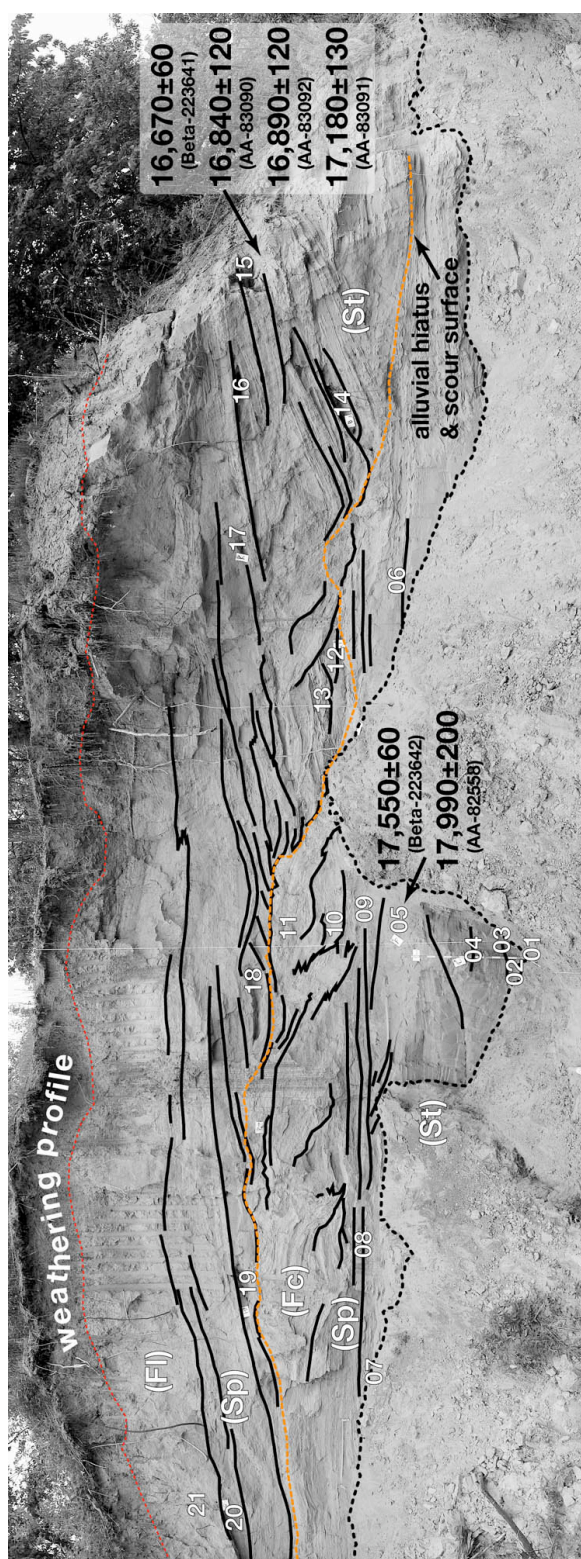


Figure 4.4. Kulas Quarry exposure showing stratigraphic relationships of samples and radiocarbon age results.

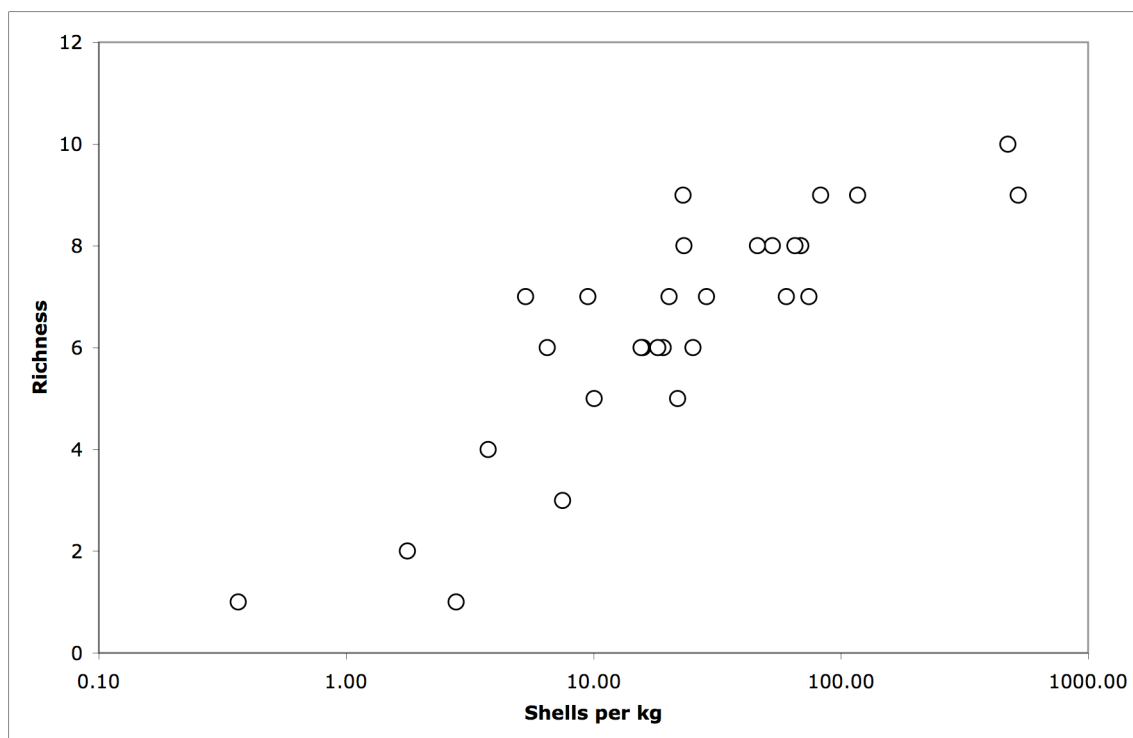


Figure 4.5. Semi-log plot of Shells per kg versus richness for all samples.

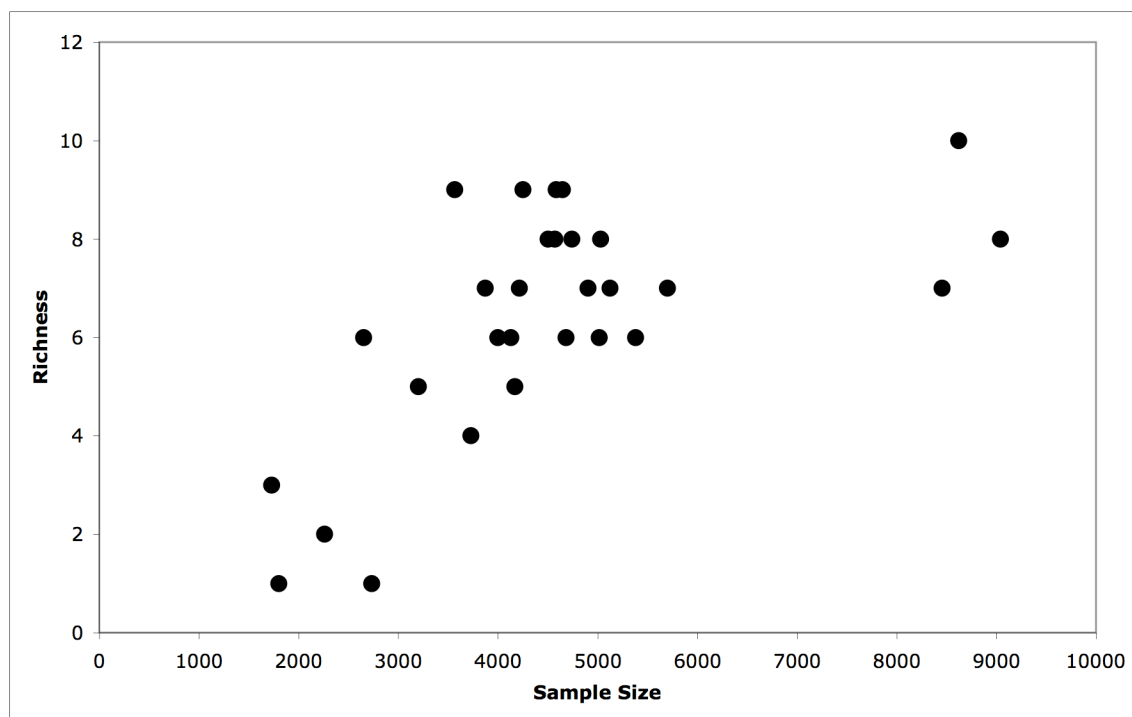


Figure 4.6A. Richness versus sample size.

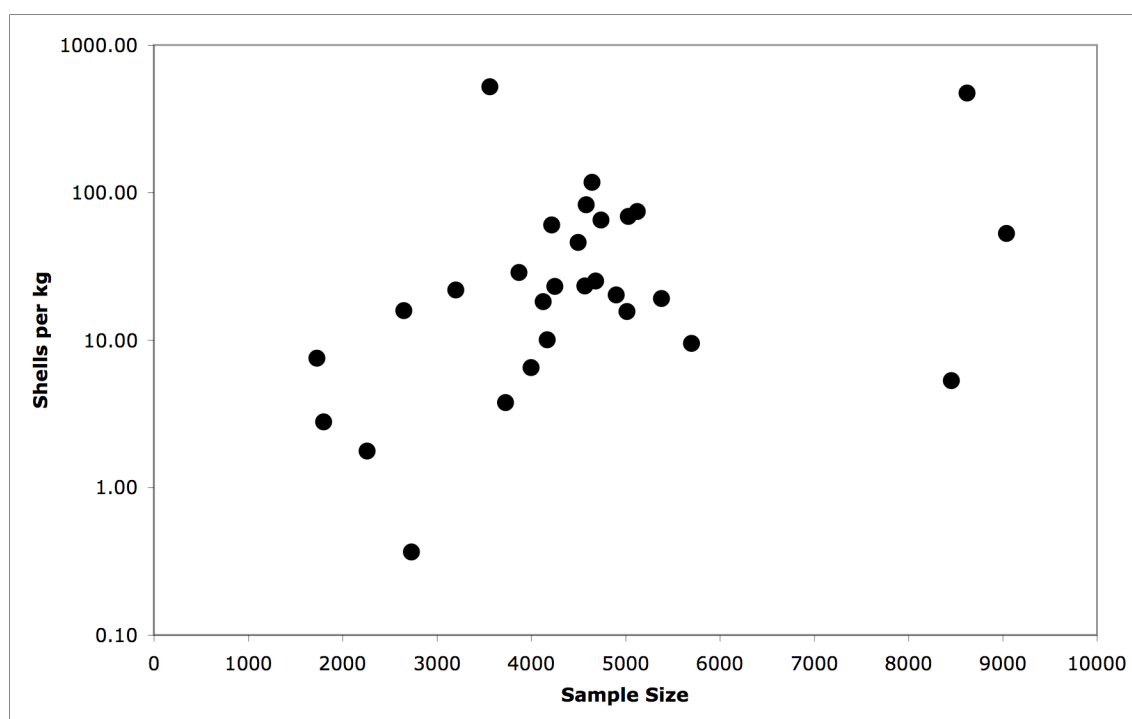


Figure 4.6B. Shells per kg versus sample size.

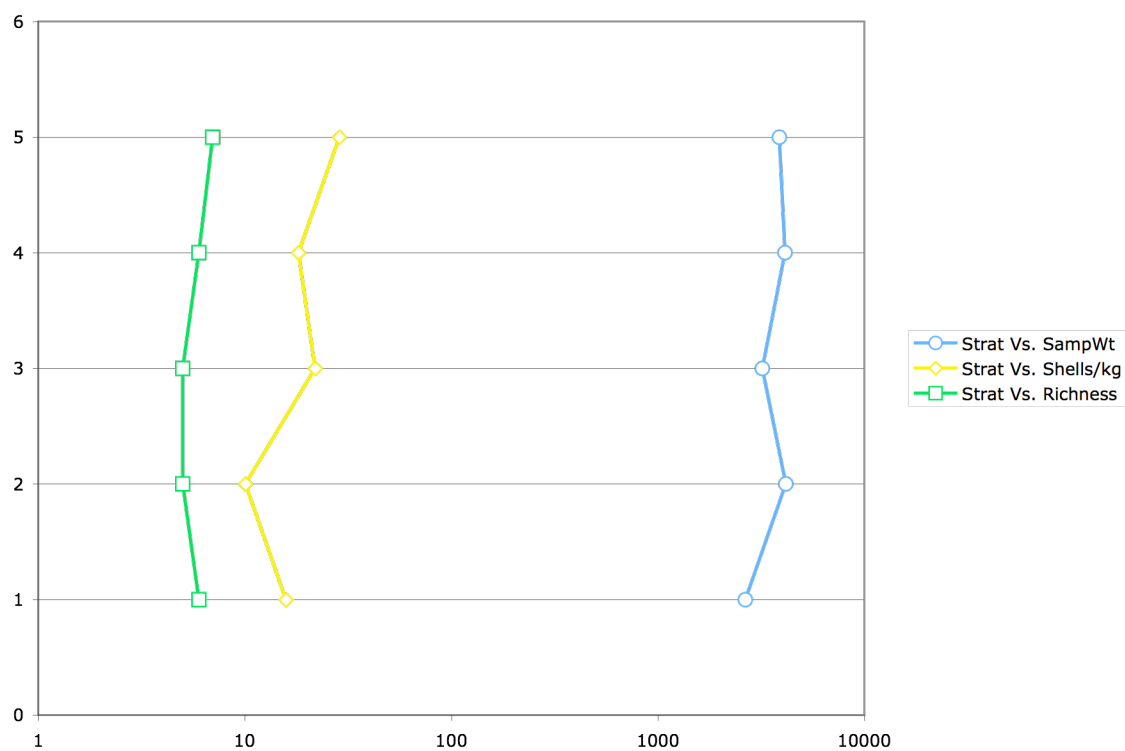


Figure 4.7A. Stratigraphic variation in Richness, Shells/kg and Sample Weight at Hwy-JJ.



Figure 4.7B. Stratigraphic variation of Richness, Shells/kg, and Sample Weight in Kulas Quarry Samples.



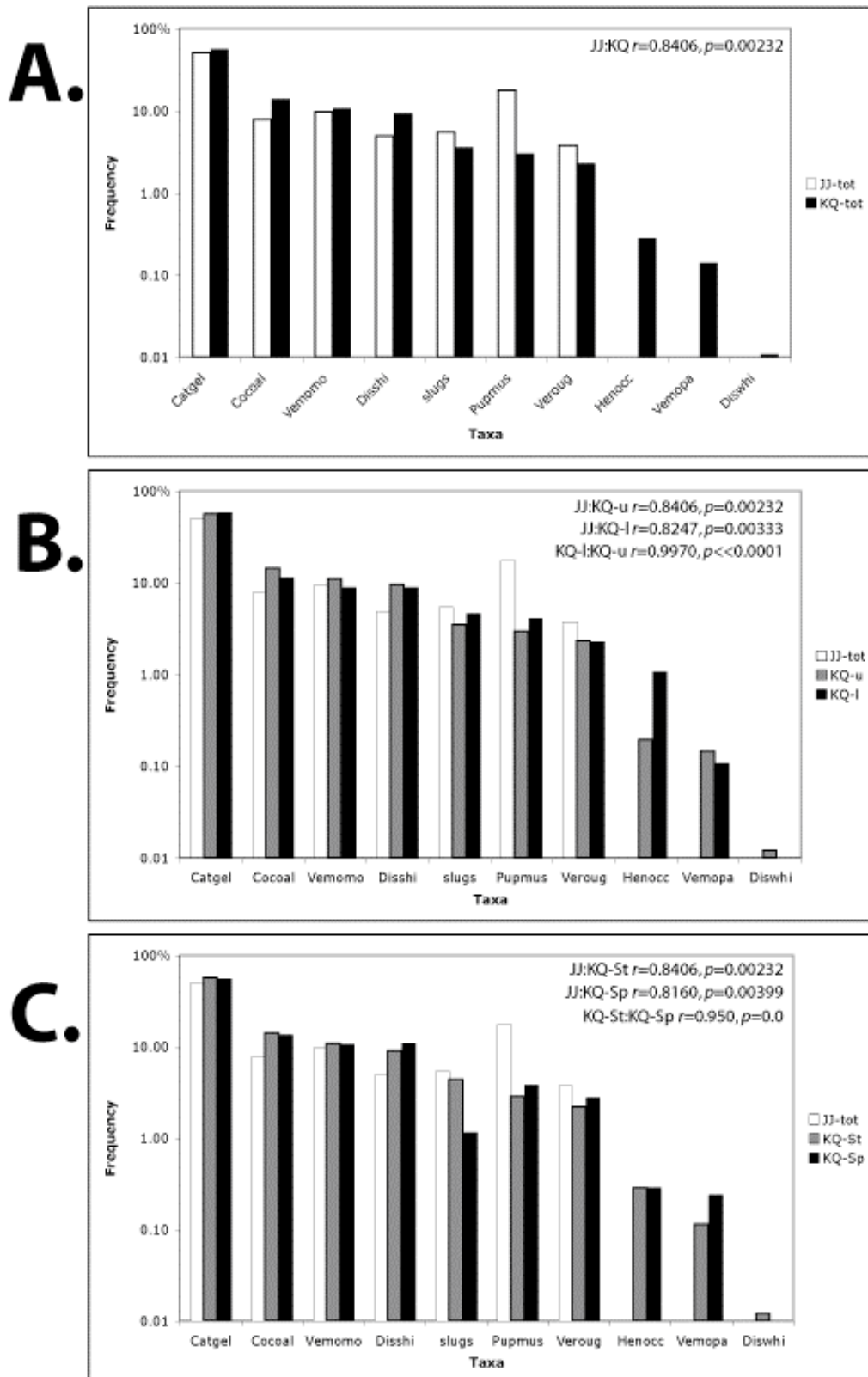


Figure 4.8. Rank abundance of terrestrial gastropod taxa from Hwy-JJ and Kulas Quarry sample groups. Spearman rank ( $\rho$ ) represents the comparison between sample groups.

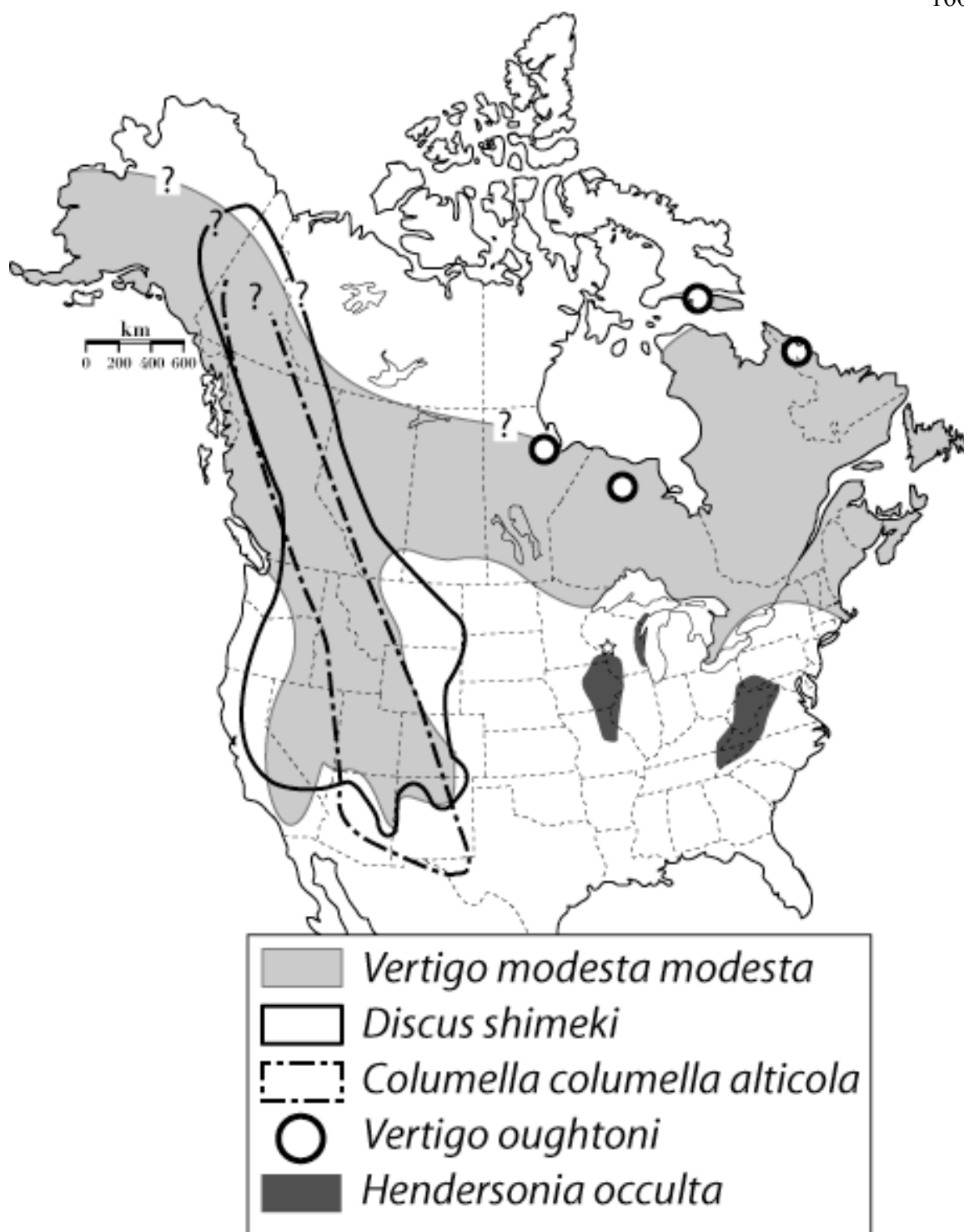


Figure 4.9. Range Map showing modern range distributions of selected gastropod taxa.



Figure 4.10. North American distribution of *Dicrostonyx* sp. (collared lemming).