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Limestone Gulch, White Mountains National Recreation Area: Natural, Cultural, and Biological Karst Reconnaissance, 2002-2005

Robin O. Mills, Robert Sattler, and Nancy H. Bigelow

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Authors

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Cover

Robert Sattler resting amongst upland alpine vegetation in the vicinity of limestone outcrops; Limestone Gulch region, White Mountains Recreation Area, Alaska.

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Limestone Gulch, White Mountains National Recreation Area: Natural, Cultural, and Biological Karst Reconnaissance, 2002-2005

By
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with contributions by
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Introduction: The Project Background

This report outlines the findings of a natural, biological and cultural survey of karstic features in the Limestone Gulch area of the White Mountains National Recreation Area (WMNRA), managed by the Bureau of Land Management – Fairbanks District Office (BLM). The WMNRA is a nearly 1 million acre contiguous land unit located in central-eastern interior Alaska, northeast of the city of Fairbanks (Figure 1). The survey occurred during the summer months of 2002 through 2005, and was prompted by an impromptu discovery of a bison bone inside of a small cave in the Limestone Gulch area of the WMNRA in the spring of 2001 (Figure 2). Radiocarbon analysis on the bone returned an assay around 13,000 before present, dating to the late Pleistocene epoch.

The potential of locating late Pleistocene paleontological and possibly even archaeological materials prompted me to develop a survey plan for this area, which was initiated the following summer. In this regard, a series of mostly volunteer surveyors from various outdoor backgrounds and specialties (i.e., spelunkers; plant and bird specialists; archaeologists; a quaternary paleoecologist; recreation specialists) were recruited to survey and record karst features in the area (see Acknowledgements). Three to five people participated in each survey for three to five days at a time. Other resource personnel in the BLM were contacted, and asked to contribute to the development of a "caving form" to be filled out by the surveyors (Appendix 1). The form prompted the surveyors to record basic information about various types of data: (1) location, (2) the nature of the

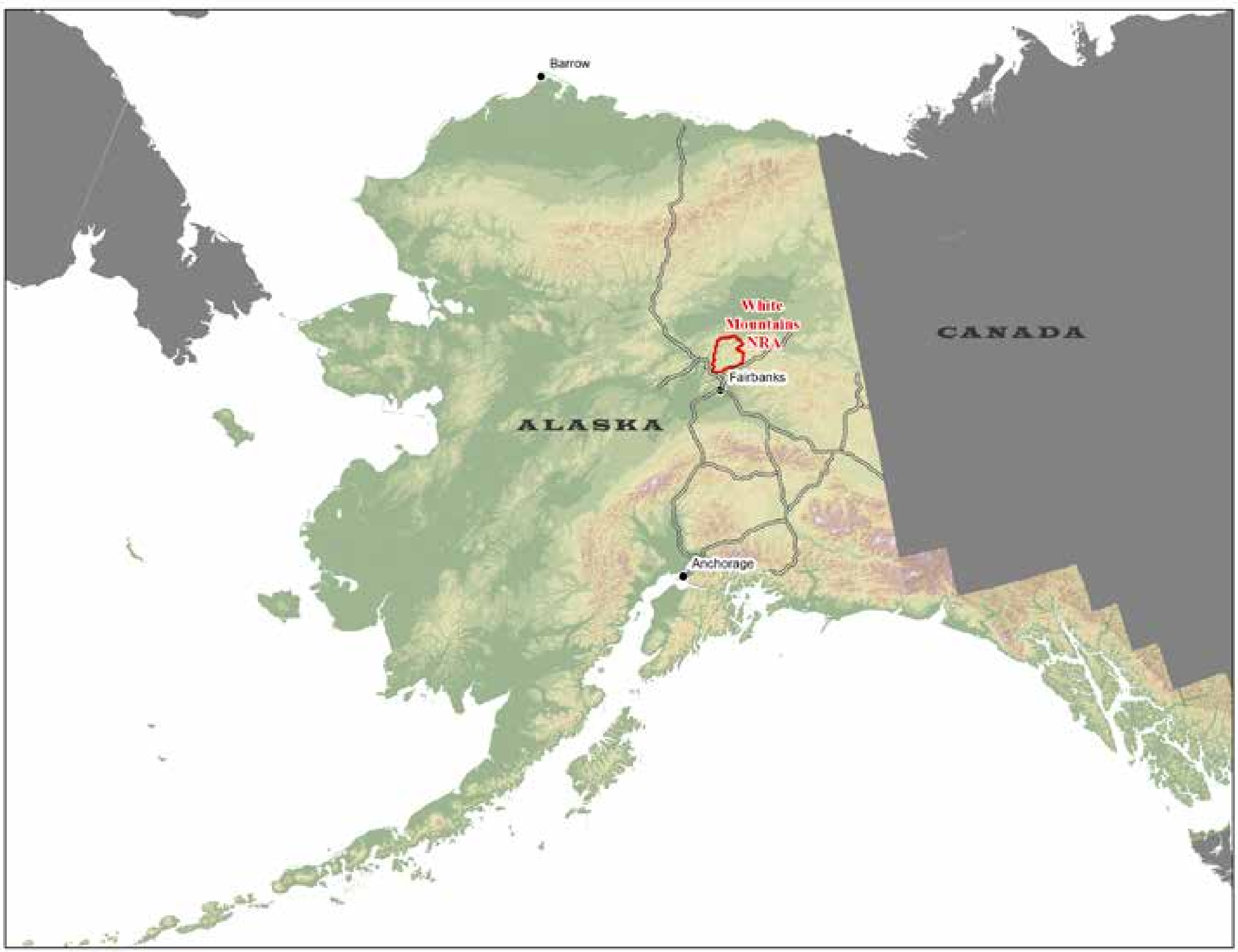

Figure 1. Location of the White Mountains National Recreation Area in Alaska.

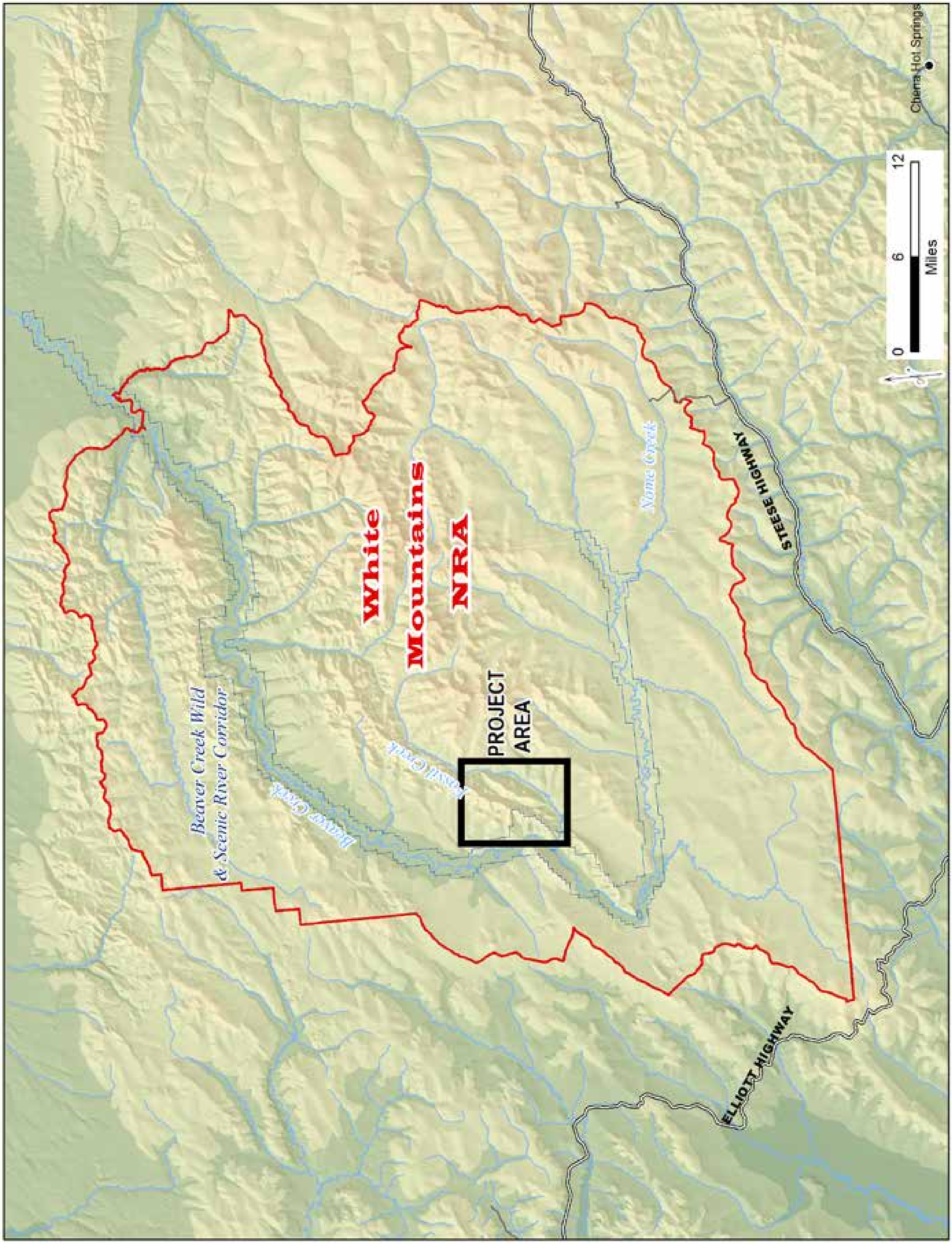

Figure 2. Location of the karst survey area in the White Mountains National Recreation Area.

karst feature, in terms of the presence of various caving features, as well as quantifiable measurements, (3) cultural/archaeological, (4) paleontological, (5) mammalian biological, including bats, (6) avian biological, (7) geological, (8) hydrological, and (9) vegetation. In addition, a standard suite of photos of each karst feature was recorded, and simple top or plan view maps were recorded for each rock shelter or cave feature. Where feasible, a standard test pit (circa 35 cm diameter) was also excavated inside each cave or rock shelter to assess its buried archaeological and paleontological potential, and the basic stratigraphy of each test pit was recorded.

The primary goal of the survey was to gather basic information in order to highlight the nature of the resources available in this largely under-surveyed area. Experts in specific fields (e.g., paleontologists; large mammal biologists; recreationists) can now use the data provided here to better plan their own field studies.

As can be expected, the quality of the data that was recorded varied widely from karst feature to feature, depending largely upon individual knowledge and the date of each survey. Simply put, the data recorded during later surveys are an improvement over those gathered during earlier surveys; as critical comments on earlier caving forms were given back to the surveyors from one trip to the next, the nature of the data gathered and its standardization improved.

Besides proactively gathering natural historical data in this area, another factor that prompted this project is the possibility of a hiking trail being constructed up Fossil Creek, from the Beaver Creek National Wild & Scenic River corridor, next to the Limestone Gulch area. The Record of Decision, Resource Management Plan for the WMNRA (1986) outlines the possibility of just such a trail being constructed. Although a fuller Environmental Assessment would likely be involved by the BLM's Eastern Interior Field Office (EIFO) if the decision to build this trail is ever made, this preliminary study should provide baseline data useful to some of the various programs that would be involved at that time (i.e., recreation, archaeology, wildlife biology).

An assortment of samples were collected during the course of the surveys, including owl pellets, soils samples, and faunal samples which include large mammal bones, microtine bones, bird bones, mollusk shell fragments, feathers, and fish bones. Appendix 2 lists all of the samples collected during these surveys. All samples have been accessioned to, and reside at the University of Alaska Museum of the North's Earth Sciences Department (accession UAMES2009.013.ESCI).

Results

Eight surveys took place, one in 2002, four in 2003, one in 2004, and two in 2005 (Figure 3). Most surveys lasted for three days. Unfortunately for the project, the 2004 and 2005 field seasons were two of the worst seasons for wildland fire in Alaska since records began to be kept in the 1950s, in terms of total acreage burned. Since our project relied upon BLM-Alaska Fire Service (AFS) contracted helicopters to transport our survey crews into and out of the Limestone Gulch region, only a limited number of surveys could be conducted during those two years. In short, the helicopters were needed elsewhere for fire-related activities, and not available for extra resource-related projects like the karst project.

Nonetheless, approximately 3,350 acres were 100% ground covered by pedestrian survey during this project, and 102 karstic features were located and recorded (Figures 4-12). Of these, 12 are natural stone arches, with the remainder being caves and rock shelters. As I could not locate a standardized definition differentiating what a "cave" is from what a "rock shelter" is, all further references to this type of feature (i.e., an indentation into but not through a rock wall) will hereafter be referred to as a "cave" in this report. The basic data from all forms for all karst features are presented in Appendix 3. Figures 13-21 provide illustrative examples of the Limestone Gulch topography in which the surveys occurred, as well as the types of vegetation and groundcover found in the area today.

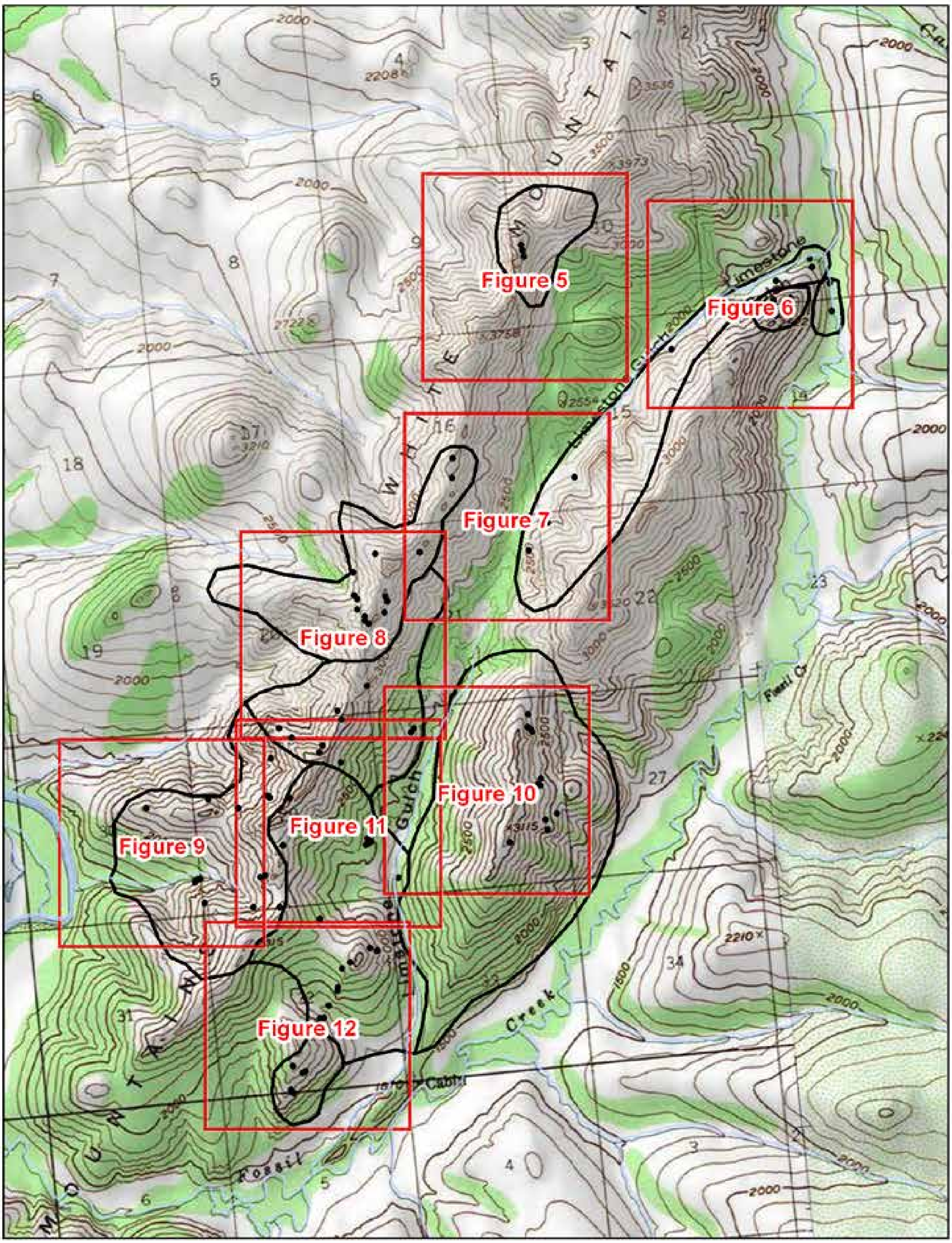

Figure 3. Boundary extents of the eight surveys in the White Mountains National Recreation Area, plus all karst feature localtions. (1) 5/23/03 – 5/25/03; (2) 6/06/03 – 6/09-03; (3) 7/03/03 – 7/04/03; (4) 8/02/03 – 8/04/03; (5) 6/05/04 – 6/07/04; (6) 7/16/05 – 7/18/05; (7) 8/27/05 – 8/29/05; (8) 7/22/02 – 7/23/02.

Basic Cave Data

In sum, most of the caves located during the surveys are relatively small. Figure 22 presents the greatest length of 76 caves whose lengths were recorded; almost two-thirds (63%; n=57) have a greatest length of 5 meters or less, while only four (5%) have lengths greater than 15 meters. Figure 23 presents the greatest width versus height for each cave mouth or entrance (n=89; one cave was not reachable). Here, 89% (n=79) of the caves had entrances smaller than 4 x 6 meters (width v. height), and 60% had entrances smaller than 2.5 x 4 meters.

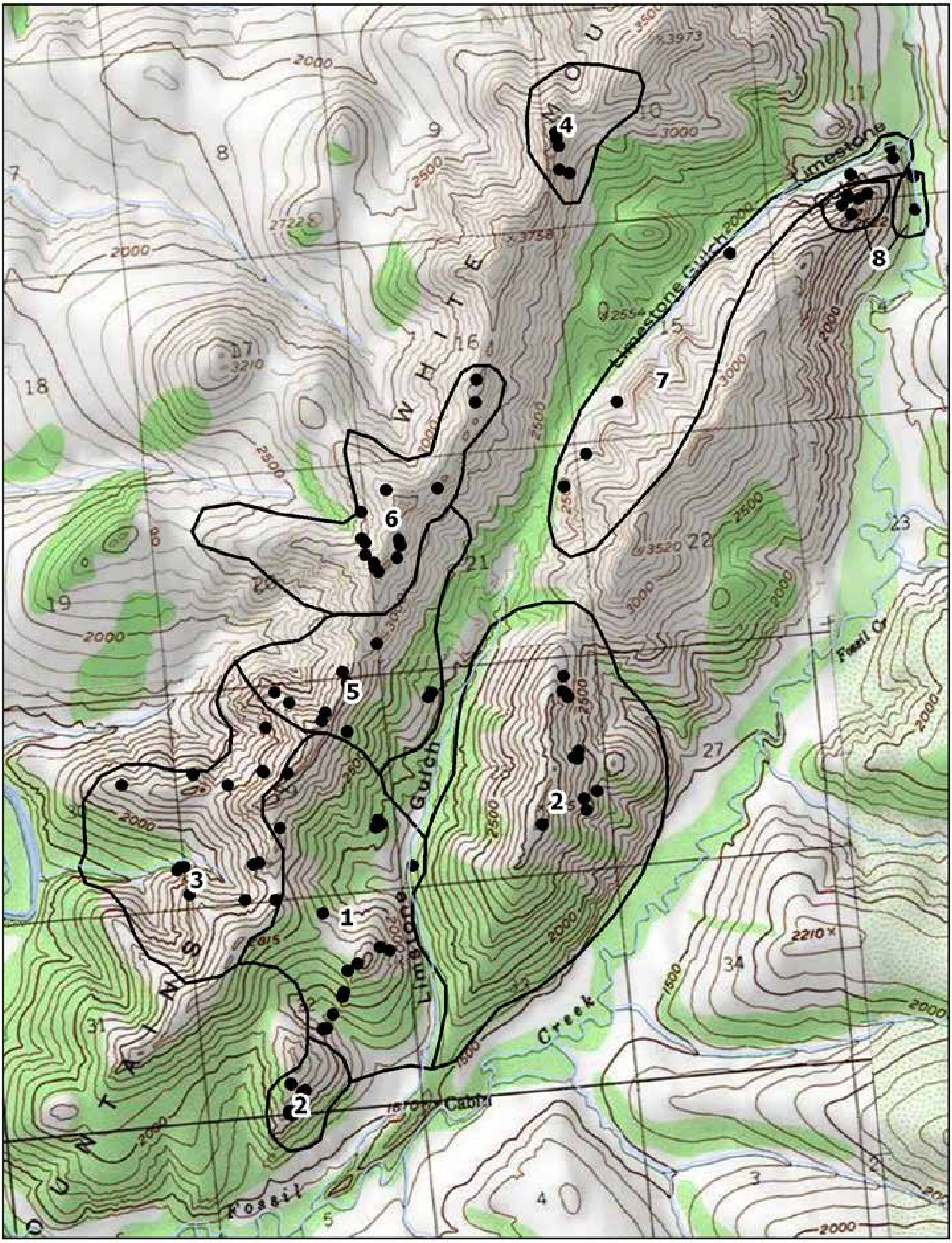

Figure 4. Map showing locations of close-up data maps, Figures 5-12.

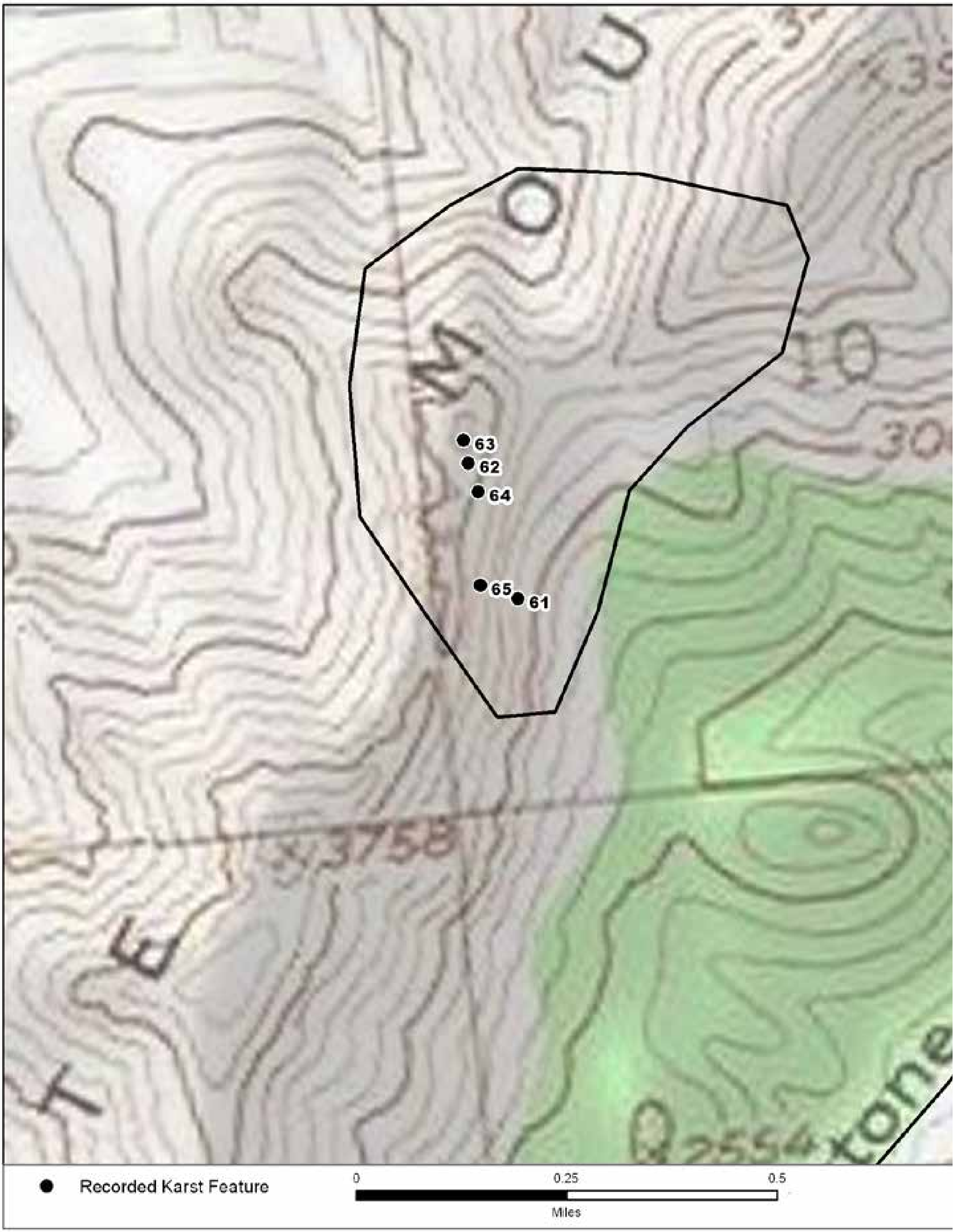

Figure 5. Close-up map showing karst feature locations, northern portion of Limestone Gulch. Refer to Figure 4 for general map locale.

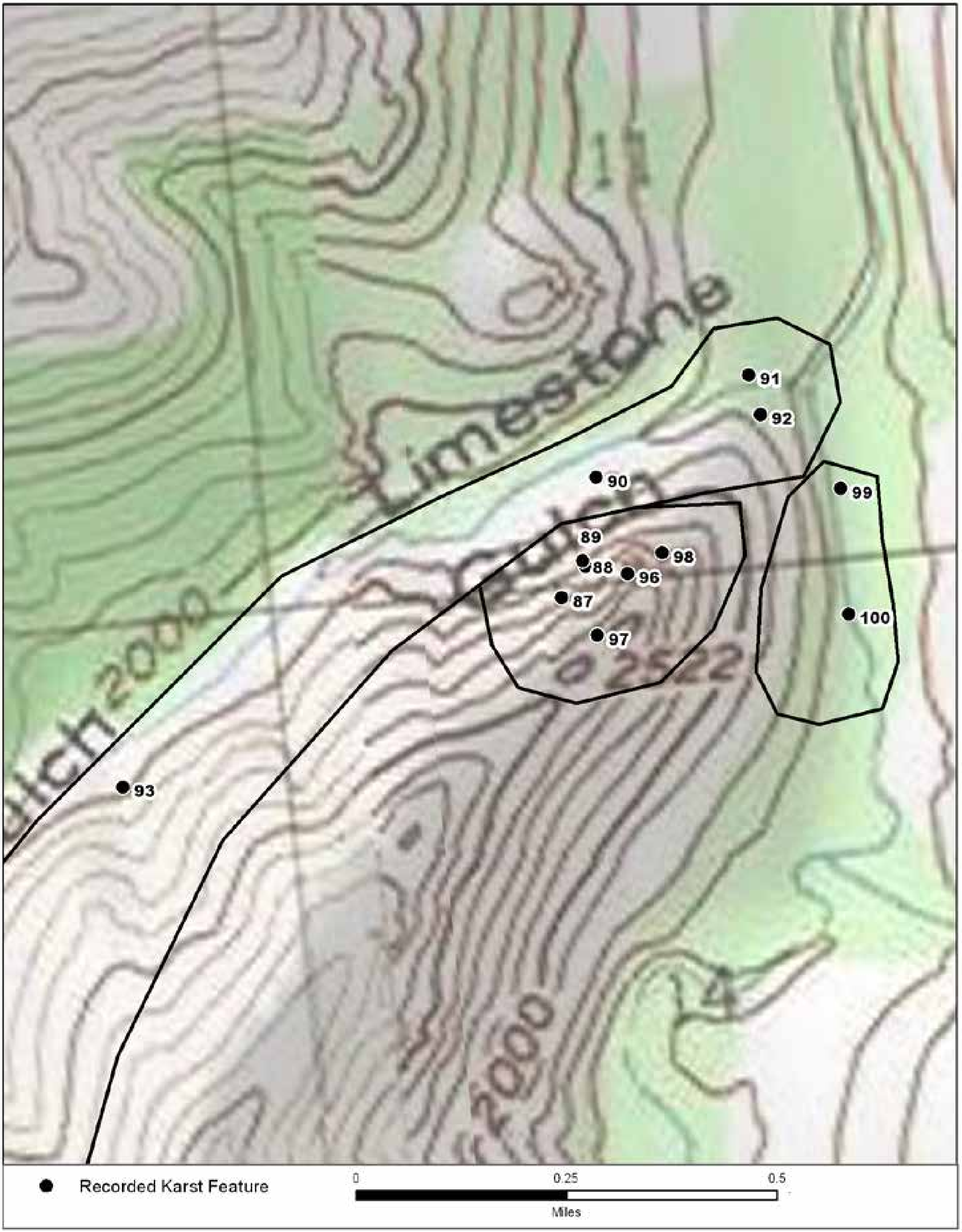

Figure 6. Close-up map showing karst feature locations, northeastern portion of Limestone Gulch. Refer to Figure 4 for general map locale.

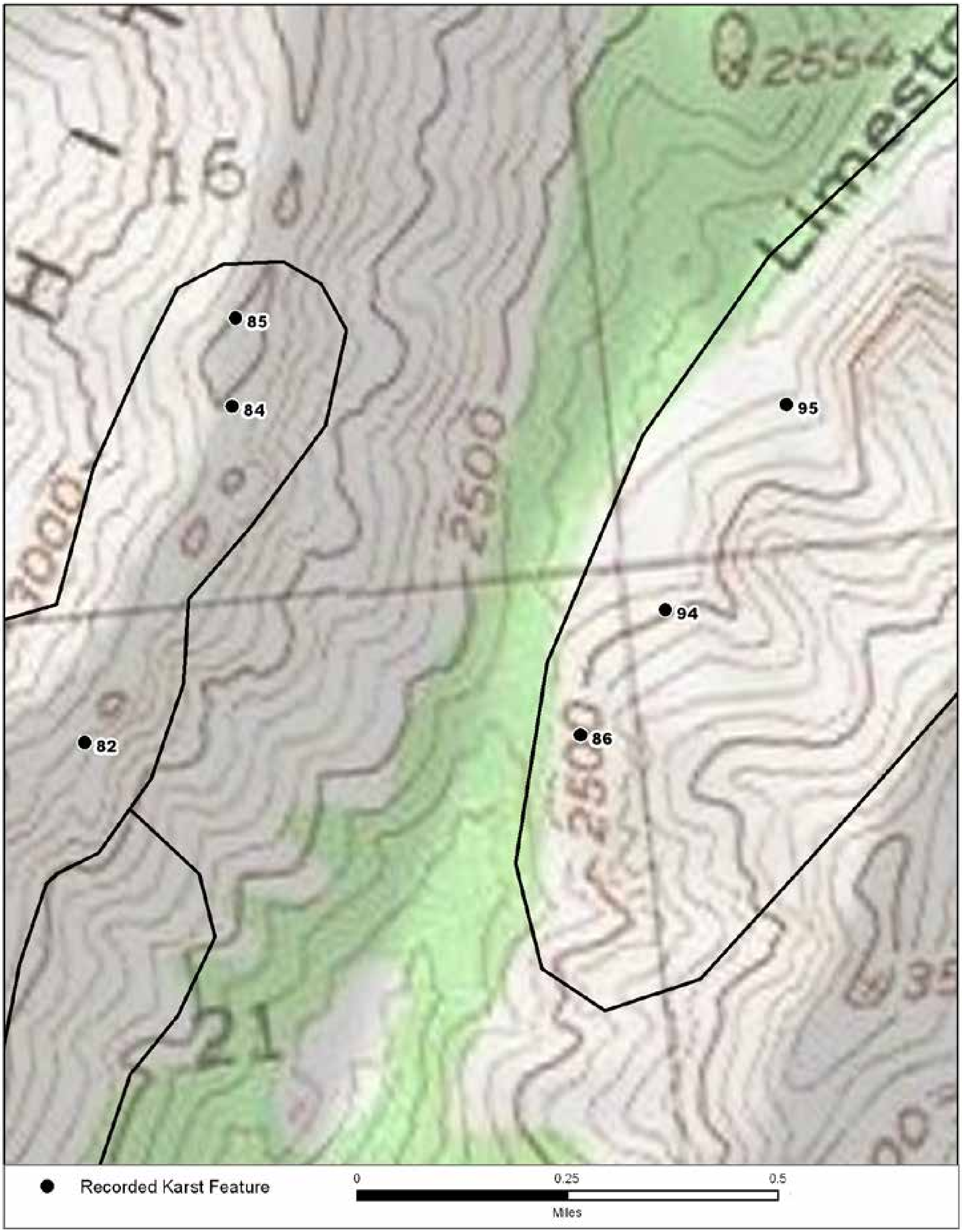

Figure 7. Close-up map showing karst feature locations, north-central portion of Limestone Gulch. Refer to Figure 4 for general map locale.

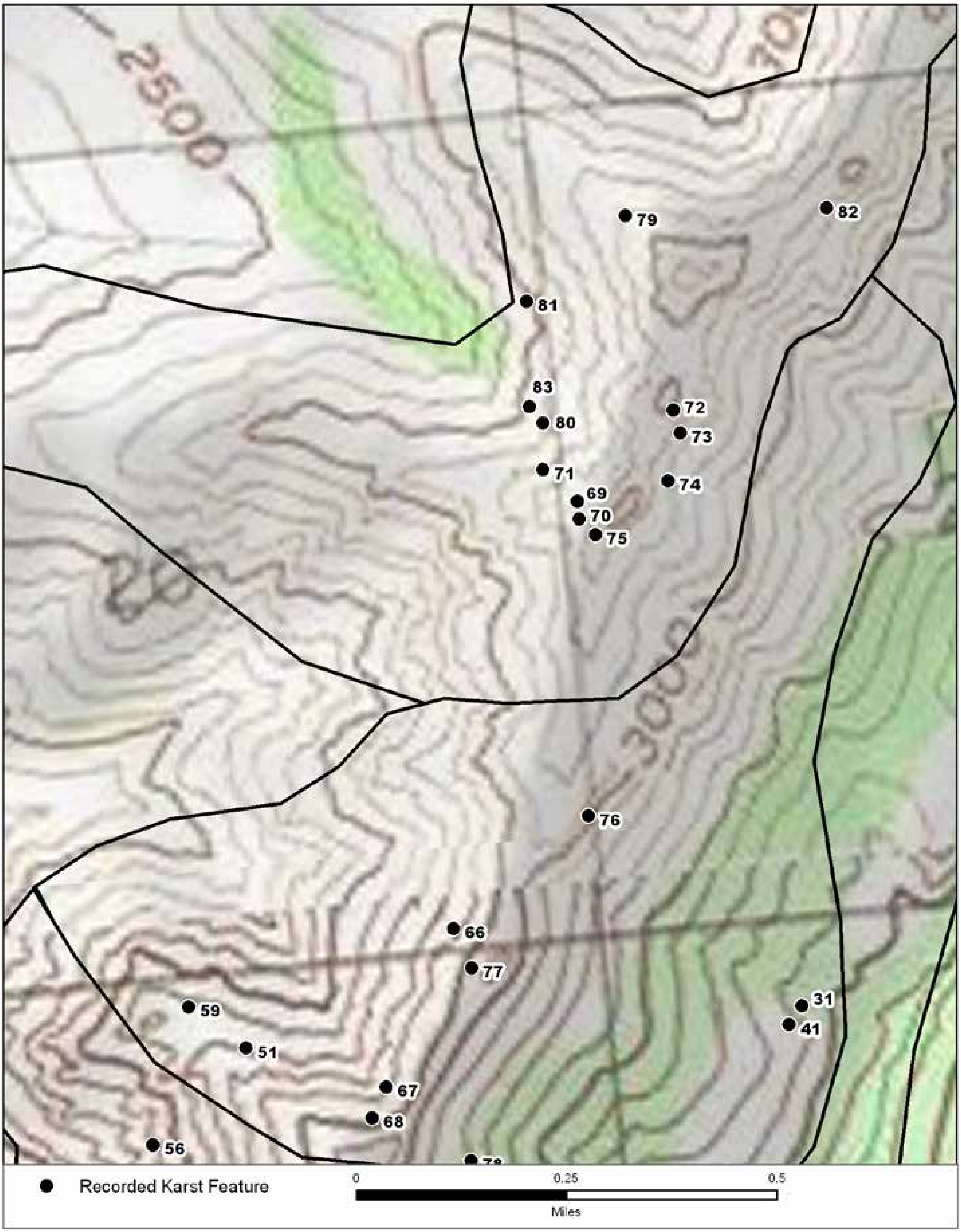

Figure 8. Close-up map showing karst feature locations, central portion of Limestone Gulch. Refer to Figure 4 for general map locale.

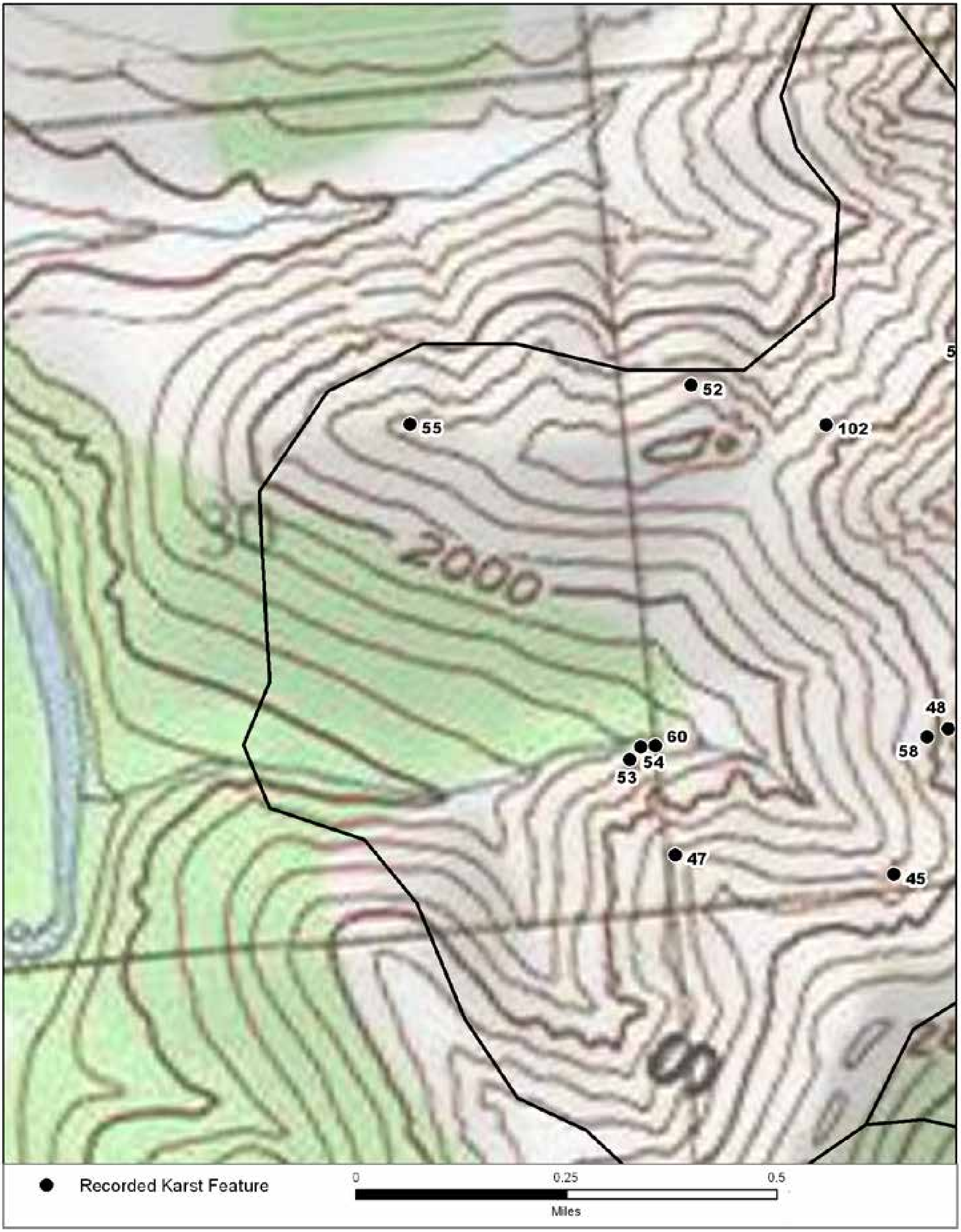

Figure 9. Close-up map showing karst feature locations, western portion of Limestone Gulch. Refer to Figure 4 for general map locale.

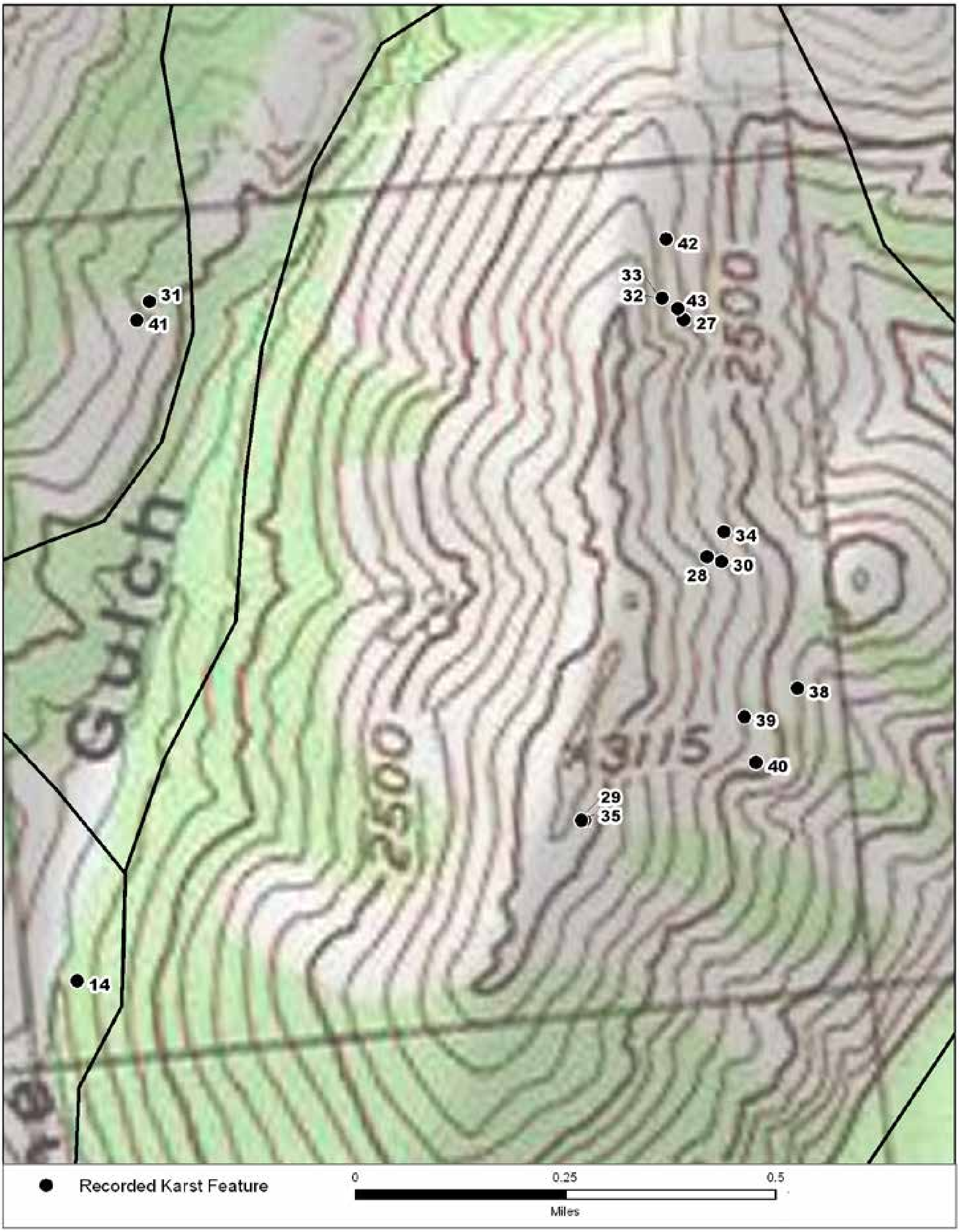

Figure 10. Close-up map showing karst feature locations, southeastern portion of Limestone Gulch. Refer to Figure 4 for general map locale.

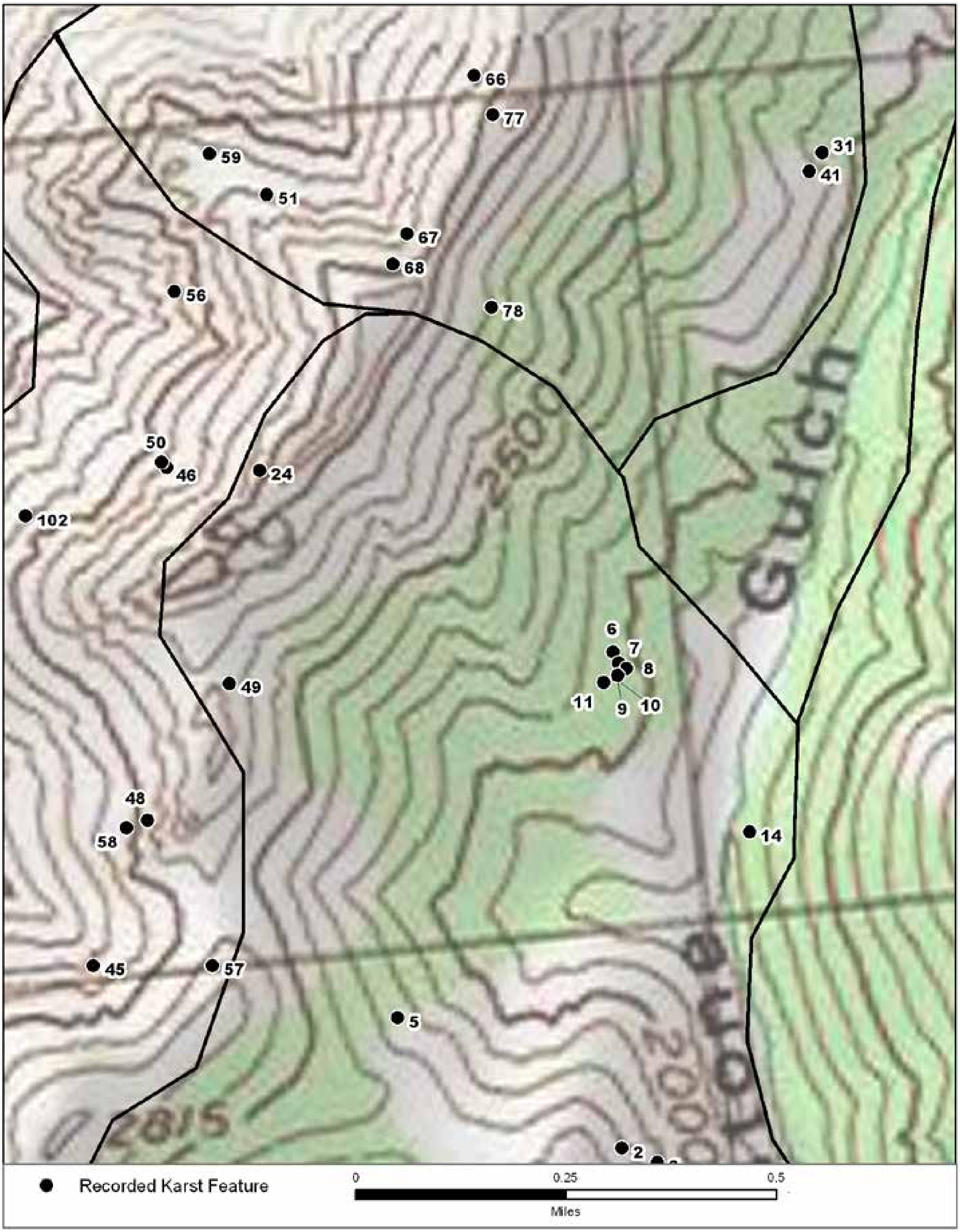

Figure 11. Close-up map showing karst feature locations, south-central portion of Limestone Gulch. Refer to Figure 4 for general map locale.

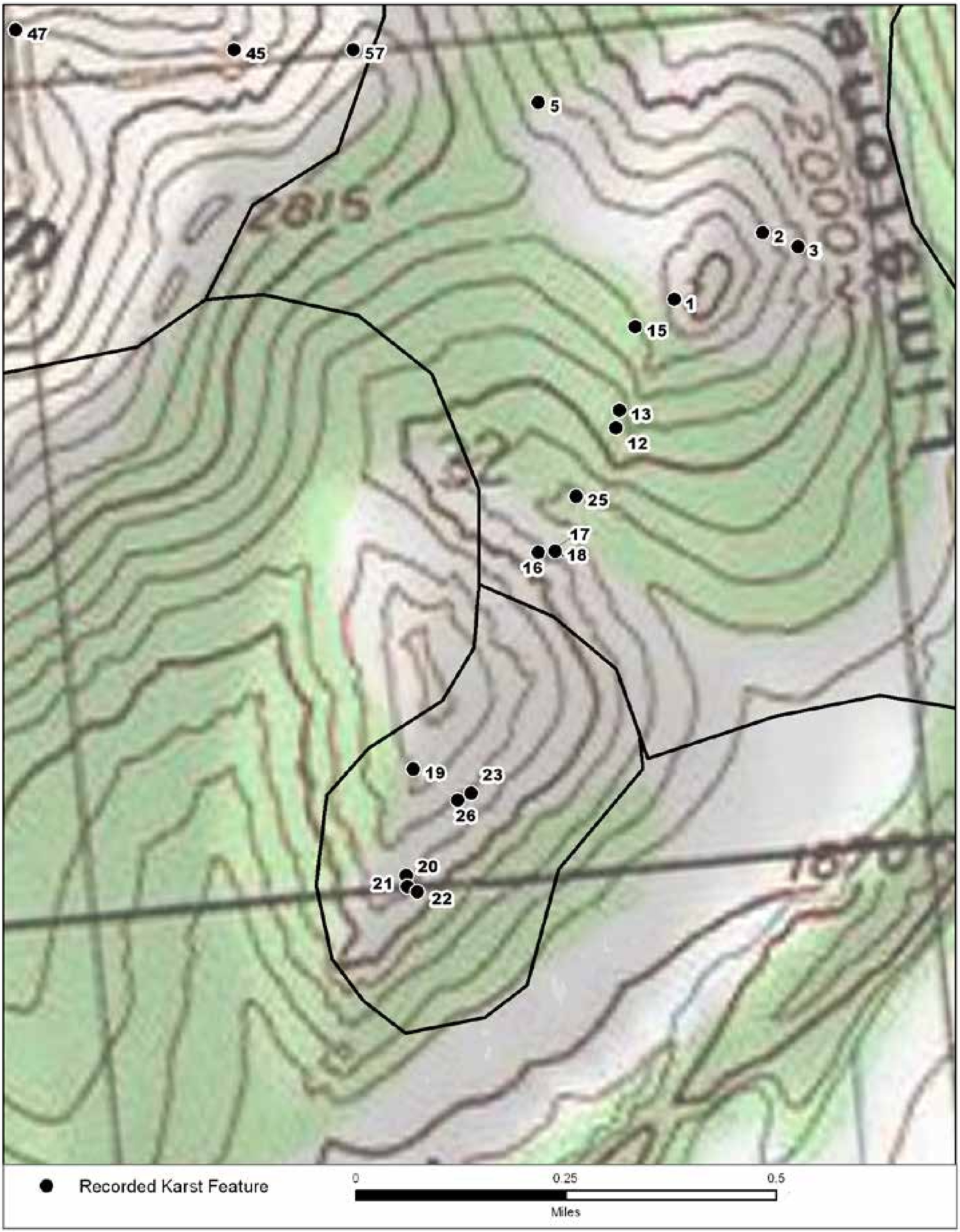

Figure 12. Close-up map showing karst feature locations, southern portion of Limestone Gulch. Refer to Figure 4 for general map locale.

Figure 13. Steve Springer and Andrea Hunter relax on a grassy hillside; Limestone Gulch region, WMNRA. Note the open rocky talus slopes in the background, and spruce trees on the lower slopes and creeping up the drainages.

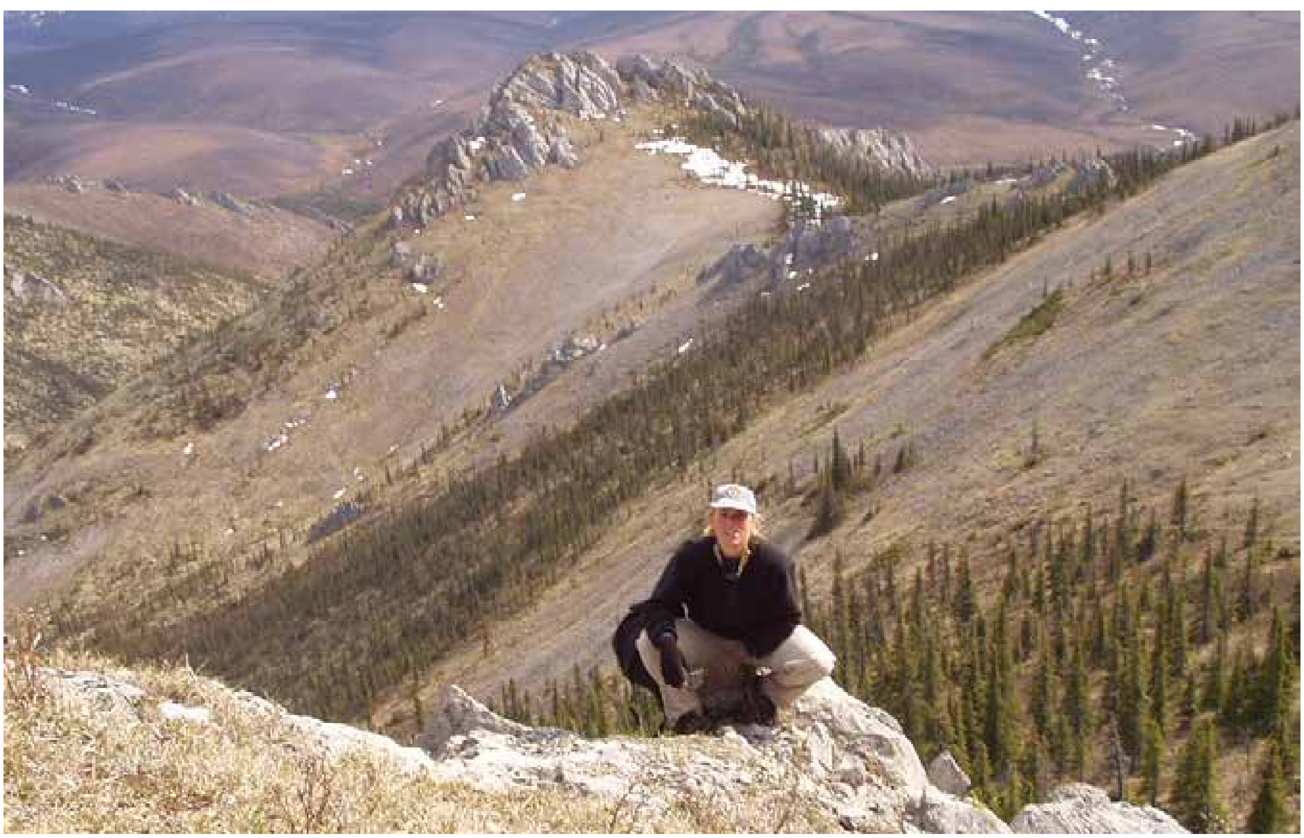

Figure 14. Andrea Hunter on an exposed grassy hillside; Limestone Gulch region, WMNRA. Note the mixed grassy-talus slopes in the background, and spruce trees on the lower slopes and creeping up the drainages.

Figure 15. Carrie Barta and Andrea Hunter on a grassy slope in front of a limestone outcrop with a cave set in it; Limestone Gulch region, WMNRA. Note the pockets of spruce on this otherwise open slope.

Figure 16. Carrie Barta on a high outcrop overlooking a limestone ridge; Limestone Gulch region, WMNRA. Note the highly variable vegetation pattern, a wide spruce area next to a talus slope area with upland alpine vegetation.

Figure 17. A steep-sided limestone ridge, with spruce and thick sphagnum moss on the slopes below; Limestone Gulch region, WMNRA. Note the tiny person near center for scale.

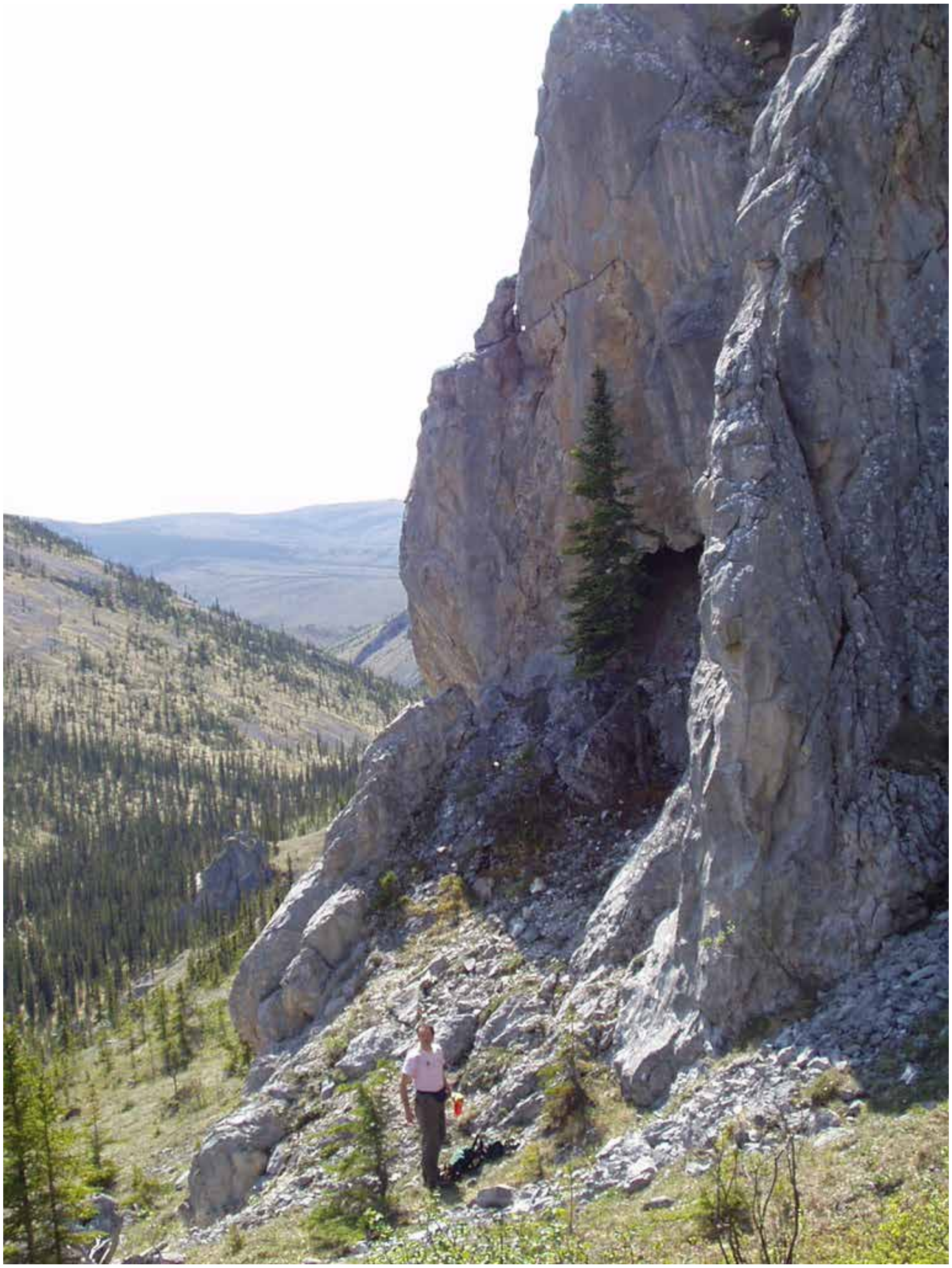

Figure 18. A surveyor assists in recording a cave in the sheer limestone slope behind the spruce tree, center of photo; Limestone Gulch region, WMNRA.

Figure 19. Limestone ridge system overlooking the Beaver Creek drainage in the vicinity of Karst Feature #46; Limestone Gulch region, WMNRA. Note the upland alpine vegetation on the slopes.

Figure 20. Robert Sattler resting amongst upland alpine vegetation in the vicinity of limestone outcrops; Limestone Gulch region, WMNRA.

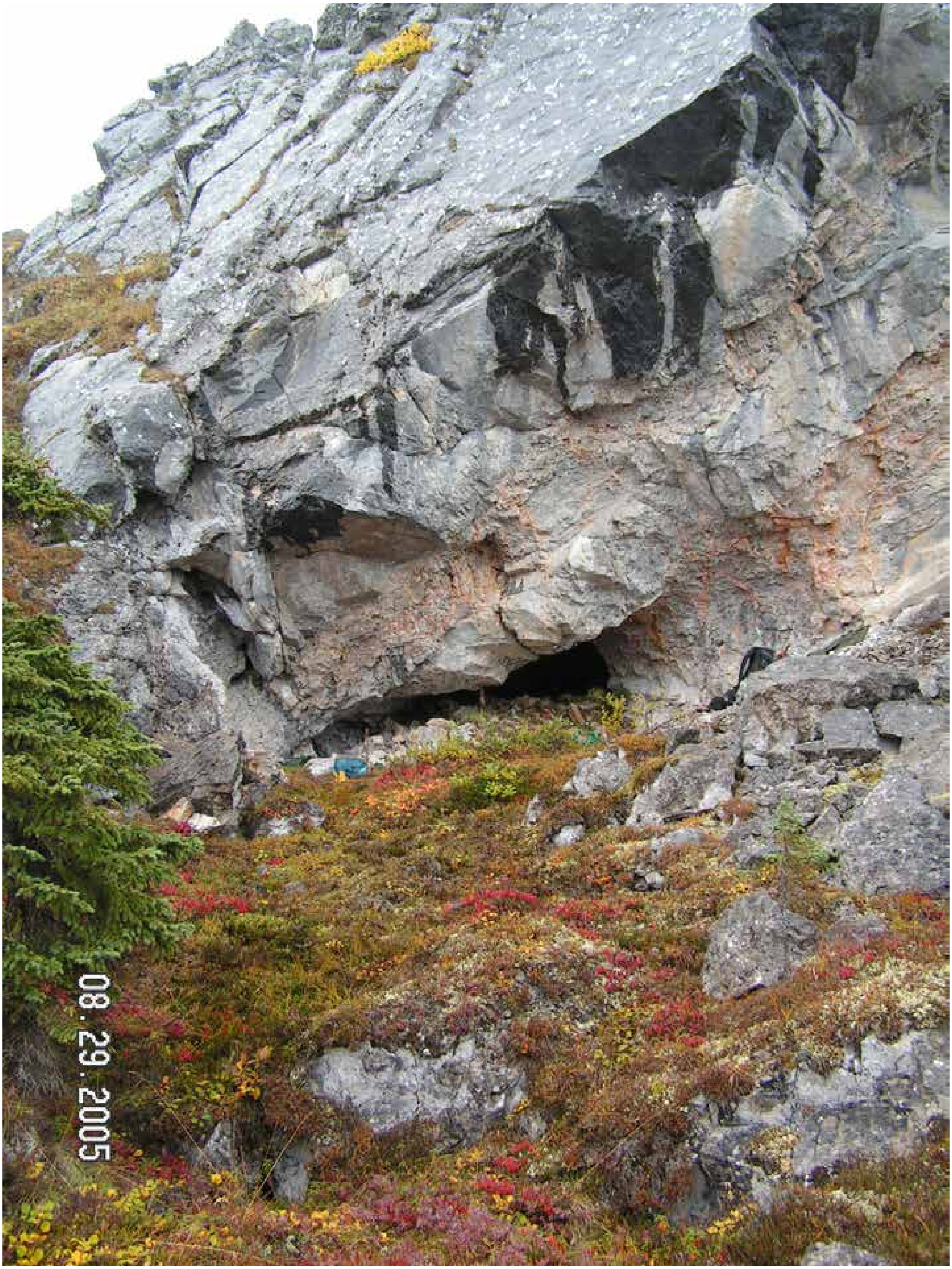

Figure 21. A cave set into a limestone outcrop, with thick upland alpine vegetation in the foreground; Limestone Gulch region, WMNRA. Note the backpacks in front of the cave for scale.

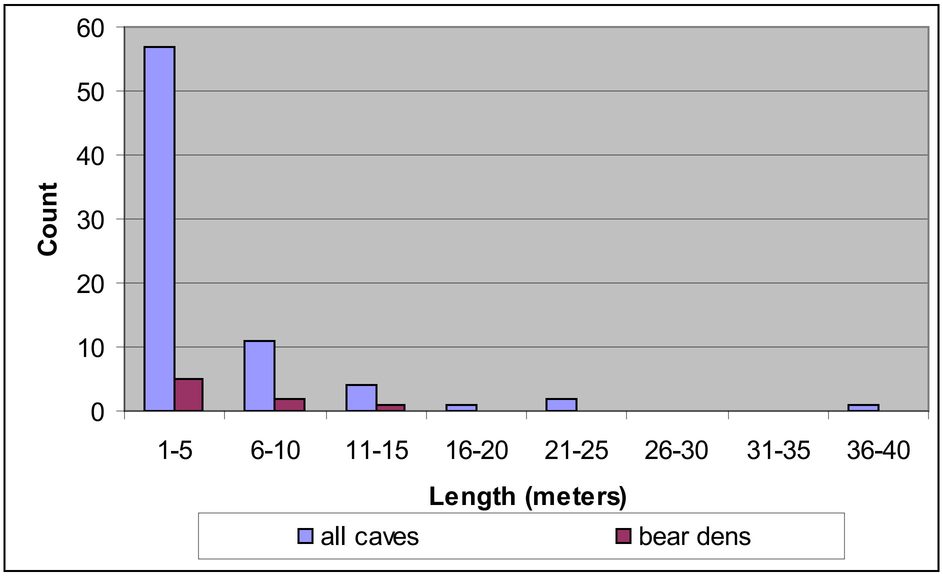

Figure 22. Greatest length of all caves (n=76 caves measured), and those with bear dens (n=9).

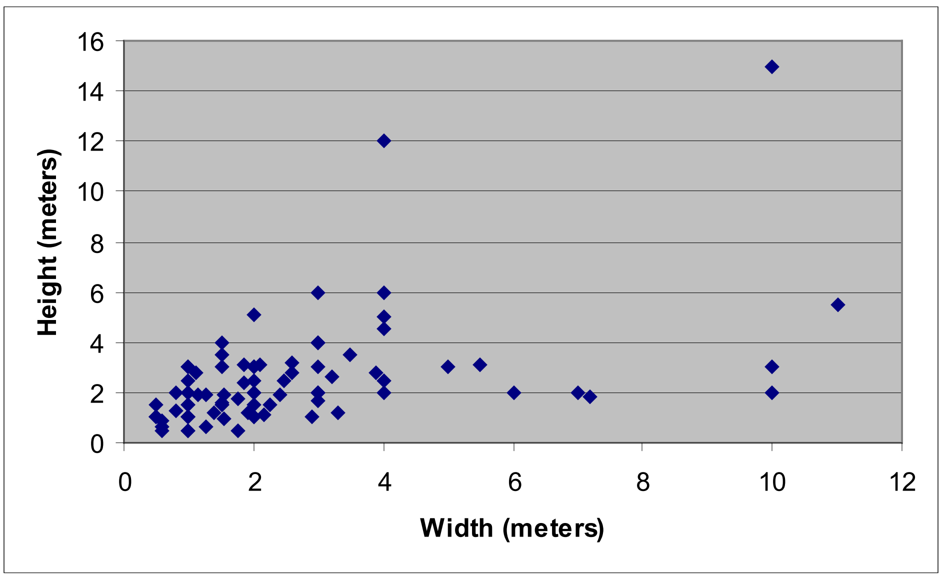

Figure 23. Cave / Rock shelter greatest width vs. height of mouth or entrance (n=89).

Likewise, most of the caves' layouts or plan views are relatively straightforward. Figure 24 presents the number of chambers present off of a cave's main entrance chamber, for all 90 caves in the study. The vast majority (82%; n=74) possess only the main entrance chamber that you initially enter when passing through the cave mouth. Of those 16 caves that have an additional chamber, only four have more than one.

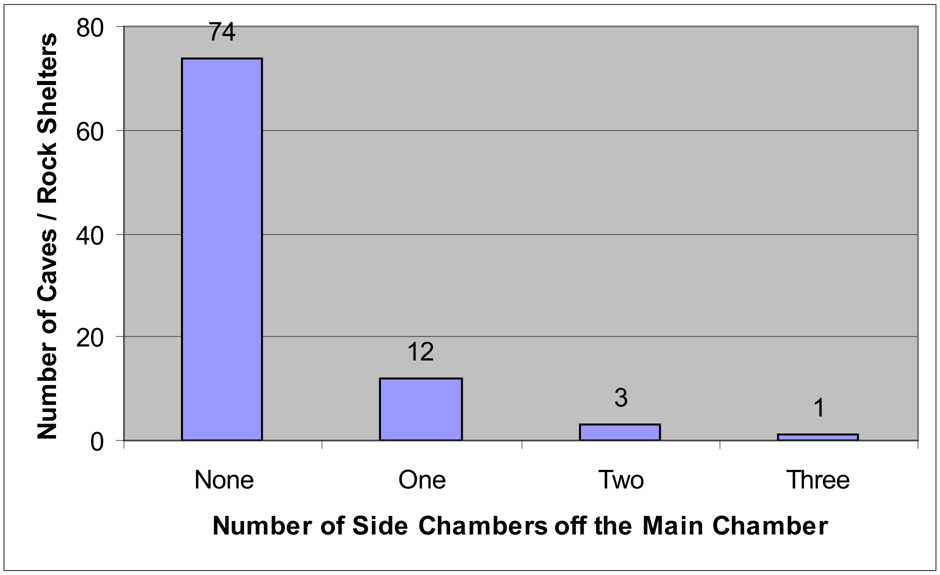

Figure 24. Number of chambers present off of the main entrance chamber (n=90).

Speleothems

An attempt was made to determine which types of speleothems, if any, are present in the caves in the survey area. Collectively, speleothems are calcium carbonate or calcium sulfate formations that form or are deposited in caves by the precipitation of solutes from seeping groundwater. Large, spectacular speleothems are an attraction to recreational and professional cavers, or spelunkers, and thus an attempt was made to note their presence in the White Mountains caves. Visually, the nature of the speleothem formations in the Limestone Gulch caves is less than fantastic; no caverns filled with large stalactites, columns, or large masses of flowstone were found. Succinctly, most of the caves in this area appear to be too active -in terms of active spalling of chunks of limestone from their walls and ceilings- for the creation of large, "impressive" speleothem formations, which can take millennia to form in relatively stable conditions.

Nonetheless, various forms of speleothems were noted in 45% (n=41) of the 90 caves examined (Figure 25). The most frequent of these were popcorn formations noted in 24 of the caves. Popcorn is small "knobbly" calcite formations on walls or ceilings. Small areas of flowstone were also noted in seven caves. Flowstone is probably the most common speleothem type, composed mostly of calcite or carbonate, and forms in growing, accumulating overlapping layers on a surface from the precipitation of actively flowing water. Five caves were noted as having moon milk deposits, which are smooth, milky white, often "bubbly" deposits that form mostly on cave walls. Boxwork, seen in three of the caves, are made from thin plates of calcite that develop out of cave walls and ceilings, forming a "honeycomb" or "box" pattern as the plates interconnect. A single instance of a two–inch long stalactite was noted in one cave; stalactites hang down from the ceilings of caves, and form when calcium carbonate and other minerals precipitate from dripping water. And lastly, one case of helictite formation was noted. This precipitate is formed when water is squeezed out of cracks in the rock, forming "bush-like" deposits projecting out of walls and ceilings.

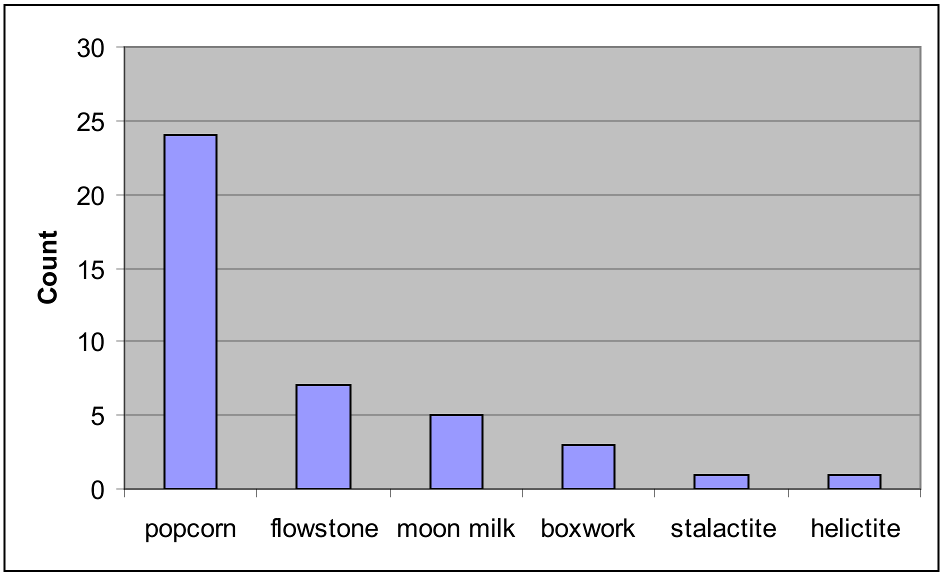

Figure 25. Numbers of caves with different types of speleothems.

Hydrology

Very little in the way of hydrological features were noted during the survey. Again, cave systems potentially attractive to spelunkers often have large, elaborate hydrological systems (e.g., underground streams/rivers, falls, etc.). However, only standing pools of water were noted in some of the caves in the White Mountains, and these were not fed by subterranean sources, but supplied instead from melted snow which accumulated during the winter months. None of these were very deep, measuring only in inches.

Biology – birds

The project was lucky to have personnel able to identify various live birds by sight and sound during many of the trips. Table 1 provides a listing of the birds that were positively identified during the surveys. In addition, 10 caves had one or more instances of direct evidence of live birds inside them or at their entrances. A number of nests were noted inside caves or directly at their entrances, including one Peregrine falcon's nest, one Townsend's Solitaire nest (with rotten eggs), two Say's Phoebe nests (one of which had two chicks and an unhatched egg), and two other unidentified species nests.

Table 1. Names of live birds noted during the survey.

COMMON NAME	LATIN NAME
American Robin	*Turdus migratorius*
Hermit Thrush	*Catharus guttatus*
Swainson's Thrush	*Catharus ustulatus*
Common Raven	*Corvus corax*
White Crowned Sparrow	*Zonotrichia cophrys*
Red-Tailed Hawk	*Buteo jamaicensis*
Tree Sparrow	*Spizella arborea*
Alder Flycatcher	*Empidonax alnorum*
Northern or Red-Shafted (common) Flicker	*Colaptes auratus cafer*
Peregrine Falcon	*Falco peregrinus*
Townsend's Solitaire	*Myadestes townsendi*
Say's Phoebe	*Sayornis saya*
Ruby-Crowned Kinglet	*Regulus calendula*
Bohemian Waxwing	*Bombycilla garrulus*
Violet-Green Swallow	*Tachycineta thalassina*
Gyrfalcon	*Falco rusticolus*
Varied Thrush	*Ixoreus naevius*
Gray Crowned Rosey Finch	*Leucosticte tephrocotis*
American Pipet	*Anthus spinoletta*

In addition, evidence of birds having been recently eaten or regurgitated were found on the surface or floor in five of the caves (Karst Features #33, 35, 37, 46, 65 and 81), including pellets and scat with bones and feathers. The following bird remains were identified by Kevin Winker, Curator of Ornithology at the University of Alaska Museum of the North. Among the remains on the floor of Karst Feature #33 was a partial avian humerus similar to a medium-sized duck (*Anseriformes*?) and a single rectrix or tail feather of a Lesser Yellowlegs (*Tringa flavipes*). The one bone found on the floor of Karst Feature #35 is a wing bone of a duck, most likely a smallish puddle duck (*Anatidae*). Those from the floor of Karst Feature #37 include 10 leg and wing bones of ptarmigans (*Lagopus muta, Lagopus lagopus*) and grouse (*Falcipennis canadensis, Bonasa umbellus*). None of the surface birds bones found in Karst Feature 46 were identified, and the owl pellet from the floor of this feature was not broken apart to determine its specific contents. An owl pellet with plastic and paper in it from the floor of Karst Feature #65 was noted in the field, but not collected. Last, a near-complete ptarmigan (*Lagopus* sp.) skeleton was collected from a small upper chamber of Karst Feature #81, on a small ledge about 3 m above the regular cave floor. Whether the animal flew in and died of its own accord, or else was a cached kill of a predator that never returned to its meal, is unknown.

Incidentally, two of the karst features had plastic and paper pieces associated with the surface remains, reflecting the inclusion of modern trash into this largely inaccessible ecosystem: the owl pellet from Karst Feature 65 has both plastic and paper embedded within it, and some small fragments of plastic were found on the floor of Karst Feature 46.

It should be mentioned that a host of bird bones were also recovered from within the tests pits dug inside of several of the caves; these remains are discussed separately under Paleontology, below.

Biology – mammals

There was no indication of bats (e.g., sightings, guano, bones, cave wall polishing) in any of the karstic features examined during this study. However, there was abundant evidence that other mammals are presently using the karst features in the Limestone Gulch vicinity. Of the 102 karst features located and recorded during the survey, 65% (n=66) had some evidence of present-day use by mammals; this total includes three of the 12 natural stone arches. As with the bird identification, discussed above, we were lucky to have survey personnel who could accurately identify various animal sign. Figure 26 presents the number of instances of different sign (i.e., mostly scat, but also including animal beds, fur, wall rubbings, and distinctive gnaw marks) of animals encountered in the karst features. In total, 120 different animal sign was noted; more than one animal sign was found in many of the features.

Not surprisingly, owing to the resident Dall's sheep (*Ovis dalli dalli*) population on the slopes of the White Mountains, sheep sign was the most prevalent animal sign noted, including 39 features where sheep scat was found. Nine of these also had sheep beds. A sheep metacarpal was also noted in one cave, apparently having been dug up by recent porcupine activity (see Paleontology*,* below). The bone was collected, but has not been radiocarbon dated. Scat from porcupines (along with recognizable porcupine gnawing and digging), marmots, bears, and wolverines was also found in the caves. Interestingly, nine of the caves also had current and relatively recent signs of bear dens in them, an item of potential interest to large-animal biologists.

In sum, the bear den caves are relatively small rooms with small entrances. Figure 22, above, includes the lengths of those caves where bear dens were located; eight of the nine bear den caves had greatest lengths of six meters or less. Likewise, Figure 27 presents the greatest width versus height for each bear den cave entrance. Contrasting this with Figure 23 (i.e., greatest width versus height for most caves in the study, n=89), above, we see that bear dens clearly fall within the small range of caves in the study area, with most of the entrances measuring smaller than 2.0 meters wide by 1.5 meters in height.

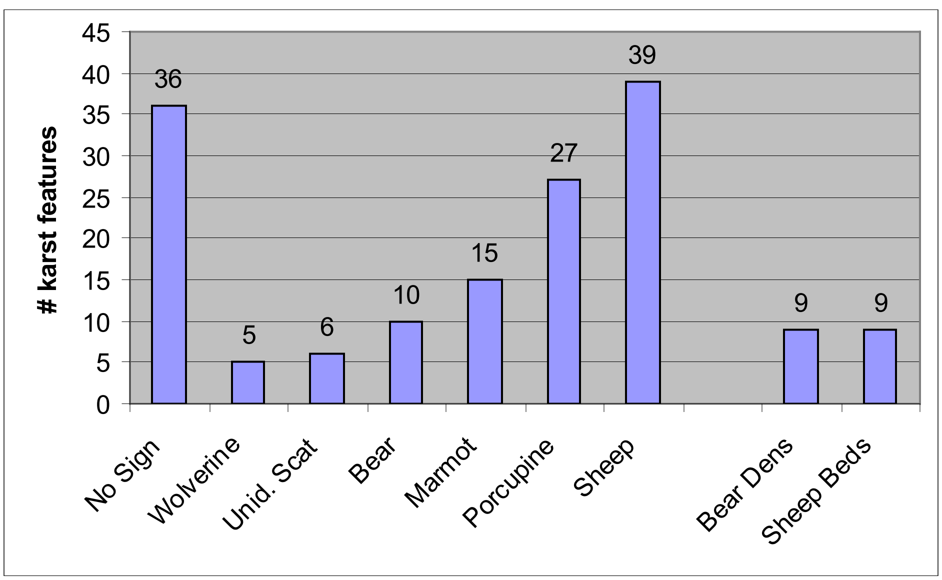

Figure 26. Numbers of instances of different types of animal sign. Sign was found in 66 karst features, totaling 120 instances of different animal sign recorded.

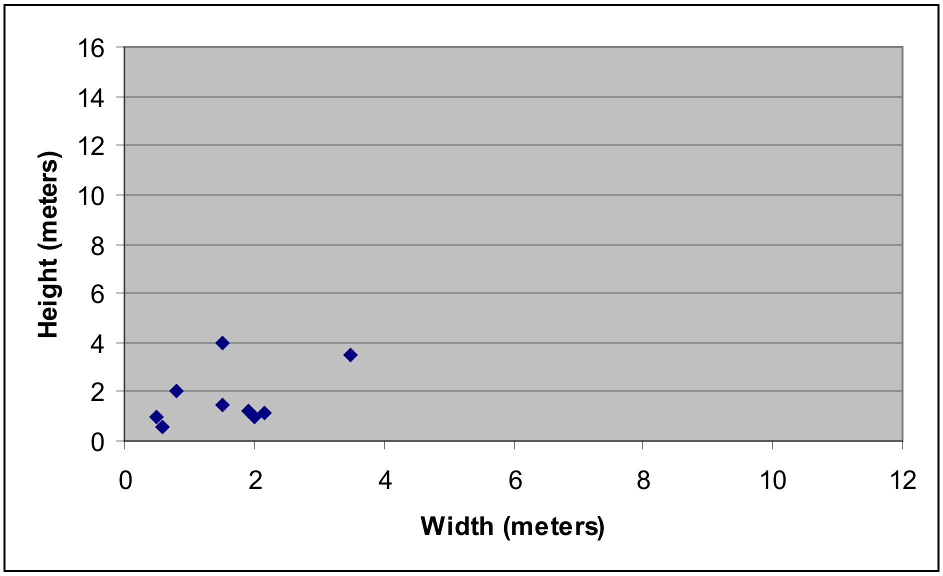

Figure 27. Cave / Rock shelter greatest width vs. height of mouths or entrances for those caves exhibiting bear dens (n=9).

In addition to the scat already referred to above, evidence of mammals having been recently eaten were found on the surface or floor in four of the caves (Karst Features #37, 46, 87, 92). Karst Feature #37 had the distal femur of a snowshoe hare (*Lepus americanus*), an unidentified microtine mandible, and about five small bone chunks of medium-large-sized mammals (e.g., sheep, caribou), including a rib fragment that has clearly been sawn through with a metal saw, this latter likely scavenged from a recent hunter's camp. Karst Feature #46, of which much more is written under Paleontology, below, had a few bones on the surface, including microtine mammal remains and a couple of metal-sawn medium-large mammal (e.g., sheep, caribou) bone fragments. Last, a medium-large mammal bone splinter was found on the surface of Karst Feature #87, and two on the surface of Karst Feature #92.

Archaeology

No prehistoric cultural artifacts were noted during the survey project, neither during the general reconnaissance for karst features, nor within and around the features themselves. Standard test pits (circa 35-40 cm diameter) were systematically dug inside the drip line of most caves encountered, specifically looking for buried cultural and paleontological materials. No cultural materials were located within any test pit. A few modern-day historic surface sites were noted during the survey, none of them historic in age (i.e., >50 years). These included a contemporary fire ring with some modern trash; likely a recent sheep hunter's camp.

Paleontology

As above, surveyors systematically attempted to dig one standard test pit (circa 35-40 cm diameter) just inside the drip line of all caves recorded. However, this could only be accomplished in 42 of the 90 caves encountered. Two main factors prevented test pits from being excavated in more than half of the caves encountered: (1) surveys carried out in May and early June (or later, in specific topographic settings) encountered frozen ground that was too frozen to be dug with hand tools, and (2) the active nature of spalling of limestone blocks from the walls and ceiling covered the present-day floor of many of the caves with thick layers of "roof fall". Regardless, of the 42 caves where test pits were excavated, four encountered buried faunal material: Karst Features #3, #34, #37, and #46.

In addition, paleontological, or potentially paleontological faunal materials were found on the floor or surface of two more of the caves examined, Karst Features #96 and #102. As explained below, these were likely originally buried materials that have been brought to the surface through natural taphonomic processes of contemporary animal digging. These six caves will each be discussed, next.

Karst Feature #3

This small cave measured 4 m maximum width by 8.5 m in maximum depth or length. The test pit in this feature reached a depth of only 30 cm and yielded a small collection of avian faunal remains. Dr. Kevin Winker, Curator of Ornithology at University of Alaska Museum of the North, examined the bird remains from this and all of the karst features in the survey, comparing them to UAM's bird faunal collections. Three of the elements were identified to genus or species. The first is a partial wing bone of a Spruce Grouse, Willow Ptarmigan, or Ruffed Grouse (*Falcipennis canadensis, Lagopus lagopus,* or *Bonasa umbellus*), the second is a lower leg bone of a Willow Ptarmigan, and the last is a wing bone of a duck, probably a mid-sized a dabbling duck (*Anas* sp.), which is a group of ducks that includes mallards, wigeons, teals, pintails and shovelers. No stratigraphic information was recorded by the surveyors; no identifiable microtine bones were excavated from the test pit; no radiocarbon dates have been run.

Karst Feature #34

This small cave measured only 1.5 m maximum width by 3.0 m in maximum depth. The test pit here measured 45 cm in depth. Numerous bird and small mammal bones, and about 10-20 small fragments of mammal bones from medium-large sized mammals (e.g., coyote, wolf, sheep, caribou) were found in the lower-most 30 cm of the test pit. The excavators described the stratigraphy as comprising dark brown "clay" (likely a silt or clayey silt) from top to bottom of the profile. The avian bones in the collection were examined by Dr. Kevin Winker, Curator of Ornithology at University of Alaska Museum of the North, who identified 12 of them to genus or species level, including three "legs" bones of a Rock Ptarmigan (*Lagopus muta*), three "hand" bone s of a ptarmigan (*Lagopus* sp.) or grouse (*Falcipennis canadensis* or *Bonasa umbellus*), a partial leg bone of a small duck (likely *Anas* sp.), a wing bone of a ptarmigan or grouse, a portion of a lower mandible of a ptarmigan or grouse, two partial wing bones of a ptarmigan (Willow most likely; *Lagopus lagopus*) or a grouse, and a partial wing bone of a passerine (songbird; *Passeriformes* sp.).

Jonathan Fiely, on the staff of the University of Alaska Museum of the North's Mammology Department, examined the microtine mandibles and cranial dentition, as studies have found that differences in dentition patterning can be used to differentiate the remains to genus and even species level. Comparative collections from UAM's Mammology Department were used. No attempt was made to identify other, post-cranial microtine faunal remains to genus or species. A total of 27 microtine mandibles and cranial dentition was indentified, including various voles (*Microtus* sp.; n=19), the North American Brown Lemming (*Lemmus trimucronatus;* n=2), an unidentified lemming (*Lemmus* sp.; n=1), and the Northern Red-Backed Vole (*Clethrionomys rutilus;* n=5). In addition, one snowshoe hare (*Lepus americanus*) distal femur was identified from the test pit. No radiocarbon dates have been run on any materials from this test pit.

Karst Feature #37

The test in this small cave, which was 10 m in maximum width by 4.0 m in maximum depth, measured 30 cm in depth. A relatively few bird and microtine mammal bones were found "near the base" of this test pit. The stratigraphy, from top to bottom, was described by the excavators as a uniform, largely non-organic silt. Only one bone from the test pit was identifiable: a leg bone of a Rock Ptarmigan (*Lagopus muta*). No radiocarbon dates have been run on any materials from this test pit.

Karst Feature #46

Karst Feature #46 – Description, by Robin O. Mills and Robert Sattler

This small "cave" or rockshelter is a fissure-expanded frost pocket that is sheltered above by a limestone outcrop (Figures 28-31). The shelter is relatively flat on the bottom and has a back chimney that rises to a small ledge approximately 3.5 m above the shelter floor. The chimney is not large enough for a person to climb through, but it appears that small animals can scamper onto a ledge that is up the chimney, which is 1 x 0.5 m in size (see hole above person's head in Figure 28). This same ledge also can and likely does serve as a raptor perch. Surface bones indicate that the same depositional processes that are occurring today also occurred in the past, as evinced from the abundant faunal remains found in the tests placed in this feature (see below). The surface bones include microtine mammal remains and a couple of metal-sawn medium-large mammal (e.g., sheep, caribou) bone fragments.

The interior of the shelter is intensively fractured and small clasts can be taken off of the wall in most of the shelter interior. Moss, and black and light green lichen grow on portions of the interior walls. Small circular vesicles appear along the limestone outcrop above the cave, as well as small solution pockets at the top of the chimney. Circular white lichens grow on the rock outcrop in abundance and are generally 1-5 cm in diameter. The inside texture of the limestone is very sharp; scalloped solution fractures on the interior surface are indicative of active spalling. However, there are in some places small popcorn speleothem growths indicating at least some degree of stability on some of the interior surface.

Figure 32 presents the floor plan of this small cave. The karst feature has an average width of about 50-60 cm and a maximum depth into the limestone of 2.2 m. The width at the mouth is about 1.2 m, and the height of the opening measures 2.5 m. About a meter in front of the dripline, the ground surface begins to drop in elevation. By about 2.5 meters in front, the increasing descent turns into a near-vertical drop of about 3-4 meters (Figure 29).

The original circa 45 x 60 cm test pit dug in 2003, placed at the dripline, uncovered hundreds of small bones from top to bottom (see Figures 31-32 for placement of the test pit). Most of the bones comprised birds and microtine mammals, but also included a few small fragments of larger bones from medium-large sized mammals (e.g., sheep and caribou-sized animals), as well as a few fish bones and even some mollusk remains. Many bones were picked out of the back dirt of the two main stratigraphic units that were recognized by the original surveyors in 2003 (i.e., an upper dark brown organic layer, and a lower gray layer). As mentioned above, one owl pellet and an assortment of small bones on the surface or floor of this feature indicate the droppings and meal remains of contemporary carnivorous birds and maybe small carnivorous mammals. It is likely that the same biological processes that resulted in these present-day surface remnants also occurred in the past, as exposed in the test pit.

Because of the rich nature of these deposits discovered in 2003, Alaskan quaternary paleontologist Robert Sattler and I returned to this cave in 2005, where we re-excavated the northern portion of the 2003 test pit. We screened all of the removed backfill from this test through a 1/8" mesh and collected two bags of faunal material: one bag of microtine mandibles and one bag of miscellaneous bones (i.e., avian; post-cranial microtine; small fragments of larger mammal bones). In addition, we also excavated a 13 x 20 cm column off of the north side of the original test (i.e., on the side away from the rear of the cave; Figure 33), and collected bulk matrix samples (soil and rock) and all faunal remains from the column in arbitrary increments *within* the three natural Stratigraphic Units noted in the column profile (see below). Although bedrock was not reached, excavation ceased when the blocky roof fall at the bottom of the pit became too large to excavate through with trowels.

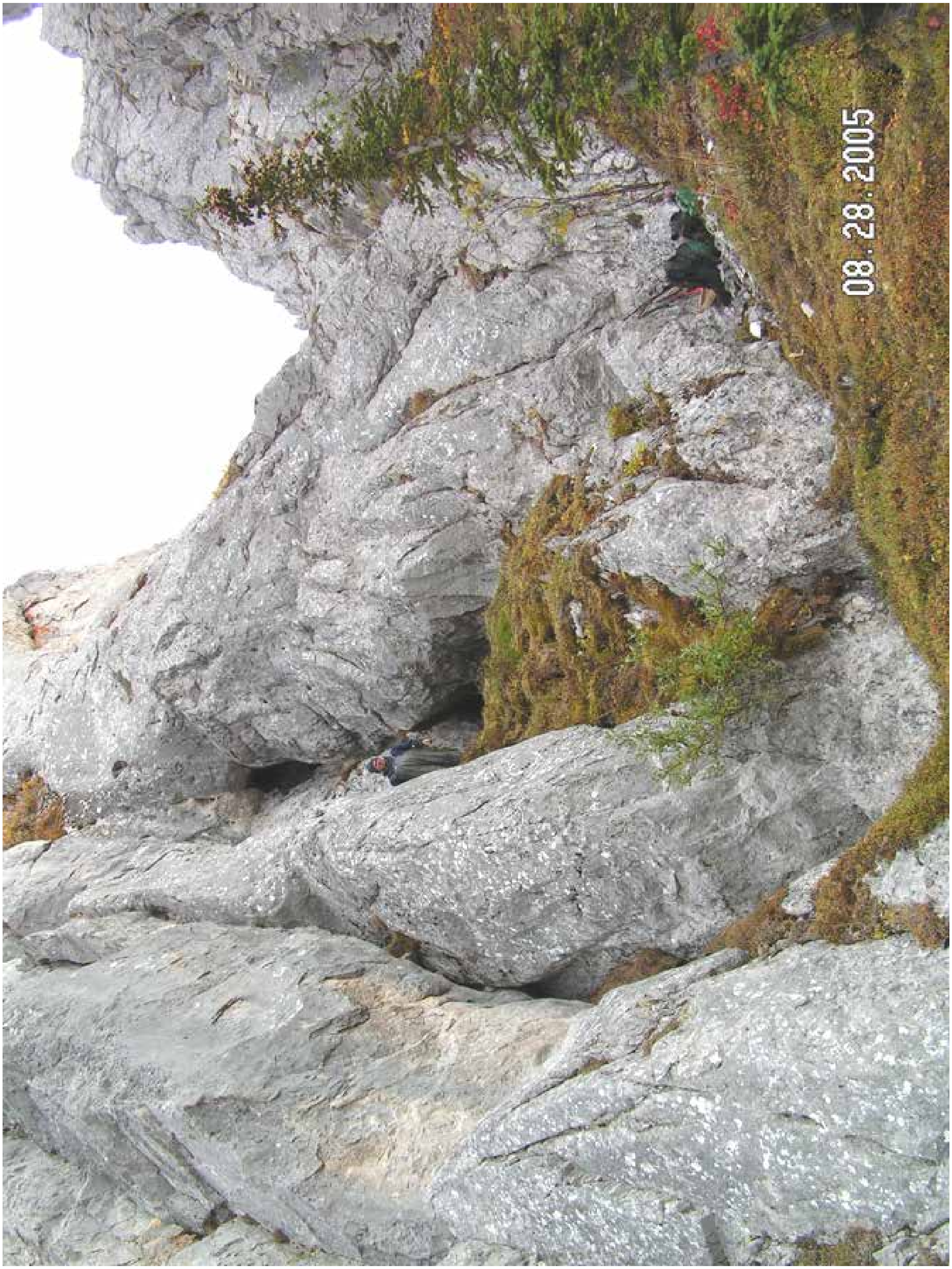

Figure 28. Karst Feature #46, immediately to the right of Robert Sattler, center of photo; Limestone Gulch region, WMNRA. Note the small cave or rock shelter is immediately right of Sattler, and the raptor perch above his head that, through a chimney, drops in to the back of the cave.

Figure 29. The steep slope directly in front of Karst Feature #46; Limestone Gulch region, WMNRA.

Figure 30. Karst Feature #46; Limestone Gulch region, WMNRA. Note the trowels in the ground in front of the mouth, for scale. The trowel with the brown wooden handle is centered in the test pit excavated in 2003.

Figure 31. Floor of Karst Feature #46; Limestone Gulch region, WMNRA. The trowel with the brown wooden handle is centered in the test pit excavated in 2003. The distance from the red-handled trowel to the back wall of the cave is only 2 meters.

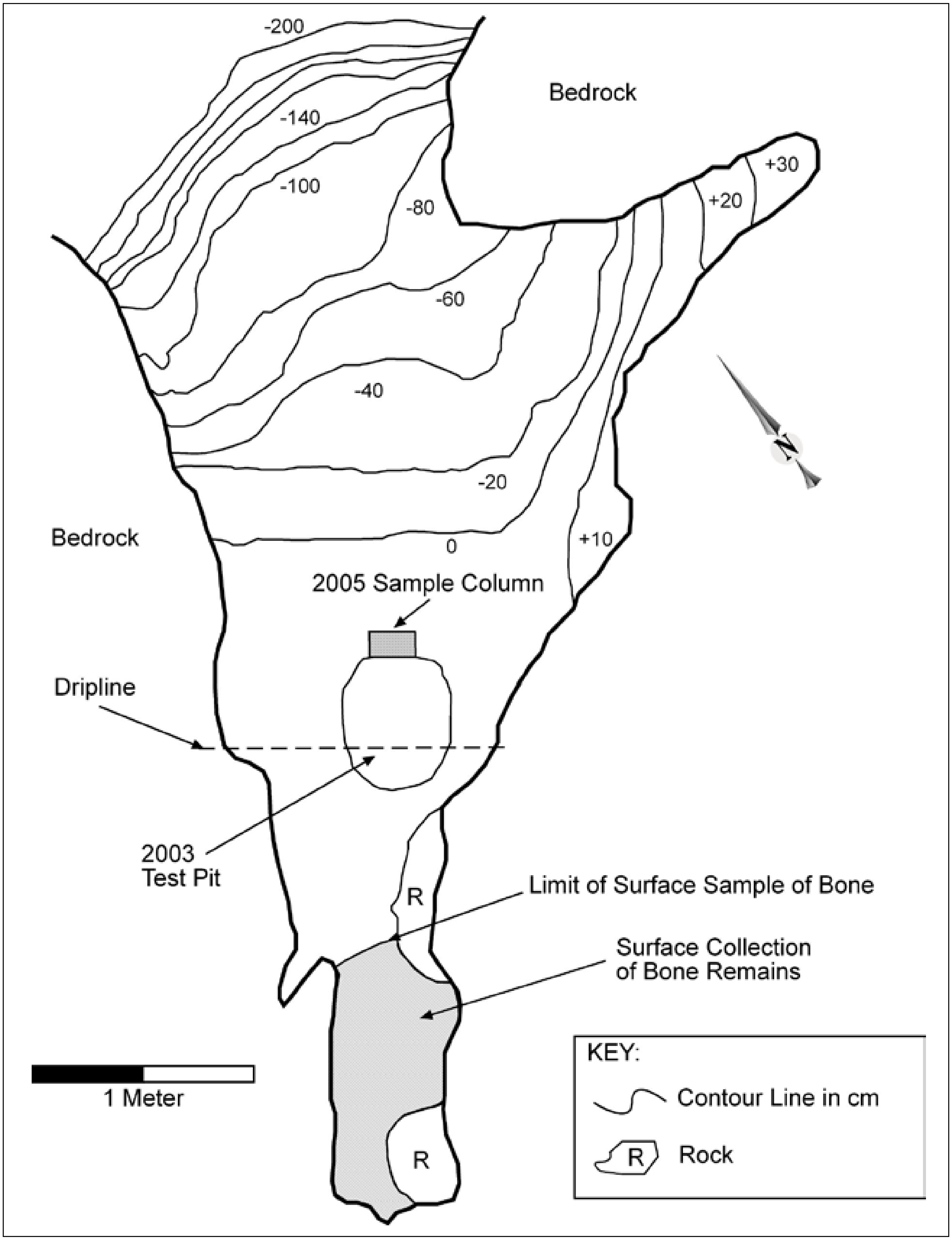

Figure 32. Floor plan view of Karst Feature #46 and area immediately to the north; Limestone Gulch region, WMNRA.

Figure 33. Karst Feature #46; Limestone Gulch Region, WMNRA. Robert Sattler in 2005 excavating a 13x20cm column off of the original 2003 test pit in this cave.

In our 2005 excavation column, we tried to excavate and collect using an arbitrary increment of 5 cm within the natural stratigraphy seen in the profile. This was largely successful in the upper part of the column, but became untenable the deeper we dug owing to the large, blocky nature of the rocks encountered, which accounted for most of the matrix in the lower portion of the pit. Thus, nine sample bags from this column were collected: Bag/Sample 1: 0-5 cm, Sample 2: 6-10 cm, Sample 3: 10-11 cm, Sample 4: 11-16 cm, Sample 5: 16-21 cm, Sample 6: 21-26 cm, Sample 7: 26-31 cm, Sample 8: 31-42 cm, Sample 9: 42-45 cm. As above, faunal materials and regurgitated owl pellets on the surface or floor of the cave from relatively recent biological activity were also collected, along with the faunal material screened from the backfill of the 2003 test pit.

Figures 34-35 present the stratigraphic profile of this excavated column. Three main Stratigraphic Units were described based upon the exposed 2005 excavated column profile:

Unit 1: 0-11 cm; includes Sample 1 (0-5 cm), Sample 2 (6-10 cm), and Sample 3 (10-11 cm); organic rich soil; dark brown organic breccia, organic silt with small angular stones; the sediment in Sample 3 contains more dense granules than the overlying 10 cm; although small animal bones were noted throughout the unit, they increase dramatically in Sample 3.

Unit 2: 11-26 cm; includes Sample 4 (11-16 cm), Sample 5 (16-21 cm), and Sample 6 (21-26 cm); less organic soil; dark gray breccia, silt/sand with larger lithic blocks (largest ca. 6-8 cm) than Unit 1; very abundant granules; abundant small animal bones were noted throughout the unit; the basal level (21-26 cm) is considerably more blocky, and seemingly more clayey than the rest of the unit; the boundary between Unit 2 and Unit 3 is a textural change.

Unit 3: 26-45cm; includes Sample 7 (26-31 cm), Sample 8 (32-42 cm), and Sample 9 (42-45 cm); seemingly more organic brown soil than Unit 2, more and larger limestone clasts and blocks, relative to Unit 2; a distinctive zone of clayey fine-grained fill is noted at 26-31 cm, with much less clasts and blocks relative to the remainder of the unit; below 31 cm there is a mass of relatively loose, unstable rubble with much less interstitial fine-grained sediment between the blocks; although small animal bones were noted throughout the unit, an increased abundance of them was noted at the base of the unit at 42-45 cm, relative to the rest of the unit; the spaces in between the larger blocks in this 42-45 cm level is dominated by small pebbles (1-2 cm) with very little fine interstitial sediment.

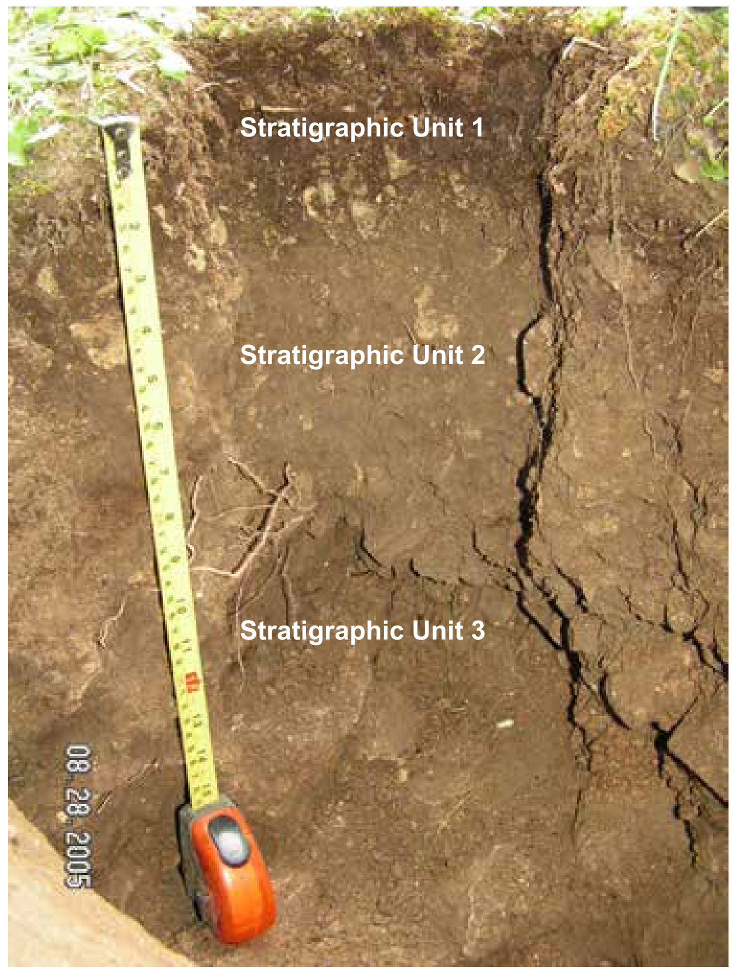

Figure 34. Stratigraphic profile of test pit column excavated in 2005 in BLM Karst Feature #46; Limestone Gulch region, WMNRA. The column, excavated off of the side of the 2003 test pit, is 20 cm wide and 45 cm deep.

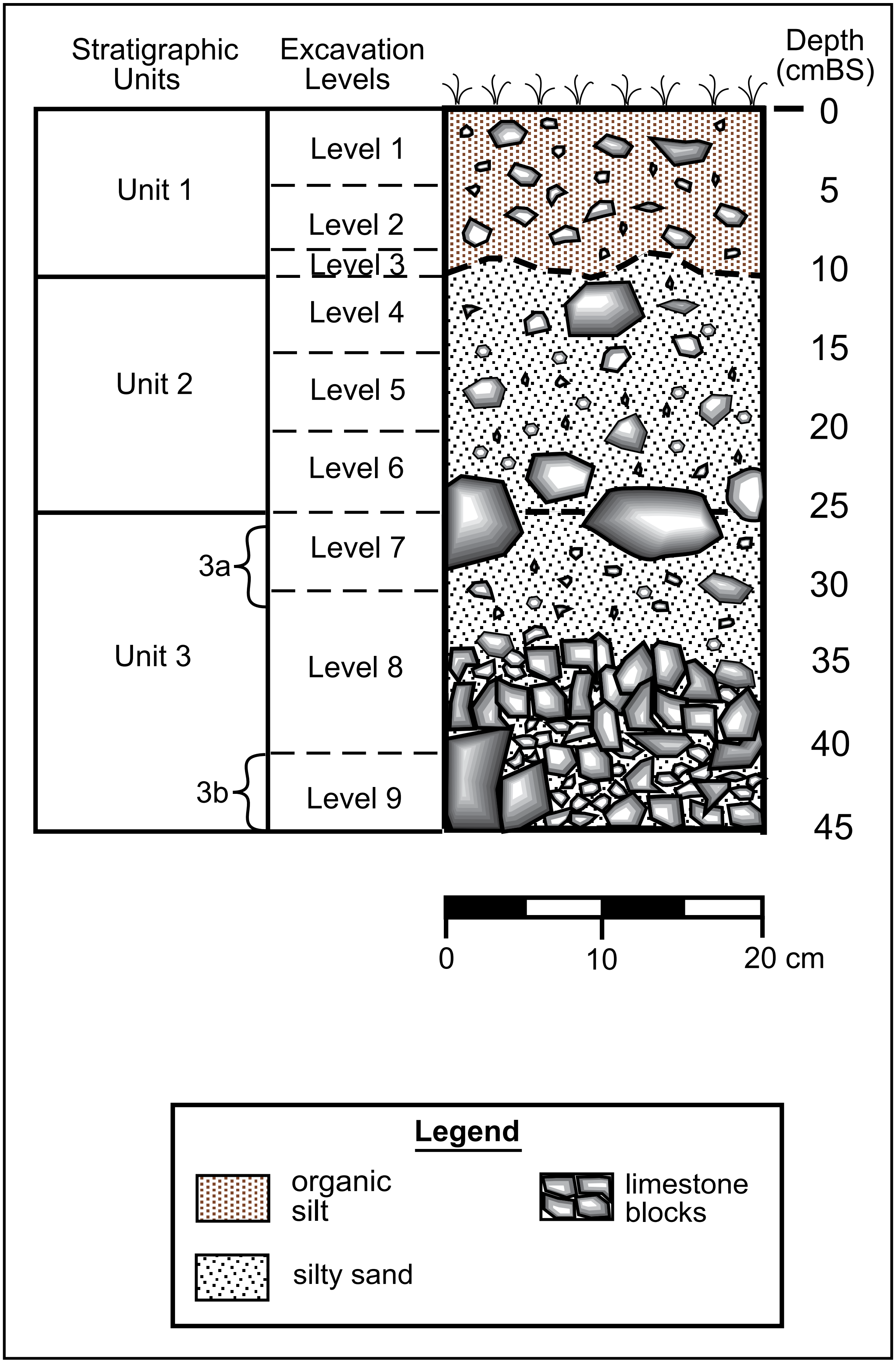

Figure 35. Schematic stratigraphic profile of test pit column excavated in 2005 in BLM Karst Feature #46; Limestone Gulch region, WMNRA.

Karst Feature #46 – Radiocarbon Dating

Four bone samples from the 2005 excavated column were submitted for radiocarbon dating, the results of which are provided in Table 2. Bone collagen was the material dated, and all assays are AMS (accelerator mass spectrometry) dates. The dating attempted to focus on the major natural stratigraphic breaks that were recognized in the field, those at 11 cm and 26 cm below the surface (see "Karst Feature #46 – Description", above). Thus, Beta-263573 was run on a bone from the 10-11 cm arbitrary level (Cal BP 3560), Beta-263574 came from the 21-26 cm level (Cal BP 9550), Beta-263575 came from the 26-31 cm level (Cal BP 7460), and Beta-263576 came the bottom-most 42-45 cm level (Cal BP 7600).

Although dating will be discussed further, below ("Karst Feature #46 – Discussion"), several things are immediately apparent from a quick perusal of the four dates. First and most obvious is the reversal witnessed with Beta-263574 (Cal BP 9550) from the 21-26 cm arbitrary level. As it is about 2000 years older than the date from the bottom-most 42-45 cm arbitrary level, and seeing as how there is no obvious reason to discount this AMS assay, it is reasonable to assume that some degree of mixing has occurred within these deposits in the past. An obvious candidate(s) for this mixing is past scraping or burrowing by animals, such as foxes, wolves, coyotes, or sheep. The degree of mixing or disturbance is presently impossible to extrapolate to the remainder of the cave's buried deposits.

Second, the two lower dates, Beta-263575 (Cal BP 7460) and Beta-263576 (Cal BP 7600), at the top and bottom of Unit 3, respectively, might at first appear to be too close together to account for nearly half of the buildup of the deposits in the stratigraphic profile. A closer examination of the profile, however, indicates what might be a rapid roof fall deposition event that accounts for most of Unit 3. If this mass of rubble actually represents a relatively rapid, *in situ* roof fall event (and not, say, a mound of pushed up debris from animal burrowing), then the two dates' closeness make sense and would, in fact, be anticipated.

And third, with the acceptance of Beta-263574 (Cal BP 9550) as a legitimate, non-contaminated date, albeit apparently displaced, then it would seem that most if not the entire Holocene record is represented in this cave's deposits.

Table 2. Radiocarbon dates from Karst Feature #46.

Beta ID	Sample Depth (cm)	Sample	Measured Radiocarbon Age BP	13C/12C Ratio (o/oo)	Conventional Radiocarbon Age BP*	Calibrated Intercept Date BP	Calibrated 1 Sigma (68%) BP	Calibrated 2 Sigma (95%) BP
263573	10-11	Small bone fragment; outer cortex of the bone of a small-medium sized mammal (~fox-caribou) or large bird; 0.24 g	3250 +/- 40	-20.8	3320 +/- 40	3560	3480-3600	3450-3640
263574	21-26	Same as Beta 263573; 0.56 g	8560 +/- 50	-21.4	8620 +/- 50	9550	9540-9560	9530-9680
263575	26-31	Same as Beta 263573, except bone fragment from a wolf-sheep-caribou sized animal; 1.99 g	6510 +/- 40	-21.4	6570 +/- 40	7460	7430-7500	7420-7560
263576	42-45	Same as Beta 263573; 0.39 g	6690 +/- 50	-20.7	6760 +/- 50	7600	7580-7660	7560-7680

Karst Feature #46 - Carbon Content and Pollen Analysis, by Nancy H. Bigelow and Robin O. Mills

Carbon Content and Pollen Analysis: Introduction and Methods

Nine samples collected from just inside the drip line of a BLM Karst Feature #46 were sub-sampled and analyzed for carbon content and pollen (see Karst Feature #46 – Description; above): Bag/Sample 1: 0-5 cm, Sample 2: 6-10 cm, Sample 3: 10-11 cm, Sample 4: 11-16 cm, Sample 5: 16-21 cm, Sample 6: 21-26 cm, Sample 7: 26-31 cm, Sample 8: 31-42 cm, Sample 9: 42-45 cm.

Carbon content was measured using Loss-On-Ignition (LOI), a technique that burns samples at 550° C and 850° C to measure organic and inorganic carbon, respectively. Prior to the analysis, the samples were dried for 60 hours in an oven at 85° C. The dried samples were then weighed before and after the burns, the weight loss indicates the amount of carbon in the sample.

% organic carbon = ((A-B)/A)*100
Where: A = dried sample weight (in grams)
B = sample weight after 550° C burn (in grams)

% inorganic carbon (as CaCO3) = ((B-C)/A)*100*0.44
Where: A = dried sample weight (in grams)
B = sample weight after 550° C burn (in grams)
C = sample weight after 800° C burn (in grams)

Sub-samples for pollen analysis were processed using standard techniques (sieving, 10% KOH, and 10% HCl washes) followed by heavy liquid separation (s.g. 2.0) and filtered with a fiberglass filter. The filter was then dissolved in hydrofluoric acid, the sample acetolized (2 minutes in a boiling water bath with acetic anhydride and sulfuric acid), washed in glacial acetic acid and water, and suspended in silicone oil (Faegri and Iversen, 1989; Moore et al., 1991). Pollen identifications were based on comparisons with published atlases (McAndrews et al., 1973; Moriya, 1976; Moore et al., 1991) and with the pollen reference collection housed at the Department of Geology and Geophysics at the University of Alaska Fairbanks.

Carbon Content and Pollen Analysis: Results and Discussion

Loss-On-Ignition of Karst Feature #46. Table 3 and Figure 36 present the results from the LOI analysis, with data provided by excavated level. Appendix 4 contains the raw LOI data. Samples collected within 11 cm (Stratigraphic Unit 1) of the surface had relatively high percentages of organic carbon (ca. 20-35%). Samples collected lower in the section (Stratigraphic Units 2 and 3) had much lower organic carbon content, about 10-15% or less. The relatively high organic carbon near the surface probably reflects both soil formation and perhaps wind deposition of plant material from outside of the rock shelter.

In contrast to the organic carbon, the inorganic carbon (as CaCO3) has the opposite distribution, with the lowest amounts in the top of the section (13%), reaching to more than 60% by the base. This pattern probably reflects a combination of carbonate dissolution from the surface sediments and redeposition deeper in the section and primary deposition of lithologic carbonate (i.e., rock spall) and bones within the section. The sieved fraction (>= 250 micron) of the pollen subsamples contain both bone and carbonate fragments from 10 cm and lower. Sub-samples from the top 10 cm contain primarily organic debris, with minor amounts of lithologic carbonate.

Table 3: Carbon content of samples from Karst Feature #46 (measured as loss-on-ignition), by excavated level.

Statigraphic Unit	Sample depth (cm)	Organic Carbon (%)	Inorganic Carbon (%)
Unit 1	0-5	35.6	13.6
	5-10	28.2	20.6
	10-11	20.1	30.7
Unit 2	11-16	13.0	45.8
	16-21	14.2	40.0
	21-26	12.0	44.5
Unit 3	26-31	12.6	42.2
	31-42	11.2	53.0
	42-45	7.4	61.4

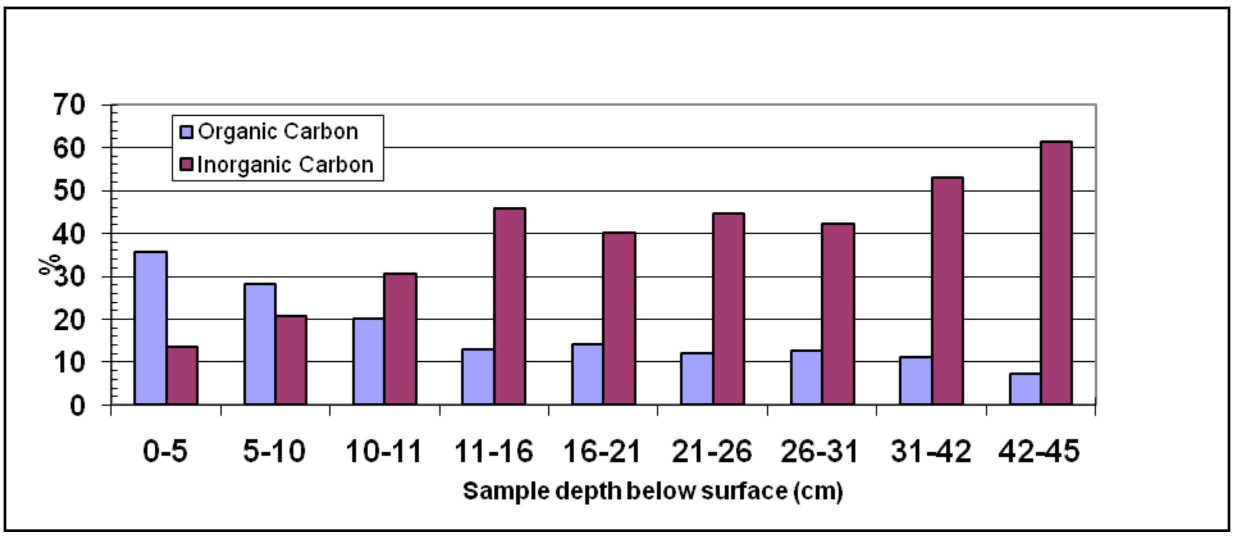

Figure 36. Carbon content of samples from Karst Feature #46 (measured as loss-on-ignition).

The LOI raw data for the individual levels were added together per Stratigraphic Unit (see Karst Feature #46 – Description, above), and the organic carbon and inorganic carbon percentages were recalculated. Figure 37 presents these results, which serve to highlight more clearly the data trends observed above regarding the decreasing amounts of organic carbon, and increasing amounts of inorganic carbon, found in the excavated column with increasing depth.

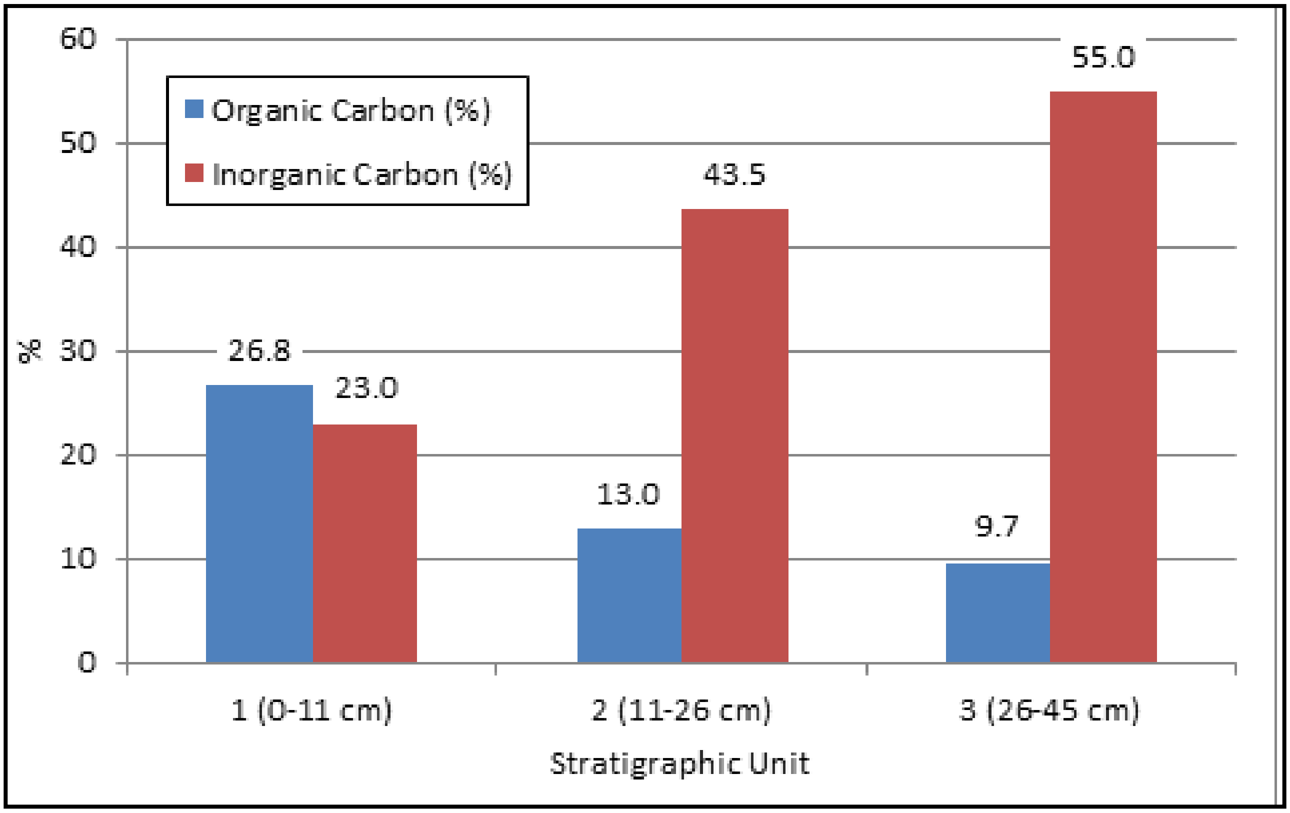

Figure 37. Carbon content of samples from Karst Feature #46 (measured as loss-on-ignition), by stratigraphic Unit.

Pollen Analysis. Appendix 5 contains the raw pollen data and percentages, both by excavation level and Stratigraphic Unit. Figure 38 presents all of the pollen and spore results by excavation layer, while Figures 39-40 focus specifically upon the pollen producers, with data grouped by Stratigraphic Unit. Pollen percentages in this analysis are calculated on two pollen sums. The percentages of trees, shrubs, and herbs are based on the sum of those taxa. This is the basic pollen sum. The percentages of all spore-producers are calculated on the sum of the spore-producers PLUS the sum of the trees, shrubs, and herbs. The reason for the two sums is to prevent the spore-producers from overwhelming the trees, shrubs, and herbs in the percent calculation.

Overall, the pollen and spore preservation in these samples was marginal. This is due to two main factors: mechanical wear on the pollen and spores during and after deposition, and repeated wetting and drying of the samples in a basic environment. Sporopollenin (the material forming the grain walls) is sensitive to high pH and most of the grains are somewhat- to highly degraded. The high indeterminable counts (up to nearly 40 per 100 identifiable tree, shrub, and herb grains) are due to this mechanical and chemical wear on the grains. On the whole, the pollen samples were difficult to count and for this reason the pollen counts stopped when at least 100 tree, shrub, and herb pollen grains were encountered.

The pollen results indicate that birch (*Betula*) and alder (*Alnus*) have been abundant in the region and were probably growing locally at Karst Feature 46 for the depositional history of the sediments. Salix is present but uncommon around the feature today, and the pollen data suggests this has been the case throughout the Holocene.

The spruce (*Picea*) pollen presents an interesting history, with its apparent local arrival within Stratigraphic Unit 1 (0-11 cm below surface). The consistent but low percentages (<10%) of spruce below Stratigraphic Unit 1 suggests it was growing in the region, but probably wasn't present right at the rock shelter. The post-glacial expansion of spruce in the interior dates to about 8000 to 9000 radiocarbon years ago (Anderson et al., 2004). Whether the spruce rise at Karst Feature #46 reflects the postglacial spruce expansion or whether spruce was a late arrival at the site is still unclear. However, a pollen analysis at Oops Lake on lower Fossil Creek in the White Mountain National Recreation Area (Finney and Krumhardt, 2004), only 3.7 miles (6 km) southwest of Karst Feature #46, suggests that spruce wasn't locally present there until after about 4800 radiocarbon years ago. These data are re-enforced by the Karst #46 data, where the base of Stratigraphic Unit 1 has provided a date of 3320 radiocarbon years ago (see Karst Feature #46 – Radiocarbon Dating, above).

The spore-producers provide additional insight into the vegetation around Karst Feature #46. For example, the spike moss (*Selaginella selaginoides*) prefers moist and open ground, especially calcareous soil.

The ferns are the most unusual aspect of the spore-producers. Fern spore frequencies in Holocene-aged lake cores of interior Alaska are rarely greater than 10% (Ager, 1975; Hu et al., 1993; Bigelow and Edwards, 2001). In fact, the fern frequencies seen in Karst Feature #46 are more similar to sites in southern Alaska, especially during the early Holocene (Peteet, 1991; Hu et al., 1995; Cwynar, 1990; Ager, 2000).

The high frequency of fern spores in the samples from Karst Feature #46 is partly explained by the difference in pollen depositional mechanisms in terrestrial sediments *versus* in lakes. The spores and pollen preserved in lakes reflects a higher proportion of the regional vegetation than they do in terrestrial sediments (Jacobson and Bradshaw, 1981). The reason is lakes collect pollen from inlet streams, surface run-off, and from the air. In contrast, the pollen preserved in Karst Feature #46 is mainly from the air, and perhaps from some internal run off. As a result, the pollen and spore data reflect a relatively high proportion of the vegetation growing just outside the rock shelter. After looking at photographs karst feature made during site visits, it appears that ferns are abundant at the entrance to the rock shelter today. The spore analysis indicates they have been growing there for the duration of sedimentation in the rock shelter, which according to the radiocarbon data seems to span most of the Holocene. While ferns are a diverse group of plants, all ferns prefer moist settings, indicating that water has not limited the vegetation at the rock shelter.

Lastly, a few *Encalypta*-type and *Botrychium* spores were also noted in some samples. *Encalypta* today is found on dry open settings while most *Botrychium* species are found on grassy slopes (Hultén, 1968; Brubaker et al., 1998); both probably grew (and perhaps do today) just outside the rock shelter.

The pollen analysis suggests the vegetation around the rock shelter was mainly a birch and shrub tundra with spruce trees present in the latter part of the record. The cave entrance has probably been well-covered by ferns for a long time, and the abundance of spores in general suggest water has been at least locally abundant for the duration of sediment deposition.

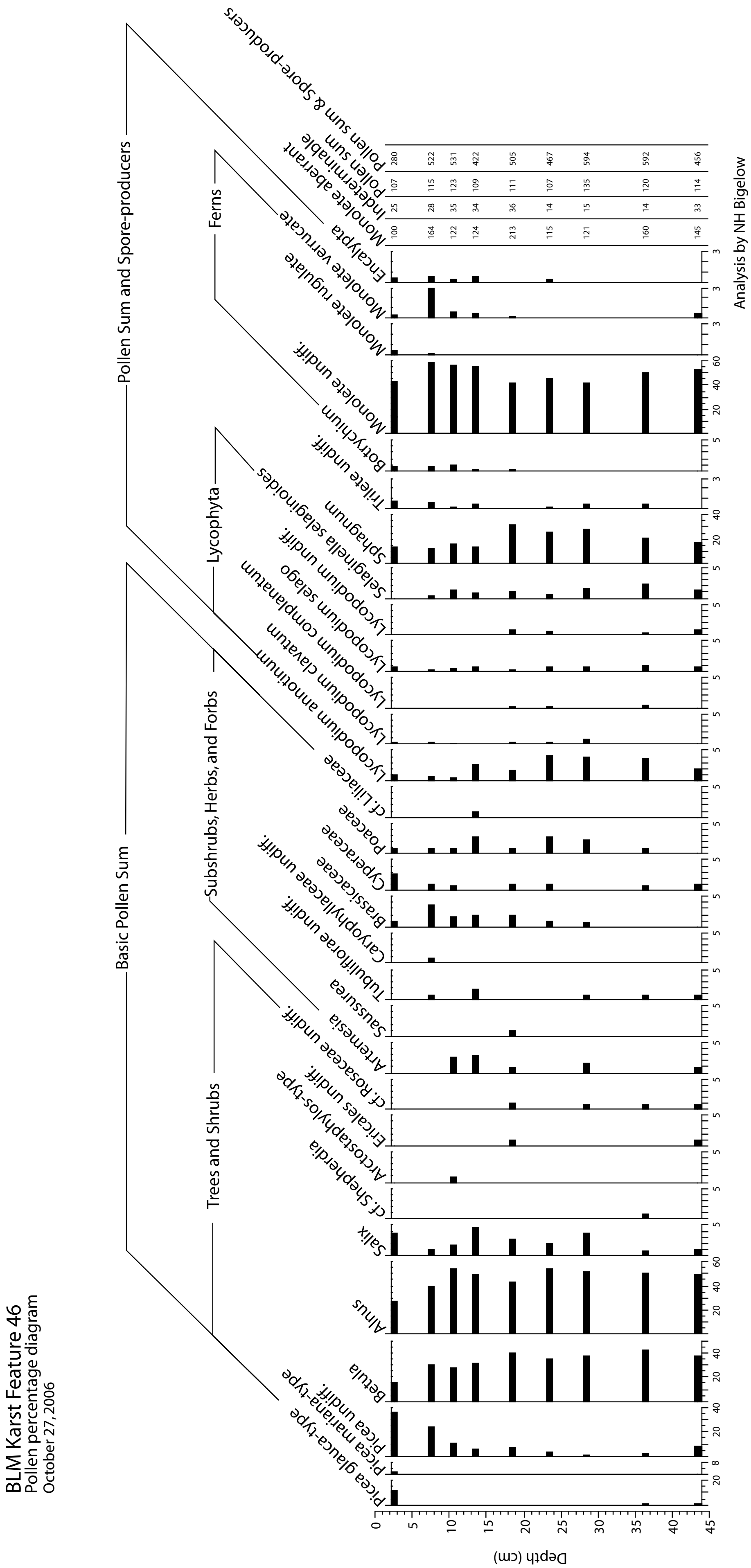

Figure 38. Pollen and spore percentage diagram for Karst Feature #46. Note scale changes with the minor taxa. See text for explanation of percent calculations.

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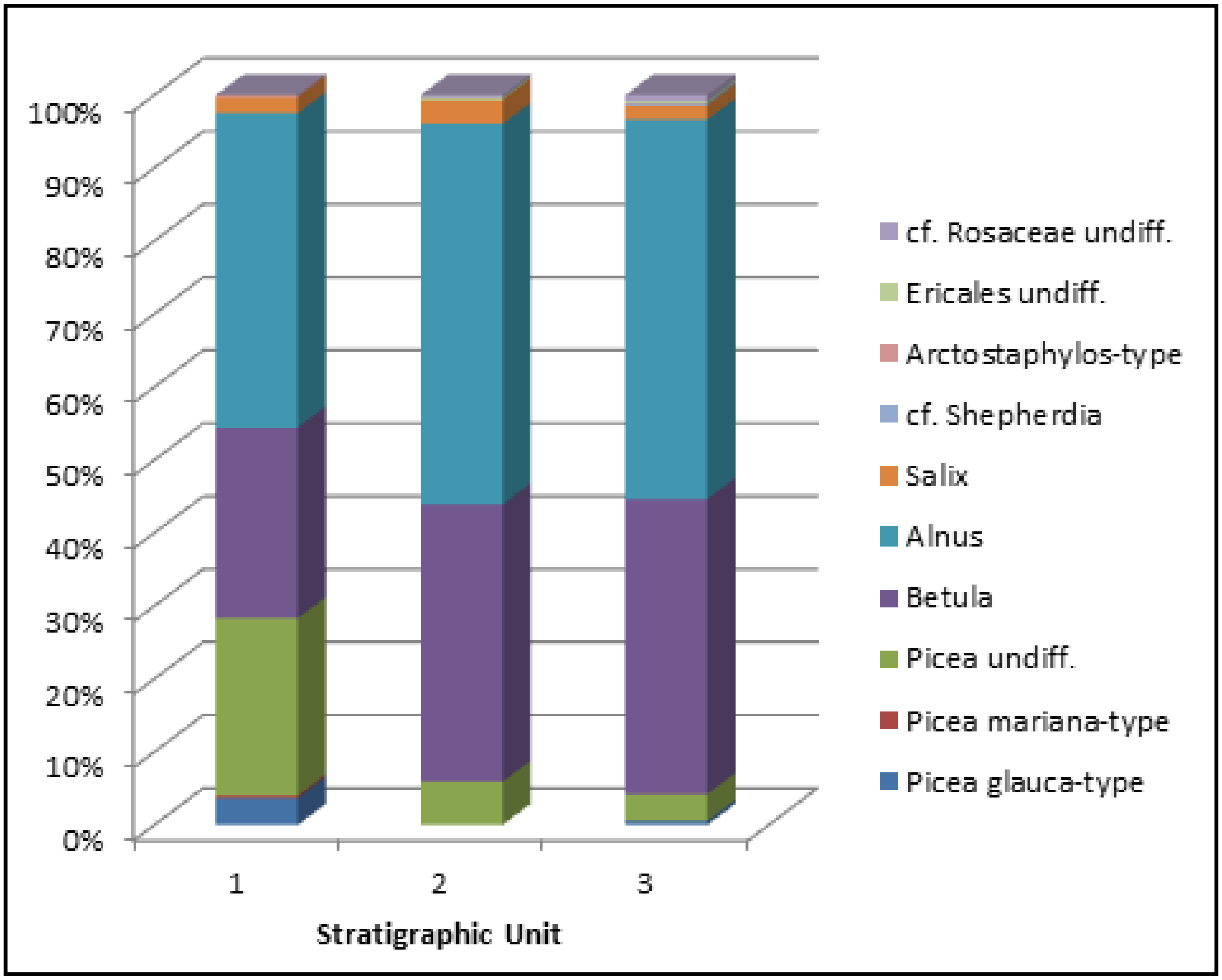

Figure 39. Pollen percentage diagram for Karst Feature #46, for trees and shrubs only, by Stratigraphic Unit. See text for explanation of percent calculations.

Karst Feature #46 – Mammalian Faunal Remains

Hundreds of skeletal elements of mammals were excavated from both the original 45 x 60 cm test pit dug in 2003, and the subsequent 13 x 20 cm column excavated in 2005. Bags of fauna from the 2003 test pit were collected from the two gross stratigraphic layers recognized by the excavators at that time: (1) an upper dark brown organic soil, corresponding to Stratigraphic Unit 1 (described above), and (2) from all of the underlying dark gray silt and jumbled limestone blocks below that layer, corresponding to Stratigraphic Units 2 and 3. Bags from the 2005 column, as explained above, were excavated, when possible, by 5 cm arbitrary levels within the three naturally occurring Stratigraphic Units that were recognized in the field. Because the 2005 material was excavated in a more controlled manner, I decided to focus our efforts on the faunal remains obtained from this column.

The overwhelming majority of the mammal bones from the column (and from the larger 2003 test pit, for that matter) are from microtine mammals. Jonathan Fiely, on the staff of the University of Alaska Museum of the North's Mammology Department, examined the microtine mandibles and cranial dentition, as studies have found that differences in dentition patterning can be used to differentiate the remains to genus and even species level. Comparative collections from UAM's Mammology Department were used. No attempt was made to identify other, post-cranial microtine faunal remains to genus or species. The results are found in Table 4, and illustrated in Figure 40.

In total, 118 cranial and mandibular dentition sets were identified to either genus or species. The majority (74; 63%) could only be identified to the genus *Microtus* spp. (i.e., an assortment of voles). Other identified species include the Northern Red-Backed Vole (*Clethrionomys rutilus*) (30; 25%), the North American Brown Lemming (*Lemmus trimucronatus*) (13; 11%), and the Northern Bog Lemming (*Synaptomys borealis*) (1; 1%).

For purposes of discussion, I will assume several things in regards to the microtine data. (1) I will assume that most if not all of the remains are the results of meals from, most likely, raptors roosting above the rockshelter floor (see Karst Feature #46 – Description, above). This process continues today, as a host of small animal bones and one owl pellet were found on the present-day surface, along with bird whitewash on the walls. (2) I will assume that predators have grabbed a representative sample of microtines from the landscape surrounding the vicinity of Karst Feature #46 over time. (3) I will assume that the deposits are not *overly* mixed from past taphonomic activities, so that they retain some measure of stratigraphic integrity. (4) I assume that my sample size is large enough to be representative of past dynamics. In sum, if we assume these conditions, then there appears to have been little change in the microtine species composition in the general vicinity of Karst Feature #46 over most of the Holocene.

By combining the data from the separate excavation levels into the three Stratigraphic Units outlined above (Figure 41), the data *may* indicate an increased presence of *Lemmus trimucronatus* and *Clethrionomys rutilus* relative to the *Microtus* species during the latter part of the Holocene. Here, we see the percentage of *Microtus* in the samples dropping from 66% and 62% of samples in Stratigraphic Units 2 and 3, to 50% of the samples in Stratigraphic Unit 1. Unfortunately, the numbers of identified specimens in Stratigraphic Unit 1 is quite small (n=15), and may not be statistically reliable.

Table 4. Identified microtine cranial and mandibular dentition from the soil column excavated in Karst Feature #46 in 2005, by excavation level (NISP). (*Includes one *Microtus oeconomus*, or the Tundra or Root Vole. All remaining *Microtus* remains were identified as *Microtus spp.*).

	Microtus (various voles)	*Lemmus trimucronatus* (North American Brown Lemming)	*Clethrionomys rutilus* (Northern Red-Backed Vole)	*Synaptomys borealis* (Northern Bog Lemming)	
Surface	1				1
0-5 cm	1	1	1		3
5-10 cm	5*	3	1		9
10-11 cm	1		1		2
11-16 cm	14	5	4		23
16-21 cm	9		5		14
21-26 cm	12		4		16
26-31 cm	8	1	4		13
31-42 cm	10	2	4		16
42-45 cm	13	1	6	1	21
	74	13	30	1	118

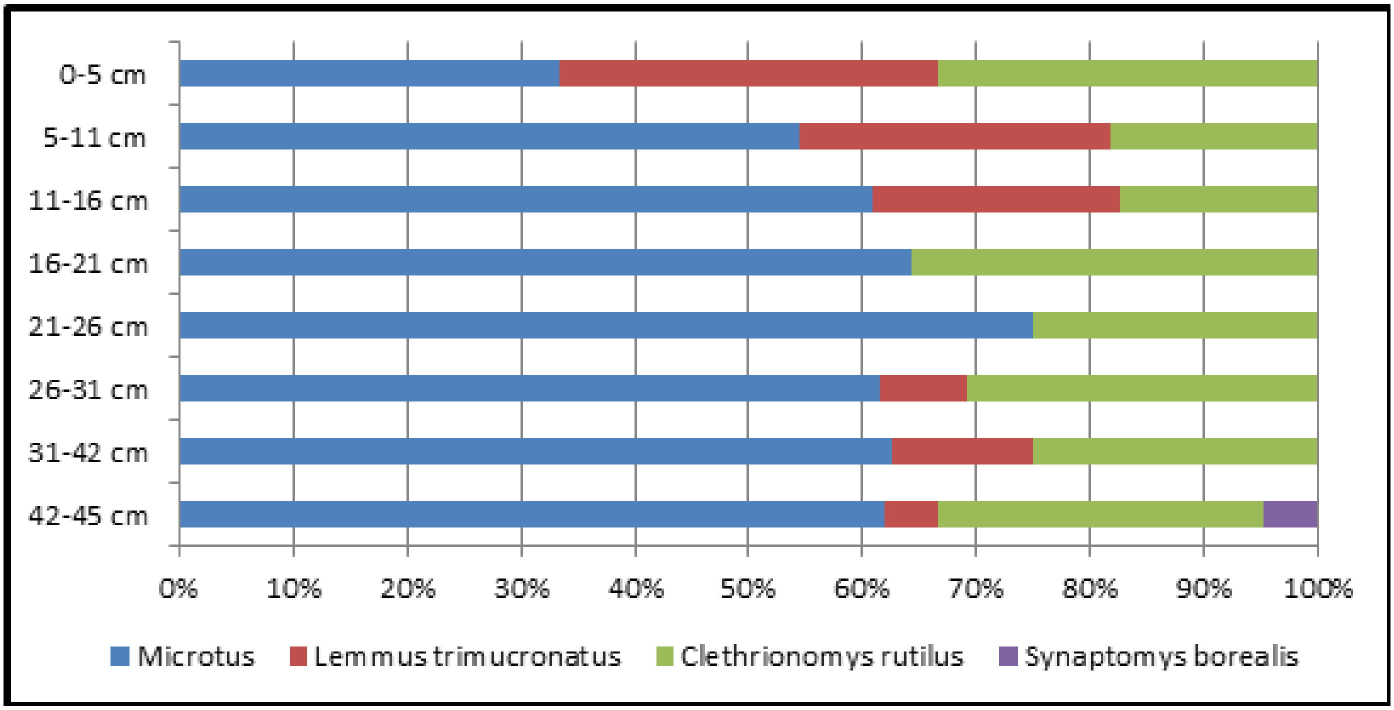

Figure 40. Identified microtine cranial and mandibular dentition from the soil column excavated in Karst Feature #46 in 2005, by excavation level (percentages).

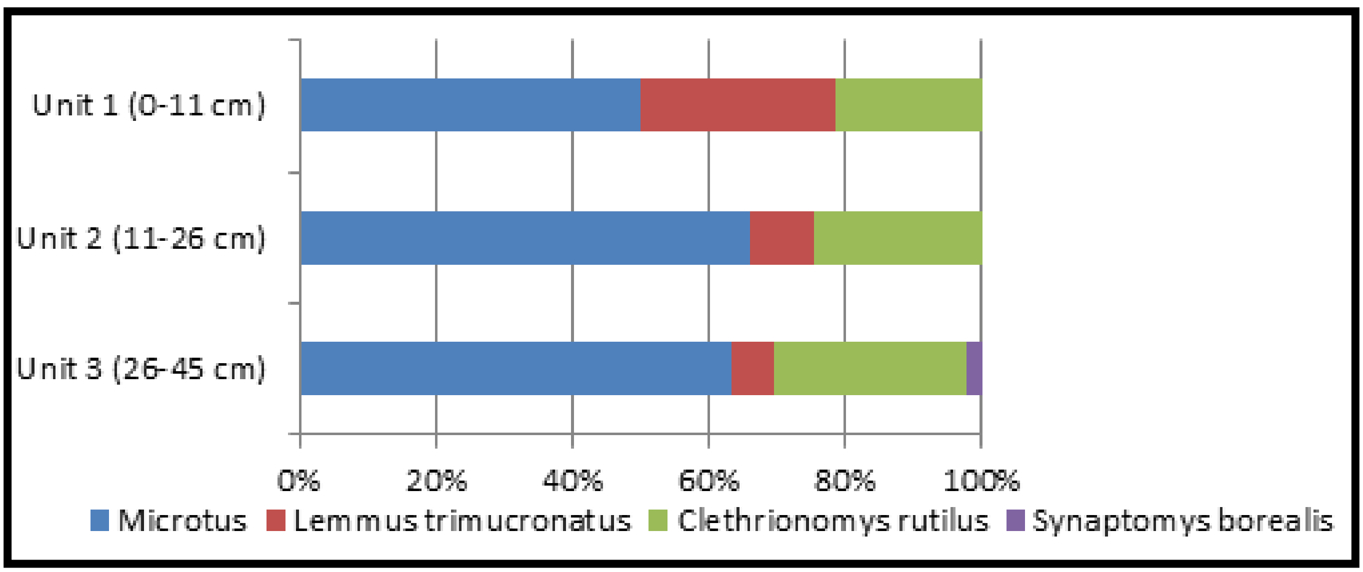

Figure 41. Identified microtine cranial and mandibular dentition from the soil column excavated in Karst Feature #46 in 2005, by stratigraphic Unit (percentages).

The known range of all present species of *Microtus* in Alaska includes the White Mountains, except for the St. Matthew Island Vole (*Microtus abbreviates*) which is found only on Hall and St. Matthew islands in the Bering Sea. These others include the Long-tailed Vole (*Microtus longicaudus*), the Meadow Vole (*Microtus pennsylvanicus*), the Singing Vole (*Microtus miurus*), the Tundra Vole (*Microtus oeconomus*), and the Yellow-cheeked Vole (*Microtus xanthognathus*). The ranges of each of these species are quite widespread and found throughout large swaths of North America or around the circumpolar north, and found in a diverse array of ecological niches and habitats (http://www.iucnredlist.org; http://en.wikipedia.org).

Lemmus trimucronatus is found throughout the entire interior of Alaska and the North Slope, inhabiting arctic tundra or subarctic alpine tundra above tree line. It is also a widespread species, found throughout much of northern North America and Asia. Similarly, *Clethrionomys rutilus* is found all over the interior of Alaska, excepting the extreme North Slope well above the Brooks Range, and is typically found in northern shrub vegetation, most forest types found in the Alaskan interior, tundra settings, as well as rock fields and talus slopes. Last, *Synaptomys borealis* is found throughout most of central interior Alaska, much of Canada, and into the northern United States, inhabiting wet northern forests, bogs, tundra and meadows (http://www.iucnredlist.org; http://en.wikipedia.org).

Even if the decrease in relative amount of *Microtus* during the late Holocene is an accurate reflection of past biological populations, the habitats of most if not all of the species found in the test unit largely overlap. For instance, it is not as if some microtines only inhabit ranges that today are found north of, or south of, their present-day range. Such data would indicate different landscape conditions than those found today. Unfortunately, that does not appear to be the case. The microtine data presented here appear to be too coarse-grained to serve as a proxy for assessing ecological changes throughout the Holocene.

In addition to microtines, other mammalian faunal remains were found in the 2003 test pit and 2005 column. The majority of these are small, unidentified long bone shaft fragments derived from unidentified medium-large sized mammals (e.g., sheep, caribou) of unknown maturity. Such fragments were used to procure the radiocarbon assays for this rockshelter. In addition, two elements were extracted from *in situ* deposits in the sidewall of the 2005 excavated column: (1) a complete tooth with root of either a marten (*Martes Americana)* or mink (*Mustela vison*) was found at 22 cm below surface, and (2) a distal portion of a second phalanx of a caribou (*Rangifer tarandus*) was found at 29 cm below surface.

Karst Feature #46 – Avian Faunal Remains

Hundreds of skeletal elements of birds were excavated from both the 2003 test pit and the 2005 13 x 20 cm column, in the same manner as described above for the mammalian fauna. As above, I decided to focus our efforts on the avian remains from the tightly controlled column excavated in 2005. Dr. Kevin Winker, Curator of Ornithology at University of Alaska Museum of the North, examined the bird remains, comparing them to UAM's bird faunal collections. Many remains could not be identified to genus or species owing to the fragmentary nature of the assemblage, and to the fact that some avian skeletal elements have not been found to be diagnostic to species. The results are found in Table 5.

All of the identified remains, with the exception of one bone, come, or likely come from only three prey species: Rock Ptarmigan (*Lagopus muta*), Spruce Grouse (*Falcipennis canadensis*), and Ruffed Grouse (*Bonasa umbellus*). The sole exception is a tarsometatarsus of a Northern Hawk Owl (*Surnia ulula*) found in excavation level 10-11 cm, at the bottom of Stratigraphic Unit 1. The ptarmigan and grouse elements are found throughout the column, in no apparent pattern of increasing or decreasing occurrence. Based upon the avian and the radiocarbon data, little more can be said except that ptarmigan and grouse were available and fed upon for much of the Holocene in the general area of Karst Feature #46.

Table 5. Identified avian fauna from the soil column excavated in Karst Feature #46 in 2005, by excavation level (NISP). (*Alaska Biological Survey, Inc. Forensic Services, Case 0901).

Stratigraphic Unit	Excavation Level	ABSR No.	ID	Scientific Name
Unit 1	0-50 cm	5	“hand” bone of a ptarmigan	Lagopus sp.
Unit 1	0-50 cm	6	“hand” bone of a ptarmigan	Lagopus sp.
Unit 1	0-50 cm	8	partial coracoid of a ptarmigan (probably) or a Ruffed Grouse	Lagopus sp. or Bonasa umbellus
Unit 1	5-10 cm	7	metacarpal bone of a ptarmigan or Spruce Grouse	Lagopus sp. or Falcipennis canadensis
Unit 1	5-10 cm	9	partial femur of a ptarmigan (probably) or a grouse	Lagopus sp. or Falcipennis or Bonasa
Unit 1	5-10 cm	10	partial tarsometatarsus of a Spruce Grouse or possibly Ruffed Grouse	Falcipennis canadensis or Bonasa umbellus
Unit 1	5-10 cm	11	part of an ulna of a galliform, probably ptarmigan but could be Ruffed Grouse	Lagopus sp. or Bonasa umbellus
Unit 1	5-10 cm	12	“hand” bone of a ptarmigan	Lagopus sp.
Unit 1	5-10 cm	13	upper end of a leg bone of a grouse or ptarmigan	Falcipennis or Bonasa or Lagopus
Unit 1	5-10 cm	14	tip of a lower mandible of a grouse or ptarmigan	Falcipennis or Lagopus
Unit 1	5-10 cm	15	“hand” bones of a galliform, likely a ptarmigan (mni = 2)	Lagopus sp.
Unit 1	10-11 cm	2	tarsometatarsus of a Northern Hawk Owl	Surnia ulula
Unit 1	10-11 cm	3	“hand” bone of a ptarmigan or grouse	Lagopus sp. or Falcipennis canadensis
Unit 1	10-11 cm	4	“hand” bone of a galliform, probably ptarmigan but possibly a grouse	Lagopus sp. or Falcipennis or Bonasa
Unit 2	11-16 cm	16	distal end of a fibula of a grouse or ptarmigan	Lagopus sp. or Falcipennis canadensis
Unit 2	16-21 cm	17	partial pelvis of a ptarmigran or grouse	Lagopus sp. or Falcipennis canadensis
Unit 2	16-21 cm	18	partial leg bone of a grouse or ptarmigan	Bonasa umbellus or Lagopus sp.
Unit 2	21-26 cm	19	partial leg bone of a ptarmigan (probably Rock) or, less likely, a Spruce Grouse	Lagopus muta (probably) or Falcipennis canadensis
Unit 2	21-26 cm	20	tarsometatarsus of a ptarmigan, probably Rock Ptarmigan	Lagopus muta (probably)
Unit 2	21-26 cm	21	partial leg bone of a grouse or ptarmigan (closest to Ruffed Grouse)	Bonasa umbellus or Lagopus sp.
Unit 3	26-31 cm	22	leg bone of a ptarmigan, probably Rock Ptarmigan	Lagopus muta
Unit 3	26-31 cm	23	partial lower mandible of a ptramigan or grouse	Lagopus sp. or Falcipennis or Bonasa
Unit 3	31-42 cm	24	partial coracoid of a ptarmigan or grouse; closest to Rock Ptarmigan	Lagopus muta (probably) or Falcipennis or Bonasa
Unit 3	31-42 cm	25	partial carpometacarpus (wing bone) of a Spruce Grouse or a ptarmigan	Falcipennis or Lagopus
Unit 3	31-42 cm	26	partial ulna (wing bone) of a ptarmigan, probably Willow Ptarmigan	Lagopus lagopus (probably) or a large L. muta
Unit 3	42-45 cm	27	partial distal wing bone of a ptarmigan or grouse	Lagopus sp. or Falcipennis or Bonasa
Unit 3	42-45 cm	28	partial distal wing bone of a grouse or ptarmigan	Bonasa umbellus or Lagopus lagopus
Unit 3	42-45 cm	29	partial tarsometatarsus of a Rock Ptarmigan (probably), or small Willow Ptarmigan or a grouse	Lagopus muta (probably) or L. lagopus or Falcipennis or Bonasa

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Karst Feature #46 – Other Faunal Remains

In addition to the mammalian and avian skeletal remains discussed above, other faunal remains were found in the original 2003 test pit, including two mollusk bivalve shell remains (Dr. Nora Foster; personal communication 2011) and a few fish remains. The shell fragments have not been further identified to genus or species. The fish elements, including vertebrae, cranial fragments, scales, and a portion of a soft fin ray, were identified and examined by Dr. Andres Lopez, Curator of Fishes at the University of Alaska Museum of the North in Fairbanks (personal communication 2011). He indicates that the remains likely belong to northern pike (*Esox lucius*). Although a conclusive identification was not possible, he points out that most other Alaskan freshwater fishes can be ruled out, and that the remains are definitely not from a species of Pacific salmon. A minimum number of only one fish is present.

Karst Feature #96

In the spring of 2001, Tim DuPont, one of BLM's Outdoor Recreation Planners, found a bone on the inside surface of a small cave in Limestone Gulch. The bone is a worn *Bison* sp. right lunate, or intermediate carpal. I identified the bone using mammalian comparative collections at the University of Alaska Museum of the North, where the bone is now accessioned (UAMES2009.013.ESCI, Bag 27a). Then-Alaska Quaternary Center director and paleontologist Dr. Paul Matheus concurred with this identification (personal communication 2002), and extracted a sample for dating. The sample was radiocarbon dated in January 2002 by the NSF-Arizona Accelerator Mass Spectrometry Laboratory, at the University of Arizona, which returned a date of 13,300 +/-160 (uncal C14 age BP; AA44530; C13 ratio -20, F 0.1909+/-0.0038). This bone dates to about 15,500-16,000 calendar years BP. DuPont found and returned one other large-mammal bone from the surface of the cave in 2001; more on this bone, below. I returned to the cave in July 2002 with quaternary paleontologist Robert Sattler for a more detailed description and analysis.

The cave is near the top of the southern-most ridge of the two parallel ridges that form Limestone Gulch. The mouth of this nearly directly north-facing cave is 1-2 m wide, and 3-4 m tall. It has a wide view over the valley floor in between the two parallel ridges that form Limestone Gulch, although much of this view is partially obstructed by a large standing rock down slope from the cave mouth. This cave is a relict solution feature.

After passing southward through the mouth and into the cave, the area widens into an "antechamber" about 1.5 m wide (E-W) by about 1.5 m depth (N-S). See Figure 42 for both plan and side views of the cave. The floor of the antechamber is covered with loose gravelly roof fall or scree (<1 cm pieces), which forms a roughly 10 cm thick layer on the antechamber floor. Underlying the scree is a saturated coarse sandy silt/clay. After passing through the mouth, there is a small "side room" off of the antechamber, extending about 2 m in length to the ENE, and measuring about 50 cm wide and a maximum of 1 m in height. Scree also covers the floor of this "side room".

After entering the "antechamber", you can proceed further into the cave, southward, by either crawling under or climbing over a rock arch, which leads south into a "back room". This "back room" measures about 5 m in depth/length (N-S), and about 2 m wide at its northern end immediately next to the "arch". The chamber's floor width tapers to roughly 50 cm at its rear or southernmost extent.

A test pit placed in the middle of the "back room" revealed frozen sediment at a depth of only 5-7 cm below the surface, even during the height of the summer. The surface sediments consist of coarse blocks of roof fall and breccia that is believed to be backfill from an animal excavation in the fill at the back of the chamber. Below this coarse surface deposit is a thin layer of smaller, more sorted pebbles most of which are approximately 1 cm in diameter. Below the two stratigraphic units of angular blocky limestone clasts is a distinctive silty clay with limestone granules and small pebbles. The upper couple of centimeters of this unit was thawed and saturated. This unit was sampled for sediment analysis. While excavating the test pit, Sattler found and collected three large-mammal bone fragments on the surface of the coarse blocks of roof fall and reworked breccia. One of these three bones is a longbone diaphysis fragment of a left humerus of a *Bison* sp. The remaining two fragments refit with the other bone fragment picked up a year earlier by DuPont in 2001. These three bones refit into the proximal portion of a *Bison* sp. ulna. This identification was made using comparative paleontology collections at the University of Alaska Museum of the north, with Dr. Patrick Druckenmiller, paleontologist and curator of the Earth Sciences Department at UAM, concurring with this identification.

Beyond the three bones picked up on the surface of the backroom in 2002 was a small trough, and the reverse angle of repose of the mound of breccia of this trough indicated to Sattler that the trough was probably excavated relatively recently by bears. Further back in the cave the walls of the chamber constrict into a small fissure and in this area is residual ice and hoar frost. In the deepest area of the chamber is a carnivore scat, some small twigs, and a wood stick all of which were clearly brought into the cave by one of the animals in the local fauna.

The identified and dated bison lunate found in 2001 derived from the surface of the “antechamber”. In 2002, the scree in this “antechamber” was non-systematically troweled, and eight small fragments (< 5 cm length) of unidentified large-mammal bone were found either directly on top of the scree, or else within its uppermost three centimeters. No excavation into the lower coarse silt was made in the “antechamber”. These bone fragments were collected. As there was evidence of (probably) bear digging in the “back room”, with *Bison* sp. bone fragments found on the surface of the loose scree at that locale, it is assumed that the loose surface scree and bone fragments from the “antechamber” also derived from this taphonomic activity. Based upon this limited data, we feel it is probable that additional late Pleistocene faunal remains are present in this cave’s perennially frozen deposits.

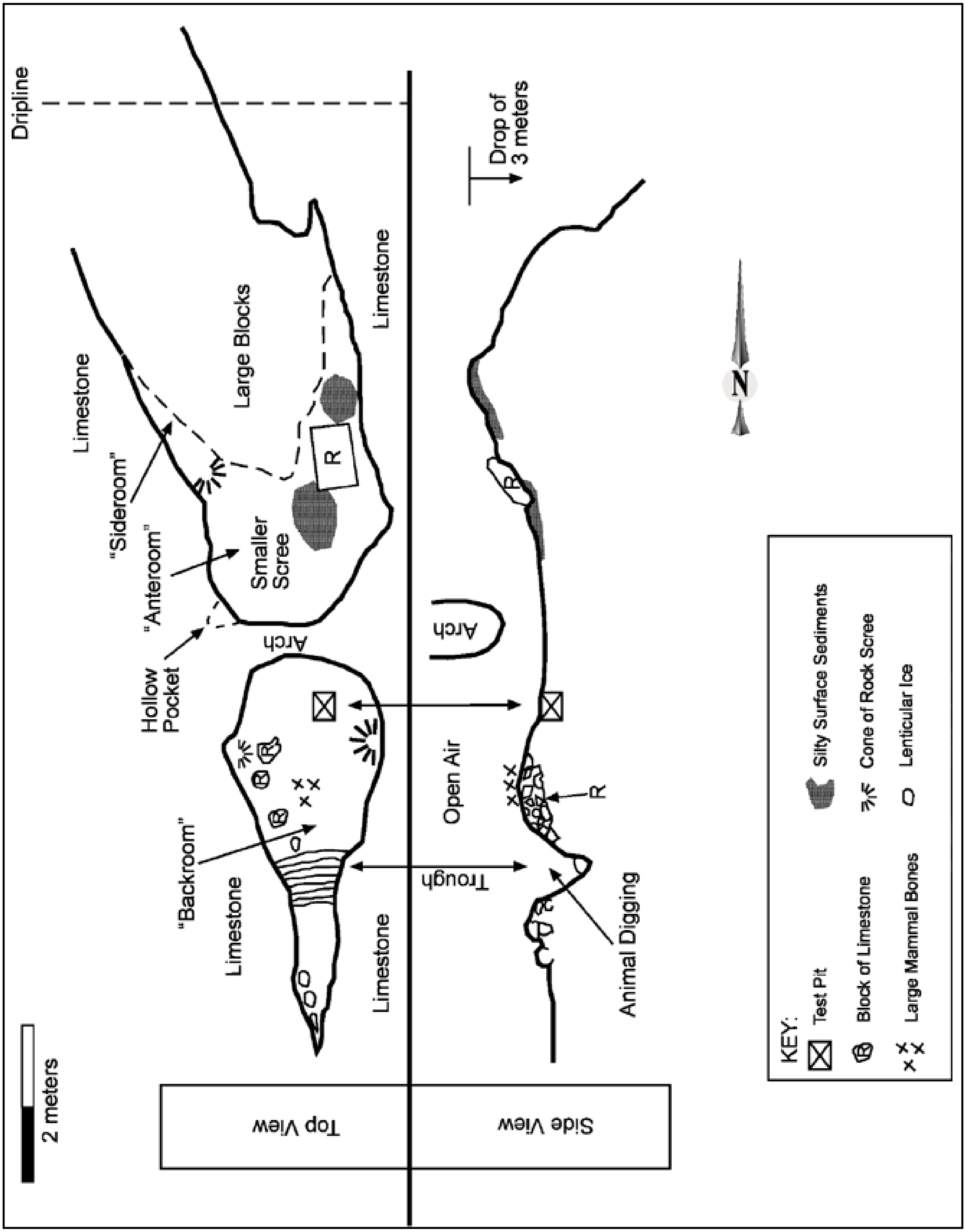

Figure 42. Floor plan view and side view of Karst Feature #96; Limestone Gulch region, WMNRA.

Karst Feature #102

Although a variety of small mammal and bird bones were found on the surface of a handful of the caves, most of these appear to be relatively recent accumulations, and largely the result of present-day raptor feeding and roosting. In addition to Karst Feature #96 (see above), one other cave produced a bone found on the surface that is possibly hundreds if not thousands of year old. Although it remains undated, a sheep (*Ovis dalli dalli*) metacarpal was located in the rear chamber of Karst Feature #102. This bone was located on top of a small backdirt pile immediately adjacent to a small porcupine-excavated pit. Plentiful porcupine scat all around the area, along with quills, identified the culprit. Based upon the provenance of the find, we feel confident that the porcupine activity dug up the bone from a buried context.

Summary of the White Mountains Karst Surveys

Between 2002 and 2005, eight surveys were conducted in the Limestone Gulch area of the White Mountains National Recreation Area, managed by the Bureau of Land Management's Fairbanks District Office (Figures 1-2). In total, about 3,350 acres of limestone peaks, valleys, and slope were thoroughly surveyed for karstic features (Figure 3), including caves, rock shelters and natural stone arches. A total of 102 such features were located (Figures 4-12), and basic biological, physical/natural, and cultural/paleontological attributes were recorded for each locale. These raw data are presented in Appendix 3. A variety of modern and paleontological biological samples were collected from some of the features (Appendix 2).

This report briefly outlines the basic findings of the 102 karst features examined. Succinctly, no large cave systems were found (e.g., 100s or 1000s of meters in length); in fact, the overwhelming majority of the caves and rockshelters that were located (93%, n=71 of 76 measured) had greatest lengths of 15 meters or less. Likewise, no "spectacular" speleothem formations, nor any underground hydrological systems, were located in any of the caves, which could serve to attract recreational hikers and spelunkers. Similarly, no historic or prehistoric cultural resources were encountered during the survey, whether inside the caves or in the surrounding landscape.

There is abundant evidence that various animals on the landscape today utilize these karst features for both short and long-term shelter. Birds were directly sighted using some of the caves, bird nests were located inside some caves or at their entrances, and faunal and pellet evidence of raptor feeding and roosting were present in some of the caves. Most of the caves (65%, n=66) had scat and other signs of mammal use, including sheep, porcupine, marmot, bear and wolverine, in decreasing frequency. Evidence of bear dens were found in nine of the caves examined. Several of the caves were found to contain late Pleistocene and Holocene deposits, and hold further paleontological interest.

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Appendix 1.
Cave/Rock Shelter Inventory Form

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CAVE / ROCKSHELTER INVENTORY FORM

Cave/ Rockshelter Name: WM-06-_______ **Date:**_______________
Recorders:_______________
Location: 1/4 Sec./T/R/ Merid.:_______________
Quad Map:_______________ Other:_______________
Latitude:_______________ Longitude:_______________

Photos (Roll # and Frames):_______________

A. BASIC DATA

Cave or **R**ockshelter?________; Max. entrance breadth/width (m)_________; Max. entrance height (m)_________;
Max. length (mouth to rear of cave) (m)_________; Max. Vertical depth/drop (m) ______________;
Entrance looking out orientation_________; Entrance elevation__________
Chambers off main entrance (indicate if lower level than main cave, and size if possible):

____

Chimneys?:______; Water?_____; Dripping?_____; Flowing?_____;
Pool?_____, pool size – e.g. <1 ft^3, > 1 ft^3_______
Description_______________

____

____

B. CULTURAL/PALEONTOLOGY DATA

Surface:
______hearth/ fireplace? ; _____ prehistoric/lithic artifacts?; _____ historic artifacts?; _____bones?; ______other?
Describe/List all (closeup photos of historic; **collect** diagnostic lithics):_______________

____

____

Paintings/petroglyphs? Describe & Photo_______________

____

Test Pit (mark on map). _____ cm diameter; _____ cm depth; ______ bones/ artifacts/ charcoal?
Describe Basic T.P. Stratigraphy:_______________

____

Bags Collected? ______ Label with sequential bag number, date, cave/rockshelter number, initials.

C. GEOLOGICAL/ MINERALOGICAL. Describe and Photo any interesting cave formations,
speleothems, sediments, or similar such features_______________

____

____

D. HYDROLOGICAL DATA (Describe and Photo any interesting hydrological features)

____

____

E. VEGETATION DATA (list according to your knowledge)

Mouth of cave:_______________

Vicinity of cave:_______________

F. BIOLOGY DATA

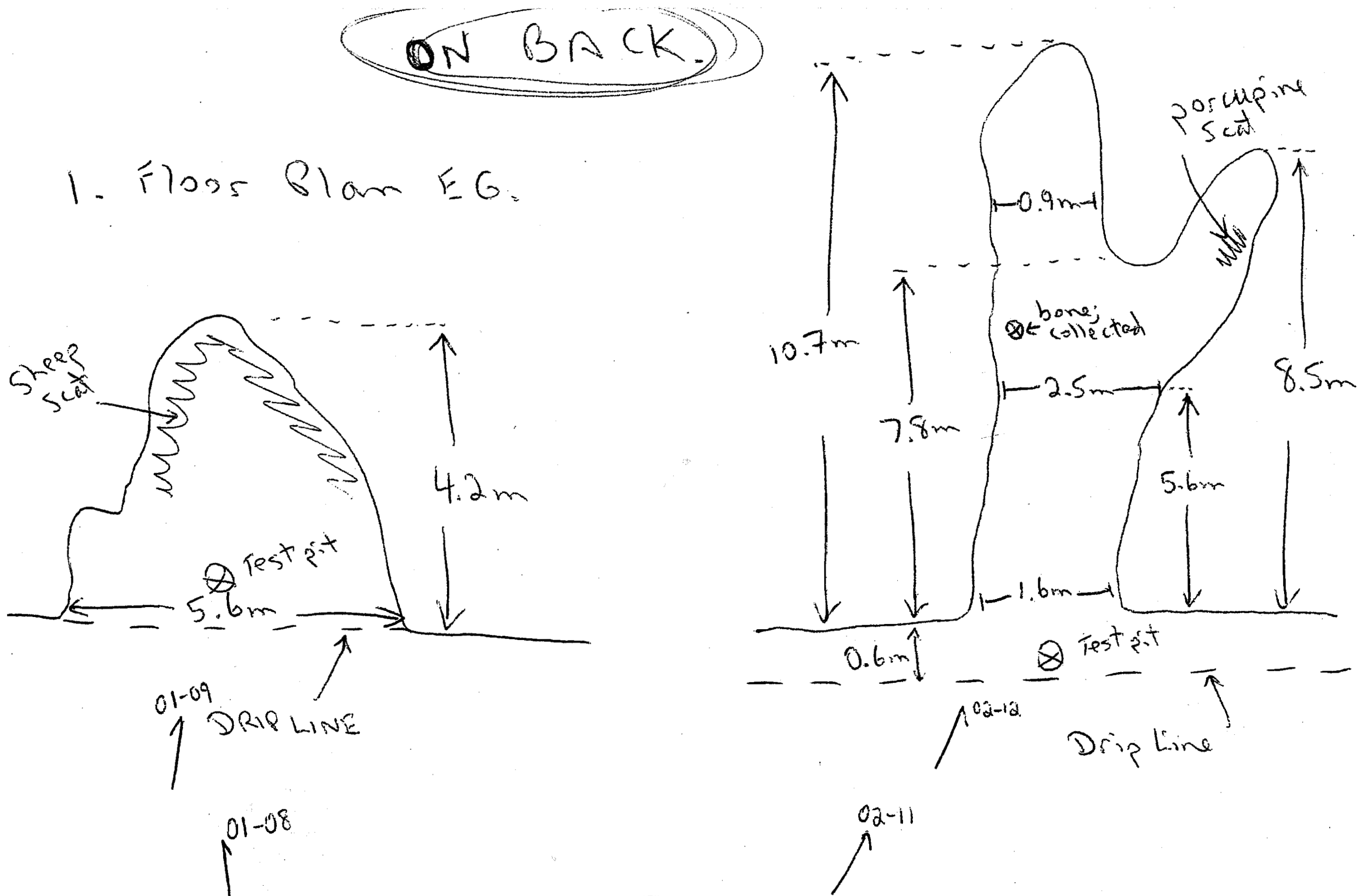
Evidence of Bats (photos if possible):
Bats (#)_______ ; Bat guano? (similar to mouse droppings, not in piles, **collect**)________
Bat bones? (check wall/ ceiling crevices; **collect**)_______
Polishing on walls/ceiling (possible bat roosting areas)?____________________

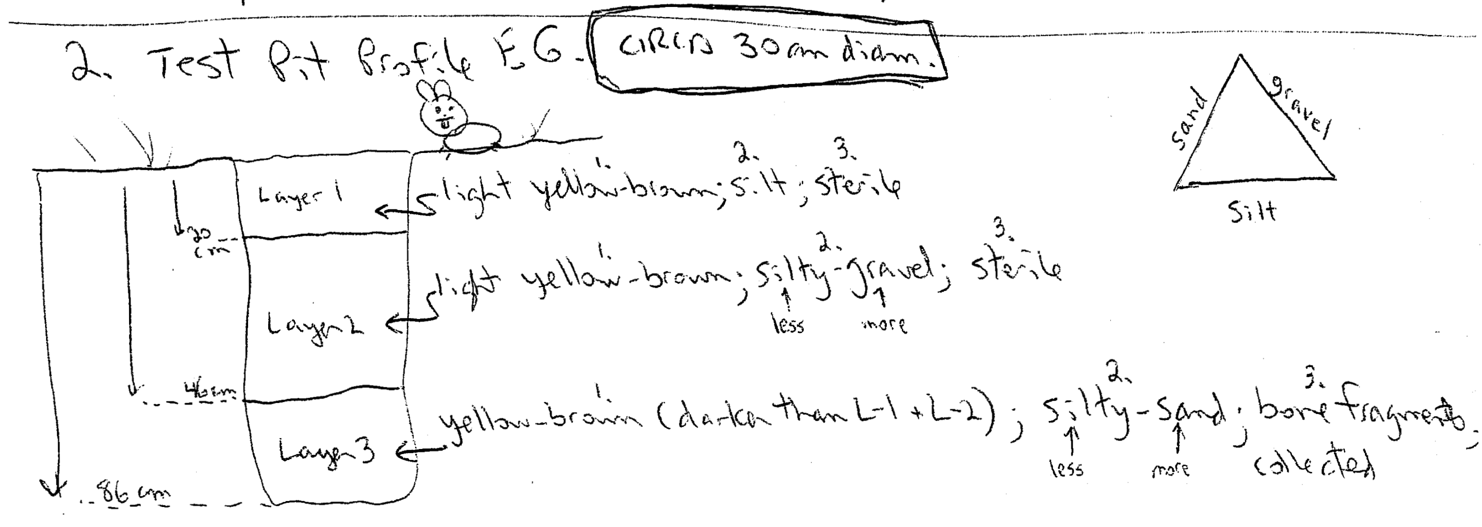
Mammals physically present:______________________________________
Other bones (photograph, possibly collect)______________________________
Mammal sign or scat? (list species; tree/ bone/ stick gnawing; **collect** non-sheep or porcupine scat:)________________

Birds (id to species if possible):
Owls?______________________ ;Swallows?______________________
Other birds?______________________________________

Invertebrates (Beetles, centipede, spider springtails, other)______________________

G. SKETCH MAPS (1. Basic Floor Plan View Sketch of Cave/Rockshelter, with basic measurements; 2. Basic Profile Sketch of Dirt Layers in the Test Pit)





Appendix 2. Samples collected and accessioned to the University of Alaska Museum of the North, Earth Sciences Department (UAMES2009.013ESCI)

Collected Sample #	BLM Karst	Description	UAMES2009.013. ESCI. Bag #
1	96	*Bison sp.* lunate; collected from surface of "anteroom" in 2001.	27
2	96	Sediment sample; lower silty clay from test pit.	
3	96	Nine large mammal bone fragments from surface & upper 1" loose surface rock of "antechamber".	27
4	96	Three large mammal bone fragments collected on surface of "backchamber".	26
5	96	Sediment sample; lower layer from Test Pit #1.	
6	96	Granule sedminent sample; small, fluvially rounded pebbles from surface of rear of main chamber.	
7	3	Soil & bones from test pit.	17
8	33	Surface bird bones & 1 feather.	18
9	34	Test pit bones & soil, from the lower 30 cm of this 45 cm deep test pit	19
10	35	One bird bone on surface.	20
11	37	Bones on surface.	21
12	37	Bones found at base of test pit.	21
13	46	Test pit 2003; bones collected from all layers	1
14	46	Test pit 2003; bones collected from Layer 2.	2
15	46	Test pit 2003; bones collected from Layer 3.	3
16	46	Bones and regurgitated pellet from surface surface (2005).	4
17	46	Sample 1 of 9 (0-5 cm bs) of 2005 column test, off of original 2003 test pit.	5
18	46	Sample 2 of 9 (5-10 cm bs) of 2005 column test, off of original 2003 test pit.	6
19	46	Sample 3 of 9 (10-11 cm bs) of 2005 column test, off of original 2003 test pit.	7
20	46	Sample 4 of 9 (11-16 cm bs) of 2005 column test, off of original 2003 test pit.	8
21	46	Sample 5 of 9 (16-21 cm bs) of 2005 column test, off of original 2003 test pit.	9
22	46	Sample 6 of 9 (21-26 cm bs) of 2005 column test, off of original 2003 test pit.	10
23	46	Sample 7 of 9 (26-31 cm bs) of 2005 column test, off of original 2003 test pit.	11
24	46	Sample 8 of 9 (31-42 cm bs) of 2005 column test, off of original 2003 test pit.	12
25	46	Sample 9 of 9 (42-45 cm bs) of 2005 column test, off of original 2003 test pit.	13
26	81	Complete bird skeleton on surface.	22
27	82	Mammal scat.	23
28	87	Mammal longbone fragment on surface at rear of lower-most chamber.	24
29	92	Two mammal longbone fragments from surface, center of cave.	25
30	102	Porcupine-excavated sheep metacarpal.	28
31	46	Faunal material from backdirt of 2003 test pit. Screened through 1/8" mesh in 2005.	15
32	46	Faunal material from backdirt of 2003 test pit. Screened through 1/8" mesh in 2005.	16

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Appendix 3. Karst Data 2002-2005 Database (Refer to inclosed CD)

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Appendix 4. Karst Feature #46, Limestone Gulch Region, WMNRA. Loss-On-Ignition data from 2005 column excavation

Sample depth (cm)	Sample mid-depth	Crucible no.	Crucible wt.	Cruc. + wet sed wt.	wet sed wt.	Cruc. + dry sed. wt.	dry sed. wt.	post 550 sed. wt. + crucible wt.	post 550 sed wt	%LOI 550	post 850 wt. + crucible wt.	post 850 wt.	%CaCO3	Oven
0-5	2.5	500	9.274	10.052	0.778	9.693	0.419	9.544	0.270	35.561	9.519	0.245	13.560	Matheus
5-10	7.5	501	9.522	10.176	0.654	9.930	0.408	9.815	0.293	28.186	9.778	0.256	20.611	Matheus
10-11	10.5	502	8.263	9.128	0.865	8.899	0.636	8.771	0.508	20.126	8.685	0.422	30.732	Matheus
11-16	13.5	503	9.469	10.357	0.888	10.144	0.675	10.056	0.587	13.037	9.920	0.451	45.791	Matheus
16-21	18.5	504	8.774	9.743	0.969	9.478	0.704	9.378	0.604	14.205	9.254	0.480	40.031	Matheus
21-26	23.5	505	9.383	10.609	1.226	10.389	1.006	10.268	0.885	12.028	10.071	0.688	44.506	Matheus
26-31	28.5	506	9.861	10.824	0.963	10.550	0.689	10.463	0.602	12.627	10.335	0.474	42.222	Matheus
31-42	36.5	507	9.384	10.709	1.325	10.683	1.299	10.538	1.154	11.162	10.235	0.851	53.013	Matheus
42-45	43.5	508	9.261	11.051	1.790	11.022	1.761	10.892	1.631	7.382	10.416	1.155	61.432	Matheus

Appendix 5. Karst Feature #46, Limestone Gulch Region, WMNRA. Raw pollen data from 2005 column excavation

Sample	Sample mid-depth (cm)	Picea glauca-type	Picea mariana-type	Picea undiff.	Betula	Alnus	Salix	cf. Shepherdia	Arctostaphylos-type	Ericales undiff.	cf. Rosaceae undiff.	Artemesia	Saussurea	Tubuliflorae undiff.	Caryophyllaceae undiff.	Brassicaceae	Cyperaceae	Poaceae	cf. Liliaceae	Lycopodium annotinum	Lycopodium clavatum	Lycopodium complanatum
Raw Number Counts																						
0-5 cm	2.5	12.0	1.0	39.0	17.0	29.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	3.0	1.0	0.0	3.0	1.0	0.0
5-10 cm	7.5	0.0	0.0	27.0	34.0	45.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	4.0	1.0	1.0	0.0	4.0	1.0	0.0
10-11 cm	10.5	0.0	0.0	13.0	34.0	66.0	2.0	0.0	1.0	0.0	0.0	3.0	0.0	0.0	0.0	2.0	1.0	1.0	0.0	2.0	1.0	0.0
11-16 cm	13.5	0.0	0.0	6.0	34.0	53.0	5.0	0.0	0.0	0.0	0.0	3.0	0.0	2.0	0.0	2.0	0.0	3.0	1.0	11.0	0.0	0.0
16-21 cm	18.5	0.0	0.0	8.0	44.0	48.0	3.0	0.0	0.0	1.0	1.0	1.0	1.0	0.0	0.0	2.0	1.0	1.0	0.0	9.0	1.0	1.0
21-26 cm	23.5	0.0	0.0	4.0	38.0	58.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	3.0	0.0	19.0	1.0	1.0
26-31 cm	28.5	0.0	0.0	2.0	51.0	69.0	5.0	0.0	0.0	0.0	1.0	2.0	0.0	1.0	0.0	1.0	0.0	3.0	0.0	23.0	5.0	0.0
31-42 cm	36.5	1.0	0.0	2.0	51.0	60.0	1.0	1.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	1.0	1.0	0.0	22.0	0.0	2.0
42-45 cm	43.5	1.0	0.0	9.0	42.0	56.0	1.0	0.0	0.0	1.0	1.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	9.0	0.0	0.0
Raw Numbers Percentages																						
0-5 cm	2.5	11.2	0.9	36.4	15.9	27.1	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	2.8	0.9	0.0	1.1	0.4	0.0
5-10 cm	7.5	0.0	0.0	23.5	29.6	39.1	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.9	3.5	0.9	0.9	0.0	0.8	0.2	0.0
10-11 cm	10.5	0.0	0.0	10.6	27.6	53.7	1.6	0.0	0.8	0.0	0.0	2.4	0.0	0.0	0.0	1.6	0.8	0.8	0.0	0.4	0.2	0.0
11-16 cm	13.5	0.0	0.0	5.5	31.2	48.6	4.6	0.0	0.0	0.0	0.0	2.8	0.0	1.8	0.0	1.8	0.0	2.8	0.9	2.6	0.0	0.0
16-21 cm	18.5	0.0	0.0	7.2	39.6	43.2	2.7	0.0	0.0	0.9	0.9	0.9	0.9	0.0	0.0	1.8	0.9	0.9	0.0	1.8	0.2	0.2
21-26 cm	23.5	0.0	0.0	3.7	35.5	54.2	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.9	2.8	0.0	4.1	0.2	0.2
26-31 cm	28.5	0.0	0.0	1.5	37.8	51.1	3.7	0.0	0.0	0.0	0.7	1.5	0.0	0.7	0.0	0.7	0.0	2.2	0.0	3.9	0.8	0.0
31-42 cm	36.5	0.8	0.0	1.7	42.5	50.0	0.8	0.8	0.0	0.0	0.8	0.0	0.0	0.8	0.0	0.0	0.8	0.8	0.0	3.7	0.0	0.3
42-45 cm	43.5	0.9	0.0	7.9	36.8	49.1	0.9	0.0	0.0	0.9	0.9	0.9	0.0	0.9	0.0	0.0	0.9	0.0	0.0	2.0	0.0	0.0
Raw Number Counts																						
Strat. Unit 1 (0-11 cm)		12.0	1.0	79.0	85.0	140.0	7.0	0.0	1.0	0.0	0.0	3.0	0.0	1.0	1.0	7.0	5.0	3.0	0.0	9.0	3.0	0.0
Strat. Unit 2 (11-26 cm)		0.0	0.0	18.0	116.0	159.0	10.0	0.0	0.0	1.0	1.0	4.0	1.0	2.0	0.0	5.0	2.0	7.0	1.0	39.0	2.0	2.0
Strat. Unit 3 (26-45 cm)		2.0	0.0	13.0	144.0	185.0	7.0	1.0	0.0	1.0	3.0	3.0	0.0	3.0	0.0	1.0	2.0	4.0	0.0	54.0	5.0	2.0
Raw Numbers Percentages																						
Strat. Unit 1 (0-11 cm)		3.7%	0.3%	24.3%	26.2%	43.1%	2.2%	0.0%	0.3%	0.0%	0.0%	15.0%	0.0%	5.0%	5.0%	35.0%	25.0%	15.0%	0.0%	0.7%	0.2%	0.0%
Strat. Unit 2 (11-26 cm)		0.0%	0.0%	5.9%	38.0%	52.1%	3.3%	0.0%	0.0%	0.3%	0.3%	18.2%	4.5%	9.1%	0.0%	22.7%	9.1%	31.8%	4.5%	2.8%	0.1%	0.1%
Strat. Unit 3 (26-45 cm)		0.6%	0.0%	3.7%	40.4%	52.0%	2.0%	0.3%	0.0%	0.3%	0.8%	23.1%	0.0%	23.1%	0.0%	7.7%	15.4%	30.8%	0.0%	3.3%	0.3%	0.1%

Lycopodium selago	Lycopodium undiff.	Selaginella selaginoides	Botrychium	Sphagnum	Trilete undiff.	Dryopteris	Monolete undiff.	Monolete scabrate	Monolete verrucate	Monolete rugulate	cf. Encalypta-type	Monolete aberrant	Indetermi nable	Unknown	Exotics counted	Trees and Shrubs	Herbs and Forbs	Pollen sum	Spore-producers	Unkown /Indet	Pollen sum & Spore-producers
2.0	0.0	0.0	2.0	39.0	2.0	1.0	39.0	82.0	1.0	0.0	1.0	100.0	25.0	0.0	37.0	102.0	5.0	107.0	173.0	25.0	280.0
1.0	0.0	2.0	3.0	64.0	3.0	0.0	169.0	141.0	15.0	1.0	0.0	164.0	28.0	0.0	49.0	107.0	8.0	115.0	404.0	28.0	519.0
3.0	0.0	7.0	5.0	87.0	1.0	0.0	194.0	104.0	3.0	0.0	0.0	122.0	35.0	2.0	53.0	116.0	7.0	123.0	407.0	37.0	530.0
3.0	0.0	4.0	1.0	57.0	2.0	0.0	130.0	101.0	2.0	0.0	1.0	124.0	34.0	4.0	53.0	98.0	11.0	109.0	312.0	38.0	421.0
1.0	4.0	5.0	1.0	162.0	0.0	0.0	109.0	100.0	1.0	0.0	1.0	213.0	36.0	0.0	83.0	104.0	7.0	111.0	395.0	36.0	506.0
3.0	2.0	3.0	0.0	119.0	1.0	0.0	78.0	132.0	0.0	0.0	0.0	115.0	14.0	1.0	50.0	102.0	5.0	107.0	359.0	15.0	466.0
4.0	0.0	10.0	0.0	168.0	3.0	0.0	185.0	61.0	0.0	0.0	0.0	121.0	15.0	0.0	63.0	127.0	8.0	135.0	459.0	15.0	594.0
5.0	2.0	13.0	0.0	125.0	3.0	0.0	234.0	66.0	0.0	0.0	0.0	160.0	14.0	0.0	42.0	116.0	4.0	120.0	472.0	14.0	592.0
3.0	4.0	6.0	0.0	80.0	0.0	0.0	109.0	129.0	2.0	0.0	0.0	145.0	33.0	5.0	86.0	110.0	4.0	114.0	342.0	38.0	456.0
0.7	0.0	0.0	0.7	13.9	0.7	0.4	13.9	29.3	0.4	0.0	0.4										
0.2	0.0	0.4	0.6	12.3	0.6	0.0	32.6	27.2	2.9	0.2	0.0										
0.6	0.0	1.3	0.9	16.4	0.2	0.0	36.6	19.6	0.6	0.0	0.0										
0.7	0.0	1.0	0.2	13.5	0.5	0.0	30.9	24.0	0.5	0.0	0.2										
0.2	0.8	1.0	0.2	32.0	0.0	0.0	21.5	19.8	0.2	0.0	0.2										
0.6	0.4	0.6	0.0	25.5	0.2	0.0	16.7	28.3	0.0	0.0	0.0										
0.7	0.0	1.7	0.0	28.3	0.5	0.0	31.1	10.3	0.0	0.0	0.0										
0.8	0.3	2.2	0.0	21.1	0.5	0.0	39.5	11.1	0.0	0.0	0.0										
0.7	0.9	1.3	0.0	17.5	0.0	0.0	23.9	28.3	0.4	0.0	0.0										
6.0	0.0	9.0	10.0	190.0	6.0	1.0	402.0	327.0	19.0	1.0	1.0	386.0	88.0	2.0	139.0	325.0	20.0	345.0	984.0	90.0	1329.0
7.0	6.0	12.0	2.0	338.0	3.0	0.0	317.0	333.0	3.0	0.0	2.0	452.0	84.0	5.0	186.0	305.0	22.0	327.0	1066.0	89.0	1393.0
12.0	6.0	29.0	0.0	373.0	6.0	0.0	528.0	256.0	2.0	0.0	0.0	426.0	62.0	5.0	191.0	356.0	13.0	369.0	1273.0	67.0	1642.0
0.5%	0.0%	0.7%	0.8%	14.3%	0.5%	0.1%	30.2%	24.6%	1.4%	0.1%	0.1%										
0.5%	0.4%	0.9%	0.1%	24.3%	0.2%	0.0%	22.8%	23.9%	0.2%	0.0%	0.1%										
0.7%	0.4%	1.8%	0.0%	22.7%	0.4%	0.0%	32.2%	15.6%	0.1%	0.0%	0.0%										

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