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PRIOVAC: A PALEONTOLOGICAL RESOURCE INVENTORY OF VIRGINIA CAVES

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ABSTRACT

An inventory of the paleontological resources in Virginia caves was initiated by the authors in 1996. Invertebrate and vertebrate fossil occurrences in Virginia were examined to understand the range and scope of fossils present in caves to aid in determination as to what should constitute cave significance in the documentation of paleontological resources for Virginia's Significant Cave List. This cave study reviewed previously known vertebrate fossil sites and new vertebrate and invertebrate fossil sites before focusing on vertebrate fossil occurrences and the evidence of how they came to be deposited. As part of the inventory, to address the question of the percentage of Virginia caves that are paleontologically significant, 229 Virginia caves were examined to identify 100 caves with exposed non-human bones and/or teeth. Thirteen of the 100 caves yielded extinct or significant extirpated taxa, including one determined to have been excavated by E.D. Cope in 1867. Thirteen percent of the 100 bone caves examined or 5.7 % of the 229 study caves were documented as paleontologically significant. A selection of vertebrate cave fossils were radiocarbon dated and ranged in age from 11,986 +/- 76 to 39,300 +/- 1100 YBP. Uranium-thorium dating at one site suggests the fossil were older than 300,000 years and may be older than 450,000 YBP, indicating the age of this bone deposit is Pleistocene (Irvingtonian). A total of 43 cave sites were documented as paleontologically significant in the inventory and reported in Appendix C. PRIOVAC was recognized as an NSS Project from 2001 through 2006 and progress talks were presented at NSS Conventions in 1995, 1997, 1998, 2000, 2001, 2002, 2006, 2007, and a version of this summary in 2023 with abstracts published in the NSS Journal of Cave and Karst Studies and talks at the UIS Congresses in 1997 (Switzerland), 2001 (Brazil), and 2009 (US) published as papers in the UIS Proceedings. This paper is a summary report on PRIOVAC and the first publication of some of the bone dates and the U-Th dates.

BACKGROUND

The Commission on the Conservation of Caves was established in 1978 as a result of legislation initiated by members of the Virginia Region of the National Speleological Society, who were alarmed by the accelerated deterioration and vandalism of Virginia caves. Governor John Dalton made 11 appointments to the Commission to "study all problems incidental to cave use, protection, and conservation in Virginia (Lera, 2009)." Two important recommendations of this Commission were to establish a permanent cave commission and to strengthen the original Virginia Cave Protection Act of 1966 (Lera, 2009).

The Virginia Cave Protection Act (VCPA) of 1979 made it unlawful to disturb or damage caves and their contents, including cave surfaces, speleothems, speleogens, sediments, cave life, archaeological, historical and paleontological materials. The Act also established the Virginia Cave Commission as a permanent, governor appointed body. A primary responsibility assigned to the Cave Commission was to develop and maintain a list of significant caves in Virginia. Under the leadership of Dr. John Holsinger, the Annotated List of Significant Caves and Karst Areas in Virginia was completed in April 1980 (Holsinger, 1980). The criteria by which caves were evaluated for inclusion in this list are characterized by 11 scientific, economic, and caver perspective attribute categories: Archeological, Biological, Depth, Economic, Esthetic, Geological, Historical, Hydrological, Paleontological, Length, and Recreational. The list is a way of recognizing the most important caves in the Commonwealth of Virginia and is also a key to understanding how to protect these important caves and their resources. From the more than 2500 known Virginia caves, the initial Significant Cave List included 220 caves, of which only 10 were recognized under criteria within the Paleontological Category (Appendix A).

A PALEONTOLOGICAL INITIATIVE

The need for what would become the Paleontological Resource Inventory of Virginia Caves (PRIOVAC) was recognized in 1994, while author Hubbard was sorting through information on Virginia caves for an update of the Significant Caves List for Virginia. Members of the Virginia Cave Commission (renamed Virginia Cave Board in 1985), Virginia Speleological Survey, and other Virginia cavers had successfully recognized and documented many categories of significance for Virginia caves since the creation of the Significant Cave List. The Virginia Cave Protection Act delegated the authority to issue permits to excavate paleontological materials to the Virginia Historic Landmarks Commission

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and specified that such field investigations be carried out under supervision of the Commissioner of Archaeology of the Virginia Research Center for Archaeology and the Virginia Historic Landmarks Commission. Unfortunately, the law enacted to protect cave resources also inhibited some legitimate efforts to study these resources, especially paleontological resources under the supervision of archaeologists.

The subsequent April 1985 list (Holsinger, 1985) of 224 significant caves only included 12 caves documented with criteria within the Paleontological Category (Appendix B). Considering that 135 caves were listed with criteria within the Biological Category, Virginia caves appeared in need of additional paleontological studies. Renewed interest in the paleontological resources of Virginia caves was kindled by the discovery of bear remains in Island Ford Cave in Alleghany County. Local youth encountered the remains in 1991, while digging open a passage (Hubbard and Grady, 1997). The 1995 NSS Convention in Blacksburg, Virginia presented an opportunity to both showcase the significant Virginia cave resources known by speleologists, but also encourage cavers to identify and report previously unrecognized cave resources. A paper on the fossil bone sites in Virginia (Grady, 1995) was prepared for the Convention Guidebook. A convention talk on the paleontological resources in Virginia caves was presented (Hubbard, 1997). Two goals of the presentation were: 1) stimulate caver awareness of the types of paleontological materials found in caves, and 2) initiate an aggressive program for documenting paleontological significance in Virginia caves. The subsequent dialog about paleontological resources in caves stimulated a team approach for simultaneously a) collecting appropriately and identifying animal remains to document important fauna and b) seek additional evidence to better understand the processes by which these animal remains came to be deposited and exposed. The success of the 1995 NSS Convention presentations prompted author Hubbard, a process-oriented geologist with the Virginia geological survey, to reach out to the second author, Grady, a paleontologist with the Smithsonian Institution who was actively working with paleontological cave resources in West Virginia, to further the paleontological studies in Virginia caves.

PALEONTOLOGICAL COLLECTION PERMITS

After passage of the Virginia Cave Protect Act of 1979, members of the Virginia Cave Commission unsuccessfully attempted to move the authority to issue permits for excavation of paleontological materials in caves away from archaeological agencies. The Commonwealth of Virginia entered into a cooperative arrangement with The Nature Conservancy to create the Virginia Natural Heritage Program in 1986. In 1988, the Natural Heritage Program came under the direction of the Virginia Department of Conservation and Recreation, which also oversaw the Virginia Cave Board. With the passage of The Virginia Natural Area Preserves Act in 1989, the Natural Heritage Program was empowered to conserve Virginia's biodiversity through inventory, protection and stewardship. Henceforth the Natural Heritage Program oversaw the issuing of cave collection permits for biospeleological inventories, and, with concurrence of the Director of the Department of Historical Resources, also archaeological, paleontological, prehistoric, and historic features. Starting in 1990, the senior author was issued cave collection permits for biospeleological inventories of Virginia caves and, between 1992 and 1995, cave collection permits for disturbed archaeological materials for the NSS recognized Marginella Burial Cave Project. In 1994, the authors were finally successful in having a cave collection permit issued to author Grady for excavation of the Island Ford Cave bear, subsequently identified as the extinct giant short-faced bear *Arctodus simus* (Grady, 1997).

PALEONTOLOGICAL DEPOSITS IN VIRGINIA CAVES

Paleontology is the study of prehistoric life preserved as fossils. The caves of Virginia are mostly solutional caves developed in carbonate rocks deposited from the Cambrian to Mississippian. Caves represent an important setting for fossil records because the sheltered alkaline environments of some Virginia caves permit better long-term preservation of bone and teeth than most of Virginia's surface sediment environments. Fossil remains may include extinct species that are no longer living today, as well as extant species that are still living today. Some species may span multiple geologic periods and examples of living species known from the fossil record that still exist elsewhere due to climatic shifts and are known as extirpated species where they no longer occur. The depositional settings of cave fossils are diverse. An excellent illustration of many cave fossil settings is provided by Sutcliffe (1976) and a modified illustration is provided in Alcover (1992). Cave fossil settings include deposits in the carbonate rocks in which the caves are dissolved and may be exposed in the cave walls, ceiling or floor. Wash-in of animal remains may represent whole or fragmental remains transported by erosional processes into cave openings or entrances or paleo-entrances, that may subsequently become choked with sediment. Vertical entrances and drops within caves have fatally injured or trapped the overly curious or inattentive visitors. Some animals may have briefly fed or sheltered in caves or utilized caves as den sites for hibernation and/or rearing their young, while depositing remains of their prey and occasionally their young or themselves if they perished in their den. Some raptors, such as owls, have utilized the twilight zones of caves as roosts, transporting prey into caves and sometimes harvesting cave bats and depositing bone bearing pellets. Woodrats gather food and nest materials from outside of caves into their middens, which often include mineral rich bones, teeth and

other items that preserve tooth gnaw marks (Andrews, 1990; Schubert and Mead, 2019). Additional contributions can also result from other caves-using-animals such as bats, other rodents and birds, and salamanders.

Generally, cave sediments are stratigraphically deposited with the oldest sediments beneath younger sediments, such that remains of extinct or extirpated species are buried beneath younger sediments. Natural disruptions to this normal stratigraphic order that may expose older buried fossil bearing sediments include: burrowing animals and bear wallows, truncation and re-deposition by vadose waters, and stratigraphic mixing by deposition of transported ceiling passage sediments atop of floor sediments and erosion by epi-karstic waters. Human disruptions of sediment stratigraphy include mining for saltpetre (nitrates) and other materials, cave burials, and passage modifications for various other purposes, including cave commercialization, food storage, development of water supplies, and cave exploration.

PRIOVAC

The **P**aleontological **R**esource **I**nventory **O**f **V**irgini**A** **C**aves (PRIOVAC) began formally in early 1996. The inventory includes known and newly recognized paleontological resources. Both Grady and Hubbard were professional scientists and, in their spare time, cavers actively working to document cave resources. Grady mainly caved in West Virginia specializing in cave paleontology, whereas Hubbard primarily caved in Virginia working to document significant cave resources. The application for a cave collection permit to collect exposed non-human bone, teeth, and other fossil material from Virginia spelean environments for a paleontological inventory of the caves of the Commonwealth of Virginia was submitted on 23 January 1996. After numerous discussions of concerns about avoiding disturbances of archaeological resources, the cave collection permit was issued 1 November 1996.

Over a decade earlier, author Grady worked with fellow Smithsonian paleontologist Dr. Ralph Eshelman in a compilation of the "Quaternary vertebrate localities of Virginia and their avian and mammalian fauna." They were invited to present their work at the Symposium on the Quaternary of Virginia in 1984. Eshelman and Grady (1986) documented 77 Virginia localities, of which 28 were cave or karst features that had yielded a record of an extinct or significant extirpated taxon. This work provided the bulk of the known cave paleontological resources to assess under PRIOVAC.

Because Hubbard was actively mapping the karst of southwestern Virginia and Grady was working in the Paleobiology Department in the Smithsonian Institution, the plan was for Hubbard to sample exposed paleontological deposits in caves and other karst environments and document the nature of the deposits, and for Grady to provide the identifications of the remains. Grady and Hubbard would then revisit paleontological resources determined to be significant based on the taxon or depositional environment.

ABBREVIATIONS

AA - University of Arizona's NSF Arizona Accelerator Mass Spectrometry Laboratory, Tucson, Arizona.
CM – Carnegie Museum of Natural History, Pittsburgh, Pennsylvania
MM - McMaster University, Hamilton, Ontario, Canada
USFS – United States Forest Service
USNM – National Museum of Natural History, Smithsonian Institution, Washington D.C.
VMNH – Virginia Museum of Natural History, Martinsville, Virginia

PALEONTOLOGICAL RECORDS PRIOR TO PRIOVAC

As noted above, Eshelman and Grady's (1986) work provided 28 cave or karst features that had yielded record(s) of extinct or significant extirpated vertebrate taxon, which are listed below. A number of these caves were visited to examine their paleontological deposits and their depositional setting or context and are underlined. See the following section - The Virginia Cave Significance Criteria for the Paleontology Category **-** for a discussion on paleontological significance. All reported identifications and classifications follow the original publications.

Back Creek Caves No. 1 and 2, Bath County; Eshelman and Grady's No.s 3 and 4 are actually rock shelters containing deposits dated as Late Pleistocene/early Holocene based on faunal assemblage with owl roosts recognized as the primary depositional process. Paleontological significance include the records of the extinct peccary *Mylohyus* sp. (No. 1), and significant extirpated taxa: arctic shrew *Sorex arcticus* (No. 2), chipmunk *Tamias* (formerly *Eutamias)* sp. now *Tamias* sp. (No. 2), thirteen-lined ground squirrel *Ictidomys* (formerly *Spermophilus*) *tridecemlineatus* (No.s 1 & 2), heather vole *Phenacomys intermedius* (No.s 1 & 2), yellow-cheeked vole *Microtus xanthognathus* (No.s 1 & 2), northern bog lemming *Synaptomys borealis* (No.s 1 & 2) (Guilday et al., 1977; Jones et al., 1984; Carnegie Museum of Natural History (CMNH) collection data; McDonald et al., 1998).

Clarks Cave, Bath County, Eshelman and Grady's No. 11 has deposits from the Late Pleistocene based on the faunal assemblage with owl roosts recognized as the primary depositional process. Paleontological significance includes the first Virginia record of the extinct dire wolf *Aenocyon* (formerly *Canis)* cf. *C. dirus* and the significant extirpated taxa: Arctic shrew *Sorex arcticus*, New England cottontail *Sylvilagus transitionalis*, least chipmunk *Tamias* (formerly

Eutamias) *minimus*, thirteen-lined ground squirrel *Ictidomys* (formerly *Spermophilus) tridecemlineatus*, heather vole *Phenacomys intermedius*, yellow-cheeked vole *Microtus xanthognathus*, northern bog lemming *Synaptomys borealis*, ermine *Mustela erminea* (Guilday et al., 1977; Jones et al., 1984; Grady, 1995; McDonald et al., 1998).

Darty Cave, Scott County, Eshelman and Grady's No. 17 has deposits from the Late Pleistocene based on the faunal assemblage with owl roosts recognized as the primary depositional process. Paleontological importance includes the records of the significant extirpated heather vole *Phenacomys* sp. and caribou *Rangifer tarandus* (CMNH collection data; McDonald et al., 1998).

Earlys Cave (aka Earlys Pit), Wythe County, Eshelman and Grady's No. 20 has deposits from the Mid Pleistocene based on the faunal assemblage. Paleontological significance includes the records of the extinct ground sloth *Megalonyx* cf. *M. jeffersonii*, extinct complex-toothed horse *Equus* cf. *E. complicatus*, extinct tapir *Tapirus* sp. and extinct long-nosed peccary *Mylohyus* sp. (Cope, 1869a and b; Hay, 1923, Guilday, 1962a; Jones et al., 1984; Grady, 1995; McDonald et al., 1998). Note, the flat-headed peccary *Platygonus compressus* was mistakenly listed in Eshelman and Grady and is not found at this location.

Edinburg Fissure, Shenandoah County, Eshelman and Grady's No. 22 has deposits from the Late Pleistocene based on the faunal assemblage. Paleontological significance includes the records of the extinct tapir *Tapirus* sp., extinct peccary *Mylohyus* sp., extinct stag-moose *Cervalces* sp. and the extirpated yellow-cheeked vole *Microtus xanthognathus* (U. S. National Museum of Natural History (USNM) collection data; McDonald et al., 1998).

Eggleston Fissure, Giles County, Eshelman and Grady's No. 24 has deposits from the Late Pleistocene based on the faunal assemblage. Paleontological significance includes the records of the extirpated northern bog lemming *Synaptomys borealis*, and caribou *Rangifer tarandus* (CMNH collection data; McDonald et al., 1998).

Gardners Cave, Wythe County, Eshelman and Grady's No. 27 has deposits from the Late Pleistocene based on the faunal assemblage. Paleontological significance includes the record of the extinct peccary *Platygonus* sp. (Guilday, 1962b; USNM collection data; Grady, 1995; McDonald et al., 1998).

Gillespies Cliff Cave, Tazewell County, Eshelman and Grady's No. 28 has deposits of mixed Late Pleistocene and Holocene based on the faunal assemblage with owl roosts recognized as the primary depositional process. Paleontological significance includes the records of the extirpated yellow-cheeked vole *Microtus xanthognathus*, bog lemming *Synaptomys* sp. (CMNH collection data; McDonald et al., 1998).

Holston Vista Cave, Washington County, Eshelman and Grady's No. 30 has deposits from the Late Pleistocene/ Holocene based on the faunal assemblage with owl roosts suggested as the possible depositional process. Paleontological significance includes the records of the extirpated arctic shrew *Sorex arcticus*, thirteen-lined ground squirrel *Ictidomys* (formerly *Spermophilus) tridecemlineatus*, heather vole *Phenacomys* sp., yellow-cheeked vole *Microtus xanthognathus*, bog lemming *Synaptomys* cf. *S. borealis* (CMNH collection data; McDonald et al., 1998).

Jasper Saltpetre Cave, Lee County, Eshelman and Grady's No. 33 has deposits from the Mid Pleistocene based on the faunal assemblage. Paleontological significance includes the records of the extirpated pika *Ochotona* sp. and the northern bog lemming *Synaptomys borealis* (Guilday, 1979; Jones et al., 1984; CMNH collection data; Grady, 1995; McDonald et al., 1998).

Klotz Quarry Cave No. 5, Giles County, Eshelman and Grady's No. 35 has deposits from the Late Pleistocene based on the faunal assemblage with owl roosts recognized as the primary depositional process. Paleontological significance includes the records of the extirpated bog lemming *Synaptomys* sp. and caribou *Rangifer tarandus* (CMNH collection data; McDonald et al., 1998).

Lane Cave, Scott County, Eshelman and Grady's No. 37 has a deposit from the Late Pleistocene based on the occurrence of the extinct Jefferson's ground sloth *Megalonyx jeffersonii* (USNM 23734) (Holsinger, 1967; Grady, 1995; McDonald et al., 1998).

Loop Creek Quarry Cave, Russell County, Eshelman and Grady's No. 39 has deposits from the Late Pleistocene/ early Holocene based on the faunal assemblage with owl roosts recognized as the primary depositional process. Paleontological significance includes the record of the extirpated ground squirrel cf. *Ictidomys* (*Spermophilus*) sp. and heather vole *Phenacomys* sp. (CMNH collection data; McDonald et al., 1998).

Luray Caverns, Page County, Eshelman and Grady's No. 40 produced a large cat specimen suspected to be from the Pleistocene. Hovey (1882) considered the remains to represent *Panthera* sp. or *Felis atrox* (now *Panthera atrox*), while McDonald et al. (1998) refers to this as the lion (*P. atrox*).

Meadowview Cave, Washington County, Eshelman and Grady's No. 41 has deposits from the Late Pleistocene based on the faunal assemblage. Paleontological significance includes the records of the extinct beautiful armadillo *Dasypus* cf. *D. bellus* and the extirpated heather vole *Phenacomys* sp. (Guilday and Parmalee, 1972; Jones et al., 1984; Klippel and Parmalee, 1984; CMNH collection data; McDonald et al., 1998).

Natural Chimneys Caves No. 1 & 2 (aka Brown's Cave and Cave of the Wooden Steps), Augusta County, Eshelman and Grady's No. 43 has deposits from the Mid Pleistocene based on the faunal assemblage with owl roosts recog-

nized as the primary depositional process. Paleontological significance includes the records of the extinct giant beaver *Castoroides ohioensis*, extinct peccary *Mylohyus* sp. and significant extirpated taxa: arctic shrew *Sorex arcticus*, thirteenth-lined ground squirrel *Ictidomys* (*Spermophilus*) *tridecemlineatus*, heather vole *Phenacomys* cf. *P. intermedius*, yellow-cheeked vole *Microtus xanthognathus*, northern bog lemming *Synaptomys borealis*, long-tailed weasel *Mustela* cf. *M. frenata*, and extralimital red squirrel *Tamiasciurus hudsonicus* (Guilday and Bender, 1960; Wetmore, 1962; Guilday, 1962b; Guilday and Parmalee, 1972; Jones et al., 1984; Fay, 1984; Anderson, 1984; Grady, 1995; McDonald et al., 1998).

Pembroke Railroad Cave No. 1, Giles County, Eshelman and Grady's No. 47 has a deposit from the Late Pleistocene based on faunal assemblage. Paleontological significance includes the records of the extinct peccary *Mylohyus* sp. and extinct fugitive deer *Sangamona*? sp. (CMNH collection data; McDonald et al., 1998).

Rass Hole (aka. Corbett's Cave), Highland County, Eshelman and Grady's No. 50 has a deposit from the Late Pleistocene based on the occurrence of the extinct peccary *Platygonus* sp. (CMNH collection data; McDonald et al., 1998).

Ripplemead Quarry Fissure, Giles County, Eshelman and Grady's No. 51 has deposits from the Late Pleistocene/Holocene based on faunal assemblage with owl roosts and natural accumulation recognized as the primary depositional processes. Paleontological significance includes the records of the extinct tapir *Tapirus* sp. and extinct peccary *Mylohyus* sp. (Weems and Higgins, 1977; Jones et al., 1984; Grady, 1995; McDonald et al., 1998).

Skyline Caverns, Warren County, Eshelman and Grady's No. 56 has a deposit from the Late Pleistocene based on faunal assemblage. Paleontological significance includes the record of the extinct peccary *Platygonus* sp. (USNM collection data; McDonald et al., 1998).

Strait Canyon Fissure, Highland County, Eshelman and Grady's No. 59 has deposits from the Late Pleistocene based on ^{14}C date of 29,870 +1800/-1400 yr B.P. with natural accumulation recognized as the primary depositional processes. Paleontological significance also includes the records of the extinct round-tailed muskrat *Neofiber leonardi*, extinct American mastodon *Mammut americanum*, extinct complex-toothed horse *Equus complicatus*, extinct Vero tapir *Tapirus* cf. *T. veroensis*, extinct long-nosed peccary *Mylohyus fossilis*, extinct woodland musk ox *Bootherium* (*Symbos cavifrons),* and the extirpated northern bog lemming *Synaptomys borealis*, heather vole *Phenacomys intermedius*, moose *Alces alces* (Guilday, 1982b; Jones et al., 1984; Fay, 1984; Anderson, 1984; CMNH and USNM collection data; Grady, 1995; McDonald et al., 1998, lists the musk ox as Harlan's Musk Ox *Bootherium bombifrons*).

Unknown, (cave ?), Clarke County, Eshelman and Grady's No. 63 is Late Pleistocene/Holocene based on faunal assemblage. Paleontological significance includes the record of the extirpated yellow-cheeked vole *Microtus xanthognathus* (USNM collection data; McDonald et al., 1998). Note: This record is included here with the addition of '(cave ?)' because author Grady recalls this material was encrusted with travertine indicative of a cave or karst environment.

Unnamed Cave, Smyth County, Eshelman and Grady's No. 65 has deposits from the Late Pleistocene/Holocene based on faunal assemblage. Paleontological significance includes the records of the extinct American mastodon *Mammut americanum* and extinct peccary *Platygonus* sp. (Radford University collection data; McDonald et al., 1998).

Vickers Cave, Washington County, Eshelman and Grady's No. 68 has deposits from the Pleistocene based on faunal assemblage. Paleontological significance includes the record of the extinct peccary *Platygonus vetus* (Guilday, 1971a; CMNH collection data; McDonald et al., 1998).

Wills Cave (aka Fraleys Cave), Washington County, Eshelman and Grady's No. 73 has deposits from the Late Pleistocene for records of the extinct tapir *Tapirus* sp. and peccary *Mylohyus* sp. (CMNH collection data; McDonald et al., 1998).

Winding Stair Cave, Scott County, Eshelman and Grady's No. 76 has deposits from the Late Pleistocene based on the records of the extinct tapir *Tapirus* sp. and extinct fugitive deer *Sangamona*? sp. (CMNH collection data; McDonald et al., 1998).

THE VIRGINIA CAVE SIGNIFICANCE CRITERIA FOR THE PALEONTOLOGY CATEGORY

All aspects of paleontological significance are of interest in documenting Virginia's Significant Caves. The Paleontological Category for significant caves and karst areas was defined as "caves that have yielded the skeletal remains of prehistoric animals and are thus important sites for fossil bone deposits; or caves containing pollen or old fills that can be dated and utilized as indicators of ancient climatic conditions or events (Holsinger, 1980)." As noted above, most of the Virginia caves are developed in carbonate rocks and many caves contain impressive arrays of the host rock invertebrate fossils displayed in ceilings, walls, floors, and specimens eroded from the limestone and secondarily concentrated in some cave sediments. Exceptional examples of host rock fossils may qualify as paleontologically significant and the listing of particular caves for the Paleontology Category. Studies of pollen or other plant material preserved in cave sediments also may qualify caves with exceptional records of past climatic biome documentation for the Paleontology Category listing. One of the ten caves listed for Paleontological significance in the 1980 List (Pig Hole, Appendices A & B) contains extensive ancient bat guano deposits. Ancient life is a key distinction in the qualification for the Paleonto-

logical Category with respect to the clause "ancient climatic conditions and events." A stratigraphic section of sediments preserving one or more magnetic reversals is geologically significant, but not necessarily paleontologically significant without reference to ancient life forms. Ancient climatic conditions defined by chemical signatures of sediments may qualify for the newer Atmospheric Category first recognized in 1997, but not necessarily the Paleontological Category. The original Paleontological Category definition referenced animal and plant evidence of ancient biome documentation, but neglected to include fungi, potist, and monera (bacteria) kingdom evidence, which may qualify as paleontologically significant.

Figure 1. In situ extinct *Mammuthus primigenius* lower third molar embedded in sediments in Endless Caverns.

The PRIOVAC project ultimately focused on the Pleistocene vertebrate fossils found in Virginia's caves. The presence of remains of one or more extinct vertebrate species constitutes a significant paleontological cave record with respect to the Virginia Significant Cave List. The finding of extirpated species remains in a cave is important for those species that now reside elsewhere due to climatic shifts and may also be considered paleontologically significant. Examples of extinct and extirpated species that disappeared from Virginia in the last couple centuries due to human impacts are not considered paleontologically significant in this work and include the extinct passenger pigeon *Ectopistes migratorius*, extirpated porcupine *Erethizon dorsatum*, extirpated grey wolf *Canis lupus*, and extirpated elk *Cervus elaphus*, unless those remains date as Pleistocene or older. Bison and black bear are two records that also are of interest paleontologically and records that date as Pleistocene or older may be considered significant. Trace fossil evidence such as bear wallows and large claw marks, which are indistinguishable between bear and large cats, are of interest paleontologically and those that date as Pleistocene or older may be considered significant.

SUPPLEMENTAL AND NEW PALEONTOLOGICAL FINDS IN VIRGINIA

Clarks Cave, Bath County, Eshelman and Grady's No. 11 is listed above; a PRIOVAC supplemental collection in May 1997 included 22 mammalian taxa, as well as several birds and snakes. Noteworthy fauna include the extirpated heather vole *Phenacomys intermedius*, extirpated yellow-cheeked vole *Microtus xanthagnathus*, and extirpated northern bog lemming *Synaptomys borealis* (mixed taxa USNM 609115).

Earlys Cave, Wythe County, Eshelman and Grady's No. 20 is listed above; contains remarkable evidence of Cope's (1869a, b) nineteenth century excavations and included pick and mattock marks through travertine layers and calcareous cemented sediment. Hay (1923) suggested these were Mid-Pleistocene deposits; however, considering Guilday's (1962) rejection of Cope's two new genera and five new species we believe these are Late Pleistocene deposits. PRIOVAC collections in June 1997 – May 1998 of these deposits included 18 taxa (including the extinct horse *Equus* sp.) from Earlys Cave (USNM 610270; Grady, 1992; Grady and Hubbard, 2000).

Earlys Pit, adjacent to the above cave is a separate site. PRIOVAC collections in June 1997 – May 1998 of these deposits, which we believe are Late Pleistocene, included the extinct horse *Equus* sp. (USNM 610271; Grady and Hubbard, 2000).

Endless Caverns, Rockingham County – In September 1996 caver/owner Wade Berdeaux recognized a tooth of the extinct wooly mammoth *Mammuthus primigenius* embedded in sediment in the non-commercial section of the cave and contacted the authors. The lower third molar (Fig. 1) was deposited by a debris flow through a former opening and exhibited only minor postmortem damage. The wear pattern indicates partial eruption and suggests the individual was in excess of 30 years in age at the time of death (Hubbard and Grady, 1997, 1999). The presence of a mammoth, a grazer, at this site, along the flank of Massanutten Mountain, may indicate the cave was overlain by a grassland or prairie habitat. Although there are other records of mammoth remains in Virginia, this is the first record from a cave (Grady et al., 1997). Approximately 110 m ESE from the historic entrance or approximately 85 m WNW from the former mammoth entrance, a bone excavated during commercial trail modifications was identified as the right humerus of the

Figure 2. Fred Grady with extinct *Arctodus simus* partial remains from Island Ford Cave at Smithsonian Institution in Chip Clark image.

flat-headed peccary *Platygonus compressus*; mixed taxa (USNM 610286) (Hubbard and Grady, 1997; site 81 in McDonald et al., 1998), but addition observation failed to locate addition remains of the peccary and evidence of a depositional context.

Island Ford Cave, Alleghany County - In 1991, NSS cavers Russ Carter, Dave Collings, and Tom Spina, with the help of the late Jack Hanner (a professor at Dabney S. Lancaster Community College) recovered an array of large bones that local youth had found digging open a passage approximately 220 m beyond the entrance. Subsequent excavations, under permit, yielded the partial skeleton of a giant short-faced bear *Arctodus simus* (USNM 521336) (Fig. 2). The remains were of a relatively small, but mature, adult and probably a female specimen (Grady, 1997; site 78 in McDonald et al., 1998). The individual may have died, possibly by drowning, during hibernation. Besides representing the first record of the species in Virginia, it appears to be one of the most complete specimens yet found (Hubbard and Grady, 1997). PRIOVAC investigators Hubbard and Grady attempted a radiocarbon bone date (AA45374) on a bone fragment of *A. simus*, but the sample contained insufficient collagen and only yielded a date of >29,000 YBP [AA45374]. Eventually, Dr. Blaine Schubert was able to date a tooth of *A. simus* from the cave as 34,080 +/-480 ^{14}C YBP (Grady and Schubert, 2007; Schubert, 2010 (Table 1). Based on a tip from Dr. Lynn Ferguson, Grady and Hubbard located a second bone matrix site (IF2a) that yielded an unerupted single tooth plate of a fetal extinct Mammoth *Mammuthus* sp.; remains of the extirpated thirteen-lined ground squirrel *Ictidomys* (formerly *Spermophilus*) *tridecemlineatus*; extirpated vole *Phenacomys* sp.; extirpated prairie vole *Microtus* cf. *M. ochrogaster*; and extirpated yellow-cheeked vole *Microtus xanthognathus*. A ^{14}C date of 33,000 +/- 1,700 YBP [AA42514] was obtained from a bone fragment in IF2a. A third (IF2b) bone matrix site was initially thought to be a discontinuous segment of IF2a and yielded remains of the extirpated vole *Phenacomys* sp., but it subsequently dated older than IF2a: AA45375 yielded a ^{14}C date of 39,300 +/- 1,100 YBP. A fourth bone matrix site (IF3) yielded a molar of the extinct dire wolf *Aenocyon dirus*; remains of the extirpated thirteen-lined ground squirrel *Ictidomys* (formerly *Spermophilus*) *tridecemlineatus*; extirpated heather vole *Phenacomys* sp.; extirpated prairie vole *Microtus* cf. *M. ochrogaster*. IF3 yielded a ^{14}C bone date of 11,986 +/-76 yr BP [AA45376] (Grady and Hubbard, 2009). Mixed taxa IF3 (USNM 610236).

Lane Cave, Scott County, Eshelman and Grady's No. 37 is listed above, the site where Jefferson's ground sloth *Megalonyx jeffersonii* was excavated (Holsinger, 1967). A large sliver of bone was found and collected from the sidewall of the sloth's excavation pit in a July, 1997 PRIOVAC supplemental collection. This fragment yielded a previously unpublished radiocarbon ^{14}C bone date of 28,700 +/-1000 YBP [AA42515].

Prince Albert Cave (Sugar Run System), Giles County - While the excavation of the giant short-faced bear *Artodus simus* in Island Ford Cave was underway, cavers Mike Ficco, Andrea and Mike Futrell made a paleontological discovery in a cave in Giles County. They found a fragmented tooth of the extinct American mastodon *Mammut americanum* (USNM 636277; Hubbard and Grady, 1997; site 79 in McDonald et al., 1998). The tooth was a lower third molar and was found in a fill of sandstone cobbles deposited by a sinking surface stream. The postmortem abrasion and damage to the tooth is significant and precludes a tooth-wear assessment of the age of the mastodon at the time of death.

Russells Reserve Cave, Bath County – In November of 2005, caver Phil Lucas approached us about a project cave with bear skulls and other skeletal remains. The other skeletal remains included the partial skull (Fig. 3) of a juvenile extinct tapir *Tapirus veroensis* (Graham and others, 2019; USNM 546112) and some of its post-cranial bones (Grady et al., 2006).

Winding Stair Cave, Scott County, Eshelman and Grady's No. 76 listed above, a PRIOVAC supplemental collection in March 1998 yielded the new record of an upper molar of Harlan's Musk Ox *Bootherium bombifrons* (Grady and Hubbard, 2001a; USNM 610272).

A PALEONTOLOGICAL EXPERIMENT: THE SEARCH OF 100 CAVES

The dominant motivation in forming PRIOVAC was to contribute to the paleontological knowledge of Virginia's caves, a category of significance with very little representation in the initial Virginia Significant Cave Listings of 1980 and 1985. We pondered the question of the percentage of known caves that have significant paleontological resources. The idea of searching 100 caves for paleontological significance was a start, except that our permit only allowed for collection of exposed, non-human, bone and teeth. Another complication was the nine-month delay in actually obtaining our per-

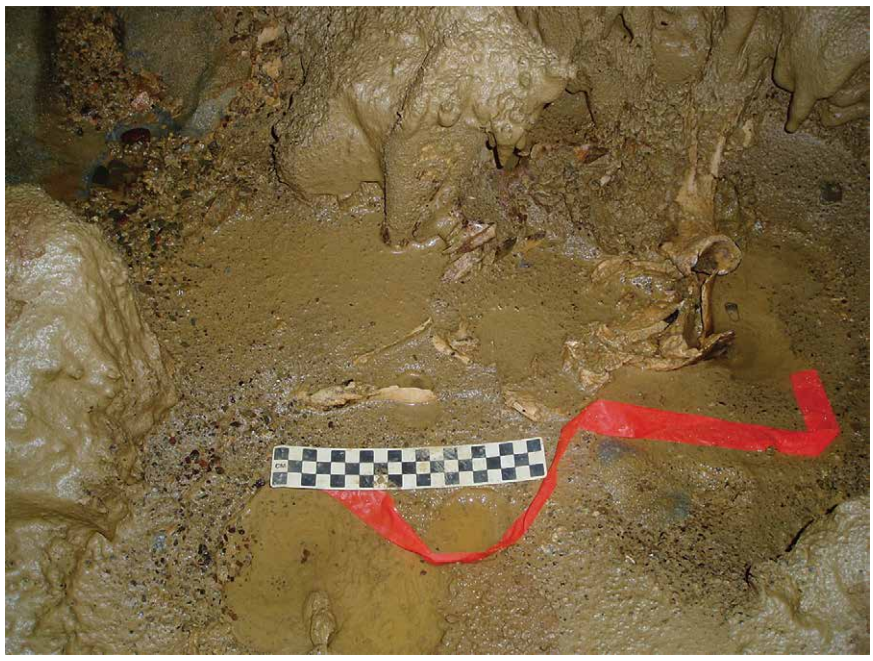

Figure 3. In situ upside-down partial skull of a juvenile extinct *Tapirus veroensis*, above scale (in cm) and flagging tape, in Russells Reserve Cave in Phil Lucas image.

mit; however, copies of Gilbert (1993) and Bass (1995) allowed the field inventory to begin, by osteological observation, rather than collection, through most of 1996. That goal of documenting 100 caves with exposed bone or teeth took five years and visits to 229 different Virginia caves to meet this goal.

An elaboration on how the 229 caves were selected is related to the detail that simultaneous to the vertebrate collections, the living cave invertebrates were also collected in an otherwise unrelated biospeleological inventory. Cave selection included new caves found during karst mapping, known caves lacking a previous biospeleological inventory, and known caves with significant gaps in the known living invertebrate fauna. Bat and woodrat bones, as well as skeletal material still retaining flesh or fragmental bone without an epiphysis (terminal end), were considered inadequate to qualify a bone cave. Of those 100 bone caves, 13 yielded elements of extinct or significant extirpated vertebrate species and one historically known paleontologically significant cave was rediscovered. In simple statistical terms, 13 percent of the caves with exposed bones or teeth proved to be paleontologically significant and 5.7 percent of the 229 different caves, with or without exposed bone or teeth, were found to be paleontologically significant. This was a statewide survey rather than a localized study as the 100 caves were visited in 21 of the 27 karst counties of Virginia and the paleontologically significant caves were distributed over seven of the 27 karst counties.

Ten of these sites were newly recognized paleontological caves as follows:

Bush Handline Cave, Russell County, is a small cave about 18 m in length. A steep entrance slope yielded a tooth of the extinct Harlan's Musk Ox *Bootherium bombifrons* (USNM 610292; January 2000); probably a wash-in, but possibly a woodrat contribution to this Late Pleistocene deposit.

Campbell Cave, Wythe County, is 610 m long with stream and dry passages that were visited and mapped in conjunction with the Wythe County Cave Survey. An upper portion of an ulna of the extinct Leidy's peccary *Platygonus vetus* was collected in a paleo-stream passage (March 2000) along with horse *Equus* sp. (November 1999). The peccary element is Pleistocene in age and probably washed into the cave (USNM 610217).

Cedar Hill Cave, Rockingham County, Eshelman and Grady's No. 8 was not characterized as to age of the deposit and had no extinct or significant extirpated records in the USNM collections from its study, so is not listed above. In April 1999, – a partial tooth of an extinct musk ox *Bootherium* sp. (Grady and Hubbard, 2001a; USNM 636280) was collected; this record establishes that deposits associated with the entrance pit extend into the late Pleistocene.

Lost Lake Cave, Scott County, is a small cave previously used as a water source. A Late Pleistocene upper first or second molar of the extinct Vero tapir *Tapirus veroensis* (USNM 546116; May, 1997; Grady et al., 1998; site 83 in McDonald et al., 1998) was collected without a root, suggestive of possible transportation by a woodrat.

Melrose Caverns, Rockingham County, is a former commercial cave previously known as Virginia Caverns and Blue Grotto listed in McGill's (1933) Caverns of Virginia. An element of the extirpated heather vole *Phenacomys intermedius* was collected in March 2000. Subsequent surficial collections of the extirpated pocket gopher Geomys sp. and the extinct long-nosed peccary *Mylohyus fossilis* led us to request a permit to excavate a one by two-meter area of bone matrix in a wall niche. The site has yielded an assemblage of 47 vertebrate taxa including amphibians, fish, birds, reptiles, and mammals. The bone deposit appears to represent the den site of a small mammalian carnivore and possibly other contributors (Hubbard and Grady, 2001; USNM 610235). This Pleistocene aged deposit yielded the first Virginia record of the pocket gopher *Geomys* sp., an extirpated taxon that now lives in western, southwestern, and southern U.S. and the extirpated round tailed muskrat *Neofiber* cf. *N. alleni*, another form that now lives in the southern U.S. The Melrose fauna includes other extirpated forms that now live in the west: the prairie vole *Microtus ochrogaster* and the thirteen-lined ground squirrel *Ictidomys* (*Spermophilus*) *tridecemlineatus*; extirpated forms that now live in more north-

ern areas: the heather vole *Phenacomys intermedius* and the northern bog lemming *Synaptomys borealis* and extinct long-nosed peccary *Mylohyus fossilis*. Another taxon of local significance is the hellbender salamander *Cryptobranchus alleghaniensis*, which is extirpated from the Potomac River Basin.

Figure 4. Cross sectioned 44 cm tall stalagmite with three marked locations for uranium-thorium dating of spar from Melrose Caverns fossil deposit.

The nearest *Geomys* sp. occurrence was a fossil record in New Trout Cave in Pendleton County, West Virginia. Lower levels of the New Trout Cave deposit date older than 30,000 years ago and contain *Geomys* sp. and *Cryptobranchus alleghaniensis*, but the yellow-cheeked vole *Microtus xanthognathus*, is not present. *Geomys* sp. and *Cryptobranchus alleghaniensis* have not been found in the upper levels of latest Pleistocene age, where the extirpated *Microtus xanthognathus* is relatively common (Grady and Hubbard, 2001b).

Two attempts to date the Melrose Caverns deposit failed when no collogen was found in the bone sample sent for AMS dating (AA40005; September 2000). A second bone date failed when too little collagen (0.18 %) was found in an AMS dating attempt (AA45377; October 2001). Subsequent excavation of the site fully exposed the base and then continued beneath the former location of an inactive stalagmite without changes in the taxa found. Both top and middle spar layers of the stalagmite had very low uranium but were uranium-thorium datable (Fig. 4). The top sample yielded an age of 373 +105/-54 ka and the middle sample an age of 382 +262/-72. These late Irvingtonian dates are previously unpublished and thought to represent the age of this significant bone matrix deposit.

Ruffners Cave No. 1, Page County, is the second largest cave in the county (Douglas, 1964: 350) and has two entrances. The 6 m pit entrance is the associated depositional setting for the Late Pleistocene lower canine and metatarsal elements of the extinct flat-headed peccary *Platygonus compressus* (Hubbard and Grady, 1997; February, 1996; site 80 in McDonald et al., 1998).

Slip Sliding Away Cave, Scott County, is a small cave with a 17 m slope – drop – slope entrance. A premolar of the extinct Vero tapir *Tapirus veroensis* (USNM 546115; March, 1997; Grady et al., 1998; site 82 in McDonald et al., 1998) could represent a wash-in or pit-fall environment for this Late Pleistocene site.

Starr Chapel Saltpetre Cave, Bath County is a large multi-mile long maze cave with a Pleistocene bone deposit based on faunal assemblage. Paleontological significance includes tooth fragments of the extinct American mastodon *Mammut americanum* (VMNH 121161); teeth of the extinct Vero tapir *Tapirus* cf. *T. veroensis* (VMNH 129850 and VMNH 129851); tooth of the extinct long-nosed peccary *Mylohyus fossilis* (VMNH 129852); tooth of the extirpated round-tailed muskrat *Neofiber* sp. (VMNH 121189); tooth of the extirpated pocket gopher *Geomys* sp. (VMNH 121077); a tooth fragment the caribou *Rangifer* cf. *R. tarandus* (VMNH 121156) documented by PRIOVAC collection data. The site was found during a mapping trip in September 1996 and confirmed on a subsequent Grady trip in July 1999 with the identification of a peccary tooth fragment and possible tapir tooth fragment. Collections were delayed until 2017 when US Forest Service permission and a Virginia cave collection permit were obtained. Further complications with curation specifications led to a shift in curation from the Smithsonian Institution to the Virginia Museum of Natural History in Martinsville, Virginia. The first publication of the initial surface collection, which remained cached in the cave for 18 years, plus shallow sampling of a one by two-meter area was reported in a poster at the 78th SVP meeting (Hastings, et al., 2018). The site remains under study.

Figure 5. Glove below molar fragment of an extinct *Mammut americanum* in Stewart Monk Cave.

Stewart Monk Cave, Russell County, is a small cave with a fissure entrance and sediment fills. A fragment of a molar (Fig. 5) of the extinct American mastodon *Mammut americanum* (USNM 610230) was collected in this Pleistocene wash-in site in April, 1999; a radiometric date was attempted on a fragment of the tooth root but failed when no collagen was found.

Unthanks Cave, Lee County, is a large cave with some steam passage that sumps closed for years at a time. The late caver Bill Keith had passed the Easter Pig Siphon and found a large leg bone protruding from a muddy streambed. Not knowing how long the siphon would remain open, he pulled the bone free of the mud and carefully padded and packed up the bone to move it beyond the sump area. The bone, a tibia, was found to be missing the proximal epiphysis (upper end) and was not identifiable. A September 1997 trip beyond the siphon relocated the site of the find and revealed the proximal end of the tibia, as well as the fragmental fibula, embedded in a gravel pocket in the limestone floor of the intermittent stream. The reassembled tibia and fibula (Fig. 6) were identified as from the extinct giant short-faced bear *Arctodus simus* (Hubbard and Grady, 2006; USNM 635774; site 84 in McDonald and others, 1998). A tibial spongy bone fragment yielded a previously unpublished radiocarbon ^{14}C bone date of 12,080 +/-130 YBP [AA40006].

Figure 6. Fred Grady holding reassembled tibia and fibula of an extinct *Arctodus simus* from Unthanks Cave.

Three additional paleontologically significant caves listed in the Supplemental and New Paleontological finds in Virginia section above were rediscovered during the 100 bone-cave search. They were known through literature and museum collections to Grady, but were unfamiliar to Hubbard during field work. An upper molar of the extinct Harlan's Musk Ox *Bootherium bombifrons* (USNM 610272) was collected in Winding Stair Cave in March 1997, after coaxing a nesting buzzard out of the entrance. This cave is also paleontologically significant for the occurrence of the extinct tapir *Tapirus* sp. and the extinct fugitive deer *Sangamona*? sp. documented by CMNM collection data noted in Eshelman and Grady (1986). Although not all consider buzzards raptors, the active nest, may suggest a raptor depositional context may have been viable in the past.

Earlys Cave contains remarkable evidence of Cope's (1869a, b) nineteenth century excavations and includes pick and mattock marks through travertine layers and calcareous cemented sediment; a single unerupted lower deciduous third or fourth premolar of the extinct horse *Equus* sp. was collected among 18 taxa (USNM 610270; Grady, 1992; Grady and Hubbard, 2000). Adjacent Earlys Pit contains similar paleontological deposits (USNM 610271; Grady and Hubbard, 2000) but without evidence of Cope's excavations. PRIOVAC collections in June 1997 – May 1998 of these deposits included the extinct horse *Equus* sp.

PRIOVAC DATING

Two different radiometric dating techniques were employed on PRIOVAC sites. Radiocarbon dating is the most economical of the two, but it can only date sites up to 50,000 YBP. A total of 10 bone and tooth specimens were submitted for ^{14}C dating in 2000-2001 through The University of Arizona's NSF Arizona Accelerator Mass Spectrometry (AMS) Laboratory. These specimens represent nine sites in six different caves. One sample was from historic times (Campbell Cave's horse), three samples failed to yield dates, but were believed older than 50,000 years based on the nature of these deposits (Stewart Monk Cave's Mastodon and two from Melrose Cave) and six sites in three caves were dated as late Pleistocene (Table 1). These six dates ranged from 11,986 +/- 76 [AA45376] to 39,300 +/- 1100 [AA45375] YBP and include previously unpublished dates for two extinct taxa: 12,080 +/- 1700 YBP [AA40006] for the Unthanks Cave giant short-faced bear *Arctodus simus* and 28,700 +/- 1000 YBP [AA42515] for the Lane Cave Jefferson's ground sloth *Megalonyx jeffersonii*. The Island Ford Cave giant short-faced bear *Arctodus simus*, would ultimately date older in Schubert's tooth date (34,080 +/-480 YBP; Grady and Schubert, 2007; Schubert, 2010) than our too low of collagen bone date of >29,900 YBP [AA45374].

Uranium-thorium dating of calcite formations assesses trace amounts of uranium precipitated from water and the radiometric decay products of the uranium. A calcite stalagmite that extended through 27 cm of the upper portions of the Melrose bone deposit was undermined and collected in the site excavation. The 44 cm by 6 to 7 cm speleothem was longitudinally sliced and spar sampled from basal, medial and top layers. U-Th dating by mass spectrometry was done through the McMaster University in Ontario, Canada (Table 2).

Table 1. PRIOVAC Radiocarbon Dates.

Sample #	Cave	Element	Submitted	% Collagen	δ13C	Date BP
AA37861	Stewart Monk Cave	Mammut tooth root	14-Apr-00	none	…	…
AA37862	Campbell Cave	Equus bone slice	14-Apr-00	…	-20.8	213 +34
AA40005	Melrose Caverns	bone fragment	15-Sep-00	none	…	…
AA40006	Unthanks Cave	Arctodus tibia spongy bone	15-Sep-00	2.38%	-19.2	12,080 +130
AA42514	Island Ford 2	bone fragment	5-Mar-01	?2.5%	-18.3	33,000 +1700
AA42515	Lane Cave	Megalonyx bone sliver	5-Mar-01	?1.3%	-21.5	28,700 +1000
AA45374	Island Ford 1A	Arctodus bone chip	4-Oct-01	0.70%	-18.8	>29,900
AA45375	Island Ford 2B	bone chip	4-Oct-01	…	-19.2	39,300 +1100
AA45376	Island Ford 3A	tooth root	4-Oct-01	…	-20.3	11,986 +76
AA45377	Melrose Caverns	snowshoe rabbit leg	4-Oct-01	0.18%	…	…

The age of the basal spar could not be determined accurately because the $230^{Th}/234U$ ratio was greater than 1.0, and suggestive of the presence of high detrital thorium. The very low basal U content was too low to allow the radiometric 230^{Th} signal to overwhelm the detrital 230^{Th} effects (Ford, 2002, pers. comm., 1 February 2002).

The two standard deviation error date margins are high because of the very low U content in all samples. The values of all three samples are similar, internally consistent and in proper stratigraphic order. The top and middle analyses allow us to conclude the formation is older than 300,000 years and may be older than 450,000 years (Ford, 2002, pers. comm., 28 February 2002).

DISCUSSION

The nature of the various paleontological resources found in Virginia caves and their characterization to document their level of significance is problematic. After examining various caves for significant host rock invertebrate fossils, Hubbard remained skeptical on how to document and differentiate significant examples. Sampling deposits of fossil shell lag for identification is more of a characterization of the fossil assemblage of a cave forming lithology. Many caves in Bath and Highland counties display impressive arrays of brachiopods and other invertebrate remains in Devonian and Silurian lithologies both *in situ* as wall, floor and ceiling displays and as weathered fossil shells in floor sediments. The differentiation of exceptional versus typical left us undecided. In contrast, a single cave in Lee County, displays up to two-inch long examples of an unidentified gastropod species weathered in relief like small hornet nests hanging from wall and ceiling rock that can be imaged for the documentation and is easily recognized as significant. Uncertain on how to justify examples of host rock invertebrate fossil displays as paleontologically significant, therefore, our project focused on documenting Pleistocene vertebrate fossils.

The Virginia karst, where the majority of our solutional caves occur, is a covered karst mantled by soils and unconsolidated sediments. Most caves in Virginia also contain accumulations of sediment that are typically stratigraphically layered with the youngest layers overlying older layers. The vertebrate fossil remains of extinct, extirpated, and extant fauna of late Pleistocene or earlier ages are usually buried under recent (Holocene) sediments less than 11,000 years old. We previously mentioned some of the natural disruptions to the normal stratigraphic order that can result in the exposure of older fossils, as well as human disruptions of sediment stratigraphy that may expose buried fossils. It is important to note that the sediments that overlay Pleistocene and older sediments are also important. These overlying sediments provide habitat for the invertebrate and many of the bacterial, fungal, and other fauna inhabiting the caves and may contribute to the understanding of the biological significance of the cave. Overlying sediments may also contain records of historic and prehistoric cave use.

Concerns by representatives of the Department of Historical Resources over potential damage to historic and prehistoric cave resources resulted in the nine-month delay in the issue of our primary study permit, restricting us to sampling only exposed non-human bone and tooth remains. With those concerns in mind, subsequent excavation permits were only requested when non-recent extinct taxon were found exposed in a bone matrix deposit. In caves elsewhere, human history may extend well into the Pleistocene potentially linking archaeological and paleontological interests in fossil bone sites.

Twilight-zone deposits of multiple species of small to medium sized vertebrates are typical of raptor roost sites. Dark zone deposits containing scores of vertebrate species typically are thought to characterize a den or lair site, unless the location is in a pit or beneath a former vertical or steep slope entrance. Most of these sites are probably very significant. In more than one of the caves

Table 2. PRIOVAC U-Th Dates

Sample	U content	234U/238U	230Th/234U	230Th/232Th	Age	Comment
Top	0.1143 ppm	1.1	0.999	82	372 ka +105/-54 ka	…
Middle	0.08 ppm	1.807	0.996	223	382 ka +262/-72 ka	…
Base	0.0744 ppm	1.132	1.649	38	could be >350 ka	230Th/234U >1.0

recognized in this paper, a single tooth record of an extinct species was recovered. Some finds can be characterized as a wash-in, erosional on a steep slope or possibly a woodrat contribution. In each of these cases, a cave contained a depositional environment that preserved remains of an identifiable extinct taxon. Even more importantly, because no excavation (other than to safely extract a partially exposed tooth) were performed at any of these single tooth sites, consequently we have no idea what other elements of the same species or others may remain buried *in situ*. Even in the cases where we suspect the tooth was transported by a woodrat based on the presence of gnaw marks, we have no idea how many other teeth or bone elements were cached and remain buried. Individual fossil evidence suggests peccaries, Jefferson's ground sloth and perhaps tapirs ventured beyond cave entrances into dark-zones, as do bears, porcupines and raccoons today. Individual teeth may have been transported within a cave by both biological agents (e,g;. woodrats) or nonbiological agents (i.e. erosional processes) within the cave. Our recognition of single tooth records of an extinct taxon as significant may be considered as tenuous by some, but they are paleontological records in an under investigated discipline within the cave sciences. If these occurrences were observed associated with any bone matrices suitable for excavation and clearly unrelated to historic or prehistoric human activities, permits would have been applied for as in three other sites documented herein.

It is interesting to note that the late Pleistocene date range of our ^{14}C dates 11,986 +/- 76 [AA45376] to 39,300 +/- 1100 YBP [AA45375] represent the range of dates over the four sites in Island Ford Cave. Initially we thought three of these sites represented erosional segments of a sprawling lair of the resident *Arctodus simus* or perhaps a short linage of multiple generations; however, dating revealed only one of these sites (2A, 33,000 +/-1700 YBP [AA42514]) is roughly contemporaneous with the bear (34,080 +/-480 YBP). The diversity of taxa found at these sites begs the question of what other predators contributed to these sites. The unidentified fish and amphibian taxa of these three bone matrix sites, curated in the Smithsonian Institution, potentially represent an interesting study of the aquatic vertebrate life, despite the prey bias, spanning over 40,000 years with comparison to the present vertebrate fauna inhabiting the adjacent Jackson River.

Because our work was limited to cave sites with exposed non-human bone and teeth, our study has only addressed the proverbial tip of the iceberg of the paleontological resources in only a few hundred caves. Based on the results of the 100 bone cave survey and the scarcity of cave paleontologists working within Virginia, we suspect the actual documentation of these resources will remain an order or two of magnitude underrepresented. Along with resource documentation, the conservation of cave resources is of importance. We still need to continue to recognize and document significant paleontological resources while respecting the significant ecosystems, as well as the archaeological resources associated with or adjacent to cave fossil deposits.

SUMMARY

The PRIOVAC project was initiated in 1996 to inventory known and newly recognized paleontological resources to contribute to a better understanding of the paleontological resources present in Virginia caves. Paleontological is one of the scientific, economic, and caver perspective attribute categories by which caves are evaluated for inclusion in Virginia's Significant Cave List. The list is a way of designating what the Virginia Cave Board and its designees consider the most important caves in the Commonwealth of Virginia and is also a key to understanding how best to protect these important caves. From its inception, the Significant Cave List was conceived to document our most important caves by recognition of their significance based on their scientific, natural and cultural attributes. From the more than 2500 known Virginia caves, the initial Significant Cave List from 1980 included 220 caves, of which only ten were recognized under the criteria within the Paleontological Category. Five years later, the Significant Cave List of 1985 included 224 caves, of which only 12 were recognized within the Paleontological Category. The PRIOVAC project considered the range of paleontological resources found in Virginia caves before focusing on Pleistocene vertebrate remains and documented the paleontological significance of seven of the ten caves in the 1980 listing and eight of the 12 caves in the 1985 listing mostly through the inventories of the known significant paleontological resources reported in Eshelman and Grady (1986).

With a series of cave collection permits, PRIOVAC investigators conducted field inventories of known and new paleontological resources in Virginia caves. The project considered the question of what percentage of Virginia caves contain significant paleontological resources. A plan to examine an additional 100 caves was modified considering the shift in the project focus to Pleistocene vertebrate remains and the limitation that cave collection permits only allowed

sampling of exposed, non-human bones and teeth. A total of 229 caves were examined to identify 100 caves with exposed non-human bones and/or teeth, of which 13 yielded extinct or significant extirpated taxa, one of which was recognized as one studied by E.D. Cope in 1867. In other words, thirteen percent of the 100 bone caves examined or 5.7 % of all 229 caves revealed remains of paleontologically significant taxa.

In all, PRIOVAC documented the paleontological significance of the 28 cave sites reported in Eshelman and Grady (1986) along with another 15 paleontologically significant caves that are summarized in Appendix C of the Inventory of Cave and Karst Paleontological Resources. These 43 significant caves extend our knowledge in the Paleontology Category of cave significance to about one percent of the approximately 4,000 currently known Virginia caves.

Excavation permits were granted for one-to-two-meter areas of bone matrix sites in three caves with identified extinct and significant extirpated taxa, allowing the documentation of the very significant Pleistocene bone deposits in Island Ford Cave, Melrose Cave and Starr Chapel Saltpetre Cave (a U.S. Forest Service owned cave requiring a USFS permit).

Two different radiometric dating techniques were employed on nine sites in six different caves. Radiocarbon dating of six sites in three caves reveal they are Late Pleistocene in age and range from 11,986 +/- 76 [AA45376] to 39,300 +/- 1100 YBP [AA45375]. Four of these dates and this date range are from Island Ford Cave. All four sites were initially believed to represent isolated segments of a sprawling lair site of the Island Ford Cave giant short-faced bear *Arctodus simus*; however, radiocarbon dating revealed the actual bear remains and one of three distal bone matrix sites as roughly contemporary at 33,000 $\pm$1700 YBP [AA42514].

Two other dates represent extinct taxa: 12,080 +/- 1700 YBP [AA40006] for the Unthanks Cave giant short-faced bear *Arctodus simus* and 28,700 +/- 1000 YBP [AA42515] for the Lane Cave Jefferson's ground sloth *Megalonyx jeffersonii*. Uranium-thorium dating of a 44 cm by 6 to 7 cm calcite stalagmite that extended through the upper 27 cm of the Melrose Caverns bone deposit yielded mid and upper formation spar dates of 382 ka +262/-72 ka and 372 ka +105/-54 ka, respectively and reveal much of this deposit, which extends well below the formation's base level, is older than 300,000 years and may be older than 450,000 YBP, dating this bone deposit as Pleistocene (Irvingtonian).

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APPENDIX A

Significant Caves List of 1980: Caves of Paleontological Significance
Natural Chimneys Cave No. 1, Augusta County:
Natural Chimneys Cave No. 2, Augusta County:
Clarks Cave, Bath County: excavation of Pleistocene bone deposits
Pig Hole, Giles County: (?)
Salamander Cave, Giles County: Pleistocene bear remains reported
Gilley Cave, Lee County: excavated paleontologically in the late 1800's (under the name Ely Cave)
Jasper Saltpetre Cave, Lee County:
Lane Cave, Scott County: nearly intact ground sloth (*Megalonyx jeffersoni*) excavated
Vickers Cave, Washington County: Pleistocene bone deposit
Wills (Fraleys) Cave, Washington County:

APPENDIX B

Significant Caves List of 1985: Caves of Paleontological Significance
Natural Chimneys Cave No. 1, Augusta County:
Natural Chimneys Cave No. 2, Augusta County:
Black Oak Cave: Bath County:
Clarks Cave, Bath County: excavation of Pleistocene bone deposits
Pig Hole, Giles County:
Salamander Cave, Giles County: Pleistocene bear remains reported
Corbett Cave, Highland County:
Gilley Cave, Lee County: excavated paleontologically in the late 1800's (under the name Ely Cave)
Jasper Saltpetre Cave, Lee County:
Lane Cave, Scott County: nearly intact ground sloth (*Megalonyx jeffersoni*) excavated
Vickers Cave, Washington County: Pleistocene bone deposit
Wills (Fraleys) Cave, Washington County:

APPENDIX C

PALEONTOLOGICALLY SIGNIFICANT VIRGINIA CAVE AND KARST SITES

Back Creek Caves No. 1 and 2, Bath County, are actually rockshelters with Late Pleistocene/early Holocene deposits based on faunal assemblage with owl roosts recognized as the primary depositional process. Paleontological significance include the record of the extinct peccary *Mylohyus* sp. (No. 1), and the significant extirpated taxa: arctic shrew *Sorex arcticus* (No. 2); chipmunk *Tamias* (formerly *Eutamias)* sp. now *Tamias* sp. (No. 2); thirteen-lined ground squirrel *Ictidomys* (formerly *Spermophilus) tridecemlineatus* (No.s 1 & 2); heather vole *Phenacomys intermedius* (No.s 1 & 2); yellow-cheeked vole *Microtus xanthognathus* (No.s 1 & 2); northern bog lemming *Synaptomys borealis* (No.s 1 & 2). Eshelman and Grady's no.s 3 and 4 (1986).

Bush Handline Cave, Russell County, is a small cave about 18 m in length. The cave yielded a Late Pleistocene tooth of the extinct Harlan's musk ox *Bootherium bombifrons* (USNM 619292; PRIOVAC January 2000); a wash-in or woodrat primary depositional process is suspected.

Campbell Cave, Wythe County, is 610 m long with stream and dry passages that were visited and mapped in conjunction with the Wythe County Cave Survey. A Pleistocene upper portion of ulna of the extinct Leidy's peccary *Platygonus vetus* (USNM 610217; PRIOVAC March 2000) is probably due to a wash-in depositional process.

Cedar Hill Cave, Rockingham County, contains a Late Pleistocene/early Holocene deposit with the pit entrance being the primary depositional process. Paleontological significance is due to a partial tooth of an extinct musk ox *Bootherium* sp. (USNM 636280; PRIOVAC April 1999.

Clarks Cave, Bath County, has deposits known as Late Pleistocene based on faunal assemblage with owl roosts recognized as the primary depositional process. Paleontological significance includes the first Virginia record of the extinct dire wolf *Aenocyon* (formerly *Canis)* cf. *C. dirus* and significant extirpated taxa: Arctic shrew *Sorex arcticus*; New

England cottontail *Sylvilagus transitionalis*; least chipmunk *Tamias (formerly Eutamias) minimus*; thirteen-lined ground squirrel *Ictidomys* (formerly *Spermophilus) tridecemlineatus*; heather vole *Phenacomys intermedius*; yellow-cheeked vole *Microtus xanthognathus*; northern bog lemming *Synaptomys borealis*; ermine *Mustela erminea*. Eshelman and Grady's no. 11 (1986).

Corbett's Cave, See RASS Hole

Darty Cave, Scott County, has deposits from the Late Pleistocene based on faunal assemblage with owl roosts recognized as the primary depositional process. Paleontological importance includes the records of the extirpated heather vole *Phenacomys* sp.; caribou *Rangifer tarandus*. Eshelman and Grady's no. 17 (1986).

Earlys Cave and Earlys Pit, Wythe County, have deposits recognized as Late Pleistocene based on faunal assemblage. Paleontological significance includes the record of an extinct ground sloth *Megalonyx* cf. *M. jeffersonii*; extinct complex-toothed horse *Equus* cf. *E. complicatus*; extinct tapir *Tapirus* sp.; extinct peccaries *Mylohyus* sp. Eshelman and Grady's no. 20 (1986), supplemental PRIOVAC collections June 1997 – May 1998 included extinct horse *Equus* sp. (Earlys Pit; USNM 610271; and 18 taxa (including the extinct horse *Equus* sp.) from Earlys Cave USNM 610270). Earlys Cave is earliest known cave site professionally investigated (8 September 1867 by E.D. Cope) for paleontological resources in Virginia.

Edinburg Fissure, Shenandoah County, has deposits from the Late Pleistocene based on faunal assemblage. Paleontological significance includes the records of the extinct tapir *Tapirus* sp.; extinct peccary *Mylohyus* sp.; extinct stag-moose *Cervalces* sp. and the extirpated yellow-cheeked vole *Microtus xanthognathus.* Eshelman and Grady's no. 22 (1986).

Eggleston Fissure, Giles County, has deposits from the Late Pleistocene based on faunal assemblage. Paleontological significance includes the records of the extirpated northern bog lemming *Synaptomys borealis*; caribou *Rangifer tarandus*. Eshelman and Grady's no. 24 (1986).

Endless Caverns, Rockingham County, has deposits recognized as Late Pleistocene based on faunal assemblage. Paleontological significance includes the lower third molar of the extinct wooly mammoth *Mammuthus primigenius* deposited by a debris flow through a former opening; right humerus of the extinct flat-headed peccary *Platygonus compressus* (USNM 610286; caver sourced with PRIOVAC) of unknown depositional process.

Gardners Cave, Wythe County, has deposits from the Late Pleistocene based on faunal assemblage. Paleontological significance includes the record of the extinct peccary *Platygonus* sp. Eshelman and Grady's no. 27 (1986).

Gillespies Cliff Cave, Tazewell County, has deposits from the mixed Late Pleistocene and Holocene based on faunal assemblage with owl roosts recognized as the primary depositional process. Paleontological significance includes the records of the extirpated yellow-cheeked vole *Microtus xanthognathus*; bog lemming *Synaptomys* sp. Eshelman and Grady's no. 28 (1986).

Holston Vista Cave, Washington County, has deposits from the Late Pleistocene/Holocene based on faunal assemblage with owl roosts recognized as the primary depositional process. Paleontological significance includes the records of the extirpated arctic shrew *Sorex arcticus*; thirteen-lined ground squirrel *Ictidomys* (formerly *Spermophilus*) *tridecemlineatus*; heather vole *Phenacomys* sp.; yellow-cheeked vole *Microtus xanthognathus*; bog lemming *Synaptomys* cf. *S. borealis*. Eshelman and Grady's no. 30 (1986).

Island Ford Cave, Alleghany County, has Late Pleistocene deposits based on ^{14}C dating and faunal assemblage. Paleontological significance includes partial remains of a short-faced bear *Arctudus simus* (USNM 521336) representing the first record of the species in Virginia and dated 34,080 +/-480 ^{14}C YBP. PRIOVAC investigations found three additional deposits: a bone matrix site (IF2a) dated 33,000 +/- 1,700 YBP [AA42514] and yielded a unerupted single tooth plate of a fetal extinct Mammoth *Mammuthus* sp.; extirpated thirteen-lined ground squirrel *Ictidomys* (formerly Spermophilus) *tridecemlineatus*; extirpated vole *Phenacomys* sp.; prairie vole *Microtus* cf. *M. ochrogaster*; and yellow-cheeked vole *Microtus xanthognathus*. A second bone matrix site (IF2b) dated 39,300 +/- 1,100 YBP [AA45375] and yielded remains of the extirpated vole *Phenacomys* sp. A third bone matrix site (IF3) dated 11,986 +/-76 YBP [AA45376] and yielded a molar of the extinct dire wolf *Aenocyon dirus* (the second record of this species from the state); extirpated thirteen-lined ground squirrel *Ictidomys* (formerly *Spermophilus*) *tridecemlineatus*; vole *Phenacomys* sp.; prairie vole *Microtus* cf. *M. ochrogaster*; (mixed taxa IF3, USNM 610236; PRIOVAC).

Jasper Saltpetre Cave, Lee County, has deposits from the Mid Pleistocene due to the paleontological significant records of the extirpated pika *Ochotona* sp. and northern bog lemming *Synaptomys borealis*. Eshelman and Grady's No. 33 (1986).

Klotz Quarry Cave No. 5, Giles County, has deposits from the Late Pleistocene based on faunal assemblage with owl roosts recognized as the primary depositional process. Paleontological significance includes the records of the extirpated bog lemming *Synaptomys* sp.; caribou *Rangifer tarandus*. Eshelman and Grady's No. 35 (1986).

Lane Cave, Scott County, has a deposit from the Late Pleistocene for a record of the extinct Jefferson's ground sloth *Megalonyx jeffersonii* (USNM 23734); Eshelman and Grady's No. 37 (1996) sourced; 1997 PRIOVAC supplemental collection of a bone sliver yielded a previously unpublished radiocarbon ^{14}C bone date of 28,700 +/-1000 YBP [AA42515].

Loop Creek Quarry Cave, Russell County, has deposits from the Late Pleistocene/early Holocene based on faunal assemblage with owl roosts recognized as the primary depositional process. Paleontological significance includes the records of the extirpated ground squirrel cf. *Ictidomys* (formerly *Spermophilus)* sp.; heather vole *Phenacomys* sp. Eshelman and Grady's No. 39 (1986).

Lost Lake Cave, Scott County, a small cave yielded a Late Pleistocene upper first or second molar of the extinct Vero tapir *Tapirus veroensis* (USNM 546116; PRIOVAC May, 1997) possibly transported by a woodrat.

Luray Caverns, Page County, has a deposit suspected as Pleistocene ? for a paleontologically significant record of the extinct large cat *Panthera* sp. indet. or *Felis atrox* (now *Panthera atrox*). Eshelman and Grady's No. 40 (1986).

Meadowview Cave, Washington County, has deposits from the Late Pleistocene based on faunal assemblage. Paleontological significance includes the records of the extinct beautiful armadillo *Dasypus* cf. *D. bellus* and the extirpated heather vole *Phenacomys* sp. Eshelman and Grady's No. 41 (1986).

Melrose Caverns, Rockingham County, is a former commercial cave previously known as Virginia Caverns and Blue Grotto, has Pleistocene (Irvingtonian) deposits based on Uranium-thorium dating and a faunal assemblage from a den site of a small mammalian carnivore and possibly other contributors. Additional Paleontological significance includes the extinct long-nosed peccary *Mylohyus fossilis*; the first Virginia record of the pocket gopher *Geomys* sp., extirpated taxa that now live in western and southwestern U.S. and other extirpated forms that now live in the west: prairie vole *Microtus ochrogaster* thirteen-lined ground squirrel *Ictidomys* (formerly *Spermophilus*) *tridecemlineatus*; extirpated forms that now live in more northern areas: heather vole *Phenacomys intermedius* and the northern bog lemming *Synaptomys borealis*; the hellbender salamander *Cryptobranchus alleghaniensis*, which is extirpated from the Potomac River Basin (mixed taxa USNM 610235; PRIOVAC). A stalagmite based in and extending through upper portions of the deposit yielded upper and mid-level spar samples dated as 373 +105/-54 ka and 382 +262/-72 ka, respectively.

Natural Chimneys Caves No. 1 & 2 (aka Brown's Cave and Cave of the Wooden Steps), Augusta County, has deposits from the Mid Pleistocene based on faunal assemblage with owl roosts recognized as the primary depositional process. Paleontological significance includes the records of the extinct giant beaver *Castoroides ohioensis*; extinct peccary *Mylohyus* sp. and records of the significant extirpated taxa: arctic shrew *Sorex arcticus*; thirteenth-lined ground squirrel *Ictidomys* (formerly *Spermophilus*) *tridecemlineatus*; heather vole *Phenacomys* cf. *P. intermedius*; yellow-cheeked vole *Microtus zanthognathus*; northern bog lemming *Synaptomys borealis*; long-tailed weasel *Mustela* cf. *M. frenata*; extralimital red squirrel *Tamiasciurus hudsonicus* cf. *T. h. tenduidens*. Eshelman and Grady's No. 43 (1986).

Pembroke Railroad Cave No. 1, Giles County, has a deposit from the Late Pleistocene based on faunal assemblage. Paleontological significance includes the records of the extinct peccary *Mylohyus* sp.; extinct fugitive deer *Sangamona*? sp. Eshelman and Grady's No. 47 (1986).

Prince Albert Cave, Giles County, yielded the Late Pleistocene washed-in fragmental tooth of the extinct American mastodon *Mammut americanum* (USNM 636277; caver sourced with PRIOVAC), a lower third molar.

RASS Hole (aka. **Corbett's Cave**), Highland County, has a deposit from the Late Pleistocene based on a record of the extinct peccary *Platygonus* sp. Eshelman and Grady's No. 50 (1986).

Ripplemead Quarry Fissure, Giles County, has deposits from the Late Pleistocene/ Holocene based on faunal assemblage with owl roosts and natural accumulation recognized as the primary depositional processes. Paleontological significance includes the records of the extinct tapir *Tapirus* sp.; extinct peccary *Mylohyus* sp. Eshelman and Grady's No. 51 (1986).

Ruffners Cave No. 1, Page County, is the second largest cave in the county and has two entrances. The 20-foot pit-fall entrance is the depositional setting for the lower canine and metatarsal elements of the extinct Late Pleistocene flat-headed peccary *Platygonus compressus* (PRIOVAC February, 1996).

Russells Reserve Cave, Bath County, has Late Pleistocene deposits, which yielded the paleontologically significant remains of a juvenile extinct Vero tapir *Tapirus veroensis* (USNM 546112; caver sourced with PRIOVAC).

Skyline Caverns, Warren County, has a deposit from the Late Pleistocene based on faunal assemblage. Paleontological significance includes the record of the extinct peccary *Platygonus* sp. Eshelman and Grady's No. 56 (1986).

Slip Sliding Away Cave, Scott County, is a small cave with a Late Pleistocene wash-in or pit-fall occurrence of a paleontologically significant premolar of the extinct Vero tapir *Tapirus veroensis* (USNM 546115; PRIOVAC March, 1997).

Starr Chapel Saltpetre Cave, Bath County is a large multi-mile long maze cave with a Pleistocene bone deposit based on faunal assemblage. Paleontological significance includes remains of the extinct American mastodon *Mammut americanum* (VMNH 121161); extinct the Vero tapir *Tapirus* cf. *T. veroensis* (VMNH 129850 and VMNH 129851); extinct long-nosed peccary *Mylohyus fossilis* (VMNH 129852); and the significant extirpated round-tailed muskrat *Neo-*

fiber sp. (VMNH 121189); pocket mouse *Geomys* sp. (VMNH 121077); caribou *Rangifer* cf. *tarandus* (VMNH 121156). PRIOVAC collections.

Stewart Monk Cave, Russell County, is a small cave with a fissure entrance and sediment fills. The cave yielded a paleontologically significant Pleistocene fragment of a molar of the extinct American mastodon *Mammut Americanum* (USNM 610230; PRIOVAC April 1999).

Strait Canyon Fissure, Highland County, has deposits from the Late Pleistocene based on ^{14}C date of 29,870 +1800/-1400 YBP with natural accumulation recognized as the primary depositional processes. Paleontological significance also includes the records of the extinct round-tailed muskrat *Neofiber leonardi*; extinct American mastodon *Mammut americanum*; extinct complex-toothed horse *Equus complicatus*; extinct Vero tapir *Tapirus* cf. *T. veroensis*; extinct long-nosed peccary *Mylohyus fossilis*; extinct woodland musk ox *Bootherium* (formerly *Symbos cavifrons*) *bombifrons*; and records of the significant extirpated northern bog lemming *Synaptomys borealis*; heather vole *Phenacomys intermedius*; moose *Alces alces*; McDonald et al. (1998) list the musk ox as Harlan's Musk Ox *Bootherium bombifrons.* Eshelman and Grady's No. 59 (1986).

Unknown, (cave ?), Clarke County, is Late Pleistocene/Holocene based on faunal assemblage. Paleontological significance includes the record of the extirpated yellow-cheeked vole *Microtus xanthognathus.* Eshelman and Grady's No. 63 (1986). Note: This record is included here with the addition of '(cave ?)' because Grady recalled this material was encrusted with travertine indicative of a cave or karst environment.

Unnamed Cave, Smyth County, has deposits from the Late Pleistocene/Holocene based on faunal assemblage. Paleontological significance includes records of the extinct American mastodon *Mammut americanum*; extinct peccary *Platygonus* sp. Eshelman and Grady's No. 65 (1986).

Unthanks Cave, Lee County, is a large cave with some stream passage that sumps closed for years at a time and contained a Late Pleistocene ^{14}C dated occurrence of the paleontologically significant extinct giant short-faced bear *Arctodus simus* (USNM 635774; caver sourced with PRIOVAC September, 1997), a spongy bone fragment of the tibia yielded a ^{14}C bone date of 12,080 +/-130 YBP [AA40006].

Vickers Cave, Washington County, has deposits from the Pleistocene (Illinoian?) based on faunal assemblage. Paleontological significance includes the record of the extinct peccary *Platygonus vetus*. Eshelman and Grady's No. 68 (1986).

Wills Cave, Washington County, has deposits from the Late Pleistocene for records of the extinct tapir *Tapirus* sp.; peccary *Mylohyus* sp. Eshelman and Grady's No. 73 (1986).

Winding Stair Cave, Scott County, has deposits from the Late Pleistocene based on the records of the extinct tapir Tapirus sp.; extinct fugitive deer *Sangamona*? sp. Eshelman and Grady's No. 76 (1986). A PRIOVAC supplemental collection yielded an upper molar of the extinct Harlan's musk ox *Bootherium bombifrons* (USNM 610272; March, 1998) and an active buzzard nest at the time of this collection may suggest a viable raptor depositional context in the past.