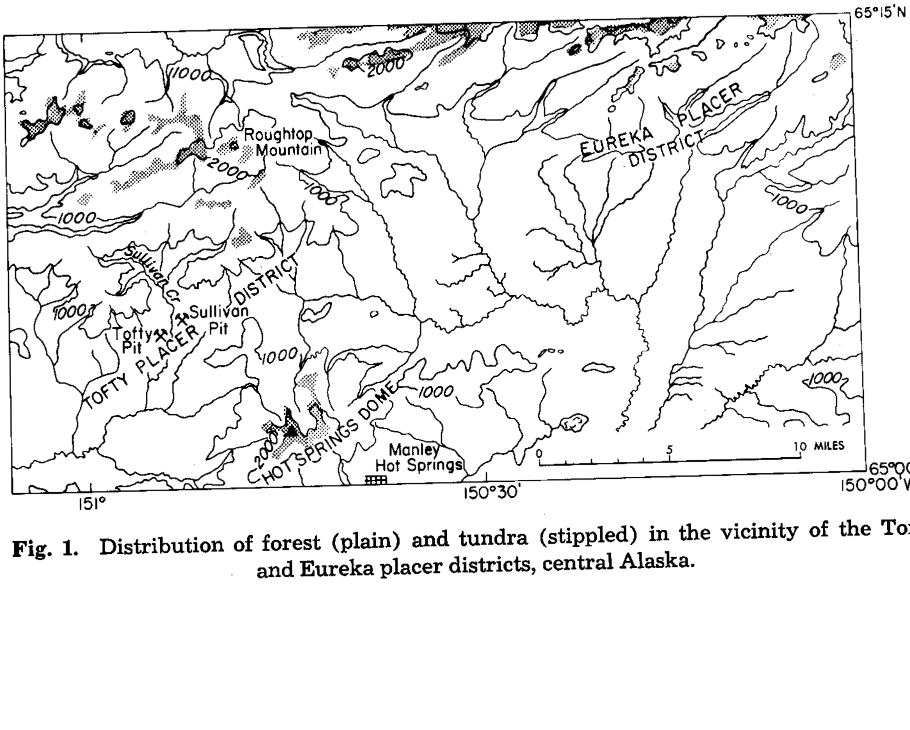

Fig. 1. Distribution of forest (plain) and tundra (stippled) in the vicinity of the Tofty and Eureka placer districts, central Alaska.

TUNDRA RODENTS IN A LATE PLEISTOCENE FAUNA FROM THE TOFTY PLACER DISTRICT, CENTRAL ALASKA*

C. A. Repenning, D. M. Hopkins, and Meyer Rubin†

Introduction

LATE Pleistocene sediments in central and northern Alaska have yielded abundant remains of a varied large-mammal fauna (Frick 1930, Péwé 1957, p. 18). Remains of small mammals are no doubt equally abundant, but because they are less conspicuous, fewer have been collected. The late Pleistocene rodents of Alaska may include no extinct forms and physically are less spectacular than the larger mammals. However, we feel that because of their greater ecologic sensitivity, their stratigraphic significance in Alaska will prove to be far greater than that of the larger mammals. This paper is the first to describe a fossil rodent fauna from Alaska, although many published references to the presence of rodents in the Pleistocene of Alaska have appeared and a few generic lists have been published. The paleogeographic and paleoclimatic significance of the fossil rodents and their stratigraphic setting in the deposits of the Tofty placer district are also described.

During a study of the bedrock and Pleistocene geology of the Tanana A-1 and A-2 quadrangle (1:63,360) in central Alaska, Hopkins and Bond Taber discovered, in 1956, a zone containing abundant remains of small rodents, as well as wood, insects, mollusks, and the bones of large mammals. These fossils were found in a sequence of gravel, silt, and peat exposed in the walls of the Sullivan mining pit and in ditches and gullies adjoining the pit (Figs. 1 and 2). Radiocarbon dating of associated wood indicates that the fossils were deposited in their present positions very recently; however, because of the climatic changes they suggest and because they are associated with fossils of larger mammals now extinct, the fossils must have been derived from sediments in the immediate area, which probably are late Pleistocene in age.

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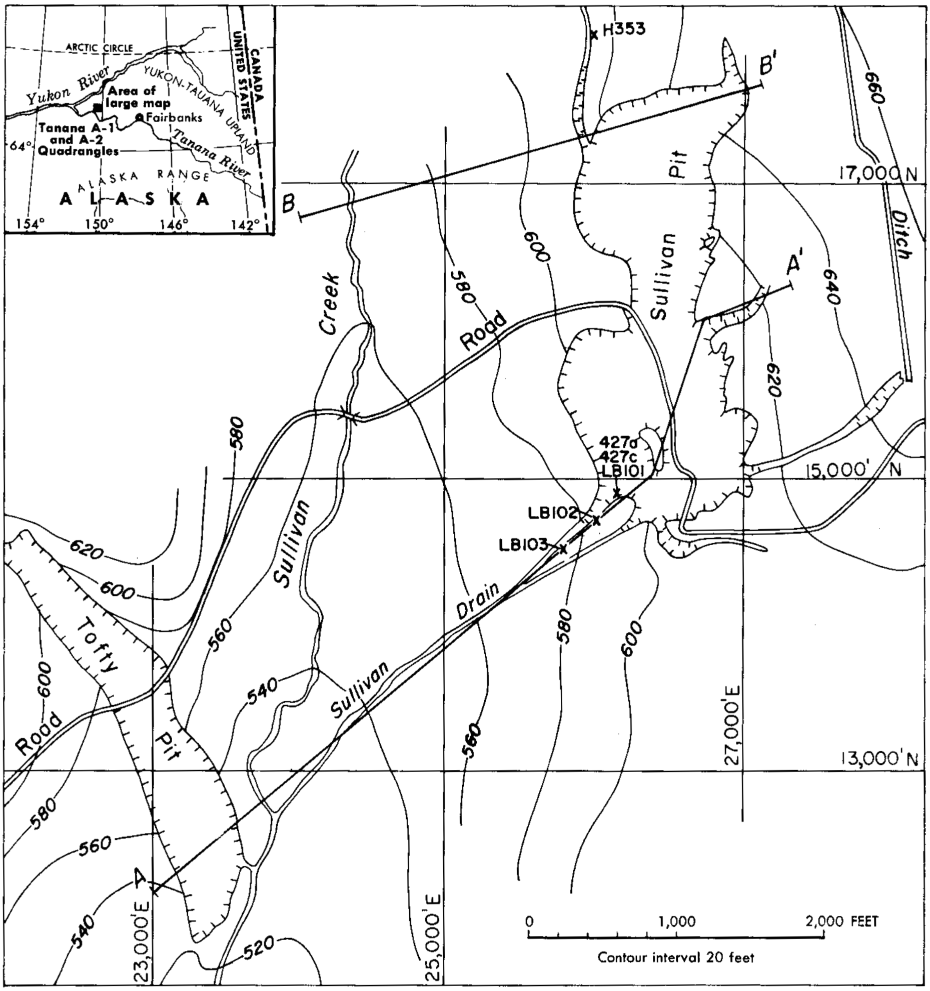
* Publication authorized by the Director, U.S. Geological Survey.

† U.S. Geological Survey, Menlo Park, Calif., and Washington, D.C.

Much additional fossil material was obtained by screen-washing sediments of the fossiliferous zone near the Sullivan pit during the summers of 1957 to 1961. Vertebrate remains collected during the period 1959-61 were identified by Repenning. Those collected in 1956 and 1957 were identified



After Thomas, 1957, Fig. 24.

Fig. 2. Area of the Sullivan and Tofty pits, showing location of fossil collections and fence diagram.

by G. E. Lewis, C. B. Schultz, L. G. Tanner, and T. M. Stout; these specimens are reported here but they have not been examined by Repenning. Wood from various parts of the sequence was dated by the radiocarbon method by Rubin.

We are grateful for the courteous assistance of R. L. Rausch and Kazimierz Kowalski, who kindly provided fossil and recent rodent material for comparative study; to S. B. Benson for permission to examine Recent rodent material in the Museum of Vertebrate Zoology at the University of California; to Bond Taber, who studied the petrography of the silt and collaborated in all aspects of the field investigation; to D. W. Taylor and G. D. Hanna, who identified mollusks from the fossiliferous zone; to Virginia Page, who examined wood collected at various stratigraphic levels; to C. H. Lindroth and R. E. Warner, who identified the insects; and to Gus Benson for information on the history of mining in the Tofty area. D. S. McCulloch, T. L. Péwé, R. L. Rausch, T. M. Stout, and F. C. Whitmore reviewed the manuscript and offered many helpful suggestions.

Geographic and geologic setting

The Sullivan pit is the principal mining excavation in the Tofty placer district (Thomas 1957, Wayland 1961); it lies at an altitude of about 600 ft. near the centre of the Tanana A-2 quadrangle (1:63,360) in central Alaska, 15 miles southeast of the Yukon River and 8 miles north of the Tanana River (Figs. 1 and 2). Thus it lies near the west end of the Yukon-Tanana upland, a region of rolling ridges and broad valleys mostly higher than 300 ft. and lower than 3,000 ft. Valley topography in this part of the Yukon-Tanana upland shows a pronounced asymmetry. South- and west-facing slopes are typically gentle and smooth; east- and north-facing slopes are steep and gullied (Hopkins and Taber 1962). The asymmetry has resulted from persistent migration of large and small streams against their western and southern banks while slowly downcutting. The process continued intermittently throughout much of Pleistocene time. The migrating streams left a thin, discontinuous veneer of gravel, in many places auriferous, on the long, smooth slip-off slopes.

Late in Pleistocene time, the long period of stream downcutting was interrupted, probably as a result of aggradation of the Tanana River, which at that time was overloaded with glacial outwash. Although most of the Yukon-Tanana upland was unglaciated during the cold cycles of the Pleistocene, the Tanana River and its tributaries from the south carried large quantities of outwash contributed by glaciers in the Alaska Range. Strong southwest winds redistributed sandy sediments on the outwash plains and swept finer silt northeastward to be deposited in broad valleys and less thickly on hillslopes just north of the Tanana River (Péwé 1955). Much of the silt was soon redistributed by melt- and rain-water; it finally accumulated in the valley bottoms as well-bedded silt rich in organic debris. Silt that accumulated in this way is locally thicker than 175 ft. in the Tofty placer district. During this interval Sullivan Creek and most other streams in the Tanana A-2 quadrangle began to aggrade, although they continued to cut preferentially against their western and southern valley walls. In Recent time, the streams of the Tanana A-2 quadrangle began to cut into their valley fills, but in most places they are still insulated from their bedrock floors by alluvium and loess several tens of feet thick.

The Tofty mining district lies in the zone of discontinuous permafrost; the Pleistocene sediments in most places are perennially frozen to depths of more than 100 ft. Seasonal thawing penetrates 2 or 3 ft. in the poorly drained lowlands of the mining district.

The vegetation in the Tanana A-2 quadrangle and throughout the Yukon-Tanana upland consists of white spruce-birch taiga at altitudes below 1,500 to 2,000 ft. (Sigafoos 1958). Higher areas are covered with high shrubby vegetation dominated by alder and dwarf birch, but small, discontinuous areas of tundra vegetation are found on the summits of some of the higher and broader ridges, mostly above altitudes of 2,000 ft. The largest area of tundra vegetation in the Tanana A-1 and A-2 quadrangles is only 4.5 miles long and 1 mile wide (Fig. 1). The nearest area of extensive tundra environments lies in the higher parts of the Alaska Range, 100 miles to the south. However, geomorphic evidence in the Tanana A-1 and A-2 quadrangles suggests that the timberline was lowered at least 1000 ft. and that tundra environments were much more extensive at some time in the past. In addition to the evidence of the fossil remains to be discussed in this paper, Hopkins has found weathered and stabilized granite rubble, evidently moved by ancient frost action at altitudes as low as 600 ft. Granite rubble is moved by present-day frost action in the Tanana A-1 and A-2 quadrangles only above timberline at altitudes over 2,000 ft.

The modern fauna of the Tanana A-2 quadrangle is that characteristic of the interior white spruce-white birch taiga; tundra elements are apparently lacking.

History of exploration and mining

The history of exploration and mining in the Tanana A-1 and A-2 quadrangles is briefly reviewed because the activities of early prospectors and miners may have been responsible for the very recent cycle of erosion and sedimentation that resulted in the deposition of the richly fossiliferous part of the sequence of unconsolidated sediments in and near the Sullivan pit.

Exploration of the western part of the Yukon-Tanana upland began in the 1860's, but the white population remained very small and confined to a few trading posts along the two large rivers until about 1895 (Mertie 1934, p. 163-166). Intensive prospecting began in the late 1890's; gold was discovered in the Eureka district in 1898 and in the Tofty district in 1906. Evidently the large numbers of white prospectors in the area during these years led to a series of devastating forest fires, for Eakin notes in 1913 (p. 12-13) that "fully four-fifths of the timbered areas have been burned over in the last decade, and during most of the summer of 1911 a number of fires were burning in different parts of the region".

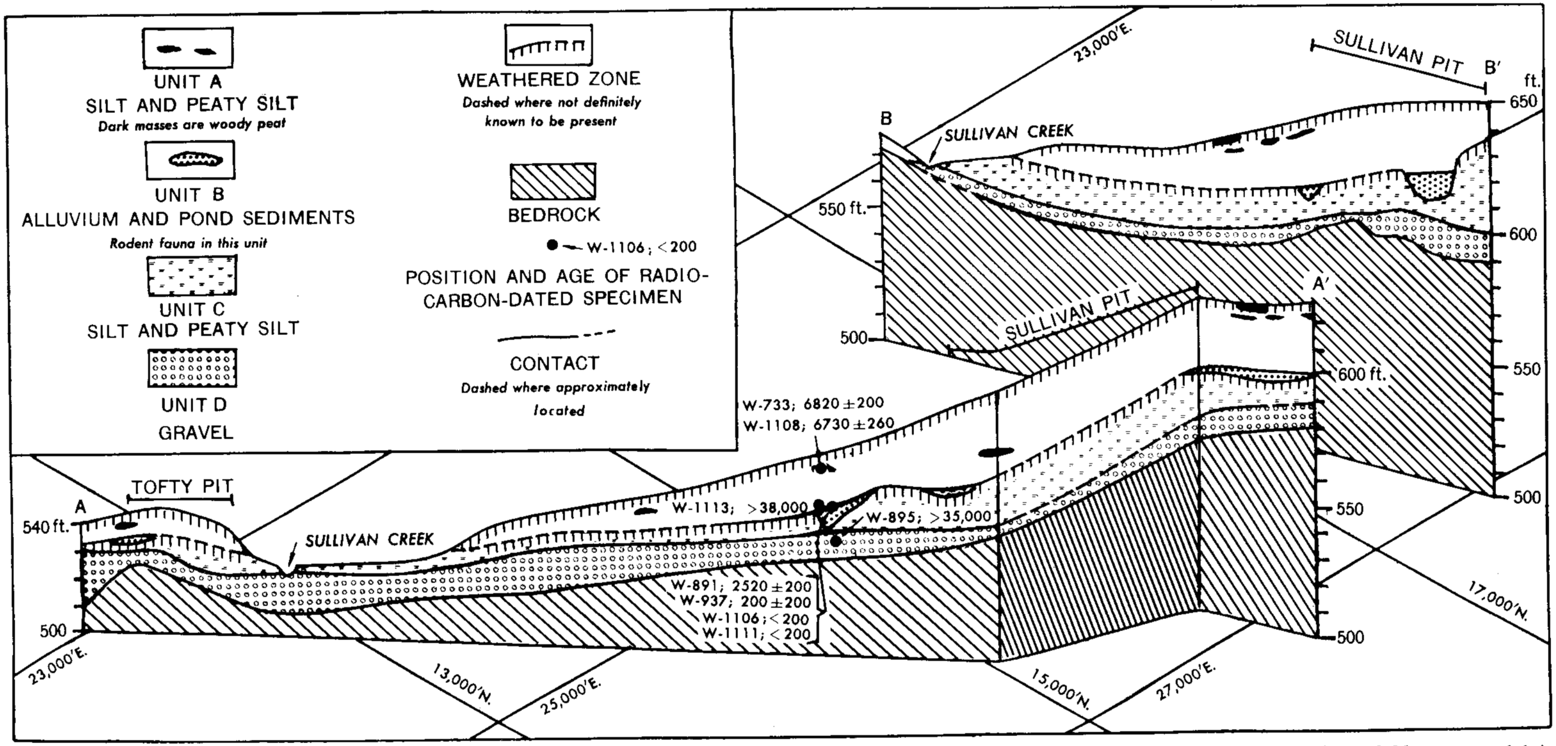
After 1906 gold and tin were extracted in the Tofty placer district from thin fluvial gravel underneath fine-grained sediments several tens of feet thick. Most of the mining was by sinking shafts through the mantle and drifting in the gravel on bedrock, but between 1915 and 1951 gold and tin were mined by open-pit methods in two large excavations, the Sullivan pit and the Tofty pit. The Sullivan pit, the larger of the two, is located on the eastern slope of Sullivan Creek valley; the pit lies about 0.25 mile east of the creek and has a total length of about 0.5 mile (Fig. 2). Open-pit mining began in 1915 near the point where the present road enters the southeastern corner of the Sullivan pit. A drainage ditch approximately on the site of the present Sullivan drain was excavated in the same year, and a ditch bringing water from upper Sullivan Creek and extending parallel to the east margin of the Sullivan pit must have been excavated at about the same time.

Open-pit placer mining operations in areas in Alaska where the auriferous gravel lies under a deep mantle of frozen silt and peat proceed in three steps: first, the living vegetation is stripped off; then the frozen silt is removed by "hydraulicking," that is, thawing and washing the sediments out of the way; and finally the gravel is excavated and washed through sluice boxes.

Either the fires or the hydraulic mining may have resulted in a considerable redistribution of fine-grained sediments in parts of the Tofty area. No eye-witness accounts of soil erosion following the fires have come to our attention, but one can imagine that severe ground fires might have destroyed the ground cover and blackened the surface in large areas; this could have led to rapid thawing of previously frozen sediments and thus to a cycle of gullying on the steeper slopes and redeposition in the flat areas. Hydraulic mining, too, may have led to the deposition of alluvial-fan-like accumulations of sediments in restricted areas downslope from the larger mining excavations.

Stratigraphy of the unconsolidated deposits in and near the Sullivan pit

The unconsolidated sediments in and near the Sullivan pit rest upon a slightly terraced and channeled bedrock surface that has a general southwesterly slope and is carved in slate, phyllite, and graywacke of Cretaceous age. The unconsolidated deposits range in total thickness from 35 to 135 ft. (Fig. 3). Four stratigraphic units can be recognized: the upper two, unit A and unit B, are very young and were deposited less than 200 and more than 45 years ago (between A.D. 1760 and 1916); the lower two, unit C and unit D, are of late Pleistocene, probably Wisconsin age. Unit A consists of 10 to 30 ft. of stratified silt and peaty silt with interbeds of peat; unit B is a series of channel and pond deposits of sand and fine gravel locally 7 ft. thick but more typically 1 or 2 ft. thick; unit C consists of 5 to 20 ft. of silt and peaty silt similar to unit A; and unit D is a nearly continuous layer of well-sorted



Data from Thomas (1957) and Hopkins (field notes 1956-61).

Fig. 3. Fence diagram showing the stratigraphy of unconsolidated sediments in and near the Sullivan pit.

pebble gravel that is 10 to 20 ft. thick in most places. The fossil rodents described here were collected in unit B.

Table 1. Fossil fauna recovered from units A and B in and near the Sullivan pit, Tofty placer district, central Alaska.

	Unit A	*Unit B*
MOLLUSCA		
PELECYPODA		
Pisidium sp. (GDH, DT)*		x
GASTROPODA		
Valvata lewisi Currier (DT, GDH)	x	x
Lymnaea sp. (DT)		x
Succinea strigata Pfeiffer (GDH)	?	x
INSECTA		
***Pterostichus* (*Stereocerus*) *haematopus* Dej. (CHL)		x
Lepidophora cf. *lineaticollis* Kirby (REW)	x	
Dystictidae (REW)	x	
VERTEBRATA		
Small fish (CAR)		x
Lepus sp. (CAR)		x
***Spermophilus* (*Spermophilus*) *undulatus* (Pallas) (CAR)		x
Castorid (beaver-gnawed wood recognized in field)	x	x
***Dicrostonyx torquatus* (Pallas) (CAR)		x
***Lemmus sibiricus* Kerr (CAR)		x
Synaptomys sp. (TMS)		x
Clethrionomys sp. (TMS)		x
***Microtus* (*Stenocranius*) *miurus* Osgood (CAR)		x
Microtus large sp. (CAR)		x
†Proboscidean (GEL, CAR)		x
†*Equus* small sp. (CAR)		x
Cervid, cf. *Rangifer* (CAR)		x
Cervid, cf. *Alces* (CAR)	x	x
Hypsodont bovid (sheep or goat) (CAR)		x
†*Bison* sp. (GEL)	x	x

*Initials in parentheses after each name indicate person responsible for identification: GDH = G. Dallas Hanna, California Academy of Science; DT = Dwight Taylor, U.S. Geological Survey; REW = Rose Ella Warner, U.S. Department of Agriculture; GEL = G. E. Lewis, U.S. Geological Survey, and C. B. Schultz and L. G. Tanner, Nebraska State Museum; CAR = Charles A. Repenning, U.S. Geological Survey; TMS = T. Mylan Stout, Nebraska State Museum; CHL = Carl H. Lindroth, Lund University, Sweden.
**Not present in area today and suggestive of a tundra environment.
†Extinct in Alaska.

Unit A consists chiefly of micaceous silt and peaty silt. The material is structureless in some places and thin bedded or laminated in others; it ranges in colour from medium grey through olive grey to dusky yellowish brown. Lenses of pond silt a few feet thick, lenses of black sedge(?) peat and reddish moss peat a few inches thick, and pebble lenses as much as half an inch thick are common. Single, discontinuous and distorted thin layers of white or pink silt, rich in grains of charcoal but poor in more finely divided organic matter, are present at different levels in several exposures; these evidently are thin oxidized zones resulting from local ground fires that took place during the accumulation of the silt.

A soil profile 3 to 5 ft. thick in the upper part of unit A consists of a zone in which the silt has been oxidized to a mottled pale yellowish brown and in which the original sedimentary structures have been largely obliterated and replaced by an irregular platey parting. In a few places the basal 1 or 2 ft. of unit A consist of similar bleached and weathered silt, which grades downward into the weathered zone at the top of unit C.

Organic remains are abundant throughout unit A; in addition to the vertebrate and molluscan remains listed in Table 1, screen-washing has yielded fragments of charcoal, flakes of vivianite, faecal pellets of several types, black spherical seeds, tufts of grass or sedge, and fragments of mosquitoes and a wasp. Foliage and logs as large as 3 inches in diameter of spruce, birch, alder, and willow are common in the upper 4 to 8 ft. of the unit, and small wood fragments of a conifer are present in the lower 1 or 2 ft. of the unit. However, a zone extending from within 1 or 2 ft. of the base to within 4 to 8 ft. of the top contains no spruce needles and only sparse twigs and sticks generally smaller than 0.5 inch in diameter; all the wood examined in this zone is from angiosperm species.

Birch logs extracted from a mass of beaver-gnawed wood in the upper, woody part of unit A in the Sullivan drain have radiocarbon ages of 6,820 ± 200 and 6,730 ± 260 years (Geol. Surv. Radiocarbon Lab. Nos. W-733 and W-1108). Wood from 1 ft. above the base of unit A in the same exposure is more than 38,000 years old (W-1113). Unit A forms the present surface throughout the area of the pit; this surface is overgrown with alders and willows with a scattering of birch and spruce trees. The two largest trees growing beside the Sullivan drain in 1961 were slightly more than 40 and 45 years old.

Unit B, the unit from which the fossil rodent fauna was obtained, is a discontinuous channel filling consisting in some places of iron-stained, alluvial sand and fine gravel, and in others of moderate reddish brown, cross-bedded pond sand and silt. The unit is overlain with a sharp but conformable contact by the sediments of unit A, and it occupies channels cut to depths of 2 to 15 ft. into the sediments of unit C. The larger clasts are subrounded pebbles of slate and phyllite, rare angular pebbles of vein quartz, rounded lumps of silt and peat, and logs up to 2 or 3 inches in diameter. Wood of coniferous trees, including a stump about 2 inches in diameter, has been recovered. A few beaver-gnawed wood fragments are present. Shreds of mosses and of grasses or sedges, skins of berries, black spherical seeds, charcoal, and faecal pellets of several types are prominent in the finer fractions. Especially abundant are fragmentary hollow tubular concretions 0.12 in. in diameter and 0.25 in. long, evidently the casts of roots of grasses, sedges, or herbaceous plants. Large bones are common, and bones and teeth of rodents are recovered in nearly every screenful. Shells of aquatic mollusks and land snails are conspicuous in many exposures. In addition to the fossil vertebrates, mollusks, and insects listed in Table 1, the unit has yielded egg cases, probably of snails, and leaves tentatively identified as Labrador tea (*Ledum* sp.) and cranberry (*Vaccinium vitis-idaea*).

Two logs from unit B have radiocarbon ages of less than 200 years (W-1106, W-1111), a third has an age of 200 ± 200 years (W-937), and a fourth one of 2,520 ± 200 years (W-891).

Unit C consists of well-bedded olive grey to dark grey silt and peaty silt representing loess and redeposited loess generally similar to that constituting unit A, but unit C contains no lenses of woody peat and no fire-oxidized horizons. Small pebbles are scattered sparsely through the unit. Wood is scarce and consists of scattered twigs less than 0.5 in. in diameter; none of the fragments examined represent coniferous genera. A weathering profile 4 to 6 ft. thick has been imposed upon sediments making up the upper part of the unit. It consists of a zone in which the silt has been oxidized to a greenish-grey to dusky yellow colour, and it is irregularly mottled light brown along vertical joints. Sedimentary structures have been obliterated but the weathered zone commonly shows an irregular platey parting like that in the very young soil at the top of unit A. In places where unit B is missing, the weathered zone in the upper part of unit C simply fades out upward in a gradational contact with the unweathered sediments that comprise the bulk of unit A. The base of unit C grades downward into the gravelly sediments of unit D.

No vertebrate fossils have been found in place in unit C. Screen-washing has yielded shreds of mosses and grasses or sedges and sparse remains of beetles.

Unit D consists of alluvial sandy pebble gravel containing thin interbeds of sand, silt, and peaty silt near the top. The clasts consist chiefly of subrounded phyllite, slate, graywacke, and vein-quartz pebbles less than 3 in. across, but a few cobbles and boulders of vein quartz, diorite, and quartz-tourmaline-cassiterite rock are present. Small pieces of wood as much as 0.5 in. in diameter are occasionally found in the gravel. None of the fragments examined are of coniferous genera. A wood fragment near the top of the unit has a radiocarbon age of more than 39,000 years (W-895).

Age of the sediments

Units C and D are probably of Wisconsin age, although their age cannot be established precisely.

The gravel of unit D rests directly on bedrock and appears to represent the bed load of Sullivan Creek during the period that it was slowly widening its valley by persistent cutting against the west bank. Thus, the gravel is probably of different ages in different places. Gravel near the present course of the stream should be relatively young, and gravel eastward and higher on the slopes should be relatively old. Wood from the top of the gravel exposed in the Sullivan drain has a radiocarbon age of more than 39,000 years, suggesting that the gravel there was deposited before late ("classical") Wisconsin time. The small size of the wood and the absence of coniferous wood suggest that unit D was deposited at a time when spruce trees were absent in the area of the Sullivan pit and that unit D accumulated during an interval of cold climate in early Wisconsin time.

The silty sediments of unit C record a period during which loess or reworked loess accumulated in Sullivan Creek valley, followed by a period of non-deposition and soil development. The fine sediments of unit C rest with gradational, interbedded contact upon the gravel of unit D in the few places where the contact is exposed, suggesting that unit C is only slightly younger than unit D. The scarcity and small size of wood fragments suggest that trees were either absent or sparse and scrubby during the time that unit C was accumulating but the presence of large birch logs 6,700 and 6,800 years old reworked into unit A indicates that forest trees must have recolonized the Tofty area by at least 6,800 years ago. For these reasons, we believe that unit C was deposited during a period of rapid loess accumulation within the Wisconsin glacial cycle and that sedimentation ended more than 6,800 years ago. The weathered zone at the top of unit C is comparable in thickness and intensity of development to the soil profile that has formed in the top of unit A within a period of less than 200 years. Units C and D contain no evidence that they were deposited prior to a major interglacial warming; therefore, we do not believe that they could be as old as Illinoian. Evidently the weathered zone at the top of unit C formed the ground surface in the area of the Sullivan and Tofty pits throughout parts of Recent time, prior to the deposition of unit B.

Units A and B must have been deposited after the lifetime of the youngest wood in unit B and before the oldest trees on the present surface began to grow. Two of the analyzed four logs from unit B have radiocarbon ages of less than 200 years, and the oldest living tree examined on the surface of unit A began growing shortly before A.D. 1916; thus, units A and B were deposited less than 200 years and more than 45 years before 1961. However, the presence of bones of extinct mammals and of wood having radiocarbon ages of 2,500, 6,700, 6,800, and more than 38,000 years indicates that units A and B consist largely of material reworked from older sediments; these remains eliminate the possibility that the deposition of units A and B might be the result of a very recent cycle of renewed loess deposition associated with glacial advances in the Alaska Range during the last 200 years. Evidently units A and B record an episode between 1760 and 1915 during which material was excavated or eroded from older sediments higher on the slopes and redeposited in and near the Sullivan and Tofty pits.

The cause of this recent cycle of erosion and redeposition cannot be determined with certainty. We have entertained the possibility that units A and B might represent tailings that were deposited during hydraulicking and sluicing operations during the earliest days of mining. If this were true, however, artifacts such as metal objects, sawed or chopped wood, and sawed or knife-cut bone would be incorporated into the sediments. None have been found, even after a specific search in 1961. Furthermore, trees began to grow on the upper surface of unit A near the Sullivan drain at least as early as 1916, only one year after the Sullivan pit was first opened. The period of deposition of unit A in that area must have encompassed several years because the unit contains thin layers of moss and sedge (?) peat as well as fire-burned zones; these must reflect interruptions in sedimentation that lasted long enough to permit vegetation to grow on the surface of the accumulating sediments. Moreover, some of the areas in which units A and B are present do not lie downslope from areas that have been mined. It seems more likely that units A and B were deposited after the devastating forest fires that are reported to have taken place around the turn of the century and that the recent cycle of sedimentation was caused by thawing and gullying of freshly exposed, fire-blackened surfaces of older silty sediments exposed on nearby slopes. Whatever the cause of the recent cycle of sedimentation, older fine-grained sediments from which the bones, fossil wood, and enclosing silt could have been derived are limited to altitudes below 800 feet in the areas upslope from the Sullivan pit; thus, the original positions of the fossils could hardly have lain higher than 800 feet.

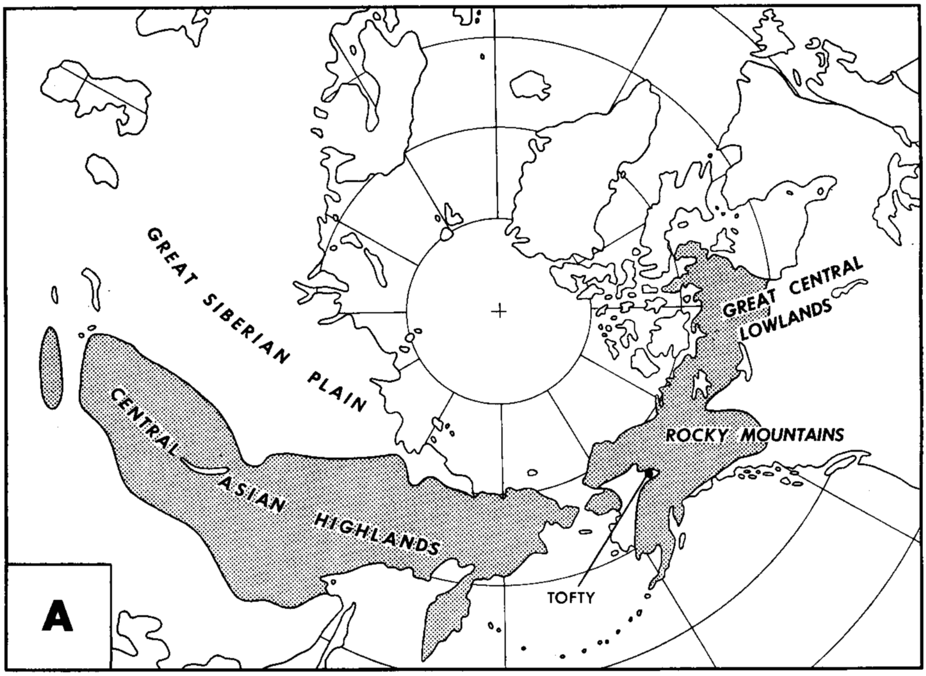
Description of the tundra rodents from Sullivan drain

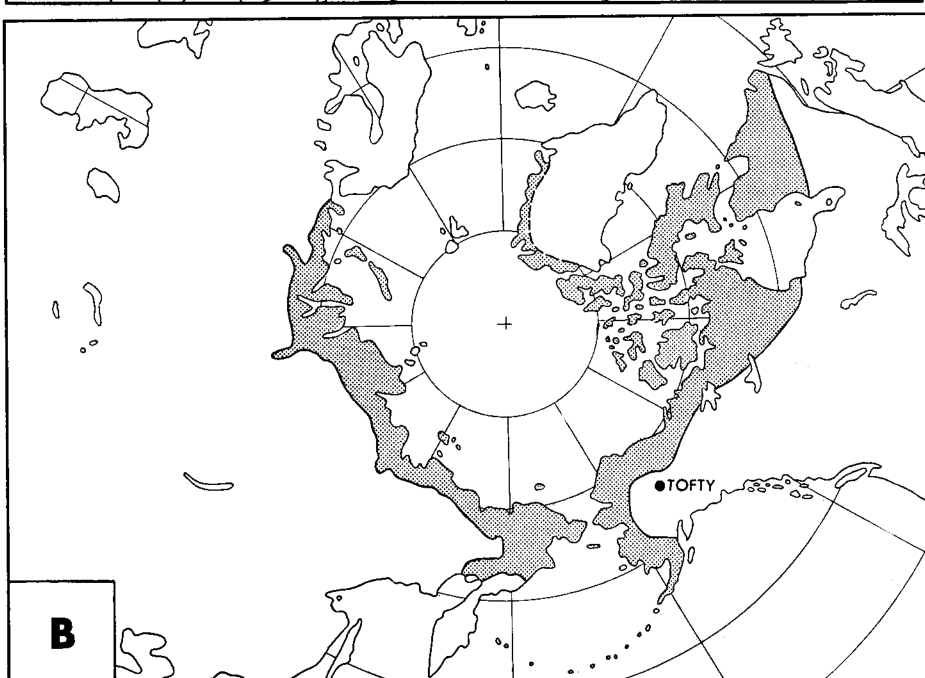
Rodents in five collections from three localities in the channel-fill sediments of Unit B in the Sullivan drain (Fig. 2) were examined by Repenning; five species are present in these collections, three in all collections and one, the arctic ground squirrel, in three of the five collections. A collection obtained from the ditch entering the north end of the Sullivan pit, examined by T. M. Stout (G. E. Lewis, written communication, 1958) and not seen by Repenning, contains two of the genera that are present in the collections from Sullivan drain and two other genera that were not present in the material seen by Repenning. Beavers are indicated by wood cuttings, but no beaver remains were found. All the rodents from the localities along Sullivan drain (except the beaver) are distinctly characteristic of a tundra environment and are absent from the fauna living in the area today. Two genera collected in Sullivan pit are present in the living local fauna. The rodents examined by Repenning all represent living circumpolar species or, in the case of the narrow-skulled vole, a New World species very closely related to the Old World equivalent. The arctic ground squirrel has been described in print from the Pleistocene organic-rich silts in creek valley bottoms near Fairbanks (Hill 1942, Péwé 1957). Most species here discussed have been described from Pleistocene faunas of the Old World (*see* Kowalski 1959, p. 97 and 101 for examples). USNM stands for the United States National Museum.

Subfamily SCIURINAE

Spermophilus (Spermophilus) undulatus (Pallas)

In North America the arctic ground squirrel or suslik has been known for years as *Citellus parryii* (Richardson). Rausch (1953, p. 121) and Ognev



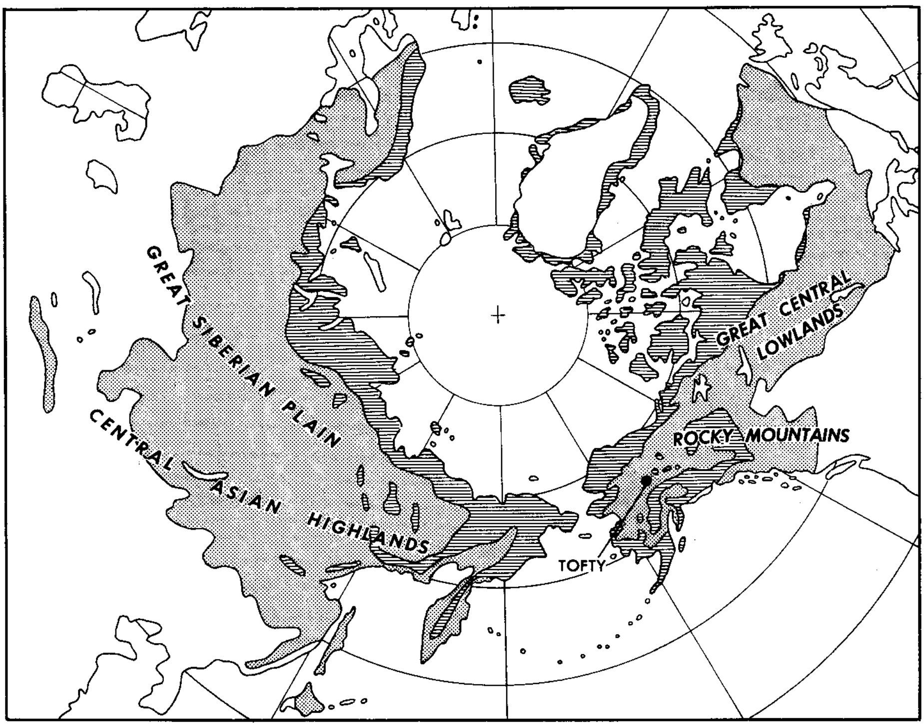


Modified from Ognev (1947 and 48), Rausch (1953), and Hall and Kelson (1959).

Fig. 4. Generalized distribution of (A) *Spermophilus undulatus;* and (B) *Dicrostonyx torquatus* (in Asia and northwestern North America) and *D. hudsonius* (in Quebec and Labrador).

(1947, p. 186) have reviewed the synonymy of the species in both Siberia and boreal North America and have applied the prior name of Pallas. Hershkovitz (1949, p. 296) has pointed out the inadequacy of *Citellus* Oken, 1816, for the generic name and the validity of *Spermophilus* Cuvier, 1825. Opinion 417 of the International Commission of Zoological Nomenclature rejects the names of Oken for nomenclatural purposes (Hemming 1956).

Material. Localities 427C, LB 101, LB 102 (see Fig. 2); fragment of palate with teeth missing, fragment of palate with right M^1 and M^2, fragment of left mandible with M_1 and M_2, isolated left P^4, and isolated left M_2.



After Bartholomew (1958) and Sigafoos (1958).

Fig. 5. Generalized distribution of tundra (hatched) and boreal forest (stippled).

Discussion. In all characters observable this ground squirrel is identical with the living suslik. In the upper teeth P^3 is relatively large, the parastyle of P^4 is very prominent, the anterior cingulum on the molars joins the protocone with an abrupt 90-degree turn giving the teeth a rectangular occlusal outline, and the cusps and lophs are high and sharp. Unfortunately, the specimens do not include the distinctive M^3. In the lower teeth the talonid basins of the molars are rugose and marked by the distinctive basin trench (Repenning 1962, p. 544). The specimens have not been compared with the living Siberian long-tailed suslik, and it is assumed that these features are characteristic of the species in that area on the strength of the synonymy of Rausch, Ognev, and others.

The present Old-World range (Fig 4A) of *Spermophilus undulatus,* when compared with the distribution of tundra and boreal forests (Fig. 5), shows a marked restriction to these two floral zones but little preference between them. The pattern of distribution avoids the great Siberian plain which, although distinctly boreal, is largely swampy taiga and seems to be an impenetrable barrier for the arctic ground squirrel. In North America the squirrel is confined to the northernmost parts of the continent, almost exclusively to tundra areas, except along the Rocky Mountains of western Canada. The squirrel is not present in the boreal forests, which extend southward to Lake Superior and are characterized by the marshy taiga of the great central lowland of North America. Similarly, the swampy taiga of the Yukon Valley in central Alaska, including the Tofty area, appears to be responsible for the absence of this very conspicuous squirrel.

Bee and Hall (1956, p. 47 and 48) state that in the area of the Arctic Slope of Alaska, "This squirrel is best adapted . . . in areas where permafrost is several feet below the surface of the ground. . . . The optimum conditions for colonization are: (1) loose soils on well-drained slopes; (2) vantage points from which the surrounding terrain can be observed; and (3) bare soils surrounded by vegetation that is in an early xerosere stage of succession."

Subfamily MICROTINAE

Dicrostonyx torquatus (Pallas)

In North America the collared lemming is generally referred to the species *D. groenlandicus* (Traill). Ognev (1948, p. 480) placed *D. groenlandicus* in synonymy with the Siberian *D. torquatus* and Rausch (1953, p. 128) concurred on the basis of additional comparison. Siberian specimens have not been compared with the late Pleistocene rodents of the Tofty area but comparisons were made with living Alaskan forms, with a mid-Würm fossil specimen from Poland, and with *Dicrostonyx hudsonius* from northeastern Canada. *Dicrostonyx hudsonius* is separable from *D. torquatus* on the basis of the morphology of both upper and lower teeth.

Material. — Found at all localities (427C, 427A, LB 102, LB 101, and LB 103); left mandible with all teeth (USNM 22833), right mandible with M_1 and M_2, right mandible with M_1, palate with left M^1 and M^2 and right M^2 (USNM 22834), isolated right and left M^1, and two isolated left M_1 (Fig. 7A). Stout refers some isolated teeth collected in the ditch entering the north end of the Sullivan pit to this genus with question.

Discussion. — There is decided variation in the shape of the T-like anterior loop of the second and third lower molars and the T-like posterior loop of the first and second upper molars of *Dicrostonyx torquatus* specimens from North America. The same is true of the anterior head of M_1. The possible significance of the dental variations in *D. torquatus*, however, could not be determined from an examination of about 40 Recent specimens from Alaska and Canada, and Asiatic forms were not available for study. The lack of the internal arm of the T on M^1 and M^2 and of the entire T on M_3 is characteristic of *D. hudsonius*.

The distribution of *Dicrostonyx torquatus* (Fig. 4B) is, for all practical purposes, the same as the distribution of tundra (Fig. 5). According to Bee and Hall (1956, p. 290), *Dicrostonyx* prefers fairly good drainage and avoids permanently saturated soil but does not require the loose soil and perfect drainage that the arctic ground squirrel requires, for it builds its nest in the base of elevated grass hummocks, which dry more rapidly and thoroughly than adjacent ground. The presence of *Dicrostonyx torquatus* in the Pleistocene sediments in and near the Sullivan pit indicates that areas of relatively dry and well-drained tundra were present during late Pleistocene time.

Guilday and Doutt (1961) recently published the first description of *Dicrostonyx* from the Pleistocene of North America, *D. hudsonius* from Pennsylvania, but Geist (1957) and Péwé (1957) have noted the presence of *Dicrostonyx* sp. in Pleistocene deposits of the Fairbanks area.

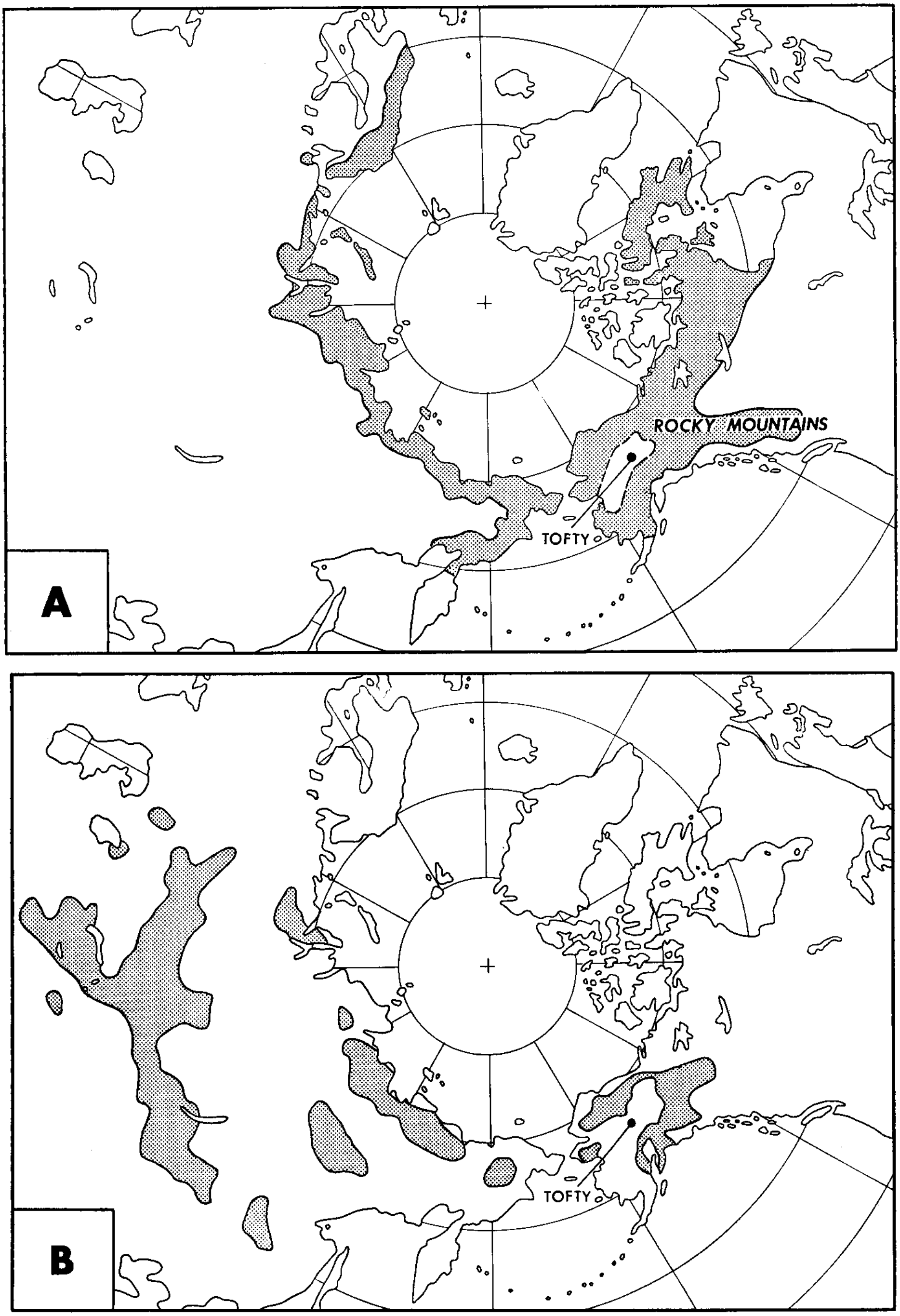
Lemmus sibiricus (Kerr)

Ognev (1948, p. 450) synonymized the North American brown lemming, called *Lemmus trimucronatus* (Richardson) since 1900, with the Siberian lemming *L. obensis* Brants which Ellerman (1949) referred to *L. sibiricus* on the basis of priority. Kowalski (1959, p. 229), in discussing *Lemmus* from the Pleistocene of Poland, states that the two Recent palearctic species are "not readily determinable on their osteological features." Sidorowicz (1960) further concludes that *L. sibiricus* is conspecific with *L. lemmus* (*Linnaeus*), which has priority.

Material. — Found at all localities; left (USNM 22935) and right mandibles with M_1 and M_2, fragment of left mandible with M_1, and seven isolated upper and lower teeth [left M^1 (USNM 22836) and left M^3 (USNM 22837) shown in Fig. 7B]. Stout tentatively refers material collected in the ditch entering the north end of the Sullivan pit to this genus.

Discussion. — In all features observable the late Pleistocene specimens from the Tofty area are identical with living Alaskan forms. No Old World specimens were examined.

The distribution of *Lemmus* is quite similar to that of *Dicrostonyx* except that *Lemmus* is present farther west on the Scandinavian Peninsula (as *Lemmus lemmus*) and *Dicrostonyx* is present farther east in northeastern Canada (as *Dicrostonyx hudsonius*) and in Greenland. *Lemmus* seems to be rather more adaptable to alpine conditions and has a greater range in the mountains of southwestern Alaska and in the Rockies in western Canada



Modified from Ognev (1948 and 50), Rausch (1953), and Hall and Kelson (1959). Significant modifications shown by dashed lines.

Fig. 6. Generalized distribution of (A) *Lemmus lemmus* (in Scandinavia) and *L. sibiricus;* and (B) *Microtus gregalis* (in Asia) and *M. miurus* in North America.

(Figs. 4B, 6A). It also has greater tolerance for dampness and, according to Bee and Hall (1956, p. 77), inhabits low ridges in wet tundra meadows along the arctic slope. It does not seem to have, on the whole, as great a tolerance for moisture as the tundra vole, *Microtus oeconomus* (*see* Fig. 126 of Bee and Hall).

The presence of the brown lemming in the taiga of the Yukon Valley, including the Tofty area, is questionable. Published records of which we are aware show it in the mountain ranges both north and south of the Yukon Valley of central Alaska and in lowland tundra areas of coastal Alaska to the north and west. Robert L. Rausch (written communication 1962) reports that he has trapped the brown lemming at, or just within, the timberline in Alaska, but has never seen it in unbroken spruce forest. In 1959 and 1960 Betty Jane Kruger of Lake Minchumina trapped local rodents for Repenning but collected no lemming. Lake Minchumina is about 90 miles southwest of Tofty and in the same drainage system. The trapping was along the south shore of the lake in level and marshy ground, with small ponds, at an altitude of about 650 feet. The flora was a spruce, willow, and grass taiga. It is felt that this is close to the environment of the Tofty area (*see* Sigafoos 1958, pl. 9) and that it is unlikely that *Lemmus sibiricus* now lives in the area. Its presence in the late Pleistocene fauna does not necessarily indicate much change of environment but strongly suggests that if the area was forested, then timberline was nearby. Except for *Clethrionomys* in the collection identified by Stout, the brown lemming appears to be the least sensitive indicator of environment in the Tofty fossil rodent fauna.

Microtus (Stenocranius) miurus Osgood

The narrow-skulled vole of Alaska and adjacent Canada is very similar to *Microtus (Stenocranius) gregalis* (Pallas) of Siberia and adjacent Mongolia, China, and Afghanistan. The similarity of other arctic rodents on either side of the Bering Strait suggests that these two voles might also be identical. Preliminary work by R. L. Rausch (1953, p. 138-139), designed to test this possibility, reveals a difference in the structure of the palate between Old and New World forms. However, the difference is not consistent (Rausch, written communication 1962). Pending completion of Rausch's study, North American forms are considered a separate species.

Material. — *Microtus miurus* is the best-represented rodent of the Tofty late Pleistocene fauna. The vole is present in all collections made from the channel-filling gravel in Sullivan drain. It was not reported by Stout from the collections in Sullivan pit. The most complete material consists of a nearly complete right mandible (USNM 22838) (Fig. 7C) and a skull lacking those parts posterior to the palate and to the frontal bones and also lacking two teeth from the right side (USNM 22839).

Discussion. — The Tofty late Pleistocene narrow-skulled vole was compared with a series of Siberian specimens representing several subspecies and with a collection of North American specimens in the Museum of Vertebrate Zoology, University of California. The late Pleistocene vole from Tofty showed no intermediate structure but was decidedly the nearctic *Microtus miurus*. The most obvious difference between the palate of the two species, although not an entirely consistent one, is the width of the posterior half of the median process of the palatine bones, the structure which Ognev (1948, p. 407, fig. 198) considers to be the posterior nasal spine, although it is not always spinelike. In most specimens of *M. miurus* (including the Tofty late Pleistocene specimen) it is a broad ramp leading from the bridge of the palatines to the posterior margin of the palate; in *M. gregalis* (including all subspecies examined) it is narrow and very spinelike.

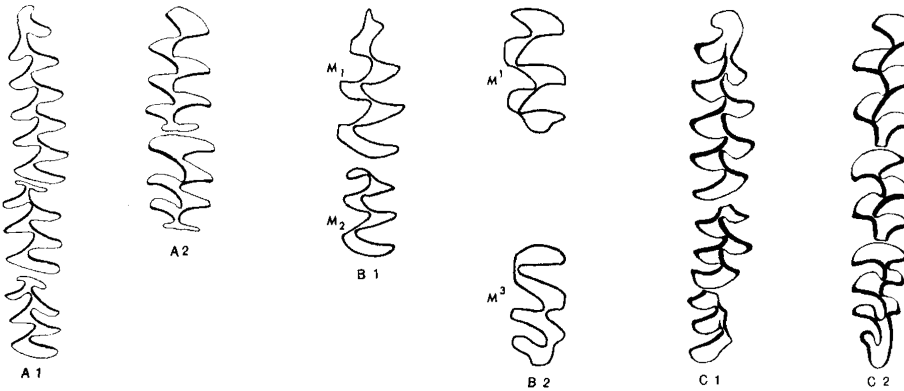


Fig. 7. Enamel pattern of the cheek teeth of (A) *Dicrostonyx torquatus;* A1 left lower teeth from locality LB 102 (U.S.N.M. 22833); A2 left upper first and second molars from locality 427-C (U.S.N.M. 22834). About ×7. (B) *Lemmus sibiricus;* B1 left lower first and second molars from locality D 427A (U.S.N.M. 22835); B2 left upper first (U.S.N.M. 22836) and third (U.S.N.M. 22837) molars; M^1 from locality LB 103 and M^3 from AHP 701D. About ×7. (C) *Microtus miurus;* C1 right lower teeth from locality LB 101; C2 left upper teeth from locality 427-C. About ×8.

The scattered distribution of *M. gregalis* includes some tundra areas along the arctic coast of Siberia and some forest areas in the highlands of Mongolia and southwestern Siberia. In many places are more or less isolated populations south of the southern limit of boreal forests. In Alaska and adjacent Canada, *M. miurus* is almost exclusively confined to alpine areas of tundra in the Brooks and Alaska Ranges and the northern Rockies. Bee and Hall (1956, p. 137) state that "the vole is partial to, and becomes most abundant on, relatively dry soils (sandy or deep soils) which are well drained and near running water." *M. miurus* appears to be the most sensitive indicator of environmental conditions present in the late Pleistocene rodent fauna of the Tofty area.

Microtus sp.

A single right M^3 of a very large species of *Microtus* is in the collections of the late Pleistocene rodent fauna of the Tofty area. It is much too large to be *M. miurus,* for it measures 2.47 mm in length and has a maximum width of 1.19 mm. It could easily belong to *M. xanthognathus* on the basis of both size and enamel pattern; however, several other species have the same pattern in this tooth and could be this large.

Other fossil mammals associated with the tundra rodents

The collection from unit B in Sullivan drain includes about 40 identified specimens of the rodents discussed above. Except for one half of a lower cheek tooth of *Lepus* sp., none of the small mammals could be part of the fauna now living in the Tofty district, nor part of the fauna that must have lived in this area since it last became forested more than 6,800 years ago. Elements of the rodent fauna living in the forest environment now, and for some time in the past, are conspicuously lacking.

In marked contrast, a collection made from unit B in Sullivan pit (locality H353) and provisionally identified by T. M. Stout contains two rodents that are represented in the living fauna of the Tofty district together with specimens tentatively referred to *Dicrostonyx* and *Lemmus.* One of these, *Clethrionomys,* is common in both forest and rocky tundra and is not particularly unusual except that it was not found in the Sullivan drain collections. The other, *Synaptomys,* inhabits swampy meadows and bogs and does not live in tundra. This marked contrast to the ecology indicated by the other rodents found in unit B suggests that a sedimentary unit intermediate in age between that of unit B and of unit C may have been present at least locally in the valley of Sullivan Creek. The absence of the types of rodents now living in the Tofty area in the collections from the Sullivan drain and the recollection of Hopkins that the specimens at locality H353 in the Sullivan pit appeared to have the same preservation as the other fossils found in the area would suggest that the *Synaptomys* remains examined by Stout were not a part of the living fauna which was introduced into the fossil fauna at the time of deposition of unit B. The beaver-gnawed logs, which date as far back as 6,800 B.P., may also have been reworked from such a deposit, for the beaver is more reasonably associated with the ecology of *Synaptomys* than with tundra, although beavers have been reported in areas beyond timberline along streams where large willows are abundant.

The larger mammals found associated with the tundra rodents in unit B are all typical of the late Pleistocene of Alaska. At least half of these are now extinct. Insofar as present information would indicate, none of the larger mammals are helpful in distinguishing between tundra and forest environments.

Age and significance of the faunal remains

The organic remains found in units A and B represent a mixture of tundra and forest forms, probably of diverse ages. Some of the remains, including the rooted spruce stumps, the remains of the bog lemming, *Synaptomys,* the red-backed vole, *Clethrionomys,* and the fragments of beaver-gnawed wood, seem to record a forest environment not unlike the present environment of the Tofty area; that such an environment has existed in the Tofty area for at least 6,800 years is indicated by the radiocarbon age of a large beaver-gnawed birch log from unit A. However, other fossils, including the beetle, *Pterostichus (Stereocerus) haemotopus,* and most of the rodents, represent forms more or less strictly confined to open environments; they are most typically found in tundra environments at or beyond timberline, and none of them are known to live in the western part of the Yukon-Tanana upland at the present time [C. H. Lindroth remarks that the normal habitat of *P. (S.) haemotopus* is in "rather dry sand or gravel with low but dense vegetation, where *Empetrum* (a prostrate tundra plant) is predominating" (written communication 1961)]. Unit C appears to record such an open environment; for lack of any other available source, the fossil tundra rodents must have been concentrated from these sediments or, physically less likely, from the gravel of unit D. Nothing in the stratigraphy, fauna, or radiocarbon dating suggests an age older than early Wisconsin for any part of the sequence in and near the Sullivan pit; it seems likely, therefore, that the tundra animals lived in the Tofty area during Wisconsin time and that they became extinct locally when the area was recolonized by forest vegetation more than 6,800 years ago. The presence of their remains in and near the Sullivan pit thus indicates that during the colder parts of late Pleistocene time, timberline lay at an altitude lower than 800 feet above sea-level, at least 1,300 feet below its present position in central Alaska.

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