Lupinus arcticus Wats. Grown from Seeds of Pleistocene Age

Abstract. *Seeds of the arctic tundra lupine* (Lupinus arcticus) *at least 10,000 years old were found in lemming burrows deeply buried in permanently frozen silt of Pleistocene age in unglaciated central Yukon. They readily germinated in the laboratory and have since grown into normal, healthy plants.*

In July 1954, Mr. Harold Schmidt, a Yukon mining engineer, discovered a number of rodent burrows in muck (a mining term for frozen silt, generally consisting of loess or reworked loess with some organic matter) deposited near Miller Creek, Yukon Territory. The muck face containing the burrows was exposed in the course of placer mining operations at the mouth of Miller Creek, where it enters the Sixtymile River (64°00′N, 140°49′W). The muck layer at the locality was from 8 to 12 m thick overlaying river-deposited gravel. The rodent burrows were located 3 to 6 m below the surface and consisted of well-preserved tunnels with horizontally interconnected chambers, ovate in shape and up to 30 cm long. Several of these contained the remains of a nest and fecal matter along with plant seeds, indicating that areas for nesting, defecating, and food storage were separated. Skulls and skeletons of the rodents were found in some of the chambers.

Mr. Schmidt collected one rodent skull and a number of large seeds from one such burrow. Although he mentioned the specimens to a number of his associates, the scientific significance of the seeds was not realized until 12 years later when a staff member of the National Museum of Canada visited the area and learned of the discovery. Fortunately, during the 12 years, Mr. Schmidt had kept the specimens in a dry place.

Burrows and nests of small rodents, deeply buried in perennially frozen organic silt of late Pleistocene age have been reported from central Alaska (*1–4*). Skulls or complete skeletons were found in many of these burrows, as well as coprolites and food caches composed of the seeds of many kinds of tundra plants. Péwé *et al.* (*4*) reported that, as determined by carbon-14 dating, a nest and the remains of the arctic ground squirrel (*Citellus undulatus*) were 14,860 ± 840 years old.

A comparison with the much-better-known Pleistocene deposits from unglaciated central Alaska clearly suggests that the geological history and age of those from Miller Creek is similar. Before 1932, muck deposits near the mouth of Sixtymile River produced a quantity of as yet undated bones of prehistoric mammals (*5*). Two of the four species identified (*Mammuthus* cf. *primigenius* and *Equus* cf. *lambei*) are extinct; bison no longer exist in the Yukon where only the fourth, caribou, is still present.

The rodent skull from Miller Creek, which is deeply stained and rather fragile, has been identified as being that of the collared lemming, *Dicrostonyx groenlandicus* (*D. torquatus*). Repenning *et al.* (*3*) discussed the significance of the presence of this animal in Pleistocene deposits 80 km west of the Fairbanks area of central Alaska, and in their Fig. 4 showed its present world distribution. The collared lemming is an animal of arctic and high-alpine tundra; it evidently occupied the Miller Creek area during the cool period of rapid loess deposition before the postglacial warming which began in central Yukon about 10,000 years ago (*6*); this animal no longer occurs there, but Youngman (*7*) reported its presence in what appears to be a high-altitude refugium in the Ogilvie Mountains less than 160 km northeast of Miller Creek.

The seed sample given to us by Mr. Schmidt consists of about 2 dozen large seeds readily identified as being those of the arctic lupine (*Lupinus arcticus*), today a common species of tundra and subalpine forest. It ranges from the Bering Strait across northern and central Alaska. Yukon Territory, and northern Mackenzie district, reaching the Arctic Coast and Banks, and Victoria Islands, and extending south in the mountains of southern Alaska and northern British Columbia. In Alaska and Yukon it readily invades areas of disturbed soil along roads and recent clearings.

About half of the seed was in remarkably good state of preservation, with the seed coat as hard and shiny as that of freshly collected seed of this species. In the remainder, the seed coat showed cracks, some quite superficial, some actually exposing the embryo. A selection of the best-preserved seed was placed on wet filter paper in a petri dish where six germinated within 48 hours. In due course the six young plants were transferred to pots placed in a cool greenhouse where they have since grown into normal and healthy young plants indistinguishable from young plants of *Lupinus arcticus* (Fig. 1). At the age of 11 months, one plant developed a few flowers. In the Arctic the first flowering does not normally occur until the 3rd year.

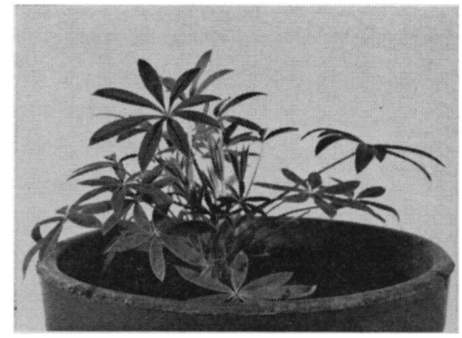

Fig. 1. *Lupinus arcticus* grown from seed at least 10,000 years old.

The somatic number of chromosomes was found to be 96, a value which agrees with counts made for plants grown from seed of recent origin from the vicinity of Whitehorse, Yukon Territory. However, this number is twice that reported for *Lupinus arcticus* from near Umiat in northern Alaska (*8*) and Anchorage (*9*), as well as for other species of lupines native to Yukon and Alaska. More chromosome counts and growth studies are needed before the significance of this unexpected difference can be evaluated.

The habitat of the collared lemming is in arctic and high-alpine tundra well north of the polar treeline. Its burrows and nests are dug in well-drained soil close to the surface and just below the vegetation layer. In a truly arctic environment the ground in which the burrows and nests are situated will thus be frozen the greater part of the year. Unlike the tundra ground squirrel, the collared lemming does not hibernate, and during the winter its stored food is augmented by vegetable matter obtained by tunneling under the snow that in winter covers its burrow.

Under normal conditions a lemming burrow would be poorly ventilated and seed stored in it would certainly be subject to dampness and mold during the summer months. To explain how the lupine seed from Miller Creek could have remained viable, we think it necessary to assume that some catastrophic event, such as a landslide or, perhaps, the deposition of a deep layer of volcanic ash, caused the prehistoric tundra at Miller Creek to be buried, in spring or early summer when the vegetation layer was still frozen. This would have smothered the inhabitants of the burrow, and prevented the soil around it from thawing; also, it would have caused the permafrost level to rise, thereby assuring that the lupine seed would remain dry and continually frozen.

Ødum (*10*) has reported that in archeologically dated sites in Denmark, under optimal conditions of moisture and oxygen deficiency, seed of a large number of common weeds may remain viable for many centuries, and that seed of *Chenopodium album* and *Spergula arvensis* germinated after remaining dormant for 1700 years. The previous record for seed longevity, however, is probably that of the sacred lotus (*Nelumbium nuciferum*) dormant for 2000 years in a far-Eastern peat bog (*11*). If, under suitable conditions, seed have survived in unfrozen soil for so long, it would seem reasonable to predict that seed stored dry and at temperatures well below freezing, could remain viable indefinitely.

Rorippa barbareaefolia, aberrant from other members of the genus by its four-valved pods, together with *Descurainia sophioides* and *Senecio congestus*, are so common on fresh, water-deposited tailings in the placer mining districts of Alaska and Yukon that sourdough miners firmly believe that these plants grew from seed dormant in the frozen muck brought to the surface by placer mining operations. A more likely explanation is that all three are pioneer species on freshly disturbed soil (*12*). Whereas *Descurainia sophioides* and *Senecio congestus* are widespread and ubiquitous throughout northern and central Alaska and Yukon, *Rorippa barbareaefolia* apparently is restricted to the placer mining districts where its rather erratic and sporadic occurrence might suggest the occasional release of seed from once-frozen silts of Pleistocene age (*13*).

The frozen muck deposits of unglaciated Alaska have yielded a variety of plant remains, including diaspores (*2*). With the technique described by Ødum (*10*) it might well be worth testing carefully selected and dated cores from muck deposits to see if viable plant seed or spores might not occur in them.

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Rotation of Venus: Continuing Contradictions

Abstract. *Optical observations of Venus have yielded various values of the rotation period extending from less than one to several hundred days. Radar observations give a retrograde rotation of the solid globe in 244 ± 2 days. Recent ultraviolet photographs, however, show relatively rapid displacements of clouds in the high atmosphere of Venus which suggest a retrogrode rotation in only 5 days. The two rates seem to be physically incompatible.*

The history of reported determinations of the rotation period of Venus has been cluttered with inconsistencies and contradictions. Optical observations of the cloud-covered planet have led various observers to report values ranging from less than one day to several hundred, including the so-called "synchronous" period of 225 days which is equal to one orbital revolution (*1*). In general, very little observational evidence has been produced to substantiate any of these various divergent results; but, in 1956, high-dispersion spectra obtained by Richardson (*2*) showed small Doppler displacements corresponding to a retrograde rotation with a period of 14 days. Richardson's probable error, unfortunately, was as large as the observed rotation and little attention was given to his results. Ironically, spectroscopic measures by Slipher (*3*) in 1903 and St. John and Nicholson (*4*) in 1923 also indicated retrograde rotation, but the results were discounted because they felt it unlikely that Venus would rotate in the opposite direction to the earth and Mars.

Radar measurements of the rotation of Venus were introduced in 1961 with the announcement that "the planet rotates very slowly" (*5*). Other radar Doppler observations made in 1961 suggested that the rotation was retrograde (*6*) and a few years later the rotation was reported to be definitely retrograde with a period 250 ± 40 days about an axis approximately normal to the ecliptic (*7*). Recently Dyce and Pettengill (*8*), using the frequency dispersion of time-gated radar echos, have given the rotation period as 244.3 ± 2 days retrograde, with the axis of rotation inclined $-89°.1 \pm 1°$ to the ecliptic. It would seem as though the question of the rotation of Venus had finally been settled by radar.

Photographically, Venus is nearly featureless throughout most of the visible spectrum. In blue light, however, dusky shadings are noticeable, while in ultraviolet light, where we are presumably viewing the upper levels of the planet's atmosphere, these irregular markings are more enhanced and become the characteristic features of the photographic image. Last year, observers at the French high-altitude observatory at Pic-du-Midi obtained several sequences of ultraviolet photographs, with intervals varying between 2 and 6 hours, during which the markings were observed to move. Measurements of the motions of these ultraviolet "clouds" as they moved away from the sunrise terminator (the line on the planet separating sunlight and darkness) suggested a retrograde rotation period of approximately 4 days (*9*).

Subsequently, photographs taken in June and July 1966 at the New Mexico State University Observatory confirmed the cloud motions reported by the French astronomers. Throughout 1966, however, only the region near the morning terminator of Venus could be observed, and it was quickly noted that the observed cloud motions could just as readily be explained by