SOURCE AREAS OF NORTH CORDILLERAN ENDEMIC PLANTS: EVIDENCE FROM SHEEP AND OUTPOST MOUNTAINS, KLUANE NATIONAL PARK, YUKON TERRITORY.

With 6 figures and 5 tables

STUART A. HARRIS

Zusammenfassung: Herkunftsgebiete von Endemiten der North Cordillera. Ergebnisse von Sheep und Outpost Mountain, Kluane National Park, Yukon Territory

Die Höhenverteilung von vaskulären Pflanzen wird für einen Abschnitt beschrieben, der sich in NW-SO-Richtung vom Gipfel des Sheep Mountain über den Slims River zu dem des Outpost Mountain am Kluane Lake, Yukon Territory (61° 01' N, 138° 24' W) erstreckt. Zehn Prozent der Taxa sind lokale Arten, endemisch in den Nördlichen Kordilleren, ungeachtet der Vegetationszone oder der Ausrichtung. Die Ausrichtung der Hänge hat Einfluss auf die Gesamtzahl der Arten und auch auf die Zonierung der Vegetation eines Berges, aber nicht auf den Prozentsatz der Taxa eines gegebenen geographischen Ursprungs. Eine Analyse der bekannten Verteilung von Arten der Nördlichen Kordilleren ergab drei Hauptzentren der Artbildung, von denen das niederschlagsarme Gebiet nördlich der Wrangell–St. Elias Kette (69 Taxa oder 72% der gesamten Arten) das wichtigste darstellt. Die anderen sind der Brooks Range mit den nördlichen Yukon-Bergen (13 Taxa) und die Kenai Halbinsel, Alaska (12 Taxa).

Summary: When Late Wisconsin ice sheets inundated most of Canada, they destroyed the pre-existing vegetation along a 1,600 km north-south section of the Canadian Cordillera. The vegetation next to these ice masses had to adapt to great climatic changes, and part of this adaptation resulted in the evolution of new species (HULTÉN 1968). During deglaciation, the vegetation migrated back into the previously glaciated areas, but the new species usually experienced more difficulty in colonizing the deglaciated areas due to being adapted to specific environmental conditions. As a result, their present-day distribution is centred on the area in which they evolved, whereas the rest of the flora had been selected and were adapted to survive under a wider range of environmental conditions. One of these areas of speciation lay on the eastern margin of Beringia on the north and northwest flank of the former Cordilleran ice sheets. Kluane Lake lies just within the glaciated zone and is therefore a good place to explore the numbers and presence of the new species. The elevational distribution of vascular plants is described for a NW-SE transect across the Slims River valley from the top of Sheep Mountain to the top of Outpost Mountain, at Kluane Lake, Yukon Territory (61° 01' N, 138° 24' W.). Ten percent of the taxa are local species endemic to the North Cordillera, regardless of vegetation zone or aspect. Aspect altered the total number of species on a mountain and also the vegetation zonation, but not the percentage of taxa from a given geographic source. An analysis of the known distribution of North Cordilleran species indicates that there are three main centres of speciation, of which the rain-shadow area north of the Wrangell–St. Elias Range is the most important (69 taxa or 72% of the total species). The others are the Brooks Range and north Yukon mountains (13 taxa) and the Kenai Peninsula, Alaska (12 taxa).

1 Introduction

HULTÉN (1968) indicated that the vascular flora of the Northern Cordillera of Alaska and the Yukon Territory included local endemics, i.e, taxa that have a limited distribution centred on part of one of the mountain ranges there. Subsequent work (e.g., CODY 1996; CODY et al. 1998, 2000, 2001, 2002; COOK et al. 2002) has refined the synonomy and distribution of these species to a considerable extent, but there has been no comprehensive study of the source areas of these species. However this has to be determined before the repopulation of the formerly glaciated areas along the Cordillera can be elucidated.

The kernel of this idea of localised speciation can be summarized as follows. When the Late Wisconsin ice sheets expanded across most of Canada, they destroyed the pre-existing vegetation. This included a 1,600 km north-south length of the Cordillera. The vegetation in the adjacent areas had to survive a marked climatic change, and part of that adaptation appears to have involved the evolution of new species that could survive better under the new conditions (HULTÉN 1968). During deglaciation, the vegetation recolonised the previously glaciated areas, but the most of the new species could not usually migrate as quickly as the older species into these areas due to being adapted to very specific climatic conditions. As a result, their present-day distribution is usually centred on the area in which they evolved. In contrast, the older species can survive under a much wider range of environmental conditions. One of these areas of speciation lay to the north and northwest of the ice sheets on the eastern margin of Beringia.

There are also few publications giving details of the differences in vegetation and soils in the areas of Yukon and Alaska underlain by permafrost. It is well known that the vegetation develops in response to aspect changes at higher latitudes (JOHNSTON 1981, 35), and this asymmetric vegetation pattern is particularly marked in rain shadow areas in the lee of the high mountain ranges of southern and central Yukon. A good example is the contrast between the southeast slopes of Sheep Mountain and the northern slopes of Outpost Mountain at the southern end of Kluane Lake (Figs. 1–3). Because their floras have been studied by numerous field parties from the Universities of British Columbia, Calgary, etc., based at the Arctic Institute of North America field station, it is the best known area within this part of the Cordillera (PORSILD 1966; NEILSON 1972; HOEFS et al. 1975; HARRIS 1990; HARRIS a. MCDERMID 1991; HARRIS a. GUSTAFSON 1993). This paper summarizes the available information from those studies (literature review and unpublished field data) to show the differences in vascular flora along a NW to SE transect from the top of Outpost Mountain to the summit of Sheep Mountain. An examination is also made of the areal distribution of the various North Cordilleran endemics that have been identified in the literature and it will be shown that the Kluane area is one of three loci of speciation along the northern margin of the former Cordilleran ice sheet.

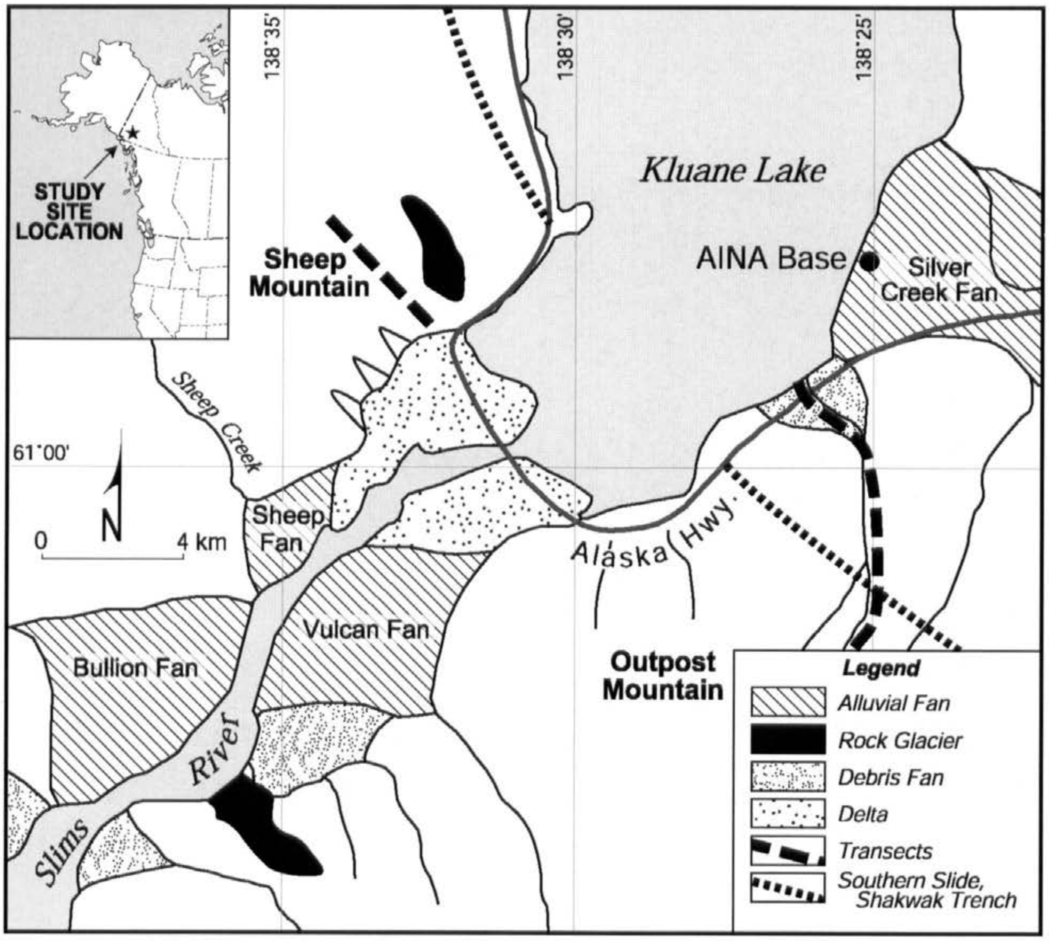


Fig. 1: Location of the transect on Sheep Mountain and Outpost Mountain, Kluane, Yukon Territory
Lage des Transekts auf Sheep Mountain und Outpost Mountain, Kluane, Yukon Territory

Fig. 2: Outpost Mountain as seen from the northwest
Outpost Mountain von Nordwesten gesehen

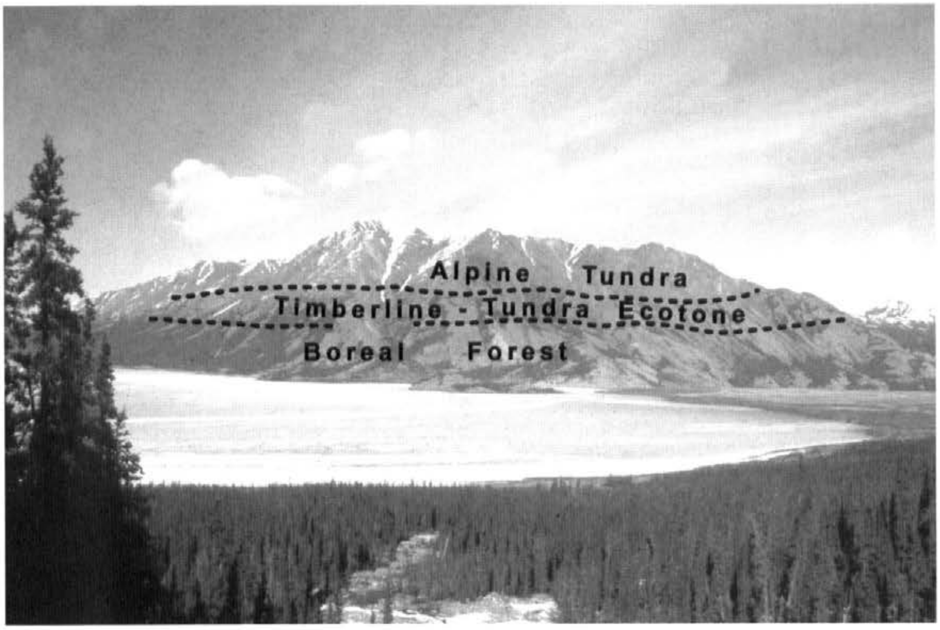


Fig. 3: Sheep Mountain viewed from the east. The boundaries between the major vegetation zones recognised by HOEFS et al. (1975) are also indicated
Sheep Mountain von Osten gesehen. Dargestellt sind auch die Grenzen zwischen den Haupt-Vegetationszonen nach HOEFS et al. (1975)

2 Past Work

NEILSON (1972) provided a checklist based on the earlier collections of vascular plants from the adjacent area housed in a number of different herbaria. Subsequently, HOEFS et al. (1975) provided a detailed phytosociological analysis on the east side of Sheep Mountain (shown in the photograph, Fig. 2), which included maps of the main vegetation associations and associated climatic zonation. Three biogeoclimatic zones were identified. The boreal zone extends from Kluane Lake at 781 m to about 1,100 m (treeline). In this zone, white spruce (*Picea glauca* (Moench.) Voss) forests represent the climatic climax vegetation on mesic sites. Drier sites are occupied by various grassland (steppe) associations. Intermediate sites are characterized by stands of balsam poplar (*Populus balsamifera* L. ssp. *balsamifera*) or bearberry (*Arctostaphylos uva-ursi* (L.) Spreng.). The timberline-tundra ecotone consists of birch-willow (*Betula-Salix*) shrub associations, although dry sites with grassland dominate. This is the approximate level of treeline (upper limit of closed forest – KÖRNER 1998) because white spruce above this elevation is in the krummholz form. The highest krummholz (timberline) lies at about 1,350 m, with alpine tundra dominated by grasses such as *Alopecurus alpinus* J. E. Smith, *Elymus alaskanus* (Scribn. and Merr.) A. Löve ssp. *borealis* (Turcz.) Löve and Löve, *E. trachycaulus* (Link.) Gould ex Shinners ssp. *violaceus* (Hornem.) A. and D. Löve, *Hierochloe hirta* (Schrank) Borbas ssp. *arctica* G. Weim., *Poa alpina* L., *P. arctica* R. Br., and *P. leptocoma* Trin. occurring above this elevation.

BLOOD et al. (1975) described the forest types on Outpost Mountain (Fig. 3) as being coniferous and dominated by white spruce, although black spruce is actually more abundant. HARRIS (1987a, 1987b) described the variations in the depths of the active layer / permafrost table with altitude and vegetation cover on Outpost Mountain. ALLEN (1982) also described the soils and boreal forest cover when studying the dendrochronology of the Slims River valley. White spruce forms open boreal forests with *Salix* spp. at the wetter sites, and black spruce (*Picea mariana* (Mill.) B.S.P.) on wet sites at low elevations. Above 1,200 m (treeline), these are replaced by the birch-willow thickets which are typical of timberline ecotones in wetter climates at this latitude (e.g., on the Kamchatka Peninsula). It grades into alpine tundra at timberline at about 1,450 m.

In addition, HARRIS a. MCDERMID (1991, 1998) studied the vegetational succession resulting from the periodic debris flows on Sheep Mountain and also described the soils. HOEFS et al. (1975) provided data on the vegetation that occurred on the Slims River delta. HARRIS (1990) carried out a detailed study of the causes and dynamics of the saline soils developed in the alluvial deposits, and discussed the relationship between salinity and plant distribution. Together, these provide additional detailed information on the taxa present along the transect.

3 Study area

Sheep and Outpost Mountains (Fig. 1) are located on the NW and SE sides of the Slims River Valley, where the river flows into Kluane Lake (61° 01' N, 138° 24' W). The south side of the Shakwak trench lies along the NE side of both mountains and was formed by the Denali fault (CAMPBELL a. DODDS 1984). The rocks forming the mountains are primarily Palaeozoic slates, greywackes, conglomerates and greenstones (WHEELER 1963), while lateral moraines of Late Wisconsin age are plastered on the lower over-steepened slopes of the valleys. The upper mountain slopes (above 1,800 m) did not undergo glaciation (DENTON a. STUIVER 1966). The glaciers retreated to the mouth of the present Slims River by 12,500 years B.P. and had regressed to the present position of the Kaskawulsh glacier by about 9,780 years B.P. Debris flow fans are a conspicuous part of the landscape (HARRIS a. GUSTAFSON 1993).

Mean annual temperature at Haines Junction (east of Kluane) is –3.2°C (ENVIRONMENT CANADA 1982), with a mean annual precipitation of 292 mm. At Kluane Lake, the values are –2.7°C and 224 mm, but the mean annual temperature decreases southwards, while precipitation amounts increase due to increasing altitude and proximity to the 100 km wide Icefields of the St. Elias Range. Winter snow tends to blow off the grassy slopes of Sheep Mountain, making them an ideal wintering ground for Dahl Sheep. Snow is also partly moved off the tundra into the birch-willow shrub thickets. Typical mean winter snow depths at Kluane Lake would be about 50 cm, whereas it may be 2 m deep in the thickets. The snow cover normally melts by mid-May by the lake and on the lower, southeast-facing slopes of Sheep Mountain, but persists until July within the birch-willow thickets and alpine tundra on the north-facing slopes of Outpost Mountain.

Permafrost is discontinuous on the upper middle slopes of Sheep Mountain, while active rock glaciers are found above 1,400 m. Permafrost is absent on the Slims River flood plain, although seasonal frost may penetrate to 4 m (HARRIS 1990). Continuous permafrost is present on Outpost Mountain, with active layer depths ranging from under 30 cm in closed canopy boreal forest with thick moss, 50–60 cm under open canopy boreal forest, to over 120 cm beneath the birch-willow shrubs. The active layer is thinnest under alpine tundra.

The soils on the lower slopes of Sheep Mountain show palaeosols with a 50 cm mollic horizon overlying a C_{Ca}, while those at the foot of the slope may exhibit salt accumulation. Above 1,300 m, the soils are leached of carbonates produced in the weathering process, but are Entisols or Inceptisols. Saline soils (Solonchaks and Solonetz) occur on the flood plain, where all profiles show poor drainage in the lower horizons (Gleysols). Saline springs occur at a number of locations, the salts being primarily magnesium sulphate (HARRIS 1990). The soils on Outpost Mountain and those under tundra on Sheep Mountain are either Cryosols (permafrost within 1 m) or Orthic Brunisols (ALLEN 1982). The latter are considerably more moist than the soils under grassland or poplar stands on Sheep Mountain.

4 Methods

Figure 1 shows the location of the transect which runs from the crest of Outpost Mountain to the summit of Sheep Mountain, across the Slims River delta. Field observations and collections were made in several years (1980–2000) and at varying seasons. A detailed survey of the species present every 30 m along the transects was carried out in 1991 on Sheep Mountain and in 1986 on Outpost Mountain. The literature was consulted for additional information on species distribution along the transect and this was combined with data in field notes and the herbarium specimens collected by various University of Calgary field teams since 1980. Both 50 m transects along the contour and 1 m and 5 m plots were employed. The specimens in the University of Calgary herbarium (UAC) were examined, but the bulk of the specimen sheets are from the author's own collection (UAC 60,000–71,000). Ian MacDonald identified many of the sedges, Kathleen Wilkinson identified most of the grasses, while Bonnie Smith (University of Calgary) and W. J. CODY (Research Branch, Agriculture Canada) kindly identified or verified some of the more difficult taxa. G. W. Argus identified many of the willows. The nomenclature follows CODY (1996) where possible, although HULTÉN (1968) and COOK et al. (2002) were used as a guide for distributions of the plants in Alaska.

The assignment of geographic distribution follows HULTÉN (1937–1971), HITCHCOCK et al. (1950–1969), PORSILD and CODY (1979), MOSS (1983), and CODY (1996), checked with PESCHKOVA (various dates). Species designated as members of the Circum-Arctic group are renamed the "Circum-Subarctic" group to distinguish them from the endemic flora found along the Arctic coasts of the northern continents and islands (see TALBOT et al. 1999).

The actual groups represented include "North American" used for taxa found across northern Canada and the United States, and "Cordilleran" for taxa distributed only along the Cordillera from the south (Colorado and/or California) to Yukon and Alaska. Taxa occurring mainly south of British Columbia and Alberta within the Cordillera are included in the "Southern Cordilleran" group, while those found mainly in the mountains of British Columbia and Alberta are referred to as "Middle Cordilleran" taxa. As already noted, "North Cordilleran" taxa are those chiefly occurring in the Yukon Territory and Alaska. There are the usual "Beringian" taxa that occur on both sides of the Bering Strait, as well as the "Circum-Subarctic" taxa found in the mainland areas around the Arctic Ocean. There are also a few taxa that HULTÉN called "Amphi-Atlantic", because they are found on both sides of the Atlantic Ocean, as well as some species that flourish either on the Prairies or in the more arid parts of the mountains (the "Cordilleran/Prairie" taxa). Finally there are occasional species that have been introduced by humans from other Continents.

5 Results

Table 1 provides the data on elevational distribution of the vascular plants on the two mountains along the transects in figure 1.

5.1 Species present

Altogether, 295 taxa are represented in the collections, of which only 189 (64.1%) occur on Outpost Mountain. Sheep Mountain has 244 taxa (82.7%), while 138 (46.8%) of the total taxa only occur on one mountain or the other. Of these, 29 are found only on Outpost Mountain. More species of orchids occur on the moist lower slopes of Outpost Mountain than on all of Sheep Mountain, although the fern, *Cystopteris fragilis* (L.) Bernh., only occurs on Sheep Mountain.

On the Slims River alluvium, a specialized flora is found that is adapted to saline conditions, e.g., *Aster yukonensis* Cronq., *Plantago maritima* L. ssp. *juncoides* Lam., and *Ranunculus cymbalaria* Pursh. Some of these species are also found on the slightly saline soils at the foot of Sheep Mountain. On the nonsaline parts of the flood plain, pioneer plants such as *Descurainia sophia* (L.) Webb., *Carex microglochin* Wahlenb., and *Artemisia alaskana* Rydb. are present.

Table 1: Comparison of the elevational distribution of vascular plant taxa on the north-facing slope of Outpost Mountainand the southeast-facing slopes of Sheep Mountain, Kluane

Vergleich der Höhenverteilung von Gefäßpflanzenarten am nordexponierten Hang der Qutpost Mountain und an den südexponierten Hängen des Sheep Mountain, Kluane

Family	Name	Outpost Mountain		Sheep Mountain		Geographic distribution
		Minimum elevation (m)	Maximum elevation (m)	Minimum elevation (m)	Maximum elevation (m)	#
Equisetaceae	*Equisetum arvense* L.	781	838	1222	1696	C
	E. palustre L.	785		781	785	C
	E. scirpoides Michx.	814	1173	1192	1911	C
	E. variegatum Schleich.	814	853	781	1362	C
Polypodiaceae	*Cystopteris fragilis* (L.) Bernh.			1120	2164	C
Pinaceae	*Picea glauca* (Moench.) Voss.	781	1311	781	1353	N. Am.
	P. mariana (Mill.) B.S.P.	781	853	781		N. Am.
Cupressaceae	*Juniperus communis* L.	781	1295	781	1422	C
	J. horizontalis Moench	814	823	785	1265	N. Am.
Scheuchzeriaceae	*Triglochin maritimum* L.	781	838	781		C
	T. palustre L.	781	811	781	800	C
Gramineae	*Agrostis mertensii* Trin. ssp. *mertensii* *			1926		C
	Alopecurus alpinus J. E. Smith	1676	1707	1634	1640	C
	Arctagrostis latifolia (R, Br.) Griseb.	975	1036	1220	1353	Ber.
	Bromus pumpellianus Scribn. var. *pumpellianus*	781	899	800	1314	Ber.
	B. pumpellianus Scribn. var. *tweedyi*			940	1180	Ber.
	Calamagrostis canadensis (Michx.) Beauv. ssp. *canadensis* *			1020		N. Am.
	C. purpurascens Michx. var. *purpurascens*	781	838	781	1936	Ber.
	C. stricta (Timm.) Koeler ssp. *inexpansa*	781	938	783		Ber.
	C. stricta (Timm.) Koeler ssp. *stricta* (Gray) C. W. Greene	781		781	783	C
	Deschampsia caespitosa (L.) Beauv.	781	823	781	800	C
	Elymus alaskanus (Scribn. and Merr.) A. Love ssp. *alaskanus*			781	1100	Cord.
	E. alaskanus (Scribn. and Merr.) A. Love ssp. *borealis* (Turcz.) Love and Love *			1384	1512	C
	E. calderi Barkworth			781	1512	N. Cord.
	E. glaucus Buckl.			781	800	N. Am.
	E. trachycaulus (Link.) Gould ex Shinners ssp. *glaucus* (Pease and Moore) Cody	781	838			N. Am.
	E. trachycaulus (Link.) Gould ex Shinners ssp. *novae-angliae* (Scribn.) Tzvelev.	781	884			N. Am.
	E. trachycaulus (Link.) Gould ex Shinners ssp. *subsecundus* (Link.) Gould	781	850	850		N. Am.
	E. trachycaulus (Link.) Gould ex Shinners ssp. *violaceus* (Hornem.) A. and D. Love	781	1280	1382	2164	N. Am.
	Festuca altaica Trin.	809	1478	780	1860	Ber.
	F. baffinensis Polunin			1782	1926	N. Am.
	F. brachyphylla Schultes and Schultes			1250	1926	C
	Hierochloe alpina (Sw.) R. and S. ssp. *alpina*	1676	1706			C
	H. hirta (Schrank) Borbas ssp. *arctica* G. Weim.			1600	1606	C
	Hordeum jubatum L.	781	838	781		Ber.
	Leymus innovatus (Beal) Pilger *			1408		Cord.
	Poa alpina L.	781	1676	1374	1823	C
	P. arctica R. Br. ssp. arctica			1590	1938	C
	P. arctica R. Br. ssp. lanata (Scribn. and Merr.) R. J. Soreng			1608	1911	Ber.
	P. glauca Vahl.			804	1150	C
	P. leptocoma Trin.			1590	1756	Ber.
	Puccinellia nuttalliana (Schult.) Hitch.	781	823	781		N. Am.
	Setaria viridis (L.) Beauv. *	781				Introduced
	Trisetum spicatum (L.) Richt.	781	1707	1340	1941	C

Family	Name	Outpost Mountain		Sheep Mountain		Geographic distribution #
		Minimum elevation (m)	Maximum elevation (m)	Minimum elevation (m)	Maximum elevation (m)	
Cyperaceae	*Carex aquatilis* Wahlenb. ssp. *aquatilis*	781	838	781	800	C
	C. aurea Nutt.	811		781	800	N. Am.
	C. capillaris L. ssp. *capillaris* *	781	838	781		C
	C. concinna R. Br.			781	1676	N. Am.
	C. fillifolia Nutt.			805	1938	N. Am.
	C. garberi Fern. ssp.*bifaria* (Fern.) Hulten			781		N. Am.
	C. gynocrates Wormskj.	811				C
	C. lasiocarpa Ehrh. ssp. *americana* (Fern.) Hulten *			1220		N. Am.
	C. maritima Gunn.	781		781		C
	C. membranacea Hook.			1608	1859	Ber.
	C. microchaeta Holm.			1324	1772	N. Cord.
	C. microglochin Wahlenb.	781		781		AmphiAtlantic
	C. nardina Fries.			1926		C
	C. obtusata Liljeb.			1140		Ber.
	C. parryana Dewey var. *halli*	781		781	800	N. Am.
	C. petricosa Dewey			1350		N. Cord.
	C. podocarpa R. Br.			1552	1794	Ber.
	C. raynoldsii Dewey *	1448				S. Cord.
	C. rupestris All.			1274	1941	C
	C. scirpoidea Michx.			1180	1938	Ber.
	Eriophorum angustifolium Honckn.	781	853	781		C
	E. brachyantherum Trautv.	781	853	781		C
	Kobresia myosuroides (Vill.) Fiori and Paol.			1315	1941	C
	Scirpus rollandii Fern.			781		C
Juncaceae	*Juncus alpinoarticulatus* Chaix in Vill ssp. *americanus* (Farwell) Hamet-Ahti	781	800			C
	J. balticus Willd. var. *alaskanus* (Hulten) A.E.Porsild	781	814	781	800	Ber.
	J. balticus Willd. var. *littoralis* Engelm.	781	815	781		N. Am.
	J. castaneus Smith ssp. *castaneus*	781	812	781		C
	Luzula arctica Blytt ssp. *arctica*	1463				C
Liliaceae	*Lloydia serotina* (L.) Rchb.	1433	1707	1618	1936	Ber.
	Maianthemum stellatum (L.) Link	1200		869	1143	N. Am.
	Tofieldia coccinea Richards *	790	853			C
	T. pusilla (Michx.) Pers.	790	800	781		C
Michx	*Zygadenus elegans* Pursh.	781	1463	781	1760	Cord.-Prairie
Orchidaceae	*Corallorhiza trifida* Chat.	781	846			C
	Cypripedium passerinum Richards	781	884	812	835	C
	Plantanthera dilatata (pursh.) Lindl.	781				N. Am.
	P. obtusata (Pursh.) Lindl.	785				N. Am.
	Spiranthes romanzoffiana Cham. and Schlecht. *	785				N. Am.
Salicaceae	*Populus balsamifera* L. ssp. *balsamifera*	781	789	781	1200	N. Am.
	P. tremuloides Michx.			783	1146	N. Am.
	Salix alaxensis (Anderss.) Cov. ssp. *alaxensis*	781	810	781	1702	Ber.
	S. alaxensis (Anderss.) Cov. ssp. *longistylis* (Rydb.) Hulten	781	838	781	800	N. Cord.
	S. arbusculoides Anderss.	781	1200			N. Am.
	S. arctica Pall. ssp. arctica	1524	1707	1382	1776	C
	S. barrattiana Hook. *	1341	1494	1630	1850	Cord.
	S. bebbiana Sarg.	781	823			N. Am.
	S. brachycarpa Nutt. ssp. *brachycarpa*	914	1372	781	1360	N. Am.
	S. brachycarpa Nutt. ssp. *niphoclada* (Rydb.) Argus	781	1554	781	1638	N. Am.
	S. glauca L. ssp. *acutifolia* (Hook.) Hulten	781	1554	781	1422	N. Am.
	S. glauca L. ssp. *glabrescens* (Anderss.) Hulten			1448		Cord.
	S. lanata L. ssp. *richardsonii* (Hook.) Skvortsov	1128	1219	1176	1420	Ber.

Family	Name	Outpost Mountain Minimum elevation (m)	Outpost Mountain Maximum elevation (m)	Sheep Mountain Minimum elevation (m)	Sheep Mountain Maximum elevation (m)	Geographic distribution #
	S. myrtillifolia Anderss.			781	1420	N. Am.
	S. niphoclada x *S. setchelliana*			1180		N. Cord.
	S. novae-angliae Anderss.	853	1402	781		Cord.
	S. planifolia Pursh. ssp. *planifolia*			781		N. Am.
	S. polaris Wahlenb.	1463	1707	1310	1911	C
	S. reticulata L. ssp. *reticulata*	781	1585	1180	1911	C
	S. rotundifolia Trautv. ssp. *dodgeana* (Rydb.) Argus			1750	1936	N. Cord.
	S. setchelliana Ball.	781	783			
Betulacaceae	*Betula glandulosa* Michx.	1036	1463	1190	1426	N. Am.
	B. nana L. ssp. *exilis* (Sukatsch.) Hulten *	1036	1463			Ber.
Santalaceae	*Comandra umbellata* (L.) Nutt. ssp. *pallida* (A. DC.) Piehl *			781	890	N. Am.
	Geocaulon lividum (Richards.) Fern.	781	975	781	1162	N. Am.
Polygonaceae	*Oxyria digyna* (L.) J. Hill	1494	1737	1440	1911	C
	Polygonium viviparum L.	1494	1737	1222	1840	C
Chenopodiaceae	*Chenopodium capitatum* (L.) Asch.			1100		Ber.
	Eurotia lanata (Pursh.) Moq.	781	817	781	1282	N. Am.
Portulacaceae	*Montia bostockii* (A. E. Porsild) Welsh	1524	1600	1656	1664	N. Cord.
	M. sarmentosa (C. A. Mey.) Robins.	1372	1737	1656	1911	Ber.
Caryophyllaceae	*Arenaria longipedunculata* Hulten	800				Cord.
	Cerastium arvense L.	800		781		C
	C. beeringianum Cham. and Schlecht.	1326	1372	1370	2164	Ber.
	Minuartia biflora (L.) Schinz. and Thell.			1600	1720	C
	M. obtusiloba (Rydb.) House			1580	1878	Ber.
	M. rossii (R. Br.) Graebn.			936	1860	N. Am.
	Silene acaulis L. ssp. *acaulis*	1570	1737	835	1941	C
	S. involucrata (Cham. and Schlecht.) Bocquet ssp. *involucrata*			1936		C
	S. uralensis (Rupr.) Bocquet ssp. *uralensis*	1402	1585	1760	1941	C
	Stellaria longipes Goldie	781	1326	1570	2164	C
Ranunculaceae	*Aconitum delphinifolium* DC. ssp. *delphinifolium*	1204	1585	1246	1672	Ber.
	Anemone drummondii S. Wats. var. *lithophila* (Rydb.) C. L. Hitchc.	1524	1737	1784	1950	M. Cord.
	A. multifida Poir.			781	1520	N. Am.
	A. narcissifolia L.ssp. interior Hulten			800	940	N. Cord.
	A. parviflora Michx.	809	1737	781	1911	Ber.
	A. richardsonii Hook.	1433	1463	1550	1690	Ber.
	Delphinium brachycentrum Ledeb.			1662	1682	Ber.
	D. glaucum S. Wats.			1550	1665	Cord.-Prairie
	Pulsatilla ludoviciana (Nutt.) Heller			785	1512	Ber.
	Ranunculus cymbalaria Pursh.	781	823	781		C
	R. nivalis L.			1724	1805	C
	R. pedatifidus Sm. ssp. *affinis* (R. Br.) Hulten	1310	1524	1724	1805	C
	R. pygmaeus Wahlenb.			1648	1810	C
	R. sulphureus Sol.	1676	1737	1530	1645	Ber.
Papaveraceae	*Papaver macounii* Greene ssp. *discolor* (Hulten) Randell			1365	1935	Ber.
Cruciferae	*Arabis drummondii* Gray	1372	1448			N. Am.
	A. holboellii Hornem. var. *retrofracta* (Grah.) Rydb.			810	900	N. Am.
	Cardamine purpurea Cham. and Schlecht.	1143	1737	1640	1650	Ber.
	Descurania sophia (L.) Webb. *	781				Introduced
	Daraba alpina L.			1432	1936	C

Family	Name	Outpost Mountain		Sheep Mountain		Geographic distribution
		Minimum elevation (m)	Maximum elevation (m)	Minimum elevation (m)	Maximum elevation (m)	#
	D. borealis DC.	781		1180		Ber.
	D. cana Rydb.	1463		1448	1618	N. Am.
	D. cinerea Adams			1740	1936	C
	D. glabella Pursh.	781		1707	1810	C
	D. longipes Raup.	1448				Cord.
	D. praealta Greene			1550	1640	Cord.
	D. stenoloba Ledeb.			1730	1740	Cord.
	Erysimum angustatum Rydb.	781		850		N. Cord.
	E. cherianthoides L.	781		1370		C
	E. inconspicuum (S. Wats.) MacMill.	781	783	781	1000	N. Am.
	E. pallasii (Pursh.) Fern.			1782	1938	C
	Parrya nudicaulis (L.) Regel	1097	1311	1642	1936	Ber.
	Smelkowskia borealis (Greene) Dury and Rollins ssp. *borealis*			1570	2164	N. Cord.
Crassulaceae	*Rhodiola rosea* L. ssp. *integrifolia* (Raf.) Hara			1540	1866	Ber.
Parnassiaceae	*Parnassia kotzbuei* Cham. and Schlecht.	782	1494	1560	1911	Ber.
	P. palustris L. var. *neogaea* Fern.			781	1420	N. Am.
Saxifragaceae	*Saxifraga bronchialis* L. ssp. *funstonii* (Small) Hulten	1433	1494			Ber.
	S. flagellaris Willd. ssp. *setigera* (Pursh.) Tolm.	1646	1737			Ber.
	S. hieracifolia Waldst. and Kit.	1494	1737	1632	1756	C
	S. hirculus L.	1524	1615			C
	S. lyallii Engler ssp. *hultenii* (Calder and Savile) Calder and Taylor	1478				N. Cord.
	S. oppositifolia L. ssp. *oppositifolia*			781	1200	C
	S. razshivinii Zhmylev			1645	1804	Ber.
	S. reflexa Hook.	1676	1737	1810	1936	N. Cord.
	S. tricuspidata Rottb.			1090	1936	N. Am.
Rosaceae	*Chamaerhodos erecta* (L.) Bunge ssp. *nuttallii* (Pickering ex Rydb.) Hulten	781	788	781	1390	Ber.
	Dryas alaskensis A. E. Porsild *			1880		N. Cord.
	D. drummondii Richards.	781	800	781	800	N. Am.
	D. integrifolia M. Vahl ssp. integrifolia	781	914	1280	1936	N. Am.
	D. integrifolia M. Vahl ssp. *sylvatica* (Hulten) Hulten	823		790	955	N. Cord.
	Potentilla anserina L.	781	800	781		C
	P. biflora Willd. *			1460		Ber.
	P. bimundorum Sojak	781	788	781	800	C
	P. diversifolia Lehm.			1660	1730	Cord.
	P. fruticosa (L.) ssp. *floribunda* (pursh.) Elkington	781	790	781	1830	C
	P. hyparctica Malte			880	1938	C
	P. littoralis Rydb.			1150	1936	Cord.
	P. nivea L.			800	1938	C
	P. norvegica L.	814				C
	P. pensylvanica L.	960		781	1070	N. Am.
	P. rubricaulis Lehmann *	781	1067	781	1911	N. Am.
	P. uniflora Ledeb.			1804	1936	Ber.
	Rosa acicularis Lindl.	781	1006	781	1180	C
Leguminosae	*Astragalus alpinus* L.	790	1524	1280	1380	C
	A. americanus (Hook.) M. E. Jones			781		N. Am.
	A. australis (L.) Lam.	790		840	860	N. Am.
	A. nutzotinensis Rousseau			1568	2164	N. Cord.
	A. umbellatus Bunge	1097	1737	1540	1618	Ber.
	A. williamsii Rydb.			790	910	N. Cord.
	Hedysarum alpinum L.	781	1097	800	1850	N. Am.
	H. boreale Nutt. var. *mackenzii* (Richards.) Welsh	781	1097	781	900	N. Am.

Family	Name	Outpost Mountain Minimum elevation (m)	Outpost Mountain Maximum elevation (m)	Sheep Mountain Minimum elevation (m)	Sheep Mountain Maximum elevation (m)	Geographic distribution #
	Lupinus arcticus Wats. ssp. *arcticus*	823	1570	781	1880	N. Cord.
	Oxytropis campestris (L.) DC. ssp. *varians* (Rydb.) Cody	785	838			C
	O. deflexa (Pall.) DC.			1580	1911	Cord.
	O. huddelsonii A.E.Porsild			1310	1942	N. Cord.
	O. maydelliana Trautv.	1585	1646			Ber.
	O. nigrescens (Pall.) Fisch. ssp. *nigrescens*	1570				Ber.
	O. scammaniana Hulten	945	1737			N. Cord.
	O. sericea Nutt. ssp. *spicata* (Hook.) Cody *	781	823	790	800	Cord.-Prairie
	O. splendens Dougl.			830		Cord.-Prairie
	O. viscida Nutt.	781	853	781	1938	Cord.
Linaceae	*Linum lewisii* Pursh.	781	823	810	1280	N. Am.
Empetraceae	*Empetrum nigrum* L. ssp. *hermaphroditum* (Lge.) Bocher			1250	1270	C
Elaeagnaceae	*Elaeagnus commutata* Bernh.	781	914	781		N. Am.
	Shepherdia canadensis (L.) Nutt.	781	1280	781	1380	N. Am.
Onagraceae	*Epilobium angustifolium* L.	781	1311	781	1690	C
	E. latifolium L.	781	1250	781	1911	C
Umbelliferae	*Heracleum lanatum* Michx.	781	823			Ber.
Pyrolaceae	*Moneses uniflora* (L.) Gray	823	1097			C
	Orthilia secunda (L.) House	823	975	800	1350	C
	Pyrola asarifolia Michx.			781	1320	Ber.
	P. grandiflora Radius	781	1036	1190	1750	C
Ericaceae	*Arctostaphylos alpina* (L.) Spreng.			1310	1430	C
	A. rubra (Rehd. and Wils.) Fern.	781	945	814	1414	Ber.
	A. uva-ursi (L.) Spreng.	781	991	781	1420	C
	Cassiope tetragona (L.) D. Don ssp. *tetragona*	884	1692	1180	1880	C
	Ledum decumbens (Ait.) Lodd. *	781	914			Ber.
	L. groenlandicum Oeder	781	991	810	1380	N. Am.
	Rhododendron lapponicum (L.) Wahlenb.			1178	1318	C
	Vaccinium uliginosum L.	1128	1433	1180	1444	C
Primulaceae	*Dodecatheon frigidum* Cham. and Schlecht.	1128	1737	1610	1880	Ber.
	Primula incana M. E. Jones	781	884	781	1880	N. Am.
Gentianaceae	*Gentiana prostrata* Haenke	781	1478	1580	1880	Ber.
	Gentianella propoinqua (Richards) J. M. Gillett ssp. *propinqua*	781	1494	1190	1910	Ber.
	Lomatogonium rotatum (L.) Fries ssp. *tenuifolium* (Griseb.) A. E. Porsild			795		C
Polemoniaceae	*Polemonium acutiflorum* Willd.	1280	1737	1555	1790	Ber.
	P. boreale Adams			1648		Ber.
	P. pulcherrimum Hook.			781	1926	Ber.
Boraginaceae	*Lappula occidentalis* (Wats.) Greene	781	900	781		Ber.
	L. squarrosa (Retz.) Dumont			1282	1570	Introduced
	Mertensia paniculata (Ait.) G. Don var. *paniculata*	781	1509	781	1991	N. Am.
	Myosotis alpestris Schm. ssp. *asiatica* Vesterg.	1433	1707	781	1910	Ber.
Scrophulariaceae	*Castilleja caudata* (Pennell) Rebr.	853	1524			Ber.
	C. hyperborea Pennell	1524	1737	853	1936	Ber.
	C. yukonis Pennell	781	1006	781	800	N. Cord.
	Pedicularis capitata Adams	1113	1676	1180	1770	C

Family	Name	Outpost Mountain Minimum elevation (m)	Outpost Mountain Maximum elevation (m)	Sheep Mountain Minimum elevation (m)	Sheep Mountain Maximum elevation (m)	Geographic distribution #
	P. labradorica Wirsing	781				Ber.
	P. lanata Cham. and Schlecht.	1463	1570	1440	1880	Ber.
	P. langsdorfii Fisch. ssp. *arctica* (R. Br.) Pennell ex Hulten	1478	1600	1737	1768	Ber.
	P. oederi Vahl. *	991	1234			C
	P. sudetica Willd.	783	1295	781	800	C
	Penstemon gormanii Greene	782	960	781	1350	N. Cord.
Oropbanchaceae	*Orobanche fasciculata* Nutt. *			830		N. Am.
Plantaginaceae	*Plantago canescens* Adams			1050	1314	Ber.
	P. maritima L. ssp. *juncoides* Lam.	781	814	781		C
Rubiaceae	*Galium boreale* L.	781	823	781	1170	C
Caprifoliaceae	*Linnaea borealis* L. ssp. *americana* (Forbes) Hulten var. *americana*	781	1006	781	1422	N. Am.
	Viburnum edule (Michx.) Raf.			1018	1278	N. Am.
Valrianaceae	*Valeriana capitata* Pall.	975	1737	1220	1700	Ber.
	V. sitchensis Bong.	1280	1311			Cord.
Campanulaceae	*Campanula aurita* Greene			782		N. Cord.
Compositae	*Achillea millefolium* L. ssp. *borealis* (Bong.) Breitung	781	869	781	1726	N. Am.
	A. millefolium L. ssp. *lanulosa* (Nutt.) Piper *			940		N. Am.
	Antennaria alpina (L.) Gaertn.	1417	1463	1350	1512	C
	A. media Greene			890	1530	Cord.
	A. monocephala DC. ssp. *monocephala*			1574	1850	Ber.
	A. parviflora Nutt. *			1432	1840	Cord.-Prairie
	A. rosea Greene			781	1006	N. Am.
	Arnica angustifolia Vahl in Hornem. ssp. *tomentosa* (J. M. Macoun) Douglas and Ruyle-Douglas *	781	838	1590	1820	Cord.
	A. lessingii Greene	1311	1737	1720	1794	Ber.
	Artemisia alaskana Rydb.	781	838	781	800	N. Cord.
	A. dracunculus L.			824	1520	C
	A. frigida L.	781	1280	781	1520	Ber.
	A. furcata Bieb.			980	1938	Ber.
	A. norvegica Fries ssp. *saxatilis* (Bess. ex Hook.) Hall and Clem.	1311	1737	1098	1911	Ber.
	A. rupestris L. ssp. *woodii* Neilson			860	1512	Ber.
	A. tilesii Ledeb.	781	1433	781	1705	Ber.
	Aster alpinus L. ssp. *vierhapperi* Onno	781	823	834	1500	Cord.
	A. sibiricus L.	781	1417	781	1704	Ber.
	A. yukonensis Cronq.			781	800	N. Cord.
	Crepis elegans Hook.			781		Cord.
	C. nana Richards			1310	2164	Ber.
	Erigeron acris L. ssp. *debilis* (Gray) Piper *	781	823			Cord.
	E. caespitosus Nutt.			781	1760	N. Am.
	E. compositus Pursh. var. *glabratus* Macoun	781	1524	781	1936	N. Am.
	E. grandiflorus Hook. ssp. *arcticus* A. E. Porsild			980	1500	N. Am.
	E. humulis Graham	1295	1341	1548	1911	C
	E. pallens Cronq.			1380		Cord.
	E. purpuratus Greene	1311	1737	1920	2164	N. Cord.
	E. uniflorus L. ssp. *eriocephalus* (Vahl ex Hornem.) Cronq.			1804		C
	E. yukonensis Rydb.	781		781	800	N. Cord.
	Petasites frigidus (l.) Fries ssp. *frigidus*			1180	1710	C
	P. sagittatus (Banks ex Pursh.) Gray	899	945			N. Am.
	Saussurea angustifolia (Willd.) DC. ssp. *yukonensis* (A. E. Porsild) Cody	1372	1646	1220	1911	N. Cord.

Family	Name	Outpost Mountain Minimum elevation (m)	Outpost Mountain Maximum elevation (m)	Sheep Mountain Minimum elevation (m)	Sheep Mountain Maximum elevation (m)	Geographic distribution #
	Senecio atropurpuratus (Ledeb.) Fedtsch. ssp. *frigidus* (Richards) Hulten	1097	1737	1740	1800	Ber.
	S. cymbalaria Pursh.	1676	1722	1080	1200	Ber.
	S. kjellmanii A. E. Porsild *	1707	1737			Ber.
	S. lugens Richards	781	1707	1320	1911	Cord.
	S. ogotorukensis Packer			836	1938	N. Cord.
	S. tundricola Tolm.			1730	1936	C
	Solidago multiradiata Ait.	1234	1390	781	1911	Ber.
	S. simplex Kunth	781		781	1520	N. Am.
	Taraxacum ceratophorum (Ledeb.) DC.	781		781		C
	T. lyratum (Ledeb.) DC.	781	823	1644	1800	Ber.
	Townsendia hookeri Beaman			781	1010	S. Cord.

* Range extension or new species for the Yukon based on Cody (1996).

	# Definitions.
AA	Amphi-Atlantic: Mainly occur along the shores of the Atlantic Ocean.
Ber.	Beringian: Found on both sides of the Bering Strait.
C	Circum-Subarctic: All around the northern hemisphere in the Sub-Arctic zone.
Cord.	Cordilleran: Yukon-Alaska to Oregon, California, Colorado and Wyoming.
Cord.-Prairie	Cordilleran/Prairie: Found in dry areas of the Cordillera and on the Prairie.
Introduced	Introduced: Imported by Man from another continent.
M. Cord.	Middle Cordilleran: Mainly found in southern British Columbia and Alberta.
N. Am.	North American: Found across North America.
N. Cord.	North Cordilleran: Limited to Alaska, the Yukon Territory and neighboring areas.
S. Cord.	South Cordilleran: Mainly found south of 49 degrees north along the Cordillera.

5.2 Elevational distribution

Where a given species of forb occurs on both mountains, it is normally found several hundred metres higher on Sheep Mountain than on Outpost Mountain. The actual elevational differences vary considerably from one species to another. The white spruce climax forest is continuous on the north slope of Outpost Mountain to 1,200 m, in contrast to 1,100 m for the patches of boreal forest on Sheep Mountain. The timberline ecotone continues to 1,400 m, whereas the discontinuous timberline ecotone on Sheep Mountain grades into alpine tundra at 1,350 m. Thus although comparable, the vegetation zones extend higher on Outpost Mountain than on Sheep Mountain.

5.3 Geographic groups present

The north and southeast slopes have virtually the same percentages of species from each geographic source (Tab. 2), regardless of the obvious differences in vegetation cover seen in figures 2 and 3. 30% of the taxa are Circum-Subarctic, about 26% are Beringian, while about 24% are found across North America. The striking feature is that approximately 10% of the taxa are essentially restricted to Alaska and the Yukon Territory (the North Cordilleran category in Tab. 2), supporting the idea that there has been considerable speciation in the region (Hultén 1968). The remaining 0.4 to 1.0% of the species are probably introduced by humans, and are listed as "Introduced" in table 2.

6 Discussion

There are some obvious differences between the two slopes, which are undoubtedly connected to their aspect. The southeast-facing slope of Sheep Mountain has less winter snow cover that melts much earlier in the summer. Combined with the increased insolation, the growing season is longer, but the soils are much drier. This results in far more varied micro-environments, so that there is far less boreal forest cover, and increased steppe-type vegetation on the lower slopes. Treeline is therefore lower, as is timberline. The presence of special micro-habitats such as talus slopes, permits species such as *Cystopteris fragilis* to be present. The grazing of the Dahl Sheep favours the dominance of grasses and dwarf sages, e.g., *Artemisia frigida L.*, and *A. rupestris* L. ssp. *woodii* Neilson, but there is enough boreal forest in the gullies to permit a good number of forest species to survive.

On Outpost Mountain, the north-facing slope has a cover of typical boreal forest on the steep slopes, with a typical range of forest species. The timberline ecotone has plenty of soil moisture throughout the summer growing season, while the permafrost table close to the surface ensures a similar situation at lower elevations. This results in several species of orchids flourishing here.

The difference in altitudinal range of individual species on the two mountains is almost certainly a function of temperature and moisture. It is necessary to go higher on Sheep Mountain to obtain the cooler temperatures and higher soil moisture contents found at lower elevations on Outpost Mountain. Conversely, it is impossible to find the warm dry slopes on Outpost Mountain that are needed to develop the steppe grasslands, so that a different group of plant associations is present.

The fact that the geographic ranges of the floras are so similar on the two mountains suggests that the differences in figures 2 and 3 are based on local edaphic conditions, not on different origins of the flora. The geographic ranges of the species is what might be expected, except for the large number of local endemics. The fact that there were local endemics has been known for some time, but the area in which they may have originated has not been examined in detail before.

Study of the ranges of the endemics that can be classified as North Cordilleran species suggests that they belong to three centres of speciation. The first is the Brooks Range which appears to be the centre for thirteen species (Tab. 3), of which *Oxytropis campestris* (L.) DC. ssp. *jordalli* A. E. Porsild and *Smelkowskia borealis* (Greene) Drury and Rollins ssp. *jordalli* (Drury and Rollins) Cody (Fig. 4), may be used as examples. The second species has a very limited distribution in the Brooks Range, whereas the *Oxytropis* exhibits a more widespread, disjunct distribution, suggesting it may once have been present over a much larger area along the eastern margins of the Beringian steppe. If *Antennaria ellyae* A. E. Porsild and *A. breitungii* A. E. Porsild are accepted as distinct taxa (see PORSILD a. CODY 1979), then there are at least 15 taxa originating in this region.

Table 2: Distribution of taxa on Outpost Mountain and Sheep Mountain by geographic group

Verteilung der Taxa am Outpost Mountain und Sheep Mountain nach Verbreitungsgebieten

Geographic Group	Outpost Mountain		Sheep Mountain		Transect	
Circum-Subarctic	64	33.5%	70	28.9%	93	31.4%
North American	44	23.0%	60	24.8%	68	23.0%
Beringian	51	26.7%	64	26.4%	76	25.7%
North Cordilleran	17	8.9%	25	10.3%	28	9.5%
Cordilleran	8	4.2%	14	5.8%	17	5.7%
South Cordilleran	1	0.5%	1	0.4%	2	0.7%
Middle Cordilleran	1	0.5%	1	0.4%	1	0.35%
Cordilleran/Prairie	2	1.1%	5	2.1%	5	1.7%
Amphi-Atlantic	1	0.5%	1	0.4%	1	0.35%
Introduced	2	1.1%	1	0.4%	3	1.0%
Total	191		242		294	

Circum-Subarctic:	All around the northern hemisphere.
North American:	Found across North America.
Beringian:	Found on both sides of the Bering Strait.
North Cordilleran:	Limited to Alaska and the Yukon, and neighbouring areas.
Cordilleran:	Yukon-Alaska to Oregon, California, Colorado, and Wyoming.
South Cordilleran:	Mainly south of 49°N.
Middle Cordilleran:	Mainly found in southern British Columbia and Alberta.
Cordilleran/Prairie:	Found in Cordillera and on Prairie.
Amphi-Atlantic:	Mainly occur around the shores of the Atlantic Ocean.
Introduced:	Imported by Man from another continent.

Table 3: The North Cordilleran endemic taxa of the Brooks Range and adjacent mountains of the Yukon Territory
Endemische Taxa im Bereich der Brooks Range und in angrenzenden Gebirgen des Yukon Territory

Family	Species
Salicaceae	*Salix ovalifolia* Trautv. var. *arctolitoralis* (Hulten) Argus
Portulacaceae	*Claytonia ogilviensis* McNeil
Papaveraceae	*Papaver mcconnellii* Hulten
Cruciferae	*Smelkowskia borealis* (Greene) Drury and Rollins ssp. *jordalii* (Drury and Rollins) Cody
Saxifragaceae	*Saxifraga bronchialis* L. ssp. *codyana* (Zhmylev) Cody
Leguminoseae	*Oxytropis campestris* (L.) DC. ssp. *jordalii* (A. E. Porsild) Hulten *O. campestris* (L.) DC. ssp. *roaldii* (Ostenf.) Cody *O. nigrescens* (Fisch.) DC. ssp. *lonchopoda* (Barneby) Cody
Scrophulariaceae	*Pedicularis labradorica* var. *sulphurea*
Compositae	*Antennaria densifolia* A. E. Porsild *A. friesiana* (Trautv.) Ekman ssp. *alaskana* (Malte) Hulten *A. friesiana* (Trautv.) Ekman ssp. *neoalaskana* (A. E. Porsild) Bayer and Stebins *Erigeron hyperboreus* Greene *E. muirii* Gray

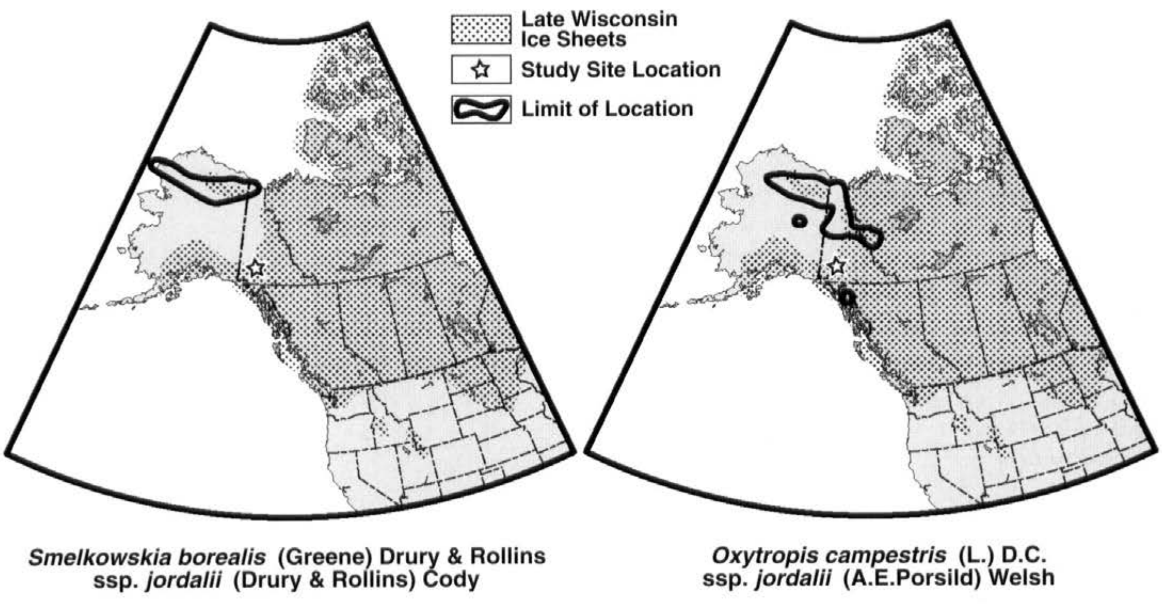


Fig. 4: Distribution of two of the North Cordilleran endemic species that originated in the Brooks Range. The hatched area represents the area glaciated during the Late Wisconsin maximum, while the star indicates the location of the transect

Verteilung zweier endemischer Arten der North Cordillera mit Ursprung in der Brooks Range. Die schraffierte Fläche entspricht dem vergletscherten Gebiet zum Late Wisconsin Maximum, während der Stern die Lage des Transekts kennzeichnet

Table 4: The North Cordilleran endemic taxa that evolved on the mountains in the rain shadow of the Wrangell–St. Elias mountains in the eastern part of Beringia. Also listed are their occurrences along the Outpost–Sheep Mountain transect

Endemische Taxa der North Cordillera, die sich im Gebirge im Regenschatten der Wrangell–St. Elias Mountains im östlichen Teil von Beringia entwickelten. Ebenso sind ihre Vorkommen entlang des Outpost–Sheep Mountain Transekts aufgeführt

Species	Outpost Mountain	Sheep Mountain
Cryptogramma crispa (L.) *Br. var. sitchensis (Rupr.)* C. Ch.		
Elymus alaskanus (Scribn. and Merr.) A. Love ssp. *alaskanus*		X
E. calderi Barkworth		X
E. trachycaulus (Link.) Gould ex Shinners ssp. *teslinensis* Porsild and Senn		
Poa arctica R. Br. ssp. *longiculmis* Hulten		
P. porsildii Gjaerevoll		
Puccinellia interior Th. Sor.		
Carex microchaeta Holm.		X
C. petasata Dewey		
C. petricosa Dewey		X
C. praticola Rydb.		
Trichophorum pumilum (M. Vahl.) Schinz. and Thell. var. *rollandii*		
Salix alaxensis (Anderss.) Cov. ssp. *longistylis* (Rydb.) Hulten	X	X
S. rotundifolia Trautv. ssp. *dodgeana* (Rydb.) Argus	X	X
S. setchelliana Ball.	X	
Minuartia dawsonensis (Britt.) Mattf.		
Polygonium alaskanum Wight ex Hulten		
Montia bostockii (A. E. Porsild) Welsh	X	X
Silene williamsii Britt.		
Stellaria alaskana Hulten		
Nymphaea tetragona Georgi ssp. *leibergii* (Morag) Porsild		
Papaver nudicale L. ssp. *americanum* Randel		
Erysimum angustatum Rydb.	X	X
Smelkowskia borealis (Greene) Dury and Rollins ssp. *borealis*	X	X
Saxifraga lyallii Engler ssp. *hultenii* (Calder and Saville) Calder and Taylor	X	
S. nelsoniana D. Don ssp. *porsildiana* (Calder and Savile) Hulten		
S. reflexa Hook.	X	X
Dryas alaskensis A. E. Porsild		X
D. integrifolia M. Vahl. ssp. *sylvatica*	X	X
Sanguisorba menziesii		
Astragalus adsergens Pall. ssp. *viciifolius* (Hulten) Walsh		
A. nutzotinensis Rousseau		X
A. williamsii Rydb.		X
Lupinus arcticus Wats. ssp. *arcticus*	X	X
L. kuschei Eastw.		
Oxytropis huddelsonii A. E. Porsild		X
O. scammaniana Hulten	X	
Douglasia alaskana (Collv. and Standl. ex Hulten) Kelso		
Douglasia arctica Hook.		
D. gormanii Constance		
Cicuta maculata L. var. *angustifolia* Hook.		
Phlox richardsonii Hook.		
Phacelia mollis Macbr.		
Cryptantha shackletteana L. C. Higgins		
Castilleja yukonis Pennell	X	X
Penstemon gormanii Greene	X	X
Synthyris borealis Pennell		
Campanula aurita Greene		X
Antennaria alborosa A. E. Porsild		
A. cryomophylla A. E. Porsild		

A. elegans A. E. Porsild		
A. incarnata A. E. Porsild		
A. philonipha A. E. Porsild		
A. rosea Greene ssp. *pulvinata* (Greene) Bayer		
A. stolonifera A. E. Porsild		
Artemisia alaskana Rydb.	X	
A. hyperborea Rydb.		
A. tilesii Ledeb. ssp. *elatoir* (Torr. and Gray) Hulten		
Aster yulonensis Cronq.		X
Erigeron grandiflorus Hook. ssp. *arcticus*		
E. purpuratus Greene	X	X
E. yukonensis Rydb.	X	X
Haplopappus macleanii Brandegee		
Saussurea angustifolia (Willd.) DC. ssp. *yukonensis* (A.E. Porsild) Cody.	X	X
Senecio ogotarukensis Packer		X
S. sheldonensis A. E. Porsild		
S. yukonensis A. E. Porsild		
Taraxacum carneocoloratum Nels.		

Table 5: The North Cordilleran taxa whose distribution is centred on the Kenai Peninsula, Alaska

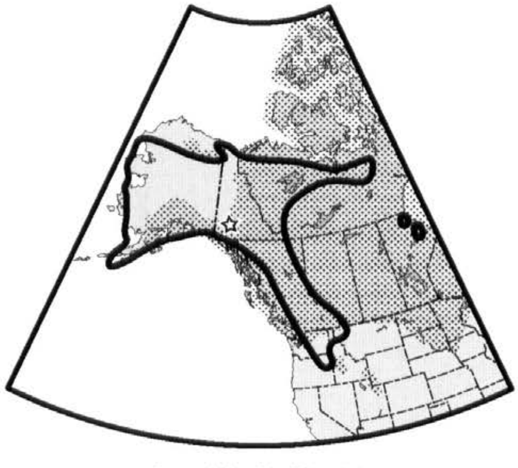
Endemische Taxa der North Cordillera, die sich auf der Kenai Peninsula, Alaska, entwickelten

Family	Species
Graminae	*Agrostis thurberiana* Hitchc. *Poaa hispidula* Vasey *Puccinellia glabra* Swallen *P. triflora* Swallen
Salicaceae	*Salix stolonifera* Cov.
Papaveraceae	*Papaver alboroseum* Hulten
Saxifragaceae	*Saxifraga nelsoniana* D. Don ssp. *pacifica* (Hulten) Hulten
Rosaceae	*Sanguisorba menziesii*
Primulaceae	*Douglasia alaskana* (Cov. and Standley) S. Kelso
Gentianaceae	*Gentiana platypetala* Griseb.
Leguminosae	*Lupinus nootkatensis* Donn
Gentianaceae	*Gentiana platypetala* Griseb.

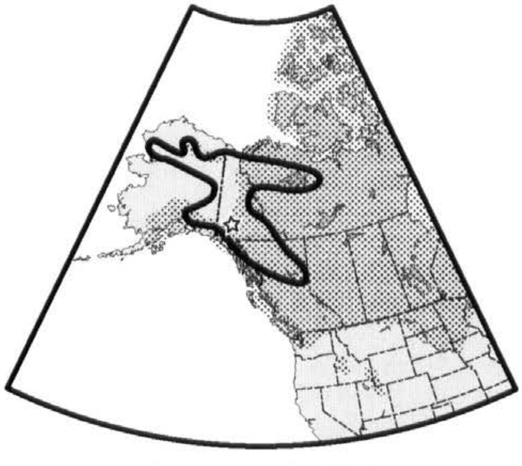
The second centre is in the southern Yukon and Alaska in the rain shadow area north of the Wrangell–St. Elias ranges. At least 68 taxa comprise this group (Tab. 4), of which 28 were found along the transect. Since the percentage of taxa relative to the local flora is similar on both mountains, it seems that aspect has no effect on plant diversity. If *Antennaria elegans* A. E. Porsild and *A. incarnata* A. E. Porsild (recognised by PORSILD a. CODY 1979) are distinct taxa, then they also originated in this area.

In general, this group of species did not migrate very far. Three exceptions are *Saxifraga nelsoniana* D. Don. ssp. *porsildiana* (Calder and Savile) Hultén, *Artemisia tilesii* Ledeb. ssp. *elatior* (Torr and Gray) Hultén, and *Salix barrattiana* Hooker that have managed to extend their ranges south to latitude 45–52° N along the Cordillera (Fig. 5). Three others *Dryas integrifolia* M. Vahl. ssp. *sylvatica* (Hultén) Hultén, *Antennaria rosea* Greene ssp. *pulvinata* (Greene) Bayer, and *Lupinus arcticus* S. Wats. ssp. *arcticus* may have migrated eastwards along the north margin of the remnants of the Keewatin ice cap.

The third likely centre of speciation is in south Alaska, centred on the Kenai Peninsula (Fig. 6), and comprised of at least twelve species (Tab. 5). Two grasses (*Puccinellia glabra* Swallen and *P. triflora* Swallen) do not appear to have migrated much, whereas *Salix*

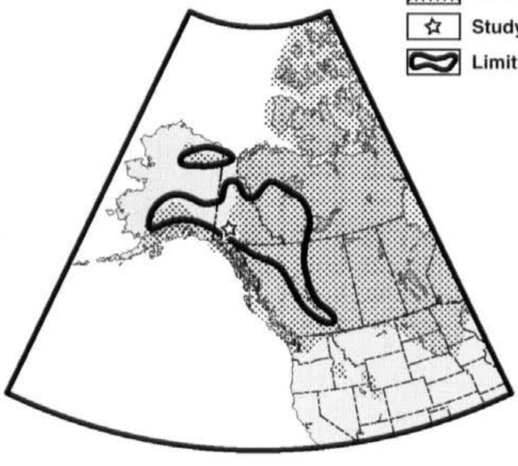


Artemisia tilesii Ledeb.
ssp. *elatior* (Torr.& Gray) Hulten

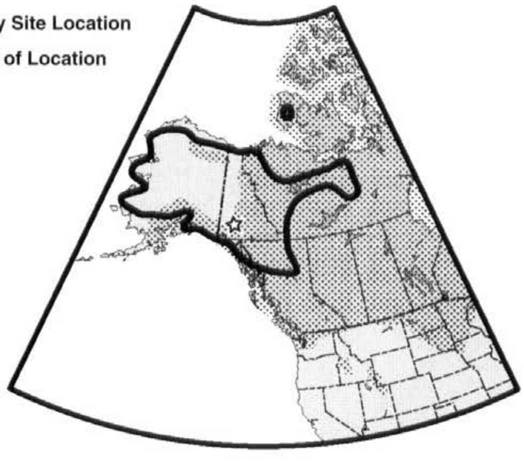


Dryas integrifolia M.Vahl.
ssp. *sylvatica* (Hulten) Hulten

Late Wisconsin Ice Sheets
☆ Study Site Location
Limit of Location

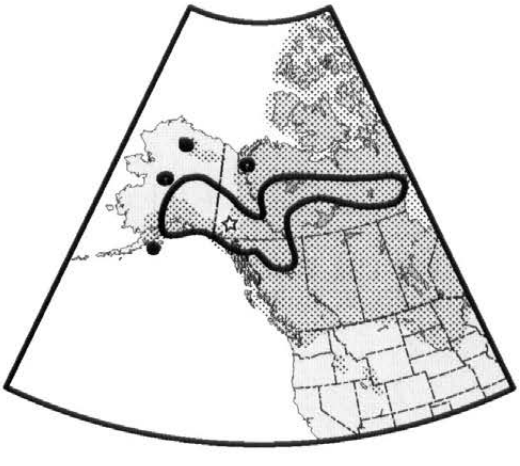


Salix barrattiana Hooker



Lupinus S.Wats
ssp. *arcticus*

Saxifraga nelsoniana D.Don
ssp. *porsildiana* (Calder & Saville) Hulten



Antennaria rosea Greene
ssp. *pulvinata* (Greene) Bayer

◁ *Fig. 5:* Distributions of six of the North Cordilleran endemic species that originated in the rain shadow area of the north slope of the Wrangell–St. Elias Range. The hatched area represents the area glaciated during the Late Wisconsin maximum, while the star indicates the location of the transect

Verteilung von sechs endemischen Arten der North Cordillera mit Ursprung im Regenschattengebiet des Nordhangs der Wrangell–St. Elias Range. Die schraffierte Fläche entspricht dem vergletscherten Gebiet zum Late Wisconsin Maximum, während der Stern die Lage des Transekts kennzeichnet

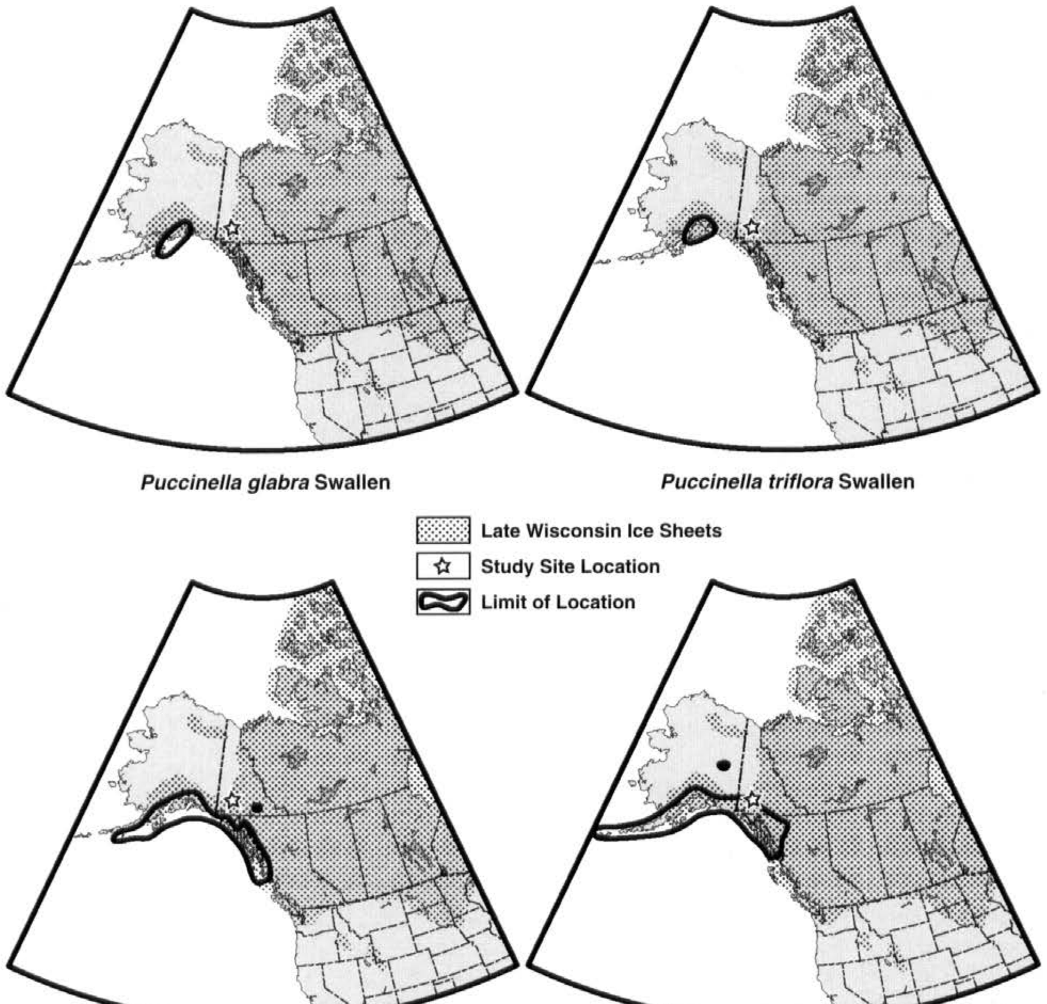


Fig. 6: Distributions of four of the North Cordilleran endemic species that originated on the Kenai Peninsula, Alaska. The hatched area represents the area glaciated during the Late Wisconsin maximum, while the star indicates the location of the transect

Verteilung von vier endemischen Arten der North Cordillera mit Ursprung auf der Kenai Pensinula, Alaska. Die schraffierte Fläche entspricht dem vergletscherten Gebiet zum Late Wisconsin Maximum, während der Stern die Lage des Transekts kennzeichnet *stolonifera* Cov. has a distribution westwards along the Aleutian Islands and eastwards to the Alaska panhandle. These species also show minor disjunct populations north of the Wrangell–St. Elias ranges (Fig. 6), but have quite a different range compared to the species that evolved on the Queen Charlotte refugium (CALDER a. TAYLOR 1968).

7 *Conclusions*

Sheep Mountain faces southeast and has a mixed vegetation cover of steppe-grasslands on the lower slopes with boreal forest in gullies. Outpost Mountain faces north and is covered by a closed canopy of boreal forest. Above 1,100 m on Sheep Mountain and 1,200 m on Outpost Mountain, the boreal forest is replaced by birch-willow thickets. Timberline (base of the alpine tundra) lies at 1,350 m on Sheep Mountain and 1,450 m on Outpost Mountain. This appears to be due to warmer temperatures, a longer growing season, and less soil moisture on Sheep Mountain. Considerably more species are found on Sheep Mountain due to the greater variety in plant associations of the steppe-grasslands. However, a comparison of the geographic ranges of the taxa shows they are present in virtually identical proportions on the two contrasting slopes. About 31% of the species are Circum-Subarctic, 24% are North American, and 26% are Beringian, as would be expected, but about 10% are local North Cordilleran endemics. A study of the ranges of the North Cordilleran endemics suggests that there are three separate centres of speciation. The Brooks Range is a minor centre (13 species), as is the Kenai Peninsula (12 species). However at least 68 species evolved along the rain shadow zone on the north side of the Wrangell–St. Elias Range. Of these, 28 species were encountered on the Sheep Mountain – Outpost Mountain transect, i.e., it lies in the middle of the area in which 70% of the North Cordilleran endemics evolved. The evidence suggests that speciation occurred independently of major biome or aspect, while the large representation suggests that the transect includes most of the vegetation associations and climatic zones in the region.

Acknowledgements

The author is indebted to Dr. Wayne Strong of Calgary, who made valuable suggestions to improve the paper, and to the many former students who have worked in the field in the Yukon with him over the last 24 years.

References

ALLEN, H. D. (1982): Dendrochonological studies in the Slims River valley, Yukon Territory. Unpublished M.Sc. Thesis, Department of Geography, University of Calgary.

BLOOD, D. A. et al. (1975): The soil, vegetation and wildlife resources of five potential transportation corridors in Kluane National Park, Yukon. Report to Prairie region, Parks Canada. Winnipeg.

CALDER, J. A. a. TAYLOR, R. L. (1968): Flora of the Queen Charlotte Islands. Part I. Systematics of the vascular plants. Canadian Department of Agriculture Research Branch. Monograph 4, 1.

CAMPBELL, R. B. a. DODDS, C. D. (1984): Terraces of the St. Elias Mountains, Yukon, British Columbia and Alaska. Geological Society of America. Abstracts with Programs 16.

CODY, W. J. (1996): Flora of the Yukon Territory. Ottawa.

CODY, W. J.; KENNEDY, C. K. a. BENNETT, B. (1998): New records of vascular plants in the Yukon Territory. In: Canadian Field-Naturalist 112, 289–328.

– (2000): New records of vascular plants in the Yukon Territory II. In: Canadian Field-Naturalist 114, 417–443.

– (2001): New records of vascular plants in the Yukon Territory III. In: Canadian Field-Naturalist 115, 301–322.

CODY, W. J.; KENNEDY, C. K.; BENNETT, B. a. LOEWEN, V. (2002): New records of vascular plants in the Yukon Territory IV. In: Canadian Field-Naturalist 116, 446–474.

COOK, M. B. a. ROLAND, C. A. (2002): Notable vascular plants from the Wrangell–St. Elias National Park. In: Canadian Field-Naturalist 116, 192–304.

DENTON, G. H. a. STUIVER, M. (1966): Neoglacial chronology, northeastern St. Elias Mountains, Canada. In: American Journal of Science 264, 577–599.

ENVIRONMENT CANADA (1982): Canadian Climate Normals, 1951–1980. Atmospheric Environment Service, Department of Supply and Services, Ottawa. The North-Y. T. and N. W. T.

HARRIS, S. A. (1987a): Influence of organic (Of) layer thickness on active-layer thickness at two sites in the western Canadian Arctic and Subarctic. In: Erdkunde 41, 275–285.

– (1987b): Altitude trends in permafrost active layer thickness, Kluane Lake, Yukon Territory. In: Arctic 40, 179–183.

– (1990): Dynamics and origin of saline soils on the Slims River delta, Kluane National Park, Yukon Territory. In: Arctic 43, 159–175.

HARRIS, S. A. a. GUSTAFSON, C. A. (1993): Debris flow characteristics in an area of continuous permafrost, St. Elias Range, Yukon Territory. In: Zeitschrift für Geomorphologie, N.F., 37, 41–56.

HARRIS, S. A. a. MCDERMID, G. (1991): An assessment of the environmental hazards at the Sheep Mountain Kiosk, Kluane National Park. Contract Report to Parks Canada.

– (1998): Frequency of debris flows on the Sheep Mountain fan, Kluane Lake, Yukon Territory. In: Zeitschrift für Geomorphologie, N. F., 42, 159–175.

HITCHCOCK, C. L. et al. (1950–1969): Vascular plants of the Pacific Northwest, vols. 1–5. Seattle, Washington.

HOEFS, M.; COWAN, I. McT. a. KRAJINA, V. J. (1975): Phytosociological analysis and synthesis of Sheep Mountain, southwest Yukon Territory, Canada. In: Syesis 8, Supplement 1, 125–228.

HULTÉN, E. (1937): Outline of the history of arctic and boreal biota during the Quaternary period. Stockholm.

– (1958): The amphi-Atlantic plants and their phytogeographical connections. Kungliga Svenska Vetenskapsacademiens Handlingar 7. Stockholm.

– (1964): The circumpolar plants. 1. Vascular Cryptogams, conifers, monocotyledons. Kungliga Svenska Vetenskapsacademiens Handlingar 8. Stockholm.

– (1968): Flora of Alaska and neighbouring Territories. Stanford.

– (1971): The circumpolar plants. 2. Dicotyledons. Kungliga Svenska Vetenskapsacademiens Handlingar 13. Stockholm.

JOHNSTON, G. H. (ed.) (1981): Permafrost engineering design and construction. Toronto.

KÖRNER, G. A. (1998): A re-assessment of high elevation treeline positions and their explanation. In: Oecologia 115, 445–459.

MOSS, E. H. (1983): Flora of Alberta. 2nd Ed. revised by J. H. PACKER. Toronto.

NEILSON, J. A. (1972): A checklist of vascular plants from the Icefield Ranges Research Project Area. In: BUSHNELL, V. C. a. RAGLE, R. H. (eds.): Icefield Ranges Research Project, Scientific Results 3. New York, 221–239.

PESCHKOVA, G. A. (1979): Various dates. In: Malysev, L. I. a. Peschkova, G. A.: Flora Sibiriae Centralis. 14 vols. Novosibirsk. [In Russian]

PORSILD, A. E. (1966): Contributions to the flora of southwestern Yukon Territory. National Museum of Canada. Bulletin 216. Ottawa.

PORSILD, A. E. a. CODY, W. J. (1979): Vascular plants of the Continental Northwest Territories, Canada. National Museum of Natural Sciences. Ottawa.

TALBOT, S. S.; YURTSEV, B. A.; MURRAY, D. F.; ARGUS, G. W.; Bay, C. a. ELVEBAKK, A. (1999): Atlas of rare endemic vascular plants of the Arctic. Conservation of Arctic Flora and Fauna. Technical Report 3. Anchorage.

WHEELER, J. O. (1963): Kaskawulsh – Geology. Geological Survey of Canada, Map 1134A. Ottawa.