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White Spruce above and beyond Treeline in the Arrigetch Peaks Region, Brooks Range, Alaska

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ABSTRACT. White spruce trees occur in the Arrigetch Creek valley and its tributaries at great distances above and beyond current treeline, which is at 760 m elevation. The highest tree found is at 1465 m elevation on a south-facing limestone slope. Trees also occur up to 5.0 km beyond treeline on granitic parent rock. These trees appear to occur at the highest elevation north of the Arctic Circle in North America and include some of the highest trees in Alaska.

Key words: Brooks Range, Alaska, treeline, white spruce, seed dispersal

RÉSUMÉ. On trouve des épicéas blancs dans la vallée du ruisseau Arrigetch et de ses tributaires à des distances bien au-delà de la limite forestière actuelle, qui se trouve à une élévation de 760 m. L'arbre le plus élevé est à 1465 m d'élévation sur un versant de calcaire exposé au sud. Certains arbres se trouvent aussi jusqu'à 5.0 km au-dessus de la limite forestière, croissant dans de la roche mère granitique. Ces arbres semblent croître à leur plus haute élévation au nord du cercle arctique en Amérique du Nord et comprennent peut-être les arbres les plus élevés en Alaska.

Mots clés: chaîne de Brooks, Alaska, limite forestière, épicéa blanc, dispersion des graines

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INTRODUCTION

While conducting research on arctic-alpine tundra ecosystems in the Arrigetch Peaks region (Fig. 1) from 1978 to 1980, the author occasionally found white spruce (*Picea glauca* [Moench] Voss) trees hundreds of m above and several km beyond the last cone-bearing trees. Reports of treeline stability in Alaska are varied. As early as the 1920s, Mertie (1925) was surprised to find trees at 1060 m elevation in the Brooks Range, at higher elevation than in the Alaska or Coast ranges. Elsewhere in the Brooks Range seedlings above treeline are reported by Garfinkel and Brubaker (1980), Goldstein (1981) and Odasz (1983). However Drew and Shanks (1965) and Densmore (1980) showed treeline to be in equilibrium. In western Alaska Hopkins (1972) has found that treeline has advanced since the 1940s. In interior Alaska, Marchand (1976), Haugen and Brown (1978) and Viereck (1979) all report that treeline is not in equilibrium with the current climate. In the Alaska Range Denton and Karlen (1977) report tree remains 76 m above present treeline but no recent change in treeline. In southern Alaska Griggs (1934) reported treeline to be advancing.

The twentieth-century warming trend in Alaska documented by Hamilton (1965a, 1965b), Blasting and Fritts (1973) and Garfinkel and Brubaker (1980) may be responsible for what treeline changes are occurring. The pollen record indicates that white spruce was established south of the Brooks Range 5000-6000 years ago, became established in the Alatna Valley 1500 years ago and may still be slowly advancing northward (Brubaker *et al.*, 1983).

In Canada, Nichols (1976) hypothesized that the modern warming is too small to advance treeline and present reproduction should be looked for within the forest zone. Larsen (1965, 1974, 1980) and Savile (1972) feel that tree islands at treeline are relicts of a much warmer interval. Elliott (1979a, 1979b, 1979c) has shown that sexual reproduction rarely, if ever, occurs in spruce at treeline in Keewatin but does occur in Labrador-Ungava.

The continental divide in the Arrigetch Peaks region runs north and south, separating the Alatna River drainage on the east from the Kobuk River drainage to the west (Fig. 1). Treeline in the Alatna River-Arrigetch Creek region occurs at 700-760 m elevation (Murray, 1974; Cooper, 1983), while in the Kobuk valley treeline occurs at 680 m elevation on north-facing slopes and 550 m on south-facing slopes (Goldstein, 1981). Moist air masses from the Pacific Ocean and Bering-Chukchi seas enter the Brooks Range from the west and southwest and are funnelled up the east-west trending Kobuk and Noatak River valleys. At the heads of these valleys the Arrigetch and Igikpak plutons (Brosge and Pessel, 1977; Nelson and Grybeck, 1978) created extensive highlands, which impede the eastward movement of air masses.

Some botanical differences between the vegetation of the Kobuk and Alatna River sides of the Arrigetch Peaks are significant. The ferns *Cystopteris montana* (Lam.) Bernh. and *Dryopteris dilatata* (Hoffm.) Beauv. ssp. *americana* (Fisch.) Hult. and the grass *Calamagrostis canadensis* (Michx.) Beauv. are locally common in forest openings and low elevation arctic-alpine tundra around Walker Lake and Kaluluktok Creek in the Kobuk drainage. In the Alatna River drainage the two ferns are very rare and restricted to springs, and the grass occurs at the border of ponds and on disturbed sites. This appears to indicate increasing continental influences on the Alatna River side of the Arrigetch Peaks. This was also shown by Ellis *et al.* (1981) and can influence the elevation of treeline (Wardle, 1974).

This paper documents interesting occurrences of white spruce at high elevations north of the Arctic Circle and thus contributes substantially to treeline ecology and distribution.

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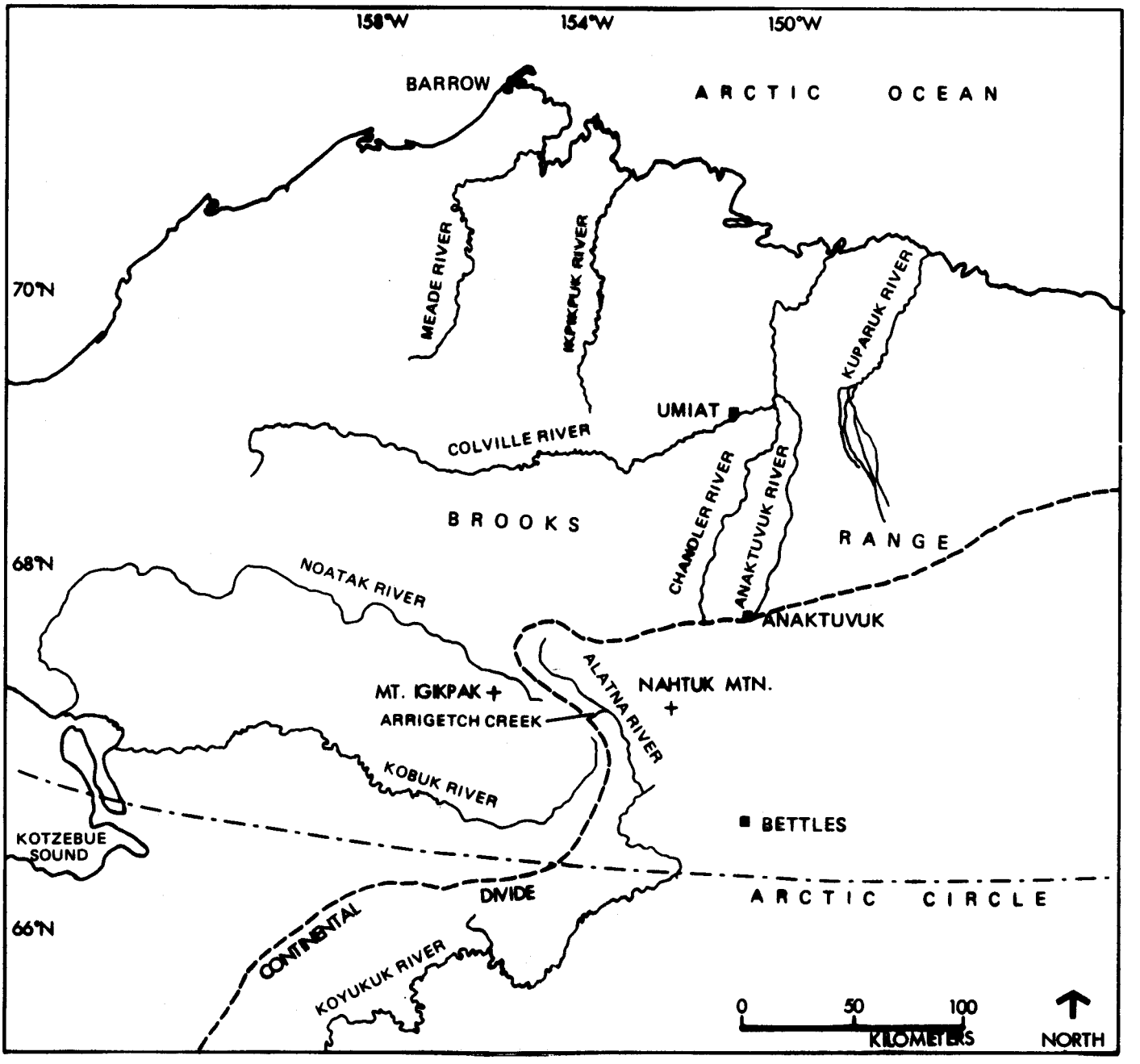

FIG. 1. Sketch map of northern Alaska.

METHODS

When trees were found, their positions were recorded by taking compass readings to high peaks in the area. Height of the tree was measured and its elevation, habitat and health noted. Where possible a minimum age of the tree was estimated by counting the bud scale scars on the trunk. Trees would have to be cut down to accurately determine their age, and this was not done. Regional vegetation was classified according to standard Braun-Blanquet methods (Westhoff and Maarel, 1978) and is presented in Cooper (1983). Nomenclature follows that of Hulten (1974) for vascular plants and Thomson (1979) for lichens. Bedrock types are from the map of Brosge and Pessel (1977) and elevations were estimated from the U.S.G.S. Survey Pass 1:250 000 scale topographic map.

RESULTS

Tree data is presented in Table 1, and the locations of these trees are shown in Figure 2. The trees occurred on all three bedrock types that outcrop in the Arrigetch Creek valley: granite, limestone and shale. Some trees showed dieback on a few branches, but no dead trees were found. While bud scale

TABLE 1. Tree and habitat data

Tree number	Height (cm)	Circum. (cm)	Elev. (m)	Dist. (km)	Age (yrs)	Aspect	Vegetation type	Rock type
1	56	5.3	884	1.4	14+	W	Cate-Clst	gr
2	79	—	875	1.3	—	W	Cate-Clst	gr
3	60	7.0	870	3.7	—	S	Cate-Clst	gr
4	37.5	4.0	914	5.0	10+	flat	Cate-Clst	gr
5	11	1.0	910	1.6	5+	flat	Casc-Vaul	gr
6	51	4.5	770	.25	12+	N	Casc-Droc	li
7	112	—	975	.5	—	S	Heal-Elin	li
8	98	—	980	.5	—	S	Heal-Elin	li
9	26.5	3.5	1465	2.0	12+	S	Talus	li
10	24	2.6	1067	1.6	—	E	Casc-Droc	li
11	18	—	1006	1.0	—	S	Casc-Droc	li
12	14	—	1036	.5	—	S	Casc-Droc	sh

dist km = distance from the nearest cone-bearing trees.
circum cm = circumference of bole, 1 cm above the ground surface.
Cate-Clst = Alliance *Cassiope tetragona-Cladonia stellaris*.
Casc-Vaul = Association *Carex scirpoidea-Vaccinium uliginosum*.
Casc-Droc = Association *Carex scirpoidea-Dryas octopetala* ssp. *octopetala*.
Heal-Elin = Alliance *Hedysarum alpinum* ssp. *americanum-Elymus innovatus*.
Talus = broken rock.
gr = granite and gneiss.
li = limestone and marble.
sh = shale.

scar counts were not done of all the trees, it is clear that these trees do not represent the effects of just a few warm summers.

Tree number 9 (Figs. 3 and 4) occurred in a coarse limestone blockfield at 1465 m, the highest in elevation. Only scattered vascular plants were present, and this particular tree occurred in a patch of *Salix arctica*. The highest trees all occurred on south-facing slopes and were in protected habitats. Trees 2, 11 and 12 occurred in shallow snowbeds. Trees 10, 11 and 12 occurred on or very near ridgetops. Tree 10 is shown in Figure 5. The broad, sloping, south-facing limestone and shale uplands in the Arrigetch valley have sparse and open vegetation, and tree seedlings probably have less severe competition than in more dense vegetation. Although black spruce (*Picea mariana* [Mill.] B.S.P.) occurs at treeline, no seedlings above treeline were found. Occasional plants of alder (*Alnus crispa* [Ait.] Pursh ssp. *crispa*) were found at elevations above 1100 m on rocky slopes.

Trees 1, 2, 3 and 4 occurred in or on the edge of thick lichen mats dominated by *Cladonia stellaris* (Opiz) Pouz + Vezda, *C. rangiferina* (L.) Web. and *C. arbuscula* (Wallr.) Rabenh. on granitic parent material (Fig. 6). Because all tributaries of Arrigetch Creek head in granite, the trees found well beyond treeline in the valley bottom all occur on granite. Trees 3 and 4 were approximately 3.7 and 5.0 km beyond and 100-150 m above treeline in the unnamed valley south of the Arrigetch Creek valley. Some trees are within 2 km of cirques. Brubaker *et al.* (1983) also report white spruce at great distances beyond treeline at Redondo Lake in the Alatna River valley.

DISCUSSION

While regional climate differences between the Alatna and Kobuk River valleys may control the small differences in their established treelines, microenvironmental differences appear to have greater influence on tree establishment and growth today. Growth and survival of *Picea* is known to be enhanced by warm growing season temperatures (Tranquillini, 1979; Black and Bliss, 1980). Protected, south-facing and valley-bottom sites provide warmer habitats. If present climate ameliorates and these trees above and beyond treeline live to reproductive age, a seed source will be available for expansion of forests. Whether or not the individual trees reported here live to reproductive age, they indicate that rapid and dramatic changes in treeline as reported by Kearney and Luckman (1983) for Alberta can occur in the southern Brooks Range.

These trees also indicate that seed dispersal in the Brooks Range can be considerably greater than the 60-90 m from the parent tree under normal conditions or 300 m with a strong wind reported by Zasada (1971) or within a horizontal distance of approximately twice the height of the tree reported by Viereck and Schandelmeier (1980). Even Marshall's 1930 estimate (Marshall, 1970) of seeds blowing up to 1000-1200 feet (305-366 m) is an underestimate. Wind in the Arrigetch region is generally light, especially in winter, when intense temperature inversions dominate. Winter snowpack, as seen in March and April 1981, is loose and without wind crusts. Although some spruce seeds were seen on the snow surface in 1981, seed transport by blowing across a hard-packed snow surface probably occurs rarely. Occasional very strong winds were experienced, especially in late summer and early fall, which is when seeds are disseminated.

These trees in the Arrigetch Creek valley include what appear to be the highest in elevation reported to date for any region north of the Arctic Circle in North America, as well as some of the highest in Alaska.

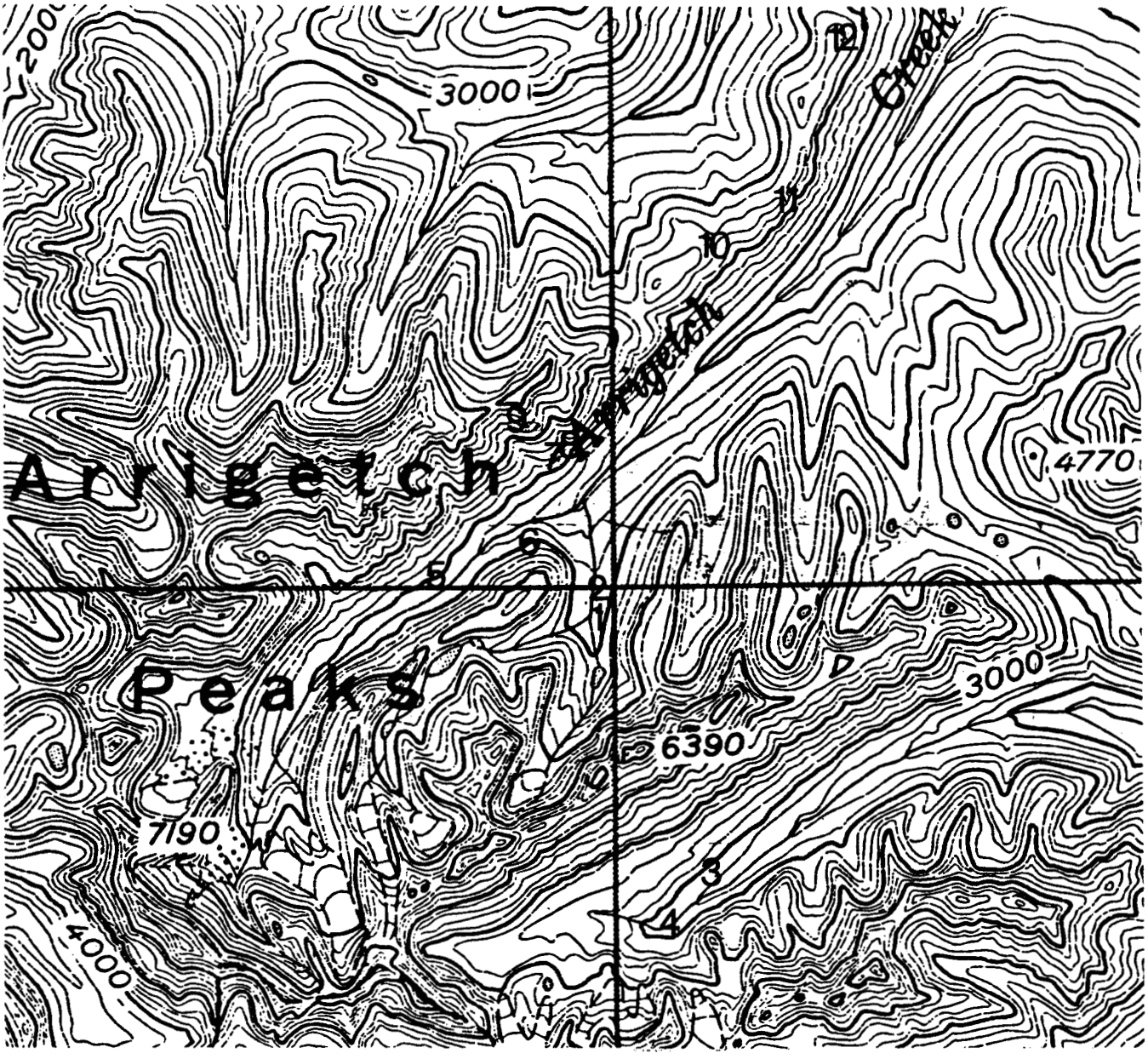

FIG. 2. Section of U.S. Geological Survey, Survey Pass Topographical Map 1:250 000 scale, showing locations of trees cited.

NOTE ADDED

During the summer of 1985, after this paper was submitted for publication, the author found white spruce at elevations up to 1495-1510 m on Fireweed Mountain, in the Wrangell Mountains near McCarthy, Alaska. McCarthy is approximately 200 miles south of the Arctic Circle. The exact location is 61°27′N longitude, 143°2′E latitude, in the west central portion of section 11, Township 5 South, Range 13 East on the McCarthy (B-6) Quadrangle, U.S. Geological Survey 1:63 360 series topographic map. The highest cone-bearing trees in this region are found at 1060-1130 m elevation. Trees were not found in the shrub tundra zone immediately above the forest zone but were scattered throughout the arctic-alpine zone above the shrub tundra. The highest trees occurred in a shallow east-facing snowbed on volcanic parent material. Most trees are somewhat gnarled, with dead branches. Ages range from approximately 10-13 years for small trees to individuals with trunks up to 7 cm in diameter that appear to be older than 50 years.

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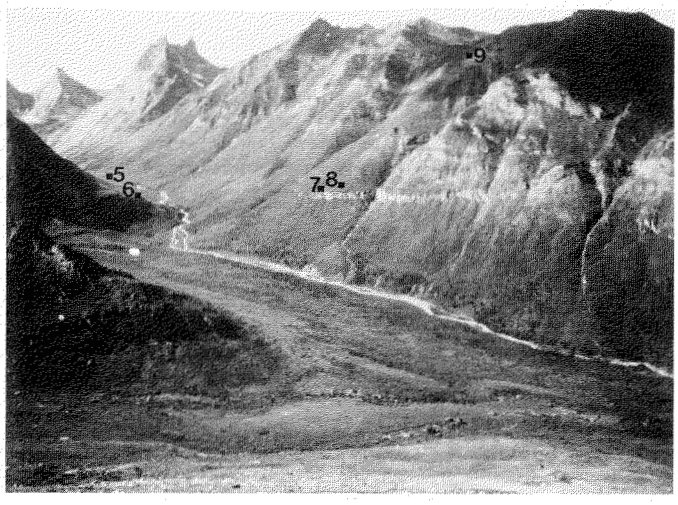

FIG. 3. Arrigetch Creek valley, showing locations of five trees above and beyond treeline. White spruce are visible as dark objects along creek. The farthest tree up this valley is number 5. The established treeline is where the creek makes a sharp bend to the right. Valley faces northeast.

FIG. 5. Tree number 10 is seen just to the left of the number 10, elevation 1067 m. Treeline is in the valley bottom to the right. Tree number 12 is just off the edge of the ridge. South is to the right.

FIG. 4. Tree number 9, located at 1465 m elevation. The tape is cm on the right and inches on the left. The plant above and below this tree is *Salix arctica*.

FIG. 6. Tree number 4, 5 km beyond treeline. Tape is in cm. Light-colored plants are *Cladonia* spp. lichens. Grass is *Festuca altaica*.

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