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Amanita* in the Rocky Mountain alpine zone, USA: New records for *A. nivalis* and *A. groenlandica

Cathy L. Cripps¹ and Egon Horak²

¹Plant Sciences and Plant Pathology Department, Montana State University, Bozeman, MT 59717-3150, U.S.A;

²Nikodemweg 5, AT-6020 Innsbruck, Austria

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Corresponding author: Cathy L. Cripps, ccripps@montana.edu. Accepted for publication June 20, 2010.
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Abstract: A limited number of *Amanita* species have been reported from cold dominated arctic-alpine environments, primarily with dwarf and shrub willows. This includes reports from Alaska, Canada, Greenland, Iceland, Scandinavia, Scotland, the Alps, and Russia. Here we report *Amanita nivalis*, *A. groenlandica* **f. alpina** n. f. and *A. vaginata* above tree line in the Rocky Mountains with *Salix reticulata*, *S. nivalis*, *S. glauca*, and *S. planifolia*. The distribution of *Amanita groenlandica* is extended to the north-central Rockies, and more definitively to the Beartooth Plateau at 3,100 to 3,400 m a.s.l. A new alpine form is described for this arctic species. *Amanita nivalis* is confirmed from numerous cirques and high passes 3,600-3,900 m a.s.l. in the southern Rocky Mountains (Front Range, Sawatch Range, San Juan Mountains), adding a disjunct component to its circumpolar distribution. These localities are thousands of miles from the Arctic and are likely near the southern-most extent of its distribution in North America. Rocky Mountain species are reported in context with arctic-alpine *Amanita* species from the Northern Hemisphere.

Key words: Agaricales, *Amanitaceae*, *Amanita groenlandica*, *Amanita nivalis*, alpine, Arctic, cold-climate fungi, ectomycorrhizal, Rocky Mountains, *Salix*, tree line

Introduction: The genus *Amanita* is known from arctic-alpine habitats throughout the Northern Hemisphere (Favre 1955, Gardes and Dahlberg 1996, Gulden et al. 1985, Hallgrímsson 1979, Hutchison et al. 1988, Knudsen & Borgen 1987, Miller et al. 1982, Watling 1985, 1987), however, there have been no formal reports of strictly alpine species from the Rocky Mountains. Only a limited number of *Amanita* species occur in cold dominated environments mainly in association with dwarf/shrub willows and dwarf birch. At least one species (*A. nivalis*) has a northern circumpolar distribution pattern.

Historical taxonomic confusion and unresolved synonymies have made it unclear as to the exact number of distinct arctic and alpine taxa of *Amanita*. To add to the confusion, the basidiomes of many alpine *Amanita* species are white, near white, or possess a whitish pileus under some environmental conditions. *Amanitas* often occur as single basidiomes in alpine habitats so intraspecific variation cannot be easily examined. Harsh arctic and alpine conditions can quickly destroy salient features, which is problematic in macromorphological evaluation. A majority of arctic-alpine *Amanita* species are in sect. *Vaginata* characterized by basidiomes with a saccate volva, absence of an annulus and non-amyloid spores (Tulloss 1994). Species within this group often lack distinct features that allow clear taxonomic separation, although molecular work has helped define subalpine species (Drehmel et al. 1999, Moncalvo et al. 2000, Weiss et al. 1998).

An extensive NSF-sponsored survey of alpine fungi along the Rocky Mountain cordillera for the Beartooth Plateau on the Montana/Wyoming border and the southern floristic zone in Colorado resulted in over 2,000 collections of alpine agarics that fall into ca. 200 species designations (Cripps and Horak 2006a, 2006b, 2008, Osmundson et al. 2005). *Amanita* species were regularly collected as part of this survey from habitats above treeline and strictly away

from the krummholz conifer zone. All are ectomycorrhizal species associated with alpine vegetation including shrub willows *Salix glauca* L. and *S. planifolia* Pursh., and dwarf willows *S. reticulata* L. and *S. arctica* Pall. Three species of *Amanita* are reported here from the Rocky Mountain alpine zone along with their ecology and in context with other arctic-alpine taxa in this genus.

Materials and Methods

Study Area

The Rocky Mountains extend along the spine of North America continuing 5,000 km north from New Mexico through Canada to Alaska. The Rocky Mountain alpine tundra, although fragmented on mountain tops, constitutes a phytogeographically significant region, comprised of the Northern, Middle, and Southern floristic provinces across a range of latitudes (Arno and Hammerly 1984). Our study examined sites south of the Canadian border, above treeline at 3,000 m a.s.l. in the north at latitude 45°N (Montana and Wyoming) and above treeline at 3,700 m a.s.l. in southern Colorado at latitudes of 37°-39°N. Portions of the alpine areas in both of these regions escaped glaciation.

Middle-Northern Floristic zone: The Beartooth Plateau is our primary study area for this floristic zone, and extends from Montana into northern Wyoming. The plateau is one of 11 situated along the MT-WY border that together comprise the most extensive alpine tundra in the lower 48 states (Anderson 1994). The Beartooth Plateau itself is about 20 km long by 10 km wide, at lat. 45°N and long 109°W. The vast sweeping gentle slopes are covered by an intricate patchwork of meadows, shrubby wetlands, grasslands and fell-fields (Cooper et al. 1997, Eversman 1995, Johnson and Billings 1962). Details of the vegetation and soils are in Anderson (1994), Bamberg and Major (1968), and Scott (1995). Soils are primarily derived from granitic material.

The collecting season for fungi is typically from mid-July to the end of August.

Southern Floristic Zone: The southern Rocky Mountains are isolated from the northern ranges by the Wyoming Plateau. The individual study sites lie in a chain along the Continental Divide at elevations from 3600 to 4000 m a.s.l. at lat. 36°-38°N. The sites include high mountain passes, unique cirques, and basins with a wealth of habitats including open windswept slopes, shrubby wetlands, extensive dwarf *Salix* and *Dryas* patches, meadows, turf, and fell-fields. A variety of soil types occur in the mountain ranges from granitic to limestone. The fruiting season is from mid-July through August or into September after which snow can close the high areas.

Ectomycorrhizal Vascular Plants: The primary ectomycorrhizal plants of these alpine areas include dwarf willow species *S. reticulata*, *S. arctica* and more rarely *S. rotundifolia* Trautv. and *S. cascadiensis* Cockll. (Cripps and Eddington 2005, Scott 1995). Shrub willows consist primarily of *S. glauca* which is more common in southern areas and *S. planifolia* which is more prevalent in the north. *Betula glandulosa* Michx. (= *B. nana* L.) is rare in the Rocky Mountain alpine zone and no *Amanita* species were recorded with this host. *Dryas octopetala* L. mats can be extensive in the Rocky Mountain alpine belt and host a limited diversity of ectomycorrhizal fungi (Cripps and Horak 2006b), however, to date no *Amanita* species have been recorded in strict association with *Dryas* for our sites.

Collection and processing

Basidiomes were collected from 1999 to 2008, primarily on the Beartooth Plateau in the North-Central Rockies and on the Front Range, Sawatch Range and San Juan Mountains to the South. Each collection was photographed, described,

drawn, and identified on subsequent completion of microscopic examination. Spores and other microscopic features were examined in 3% KOH after rehydration. Colors are from Kornerup and Wanscher (1967). Voucher specimens are in herbaria at Montana State University, Bozeman, MT (MONT) and the Institute of Integrative Biology, ETH, Zurich, Switzerland (ZT). An advantage for our study was that particular environmental conditions (high precipitation at local fungus peak season) often resulted in large fruitings that provided an opportunity to examine basidiome variation within the main alpine taxa that occur in the Rockies.

Results: Numerous basidiomes of *Amanita* were observed from 1999 and 2008 on the Beartooth Plateau sites (MT/WY) above 3,000 m a.s.l. (Fig. 1) and on the southern sites (Colorado) above 3,700 m a.s.l. The records represent three species of *Amanita* that occur above tree line (not in association with conifers) in the Rocky Mountains. Only North American collections are described here with emphasis on local ecology and distribution patterns (Table 1).

Fig. 1. Alpine area of Beartooth Plateau, Rocky Mountains, MT/WY, USA.

Table 1. Collection data for *Amanita* species in the Rocky Mountain alpine zone: *A. groenlandica* collections are from the Beartooth Plateau* near the Montana and Wyoming border, *A. nivalis* collections from Colorado**, and *A. vaginata* from the Beartooths. Cripps (=CLC) collections are in MONT and Horak (=ZT) collections are in ETHZ.

Collection	Date	Range	Location	Elev.	Hosts
<i>Amanita groenlandica</i> f. <i>alpina</i>					
Horak 6410	07 Aug-98	Beartooth	Site 1: Birch site	3,100	<i>Salix reticulata</i>
Cripps 1213	08 Aug-98	Beartooth	Site 2: Highline trail	3,100	<i>Salix</i> spp.
Cripps 1377	19 Aug-99	Beartooth	Site 1: Birch site	3,000	<i>S. reticulata</i> & <i>S. planifolia</i>
Cripps 1392	20 Aug-99	Beartooth	Site 2: Highline trail	3,100	<i>Salix reticulata</i>
Cripps 1405	21 Aug-99	Beartooth	Site 3: Frozen lakes	3,100	<i>Salix glauca/planifolia</i>
Cripps 1413	18 July-00	Beartooth	Site 2: Highline trail	3,100	<i>Salix reticulata</i>
Cripps 1585	20 July-01	Beartooth	Site 2: Highline trail	3,100	<i>Salix reticulata</i>
Cripps 1779	21 Aug-02	Beartooth	Site 4: Headwall	3,400	<i>Salix reticulata</i>
Cripps 1929	28 Aug-02	Beartooth	Site 2: Highline trail	3,100	<i>Salix cf planifolia</i>
Cripps 1970	12 Aug-03	Beartooth	Site 5: Top of Pass	3,400	<i>Salix reticulata</i> & <i>S. arctica</i>
Cripps 2313	19 July-08	Beartooth	Site 2: Highline trail	3,100	<i>Salix</i> spp.
Cripps 2328	14 Aug-07	Beartooth	Hell-roaring Plateau	3,500	<i>Salix reticulata</i>
<i>Amanita nivalis</i>					
Cripps 1235	12 Aug-98	Front	Loveland Pass	3,650	<i>Salix</i> spp.
Cripps 1415	08 July-00	San Juan	Cinnamon Pass	3,850	Dwarf <i>Salix</i> species
Cripps 1640	04 Aug-01	Sawatch	Cottonwood Pass	3,700	<i>Salix glauca</i>
Cripps 1647	04 Aug-01	Sawatch	Cumberland Pass	3,800	<i>Salix glauca</i>
Cripps 1665 (Horak 9763)	07 Aug-01	San Juan	Mineral Basin	3,650	<i>Salix reticulata</i>
Cripps 1691 (Horak 9534)	09 Aug-01	San Juan	Stony Pass	3,700	<i>S. reticulata</i> & <i>S. arctica</i>
Cripps 1720	11 Aug-01	San Juan	Black Bear Pass	3,900	<i>Salix reticulata</i>
Cripps 1727	13 Aug-01	Sawatch	Independence Pass	3,650	Not noted
Cripps 1773	15 Aug-01	Sawatch	Independence Pass	3,650	Not noted
<i>Amanita vaginata</i>					
Horak 6411	07 Aug-98	Beartooth	Site 2: Highline trail	3,100	<i>Salix</i> spp.

* Beartooth Plateau sites at 45°N, 109°W.

**Colorado sites at 37-39°N, 107°W.

Taxonomic descriptions

Amanita groenlandica Bas ex Knudsen & Borgen **f. *alpina*** n.f. (Table 1, Fig. 2)

Diagnosis. -*A typo differt pileo pallide aurantiaco, velo cremeo et odore fructifero. Holotypus varietatis CCL 1377 (MONT).*

Amanita groenlandica Bas ex Knudsen & Borgen. AA

Mycology II: 1987: 41-243.

= *A. groenlandica* nom. Prov. Bas in Clèmoncon, 1977:87.

Illustrations: Knudsen and Borgen 1987: 241; Borgen 1993:

63.

PILEUS 40-80 (-120) mm wide, hemispherical at first, then broadly convex, some slightly conic but mostly rounded, margin striate to 10 mm, color variable, often white when young, ranging from pure to mottled combination of cream with salmon tints, pinkish buff, salmon buff, pale orange (6A4), pale orange brown, pale brown, in age with silver to metallic pale brown sheen, more white in dry environmental conditions, smooth, greasy to kidskin dry; remnants of universal veil as one piece or as a few large unevenly scattered patches, dingy cream or buff color, with or without tints of pale orange to pale grayish tan (7C2, 7C3), thin to thick, edges sometimes uplifted; margin slightly sulcate in some; context thick in pileus, white.

LAMELLAE 120-160, free or just touching stipe, with few lamellulae or none, rarely dichotomous near cap edge, crowded, broad to 10 mm, rounded towards margin, white or with faint pale orange tint, more dingy cream in age; edges finely fimbriate, concolorous or darkening to gray in age.

STIPE 40-100 mm long, 10-25 mm thick, gradually enlarged towards base (slightly clavate), long, slender, straight to slightly curved, buried in soil or above ground, at first white with or without pale orange cream tints, in age with more gray or silvery tones, surface at first

floccose over all, almost pubescent, then breaking up into adder-like pattern (girdles) with a pale orange or gray silvery hue; partial veil absent; universal veil (volva) saccate, tight around base and then flaring outwards, sometimes in a star pattern or more ragged, whitish, staining ochre orange in areas or more silvery in age, fragile, easily left in ground, thin or somewhat thick; context white, turning gray in old specimens, stipe hollow. ODOR faintly fruity, becoming unpleasant in age.

BASIDIOSPORES white in deposit, (9.5-)10-12 (-13) x (9-)10-12(-13) μm , with a length range of L_R = 9-13 μm , width range of W_R = 9-12 μm , on average 11.2 x 10.4 μm , Q_R = 1.0-1.2, Q_{av} = 1.10, n= 25, globose (or subglobose), hyaline, smooth, thin-walled, inamyloid, with prominent conic- truncate apiculus, contents often guttulate with one large oil drop.

BASIDIA 60-80 x 16-20 μm , thin-walled, clavate, 4-spored, sterigmata 3-5 μm long, lacking clamp connections. CHEILOCYSTIDIA occasional, 10-25 x 22-30 μm , globose, pyriform to clavate, often with small cell below basal septum, thin-walled, lacking clamp connections.

PILEIPELLIS 20-40 μm thick, colorless with gelatinized suprapellis containing cylindrical hyphae, 3-4 μm wide; subpellis pale yellow brown in KOH, walls semi-gelatinized, interwoven, of filamentous hyphae, 4-6 μm wide, vascular hyphae pale yellow, occasionally dark yellow brown. PILEUS TRAMA primarily of swollen cells (almost cellular), (10-)20-30 μm wide to 65 μm long, narrowed at the septa, thin-walled, clamp connections absent; vascular hyphae copious, pale yellow to dark yellow brown in KOH, 4-10 μm wide, undulating.

HYMENOPHORAL TRAMA of swollen cells, 10-20(-40) μm wide with narrowed septa, thin-walled. SUBHYMENIUM of short squarish cells in chains 10 x 10 μm . UNIVERSAL VEIL primarily of filamentous cylindrical hyphae, 4-6 μm wide,

thin-walled, with y-branching, interwoven, septate, intermixed with inflated cells (sphaerocysts) 15-20 x 32-65 µm, in localized areas up to 75% of veil tissue, mostly in outer tissue, clamp connections absent.

HABITAT AND DISTRIBUTION: Scattered in mats of dwarf willow *Salix reticulata* and near shrub willows *S. planifolia* and *S. glauca* in the alpine vegetation zone. It fruits from July through August, above tree line at elevations of 3,100-3,400 m a.s.l. The alpine form occurs prolifically on the Beartooth Plateau near the Wyoming/Montana border and was not recorded from the southern Rockies.

SPECIMENS EXAMINED: USA. MONTANA, Carbon County: Beartooth Plateau, 8 July 1998, E. Horak 6410 (ZT); 19 Aug 1999, C.L. Cripps 1377 (FORM TYPE, MONT, MycoBank Number 518728); 14 July 2001, C.L. Cripps 1568 (MONT); 28 Aug 2002, C.L. Cripps 1929 (MONT); Hell-roaring Plateau, 14 Aug 2007, C.L. Cripps 2328 (MONT). WYOMING, Park County: Beartooth Plateau, 8 Aug 1998, C.L. Cripps 1213 (MONT); 20 Aug 1999, C.L. Cripps 1392 (MONT); 21 Aug 1999, C.L. Cripps 1405 (MONT); 18 July 2000, C.L. Cripps 1413 (MONT); 20 July 2001, C.L. Cripps 1585 (MONT); 21 Aug 2002, C.L. Cripps 1779 (MONT); 12 Aug 2003, C.L. Cripps 1970 (MONT).

OBSERVATIONS: Taxonomically *Amanita groenlandica* is in sect. *Vaginatae* based on inamyloid spores and lack of a partial veil. The Rocky Mountain alpine form (*forme alpina*) is robust with coloration reminiscent of a “cream-sicle” that varies from solid to mottled color combinations of cream, pale orange, and pale silvery brown. It is similar to the arctic form of *Amanita groenlandica* Bas ex Knudsen & T. Borgen (1987) personally observed in several localities in Greenland. The Rocky Mountain alpine form differs from the arctic form seen in Greenland by its taller stature, different coloration, and less viscid pileus. The alpine form is more in the pale orange brown range and is not typically dominated by gray brown or snuff brown colors as described for the arctic form (Knudsen and Borgen 1987). The universal veil is typically more cream color (not as gray as the arctic form), but can be in the gray range. Comparison of dried specimens shows a difference on reconstitution in KOH, with the arctic form veil exhibiting darker gray coloration. The odor of the alpine form is definitely fruity when young then becomes unpleasant in age, whereas specimens from the arctic are described as odorless. For our sites, this species only has been observed on the Beartooth and Hell-roaring Plateaus where it fruits in large numbers as a conspicuous element of the alpine mycota.

Fig. 2. *Amanita groenlandica* Bas ex Knudsen *forme alpina* (CLC 2328) in the Rocky Mountains. Half life size.

Amanita nivalis Grev. Scot. Crypt. Fl. 1(4): pl. 18. 1821. (Table 1, Fig. 3).

Amanitopsis nivalis (Grev.) Sacc. Syll. Fung. 5: 22. 1887.

Amanitina nivalis (Grev.) E.-J. Gilbert. Icon. Mycol. 27 (suppl. 1): 78. 1941.

Amanita vaginata var. *nivalis* (Grev.) E.-J. Gilbert. Le genre *Amanita* Persoon (Lons le-Saunier): 141. 1918.

Amanitopsis vaginata var. *nivalis* (Grev.) Peck. Ann. Rep. N.Y. State Mus. 47: 169. 1884.

Amanita vaginata f. *nivalis* (Grev.) Vesely. Ann. Mycol. 31: 279. 1933.

Amanita vaginata f. *oreina* J. Favre. Ergebn. wissenschaft. Unters. Schweiz. NatParks (5) 33: 205. 1955.

Illustrations: Gulden et al. (1985: 25), Moser and Jülich (1988: 1, 2), Campo and Bizio (2000: 177, 179, 182), Tulloss (2005), Jamoni 2008: 166-168.

PILEUS: 30-70 mm wide, convex to hemispherical when young, becoming shallow convex, to almost applanate, mostly without distinct umbo, margin distinctly striate or almost plicate-striate; color variable, ranging from whitish silver, pale gray, pale silver to pale gray brown (4C2), smooth, kidskin to slightly greasy. *Universal veil* typically absent on pileus surface, occasionally as one patch, in a few collections as scattered warts (pyramidal or not) possibly in dry conditions, variable within a local population or among collections, tissue whitish, staining pale gray. *Context* thin in pileus, white.

LAMELLAE: L=100, free or just touching stipe, typically without lamellulae; crowded, white, some with a pink cast especially when young but fading in age, drying pale orange, edges floccose, concolorous or graying.

STIPE: 40-60(-80) mm long, 5-10(-13 at base) mm thick, gradually enlarged towards base, hollow, white or with pale gray cast, minutely floccose for whole length with longitudinal pruina (not adder-like pattern). *Partial veil* absent. *Universal veil* saccate, flaring, lobed, white,

exterior can stain slightly ochre. *Context* white. *Odor* not distinctive.

BASIDIOSPORES white in deposit, 10-12(-14) x 8.5-11 µm, with a length range of $L_R=9-14$ µm and width range of $L_R=(7.5)8.5-13.5$ µm, on average 10.7 x 9.7 µm, $Q_{av}=1.1$, $Q_R=1-1.2(1.4)$, $n=25$, globose or subglobose, colorless, smooth, thin-walled, inamyloid, with prominent apiculus; content often guttulate with one large oil drop.

BASIDIA: 70-80 x 15-18(20) µm, clavate, thin-walled, 4-spored, sterigmata 3-6 µm long, clamp connection absent at base. **STERILE ELEMENTS** (paracystidia) on lamellar edges globose or clavate, 15-30 x 10-20 µm, colorless.

PILEIPELLIS 20-30 µm in depth, hyaline, with gelatinized colorless suprapellis containing hyphae 3-4 µm wide. Subpellis pale yellow brown in KOH, semi-gelatinized, thick, individual hyphae 5-17 µm in diameter, cylindrical, branched, without clamp connections; vascular hyphae 5-7 µm wide, with yellow contents in KOH, undulating, occasionally branching. **HYMENOPHORAL TRAMA** bilateral, of inflated hyphae 12-18 µm wide with constricted septa and occasional vascular hyphae same as for pileipellis. **SUBHYMENIUM:** of short cells, some inflated. **UNIVERSAL VEIL** composed mostly of filamentous hyphae, 4-6 µm wide and up to 40 µm long, a few scattered pyriform sphaerocysts 20-40 x 30-40 µm present, clamp connections absent.

HABITAT AND DISTRIBUTION: All collections are from the southern Rocky Mountains (CO) and it was found at over half of the localities visited in that state (Table 1). No representatives are reported here for northern sites however a recent collection from the Beartooth may represent this taxon. *Amanita nivalis* is a well known arctic-alpine species associated with willows; it has a circumpolar distribution and is now officially confirmed from the Rocky Mountains and lower 48 states.

SPECIMENS EXAMINED: USA. COLORADO: Summit County, Front Range, Loveland Pass, 12 Aug 1998, C.L. Cripps 1235 (MONT); San Juan County, San Juan Mountains: Cinnamon Pass, 8 July 2000, C.L. Cripps 1415 (MONT); Mineral Basin, 7 Aug 2001, E. Horak 9763 (ZT, MONT 1665); Stony Pass, 9 Aug 2001, C.L. Cripps 1691 (MONT); Black Bear Pass, 11 Aug 2001, C.L. Cripps 1720 (MONT); Chaffee/Gunnison County, Sawatch Range: Cottonwood Pass, 4 Aug 2001, C.L. Cripps 1640 (MONT); Cumberland Pass, 4 Aug 2001, C.L. Cripps 1647 (MONT); Pitkin/Lake County, Independence Pass, 13 Aug 2001, C.L. Cripps 1727 (MONT); same locality, 15 Aug 2001, C.L. Cripps 1773 (MONT), E. Horak 9534 (ZT).

OBSERVATIONS: *Amanita nivalis* is a small delicate species restricted to arctic and alpine habitats with willows. North American species exhibit the whole range of color variations from whitish to silvery gray or pale gray brown. There are wide swings in temperature and humidity in the alpine compared to the arctic, and remnants of the universal veil on the cap can vary from

absent to a few patches, and in a few collections scattered over the whole pileus as warts (also described by Knudsen and Borgen 1987). The fruiting body is less robust than *A. groenlandica* and the pileus more striate. Lamellae can be bright pink when young, changing to pale orange, and darkening on drying. The stipe is pruinose and lacks the adder-like pattern of *A. groenlandica*.

***Amanita* cf. *vaginata* (Bull.) Lam.**

Encycl.Méth. Bot. (Paris) 1: 109. 1783 (Table 1).

PILEUS 60 mm in diameter, convex to broadly umbonate-expanded, uniformly lead grey, ash grey to fuliginous, margin crenate-splitting, if moist subviscid, mat in dry condition, with whitish lumps from veil. LAMELLAE free, dense, lamellulae scattered, white, floccose pale grey edges. STIPE -80 x -18 mm, gradually attenuated towards apex, uniformly grey, conspicuously longitudinal striate, not adder patterned, minutely powdery-pruinose, hollow, solitary.

ANNULUS absent. VOLVA saccate, persisting,

Fig. 3. *Amanita nivalis* Grev. (CLC 1691=EH 9534), darker form, ZT 9808 is paler form: specimens from Colorado. Strip = 2 cm.

white (with very pale tinge). CONTEXT white. ODOR not distinctive. SPORES white, 9.5-11 µm, (sub-) globose. VOLVA composed of cylindrical hyphae, rarely intermixed with ovoid or globose cells.

SPECIMEN EXAMINED: USA: Montana, Carbon County, Beartooth Plateau, Highline Trail, alpine habitat, on soil associated with *Salix* spp., 7 Aug. 1998, E. Horak 6411 (ZT).

OBSERVATIONS: This species is reported once on the Beartooth Plateau with *Salix* and fits the description for the typical form of *A. vaginata*. This collection is characterized by a lead grey pileus, white lamellae with pale grey floccose edges, velutinous stipe without adder pattern and whitish saccate volva. It is also known from subalpine habitats in the region with aspen.

Discussion: The present contribution is the first formal in-depth report of *Amanita nivalis* and *Amanita groenlandica* from the Rocky Mountains south of the Canadian border and a new form is described for the latter.

Amanita nivalis is reported from several high-elevation basins and passes in the Front Range, the San Juan Mountains and the Sawatch Range, all in Colorado from 3,650-3,900 m a.s.l., in association with willows, primarily *Salix reticulata* and *S. glauca*. There is only one possible report of this species from northern sites despite intensive collecting efforts. Colorado may be close to the southern extent of this arctic-alpine species.

Amanita nivalis is the most well-known arctic-alpine species of *Amanita* and has a circumpolar distribution with disjunct populations in alpine areas of mountain ranges across the Northern Hemisphere (Fig. 4). The “ringless snow *Amanita*” was originally described from the Scottish Highlands (Greville 1822, reviewed in Watling 1985, 1987) and subsequently was found

in arctic-alpine areas of Greenland (Watling 1977, 1983, Knudsen & Borgen 1987), Iceland (Hallgrímsson 1972, 1979), Scandinavia (Bas 1977, Jacobsson 1984, Gulden et al. 1985), the Austrian Alps (Gerold 1986, Peitner et al. 1999), the French Alps (Bon 1985), the Italian Alps (Scaramella 1930, Bon 1987, Jamoni 2008), the Swiss Alps (Boudier & Fischer 1895, Favre 1955, Kühner 1972, Breitenbach & Kränzlin 1991, Senn-Irlet 1992), Alaska (Kobayasi 1967), and Russia (Knudsen & Mukhin 1996, Karatygin et al. 2008).

There is some taxonomic confusion in the interpretation of this species and several names may be synonymous (see Bas 1982, Campo & Bizio 2000, Knudsen & Borgen 1987, Tulloss 1994, Watling 1985, 1987), thus we prefer to treat this taxon in the broad sense here (Knudsen & Borgen 1987). *Amanita* species with the nomens of *oreina* and *hyperborea*, whether as a species, subspecies, or form need further taxonomic clarification beyond the scope of this paper (Bon 1987). There are several similar species of white to gray *Amanita* in the Rocky Mountains, but they occur in subalpine habitats with other host trees (Tulloss 1994).

The alpine form of *A. groenlandica* reported here from northern sites on the Beartooth Plateau has not been recorded yet from the southern Rocky Mountains. It appears morphologically close to *Amanita groenlandica* which was first described from Greenland (Borgen 1993, Knudsen & Borgen 1987). There are also reports of *A. groenlandica* from Canada (Hutchison et al. 1988; Ohenoja 1972), Norway and Russia (Knudsen and Mukhin 1996) (Fig. 4). The arctic form observed by us in Greenland is in our opinion distinct by different colors and lack of odor. The alpine form does not extend into the subalpine zone with conifers in the Rocky Mountains.

Other species of *Amanita* reported from Arctic-alpine habitats include *A. arctica* Bas, Knudsen

and Borgen. This white robust species was first described from Greenland (Knudsen & Borgen 1987) and has been recently found in Finland (PA Moreau, unpublished). The first author personally observed this collection, and it represents a species not yet recorded for the Rocky Mountains. However, there is one unconfirmed report of an alpine *Amanita* by this name from Eastern Canada (Hutchison et al. 1988). *Amanita mortenii* Knudsen & Borgen from Greenland appears restricted to *Betula* shrubs (Elborne & Knudsen 1990) which are not common in the Rocky Mountains alpine zone. Additional *Amanita* taxa are occasionally reported from cold-dominated climates, but on

close examination most appear associated with conifers in the krummholz zone. These records are not considered strict arctic- alpine inhabitants by our definition.

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Fig. 4. Distribution of *Amanita nivalis* and *Amanita groenlandica* in the Northern hemisphere.

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