Vegetation in the vicinity of the Toolik Field Station, Alaska

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The maps presented are components of the Arctic Geobotanical Atlas (http://www.ArcticAtlas.org/).

Explanation

Overview
This publication contains a group of vegetation maps at three scales in the vicinity of the Toolik Field Station, Alaska, which is an arctic research facility run by the Institute of Arctic Biology at the University of Alaska Fairbanks. The maps are intended to support research at the field station. The front side of this map sheet contains a vegetation map and ancillary maps of a 751-km^2 region surrounding the upper Kuparuk River watershed, including the Toolik Lake and the Imnavait Creek research areas, as well as portions of the Dalton Highway and Trans-Alaska Pipeline from the northern end of Galbraith Lake to Slope Mountain. The reverse side shows more detailed vegetation maps of the 20-km^2 research area centered on Toolik Lake and a 1.2-km^2 intensive research grid on the south side of Toolik Lake (red rectangles on Map A). All the maps are part of a hierarchical geographic information system (GIS) and the Web-based *Arctic Geobotanical Atlas* (http://www.arcticatlas.org/). The atlas also includes other map themes for all three areas and a previously published hierarchy of maps of the Imnavait Creek area (Walker et al. 1989; Walker and Walker 1996) (black rectangles on Map A). Photos and explanations of the geobotanical mapping units and the supporting field data and metadata can also be found on the website.

Maps of the Upper Kuparuk River Region
The upper Kuparuk River region has terrain typical of the Southern Foothills of the Brooks Range, including landscapes affected by three major glacial events. Map A shows the vegetation of the upper Kuparuk River region at 1:63,360-scale. Other maps show a false-color infrared satellite image (Map B), glacial geology (Map C), surficial geomorphology (Map D) and Normalized Difference Vegetation Index (NDVI)/biomass (Map E) - all at 1:225,000-scale. Maps A and C were derived from a geobotanical map of the region. The base map for the geobotanical map was a 1:25,000-scale black-and-white orthophoto-topographic map that was prepared especially for this project by Vexcel Corp., Denver, CO in 1994 from stereo pairs of 1:60,000-scale, 9 x 9-inch color-infrared aerial photographs that were obtained by NASA in 1982. The base map was prepared without ground-control points, but was registered as closely as possible to the 1:63,360 USGS map of the region. Vegetation and other geobotanical features were mapped by photo-interpretation onto 1:25,000-scale enlargements of the 1982 NASA aerial photographs. The minimum mapping unit was approximately 0.6 ha (1/8" at 1:25,000-scale). No formal accuracy assessment was performed, but 320 of the map polygons representing 3.2% of the total map polygons, and about 16% of the total map area were checked on the ground during helicopter-assisted transects in 1994. Geobotanical variables coded for each map polygon included: primary vegetation, secondary vegetation, tertiary vegetation, landform, surface deposit, primary surficial geomorphology and secondary surficial geomorphology. Secondary and tertiary types are subdominant types that cover more than 30% of a map polygon. The geobotanical map was made using methods and legends specially developed for northern Alaska (Walker et al. 1980, 1986, 1989). The GIS was developed following the integrated terrain-unit mapping approach (Dangermond and Harnden 1990). The resulting geobotanical maps were presented at conferences in 1996 (e.g., Walker et al. 1996) but remained unpublished until now. In 2007 the map boundaries were modified to register with a recent digital elevation model (DEM) of the Kuparuk River region (Nolan 2003) and the 1989 Système Probatoire d'Observation de la Terre (SPOT) image of the region (Map B). The legends were also modified to better fit the hierarchy of other maps in the *Arctic Geobotanical Atlas*.

Map A: Vegetation
The vegetation of the region was studied and mapped as part of the Arctic Long-Term Ecological Research (LTER) project at Toolik Lake and the Department of Energy R4D (Response, Resistance, Resilience and Recovery of vegetation from Disturbance) project at Imnavait Creek (Walker et al. 1994, Walker and Walker 1996). Fifty-seven plant communities and land-cover types were recognized during the mapping of the upper Kuparuk River region and are designated by the numeric GIS codes in the second column of the legend. These were grouped into the 14 physiognomic map units shown on Map A, which are compatible with the Circumpolar Arctic Vegetation Map (CAVM Team 2003) and the Alaska Arctic Tundra Vegetation Map (Raynolds et al. 2005).

Map B: False-Color Infrared Satellite Image
The French SPOT satellite data (20-m resolution) were obtained on 28 July 1989 and provides a view of the mapped region from space. The false-color infrared image shows more densely vegetated areas as brighter red tones. When compared with the glacial geology map (Map C), the older Sagavanirktok-age glacial landscapes have few lakes and redder tones indicating more dense vegetation, and the younger Itkillik-age glacial surfaces that have more lakes and grayer colors. The image data were also used to produce the NDVI/biomass map (Map E).

Map C: Glacial Geology
This map shows a simplified version of Thomas Hamilton's glacial geology map of the upper Kuparuk River region (Hamilton 2003). The glacial history of the region affects a wide variety of landscape and ecosystem properties, including topographic variation, abundance of lakes, plant production, soil carbon, spectral reflectance, biodiversity, trace-gas fluxes and heat flux of these landscapes. Glacial deposits within the upper Kuparuk River region are assigned to Sagavanirktok (middle Pleistocene, about 780-125 kya), Itkillik I (late Pleistocene, about 120-50 kya) and Itkillik II (late Pleistocene, about 25-11.5 kya) glaciations of the central Brooks Range glacial succession (Hamilton 2003). The legend units are arranged approximately from oldest to youngest.

Map D: Surficial Geomorphology
The surfaces of the landscapes in the Toolik Lake region have been modified by a variety of geomorphological processes including alluviation (movement of material by water), colluviation (movement of material by gravity) and periglacial processes (freezing and permafrost-related phenomena). Many of the surface forms have been described for the Imnavait Creek region (Walker and Walker 1996). Common surficial geomorphological features within the mapped area include sorted and nonsorted circles (frost boils), turf hummocks, gelifluction lobes and terraces, water tracks, high- and low-centered ice-wedge polygons, wetland features (strangmoor, aligned hummocks, palsas) and thermokarst features.

Map E: NDVI and Plant Biomass
NDVI is an index of vegetation greenness that can be linked to plant biomass and other biophysical properties of the vegetation, such as CO_2 and photosynthesis. The NDVI = (NIR – R)/(NIR + R), where NIR and R are the spectral reflectance values of the near-infrared (790-890 nm) and red (610-680 nm) bands, respectively. This map is derived from the same SPOT data as Map B. It is modified from an earlier version (Shippert et al. 1995) using more recent biomass information (Walker et al. 2008 in press). Water and barrens are generally displayed as black. Dry tundra and sparsely vegetated areas are displayed in gray. Vegetation density increases with darker shades of green.

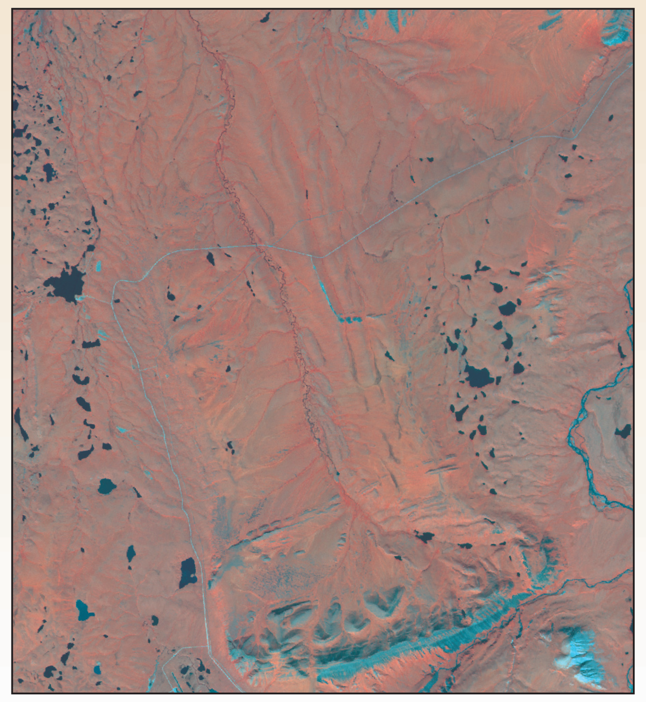
Literature Cited
CAVM Team. 2003. Circumpolar Arctic Vegetation Map. Conservation of Arctic Flora and Fauna (CAFF) Map No. 1, US Fish and Wildlife Service, Anchorage, AK.
Dangermond, J. and E. Harnden. 1990. Map data standardization: A methodology for integrating thematic cartographic data before automation. ARC News 12:16-19.
Hamilton, T. D. 2003. Surficial geology of the Dalton Highway (Itkillik-Sagavanirktok rivers) area, southern Arctic foothills, Alaska. Professional Report 121. Alaska Division of Geological and Geophysical Surveys. Fairbanks, AK.
Nolan, M. 2003. Distribution of the Star3i DEM of the Kuparuk River watershed (on CD ROM), Joint Office of Scientific Support Boulder, CO.
Raynolds, M. K., D. A. Walker and H. A. Maier. 2005. Alaska Arctic Vegetation Map, Scale 1:4,000,000. Conservation of Arctic Flora and Fauna (CAFF) Map No. 2. US Fish and Wildlife Service, Anchorage, AK.
Shippert, M. M., D. A. Walker, N. A. Auerbach and B. E. Lewis. 1995. Biomass and leaf-area index maps derived from SPOT images for Toolik Lake and Imnavait Creek areas, Alaska. Polar Record 31:147-154.
Walker, D. A., N. A. Auerbach, L. R. Lestak, S. V. Muller and M. D. Walker. 1996. A hierarchic GIS for studies of process, pattern and scale in arctic ecosystems: The Arctic System Science Flux Study, Kuparuk River Basin, Alaska. Poster presented at the Second Circumpolar Arctic Vegetation Mapping Workshop, Arendal, Norway, May 20-23, 1996.
Walker, D. A., E. Binnian, B. M. Evans, N. D. Lederer, E. Nordstrand and P. J. Webber. 1989. Terrain, vegetation and landscape evolution of the R4D research site, Brooks Range Foothills, Alaska. Holarctic Ecology 12:238-261.
Walker, D. A., et al. 2008. Arctic patterned-ground ecosystems: A synthesis of field studies and models along a North American Arctic Transect, J. Geophys. Res., doi:10.1029/2007JG000504, in press.
Walker, D. A., K. R. Everett, P. J. Webber and J. Brown. 1980. Geobotanical atlas of the Prudhoe Bay Region, Alaska. CRREL Report 80-14, US Army Cold Regions Research and Engineering Laboratory.
Walker, D. A. and M. D. Walker. 1996. Terrain and vegetation of the Imnavait Creek Watershed. Pages 73-108 *in* J. F. Reynolds and J. D. Tenhunen, editors. Landscape Function: Implications for Ecosystem Disturbance, a Case Study in Arctic Tundra. Springer-Verlag, New York.
Walker, D. A., P. J. Webber, M. D. Walker, N. D. Lederer, R. H. Meehan and E. A. Nordstrand. 1986. Use of geobotanical maps and automated mapping techniques to examine cumulative impacts in the Prudhoe Bay Oilfield, Alaska. Environmental Conservation 13:149-160.
Walker, M. D., D. A. Walker and N. A. Auerbach. 1994. Plant communities of a tussock tundra landscape in the Brooks Range Foothills, Alaska. Journal of Vegetation Science 5:843-866.

A: Upper Kuparuk River Region Vegetation

Physiognomy	Plant Communities (GIS codes)	Typical Microsites	Area (ha)	% of Map
Barren				
1. Anthropogenic barren	Roads, gravel pads and pipeline pads. (Disturbances are overlaid on pre-disturbance vegetation, so area of anthropogenic barrens are not included in the total area of the map.)	Barren roads, gravel construction pads, airstrips and gravel mines.	(270)	(0.4)
2. Lichens on rocks	Lichen communities on rocks, including *Cetraria nigricans-Rhizocarpon geographicum* (12).	Bedrock and xeric blockfields.	1,009	1.3
3. Partially vegetated barren	Complexes of vegetation with rock or soil on scree slopes (11), river gravels and other barrens (14), partially vegetated alpine areas (13) and areas dominated by nonsorted circles (15). Dominant plant communities include: *Saxifraga oppositifolia-Saxifraga eschscholtzii* (131); *Epilobium latifolium-Castilleja caudata* (141); revegetated gravel pads with *Festuca rubra* (142); *Anthelia juratzkana-Juncus biglumis* (15).	Partially vegetated barrens.	1,805	2.4
Moist graminoid tundra				
4. Tussock-sedge, dwarf-shrub, moss tundra	Moist acidic tussock-tundra complexes dominated by graminoids (31, 311). Dominant plant communities include *Eriophorum vaginatum-Sphagnum* (31) and *Carex bigelowii-Sphagnum* (3111).	Mesic to subhygric, stable, acidic (pH < 5.5) sites with shallow to moderate snow. Flat areas and gentle slopes.	29,020	38.7
5. Nontussock-sedge, dwarf-shrub, moss tundra	Moist nonacidic tundra complexes (32). Dominant plant communities include: *Carex bigelowii-Dryas integrifolia* (321), *Carex bigelowii-Dryas integrifolia* (subtypes *Equisetum arvense* (322) and *Salix glauca* (324)), *Eriophorum vaginatum-Tomentypnum nitens* (323) and *Carex bigelowii-Sphagnum,* subtype *Cassiope tetragona* (3113). Also includes a few other graminoid-dominated communities, including: *Festuca altaica-Poa glauca* (disturbed thermokarst areas) (325), *Deschampsia caespitosa-Carex saxatilis* (drained lakes) (326), *Carex podocarpa-Salix chamissonis* (snowy streamsides) (515).	Mesic to subhygric, nonacidic (pH > 5.5) sites with shallow to moderate snow. Flat areas and gentle slopes. Also miscellaneous graminoid-dominated sites including deep-snow stream margins, landslides and some rocky drained-lake basins.	13,153	17.5
Wet graminoid tundra and water				
6. Sedge, moss tundra (poor fens)	Nutrient-poor fen wetland complexes (41). Dominant plant communities include: Lower microsites: *Eriophorum scheuchzeri-Sphagnum orientale* (412) and *Eriophorum angustifolium-Sphagnum* (413). Raised microsites: *Sphagnum lenense-Salix fuscescens* (411).	Subhydric to hydric, acidic (pH < 4.5). Poor fens, meadows in colluvial basins.	1,934	2.6
7. Sedge, moss tundra (fens)	Nutrient-rich fen wetland complexes (4, 42). Dominant plant communities include: Lower microsites: *Carex aquatilis-Carex chordorrhiza* (422) and *Eriophorum angustifolium-Carex aquatilis* (423). Raised microsites: *Trichophorum caespitosum-Tomentypnum nitens* (421) and *Carex bigelowii-Tomentypnum nitens*.	Subhydric to hydric, nonacidic (pH > 4.5). Water tracks, stream margins, fens, flarks on solifuluction slopes.	1,160	1.5
8. Water and herbaceous marsh	Unvegetated water (6) and/or aquatic vegetation in lakes and streams. Dominant plant communities include: *Arctophila fulva-Hippuris vulgaris* and *Sparganium hyperboreum-Hippuris vulgaris* (43).	Hydric. Lakes, ponds and streams.	1,593	2.1
Prostrate-shrub tundra				
9. Prostrate dwarf-shrub, forb, fruticose-lichen tundra (acidic)	Dry acidic tundra complexes (21). Dominant plant communities include: *Dryas octopetala-Selaginella sibirica* (211), *Arctous alpina-Salix phlebophylla* (212); and lichen tundra *Cladonia arbuscula-Stereocaulon tomentosum* (215).	Xeric to xeromesic, acidic, wind blown to shallow winter snow cover. Ridge tops, exposed slopes, dry river terraces.	5,818	7.8
10. Prostrate dwarf-shrub, sedge, forb, fruticose – lichen tundra (nonacidic)	Dry nonacidic tundra complexes. *Dryas integrifolia-Oxytropis nigrescens* (24) and *Dryas integrifolia-Astragalus umbellatus* (22).	Xeromesic to mesic, nonacidic. Includes a wide variety of drier nonacidic habitats, including stable river terraces and nonsorted stripes on slopes.	895	1.2
11. Hemi-prostrate dwarf-shrub, fruticose-lichen tundra	Deeper snowbed complexes (23). Dominant plant communities include: *Cassiope tetragona-Carex microchaeta* (231), *Cassiope tetragona-Dryas integrifolia* (232); and *Salix rotundifolia-Sanionia uncinatus* (233).	Subxeric to mesic, acidic to nonacidic, with deep snow. Snowbeds.	2,164	2.9
12. Hemi-prostrate and prostrate dwarf-shrub, forb, moss, fruticose-lichen tundra	Dry tundra with shallow snowbeds mainly on stripe complexes. Dominant plant communities include: *Cassiope tetragona-Calamagrostis inexpansa* (214). Also includes dry areas with hemi-prostrate dwarf birch *Betula nana-Hierochloe alpina* (213).	Subxeric to mesic, acidic to nonacidic, somewhat-deeper-snow areas. Depressions on acidic ridge crests, dry glacial till and outwash; nonsorted stripes.	2,116	2.8
Erect-shrub tundra				
13. Dwarf- to low-shrub, sedge, moss tundra	Moist acidic tundra complexes dominated by shrubs. Includes shrubby tussock tundra and mainly dwarf-shrub tundra areas (3112). Dominant plant communities include: *Betula nana-Eriophorum vaginatum* (312) and *Salix pulchra-Carex bigelowii* (no code). Also acidic shrub tundra dominated by dwarf birch or willows. Dominant plant communities include: *Betula nana-Rubus chamaemorus* and *Salix pulchra-Sphagnum* (513)	Mesic to subhygric, moderate snow. Includes a wide variety of habitats with dwarf shrubs, including wet lower slopes, margins of upland water tracks, palsas and high-centered polygons.	9,045	12.1
14. Low to tall shrublands	Shrublands dominated by low and tall shrubs (5) including: 1. Shrublands along streams and water tracks dominated by diamond-leaf willow (*Salix pulchra*). Dominant plant communities include: *Salix pulchra-Eriophorum angustifolium* (511) and *Salix pulchra-Calamagrostis canadensis* (514). 2. Shrublands in riparian complexes (51) dominated by feltleaf willow (*S. alaxensis*) and lanate willow (*S. richardsonii*) (512); includes tall shrublands (5121) and low shrublands (5122). 3. Upland shrublands dominated by glaucous willow (*Salix glauca*) or alder (*Alnus crispa*) (52).	Mesic to subhydric, often with deep snow. Stream margins, upland water tracks and south-facing slopes.	5,344	7.1
		Total (excluding roads and pads)	75,056 ha	100%

Gravel Mines
Roads
Pipeline
Trails
Streams
Water tracks
200-m contours
50-m contours

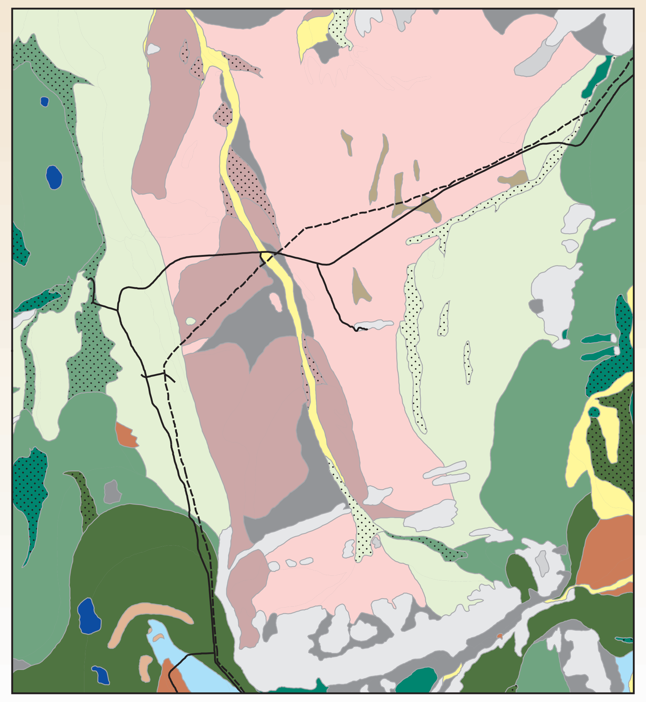
Vegetation mapping was performed in 1994 at 1:25,000 scale from 1982 NASA acquired base photography and is displayed at 1:63,360 scale. The extent of the mapped area is shown as a black rectangle on the location map to the left.



B: False-Color Infrared Image

Interpretation:
This false-color infrared image displays vegetated areas as a gradient of red tones. The brightest red areas are densely vegetated shrublands; moderate red areas are generally well vegetated surfaces, often with tussock tundra, and the dull red to brownish areas are more sparsely vegetated including dry tundra, nonacidic tundra, and wet tundra. The darkest black to bluish black areas are water. The lightest areas are light-colored bedrock (dolomite or limestone) or light-colored gravel in roads and river floodplains. Lichen covered bedrock (mostly sandstone and conglomerates) is dark grayish green.

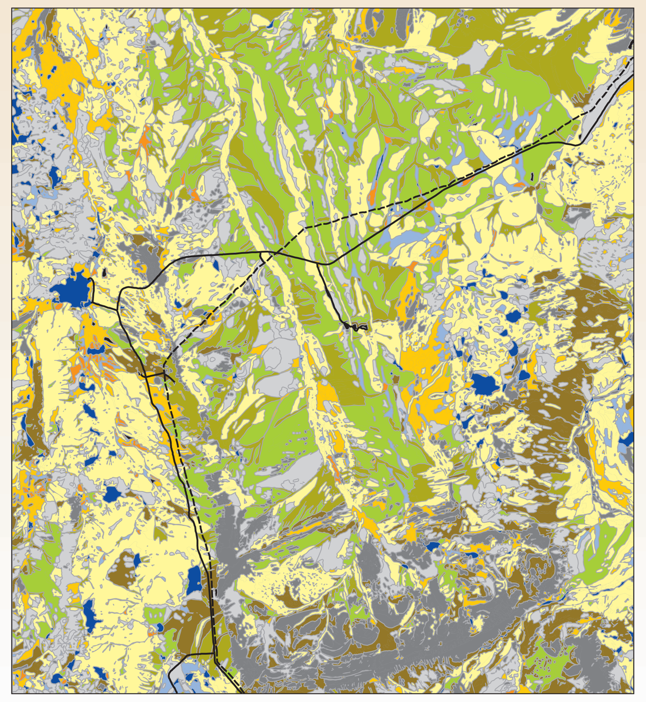
Source: SPOT imagery, 28 July 1989



C: Glacial Geology

- Bedrock
- Bedrock with discontinuous cover
- Drift of Sagavanirktok, undifferentiated
- Drift of Sagavanirktok, late advance
- Drift of Itkillik age, undifferentiated
- Drift of Itkillik Phase I
- Drift of Itkillik Phase II
- Drift of latest Itkillik readvance
- Outwash Sagavanirktok, late advance
- Outwash of Itkillik Phase I
- Outwash of Itkillik Phase II
- Outwash of latest Itkillik readvance
- Ice-contact deposits
- Active kettles
- Undifferentiated lacustrine deposits
- Undifferentiated gravel and beach deposits
- Undifferentiated colluvium
- Ice-rich silt deposits and colluvial basins
- Undifferentiated fan deposits
- Undifferentiated alluvium
- Roads
- Pipeline

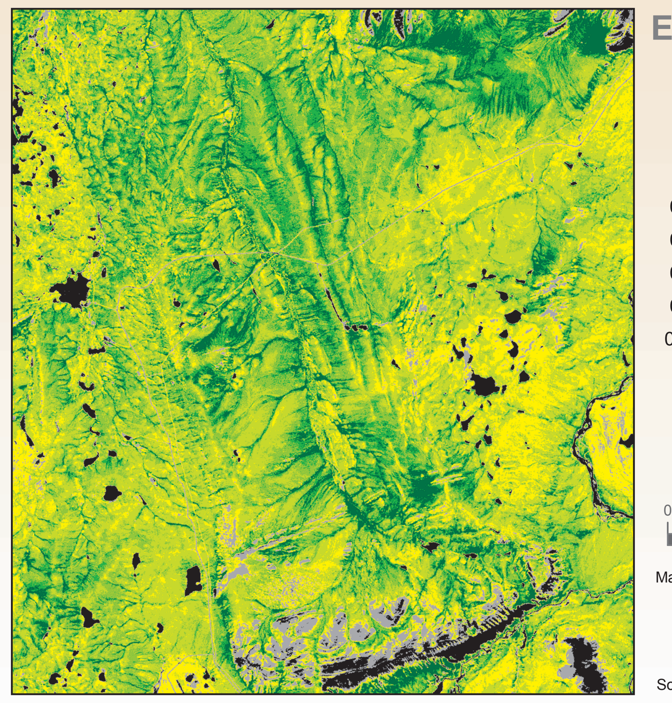
Source: simplified from Hamilton, 2003



D: Surficial Geomorphology

- Featureless
- Stony surfaces
- Non-sorted circles and/or stripes
- Gelifluction features (including lobes, terraces, turf hummocks)
- Well-developed hill-slope water tracks
- Indistinct hill-slope water tracks
- High- or flat-centered ice-wedge polygons and palsas
- Wetland surface forms (including low-centered polygons)
- Water (including thermokarsts and beaded streams)
- Irregular microrelief (glacial till, rolling relief, stream channels)
- Disturbed
- Roads
- Pipeline

Source: see vegetation map above, 1994



E: NDVI/Biomass

NDVI	Estimated Biomass (g/m^2)
< 0.14	0-25
0.14-0.32	26-75
0.33-0.40	76-150
0.41-0.45	151-300
0.46-0.48	301-500
0.49 - 0.51	501-1000
> 0.51	> 1000

0 2 4 6 8 10
Kilometers
Maps B-E displayed at 1:225,000 scale.

Source: SPOT imagery, 28 July 1989

Explanation for the maps of the Toolik Lake Area and the Toolik Lake Grid

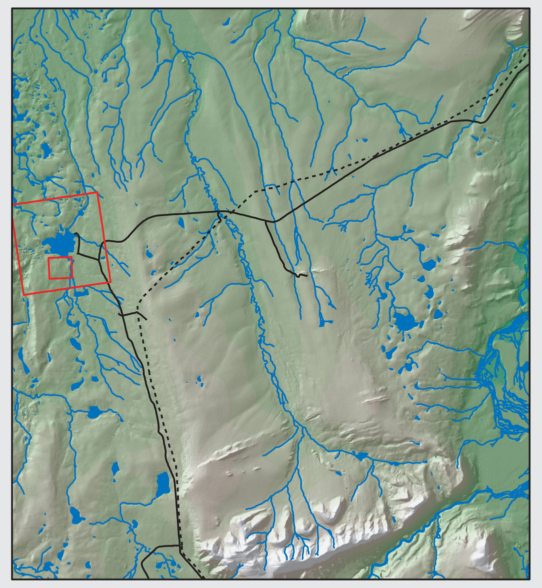


Figure 1. Location of the Toolik Lake Area (large red rectangle) and Toolik Lake Grid (small red rectangle) within the upper Kuparuk River region.

Vegetation of the Toolik Lake Area

Map F is located near the western boundary of Map A (displayed on front) and encloses a 20-km^2 area surrounding Toolik Lake that stretches from the Dalton Highway on the east to Jade Mountain on the west (large red rectangle in Fig. 1). It includes the Toolik Field Station, the old Toolik Lake pipeline construction camp gravel pad and airstrip on the northeast side of the lake and the primary terrestrial research areas on the south, west and east sides of the lake, as well as several smaller research lakes in the immediate vicinity of Toolik Lake. The area contains surfaces with irregular topography that were glaciated during the Late Pleistocene (Fig. 2 and 3).

Map F portrays the physiognomy of the dominant plant communities in each mapped polygon. Fifty-one landcover types (GIS codes are in parentheses in the second column of the legend) were recognized in the field (minimum mapping unit approximately 250 m^2). These were later grouped into the 14 physiognomic vegetation units on the map, which correspond to the same units on the 1:63,360-scale map of the upper Kuparuk River region (Map A).

Vegetation of the Toolik Lake Grid

Map G focuses on the 1.2-km^2 research grid on the south side of Toolik Lake (red rectangle on Map F and small red rectangle in Fig. 1). This area is one of the principal intensive research areas at the Toolik Lake Field Station. It includes many experimental research sites where long-term observations and experiments are being conducted, including the greenhouse and snow-fence experiments (Fig. 6-9). The grid was constructed in 1989 to provide geographic referencing for experimental plots and to provide a sampling scheme for periodic measurements of snow, active layer and plant communities.

Sixty-five plant communities were recognized (minimum mapping unit approximately 2.5 m^2) in the field (GIS codes are in the second column of the legend) and were then grouped into the 24 units appearing on the map. The vegetation units are primarily at the plant-community level (compared to the physiognomic level for the maps of the Upper Kuparuk River Region and the Toolik Lake Area). Several of the dominant plant communities in the Toolik Lake area are shown in the photos (Fig. 10-16). Details of the methods for both maps, sources for aerial photos, orthophoto topographic map, cross-reference to the Braun-Blanquet syntaxonomic plant community names (Walker et al. 1994) and other information are on the Arctic Geobotanical Atlas website, http://www.arcticatlas.org/.

Typical Plant Communities

Figure 10. Sagavanirktok-age glacial surface near Imnavait Creek. The vegetation is tussock tundra (*Eriophorum vaginatum-Sphagnum* spp.), the most common plant community on old, stable, acidic landscapes in the region. This is the dominant plant community in unit four on Maps A, F and G.

Figure 11. Blockfield with *Cetraria nigricans-Rhizocarpon geographicum*, unit two on Map A, F and G.

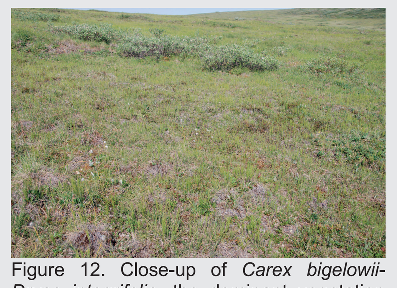


Figure 12. Close-up of *Carex bigelowii-Dryas integrifolia*, the dominant vegetation on mesic non-acidic tundra sites on Itkillik-age glacial surfaces, unit five on maps A, F and G.

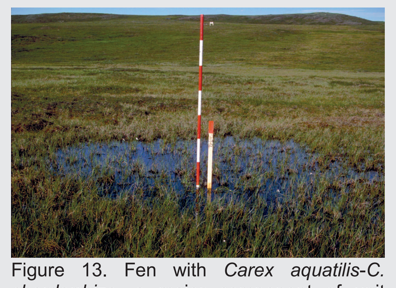


Figure 13. Fen with *Carex aquatilis-C. chordorrhiza*, a major component of unit seven on Map A and F, and unit nine on Map G.

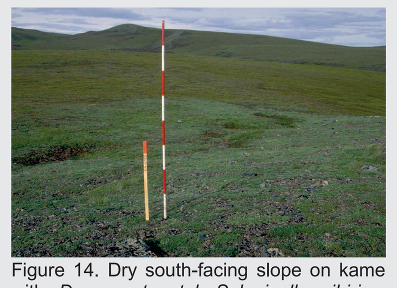


Figure 14. Dry south-facing slope on kame with *Dryas octopetala-Selaginella sibirica*, unit nine on Map A, F, and unit 13 on Map G.

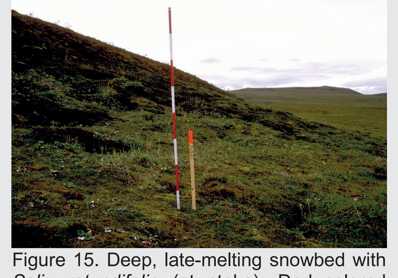


Figure 15. Deep, late-melting snowbed with *Salix rotundifolia* (at stake). Dark-colored vegetation above the stake is *Cassiope tetragona-Dryas integrifolia*, a common component of unit 11 on Map A and F and unit 17 on Map G.

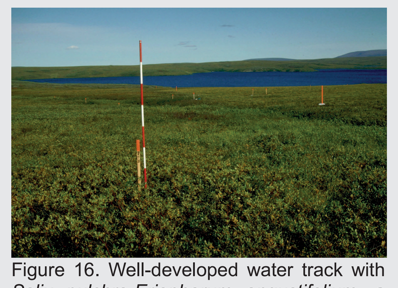
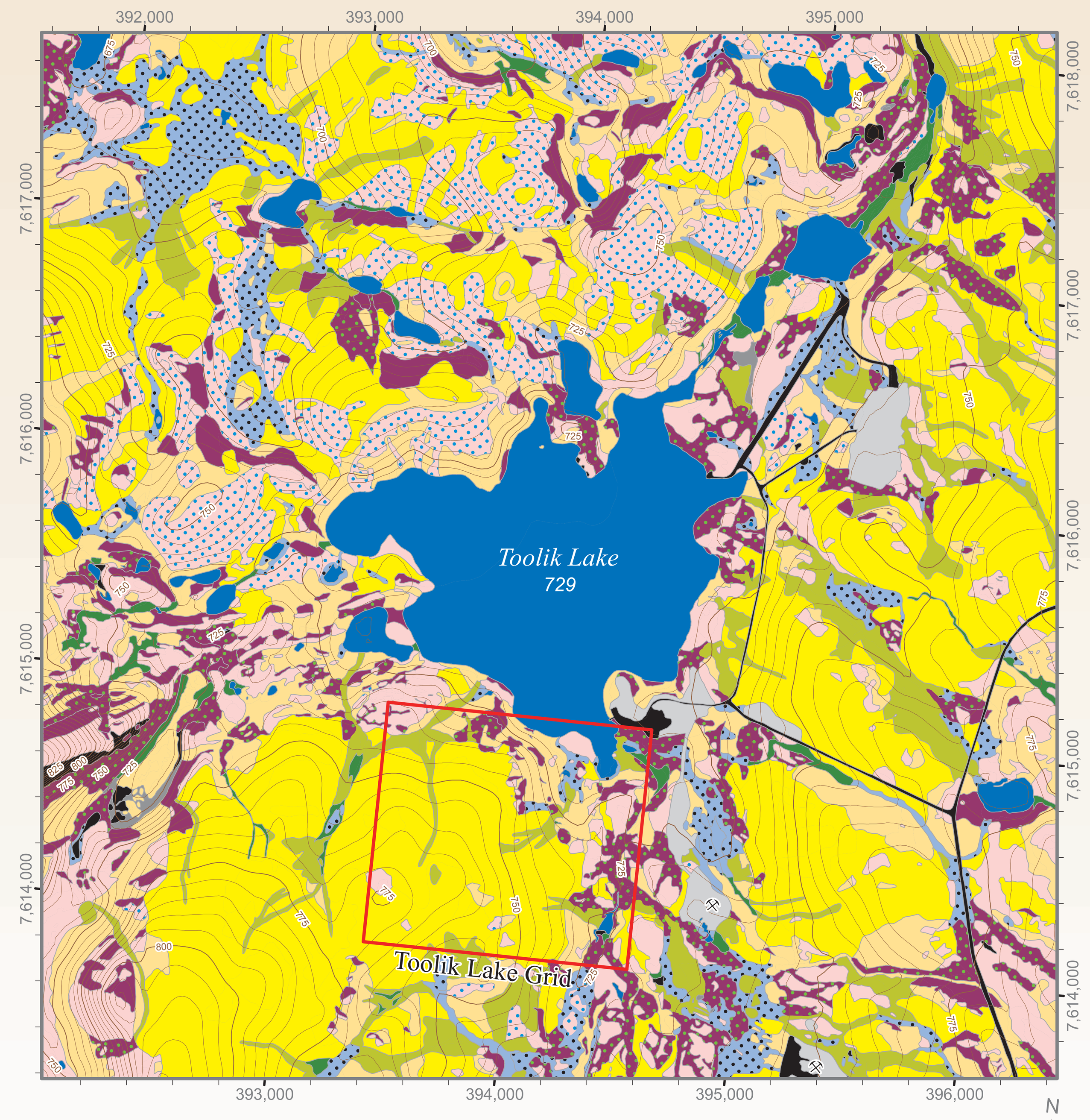


Figure 16. Well-developed water track with *Salix pulchra-Eriophorum angustifolium*, a common component of map unit 14 on Map A and Map F and unit 23 on map G.

All photos are by D.A. Walker except figures 6 and 7 which are courtesy of the Arctic LTER website (http://ecosystems.mbl.edu/ARC/terrest/maps_photos/index.html).

F: Toolik Lake Area Vegetation



Gravel Mines
25-m Contours
5-m Contours

0 500 1,000 1,500
Meters
UTM Zone 6, NAD 1983

Vegetation mapping was performed in 1991 at 1:5,000 scale from 1:5,000 scale base photography acquired in 1990. The map is displayed at 1:20,000 scale.

	Physiognomy	Plant Communities (GIS codes)	Typical Microsites	Area (ha)	% of Map
Barren					
1.	Barren	Unvegetated (91, 101).	Unvegetated natural and anthropogenic barrens.	23.8	1.2
2.	Lichens on rocks	Lichen communities on rocks, including *Cetraria nigricans-Rhizocarpon geographicum* (92).	Xeric blockfields, glacial erratics.	3.9	0.2
3.	Partially vegetated barrens and revegetated disturbed areas	Revegetated gravel pads (e.g., *Festuca rubra* or *Salix alaxensis* 102).	Partially vegetated disturbed barrens on gravel pads, abandoned roads, bulldozed areas.	24.9	1.2
Moist graminoid tundra					
4.	Tussock sedge, dwarf-shrub, moss tundra	Moist acidic tussock tundra complexes dominated by graminoids. Dominant plant communities include: *Eriophorum vaginatum-Sphagnum* (41) and *Carex bigelowii-Sphagnum* (no code).	Mesic to subhygric, acidic, shallow to moderate snow. Stable slopes. Some areas on steeper slopes with solifluction are dominated by Bigelow sedge (*Carex bigelowii*) (no code).	605.1	29.8
5.	Nontussock sedge, dwarf-shrub, moss tundra	Moist nonacidic tundra complexes. Dominant plant communities include: *Carex bigelowii-Dryas integrifolia* (42) and other subtypes of this unit (e.g., *Salix glauca* (33), *Equisetum arvense* and *Cassiope tetragona* (no codes)). Includes some miscellaneous graminoid communities mostly on disturbed areas, such as *Deschampsia caespitosa* (45); *Rumex arcticus-Carex saxatilis* (75) *Salix chamissonis-Carex aquatilis* (65); *Ranunculus pedatifidus-Poa glauca* (104).	Mesic to subhygric, circumneutral, shallow to moderate snow. Solifluction areas and somewhat unstable slopes (42), mainly on Itkillik II glacial surfaces. Some south-facing slopes have scattered glaucous willow (*Salix glauca*) (33). Also includes some miscellaneous graminoid-dominated sites: deep-snow stream margins (65), landslides, some rocky drained lake basins (45, 75) and animal dens (104).	306.8	15.1
Wet graminoid tundra and water					
6.	Sedge, moss tundra (poor fens)	Nutrient-poor fen wetland complexes. Dominant plant communities include: Lower microsites: *Eriophorum scheuchzeri-Carex rotundata* (72). Raised microsites: *Sphagnum lenense-Salix fuscescens* (71).	Subhydric to hydric, acidic (pH < 4.5). Wet meadows, poor fens in colluvial basins – mainly on older (Itkillik I) glacial surfaces.	7.8	0.4
7.	Sedge, moss tundra (fens)	Nutrient-rich fen wetland complexes. Dominant plant communities include: Lower microsites: *Carex aquatilis-Carex chordorrhiza* (no code); *Eriophorum angustifolium-Carex aquatilis* (82), *Carex aquatilis-Scorpidium scorpioides* (74). Raised microsites: *Trichophorum caespitosum-Tomentypnum nitens* (73) and *Carex bigelowii-Dryas integrifolia* (42). Includes a few other miscellaneous wetland types.	Subhydric to hydric, minerotrophic (pH > 4.5). Water tracks, stream margins, fens, flarks on solifluction slopes – mainly on younger (Itkillik II) glacial surfaces.	105.6	5.2
8.	Water and herbaceous marsh	Unvegetated water (84); graminoid marsh *Arctophila fulva* (81) and *Sparganium hyperboreus-Hippuris vulgaris* (83).	Lakes, ponds and streams; aquatic vegetation in some protected sites.	196.5	9.7
Prostrate-shrub tundra					
9.	Prostrate dwarf-shrub, fruticose-lichen tundra.	Dry acidic tundra complexes. Dominant plant communities include *Dryas octopetala-Selaginella sibirica* (12); *Arctous alpina-Hierochloë alpina*, typical subtype (14), *Salix phlebophylla* subtype (no code) or *Vaccinium vitis-idaea* subtype (17).	Xeric to xeromesic, acidic, shallow snow. Exposed sites on glacial till, outwash, ridge tops, exposed slopes, dry river terraces.	232.2	11.5
10.	Prostrate dwarf-shrub, sedge, forb, fruticose-lichen tundra (nonacidic)	Dry nonacidic tundra complexes. Dominant plant communities include *Dryas integrifolia-Oxytropis nigrescens* (13), *Dryas integrifolia-O. maydelliana* (no code), *Dryas integrifolia-Astragalus umbellatus* (16), *Dryas integrifolia-Dicranum elongatum* (18) and undifferentiated *Dryas* communities (11).	Xeromesic to mesic, nonacidic with shallow snow cover. Exposed sites on dry river terraces, recent alluvium (13); dry microsites in nonsorted-stripe complexes (16, 18). Dominated by *Dryas integrifolia*.	159.5	7.9
11.	Hemi-prostrate and prostrate dwarf-shrub, forb, moss, fruticose-lichen tundra	Snowbed communities dominated by either *Cassiope tetragona* or *Salix rotundifolia* (20). These communities are not differentiated at this scale, but include *Cassiope tetragona-Carex microchaeta* (acidic sites); *Cassiope tetragona-Dryas integrifolia* (nonacidic sites); *Salix rotundifolia-Sanionia uncinata* (deep snowbeds).	Includes all snowbed types.	93.0	4.6
12.	Hemi-prostrate dwarf-shrub, fruticose-lichen tundra	Dry or moist shrublands with very low-growing or creeping dwarf-shrubs. Dominant plant communities include *Betula nana-Hierochloë alpina* (23); *Salix pulchra-Hierochloë alpina* (24); and those dominated by *Ledum palustre* ssp. *decumbens*, *Empetrum nigrum* or *Vaccinium uliginosum* (no codes).	Subxeric to mesic, acidic, with shallow snow. Shallow depressions on dry glacial till or outwash.	121.0	6.0
Erect-shrub tundra					
13.	Dwarf-shrub or low-shrub, sedge, moss tundra	Moist acidic tundra complexes dominated by shrubs, including shrubby tussock tundra. Dominant plant communities include *Betula nana-Eriophorum vaginatum* (43) and *Salix pulchra-Carex bigelowii* (44). Also dwarf-shrub tundra dominated by dwarf birch or willows. Dominant plant communities include *Betula nana-Rubus chamaemorus* (51) and *Salix pulchra-Sphagnum* (52).	Mesic to subhygric, moderate snow. Lower slopes and upland water-track margins (43, 52), often with solifluction (44). Or palsas and high-centered polygons (51).	124.3	6.1
14.	Low and tall shrublands	A wide variety of low to tall shrublands. Dominant plant communities include those growing in upland water tracks such as *Salix pulchra-Eriophorum angustifolium* (67) and *Eriophorum angustifolium-Sphagnum squarrosum* (66); those growing along streams such as *Salix pulchra-Dasiphora fruticosa* (61) and other low (5122) and tall shrublands (5121); upland shrublands dominated by *Salix glauca* (33) and/or *Alnus crispa* (52) or *Populus balsamifera* (34) and shrublands on river gravels dominated by feltleaf willow (*S. alaxensis*) (63) or lanate willow (*S. richardsonii*) (62).	Low shrubs in upland water tracks (66, 67), streamsides (61, 62, 63) and south facing slopes (52, 34), mesic to subhydric, often with deep snow.	23.2	1.1
			Total	2027.6 ha	100%

Typical landscapes in the Upper Kuparuk River region:

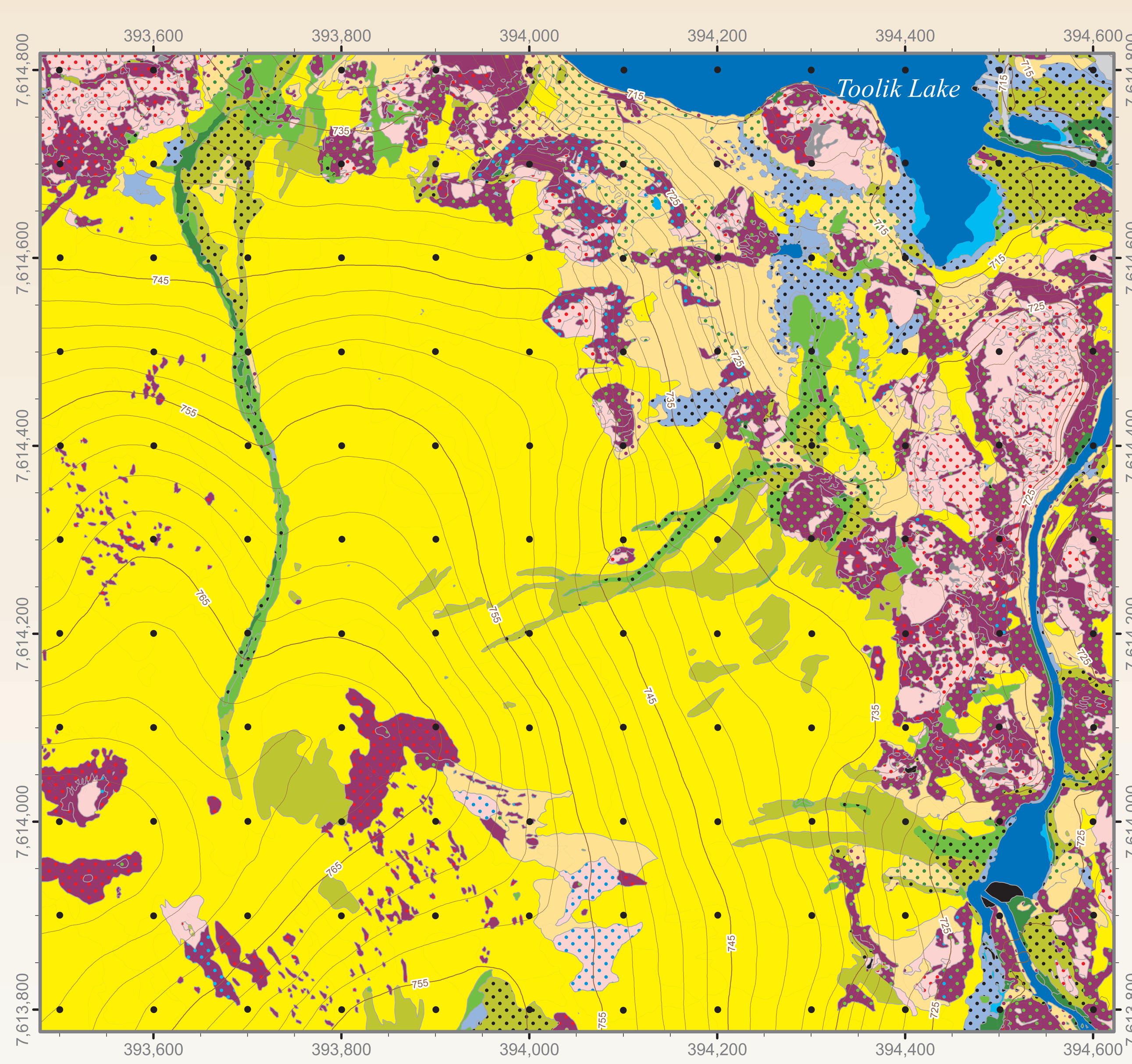
Figure 2. View looking northeast from Jade Mountain across an Itkillik II glacial landscape with numerous glacial lakes, kames and kettles.This landscape is much more vegetatively complex than the Sagavanirktok-age glacial surfaces (Fig. 3).

Figure 3. View looking southeast across the headwaters of Imnavait Creek into the Philip Smith Mountains of the Brooks Range. Vegetation is typical of the Sagavanirktok-age glacial surfaces, which cover large portions of Map A but do not occur on the terrain shown in Maps F and G.

Figure 4. Alpine area on limestone on Peak 1376 in the southeast corner of Map A, looking south into the valley of the Sagavanirktok River. The dominant vegetation is *Dryas integrifolia-Oxytropis nigrescens* (unit 10 on Map A).

Figure 5. Streamside vegetation along the inlet stream to Toolik Lake. The tallest shrubs are *Salix alaxensis*. Low shrubs along the far bank are a mix of *Betula nana* and *Salix pulchra*. The dominant vegetation unit along the stream is low to tall shrublands, unit 14 on Maps A and F, and unit 24 on Map G.

G: Toolik Lake Grid Vegetation



Grid points
10-m Contours
2-m Contours

0 100 200 300
Meters
UTM Zone 6, NAD 1927

Vegetation mapping was performed in 1991 at 1:500 scale from 1:1,000 scale base photography acquired in 1990. The map is displayed at 1:5,000 scale. The map is presented in the NAD 1927 datum so that the map coordinates will match the labels on the original

	Plant Communities (GIS codes)	Description (physiognomy and typical microsite)	Area (ha)	% of Map
Barren				
1.	Barren (901)	Unvegetated natural and anthropogenic barrens.	0.16	0.1
2.	*Cetraria nigricans-Rhizocarpon geographicum* (902)	Lichen communities on rocks. Xeric blockfields, glacial erratics.	0.11	0.1
3.	*Festuca rubra* (903); *Salix alaxensis* (904); *Epilobium latifolium* (905); *Juncus biglumis-Luzula arctica* (no code)	Partially revegetated areas. Gravel pads (903), river gravels (904, 905) and nonsorted circles (no code).	0.23	0.2
Moist graminoid tundra				
4.	*Eriophorum vaginatum-Sphagnum* (406,407); *Carex bigelowii-Sphagnum* (404, 405)	Tussock sedge, dwarf-shrub, moss tundra (tussock tundra, moist acidic tundra). Mesic to subhygric, acidic, shallow to moderate snow, stable. This unit is the zonal vegetation on fine-grained substrates with ice-rich permafrost (406, 407). Some areas on steeper slopes with solifluction are dominated by Bigelow sedge (*Carex bigelowii*) (404, 405).	65.92	54.2
5.	*Carex bigelowii-Dryas integrifolia,* typical subtype (401, 403); *Tomentypnum nitens-Carex bigelowii, Salix glauca* subtype (320)	Nontussock sedge, dwarf-shrub, moss tundra (moist nonacidic tundra). Mesic to subhygric, nonacidic (pH > 5.5), shallow to moderate snow. Solifluction areas and somewhat unstable slopes (401,403). Some south-facing slopes have scattered glaucous willow (*Salix glauca*) (320).	7.04	5.8
6.	*Carex bigelowii-Dryas integrifolia, Equisetum arvense* subtype (402); *Tomentypnum nitens-Carex bigelowii, Carex aquatilis* subtype (410)	Nontussock sedge, prostrate dwarf-shrub, horsetail, moss tundra (wetter subtypes of moist nonacidic tundra, often with abundant horsetails). Mesic to subhygric, nonacidic, moderate snow. Seepage areas below snowbeds with abundant horsetails (*Equisetum arvense*) (402) or aquatic sedge (*C. aquatilis*) in wetter areas (410).	2.22	1.8
7.	*Carex bigelowii-Dryas integrifolia, Cassiope tetragona subtype (208);* or other miscellaneous graminoid plant communities, including *Ranunculus pedatifidus-Poa glauca* (106); *Salix chamissonis-Carex podocarpa* (408); *Festuca altaica-Artemisia arctica* (412); *Poa glauca-Epilobium latifolium* (109)	Sedge, hemi-prostrate dwarf shrub, moss tundra (moist nonacidic tundra in snow accumulation areas). Mesic to subhygric, mostly nonacidic, moderate to deep snow. Inter-stripe areas in nonsorted stripe complexes on upper hill-slopes with moderate to deep snow and abundant Lapland heather (*Cassiope tetragona*). This unit also includes several miscellaneous graminoid, dwarf-shrub, forb communities that cover small areas, including animal dens (106), deep-snow stream and lake margins (106), dry snow accumulation areas (412) and stream banks (109).	1.64	1.3
Wet graminoid tundra and water				
8.	*Tricophorum caespitosum-Tomentypnum nitens* (409), *Salix fuscescens-Sphagnum lenense* (411,508), *Carex aquatilis-Sphagnum warnstorfii* (506)	Sedge, prostrate dwarf-shrub, moss tundra. Hygric to subhydric. Hummocks, strangs and raised microsites in fens (409) and poor fens in wet meadows and colluvial-basins (411, 508) and mossy colluvial basin margins (506).	0.32	0.3
9.	*Eriophorum angustifolium-Carex aquatilis,* typical subtype (501), *Carex chodorrhiza* subtype (502, 505), *Drepanocladus revolvens* subtype (503); *Carex saxatilis-Carex aquatilis* (504) and *Calliergon giganteum-Drepanocladus revolvens* (507)	Sedge, moss tundra in fens with flowing water. Subhydric to hydric. Lower microsites in colluvial basins, water tracks and stream margins (501, 502, 503, 505), wet pools on solifluction slopes (507).	2.30	1.9
10.	Unvegetated water (602)	Hydric. Streams, lakes, ponds.	5.34	4.4
11.	*Sparganium hyperboreum-Hippuris vulgaris* (603, 604); *Arctophila fulva* (601)	Herbaceous marsh. Hydric. Water to 1-m deep in lakes and ponds.	0.33	0.3
Prostrate- and hemi-prostrate dwarf-shrub tundra				
12.	*Arctous alpina-Hierochloë alpina,* typical subtype (105), *Salix phlebophylla* subtype or *Vaccinium vitis-idaea* subtype (103)	Prostrate dwarf-shrub, fruticose-lichen tundra. Xeric, acidic, shallow snow. Dry acidic tundra on well-drained glacial till, outwash and exposed sites.	5.14	4.2
13.	*Dryas octopetala-Selaginella sibirica* (101), *Dryas octopetala-Salix glauca* (102)	Prostrate dwarf-shrub, forb, fruticose-lichen tundra. Xeric, acidic, wind blown or shallow winter snow cover, stony or with considerable bare soil. Ridge crests, dry river terraces. Dominated by *Dryas octopetala* (101), occasionally with *Salix glauca* (102).	3.71	3.1
14.	*Dryas integrifolia-Oxytropis maydelliana* (108)	Prostrate dwarf-shrub, forb, fruticose-lichen tundra. Xeromesic to mesic, nonacidic, wind-blown to shallow winter snow cover. Dry slopes, river terraces, drier microsites in nonsorted stripe complexes, dominated by *Dryas integrifolia*.	0.72	0.6
15.	*Cassiope tetragona-Carex microchaeta*, typical subtype (202), *Salix glauca* subtype (203)	Hemi-prostrate dwarf-shrub, fruticose-lichen tundra. Subxeric to mesic, acidic, moderately deep snow. Acidic snowbeds (50-150 cm snow).	2.35	1.9
16.	*Cassiope tetragona-Calamagrostis inexpansa,* typical subtype (104) or *Vaccinium vitis-idaea* subtype (111); *Cassiope tetragona-Racomitrium lanuginosum* (112)	Hemi-prostrate and prostrate dwarf-shrub, forb, moss, fruticose-lichen tundra. Subxeric to mesic, acidic, shallow to moderately deep snow (<1 m deep). Nonsorted stripe complexes with shallow to moderately deep snow (104, 111).	3.54	2.9
17.	*Cassiope tetragona-Dryas integrifolia*, typical subtype (113, 204, 205)or *Boykinia richardsonii* subtype (206). Includes *Salix rotundifolia-Sanionia uncinata* (207)	Hemi-prostrate dwarf-shrub, fruticose-lichen tundra. Subxeric to mesic, nonacidic, moderately deep snow. Nonacidic snowbeds (50-150 cm snow) (113, 204, 205). Also includes deep (>3 m snow) well-drained snow-beds with *Salix rotundifolia* (207).	1.39	1.1
18.	*Betula nana-Hierochloë alpina* (302, 303), *Vaccinium uliginosum-Arctous alpina* (110); or *Ledum palustre* ssp. *decumbens-Empetrum nigrum* (201)	Hemi-prostrate dwarf-shrub, fruticose-lichen tundra. Subxeric to mesic, acidic, moderately deep snow. Depressions on glacial till or outwash (302, 303); warm snowbeds (201). Very low-growing hemi-prostrate dwarf-birch (*Betula nana*) (302, 303) or erect dwarf blueberry (*Vaccinium uliginosum* ssp. *microphyllum*) (110) or Labrador tea (*Ledum palustre* ssp. *decumbens*) (201).	7.47	6.1
Erect-shrub tundra				
19.	*Betula nana-Eriophorum vaginatum* (308)	Dwarf-shrub, sedge, moss tundra (shrubby tussock tundra dominated by dwarf birch, *Betula nana*). Mesic to subhygric, acidic, moderate snow. Lower slopes and water-track margins. Mostly on Itkillik I surfaces.	3.75	3.1
20.	*Salix pulchra-Carex bigelowii* (312, 325)	Dwarf-shrub, sedge, moss tundra (shrubby tussock tundra dominated by diamond-leaf willow, *Salix pulchra*). Subhygric, moderate snow, lower slopes with solifluction.	3.59	3.0
21.	*Betula nana-Rubus chamaemorus,* dwarf-shrub variant (306, 307) and *Cladonia arbuscula* variant (304)	Dwarf-shrub, moss tundra dominated by dwarf birch (*Betula nana*). Subhygric to hygric, acidic, moderate to moderately deep snow. Upland water tracks, margins of water tracks and lower slope areas (306, 307). Somewhat drier areas have abundant lichens (304).	2.08	1.7
22.	*Salix pulchra-Sphagnum warnstorfii* (310, 311)	Dwarf-shrub or low-shrub tundra dominated by willows (*Salix pulchra*). Subhygric, acidic, moderate to moderately deep snow. Margins of upland water tracks, palsas and high-centered polygons.	1.36	1.1
23.	*Salix pulchra-Eriophorum angustifolium* (314, 315, 318); or *Salix pulchra-Calamagrostis canadensis* (316)	Low shrublands (generally 40-100 cm tall). Subhydric to mesic, moderate to deep snow. Deeper upland water tracks with flowing water (314, 315) or riparian areas along major streams (316).	0.74	0.6
24.	*Salix alaxensis* (323, 324) or *S. richardsonii* (319) (tall shrubs)	Tall shrublands (> 2 m tall). Subhydric to mesic, nonacidic, moderate to deep snow. Stream margins dominated by tall willows, *Salix alaxensis* (323, 324) and/or *S. richardsonii* (319).	0.21	0.2
		Total	121.66 ha	100%

Research within the Toolik Lake Grid:

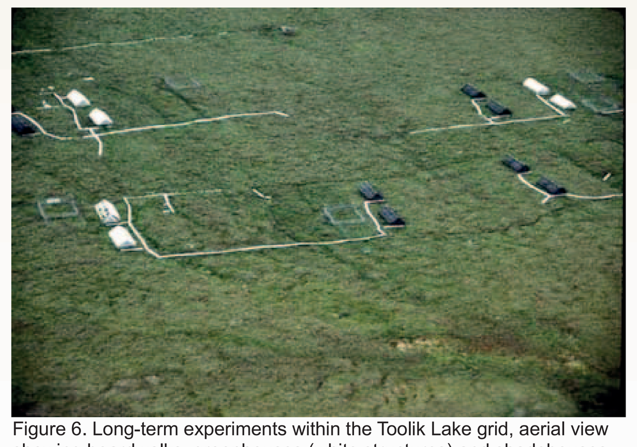


Figure 6. Long-term experiments within the Toolik Lake grid, aerial view showing boardwalks, greenhouses (white structures) and shadehouses (black structures).

Figure 7. Experimental greenhouse with the side and top opened to show enhanced growth due to added warmth. Pre-treatment shrubs were same height as vegetation in the foreground.

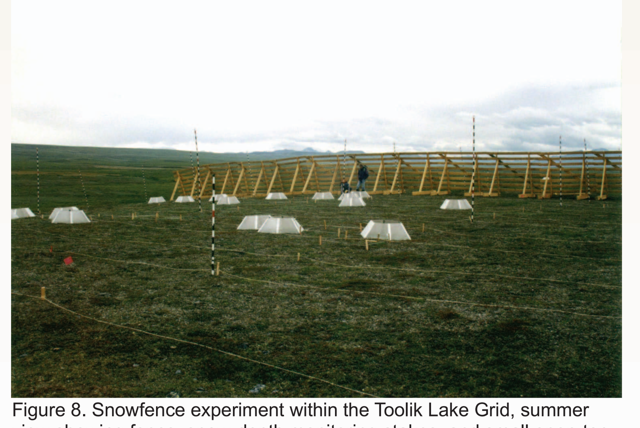


Figure 8. Snowfence experiment within the Toolik Lake Grid, summer view showing fence, snow-depth monitoring stakes, and small open-top greenhouses.

Figure 9. Winter view of snowfence experimental area showing the drift that forms behind the fence. Tall stakes are the same as striped stakes in Figure 8.

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