**PART II**

**CAVM-NORTH AMERICA WORKSHOP**

**ANCHORAGE, ALASKA, US, 14-16 JANUARY 1997**

## I. SUMMARY OF PROCEEDINGS OF THE NORTH AMERICAN CAVM WORKSHOP, USGS EROS ALASKA FIELD OFFICE, 14-16 JAN 1997

*Derived from notes taken by Carl Markon*
USGS EROS Alaska Field Office

### *Participants and funding*

The participants at the workshop included Christian Bay and Fred Daniëls (Greenland), Larry Bliss and Steve Zoltai (Canada), Mark Shasby, Mike Fleming, Carl Markon, Steve Talbot and Skip Walker (US). Funds for the Anchorage workshop were provided by the Alaska Science Center, Biological Resources Division, US Geological Survey, Anchorage. Other funding came from an Interagency Agreement between the Alaska Region US Fish and Wildlife Service, Anchorage, and the Alaska EROS Field Office, US Geological Survey, Anchorage, through an Interagency Agreement between the Alaska State Office, Bureau of Land Management, Anchorage, and the Alaska Region US Fish and Wildlife Service, Anchorage.

### *Presentations*

- Mark Shasby: Welcome and introductions.
- Steve Talbot: Welcome and acknowledgments.
- Skip Walker: Overview and schedule.
- Mike Fleming: Progress on the CIR and NDVI base maps.
- Skip Walker: Methodology for mapping in northern Alaska.
- Christian Bay: Progress in Greenland.
- Steve Zoltai/ Larry Bliss: Progress in Canada.
- Steve Talbot/Carl Markon: Progress in western and southwestern Alaska.
- Fred Daniëls: Community nomenclature.

Presentations were made by each of the participants summarizing the progress in each of the North American countries. Most of the workshop focused on developing a mapping approach for the CAVM. The discussion focused on a prototype legend and integrated map for northern Alaska, presented by Skip Walker.

### *Summary of results*

During development of a prototype map for northern Alaska, the multi-factoral vegetation coding procedure suggested at Arendal was replaced by an integrated mapping method. This approach is described in the attached abstract which also contains the legends agreed to for North America. This paper contains the final legend, and a full description of the integrated mapping methods and GIS methods.

During the first phase of the North American mapping, the integrated mapping approach will be applied to seven prototype areas in North America where we have the best information: Alaska North Slope, Yukon-Kuskokwim River Delta, Alaska, Ellesmere Island, Banks Island, Melville Hills vicinity, Ammassalik District, Southeast Greenland; Jameson Land, East Greenland and Kronprins Christian Land, Eastern North Greenland.

### *The 3rd International CAVM Workshop*

Another international workshop was proposed for GRID-Arendal in early 1998 pending funding. Key participants from each country will be invited. The primary purpose of the workshop will be to review the prototype maps from North America and finalize the plans for each region.

## METHOD FOR MAKING AN INTEGRATED VEGETATION MAP OF NORTHERN ALASKA (1:4,000,000-SCALE)

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### *Abstract*

This method consists of making several separate maps portraying different themes (e.g., landscape units, soils, bedrock geology, percent

lake cover, and vegetation complexes). The landscape units are defined by characteristics that can be observed on AVHRR imagery (mountains, hills, floodplains, etc.). The landscape-unit boundaries are used to guide the boundaries on the other thematic maps. The polygon boundaries on several of the separate thematic maps, or layers, are then integrated onto a single map sheet (the integrated terrain-unit map), which contains all the polygon boundaries. This map is then digitized and each polygon is given a unique polygon identification number. The GIS database consists of two principal files, one containing the topology information for the ITUM polygons, and the other containing the geobotanical attributes for each polygon. Separate "look-up" tables are linked to the attribute file. The look-up tables contain additional information regarding principal plant communities, and vegetation properties (dominant growth forms, dominant species, horizontal structure, production, and biomass) within each vegetation complex for each floristic subprovince/ phytogeographic zone combination.

### *Introduction*

This document contains a brief description of a GIS and remote sensing-based approach used for mapping the tundra region of northern Alaska at a scale of 1:4,000,000. The contribution is toward the development of a comprehensive method for making a circumpolar arctic vegetation (Walker 1995, Walker *et al.* 1995, map). Rather than aiming toward a single vegetation map, the goal of the integrated vegetation mapping approach described here is a vegetation database that can be used to derive a wide variety of map products and spatial analyses of the arctic region.

The integrated vegetation mapping approach is based on landscape-guided mapping espoused by the International Training Centre for Aerial Survey (ITC, now called the Institute for Aerospace Survey and Earth Sciences) in the Netherlands (Zonneveld 1988). The application of this approach to GIS technology has been most clearly presented by Dangermond and Harnden (1990) as the integrated terrain unit mapping (ITUM) approach used by the Environmental Systems Research Institute (ESRI). The approach uses the philosophy that most soil and vegetation boundaries on maps are controlled by physiographic landscape features. In the Arctic North America, this philosophy has also been well demonstrated (Everett *et al.* 1978; Walker *et al.* 1980, Zoltai and Johnson 1977, Zoltai and Pettapiece 1973). The integrated method described here requires that landscape units first be defined and mapped. Boundaries of other geobotanical elements of the landscapes, such as soils and vegetation, are then guided by the boundaries of these basic landscape units.

### *Components of the integrated vegetation map*

The final integrated terrain unit map (ITUM) is based on several map layers which are described below. The legend for each layer is presented in Table 1.

Layer 1. AVHRR CIR composite

This is the base image to which all boundaries conform. It is the northern Alaska piece of an AVHRR false color-infrared composite of the circumpolar region at 1:4,000,000-scale developed by Fleming (this volume). It displays the maximum relfectance of the vegetation for each 1x1-km pixel during the summer of 1991.

Layer 2. Topography/hydrology.

This layer is composed of data from the Alaska digital elevation model and the hydrological information in the Digital Chart of the World. This layer provides the coastal boundaries for the map and helps guide landscape-unit boundaries along rivers and major lakes and in the mountains.

Layer 3. Boundary of the study area and locations of intensive study sites.

*a. Map boundary.* This layer defines the total boundary of the study area. The position of the northern treeline was obtained from the *Major Ecosystems of Alaska* (Joint Federal-State Land Use Planning Commission for Alaska, 1973). The final map will utilize the shoreline boundary defined in the Digital Chart of the World.

*b. Location of major study sites.* This layer also portrays points of major vegetation and soil study sites in northern Alaska described in the literature. This information is important because it is used to determine the dominant communities described in the literature for each vegetation complex with the floristic subprovince/phyto-geographic zone combinations of Yurtsev (1994).

Layer 4. Floristic subprovinces and phytogeographic subzones.

This layer was not used in defining the final ITUM polygon boundaries. Because of disagreement among the CAVM working group regarding the position and validity of the these boundaries, it is suggested that these boundaries be contained in a separate overlay where they can be readily modified and overlaid on the final ITUM to help in characterizing the floristic nature of the final map. The layer shown here portrays the approximate location of Yurtsev's (1994) floristic boundaries in northern Alaska.

Layer 5. Landscape units.

The landscape unit layer is the basic element of the integrated terrain unit map, and the boundaries on this map are used to guide the boundaries on the other layers. This layer displays basic landscape units that can be recognized on the AVHRR-derived base map. These include lakes, ocean, plains, plateaus, hills (without altitudinal vegetation belts), mountains (with altitudinal belts), floodplains and deltas, glaciers, and mountain valleys. In some cases the position of mountain valleys and floodplains was difficult to delineate on the AVHRR image, and the position of landscape unit boundaries was aided by reference to mosaics of Landsat images of northern Alaska (USGS 1978, USGS EROS Data Center no date). The position of these boundaries would be further aided by including the river network and the major topographic isolines on Layer 2.

Layer 6. Percentage cover of lakes.

Spectral variation within wetland complexes at the AVHRR scale is mainly a function of lake size and density. In most cases, lakes have subpixel dimensions at the AVHRR scale (1x1-km pixels). The map boundaries were interpreted by reference to the more detailed Landsat images of the North Slope (USGS 1978, USGS EROS Data Center no date) and Sellman *et al.* (1975), who mapped the percent cover of water on the North Slope. This layer will probably be useful for helping to develop classifications based on AVHRR imagery.

Layer 7. Generalized bedrock geology.

Bedrock composition is particularly important to plant communities in areas where bedrock is near the surface and not overlain by deep unconsolidated deposits. Our studies in northern Alaska have shown that the contrast in vegetation between acidic and nonacidic substrates is striking and that there are major differences in a wide variety of important ecosystem properties and functions, including biodiversity, primary production, heat flux, and trace-gas production (Walker *et al.* submitted). The differences in the vegetation on acidic and nonacidic substrates have not been previously mapped in northern Alaska, and is necessary to use a combination of spectral information, soil, and geological information to infer the location of these tundra types. This layer generalizes the bedrock portrayed on 1:2,500,000-scale geology map of Alaska (Beikman 1980) into four categories based primarily on the pH of the soil to which these bedrock types weather. It may be desirable to add other categories [e.g. surficial geology, (Karlstrom and others 1964)] for extensive geologic formations that weather to substrates supporting unique vegetation (e.g. serpentine).

Layer 8. Soil associations.

Like the bedrock, soil maps can help in defining the location of vegetation complexes. This is particularly useful in the foothills and coastal plain, where distinctive plant community complexes are associated with acidic sandy substrates, or nonacidic loamy substrates. This layer is derived from the *Exploratory Soil Survey of Alaska* (Rieger *et al.* 1979) and modified based on information from a wide variety of sources including surficial deposit maps of the National Petroleum Reserve in Alaska (Gryc 1985, Hamilton 1986, Hamilton and Porter 1975), maps of the landscape units in the Arctic National Wildlife Refuge (USDI 1982), and personal unpublished data from numerous surveys.

Layer 9. Maximum NDVI.

NDVI has been shown to be a good surrogate of vegetation greenness. Generally, the NDVI values are highest in vegetation with greater biomass. In tundra, the NDVI can be useful to define areas of sparse vegetation, such as polar desert regions, or areas with high biomass such as shrublands. This layer portrays the maximum NDVI for each pixel during the summer of 1991. It was particularly useful for defining the boundaries of shrubland vegetation near treeline, in the mountains, areas of northwestern Alaska, and a few areas in warmer portions of the North Slope.

Layer 10. Vegetation complexes.

At 1:4,000,000 scale, the vegetation patterns are strongly related to terrain features that contain mosaics of characteristic plant communities. It is impossible to map the boundaries of individual plant communities at this scale, but it is possible to map vegetation complexes and list the typical plant communities that occur in common elements of each vegetation complex, similar to the approach used for the European vegetation map (Bohn this volume) and several Russian vegetation maps (e.g., Perfilieva this volume)).

*Delineation of vegetation boundaries.*

The vegetation complexes for Layer 10 (see Table 1) are derived from a variety of geobotanical information in the previous layers. The boundaries are, for the most part, an amalgamation of boundaries for Landscape Units (Layer 5), Generalized Bedrock Geology (Layer 7), Soil Associations (Layer 8), and Maximum NDVI (layer 9). The information used to delineate the vegetation information depends on the vegetation type, and may include various combinations of bedrock geology, substrate pH, soil texture, extent of cryoturbation, surface area covered by water, and NDVI.

*Dominant and characteristic plant communities in each vegetation complex.*

Table 2 (not shown here) presents the suite of dominant and characteristic plant communities for each vegetation complex within Yurtsev's (1994) floristic subprovinces and phytogeographic zones in northern Alaska. The table presented at the Anchorage meeting contained only the information for Subzones II and IV within the northern Alaska subprovince, and will be expanded for the other three floristic regions in northern Alaska at a later date. Wherever possible information in Table 2 is derived from vegetation studies from within the relevant subregion and subzone (Layer 3).

*Community names.*

The names of the communities are standardized. If a published Braun-Blanquet association name is available, it takes precedence over all other descriptions because this name is readily recognized by phytosociologists and contains a great deal of inherent information regarding species composition, geographic location, and habitat. If no Braun-Blanquet epithet is available, the best available description is selected as the reference plant community. The best information should contain a complete species list for the community (vascular plants and cryptogams), preferably with a table showing the abundance of the species in multiple relevés or samples. The name should contain only two species names, the dominant and a characteristic plant, preferably one that is characteristic of the floristic subregion in which the community occurs. The plant names are italicized and separated by a dash. The name is followed by the author(s) of the article in which the community is described and the date of publication. The terrain element or habitat is briefly described in parentheses.

Layer 11. Integrated terrain unit map.

A full explanation of the advantages of creating an integrated map for GIS applications are contained in "Map data standardization: a methodology for integrating thematic cartographic data before automation" (Dangermond and Harnden 1990). The method has been applied to terrain mapping at a wide variety of scales including entire continents. The advantages include: (a) use of common boundaries wherever possible for various geobotanical themes, (b) minimizing the total number of polygons stored in the GIS, (c) resolution of boundary inconsistencies between the various themes, and (d) smoothing of boundaries to eliminate unnecessary crenulations and very small polygons. It allows information from a wide variety of sources to be compiled at a common scale with the same level of accuracy and registered to the same photo base. Many very small polygons of minimal value to the final map (sliver polygons) can be eliminated by following the landscape-unit boundaries wherever possible.

Although the process of integration sounds somewhat mysterious, it is actually straightforward as long as a systematic procedure is followed. The landscape unit boundaries in Layer 5 are used as the basic set of boundaries and are carried through wherever possible by tracing them onto other layers where appropriate. New boundaries are added for other layers only where needed to properly map the information. In this way, only the minimum number of lines and polygon boundaries are used in the final ITUM.

It is recommended that the final ITUM be produced by first tracing the boundaries of the vegetation complex map (Layer 10) since this layer is already an integration of several other layers. After these boundaries are drawn, other boundaries appearing on the other layers are added. The ITUM for the northern Alaska prototype map includes information from landscape units (Layer 5); percent cover of lakes (Layer 6); bedrock geology (Layer 7); soils (Layer 7); and vegetation complexes (Layer 10).

The final ITUM should be checked to make sure that all polygons are closed.

Layer 12. Point map for off-scale units

This map contains points identifying known important off-scale units, including polar oases, balsam poplar groves, and spring communities. This layer is also not part of the ITUM.

Layer 13. Polygon ID map.

The ITUM is then digitized. This results in a raster-format file, that is then converted to a vector (or line) format using GIS software. Unique polygon ID labels are added to each polygon either automatically using GIS software or by manually creating centroids in each polygon and attaching the ID number. A final polygon ID map is then produced that shows the polygon boundaries, centroids, and polygon ID numbers. (The map at the Anchorage workshop had only five polygons with ID numbers near Point Barrow for demonstration purposes. Normally every polygon on the map would have an ID number.)

### *Geobotanical attribute coding sheet*

The geobotanical attributes for each polygon are then recorded on a coding sheet. The polygon ID map (Layer 13) is overlaid on a given thematic map (e.g. landscape units) and thematic code for each polygon is recorded. This procedure is repeated for all the map attributes (landscape unit, % lakes, bedrock, soil association, and vegetation complex). This information is then keypunched. This data file, in combination with the file containing the topological information for each polygon, makes up the basic GIS database.

### *Editing*

Separate maps are then produced for each theme and checked against the original information. A variety of consistency checks should also be made to make sure that inappropriate combinations of codes (for example, moist tundra occurring within lakes) do not occur.

### *"Look-up" tables to produce derivative maps*

The relatively small set of soil and vegetation complexes can be linked to "look-up" tables that contain a wide variety of information for each soil or vegetation unit. For example, information regarding biomass, primary production, plant growth forms, horizontal structure, and dominant species could be contained in a look-up table linked to the dominant plant community of each vegetation complex (Table 4). Similarly, the soil properties, such as texture, depth of organic horizons, and pH, could be contained in a soil look-up table.

### *Technical aspects*

1. The AVHRR base image (Layer 1) should have 3 or 4 registration marks that are aligned with registration marks on Layer 10 (the ITUM). This is necessary to register the ITUM to the base-map/image during the digitizing process.

2. The process of making the various overlays is greatly aided by special registration tabs and pins that allow the layers to be added or removed easily while maintaining perfect registration. The pins eliminate the need for registration marks on all the overlays. The pins we use are made by Burton Ternes, and the registration tabs are Pako 0.25 in. round, self-adhesive, package of 250, Part No. 750-18102.

3. Coding the polygons appearing on each layer should be done such that a dot is placed in the center of the polygon and leader line drawn from the dot to the respective code. Wherever possible the code should be contained in the polygon that it describes. For very complex maps

it may be desirable to use different colored pencils for the polygon boundaries and the codes and leader lines to avoid confusion between the leader lines and the polygon boundaries.

4. It is important that all polygons are closed and that the line work is as neat as possible with no overshoots or gaps where boundary lines meet.

### *Concluding remarks*

It may be possible to reduce the number of vegetation complexes for the final map. For consistency, the members of the CAVM project need to agree on the basic set of landscape units and vegetation complexes that will be mapped. It should be expected that additional terrain units and vegetation complexes will be required in other geographic regions as the mapping proceeds.

We need to thoroughly discuss whether this method is feasible for all members of the CAVM working group. There are potential pitfalls to a group that is largely unfamiliar with GIS methods. There are also overriding benefits including the ability to produce a wide variety of derived maps and the flexibility of the database for modeling purposes. Above all, it allows us to begin work immediately without first finalizing the ultimate vegetation legend. Considering the current disagreement regarding vegetation mapping units, an approach based primarily on mapping landscape units first seems like the best alternative.

The use of "look-up" tables is also being used to resolve classification differences among countries involved in the circumpolar soils map. Charles Tarnocai, at an International Permafrost Association meeting in Boulder, noted that by using look-up tables, each country can go ahead and proceed with mapping using their own local classification. The properties of soils, which is what most users will be interested in, are contained in a separate look-up table. It is then possible to relate these properties to the various soil units and produce maps of these properties. Similarly, the plant communities are the basic units that make up the mosaic of vegetation. There are many ways to name these communities, but the basic properties are relatively easy upon which to agree. By relating the various plant community names to a few landscape units that we can recognize on satellite imagery and then describing the communities in terms of a few basic properties such as biomass, productivity, composition and structure, we can easily produce maps of vegetation properties, in which most users are interested.

Table 1. Northern Alaska Tundra: Integrated Terrain Unit Map Legends.

**Layer 1. AVHRR CIR composite (1:4,000,000 scale) (Fleming, this volume).**

**Layer 2. Topography/ hydrology (Fleming, this volume).**

**Layer 3. (a) Boundary of study area.** Treeline is derived from the Major Ecosystems of Alaska (Joint Federal-State Land Use Planning Commission for Alaska 1973). (b) Locations of intensive vegetation and soil studies. These sites generally have detailed vegetation descriptions with complete species lists and/or good vegetation maps derived from photointerpretation.

| *Map code* | *Location* | *References* |
|---|---|---|
| 1 | Barrow | Webber 1978, 1980; Gersper 1978; Walker et al. 1995 |
| 2 | Fish Creek | Lawson et al. 1978 |
| 3 | Kuparuk Oil Field | Everett and Walker 1982 unpub. |
| 4 | Prudhoe Bay Oil Field | Everett and Parkinson 1977; Walker 1985; Walker and Acevedo 1987; Walker and Everett 1991 |
| 5 | Barter Island | Walker et al. 1995 |
| 6 | Meade River | Komarkova and Webber 1980; Everett 1980 |
| 7 | West Oumalik | Ebersole 1985 |
| 8 | Umiat | Churchill 1955; Bliss and Cantlon 1957 |
| 9 | Sagwon Upland | Walker 1995, unpub. |
| 10 | Happy Valley | Walker 1994, unpub. |
| 11 | Arctic National Wildlife Refuge | Walker et al. 1992, Jorgenson et al. 1994; Hettinger and Janz 1974 |
| 12 | Cape Thompson | Everett 1966; Johnson et al. 1966 |
| 13 | Arrigetch Mountains | Cooper 1986 |
| 14 | Toolik Lake | Walker et al. 1994 |
| 15 | Imnavait Creek | Walker et al. 1987; Walker and Walker 1996 |
| 16 | Kobuk River Valley | Racine 1976; Melchoir 1976 |
| 17 | Lake Peters | Battan 1977 |
| 18 | Noatak River | Young 19873 |
| 19 | Killik River | Murray 1974 |

**Layer 4. Floristic subprovinces and phytogeographic subzones.** Based on Yurtsev (1994).

| *Map code* | *Floristic subprovince and phytogeographic subzone* |
|---|---|
| 11 | Northern Alaska subprovince, arctic tundra (=southern high arctic) subzone |
| 12 | Northern Alaska subprovince, northern hypoarctic (=northern low arctic) subzone |
| 13 | Northern Alaska subprovince, southern hypoarctic (=southern low arctic) subzone |
| 21 | Beringian Alaska subprovince, northern hypoarctic (=northern low arctic) subzone |
| 22 | Beringian Alaska subprovince, southern hypoarctic (=southern low arctic) subzone |

**Layer 5. Landscape units.** Based on photo interpretation of AVHRR CIR composite image 1:4,000,000 (Fleming, this volume) with reference to standard false-color controlled Landsat mosaic of mainland Alaska, Scale 1:1,000,000 (USGS, Branch of Alaska Geology 1978).

| *Map code* | *Landscape Unit* |
|---|---|
| 1 | Lakes |
| 2 | Oceans |
| 3 | Plains |
| 4 | Plateaus |
| 5 | Mountain valleys |
| 6 | Hills and low mountains without altitudinal belts |
| 7 | Mountains with altitudinal belts |
| 8 | Floodplains, deltas, and outwash plains (active and recently active floodplains with fluvial landforms) |
| 9 | Glaciers and ice caps |

**Layer 6. Percentage land cover by lakes.** Based on Sellman *et al.* 1975. Percentages reflect only lakes and do not include marshes and drained lake basins.

| *Map code* | *Percent cover of lakes.* |
|---|---|
| 1 | <2% |
| 2 | 2-10% |
| 3 | 10-25% |
| 4 | 25-50% |
| 5 | 50-100% |

**Layer 7. Generalized bedrock geology.** Based on Beikman, H.M. (1980). Geologic map of Alaska. Scale 1:2,500,000. State of Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys. Units are generalized into groups that weather into acidic or nonacidic soils.

| *Map Code* | *Geologic units (Beikman 1980)* | *Bedrock category* |
|---|---|---|
| 1 | uT, Uk, KJ, J, J Tr, Tr P, JP, Mz Pz, P, JM, MD, C, I Tc, I Kc, | Primarily acidic sedimentary rocks, including siltstone, sandstone, conglomerate and shale. |
| 2 | Kif, Mz Pzif | Primarily acidic igneous and metamorphic rocks, mostly felsic instrusives, granite to granodiorite, syenite to diorite. |
| 3 | lPM, DS, lPz, lPzpC, | Primarily nonacidic sedimentary rocks, including limestone, dolomite, marble, conglomerate, and shales. |
| 4 | J Ppvm, Cvm, J Pu, | Primarily nonacidic igneous and metamorphic rocks, volcanics and ultramafic rocks, including rhyolite to dacite, trachyte to andesite, basalt, olivine, gabbro, and serpentine. |

**Layer 8. Soil associations.** Based on Rieger *et al.* (1979) and photointerpretation of AVHRR false CIR composite (Fleming, this volume) and modified with information from numerous sources including Gryc (1985), Hamilton and Porter (1975), Hamilton (1986), US Dept. of Interior (1982).

| *Map code* | *Soil code* | *Soil Association (See Rieger et al. 1979 for full description)* |
|---|---|---|
| 1 | IQ2 | Histic Pergelic Cryaquepts, loamy, nearly level to rolling association |
| 1a | IQ3 | Histic Pergelic Cryaquepts–Typic Cryofluvents, gravelly, nearly level association |
| 2 | IQ6 | Histic Pergelic Cryaquepts, loamy nearly level to rolling–Pergelic Cryofibrist, nearly level association |
| 3 | IQ7 | Histic Pergelic Cryaquepts, loamy nearly level to rolling–Pergelic Cryaquepts, gravelly, nearly level to rolling association |
| 4 | IQ8 | Histic Pergelic Cryaquepts, loamy, nearly level to rolling–Pergelic Cryaquepts, very gravelly, hilly to steep association |
| 4a | IQ11 | Histic Pergelic Cryaquepts, loamy, nearly level to rolling–Pergelic Cryumbrepts, very gravelly, hilly to steep association |
| 5 | IQ20 | Pergelic Cryaquepts–Pergelic Ruptic-Histic Cryaquepts, loamy nearly level to rolling association |
| 6 | IQ21 | Pergelic Cryaquepts–Pergelic Cryopsamments, nearly level to rolling association |
| 7 | IQ22 | Pergelic Cryaquepts, very gravelly, nearly level to rolling association |
| 8 | IQ24 | Pergelic Cryaquepts–Pergelic Cryorthents, very gravelly, hilly to steep association |
| 9 | IQ25 | Pergelic Cryaquepts–Pergelic Cryochrepts, very gravelly, hilly to steep association |
| 10 | IU2 | Pergelic Cryumbrepts–Histic Pergelic Cryaquepts, very gravelly, hilly to steep association |
| 11 | MA1 | Pergelic Cryaquolls–Histic Pergelic Cryaquepts, loamy, nearly flat to rolling association |
| 12 | MA2 | Pergelic Cryaquolls, very gravelly, nearly level to rolling association |
| 13 | MA3 | Pergelic Cryaquolls, very gravelly, nearly level to rolling–Pergelic Cryoborolls, very gravelly, hilly to steep association |
| 14 | MB2 | Pergelic Cryoborolls–Pergelic Cryaquolls, very gravelly, hilly to steep association |
| 15 | RM1 | Rough mountainous land |
| 16 | RM2 | Rough mountainous land–Lithic Cryorthents, very gravelly, hilly to steep association |
| 17 | none | Water |

**Layer 9. Maximum NDVI.** Hard-copy image at 1:4,000,000 scale derived from AVHRR composite of maximum NDVI values for each pixel. (Fleming, this volume)

**Layer 10. Vegetation complexes.** Refer to attached look-up table for dominant and characteristic vegetation communities in each complex and within each of Yurtsev's (1994) floristic provinces and phytogeographic zone in northern Alaska.

| *Map code* | *Vegetation complex* |
|---|---|
| 1 | Acidic high mountain complex with vertical zonation |
| 2 | Circumneutral high-mountain complex with vertical zonation |
| 3 | Circumneutral plateau complex |
| 4 | Mountain valley complex |
| 5 | Upland scrub complex |
| 6 | Acidic hill complex |
| 7 | Circumneutral hill complex |
| 8 | Glaciated hill complex (>15% dry elements and numerous lakes) |
| 9 | Lowland scrub complex |
| 10 | Riparian complex (including glacial outwash and rivers) |
| 11 | Acidic wetland complex (including poor fens) |
| 12 | Circumneutral wetland complex (including marshes) |

| | |
|---|---|
| 13 | Coastal wetland complex (with saline communities) |
| 14 | Bottomland evergreen forest complex |
| 15 | Upland mixed forest complex |
| 16 | Water complex |
| 17 | Glacier complex |

**Layer 11. Integrated terrain unit map.** This map contains all the polygon boundaries from all the overlays. This map is digitized and each polygon assigned a unique polygon ID number.

**Layer 12. Point map for off-scale units.**

| *Map Code* | *Characteristic* |
|---|---|
| 1 | Polar oases |
| 2 | Poplar groves |
| 3 | Major springs |

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