Reprinted from
THIRD INTERNATIONAL CONFERENCE ON PERMAFROST
Edmonton, Alberta, Canada, 10-13 July 1978
National Research Council of Canada

A GEOECOLOGICAL MAPPING SCHEME FOR ALASKAN COASTAL TUNDRA

K.R. Everett, P.J. Webber, D.A. Walker, R.J. Parkinson and J. Brown

COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
U.S. ARMY CORPS OF ENGINEERS
HANOVER, NEW HAMPSHIRE

A GEOECOLOGICAL MAPPING SCHEME FOR ALASKAN COASTAL TUNDRA

K.R. Everett, Inst. of Polar Studies, Ohio State Univ., Columbus, OH; P.J. Webber and D.A. Walker, INSTAAR, Univ. Colorado, Boulder, CO; R.J. Parkinson, Dept. of Agron., Ohio State Univ.; J. Brown, U.S.A. CRREL, Hanover, N.H., U.S.A.

A unified Geoecological mapping system has been developed for northern Alaska which recognizes in a given area a suite of landforms whose geomorphic elements control the composition and distribution of vegetation and soil. Within each landform boundary a fractional code is displayed in which the numerator consists of the geomorphic feature and its characteristic vegetation stand presented as a series of alpha-numeric units. The denominator is comprised of three elements, the soil(s), the landform type and its mean slope. Each map contains an annotated list of code symbols and is accompanied by a text in which the characteristics of the code components are discussed. The advantages of such a mapping technique include: (1) integrating on a single base a large body of diverse data into a relatively few easily detected environment units; (2) the derivation of any number of special purpose maps by selecting components of the code and/or related analytical data; (3) permitting an expansion of the code to include other kinds of geotechnical or environmental data.

SYSTÈME DE CARTOGRAPHIE GÉOÉCOLOGIQUE APPLICABLE À LA TOUNDRA LITTORALE DE L'ALASKA

On a mis au point une technique uniformisée de cartographie géoécologique pour le nord de l'Alaska, permettant d'identifier dans une région donnée une série de formes topographiques, dont les éléments géomorphiques contrôlent la composition et la répartition de la végétation et du sol. Dans les limites de chaque forme topographique, figure un code fractionnaire où le numérateur correspond à l'élément morphologique, et la végétation caractéristique est présentée sous forme de séries d'unités alphanumériques. Le dénominateur comprend trois éléments, le ou les sols, le type de forme topographique, et la pente moyenne. Chaque carte contient une liste explicative de symboles des codes, et est accompagnée d'un texte, dans lequel on décrit en détail les éléments du code. Les avantages de ce système cartographique sont: (1) l'intégration sur une base unique d'un vaste ensemble de données diverses, dans un nombre relativement faible d'unités environnementales facilement identifiables; (2) l'obtention de n'importe quel nombre de cartes spécifiques, par sélection des éléments du code et des données analytiques connexes; (3) les possibilités d'expansion du code, pour inclure d'autres types de données géotechniques ou environnementales.

СХЕМА ГЕО-ЭКОЛОГИЧЕСКОГО КАРТИРОВАНИЯ ПРИБРЕЖНЫХ РАЙОНОВ ТУНДРЫ

Разработана единая система гео-экологического картирования для условий северной Аляски. Эта система позволяет определять в заданном районе формы рельефа, геоморфные элементы которого обуславливают состав и распределение растительности и грунтов. В пределах каждой границы рельефа производится визуальная индикация дробного кода, в котором числитель отражает геоморфные особенности, а характерная растительность представлена в виде ряда альфа-числовых единиц. Знаменатель включает в себя три элемента: грунт/ы/, тип рельефа и его средний уклон. Каждая карта содержит перечень символов кода с объяснениями и сопровождается текстом, в котором описаны характеристики компонентов кода. Преимущества такого метода картирования включают в себя /1/ возможность интегрирования на единой основе большого количества разнообразной информации в относительно небольшое число легко определяемых элементов среды; /2/ возможность составления любого числа специальных карт путем отбора компонентов кода или соответствующих аналитических данных, или того и другого; /3/ возможность включения в код других видов геотехнических данных или элементов окружающей среды.

A GEOECOLOGICAL MAPPING SCHEME FOR ALASKAN COASTAL TUNDRA

K.R. Everett[1], P.J. Webber[2], D.A. Walker[2], R.J. Parkinson[1] and J. Brown[3]

[1]Institute of Polar Studies and Department of Agronomy, The Ohio State University, Columbus, Ohio, USA.
[2]Institute of Arctic and Alpine Research and Department of Environmental, Population and Organismic Biology, University of Colorado, Boulder, Colorado, USA.
[3]U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire, USA.

INTRODUCTION

The basic techniques and concepts employed in the soils and vegetation description and mapping reported in this paper are standard. They have been combined, however, with specially defined geomorphic units to produce what we believe to be a unique mapping system. The maps produced using this scheme provide an integrated view of soils and vegetation with respect to landform units underlain by continuous permafrost. They also provide the opportunity to view, singly or in combination, vegetation, soils or landform units on the same map base. Crampton and Rutter (1973) have described a system of geoecological terrain mapping in the discontinuous zone of permafrost.

APPROACH

In 1973 an area of approximately 7 km^2 was mapped at the U.S. International Biological Program (IBP) Tundra Biome site at Prudhoe Bay (Fig. 1, area A) to provide representative baseline soils and vegetation information for the area (Everett 1975, Everett and Parkinson 1977, Webber and Walker 1975).

The soils and vegetation keys recognized ten landform units, six soils and thirteen vegetation assemblages. Additionally, percent slope was included in the soils key. In 1974 soil and vegetation mapping at a scale of 1:6000 was extended to cover the majority of the Prudhoe Bay oilfield, roughly the area covered by the road network existing at that time (Fig. 1).

The soil and vegetation mapping was accomplished independently. When compared, the completed vegetation and soil maps showed a very close correspondence in map unit boundaries. This was not surprising since landforms, and their associated drainage gradients, had been recognized as the element controlling the characteristics of both soils and vegetation.

For each map a legend or key was developed which related soils or vegetation

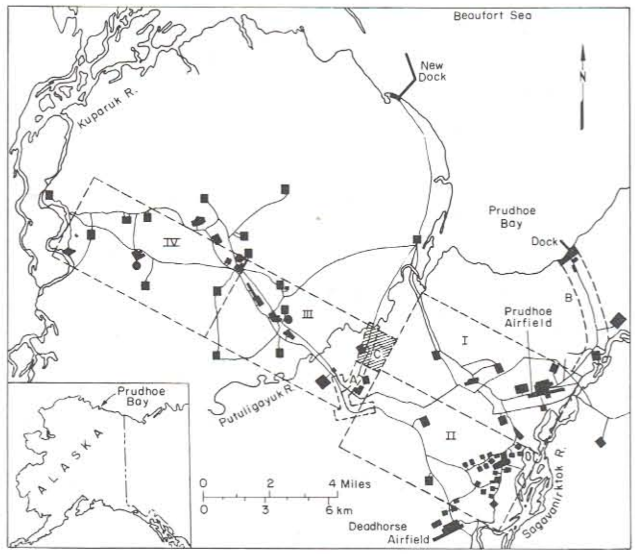
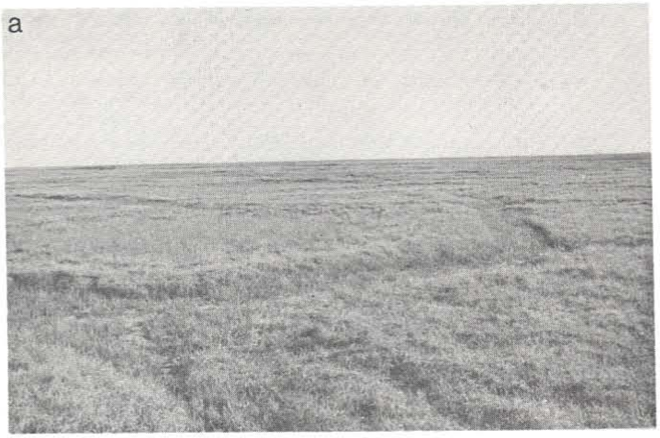


FIG 1. Index map showing the principal cultural features in the Prudhoe Bay area as of 1976. Numerals I-IV refer to master maps and soils and vegetation maps completed in 1975. A: Area mapped in 1973 in support of U.S. Tundra Biome. B: Area mapped in 1975 (not discussed in this paper). C: Area covered by master map excerpt (Fig. 3) and by the derived maps (Fig. 4).

to specific landform units and to the relief elements it contained. For example, areas composed of low-center polygons whose rim and central basin (center) height difference was greater than 0.5 m could be separated from similar areas where relief contrast was less than 0.5 m, or from other areas in which the polygonal cells were incomplete and rims low and discontinuous (Fig. 2). In the sequence just outlined there is an increase in moisture from one unit to the next—in fact, a moisture gradient is recognizable in a saturated, nearly flat environment. The relief elements within each of the landform units, e.g. the polygon rims, troughs and centers, each display unique



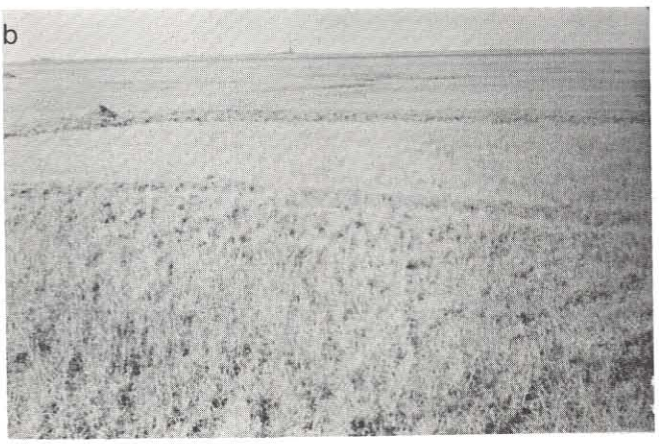


FIG. 2. Low-center polygon terrain at Prudhoe Bay. a) Central basin-rim height contrast > 0.5 m; b) central basin-rim contrast ≤0.5 m.

and recurring vegetation assemblages and soil types. In the flat, central region of the polygon the water table ranges from slightly below the surface to the surface itself. The vegetation consists of moss, Drepanocladus lycopodioides, and the sedges Carex aquatilis, C. saxatilis, and Eriophorum angustifolium. Wetter polygon centers will be dominated by the calciphilous moss Scorpidium scorpioides. The soils are composed of an upper layer or horizon between 10 and 20 cm in thickness, consisting of little-decomposed grayish-brown to yellowish-brown sedge and moss remains in a mass of living and dead sedge roots. This horizon is underlain by several to several tens of centimeters of carbonate-rich silts which are perennially frozen except for the upper few centimeters. Below this horizon may be a third one of black, highly decomposed organic materials.

The central area of the polygon is bounded by a continuous ridge, the rim, 10 to 50 cm high and up to a meter wide. Vegetation on the rim is composed of sedges (Eriophorum triste, Carex bigelowii, C. aquatilis, Dryas integrifolia), prostrate willows (Salix arctica, S. lanata, S. reticulata), mosses (dominated by Tomenthypnum nitens and Ditrichum flexicaule), and lichens (Thamnolia spp., Dactylina arctica and Cetraria spp.). The plant community as a whole is one typical of well- and moderately well-drained sites on a mesoscale. The soils are at or near water saturation to within 5 cm of the surface and consist of very dark gray-brown to black, highly decomposed organic materials which overlie similarly colored organic-rich calcareous silts. Below the bottom of the active layer black fibrous to highly decomposed organic materials may again occur. Because the rims rise rather abruptly from the centers there is usually little space for transitional elements in either vegetation or soils.

The rim descends abruptly into the trough which borders it. The trough bottom is usually less than 1 m wide and is at or below the level of the polygon center. It is moist or wet and supports nearly pure stands of Carex aquatilis; if water-filled, an aquatic moss, Scorpidium scorpioides or Calliergon sp., may dominate. The soil is shallow, consisting of 10 to 20 cm of little-decomposed organic material (sedge leaves and sheath fragments) in a net of roots. Below this horizon is gray calcareous silt or a combination of frozen silt and ice and the underlying ice wedge.

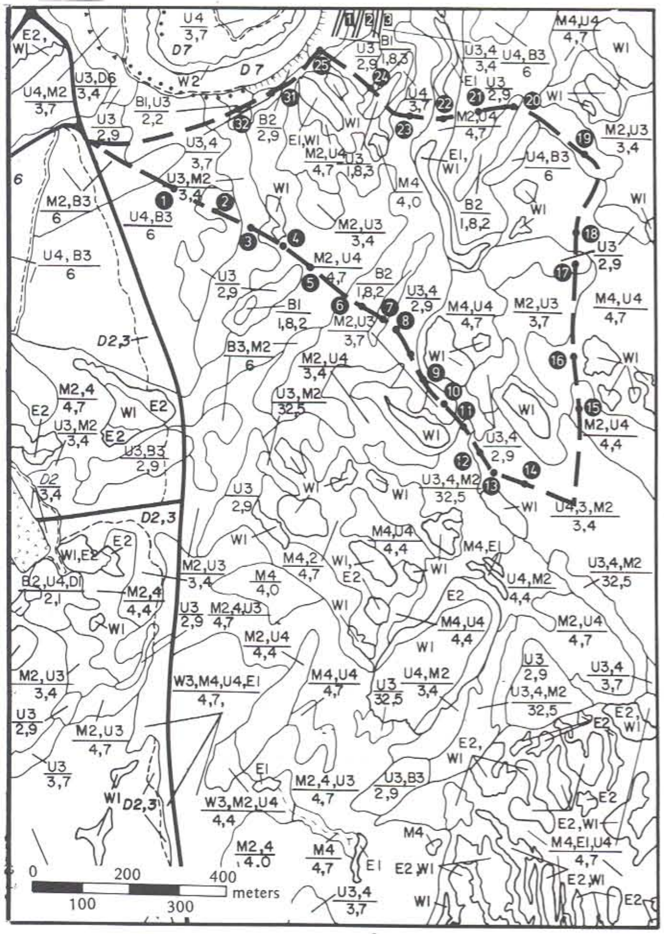
The sequence of landform elements which compose the form as just described may repeat over and over on the tundra and with them the associated vegetation and soils. The foregoing is, of course, a highly simplified picture of a single landform unit.

THE MASTER MAP

Upon completion of mapping in 1975 it was decided that the maps and the keys were enough alike that an attempt should be made to display both the soils and vegetation on a single base map and within the same landform boundaries. The landform boundaries employed in the soils map were used for the most part; however, occasionally, where significant differences between the soils and vegetation landform boundaries occurred, additional boundaries were added. The final choice of landform units was based on their areal extent and the ease with which they could be recognized on aerial photographs at a scale of 1:6000 (Everett et al. in press).

The landform boundaries were superimposed on an existing industry-prepared map which depicted the area's cultural

FIG. 3. Excerpt from master map with partial soils and vegetation legends (see Fig. 1 for location). Dashed line shows location of stations along 1976 Rolligon tests. Multiple pass lanes 1-3 (top) include sta. 26-30.



Partial vegetation legend (numerator).

Code	Characteristic vegetation species	Characteristic microsite
B – Vegetation on dry, barren or sparsely vegetated areas		
B1	*Dryas integrifolia, Oxytropis nigrescens, Carex rupestris, Distichium capillaceum, Lecanora epibryon*	Pingos, elevated ridges, edges of river bluffs.
B2	*Dryas integrifolia, Saxifraga oppositifolia, Salix reticulata, Ditrichum flexicaule, Lecanora epibryon*	Pingos, high-center polygons, rims of drained lakes.
B3	*Dryas integrifolia, Eriophorum angustifolium, Saxifraga oppositifolia, Bryum wrightii, Thamnolia subuliformis*	Frost boils.
U – Vegetation on mesic upland or well-drained areas		
U2	*Dryas integrifolia, Eriophorum vaginatum, Carex bigelowii, Tomenthypnum nitens, Ditrichum flexicaule, Thamnolia subuliformis*	Well-drained upland sites.
U3	*Dryas integrifolia, Eriophorum angustifolium, Carex bigelowii, Carex aquatilis, Tomenthypnum nitens, Thamnolia subuliformis*	Well-drained upland sites, polygon rims, and aligned hummocks.
U4	*Carex aquatilis, Eriophorum angustifolium, Dryas integrifolia, Salix reticulata, Salix arctica, Tomenthypnum nitens*	Moister upland sites, polygon rims and aligned hummocks.
U6	*Dryas integrifolia, Cassiope tetragona, Carex scirpoidea, Salix rotundifolia, Ditrichum flexicaule*	Well-drained snow banks.
U7	*Salix rotundifolia, Equisetum arvense, Salix reticulata, Eriophorum angustifolium, Carex aquatilis, Ditrichum flexicaule*	Late thawing snow banks.
U10	*Dryas integrifolia, Poa* spp., *Festuca* spp., *Astragalus umbellatus, Saxifraga* spp., *Ranunculus pedatifidus*	Pingo tops.
M – Vegetation on moist or wet, poorly drained areas		
M2	*Carex aquatilis, Eriophorum angustifolium, Pedicularis sudetica, Drepanocladus brevifolius, Cinclidium latifolium*	Low moist sites, low polygon centers and troughs, lake margins.
M4	*Carex aquatilis, Carex saxatilis, Scorpidium scorpioides*	Low, wet sites, low polygon centers, lake margins.
M5	*Carex aquatilis, Salix rotundifolia, Dupontia fisheri, Campylium stellatum*	Moist creek banks.
E – Vegetation in permanently standing water		
E1	*Carex aquatilis*	Shallow water to about 30 cm.
E2	*Arctophila fulva*	Deep water to about 100 cm.
W – Water		
W1	Lakes and ponds.	
W2	Streams and rivers.	
W3	Flooded areas caused by roads or pads.	
D – Disturbed areas		
D1	Bare earth with pioneering species (e.g. *Braya pilosa, Eriophorum angustifolium, Bryum* spp., *Funaria hygrometrica, Leptobryum pyriforme, Marchantia polymorpha*).	
D2	Trash or debris, or foreign gravel on surface of tundra.	
D3	Dust-covered areas adjacent to roads.	
D4	Vehicle tracks, deeply rutted.	
D5	Vehicle tracks, not deeply rutted.	
D6	Winter road.	
D7	Excavated areas, primarily in river gravels.	

Partial soils and landform legend (denominator).

Code (1st no.)	Taxonomic name	Identifying field characteristics
1	Pergelic Cryoboroll	A cold (Cryo) more or less freely drained soil, underlain by permafrost (Pergelic) with a dark, humus-rich, granular textured surface horizon > 18 cm thick.
2	Pergelic Cryaquoll	A cold, dark-colored, wet soil, prominently mottled in the lower part of the humus-rich, weakly granular surface horizon.
3	1) Histic Pergelic Cryaquept 2) Pergelic Cryohemist Complex	1) A cold, wet, gray mineral soil, commonly mottled, having a surface horizon > 25 cm thick, composed of predominantly organic (peaty) material. 2) A cold, wet, dark-colored soil composed of moderately decomposed organic materials to depths > 40 cm.
4	1) Histic Pergelic Cryaquept 2) Pergelic Cryofibrist Complex	1) As above. 2) A cold, wet, reddish to yellowish colored soil composed of little decomposed fibrous organic materials to depths > 40 cm.
5	Pergelic Cryorthent	A cold, somewhat freely drained gravelly soil lacking significant horizon development and generally free of organic matter.
6	Pergelic-Ruptic-Aqueptic Cryaquoll	The cold soil of frost scar areas in which a Cryaquoll soil (no. 2) is intimately associated with and interrupted by a cold, wet, gray colored and mottled mineral soil lacking any significant organic surface horizon – a Pergelic Cryaquept.

Code (2nd no.)	Landform
1	High-center polygon, center-trough contrast > 0.5 m.
2	High-center polygon, center-trough contrast ⩽ 0.5 m.
3	Low-center polygon, rim-center contrast > 0.5 m.
4	Low-center polygon, rim-center contrast ⩽ 0.5 m.
5	Mixed, including both high-center and low-center in an intricate pattern.
6	Frost scar tundra (non-sorted).
7	Strangmoor and/or large diameter, commonly discontinuous low-center polygon pattern; little or no microrelief contrast.
8	Earth hummocks associated with dissected slopes.
9	Reticulate – slightly convex polygons with hummocky microrelief, hummock-interhummock relief contrast ⩽ 15 cm.
0	Non-patterned ground or with patterned ground occupying < 20%.
P	Pingo.
A	Flood plain.

Code (3rd no.)		2	3	4	5
Slope range (%)	0–2	2–6	6–12	12–20	> 20

features as of August 1974. The soils and vegetation information was added to the landform units as a fraction symbol. The numerator displays, in alphanumeric combinations, the principal vegetation stand types. The landform unit designation, together with the principal soils and the mean slope class, are shown in numeric combinations in the denominator. The completed sheets (locations of the four map sheets are shown in Fig. 1, I-IV) are referred to as the master maps. An excerpt from one of these maps is shown in Figure 3. Each symbol is annotated in an accompanying legend. The keys for vegetation and soils are purposely simplified so that they may be used by individuals with science or engineering backgrounds but without special training in soils, botany, ecology or geomorphology. Detailed information on vegetation characteristics including stand composition and morphological, physical and chemical properties of the soils is treated in a text which accompanies the maps.

The master map then contains, on a single base, all the relevant geobotanical information for the area it covers. Such maps probably reach their maximum potential in areas underlain by permafrost which have produced landforms on which there is a maximum interrelation between soils and vegetation. Maps such as the master map also have the potential to be greatly generalized, or they may be made to reflect very special (user-oriented) data combinations. Such special purpose maps are referred to as derived maps.

THE DERIVED MAP

The derived map employs the master map base. Depending upon the user need, a single soil, vegetation or landform characteristic, or any combination of them, may be selected and the map produced will reflect only these data. The complexity of the derived map varies according to user requirements. For example, a user concerned with the maximum seasonal thickness of the active layer would require a map on which several active layer thickness categories could be identified (Fig. 4A). A map reflecting peat thickness may be needed in contingency planning for oil spills and clean-up procedures (Fig. 4B). Interpretive maps such as one depicting thickness of snow cover (Fig. 4C) require extrapolations based upon surface roughness that can be approximated from the landform units. Areas of special ecological interest may also be defined. These are essentially habitat maps on which combinations of the vegetation and landform data are used or they may be more complex, depicting areas of aesthetic value.

Perhaps the most complex of all the derived maps developed to date involve

Table 1. Rating scheme for evaluation of Rolligon impact on vegetation. Each factor is rated according to immediate impact (numerator) and predicted long-term impact (denominator).

Compression to tundra surface – refers to the bending and compressing of live and standing dead vegetation to the tundra surface so that it becomes flattened and oriented to the direction of travel.
- 0 – no observable compression of vegetation to tundra surface.
- 1 – slight compression of vegetation (1-10% of plants affected).
- 2 – moderate compression of vegetation (10-50% of plants affected).
- 3 – severe compression of vegetation (> 50% of plants affected).

Compression below water surface – refers to the compression of sedges and moss hummocks below a water surface.
- 0 – no water or no observable compression of vegetation below water surface.
- 1 – slight compression of vegetation below water surface (1-10% of plants affected).
- 2 – moderate compression of vegetation below water surface (10-50% of plants affected).
- 3 – severe compression of vegetation below water surface (> 50% of plants affected).

Displacement – refers to several categories of disturbance.
- a) tussocks of moss or *Eriophorum vaginatum* moved or overturned.
- b) displacement of wet mosses such as *Scorpidium scorpioides* and *Drepanocladus brevifolius* by splashing action.
- c) exposure of bare soil by removal of vegetation mat.
- 0 – no displacement of vegetation.
- 1 – some displacement of vegetation (1-10% of plants affected).
- 2 – moderate displacement of vegetation (10-50% of plants affected).
- 3 – severe displacement of vegetation (> 50% of plants affected).

Breakage – refers to breakage of plant stems or flowering stalks.
- 0 – no breakage observed.
- 1 – some breakage observed (1-10% of plants affected).
- 2 – moderate breakage observed (10-50% of plants affected).
- 3 – severe breakage observed (> 50% of plants affected).

Deposition – refers to accumulation of mud and moss to sides of track.
- 0 – no mud or moss accumulation at sides of track.
- 1 – few shallow patches of mud or moss.
- 2 – many shallow patches of mud or moss.
- 3 – continuous thick deposit of mud or moss.

Overall immediate impact
Rated subjectively on the basis of the 5 immediate impact scores above: 0 – no impact; 1 – slight impact; 2 – moderate impact; 3 – severe impact.

Impact following one season
Rated subjectively on the basis of the five long-term impact scores. The scale is the same as for *Overall immediate impact.*

terrain sensitivity (Fig. 4D). Such maps bring together, again within common landform units, a number of combinations of soils, vegetation and landform data which must be manipulated in response to certain given factors such as season and type and frequency of impact.

In order to gather baseline data on the reaction of the soils, vegetation and landforms to a specific impact, a field test was conducted at Prudhoe Bay in June 1976 (Walker et al. in press). A Bechtel smooth-tired Rolligon weighing approximately 11,500 kg was driven at a relatively uniform intermediate speed in a single pass across as many landform-soil-vegetation units as possible within the allotted test space (Fig. 3). The test was conducted in late spring when water levels were highest—a worst possible case because in addition to possible compaction of buoyed-up organic material and flattening of the vegetation, the passage of the Rolligon tire sucks up mosses and lichens, pushing these plants ahead and to the sides of the vehicle track where they cover and kill adjacent vegetation. Prior

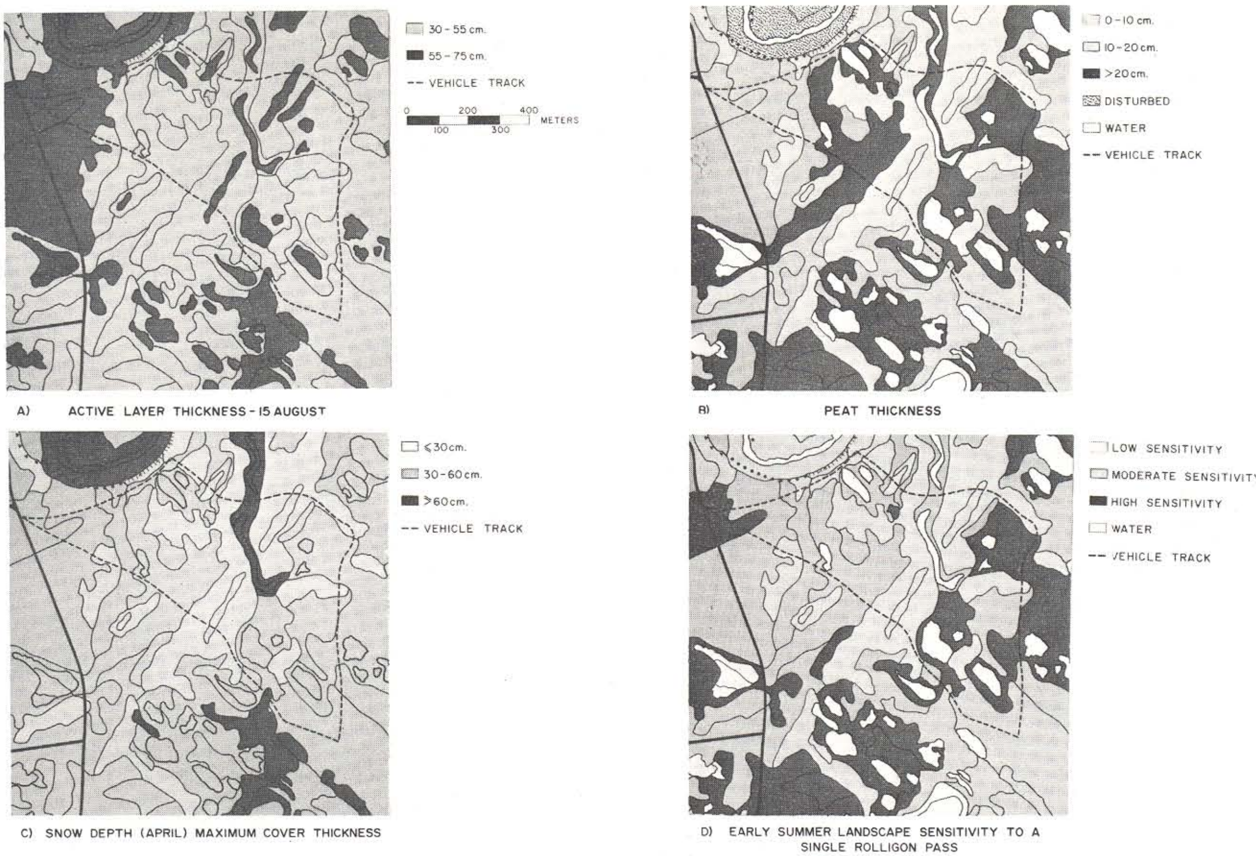


FIG. 4. Derived special-purpose maps. Maps A and B reflect quantitative data collected during the course of the survey and extrapolated to similar landform-soils units. Map C was developed using what quantitative data were available in the region based upon surface roughness (the landform unit characteristics). Map D was developed from quantified response of the vegetation and soils to a single Rolligon pass represented by the dashed line. These data were then extrapolated to similar soils-vegetation-landform units.

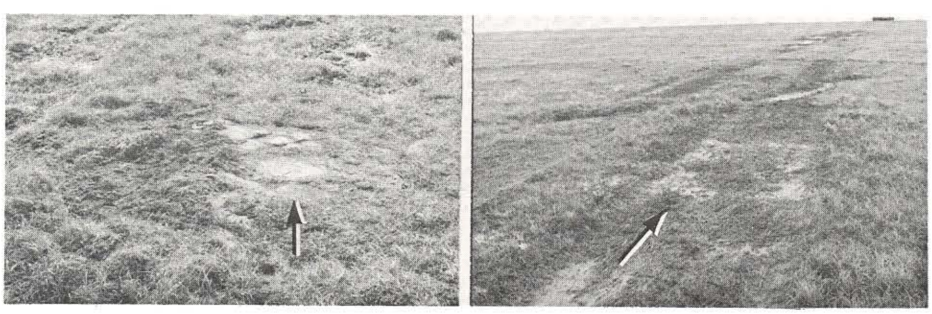


FIG. 5. Impact at two stations along the Rolligon track. Left: Station 1, a frost boil. Right: Station 3, moist, low-center polygons. Arrows indicate direction of travel.

Table 2. Vegetation impact scores for 4 of 27 stations along the single pass Rolligon track (Fig. 3).
Each station is rated for one to three vegetation numbers appearing in the numerator of the landform code. Five impact categories are rated for immediate impact (numerator) and predicted impact in 1 yr (denominator). The numerical ratings are based upon quantitative definition (not shown). The greater the number the more severe the impact. Each vegetaion unit is also given an overall immediate impact score, based on the scores in the five impact categories. An overall score for predicted (1-yr) impact is also given. Figure 5 shows areas characteristic of soils-vegetation-landform units crossed during the Rolligon test (from Walker et al., in press).

				Impact categories							
Sta.	*Landscape*	*Characterization*	*Subunit*	*Compression to tundra surface*	*Compression below water surface*	*Displace-ment*	*Break-age*	*Deposition of moss or mud*	*Immedi-ate impact*	*Predicted impact in 1 yr*	*Depth of thaw(cm) 6/29/76*
1	U4, B3 / 6	Frost boil tundra	B3, Frost boil	3/2	0/0	2/1	0/0	0/0	2	2	38.1
			U4, Upland tundra	1/1	1/1	0/0	0/0	0/0	1	1	25.8
2	U3 / 2, 9	Dry tundra	U3, Upland	1/1	0/0	1/1	0/0	0/0	1	1	15.1
3	U3, M2 / 3, 4	Dry and moist low center polygons	M2, Low center	1/1	0/0	1/1	0/0	0/0	1	1	15.5
			U3, Rim	2/1	0/0	2/2	1/1	0/0	2	1	17.6
			M2, Trough	2/1	2/2	1/1	0/0	2/1	2	1	16.3
4	M2, U4 / 4, 7	Moist area with intermittent polygons	M2, Low center	2/1	1/1	2/2	0/0	2/2	2	1	15.6
			U4, Rim	1/1	1/0	2/2	1/1	1/0	2	2	12.6
			M4, Trough	1/1	3/1	2/1	0/0	2/1	2	2	12.0

to the test an impact rating scheme was developed for both vegetation and soils. The evaluation was largely observational but could easily be employed throughout the area covered by the master map (and beyond) and could accommodate a wide array of vehicle types. The rating scheme used for vegetation is shown in Table 1. This scheme embodies a number of the principles used by Radforth (1973 a,b) in evaluating impact on muskeg areas. Table 2 is a partial presentation of the test scores with reference to the landform code. A similar, although not so detailed, rating scheme was used for soils. It reflected principally peat compression. The derived sensitivity map (Fig. 4D) was constructed using the impact and initial recovery data developed in the test. Admittedly the more complex derived maps contain a high order of subjectivity. This subjectivity, however, does not diminish the value of such maps and can be reduced in proportion as funds are made available for detailed studies.

CONCLUSIONS

In this paper we have attempted to describe a rationale for integrated mapping of soils and vegetation for arctic coastal plain tundra and to illustrate a few of the possibilities for using such maps in which landform units are the unifying elements. Such maps can provide a starting point in decisions affecting land-use allocations on the arctic coastal plain. It is felt that the keys are sufficiently general that such maps, especially derived maps, can be constructed and interpreted by individuals without specialized botanical or pedological knowledge.

ACKNOWLEDGMENTS

The mapping was initiated under the U.S. Tundra Biome Program and partially supported by NSF Grants at The Ohio State University (Grant 82371) and the University of Colorado (Grant GV-29350). In addition the Prudhoe Bay Environmental Sub-Committee supported both the mapping and logistics through unrestricted grants to the University of Alaska. The U.S. Army Cold Regions Research and Engineering Laboratory also supported both the field and report phases of the mapping project. British Petroleum and Atlantic-Richfield provided considerable logistic assistance and other cooperation, made available the topographic base maps, and gave permission to purchase some of the aerial photography.

REFERENCES

CRAMPTON, C.B. and N.W. Rutter. 1973. A geoecological terrain analysis of discontinuously frozen ground in the upper Mackenzie River Valley, Canada (1). Permafrost: The North American Contribution to the Second International Conference, Yakutsk. National Academy of Sciences, Washington, D.C., pp. 101-105.

EVERETT, K.R. 1975. Soil and landform associations at Prudhoe Bay, Alaska: A soils map of the Tundra Biome area. In Ecological Investigations of the Tundra Biome in the Prudhoe Bay Region, Alaska (J. Brown, Ed.). Biological Papers of the University of Alaska, Special Report Number 2, pp. 53-59.

EVERETT, K.R. and R.J. Parkinson. 1977. Soil and landform associations, Prudhoe Bay area, Alaska. Arctic and Alpine Research 9, pp. 1-19.

EVERETT, K.R., D.A. Walker, P.J. Webber, J. Brown and R.J. Parkinson. In press. Distribution, characterization and maps of the landforms, soils, and vegetation of the Prudhoe Bay, Alaska, region. CRREL Report.

RADFORTH, J.R. 1973a. Immediate effect of wheeled vehicle traffic on tundra during the summer. Department of Indian Affairs and Northern Development, Ottawa. ALUR Report 72-73-12, 32 p.

RADFORTH, J.R. 1973b. Long term effects of summer traffic by tracked vehicles on tundra. Department of Indian Affairs and Northern Development, Ottawa. ALUR Report 72-73-13, 60 p.

WALKER, D.A., P.J. Webber and K.R. Everett. In press. The effects of low-pressure wheeled vehicles on plant communities and soils at Prudhoe Bay, Alaska. CRREL Special Report.

WEBBER, P.J. and D.A. Walker. 1975. Vegetation and landscape analysis at Prudhoe Bay, Alaska: A vegetation map of the Tundra Biome study area. In Ecological Investigations of the Tundra Biome in the Prudhoe Bay Region, Alaska (J. Brown, Ed.). Biological Papers of the University of Alaska, Special Report Number 2, pp. 81-91.