AF

SOIL PROPERTIES OF ARCTIC FOX DENS, NORTHERN YUKON

C.A.S. Smith, Pedologist

Yukon Soil Survey Unit

Whitehorse, Yukon

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ABSTRCT

Landform and soils were described at 14 arctic fox den sites in the northern Yukon. Four sites were located on the Yukon Coastal Plain between Firth River and Clarence Lagoon and ten were located on Herschel Island. At each den site the soil profile was examined and compared with soil properties of the surrounding area.

On Herschel Island fox dens are located on eroded terrain where erosional remnant mounds are used for denning sites. On the Yukon Coastal Plain sand dunes and fluvial terraces provide the necessary relief for fox den mounds. Most dens are located on sandy parent materials. Den site location appears to be controlled by landforms rather than aspect, slope and proximity to water.

Den site active layer thickness es range from 40 to 110 cm and are always greater than in adjacent soils. Difference in active layer thickness between den site and adjacent soils is as much as 280%. Transport of nutrients by arctic foxes to the den through carcass remains and fecal material contributes toward the development of unique humus rich surface soil horizons and a lush vegetation community. Implications on soil taxonomy are discussed.

INTRODUCTION

The study of soil properties of arctic fox (Alopex lagopus) dens has usually been peripheral to the main focus of fox research projects. A number of workers have inventoried the physical characteristics of den sites and incorporated these data into general studies of arctic fox den ecology. References to landscape position and environmental conditions, specifically den burrow aspect, slope, mound relief, and proximity to water have all been discussed (MacPherson 1969, Ostbye et al. 1978, Underwood 1975). The texture of the soil (proportions of sand, silt, clay) at den sites has been reported by Eberhardt (1977), Chesemore (1969) and Sdnobnikov (1960) in varying degrees of detail. McKendrick et al. (1980) describe the impact of mammalian herbivores on the nutrient regimes of tundra soils.

This report presents data relevant to soil properites associated with arctic fox dens on the Yukon Coastal Plain (Bostock 1970) and Herschel Island, Yukon Territory. The fieldwork for this study was undertaken in conjunction with a detailed soil survey of Herschel Island. The fox den observations were made in cooperation with Cor Smits, Wildlife Branch, Yukon Department of Renewable Resources.

The physiographic settings of the two area inventoried are distinctly different. The coastal fringe of the Yukon Coastal Plain is underlain by thick deposits of fluvial, lacustrine and colluvial origin, generally more than 60 m thick. West of the Firth River where den

observations were made, the surface is almost flat, and the only relief is due to the incised stream valleys 3 - 15 m below the surface and thermokarst basins set 1.5 to 6 m below the general level of the plain (Rampton 1982). Herschel Is. lies 3 km off the coast in the Beaufort Sea. It is composed of marine sediments that have been deformed and ice-thrusted into what is now Herschel Is. (MacKay 1959, Bouchard 1974). While these deformed marine sediments are predominantly fine grained, there are numerous exposures of sand and gravel at the surface. Differential erosion has led to the development of coarse textured ridges existing within a landscapes of otherwise fine grained materials. Elevations on Herschel Is. vary from sea level to 180 m.

The objectives of the soil study were: i) to detail the geomorphic conditions of arctic fox den sites and relate them to soil map units where appropriate; ii) to describe the pedological (soil formation) features of the den sites and the surrounding area; iii) to describe the implications of these features to soil taxonomy ~~at these sites~~, and lastly, iv) to discuss our results in light of those obtained by previous workers who have examined the physical ecology of arctic fox dens.

METHODS

The methods used to identify the location of arctic fox den sites and their cataloguing procedure is given in Smits and Jessup (1985).

A total of 55 dens were identified, 36 on the mainland and 19 on Herschel Is. Landforms, soils and vegetation were described at 14 sites; 4 on the mainland and 10 on Herschel Is. Soil samples were selected from 10 sites for subsequent laboratory analyses.

Within the activities of soil survey on Herschel Is., use of 1:12,000 black and white aerial photographs allowed the allocation of each den to a particular soil delineation. Each delineation was typed according to an established map legend used during the field phase of the soil survey. For fox dens outside the soil survey area this aerial photographic typing was not undertaken.

At every site a soil pit was dug by hand on the fox den mound, usually slightly off to one side and away from any immediate burrow openings. Pits were excavated through the mound down to permafrost, usually within 1 m of the surface. Tunnels and buried bones were often ten encountered in the pit walls and these were included in the profile descriptions. Soil horizon (weathered layer) color, depth, structure and rooting abundance were all recorded in the conventional fashion for entry into the Canada Soil Information System (CanSIS) (ECSS 1983). Soils were sampled following the method outlined by Mckeague (1978) and classified according to the Canadian system of soil classification (CSSC 1978).

Following sampling, the soils were air dried, seived, and the less

than 2 mm fraction used for laboratory analyses. Methods used for the following determinations are given in Sheldrick (1984): pH in water, total carbon and nitrogen by LECO analyzer, $CaCL_2$ equivalent by gravimetric method, and particle size determination by pipette method.

RESULTS

The soil survey used eight map units to describe the landform, soil, vegetation, and erosion characteristics of Herschel Is. The majority of the inventoried fox dens are on the Island and are associated with specific map units. Table 1 presents this map legend which describes each unit in terms of a definitive combination of ecological properties.

Table 2 lists the landscape characteristics of the fox den sites grouped into the three general settings in which they were observed. The same format of data presentation is used in Table 3 and 4.

On Herschel Is. fox dens were found to occur on strongly eroded (Thrasher and Jaeger) and slightly eroded (Komakuk and Plover) map units. None were observed on the remaining units; Guillemot, Herschel, Orca and Avadlek. These cover wet polygonal ground, level tussock tundra, fluvial landforms, and marine spits and beaches respectively. On the Yukon Coastal Plain, sandy fluvial and eolian (wind-blown) materials provide suitable sites for den location. Terraces and dunes provide the necessary relief (Chesemore 1969) for den construction.

Table 1. Summary of Herschel Island Soil Survey Map Units.

MAP UNIT NAME	TERRAIN FEATURES: EROSION	TOPOGRAPHY, SURFACE EXPRESSION	PATTERNED GROUND	ACTIVE LAYER DEPTH	SOIL CLASSIFICATION	VEGETATION FEATURES: MAJOR	MINOR
Herschel (He)	None	level, upland plateaux, < 8% slope, imperfect drainage	occasional circles (non sorted) within tussocks	10-20 cm	Orthic Turbic Cryosol Regosolic Turbic Cryosol	sedge tussocks, arctic willow, moss; ericaceous shrubs common; lichen cover low	Tussocks comprised of Eriophorum dominate the veg cover; other sedges comprise only a small cover
Komakuk (Ko)	slight erosion	gently sloping 2-10%, few slumps, generally smooth	non sorted stripes and nets earth hummocks gelifluction	variable 10-30 cm occ > 30 cm on slump scars	Orthic - Regosolic Turbic Cryosol	Drier Phase: Dryas, vetch, arctic willow; other sedge common, (not Eriophorum) lichen cover considerable	Wetter Phase: Scattered to mod. cover of sedge tussocks; ericaceous shrubs common (Cassiope); low willow, arctic willow, Salix reticulata
Plover (Pl)	slight erosion	rounded ridge crests	extensive areas of non sorted circles and nets	30-50 cm	Orthic - Regosolic Turbic Cryosol	<40% non-vegetated ground; Dryas, vetch, arctic willow, graminoid; lichen cover considerable	
Jaeger (Ja)	moderate erosion	slopes 5-20%; old slumps some exposed soil	gelifluction, stripes, earth hummocks	30-50 cm > 50 cm on scars	Regosolic Turbic Cryosol, Regosolic Static Cryosol	Dryer Phase: Dryas vetch, arctic willow; forbs common, especially on hummocky terrain; low willow an lichen common	Wetter Phase: Arctic willow, moss, coltsfoot; Equisetum; lichen scarce low willow common; moss cover extensive; forbs and sedge cover may be high
Thrasher (Th)	severe erosion	slopes 15-45%, active mass movements, much exposed soil, steep hummocky ridges	earth hummocks gelifluction, thaw flow, slides	30-50 cm > 50 cm on scars	Regosolic Turbic Cryosol, Regosolic Static Cryosol	Mid to Late Succession: Rougher textured surfaces: Extensive and diverse forb cover; sparse lichen and graminoids	Smoother textured surfaces: Graminoids and willows; moss cover extensive
						Early Succession: Non-vegetated ground, bunch grasses, daisy, horsetail; conversely may be characterized by floating turf balls that are well-vegetated	
Guillemot (Gu)	none	depressional areas within upland surfaces	polygons, thermokarst ponds	10-40 cm	Organic Turbic Cryosol, Orthic Turbic Cryosol	Polygon Centres: sedge tussocks, arctic willow, moss; lichen cover low	Ice Wedges, Pond Perimeters: Sedge, willow; moss; aquatic plants and standing water common; lichen cover low.
Oica (Or)	deposition	Active fluvial fans and channel fill	occasional polygons	30-75 cm	Regosolic Turbic/ Static Cryosol	Wetter Phase: Graminoid, willow, brown moss, rumex	Drier Phase: Graminoid, Equisetum, dry moss arctic willow, Dryas, low willow, Salix reticulata, vetch, some lichen
Avadlek (Av)	Marine erosion/ deposition	spits, beaches	[illegible] polygons	>75 cm		Frequent Inundation: a) sedge, brownmoss, chickweed, standing water; b) bare sand, seaside sandwort	Less Frequent Inundation: Grass, sedge, daisy, low willow, chickweed, roseroot, arctic willow

Table 2. Summary of landscape and soil characteristics of inventoried fox den sites.

Den No.	Landscape Position	Soil Texture[1]	Drainage[2]	Depth to permafrost (cm)	Aspect	Soil Classification[3]
	Strongly eroded terrain, Herschel Is. (Trasher and Jaeger map units)					
37	erosional remnant at gully head	SL - LS	Well	95	NW	Regosolic Static Cryosol
50	erosion exposed gravel ridge	gLS	mod well	45	N	Regosolic Static Cryosol
41	eroded coastal bluff	SL	mod well	63	S	Orthic Static Cryosol
47	erosion exposed sandy ridge	SL	well	63	W	Regosolic Static Cryosol
38	steep coastal bluff	SL	well	78	NE	Regosolic Static Cryosol
44	erosional remnant near coast	FS - SIL	well	110	SW	Orthic Regosol
48	erosional remnant at gully head	SL	well	40	S	Regosolic static Cryosol
	Slightly eroded terrain, Herschel Is. (Komakuk and Plover map units)					
53	rounded upper slope at gully head	LS	well	50	S	Regosolic Static Cryosol
39	hummock on rolling terrain	S-LS	well	53	SW	Regosolic Static Cryosol
34	mound of exposed mixed sediments	peat/S	mod well	40	S	
	Yukon Coastal Plain (outside soil survey area)					
2	sand dune complex	S	rapidly	82	SW	Regosolic Static Cryosol
18	delta (Firth R.)	LS	rapidly	100+	SE	Orthic Regosol
24	delta (Firth R.)	SL/S	rapidly	80	NW	Orthic Static Cryosol
8	fluvial terrace	SiCL	imperfectly	40	SE	Orthic Turbic Cryosol

[1] USDA soil texture classes: SL - sandy loam, LS - loamy sand, g - gravelly, f - fine, SiL silt loam, s - sand, SiCL - silty clay loam.

[2] Drainage classes: refers to the degree to which water passes through the soil.

[3] Taxonomy according to CSSC (1978).

In most cases dens are located in areas of sandy soils. This is a common observation made by most researchers. There were two exceptions in this study. Den number 34 which is composed of mixed peat and sand with a shallow active layer (> 40 cm) and den 8 located in an area of fine textured slope wash (known as pediment or colluvium) also with a shallow active layer (Table 2).

Table 3 shows Herschel Is. fox dens to be located on sandy materials that differ dramatically from those of surrounding areas. On the mainland soil textures did not differ this way because dens were located on large texturally-uniform landforms. Active layers were always thicker on the fox dens, increases of up to 280% were observed on Herschel Is.

Table 3 lists the types of effects on soil classification that are seen when comparing den soil profile development with that of the surrounding area. In many cases fox den activities will cause a lowering of the permafrost table and the soils will no longer be classified as Cryosolic (type 1 effect, Table 3), or, if the permafrost table is not lowered significantly, the loss of Cryoturbation features may result in the soil no longer being classified as Turbic Cryosol but rather Static Cryosol (type 2 effect). In one case a subsurface weathered horizon (Bm horizon) was observed on the den site when none was apparent in the surrounding soil. This den soil was classified as an Orthic Static Cryosol rather than as Regosolic Static Cryosol as in the surrounding area (type 3 effect).

Table 3. Differences in soil properties between fox den mounds and adjacent sites.

Den[3] No.	Difference in soil Texture Den	Adjacent site[1]	Increase in active layer (%)	Effect on Soil classification[2]
	Strongly eroded terrain, Herschel Island			
37	S, SL	SiCL	280	1
50	LS	SC	13	2
41	SL	SiCL	110	3
47	SL	CL	152	2
44	stratified sediments		83	1
	Slightly eroded terrain, Herschel Island			
53	LS	SiCL	67	2
39	LS	SiL	68	2
	Yukon Coastal Plain			
2	S	S	13	4
18	LS	LS	10	1
8	SiCL	SiCL	17	4

[1] See footnote Table 2 for explanation of symbols.

[2] Difference in classification (CSSC 1978) between soil on fox den mound and that of adjacent site. There are four types of effect 1. Order level - Regosol vs Cryosol; 2. Great Group Level - Static Cryosol vs Turbic Cryosol; 3. Subgroup level - Orthic vs Regosolic Static Cryosol; 4. No difference in soil taxonomy.

[3] Data unavailable for sites 24, 38, - 48.

Many soils of the tundra ecosystems develop horizons rich in well decomposed organic matter (Reiger 1983, p. 123). In the study area the presence of thick, continuous Ah horizons is unique to the fox den sites. The basic characteristics of these horizons are presented in Table 4. The horizons range up to 10 cm thick and contain a minimum of 5% organic carbon. Horizons containing more than 17% organic carbon are designated as organic horizons (CSSC 1978) and are listed as F (semi-decomposed organic litter), H (well decomposed organic litter), or Oh (imperfect to poorly drained soil conditions). All horizons had dark colors and plentiful or abundant roots. The carbon to nitrogen ratios reflect degree of decomposition of the incorporated organic matter. Values reported in Table 4 are similar for those of Ah horizons elsewhere.

Figure 1 illustrates the relationship between the amount of organic carbon in the soil and the pH. Arctic soils rich in humus have been shown to be high in fulvic acid (Reiger 1983, p. 126, Lowe 1980) and this can depress soil pH values significantly at high organic matter levels. Within the surveyed area, underlying unweathered parent materials are mildly to strongly alkaline.

DISCUSSION

Geomorphic Setting and Distribution of Fox Dens

The arctic fox seems to be opportunistic with respect to den location with the areas examined in this study. If erosion or eolian deposition

Table 4. Characteristics of organic matter rich surface horizons from selected sites[1].

Den No.	Horizon type	Thickness range	Color (moist)	Rooting abundance, size[2]	Carbon (%)	Nitrogen (%)	C:N ratio	pH (H_2O)
	Strongly eroded terrain, Herschel Island							
37	Ahu	0 - 15	5 YR 3/2	P,VF & f	16.1	1.13	14	5.8
50	Ahk	7 - 8	10 YR 2/2	A, F & C	7.8	0.49	16	7.4
41	Ah	5	10 YR 3/2	A, C	5.5	0.40	14	7.9
47	Ahk	3 - 14	10 YR 2/1	A, M & C	7.9	0.57	14	7.6
	Slightly eroded terrain, Herschel Island							
53	F	8 - 10	7.5 YR 3/2	P, F	21.1	0.56	38	7.5
53	Ahk	4 - 6	7.5 YR 3/4	P, M	7.1	0.35	20	7.8
39	Ahk	3 - 10	10 YR 2/2	A, VF & F	8.8	0.62	14	7.0
	Yukon Coastal Plain							
24	H	10 - 30	2.5 YR 2.5/1	P, F & M	24.4	1.22	20	6.2
24	Ah	2 - 10	10 YR 2/1	P, F & M	8.2	1.35	6	7.9
8	Ohy	0 - 20	--	--	23.7	1.58	15	5.0

[1] For definitions of horizon type, soil, colors, and rooting - see ECSS (1983).

[2] P-plentiful, VF-very fine, F-fine, M-medium.

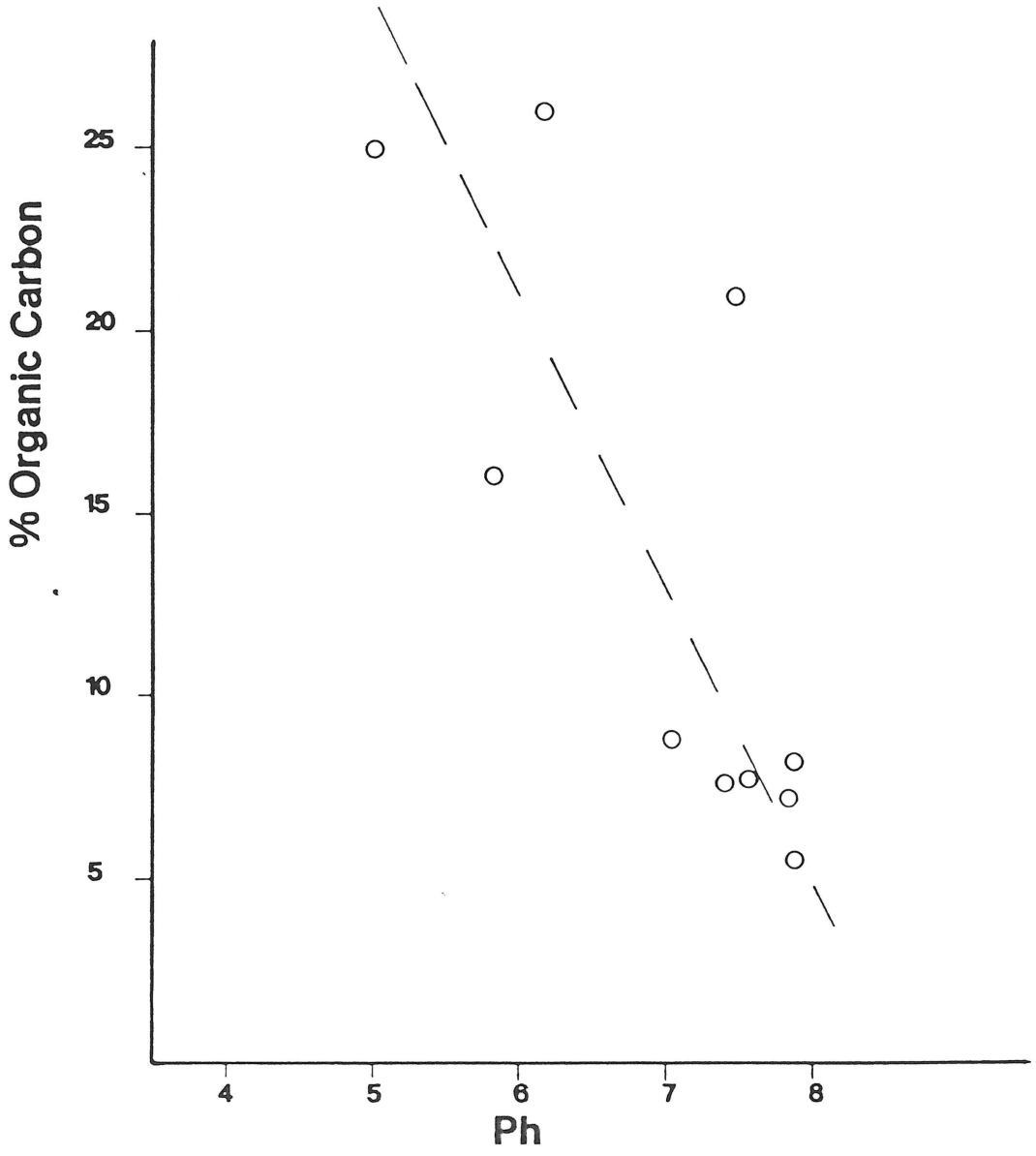

Figure 1. General trend of greater soil acidity (lower pH) with increasing organic matter content. Sample data plotted are given in Table 4.

creates a suitable mound feature then this may be used for a den site regardless of aspect, slope, or proximity to water. All dens possess a viewing vantage point, a factor considered by MacPherson (1969) to be consistent when dens are located near valleys or river flats. On the eroded landscapes of Herschel Is. fox dens were generally located at the head of gully systems on upper slope positions. These erosional remnant mounds are suitable for burrowing and offer some protection from wind.

Smits and Jessup (1985) describe the distribution pattern of fox dens on Herschel Is. as random. A range of locations for fox den sites were observed, from coastal bluffs to sites within the interior of the Island. However, no dens were observed on the non-eroded uplands, wetland areas, fluvial, or marine landforms. The dens appear to be restricted to certain terrain conditions and the soil map of Herschel can be used to make inferences about areas likely to be used for denning.

Soil Development on Fox Den Mounds

Soils on fox den mounds tend to be better drained, warmer, and have lower bulk densities than surrounding soils. They are composed of disrupted materials and surface horizons are high in humus content. Dens are preferentially located on mounded, coarse textured materials. Burrowing activities mix subsurface materials with surface materials and incorporate organic detritus into the profile. A layered effect was sometimes observed and the profile can have a "cumulic" form as seen in

Regosolic soils on floodplain environments.

Foxes transport nutrients to the den site through direct additions to the soil of carcass remains, bones, feces, and urine. Rich vegetation results, and high concentrations of roots establish themselves in the surface horizon. These later decompose in-place and increase humus content. McKendrick et al. (1980) demonstrated marked increases in levels of nitrogen, phosphorous and potassium around mammalian herbivore densities. These organic matter rich surface horizons (Ah horizons) are the most striking morphological feature of den soils.

Numerous bone fragments incorporated into the subsoil suggests that considerable redesign of tunnel systems takes place as dens mature. Some tunnels were observed to have been built immediately above the permafrost table and to depress the level by 10 - 15 cm beneath the tunnel. Presumably tunnels are dug deeper as the permafrost table drops.

Soil Taxonomy

In the Canadian System of Soil Classification Cryosolic soils are defined as ".... formed in either mineral or organic materials that have permafrost either within 1m of the surface or within 2 m if more than one-third of the pedon has been strongly cryoturbated. They have a mean annual soil temperature below 0°C" (CSSC 1978). On Herschel Is. and the Yukon Coastal Plain Cryosolic soils dominate the landscape. The most common subgroup is the Regosolic Turbic Cryosol.

Soils often differ initially between the selected den mound and the surrounding area. Den building and fox activities produce further differentiation. Soil classification may differ as the result of changes in the thickness of the active layer, disruption by burrowing of cryoturbation features within the profile, or the presence or absence of specific soil horizons. In some instances no differences between den mound and adjacent soil were observed that produced a change in the soil classification at the site.

On the Yukon Coastal Plain, active layer changes were less than on Herschel Is. (Table 3). Den 8 was the only den to be constructed on silty clay loam in this study. Sdnobnikov (1960) reports approximately 8% of his observed dens to occur on clay loam. The small size of this particular den suggests this is perhaps "youthful" as defined by MacPherson (1969).

CONCLUSIONS

The arctic fox will use the most favourable materials available in which to construct dens. They seem to prefer coarse textured soils but will utilize fine textured soils or even rock (Ostbye et al. 1978). The orientation of the dens examined in this study was not according to aspect but by topography and landscape. Eroded landscapes provide wind protection and vantage points. The range in sizes of dens and the variation in morphology of the soil profile fits the age model for fox dens proposed by MacPherson (1969).

Transport of nutrients to the site has profound ecological impact on both soil development and the floristic community. This leads to the development of unique soil properties associated with den sites (McKendrick et al. 1980).

Fox den location is controlled to a large extent by certain inheritant soil properties (texture, drainage, active layer, thickness) yet with time, many soil properties (humus content, pH, depth) are controlled to a large extent by fox den activities. A fascinating ecological relationship exists between the fox and the soil environment.

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