**Natural Resources Canada**
**Geomatics Canada**
**Centre for topographic information**
**Contrat 23258-055970/001/MTB**

# Interpretation guide of natural geographic features from ETM+ Landsat imagery and aerial photography: Tundra polygon

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**10e version, 17-06-2005**

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## Introduction

The purpose of this project is to create a visual interpretative guide to the natural geographical entities in the geospatial database (GDB) using Landsat7 ETM+ imagery and aerial photography. The methodology and information fact sheet were developed by Provencher and Dubois (2004a), and the application of this procedure to a test case has already garnered a consensus among the staff of CTI at Sherbrooke (Provencher and Dubois (2004b). The meanings of the sections of the fact sheets are explained in the appendix.

The eight natural entities in the GDB (Centre for Topographic Information, 2004) fall under eight themes that are grouped into three domains: hydrography, landforms, and vegetation (**Table 1**). In practice, for interpretive purposes they are often subdivided further and represented by 17 fact sheets.

N.B.: Elaboration of the illustrative examples and potential elements of confusion was constrained by the limited time allocated to this guide. It is recommended that they be supplemented as other cases are documented, especially from Landsat ETM+ imagery.

Table 1: Hierarchy of natural geographical entities

| **Domain** | **Theme** | **Sub-theme** | **GDB entity** | **Fact sheet** |
|---|---|---|---|---|
| Hydrography | Watercourse | Perennial watercourse | Permanent water | Permanent water |
| | | Alluvium | Intermittent water | Intermittent water |
| | | Waterfall | Water disturbance | Waterfalls and rapids |
| | | Rapids | Water disturbance | Waterfalls and rapids |
| | Waterbody | Perennial freshwater body | Permanent water | Permanent water |
| | | Alluvium, rocky surface | Intermittent water | Intermittent water |
| | | Saltwater | Permanent water | Permanent water |
| | | Alluvium, rocky surface (tidal flat) | Intermittent water | Intermittent water |
| | | Reef | Water disturbance | Reef |
| | Wetland | Tundra pond | Saturated soil | Tundra ponds |
| | | Palsa bog | Saturated soil | Palsa bog |
| | | Marsh, swamp, and uniform peat bog (wetland) | Saturated soil | Wetlands (marshes and swamps, peat bogs |
| | | String bog | Saturated soil | Wetlands (string bog) |
| Landforms | Glacial landform | Glacial debris | Landform | Glacial debris |
| | | Esker | Landform | Esker |
| | | Moraine | Landform | Moraine |
| | | Glacier, glacial ice cap, and ice shelf | Permanent snow and ice | Permanent snow and ice |
| | Periglacial landform | Polygonal soil | Landform | Tundra polygon |
| | | Pingo | Landform | Pingo |
| | Littoral landform | Barrier beach and spit | Landform (sand) | Barrier beach and spit |
| | Eolian landform | Dunes | Landform (sand) | Dunes |
| Vegetation | Wooded region | | Wooded region | Wooded region |

## 1- Feature name

Tundra polygon

## 2- Hierarchy

Landform – periglacial – polygon soils

## 3- Definition

An area of permafrost or old permafrost in which the surface of loose material has cracked and separated, forming a multitude of polygon-shaped islands that may be separated by ice.

Polygon soils include tundra polygons, ice-wedge or desiccation peat polygons, peat plateaus, sorted circles, etc. (Brochu and Michel, 1994; Hamelin and Cook, 1967; Genest, 2000; Boivin, 2005).

## 4- Summary table of identification elements

**Table 2**: Summary of elements identifying tundra polygons

| | |
|---|---|
| Form | Plan view: polygonal shape |
| Dimensions | Decametres to kilometres |
| Topographic position | Flat surface in all topographic positions |
| Drainage | Variable, from good to poor |
| Vegetation | tundra vegetation in periglacial environments |
| Means of formation | Frost or desiccation process |
| Status | Active forms in northern Canadian landmass and inherited in the south |
| Spatiotemporal variations | Stable on the human scale |
| Environment | Exclusive to permafrost and ancient permafrost environments |
| Identification in the image | Difficult if not impossible due to the narrow width of crevasses or small dimensions of polygons |
| Identification in B/W aerial photo | Polygonal forms<br>Contrast of shades between crevasses and polygons |
| Elements of confusion | None |

## 5- Characteristics

### 5.1- Specific to feature

#### 5.1.1- Form

Polygonal soils can have a variable number of sides.

#### 5.1.2- Dimensions

Diameter: variable depending on polygon type:

-tundra polygons (between 30 m and 50 m)

-desiccation polygons (between 10 m and 1 km)
-frost-crack polygons (between 10 m and 100 m)

5.1.3- Topographic position

Polygon soils occupy flat surfaces in all topographic positions.

5.1.4- Drainage

The drainage of polygon soils varies according to the nature of the materials in which they develop. Drainage ranges from good in sandy soils to poor in silty or clayey soils and in peat.

5.1.5- Vegetation

Polygons are colonized by tundra vegetation, whereas the crevasses can be favorable for the growth of certain species of shrub.

5.2- Related to feature dynamics

5.2.1- Means of formation

The main processes related to the formation of polygon soils are annual freezing, the formation of ice wedges, desiccation, frost contraction, expansion and contraction resulting from alternating wetting and drying, and tension cracking (Dionne, 1983).

5.2.2- Status

Polygon soils are active forms in northern permafrost areas. They are relics in areas in which permafrost conditions once existed.

5.2.3- Spatiotemporal variations

Polygon soils are stable on the human scale.

5.3- Related to the environment

Polygon soils develop exclusively in environments of current or past permafrost.

## 6- Optimal conditions for identification in satellite images

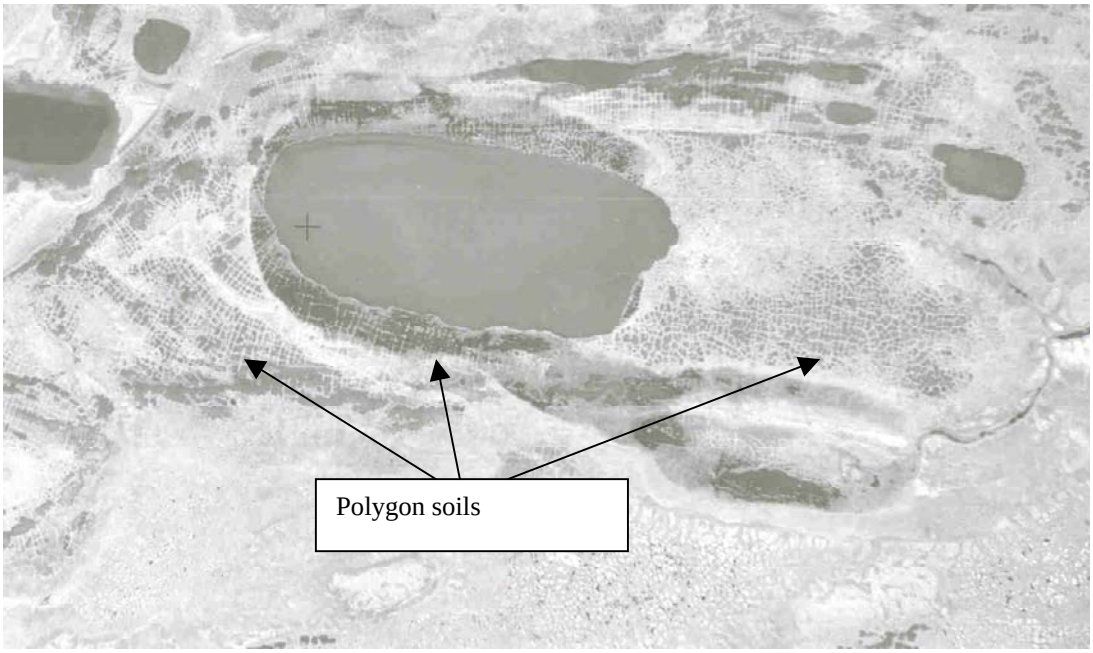
Polygon soils can be observed in aerial photographs under all conditions, regardless of observation scale.

Polygon soils are difficult to discern in ETM+ images given the narrow width of the crevasses that delimit each polygon or small polygon size.


## 7- Examples

Source : Natural Resources Canada, ESS Collection , photo KGS-791, **Black River** area (N.W.T.)

Figure 1 : Example of tundra polygons developed in a peat bog.

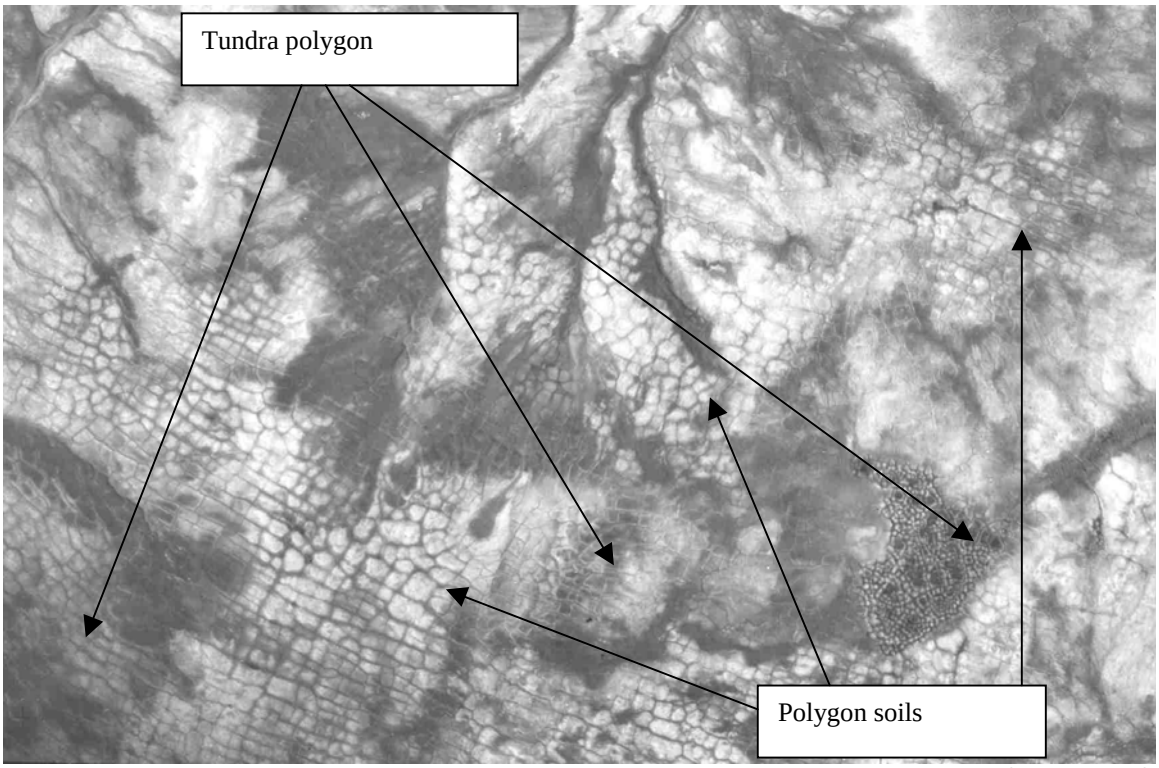



Source : photo A12704 (214), T.S.C.A.P. no 250, Map107 E, Original scale 1 : 40 000,
70°25' N – 128°10' O, **Cape Dalhousie** area (N.W.T.)

Figure 2 : Example of polygon soils developing in a thermokarstic lake becoming dry


Source : Photo A14732 (57), T.S.C.A.P. no 262, Map 77 B, Original scale 1 : 42 000, 68°43' N – 109°35' O, **Richardson Island** (Nunavut)

Figure 3 : Example of polygon soils developed on flat terrain




Source : Photo A12725 (223), T.S.C.A.P. no 13, carte 49 G, Original scale 1 : 18 000, 79°55' N – 86°00' O **Eureka Sound** North (Nunavut)

Figure 4 : Example of different types of tundra polygons and polygon soils developed in different environments

## 8- Interpretation

### 8.1- Critical path

The critical path comprises two phases: discrimination and delimitation of the form as well as its identification.

#### 8.1.1- Discrimination and delimitation

Discrimination and delimitation of polygon soils are easy in aerial photographs. The contrast between the hue of the crevasses (dark grey) and polygons (light grey) is the main factor in recognizing these forms.

Polygon soils are generally difficult to discern in ETM+ images given the narrow width of the crevasses or their small size.

#### 8.1.2- Identification

The process for identifying polygon soils requires the analyst to deal with different elements of confusion and discrimination. Discrimination accuracy is directly proportional to the analyst's knowledge and experience.

### 8.2- Verification with complementary sources of information

None

## 9- Elements of confusion

None

## 10- Bibliography

Boivin, A. (2005) Les principales formes périglaciaires : essai de classification et de synthétisation. Département de géographie et de télédétection, Université de Sherbrooke,
72 p.

Brochu, M. et Michel, J.-P. (1994) Dictionnaire de géomorphologie à caractère dimensionnel, Éditions ESKA, Guérin Universitaire, Montréal, 298 p.

Dionne, J.-C. (1983) Réseau relique de polygones de tourbe, Moyenne et Basse Côte-Nord du Saint-Laurent, Québec, Géographie physique et quaternaire, vol. 37, no 2, p. 127-146.

Genest, C.G. (2000) Dictionnaire de géomorphologie. Société de géographie de la Mauricie, Trois-Rivières, 411 p.

Hamelin, L.-H. et Cook, F.A. (1967) Le périglaiciaire par l'image. Illustrated glossary of periglacial phenomena. Les presses de l'Université Laval, Québec, 237 p.

**Appendix: the meanings of the sections**

**1. Name of entity**

The name of the entity as it appears in the GDB and in Topolan7.

**2. Position in hierarchy**

The position of the entity in the hierarchical structure of entities in the GDB.

**3. Definition**

A brief description based on the entity's principal characteristics and allowing it to be distinguished from any other natural or manmade entity in the GDB.

Only the core features are part of the definition. A detailed description of the characteristics necessary for identification is given in Section 4.

**4. Summary table of elements of identification**

Presentation of a table summarizing the entity's characteristics (Section 5), of the optimal conditions for identification on ETM+ imagery and black and white (B/W) aerial photography (Section 6), and of the elements of confusion (Section 9).

**5. Characteristics**

Categorization and description of the characteristics useful for visual identification of the entity.

**5.1. Specific to the entity**

Characteristics unique to the entity that allow all aspects useful for its identification to be grasped.

**5.1.1. Shape**

Distinction between linear, point, and areal shapes, three-dimensional pattern of the entity.

**5.1.2. Dimensions**

Expanse (length, width, diameter) and height of the entity: minima, maxima, and means.

**5.1.3. Topographic position**

Location of the entity relative to major landforms: drainage basin, mountain, plateau, plain, valley, slope, etc.

**5.1.4. Drainage**

Surface moisture, outside of saturated zones, in connection with the texture of the materials in the entity.

**5.1.5. Vegetation**

Presence of vegetation typical of the entity or patterns of plant associations making it possible to distinguish the entity.

**5.2. Relative to the entity's dynamics**

Characteristics pertaining to the origin and the state of the entity.

**5.2.1. Emplacement process**

The agent or set of agents responsible for the entity's emplacement and evolution.

**5.2.2. State**

Dynamic state of the entity: inherited or current. In the case of inherited features, we speak of paleolandforms; in the case of current landforms, we speak of their ongoing formation.

**5.2.3. Spatio-temporal variations**

Variations in the entity or its appearance that are functions of cyclical conditions (seasonal, multi-year, etc.) or event driven.

**5.3. Relative to the environment**

Characteristic of the conditions in the entity's milieu and its relationship with other entities or forms present in this milieu.

**6. Optimal conditions for identification**

Drawing on documentary sources and the experience of the participants, establishment of the optimal conditions for visual identification of the entity. Using satellite imagery, determine the capability of Landset7 ETM+ to capture the characteristics of the entity and identify the band or combination of bands best for visually distinguishing and identifying the entity. Using B/W aerial photography, identify the hues and textures that are most representative of the entity. In cases in which the relief may be significant, recommend the use of stereoscopy.

**7. Examples**

Illustrating the entity with examples reflecting several of its aspects:

**7.3. Land-based photography**

Photographs of the landscape that present one or several examples of the entity's aspects, as they might be seen from the ground.

**7.3. Aerial photography**

Oblique or vertical aerial photographs that present on or several examples of the entity's aspects, as they might be seen from the air.

**7.3. Satellite imagery**

Satellite images (from Landsat7 ETM+) that present one or several examples of the entity's aspects, as they might be seen from space.

**8. Interpretation**

Identification of the entity proceeds from interpreting the information in the imagery or aerial photography and complementary sources of information. The quality of the outcome of this interpretive activity will depend upon the knowledge and the experience of the analyst.

**8.1. Critical path**

Establishing a unique critical path of interpretation for each entity from the imagery or aerial photography on the basis of its characteristics.

**8.1.1. Distinction and delimitation**

The possibility of distinguishing and delimiting the shape on the image or aerial photograph has been established and the criteria for success have been described.

**8.1.2. Identification**

Contrasting the various elements of confusion and recognition with other entities or forms for purposes of identification.

**8.2. Use of complementary sources of information**

Complementing or cross-checking the interpretation with additional sources of information that are easily accessible, such as those on known Internet sites.

**9. Elements of confusion**

Identifying the entities and forms with which the entity in question can be confused in a table, along with the differentiating features.

**10. Bibliography**

A list of useful documents quoted in the previous sections.