Interpretation guide of natural geographic features from ETM+ Landsat imagery and aerial photography: Pingo

Léo Provencher and Jean-Marie Dubois
Geographers

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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

Pingo

2- Hierarchy

Hydrography – landform – pingo

3- Definition

A relatively large, ice-cored conical or dome-shaped mound, raised above the surrounding terrain by frost action and insulated with dirt and low vegetation (CTI, 2004).

4- Summary table of identification elements

Table 2: Summary of elements identifying pingos

Form	Plan view: circular or ovoid	
	Cross-section: conical	
Dimensions	Diameter: decametres to several hundreds of metres	
	Height: metres to about a hundred metres	
Topographic position		Lacustrine topographic depressions
Drainage	Generally good	
Vegetation	Absent or sparse herbaceous	
Means of formation		Development of an ice lens
Status	Active form	
Spatiotemporal variations		Changes slowly (decadal scale)
Environment	Lacustrine setting in a permafrost environment	
Identification in the image	Bands 4-3-2 and band 5	
Identification in B/W aerial photo	conical or ovoid	
	Smooth texture	
	Contrast of the hue with respect to the surface of water	
Elements of confusion	Palsa bog, rocky island	

5- Characteristics

5.1-   Specific to feature

5.1.1-   Form

Pingos are conical with an oval perimeter. The summit is sometimes a depression with radial cracking (Brochu and Michel, 1994).

5.1.2-   Dimensions

Diameter: varies from 10 to 500 m.
Height: varies from 1 to 100 m.

5.1.3-   Topographic position

Pingos occupy shallow lakes.

5.1.4-   Drainage

The slopes of a pingo are well-drained given their steepness. The summit may be filled with water, especially if concave.

5.1.5-   Vegetation

Pingos are generally bare, but may be covered with sparse herbaceous vegetation.

5.2-   Related to feature dynamics

5.2.1-   Means of formation

Pingos result from the development of an ice lens under mollisol in a lacustrine depression with shallow water coverage. A core of ice develops by growth of segregation ice. The ice lens pushes up the overlying mollisol, which causes the mound to rise out of the water (Figure 1). The partial or complete melting of the ice lens will eventually lead to the pingo's collapse (Hamelin and Cook, 1968).
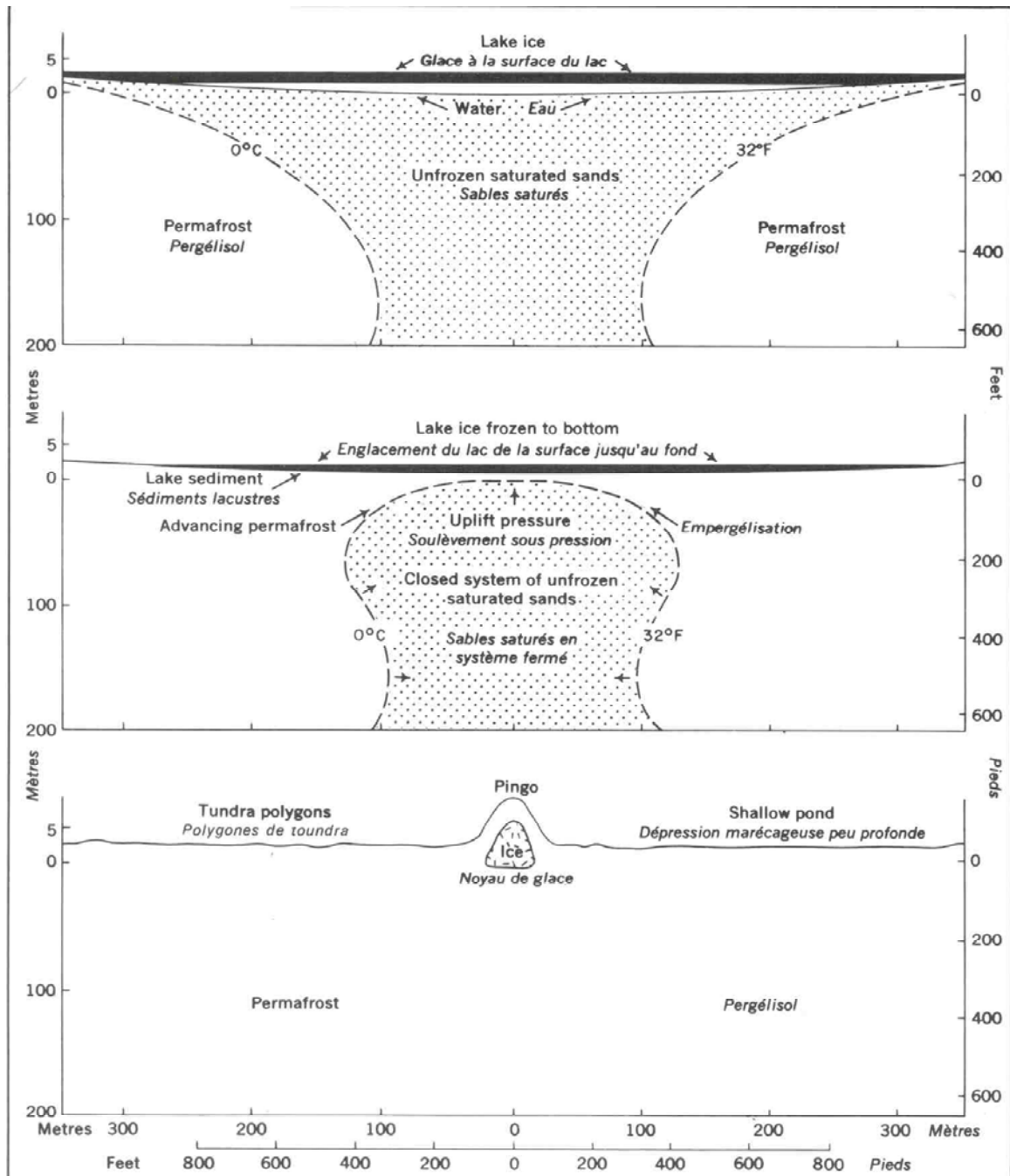
Source : Hamelin et Cook (1967)

Figure 1 : Development of a pingo

5.2.2-   Status

The pingo is an active form.

5.2.3-   Spatiotemporal variations

The pingo is stable on the human observation scale. The process of its creation and change occurs on the decadal scale.

5.3-   Related to the environment

Pingos are found in the permafrost zones of Northern Canada.

6- Optimal conditions for identification in satellite images

Pingos have an obviously conical shape in aerial photographs, especially when stereoscopy is used.

In ETM+ images, the contrast between pingos identified with the combination of bands 4-3-2 and water

identified with band 4 facilitates discrimination. Pingos may, however, be interpreted as rocky islands.
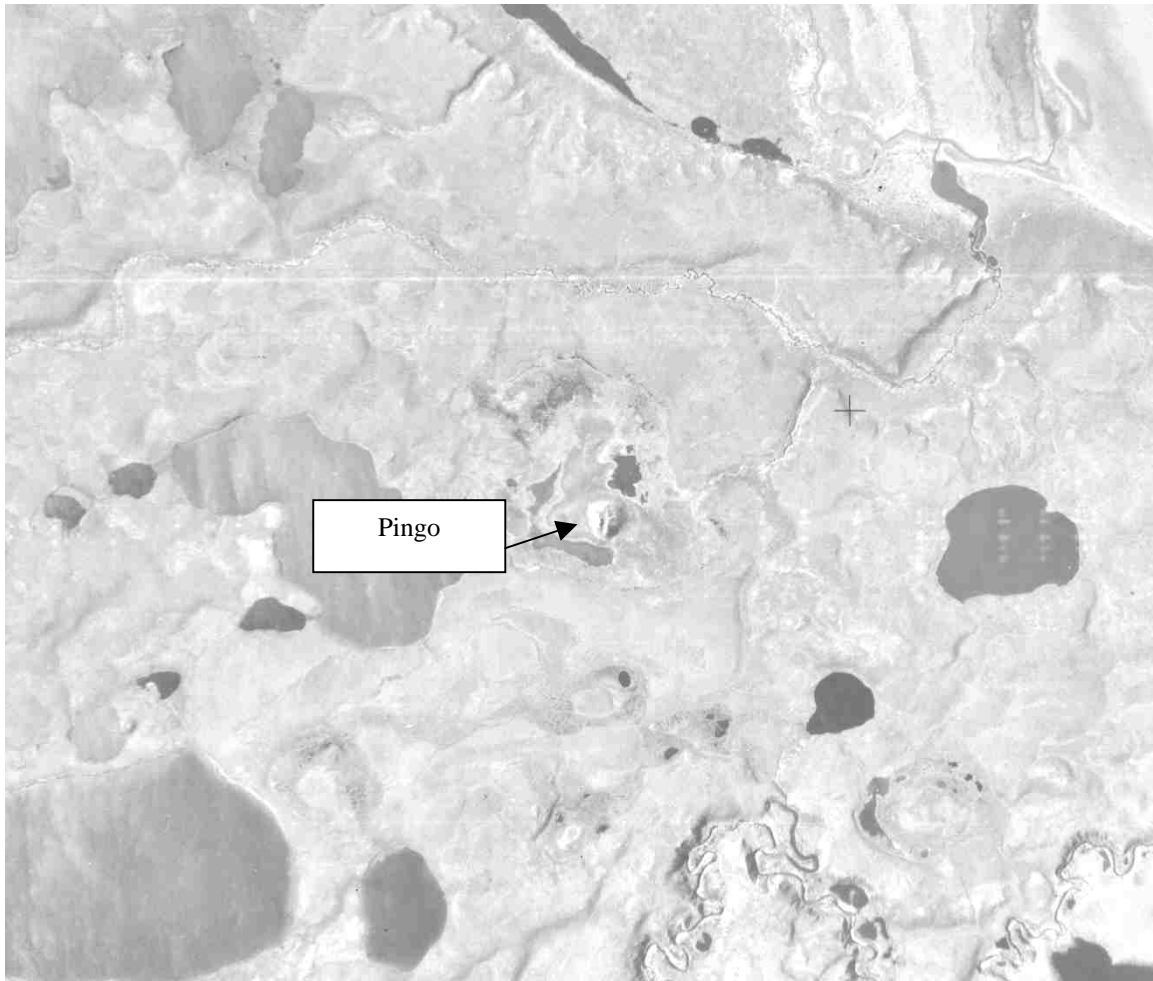
7- Examples

Source : Hamelin et Cook (1967)
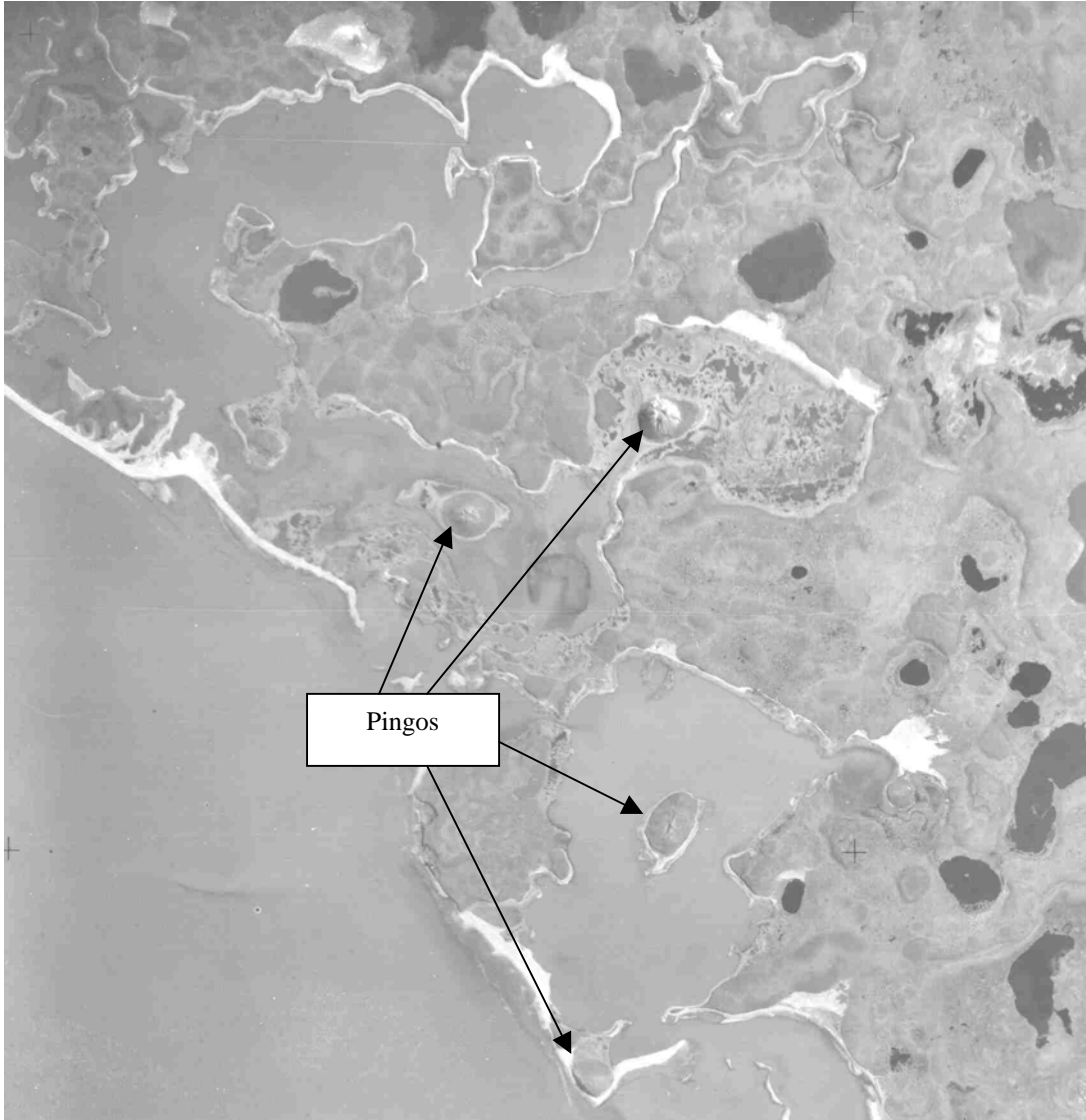
Figure 2 : Ice core in a pingo

Source : Images Canada, photo C.G.C. A89S0052, **Harding River** area (Nunavut)

Figure 3 : Example of a ground view of a 22 m high pingo

Source : photo A12857 (344), T.S.C.A.P. no 19, map 107 C/07, Original scale 1 : 40 000, 69°05' N – 134°28' O, **Kittigazuit** area (N.W.T.)

Figure 4 : Example of a pingo in a dry pond

Source : photo A12918 (93), T.S.C.A.P. no 19, Map 107 C/07, Original scale 1 : 40 000, 69°25' N – 133°10' O, **Kittigazuit** area (N.W.T.)

Figure 5 : Example of pingos in a water body

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

Pingo discrimination and delimitation are straightforward, given the fact that the structure is a large conical or ovoid mound with a summit that is often cracked.

Pingos are readily identified in ETM+ images when compared to the surface of water in band 4. Identification may, however, be problematic without stereoscopic vision due to confusion with rocky islands.

8.1.2-   Identification

The process for identifying pingos requires the analyst to deal with different elements of confusion and discrimination (Table 3). Discrimination accuracy is directly proportional to the analyst's level of knowledge and experience.

8.2-   Verification with complementary sources of information

It may be useful to consult a permafrost distribution map such as that by Kettles et al. 1997).

9- Elements of confusion

Table 3: Elements of confusion and discrimination between pingos and other features or forms

Feature or Form	Elements of Confusion	Elements of Discrimination	Examples
Palsa bog	- Similar shape	- Dimension and height - Geomorphological context	
Rocky island	- Similar shape	- Smooth texture	

10- Bibliography

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

Hamelin, L.-E. et Cook, F.A. (1967) Le périglaciaire par l'image. Les presses de l'Université Laval, Québec, 237 p.

Kettles, I.M., Tarnocai, C. and Bauke, S.D. (1997) Predicted permafrost distribution in Canada in a climate warming scenario. *in* Current Research 1997-E, Geological Survey of Canada, p. 109-115.

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.