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

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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

Dune

2- Hierarchy

Landform – eolian – landform (sand) – dune

3- Definition

According to CTI, fine, hard, granular rock or mineral fragments, including dunes. Dunes are mapped as sand on topographic maps.

In geomorphology, a dune is an accumulation (mound or ridge) of sand moved by the wind. Dunes nearly always occur in fields comprised of dunes of very different sizes.

4- Summary table of identification elements

Table 2: Summary of elements identifying dunes

Form	Plan view: elongated, oval, or crescentic Cross-section: triangular or rounded crest
Dimensions	Length: decametres to kilometres Width: decametres to a few hundreds of metres Height: metres to decametres
Topographic position	All altitudes, usually near current or old shorelines
Drainage	Excellent, except in interdunal plains
Vegetation	None or scattered herbaceous vegetation
Means of formation	Windblown sand, often on barrier beaches and spits
Status	Active dunes on current coasts Reactivated dunes on old coasts
Spatiotemporal variations	Annual or decadal modifications
Environment	Existing or old littoral, fluvial, and proglacial environments
Identification in the image	Variegated appearance of dune fields Whitish zone in bands 4-3-2
Identification in B/W aerial photo	Variegated appearance of dune fields Whitish shade and smooth texture of dunes Festooned edges
Elements of confusion	Barrier beach and spit, snow

5- Characteristics

5.1- Specific to feature

5.1.1- Form

In plan view, dunes are crescentic, oval, or elongated in shape, occurring either parallel or perpendicular the prevailing wind. Dunes rarely occur alone but usually in fields, sometimes punctuated with damp depressions

(deflation plains).

In cross-section, a dune is a mound or asymmetrical triangular or rounded ridge swept in the direction of the wind.

5.1.2- Dimensions

Length: a few tens of metres to several kilometres.

Width: a few tens of metres to a few hundreds of metres.

Height: several metres to several tens of metres.

5.1.3- Topographic position

Denuded dunes usually occur near current oceanic shorelines or major lakes. Old dune fields reactivated by the wind can be found at any altitude formerly subjected to water.

5.1.4- Drainage

Although drainage is excellent due to the permeability of the sand, deflation plains can be wet when the water table is high (**Figure 1**, **Figure 3** to **Figure 4**).

5.1.5- Vegetation

In order to be mapped as sand, dunes must be bare of vegetation, which is the case with fresh forms along current coasts (**Figure 6**), older forms in northern environments still bare of vegetation, or forms with vegetated surfaces reactivated by the wind as the result of natural processes or human activity (**Figure 6** andFigure 7).

5.2- Related to feature dynamics

5.2.1- Means of formation

Dunes are sand landforms deposited by the wind. Their development also depends on the presence of a sand reservoir. While deserts constitute the main sand reservoirs for dune formation, in Canada, the sand is primarily supplied by active and old oceanic and lacustrine shores as well as alluvial plains of major watercourses and proglacial outwash plains. Along shores, the wind picks up beach sand and deposits it on barriers and spits as well as the crests of cliffs and erosion faces. On alluvial plains and outwash plains, the wind selectively picks up sand from among the available sediments, depositing them in various forms in more protected areas. The wind also reshapes the crests of barrier beaches and spits. Dunes occur in a variety of shapes: longitudinal , transverse, crescentic, and relatively irregular mounds.

5.2.2- Status

Dunes can be active or paleolandforms (Figure 7). Only active dunes or old dunes reactivated by natural processes or human activity can be can be considered as sand.

5.2.3- Spatiotemporal variations

A dune or dune field can spread, stabilize, or reactivate over a period of several years or several decades depending on the action of the prevailing wind.

5.3- Related to the environment

Active dunes are found along current sandy shores (Figure 6), active alluvial plains, and current proglacial outwash plains. Reactivated areas of dunes can also be found in these environments.

6- Optimal conditions for identification

In aerial photographs, crescentic dunes are evident as are dune fields, which have a variegated appearance (**Figure 3**) with alternating zones of bare sand (whitish tone and smooth texture), zones with herbaceous cover (light grey tone and relatively smooth texture), and often areas of wet depressions (medium to dark grey tone and smooth texture) (Figure 7). Small and longitudinal dunes are more difficult to distinguish from barrier beaches and spits from which they often originate because they are more or less parallel to the coast (**Figure 1**). The edges of these dunes are, however, more festooned than those of barrier beaches and spits. Stereoscopy is often necessary.

In ETM+ images, the preceding major forms (crescentic dunes and dune fields) are easily identifiable in the combination of bands 4-3-2 for the same reasons. Small, aligned dunes cannot, however, be distinguished from barrier beaches or spits.

7- Examples

Source : photo J.-M. Dubois n° 90-12-00, Îles-de-la-Madeleine (Québec)

Figure 1: Example of an entirely wind-blown barrier beach. In the field, it appears dune-like; in aerial photographs, it looks more like a barrier beach.

Source : photo J.-M. Dubois n° 91-08-12, Îles-de-la-Madeleine (Québec)

Figure 2: Example of the crest of a coastal dune with a deflation plain in the foreground

Source : photo J.-M. Dubois n^{o} 91-05-17, Îles-de-la-Madeleine (Québec)

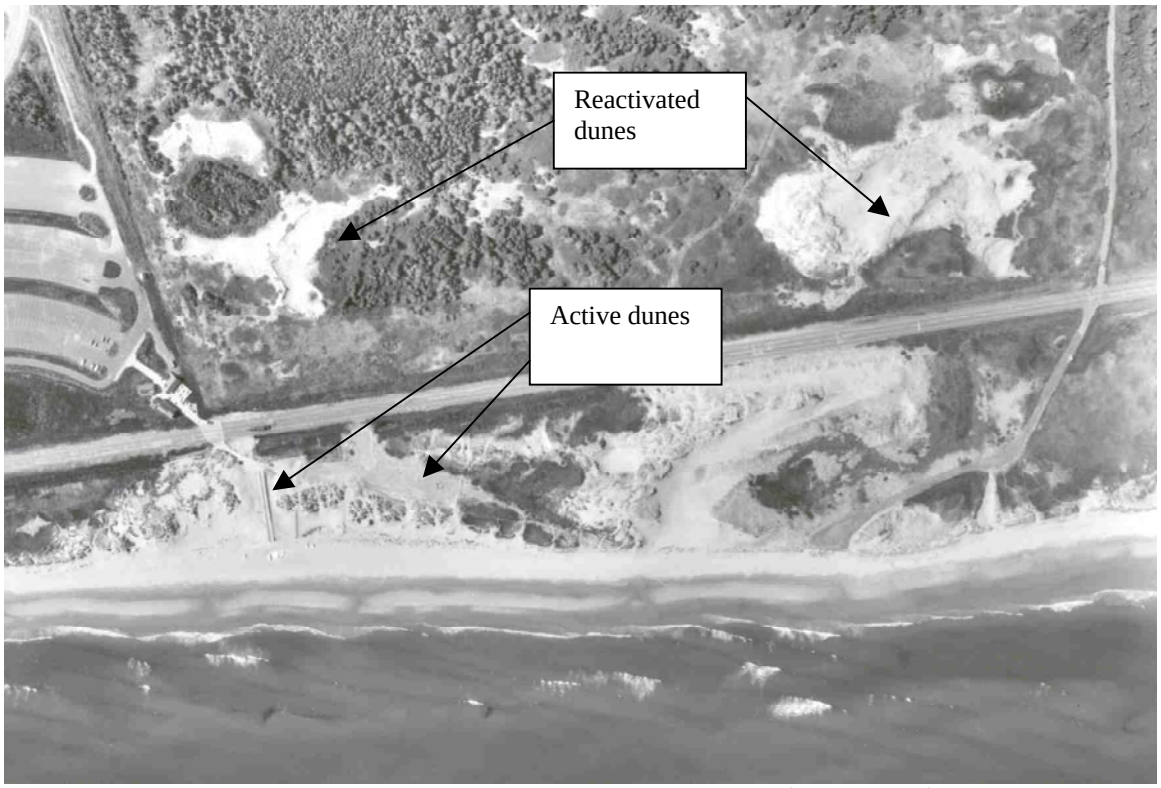
Figure 3: Example of a field of coastal dunes

Source : photo J.-M. Dubois n^{o} 91-04-33, Îles-de-la-Madeleine (Québec)

Figure 4: Example of an active dune with a wet deflation plain

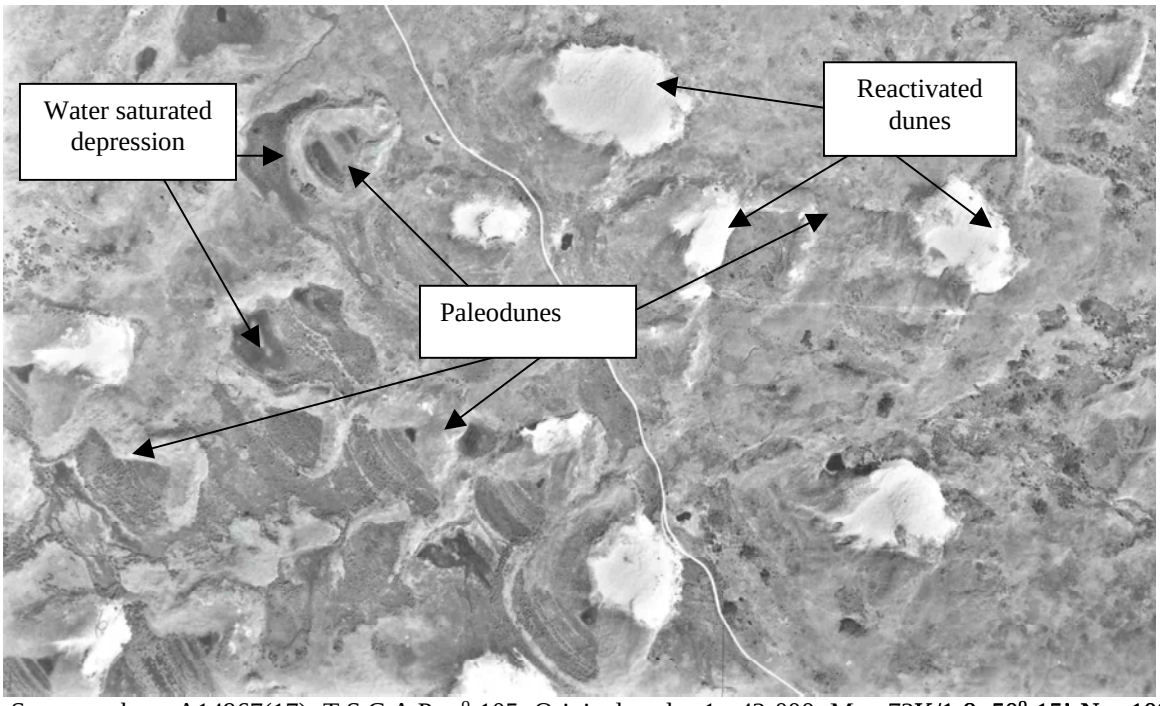
Source : photo J.-M. Dubois n° 90-06-12, Îles-de-la-Madeleine

Figure 5: Example of a dune field with a large number of wet deflation plains



Source : photo A26090(130), Original scale 1 : 5 000, Map 21L/06, 46° 26' N – 63° 12' O, North Rustico (P.E.I.) 23-06-1982

Figure 6: Example of active coastal dunes and occasionally reactivated old dunes



Source : photo A14967(17), T.S.C.A.P. n° 105, Original scale 1 : 42 000, Map 72K/1-8, 50° 15' N – 108° 15' O, Gull Lake and Roseray area (Saskatchewan)

Figure 7: Example of reactivating dunes in a field of crescentic dunes

Source : Images Canada n° GSC 2002-657, Sand Hill area (Saskatchewan)

Figure 8: Reactivated dunes in a field of stabilized dunes

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

There are few elements of confusion in discriminating or delimiting dunes and dune fields.

Active dune fields are usually areas of variable size with an irregular perimeter and are often lobed (Figures 6 and 7). Only small longitudinal and transverse dunes can be confused with active barrier beaches or spits, from which they usually have originated.

It is easy to distinguish areas of active dunes from the surrounding vegetation either by photointerpretation or with the combination of ETM+ bands 4-3-2. Dune fields with sparsely reactivated dunes are more difficult to delimit depending on the area affected by active dunes. In northern regions, dunes can be confused with snow-drifts, although they can be distinguished with bands 5 (humidity) and 6 (temperature).

8.1.2- Identification

The process for identifying dunes requires the analyst to deal with different elements of confusion and discrimination (Table 2). Discrimination accuracy is directly proportional to the analyst's knowledge and experience.

8.2- Verification with complementary sources of information

No complementary sources of information are needed but more general information about dunes can be found in Paskoff (1994) and there are many examples on the Canadian landmass in Mollard and James (1985).

9- Elements of confusion

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

Feature or Form	**Elements of Confusion**	**Elements of Discrimination**	**Examples**
Barrier beach and spit	- Elongated form - Parallel to coast - Whitish tone	- Rougher texture - Festooned edges	Figure 1
Snow (snow field)	- Whitish tone - Arced shape	- Bands 5 (moisture) and 6 (temperature)	

10- Bibliography

Mollard, J.D. et James, J.D. (1985) la photo-interprétation et le territoire canadien. Approvisionnements et services Canada, Ottawa, 424 p.

Paskoff, R. (1994) Les littoraux : impact des aménagements sur leur évolution. Masson, Paris, 256 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.