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

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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- Name of entity

Reef

2- Hierarchy

Hydrography – waterbody – water disturbance – reef

3- Definition

A large rock or boulder, in a waterbody or large watercourse, that barely breaks the surface and is devoid of vegetation.

For purposes of mapping, reefs include islets of less than 2 000 m² or 40 m in diameter. However, some of these islets may bear vegetation.

4- Summary table of elements of identification

Table 2: Summary of identifying elements for reefs

| | |
|--|--|
| Shape | View from top: scattered points |
| Dimensions | Diameter: decametres Height: less than one metre (above the waterline) |
| Topographic position | At the water's surface: less than one metre above high seas or high waters |
| Drainage | Not applicable |
| Vegetation | None |
| Emplacement process | Emergence or submergence of the relief |
| State | Relatively stable; in maritime environments, they may disappear in the Maritime Provinces and appear further north |
| Spatio-temporal variations | Daily or seasonal, depending on water levels |
| Environment | Rugged, rocky coasts |
| Identification on imagery | If submerged: combination of bands 4-3-2 or band 2 If exposed: band 4 Height: too small for detection |
| Identification with B/W aerial photography | If submerged: dark grey hue If exposed: light grey hue Coarse texture Height: by stereoscopy |
| Elements of confusion | Alluvium, rocky surface, islet, shipwreck and floating objects |

5- Characteristics

5.1- Specific to the entity

5.1.1- Shape

An irregular speckled pattern in a waterbody or large watercourse.

5.1.2- Dimensions

Diameter: from several decametres to several hundred metres.

Height: less than one metre above the water; at most, several metres in the centre.

5.1.3- Topographic position

Reefs are observed near the surface of waterbodies or large watercourses. They protrude less than one metre above the level of the high seas or, in the case of lakes and large waterbodies, the high waters. They are located at the edges of permanent or intermittent waters. Surfaces rising more than one metre above the waterline are considered islets.

5.1.4- Drainage

Not applicable.

5.1.5- Vegetation

Reefs are generally devoid of vegetation, but sparse herbaceous plant life may be found above the waterline and algae in the intertidal zone.

5.2- Relative to the entity's dynamics

5.2.1- Emplacement process

As a general rule, reefs result from the submerging of a feature of the landscape with only some small surfaces remaining above water.

In marine, estuarine, and lagoonal environments, the appearance of reefs is linked to changes in the relative sea level occurring over hundreds or thousands of years, determined by both variations in the volume of the water (eustasy) and shifts in the level of the continent (isostasy). Consequently, reefs may disappear (submerge) and others appear (elevations remain above water) as coastal areas are inundated by a rise in the relative sea level by several centimetres or decimetres per century. This is occurring in the Maritime Provinces and as far as Gaspé and southern Newfoundland. Conversely, reefs may appear (emerge) and others disappear (become islets or part of the mainland) in locations where the continent is still rising by several centimetres or decimetres per century, as is the case along all the northern coasts of the country.

In lakes, the presence of reefs is attributable to the natural or artificial submerging of topographic depressions. They may also appear or disappear because of natural, but more often artificial (dams), changes in the base levels of lakes.

In large waterbodies, the presence of reefs is primarily linked to the emergence of erosion-resistant rocky outcrops or the deposit of large boulders (glaciers, rock falls).

5.2.2- State

Reefs are relatively stable inherited formations. However, as they depend upon water levels, they appear or disappear in tandem with the fluctuations in these latter, usually over the medium or long term.

5.2.3- Spatio-temporal variations

The visibility and appearance of reefs is subject to variations that may be unique, seasonal, or annual (floods or base-water levels) in waterbodies and large watercourses, and daily or seasonal in the case of oceans, seas, estuaries, and lagoons (tides).

5.3- Relative to the environment

Aside from changes occurring over hundreds or thousands of years, reefs in the marine environment are most likely to be found in the vicinity of archipelagos and rugged coastlines. As to lacustrine environments, reefs occur in lakes with jagged, rocky shores. In large watercourses they are less common and more likely to consist of large boulders.

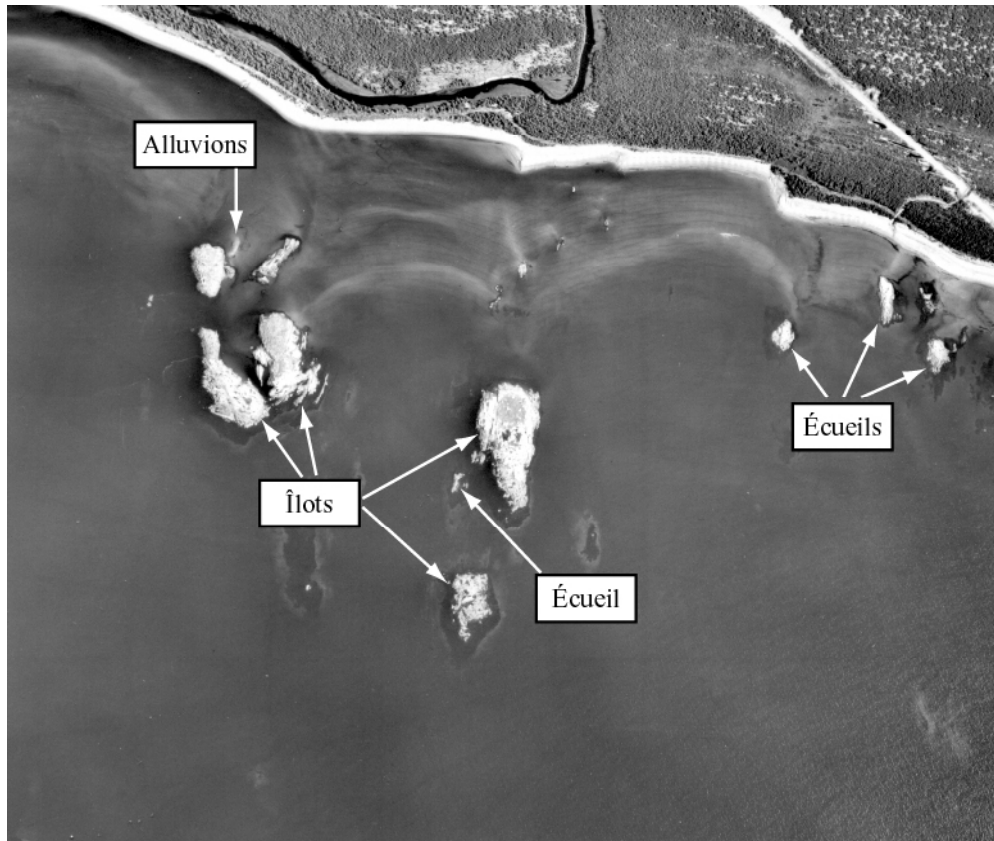
6- Optimal conditions for identification on satellite imagery

For a thorough mapping of all reefs, imagery must be taken at base-water level for watercourses and freshwater bodies and at low tide for saltwater bodies and estuaries.

On aerial photography, reefs normally cannot be confused with any other entity except islets with a surface area exceeding 2 000 m². In fact, their irregular shapes and whitish to pale-grey hue, when exposed, resemble those of islets. The texture may vary with the nature of the rock, but it is typically rough. If reefs are covered by water, their hue tends toward a darker shade of grey. The height can be assessed by stereoscopy.

On ETM+ imagery, exposed reefs and bald islets present the same signature on band 4 (IR), appearing grey. If submerged, they are invisible on band 4, but may be picked up with a combination of bands 4-3-2, or on band 2.

7- Examples



Source : photo Q67313(94), échelle originale 1 : 15 840, carte 12L/08, 50° 15' N - 62° 17' O, pointe Pashashibou, Côte-Nord du Saint-Laurent (Québec) du 16-07-1967

Figure 1 : Example of reefs where some can be mistaken with small islands or alluvium (coastal sand)

8- Interpretation

The critical path encompasses two phases: distinguishing and delimiting the form, and identifying it.

8.1- Critical path

8.1.1- Distinction and delimitation

The distinctive characteristics of reefs are their small size and low profile above the waterline, as well as the fact that they are isolated, denuded formations barely piercing the surface of the waterbody or large watercourse.

8.1.2- Identification

The identification process for a reef requires that the analyst address the various elements of confusion and recognition (Table 3). The greater the analyst's knowledge and experience, the more accurate the outcome of this labour of discrimination will be.

8.2- Cross-checking with complementary sources of information

The only complementary sources of information would be existing topographical maps, nautical charts for navigable waterways, and bathymetric maps for the remaining waterbodies and watercourses. Consultation of these documents at least makes it possible to verify, on the basis of the reported depth of the shoals, whether the presence of a reef is plausible. For information on where to find nautical charts and bathymetric maps, please consult the *permanent water* fact sheet, Section 8.2).

9- Elements of confusion

Table 3: Elements of confusion and recognition between reefs and other entities or forms

| Entity or form | Elements of confusion | Elements of recognition | Examples |
|---------------------------------|--|---|-----------------|
| Alluvium | - Similar hue and shape | - Heterogeneous texture - Geomorphic context | Figure 1 |
| Rocky surface | - Submerged form - Heterogeneous texture | - Thin cover of water | |
| Islet (barren) | - Similarity of shape, size, hue, texture, and geomorphic context | - Less high | Figure 1 |
| Shipwreck or floating object | - Appears as single point - Similar size - Whitish to greyish hue - Similar location and environment | - Geometry of the form from photography - None from imagery | |

10- Bibliography

Centre d'information topographique (2004) Norme et catalogue de la Base de données Géospatiale (BDG). Ressources naturelles Canada, Géomatique Canada, Sherbrooke, 50 p. ftp://ftp.cits.rncan.gc.ca/pub/optimum/information/document/BDG_Classes_actives.xml (visité le 06-01-2005).

Provencher, L. et Dubois, J.-M.M. (2004a) Guide d'interprétation des entités géographiques naturelles à partir des images ETM+ de Landsat-7 : I – Fiche d'identification des entités géographiques naturelles. Ressources naturelles Canada, Géomatique Canada, Centre d'information topographique de Sherbrooke, Sherbrooke, 20 p.

Provencher, L. et Dubois, J.-M.M. (2004b) Guide d'interprétation des entités géographiques naturelles à partir des images ETM+ de Landsat-7 : II – Exemple de la fiche d'identification des eskers. Ressources naturelles Canada, Géomatique Canada, Centre d'information topographique, Sherbrooke, 51 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 Landsat7 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 one 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.