ELSEVIER

International Journal of Applied Earth Observation
and Geoinformation 8 (2006) 208–223

INTERNATIONAL JOURNAL OF
APPLIED EARTH OBSERVATION
AND GEOINFORMATION

www.elsevier.com/locate/jag

Classifying airborne radiometry data with Agglomerative Hierarchical Clustering: A tool for geological mapping in context of rainforest (French Guiana)

G. Martelet *, C. Truffert, B. Tourlière,
P. Ledru, J. Perrin

BRGM, 3 av. Claude Guillemin, BP6009, 45060 Orléans Cedex 2, France

Received 1 March 2005; accepted 20 September 2005

Abstract

In highly weathered environments, it is crucial that geological maps provide information concerning both the regolith and the bedrock, for societal needs, such as land-use, mineral or water resources management. Often, geologists are facing the challenge of upgrading existing maps, as relevant information concerning weathering processes and pedogenesis is currently missing. In rugged areas in particular, where access to the field is difficult, ground observations are sparsely available, and need therefore to be complemented using methods based on remotely sensed data.

For this purpose, we discuss the use of Agglomerative Hierarchical Clustering (AHC) on eU, K and eTh airborne gamma-ray spectrometry grids. The AHC process allows primarily to segment the geophysical maps into zones having coherent U, K and Th contents. The analysis of these contents are discussed in terms of geochemical signature for lithological attribution of classes, as well as the use of a dendrogram, which gives indications on the hierarchical relations between classes.

Unsupervised classification maps resulting from AHC can be considered as spatial models of the distribution of the radioelement content in surface and sub-surface formations. The source of gamma rays emanating from the ground is primarily related to the geochemistry of the bedrock and secondarily to modifications of the radioelement distribution by weathering and other secondary mechanisms, such as mobilisation by wind or water. The interpretation of the obtained predictive classified maps, their U, K, Th contents, and the dendrogram, in light of available geological knowledge, allows to separate signatures related to regolith and solid geology. Consequently, classification maps can be integrated within a GIS environment and used by the geologist as a support for mapping bedrock lithologies and their alteration.

We illustrate the AHC classification method in the region of Cayenne using high-resolution airborne radiometric data acquired in 1996 across most of French Guiana. Access to the field in this region, almost entirely covered by tropical rainforest, is difficult, and therefore, use of airborne geophysical data is highly suitable to complement ground observations. Despite the vegetal cover, the U, K and Th maps, exhibit to the first order, a fairly good correlation with lithological units recognised by geologists in the field.

Consequently, classification of the radiometric data is globally concordant with existing 1:100,000-scale geological map. In addition, using the radioelement contents and relations between classes at different levels of classification, additional relevant information concerning weathering effects, unexpected lithological differences or transfer by erosion, are evidenced.

Keywords: Classification; Agglomerative Hierarchical Clustering; Airborne geophysics; Radiometry; Geological mapping; Regolith; Geochemistry; French Guiana; Cayenne

* Corresponding author. Tel.: +33 2 38 64 47 32; fax: +33 2 38 64 33 34.
E-mail address: g.martelet@brgm.fr (G. Martelet).

0303-2434/$ – see front matter
doi:10.1016/j.jag.2005.09.003

1. Introduction

Airborne gamma-ray spectrometry is an effective geological mapping tool in a diversity of environments. The gamma-ray response reflects the mineralogy and geochemistry of the parent material, and the derived alteration and weathering products, including residual and transported clays, sand and gravel. The continuous coverage of airborne geophysical data is particularly suitable in areas where ground access and/or observation is difficult (such as wetlands, deserts, equatorial forests, rough topography). As a result, characteristic radiometric signatures are able to contribute to litho-geochemical discrimination of bedrock and surficial formations. Applications of airborne gamma-ray spectrometric surveys have been driven primarily by the needs of the mineral industry to map geochemical anomalies (Galbraith and Saunders, 1983; Shives et al., 2000) but there is growing interest for interpreting these datasets for various other uses, primarily for regional-scale geological mapping (e.g. Jaques et al., 1997; Schetselaar et al., 2000). However, in highly weathered zones, covered by vegetation, the distribution of radioelements in the alteration profile and their possible use for geological mapping is still a topic of research (Cook et al., 1996; Wilford, 1995). Knowledge of the distribution and properties of regolith components, in relation with the basement lithologies, is essential for successful interpretation of the data (Butt and Zeegers, 1992; Butt, 2004; Dickson and Scott, 1997). Efforts have been made in this direction, using joint airborne and field data analysis (Butt, 2004; Dickson and Scott, 1997), as well as detailed petrological and geochemical analysis of weathering processes (e.g. Tardy, 1993; Walter et al., 1995; White, 2002). Applications of such regolith-solid geology predictive mapping are as diverse as, regolith mapping itself (Craig et al., 1999; Wilford et al., 1997), mineral exploration (Butt, 1995; Freyssinet and Itard, 1997) or ground water modelling (Beckett, 2003).

We illustrate our proposed approach on the Cayenne area, in French Guiana, where the existing geological map (Fig. 1) can be upgraded taking into account the geological interpretation of the airborne geophysical dataset (Delor et al., 1997). This region is almost entirely covered by tropical rain forest, with only a few roads penetrating into the forest, away from the coast. Therefore, in this context, the use of airborne gamma-ray spectrometry data can be highly effective to complement ground observations.

In order to optimise the geological mapping procedure in such difficult areas, an integrated geology/geophysics interpretation procedure has been conducted, based on the extraction of classes characterised by their homogeneous radiometric properties. This was achieved using an Agglomerative Hierarchical Clustering (AHC) procedure which is an unsupervised classification, that can be used independently from any existing geological map. This method is performed on airborne gamma-ray spectrometry gridded data (U, K and Th), and we further emphasise two particular aspects of the method: (i) we characterise the geochemical signature of the classes, providing indications for their lithological composition and (ii) depending on the level of detail in the classification, the geological significance of classes and their relation from one level to the other are discussed. The comparison of the resulting predictive maps with existing geological maps allows to separate regolith from solid geology signatures.

2. Methodology

Geological mapping progressively evolves toward the combination of field observations and remote-sensing approaches. Using airborne gamma-ray spectrometry, this is achieved by reconciling the coherent patterns of radioelement concentrations with geological field observations. Continuous coverage of gamma-ray spectrometry is crucial to extrapolate the ground punctual observations to the whole map (Jaques et al., 1997; Graham, 1993). Conversely, ground observations remain essential to constrain unequivocally the interpretation of gamma-ray spectrometry.

As Geographical Information System (GIS) software become widespread, analysis of spatial relationships between different datasets (geology, geophysical data, . . .) in order to help the geological mapping, becomes common (e.g. Jaques, 1993). However, when the number of available layers of data increases, this qualitative approach becomes difficult to apply and requires implementation of automated procedures. Historically, multivariate analysis was developed in order to help the interpretation in several scientific domains where available number of variables has drastically increased. Multivariate analysis has therefore become indispensable since cross-combining the single variables by hand was highly subjective and time consuming. In mineral exploration, mapping of potential ore deposits, which was based on the combination of many chemical elements measured on ground samples, has taken advantage of this technique (e.g. Viallefond et al., 1998). In satellite image analysis as well, with modern multi-band sensors, use of