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Generalizing surficial geological maps for scale change: ArcGIS tools vs. cellular automata model

Alex Smirnoff*, Serge J. Paradis, Ruth Boivin

Natural Resources Canada, Earth Sciences Sector, 490, de la Couronne, Québec, Québec, Canada G1K 9A9

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Abstract

Map generalization is rapidly becoming an important issue in surficial geology. One of the most complicated and least defined steps in this procedure is polygon generalization. Here we outline and compare two different approaches to a particular generalization problem, combining four large-scale maps of unconsolidated material from the Chibougamau region, Québec, Canada into a single map for the entire area. First we provide a working multi-step recipe for the ArcGIS software and then show how this procedure can be automated and outperformed through using the cellular automata (CA) model previously proposed for treating satellite images. We finally chose the CA as the preferred method as its results better meet the requirements imposed on the final product. Along the way, we also demonstrate a few ways to control the final level of generalization and show how large maps can be processed on ordinary computer equipment.

Keywords: Geological map generalization; ArcGIS; Cellular automata; CA

1. Introduction

Map generalization is rapidly becoming an important issue in surficial geology, as detailed maps covering small regions are being combined to provide regional compilation maps. For the resulting map to be readable, it is necessary to simplify polygon contours, eliminate microfeatures and aggregate groups of smaller elements into larger forms while maintaining close similarity to the original. A number of algorithms for simplification, elimination, and aggregation procedures have been proposed (e.g., Douglas and Peucker, 1973; Jones et al., 1995; De Berg et al., 1998; Saalfeld, 1999). Many of them are already implemented in modern GIS software packages. However, sequential application of these algorithms is a tedious and time-consuming procedure, which can also result in loops of operations (Galanda and Weibel, 2003). In addition, every step requires that a number of parameters be input by the user and therefore, the outcome of the entire process might be somewhat subjective. Therefore, more comprehensive approaches to map generalization are required (Galanda and Weibel, 2002).

The cellular automaton (CA) is a cell-based model known for its wide application for simulating complex systems in chemistry, physics, and biology (e.g., Chopard, 1990; Sieburg and Clay, 1991; Kier and Cheng, 1994). More recently, the CA has been

*Corresponding author. Tel.: +1 418 654 3716; fax: +1 418 654 2615.
E-mail address: alsmirno@nrcan.gc.ca (A. Smirnoff).

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introduced into other disciplines. In geography, for example, it has been widely applied to test assumptions based on urban theories (e.g., Batty et al., 1999; Webster and Wu, 1999; Wu and Webster, 2000) and simulate and plan real cities development (e.g., White et al., 1997; Li and Yeh, 2000; Ward et al., 2000). Li et al. (2001) were the first to show the advantages of using the model for cartographic application. In particular, they applied it to generalize a satellite image of Lisbon Bay, Portugal. They underlined such important CA features as: (1) creating complex spatial patterns through applying simple local transition rules, (2) generating a fractal structure naturally representing the hierarchy between local and global behavior, and (3) combining spatial information in an easy and natural way.

The objective of this study was to combine four 1:100,000 maps of unconsolidated materials from the Chibougamau region, Québec, Canada into a single 1:250,000 map covering the entire area according to requirements of various users. We approached this exercise with two different techniques. The first involved a sequential application of ArcGIS software functions while the second employed the CA model with a simple map algebra filter as a rule. We defined a few test areas from a 1:100,000 map and compared the results from both methods with requirements imposed on our exercise using a set of measures for accuracy and generalization level. This comparison demonstrates that the map produced with the CA algorithm better meets user requirements. Therefore, we selected this method for final production. Issues regarding various levels of generalization and how large maps can be generalized on standard computer equipment are also discussed in text.

Cellular or raster representation used by our CA algorithm has long been known as an appropriate environment for cartographic generalization (Schylberg, 1993). Map algebra filters have been previously applied as a single transformation in generalization of thematic maps. For example, Fuller and Brown (1996) used raster filtering as a pre-processing step in generalizing the digital land cover map of Great Britain (LCMGB) to meet the requirements of the European Commission program “Co-ordination of Information on the Environment (CORINE). Similarly, Jaakkola (1998) employed a number of map algebra transformations to produce a CORINE land cover database from a more detailed database of Finland. However, we are not aware of previous application of such filters within the frameworks of the CA model for mapping surficial geology.

2. Methodology

2.1. Input data

Between 1995 and 2003, 16 surficial geology maps of the Chibougamau area produced at a 1:50,000 scale (32G/01 through 32G/16) were published as Open Files (Paradis, 1995–1997, 2000, 2002, 2003). These maps are shown contoured by dotted lines in Fig. 1. In 2004, the maps were generalized in Arc/Info Workstation using an in-house developed set of procedures. The generalization steps included application of different algorithms, buffers and existing Arc/Info functions for simplification, aggregation, and elimination of polygons (Allary, 2002). After generalization, the maps were published as four A-Series maps at 1:100,000 scale, 2061A, 2062A, 2063A, and 2064A (Paradis, 2004).

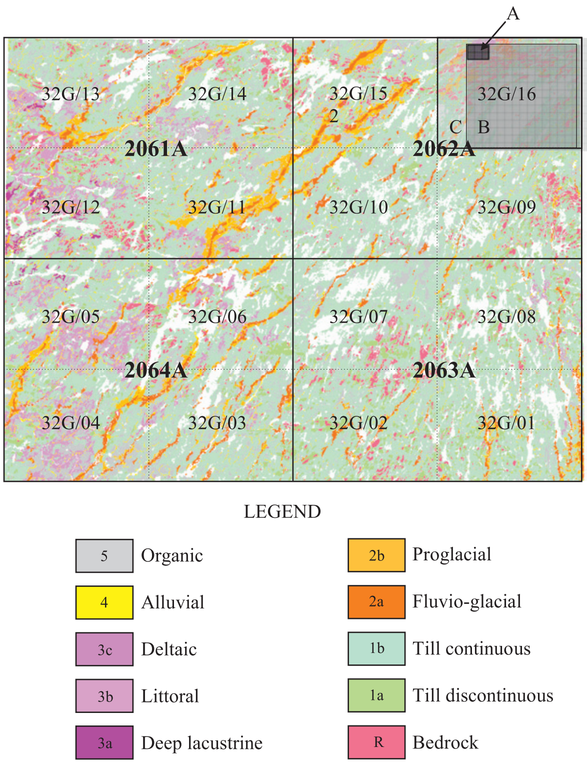

Fig. 1. Four surficial geology maps scaled at 1:100,000 that were created from 16 1:50,000 maps during first phase of project. These four maps were used as input information in order to create a single 1:250,000 map. Test clips discussed throughout article are shown in upper right corner.