The art and science of editing geological maps

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Background

Geological maps are one of the flagship products of the Geological Survey of Western Australia (GSWA). These maps are scientific publications that distil and interpret a wide range of spatially located geological data. End-users include the exploration and resources sector, geoscience researchers, the Department of Mines and Petroleum and other government departments, and the public. GSWA's 1:100 000- and 1:250 000-scale Geological Series maps are modelled on international standards, tailored to local requirements.

Originally, plotted maps were the primary mode of presenting spatially located geoscience, but with the advent of digital data acquisition and compilation, the traditional map is increasingly regarded as one component of a suite of geoscience products. GSWA maps are principally released online as PDF publications and only a limited number are plotted, mainly for distribution to State and Commonwealth collections. Despite this, the map format remains a fundamental platform for presenting geological information.

GSWA compiles and assembles maps in digital ESRI ArcGIS geospatial databases. Data compilation, by the geologist, typically takes about 12 months, although for many maps this includes a review of previously acquired data. Thereafter, the data pass through several stages of preparation, assembly in a standardised layout, peer review, editing, and approval, before publication (see figure on p.3).

About the authors

Dr Stephen White is a geologist with broad experience in academia, government and industry. Following his PhD in Geology from Otago university (New Zealand), a research post took him to Germany, Namibia, back to New Zealand and to the United Arab Emirates. Currently in the Editing and Publishing section of the Geological Survey of Western Australia he has successfully married his love of rocks with his curiosity about language and communication.

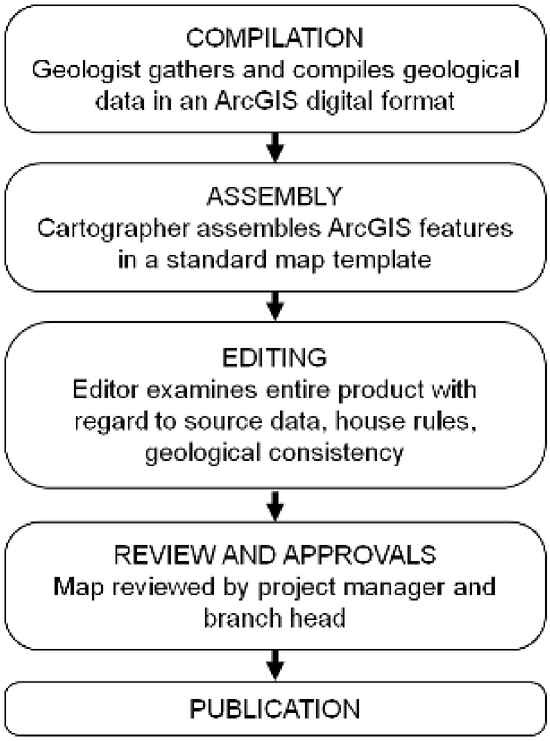
Dr Huntly Cutten is a senior geologist in the Geological Survey of Western Australia. Much of his research since 2007 has been in the Gascoyne, on sedimentary rocks as old as 2500 million years. For his PhD at The University of Western Australia (2005) Huntly studied the Gondwana plate tectonic collision history in eastern Africa. Field studies have taken him to such varied places as Tanzania and California. He has also been Adjunct Professor with National University and IT manager with BFG Aerospace.

Annick Jones holds a Diploma in cartography and is a Bachelor of Science in Geographic information Science. She is a Senior Spatial information Officer in the mapping section of the Geological Survey of Western Australia. Her current role is to operate and customise geographic information systems and other map-related software in the collection, integration, compilation and verification of spatial data.

Compilation

The geologist collects data in the field using a portable field tablet computer operating an in-house designed database (WAROX) to record rock identification and description, structural measurements and photographs. Rock samples are also collected for later analysis including geochronology and geochemistry. Back in the office, digital datasets, including aerial and satellite imagery and the geological field data, are used to compile an interpretation of the geology, which is drawn in ArcGIS as polygons and lines representing different rock types.

When complete, the ArcGIS file is handed over to GIS specialists for 'cleaning'. The data are attributed (given pre-defined identifying descriptions), and rock unit codes (a component of the attribution) are cross-checked against the standardised GSWA geology database. The cleaning process may take up to two weeks depending on the quality of the data. This is followed by a lot of interaction between the geologist and the GIS operator to resolve presentation issues. These issues can include thinning the density of structural data represented on the map, as well as polygons or lines that are too small to show on the printed map. There are usually issues to resolve regarding the legend, which is the key to all the geological units shown on the map. Each map has adjacent map sheets and the represented geology must be consistent with these. Following resolution of these technical issues, the data are made available to the Series Mapping section to assemble in map format.



Assembly

The hard copy map production process begins when all relevant data for the map are ready for extraction from the GIS section. A map generally takes 10–15 days to assemble, from extraction to first plot for review, depending on the complexity of the geology and legend.

Assembly involves bringing the geology, topography and mining data into a map template as digital layers. This stage also includes the creation of the legends and marginal information. Data layers are symbolised to conform to house standards and specifications, and features are labelled using pre-assigned text. Geological units are coloured and patterned according to an established colour scheme. Major geologic formations are assigned specific colours based on an international stratigraphic chart. To these are added overprint patterns that are used to differentiate between the sub-units. Hard copy plots, to scale, and enlargements, are provided to the assigned editor to mark up any changes and these are handed back to the cartographer who keeps them as a record of the changes.

A final copy map can be assembled in approximately 3 months, including editing and revisions, but many maps take longer because, if several map sheets from the same area are being worked on concurrently, geological edits made to one 1:100 000-scale sheet invariably feed back into changes on the other sheets in progress. This feedback loop tends to become recursive, until the geologists find a regional resolution that satisfies all current map sheets.

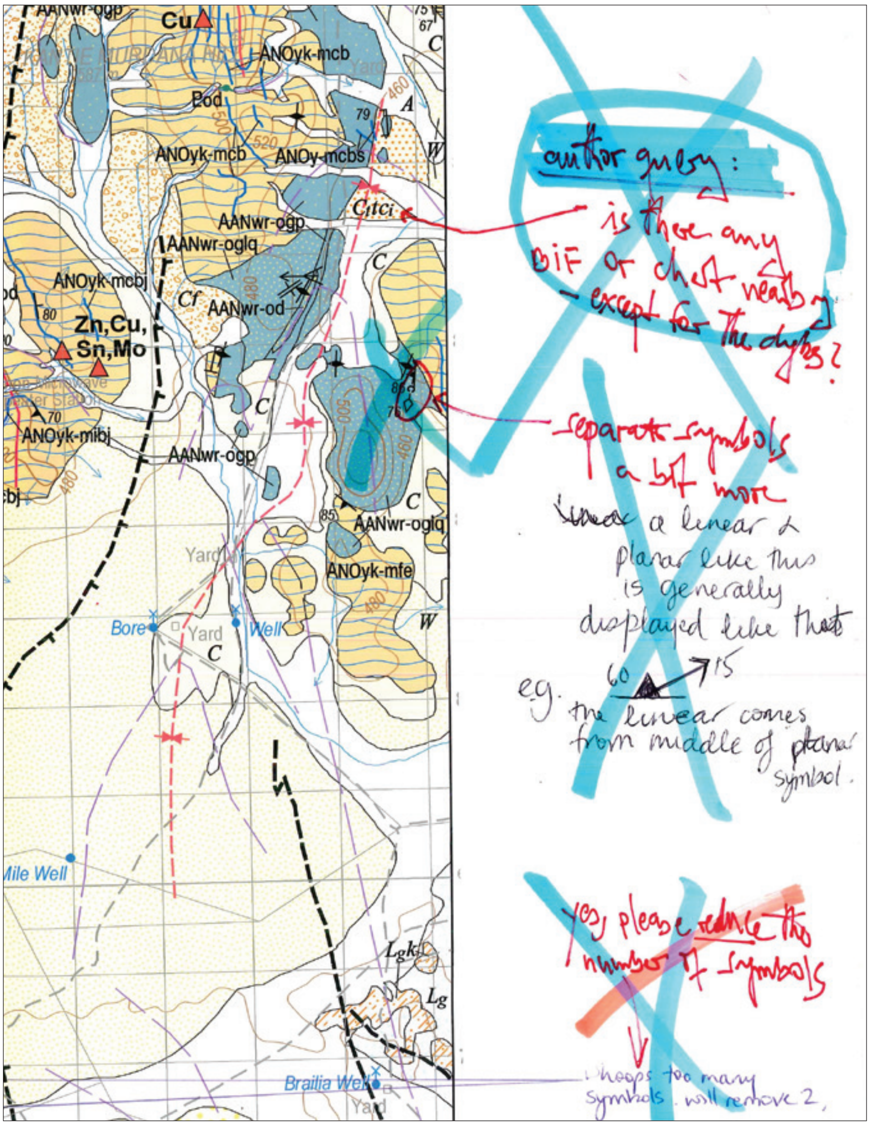
Editing

Like manuscript publications, geological maps must adhere to a GSWA 'house style', and follow a rigorous review and edit process before they're released. However, the edit also calls for specialist skills particular to both this publication type and its Geographic Information Systems (GIS)-based production process. In some respects, editing these maps is considerably more complex than editing a manuscript-type publication.

Editing comprises a combination of digital and paper-based work, and typically involves considerable discussion with the geologist and the cartographer, and commonly also other contributors, such as GIS specialists and project managers.

The technology permits a level of detail and complexity that was never possible when geological maps were compiled by hand. Nevertheless, there are practical limits to the detail that can be placed in a map before it becomes unreadable. Achieving a balance between what the geologist wants to portray and a suitable cartographic result—or what the cartographer is able to achieve with the software—can be difficult. This not uncommonly requires the editor to mediate between the competing demands and constraints, and find a solution that takes into account the reality of the geology, the reality of cartographic practicalities, and the different products the data will eventually be used for.

A full map edit typically takes between one and two weeks, or longer if significant problems are encountered. Editing begins when all map data have been submitted by the geologist to GIS and cartographic specialists, and a draft map—of which the geological legend is a central element—has been assembled.



Despite digitisation of the map production process, editing is still most effectively carried out by hand. The editor requests from the cartographer customised plots of the map sheet—for example, enlargements of the main map face, or plots that combine quantitative data without coloured geology—and marks these up using red pen. Typically, the editor will refer to a checklist to try to cover all points.

Editors develop their own methods, such as using a pen of a different colour to note questions for the geologist, and a different colour again to record the answer. Multiple generations of notes can become very confusing for the cartographer to unravel, and a succinct, methodical, colour-coded approach helps to reduce this confusion.

Standard editing or proofreading marks are generally unhelpful, because neither the geologist nor the cartographer is likely to be schooled in reading these.

The digital side of the edit mainly involves interrogating reference databases from which map features were extracted. Other editing resources include: *GSWA guide to editing maps, 2012–13* (Geological Survey of Western Australia 2012); *GSWA guide for editors* (Geological Survey of Western Australia 2011, in-house style guide); specialised geological references, such as *Glossary of geology* (Neuendorf et al. 2005); previously published maps from the same region; and general guides to editing, such as *Style manual* (Snooks & Co. 2002).

Issues and consequences

Finding a compromise between geological preferences and cartographic practicalities can have knock-on effects well beyond the bounds of the immediate geological map. This is exemplified in the following scenarios.

Map representation of rocks

Rock units are represented on maps with a rock code and a customised colour design, so the user can identify the rock unit using the map legend. Even though the code is unique to the rock and the sequence to which it belongs, the code is placed on the map against a coloured background, along with a plethora of other information. Furthermore, the colour designs used to represent similar or related rock types can be similar. So a siltstone unit belonging to one rock formation can have a similar colour design to a siltstone unit belonging to another rock formation.

On the CALYIE 1:100 000 Geological Series map (Cutten et al., 2010), siltstone units at different levels in the sequence (two different formations) are represented by the rock codes ìMEi-sl and ìMEl-sl.

When the cartographer returned the assembled map to the geologist for review before formal editing, the geologist noted that these rock codes and their colour designs were virtually indistinguishable, needing a magnifying glass to distinguish between an ‘i’ and an ‘l’. This has the potential to lead to serious misinterpretations of the geology by map users.

The editor was alerted to the problem, and asked to find a solution. Several wider implications had to be borne in mind.

To change either the rock code or the colour design on this map would make it inconsistent with nearby map sheets already published; a situation that is avoided as far as possible. However, it was agreed the rock code could not be changed, as this would invalidate the whole schema of rock codes for all related published maps. The compromise was to slightly modify the colour design to make the two units visually distinguishable, and adopt this new colour design as the standard for that unit. This solved the existing problem with the CALYIE map, but in effect constituted a change to the mapping standards for these rock units. Other existing maps will now need to be similarly changed when a new version or edition is published.

Geological legend

The geological legend summarises rock units and symbols used on the map, and gives a brief description of the rocks represented. Crucially, the legend arranges rock units in an order that has geological meaning. For example: rocks are arranged from youngest at the top to oldest at the bottom; the relationships between intrusive igneous rocks and other rocks are implied graphically; important time gaps or geological events are also represented.

However, differences in interpretation or emphasis by different geologists can result in the legend for the current map differing from that for previous, adjacent or related maps. The editor has to resolve this problem in consultation with the geologist and cartographer. Several issues that commonly arise are:

- Representing age-correlative units might be problematic.
- Older maps might have been used as the basis when constructing the current legend.
- The geologist's draft legend layout might not take account of cartographic conventions, or limitations.
- The GIS layers might have been amended since the legend was constructed, so that what the legend shows and what the map face contains might differ.
- Late-stage, wholesale rearrangements to the legend can be problematic for the cartographer, because the layout of other elements in the map can be affected.

Summary

Successful map editing depends on effective communication between the editor, the geologist, and the cartographer. There needs to be a good understanding by each of the others' roles and tasks. For example, the editor must have sufficient geological knowledge to understand the geoscientific content. The editor also needs to be familiar with several databases that underpin map compilation. The geologist needs to be aware of consequences for cartography and source databases when requesting changes to the content or layout of the map. The cartographer must be able to interpret and implement requests from the editor and author, and accommodate these within the constraints of the software.

During this panel discussion, we will explore the main stages in editing a map, demonstrating the interactions between geologist, cartographer and editor, highlighting editing issues that are unique to the GSWA map-making process, and noting ways in which it is similar to other editorial work (such as manuscripts).

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