Completion of a new national geological map series – the QMAP project

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Introduction

Geological maps provide a fundamental resource that underpins geoscience research and is widely applied into New Zealand industry and society. GNS Science and its New Zealand Geological Survey predecessor have been making geological maps of New Zealand for almost 150 years. The maps reflect the stored knowledge and the paradigms of their generation; they are interpretations based on observation and they are the testing grounds of geological concepts and process-related hypotheses. As such, geological maps have a shelf life. Continued data collection coupled with evolving ideas will render existing geological maps increasingly obsolete with time.

From 1956 until 1968 the New Zealand Geological Survey devoted most of its available resources to the production of a series of 1:250 000 geological maps covering all of the country. Known informally as the "4-mile" series (four miles to the inch, approximating the published scale), the map series was a triumph in that it portrayed regional New Zealand geology with uniformity and a consistent mapping philosophy. The series served science and other end-user needs well for several decades but, by the 1980s, amidst a highly productive period of research by government, academic and industry geologists, and the embracing of plate tectonic theory amongst others, these maps were becoming noticeably outdated.

The QMAP project

A 1992 government-instigated Review of Science in New Zealand stated "Revised geological mapping at a scale of 1:250 000 is urgently required. …" (Ministry of Research, Science and Technology 1993). A subsequent bid for funding from the newly created Foundation for Research, Science and Technology (FRST) to support a new national mapping project was successful.

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The QMAP (Quarter-million MAP) project began with a significant planning phase, in terms of individual map sheet resourcing, timing and costing as well as establishing map production processes and procedures. At any one time a core team of 10–15 geologists and technical support specialists based in the Lower Hutt and Dunedin offices of GNS Science were doing the bulk of the fieldwork, compilation and map and text production. More than 200 geologists, field assistants, GIS and text production support staff and reviewers contributed to the project over its 18 year duration (Fig. 1). Key contributions were made by subcontracted geologists with specialist local knowledge. The cooperation of New Zealand universities in allowing access to theses and other unpublished information improved the quality and efficiency of producing the new geological maps.

A pivotal early decision was to use Geographic Information Systems (GIS) software to produce lithographic quality maps; this was at the time an unproven capability. The GIS software allowed considerable experimentation in terms of map colour, symbology and layout, and substantially reduced costs compared to traditional manual cartography methods. The use of GIS software had another anticipated benefit and that has been the development of a powerful geological map spatial database. The use of GIS from the beginning has also enabled consistent terminology and data integrity standards to be established and maintained.

Mapping philosophy

Geological maps are representations of real world surface geology. They portray information about rocks, sediments and structures that have been observed by geologists in the field and interpolated, extrapolated and interpreted from there. The QMAP series is broadly chronostratigraphic (time-based) and the colours on the maps generally reflect each map unit's depositional or emplacement age, e.g. mid to pale greens represent Cretaceous rocks (145–65 million years) and yellows refer to Quaternary sediment (<2 million years). In detail, QMAP is also lithostratigraphic (rock-based), as most map units have

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formalised stratigraphic names that encompass rocks with a unique combination of composition, age, spatial extent and environment of deposition/emplacement. The QMAP series is intended for a wide audience, with even treatment of older and younger rock units, and an emphasis on deposits rather than landforms. As a general rule the uppermost deposit or rock unit more than 5 metres thick has been depicted, hence veneers of soils, tephra, loess and scree are commonly omitted. The accompanying geological legends are crucial for understanding the map. The legends not only provide a description of each map unit but they also place the map units in temporal (and to some extent spatial) context relative to each other. The legends are a pictorial representation of geological history and also provide clues as to what lies beneath the rocks at the surface, especially when used with the geological cross-sections that are presented on each map.

Science highlights

The QMAP series has resulted in a vast new accumulation of data, much of it collected during fieldwork in areas that geologically were poorly known. Many areas of Stewart Island and Fiordland for instance were unvisited prior to this and the contrast between the original 4-mile series and the QMAP series maps for these areas is marked. Through a combination of extensive ground traverses and observation, geochemistry and geochronology, a stunning pluton intrusion history has emerged in southern New Zealand. Intrusion of these rocks reflects a very high magma flux at a long-lived mid Paleozoic continental margin that evolved into a Mesozoic subduction zone on the edge of the Gondwana supercontinent (Turnbull & others 2010).

In Northland and East Cape the concept of significantly allochthonous rocks has been validated; large blocks of Cretaceous to Oligocene sedimentary and volcanic rock have been thrust southwards up to 200 km over younger rocks or other thrust packets (Isaac 1996; Mazengarb & Speden 2000; Edbrooke 2001; Edbrooke & Brook 2009). The mapping has shown that distal parts of the Northland Allochthon have largely disintegrated into melange around southern Kaipara Harbour and Whangaparaoa.

In the Taupo Volcanic Zone, QMAP developed a stratigraphic map unit approach which grouped eruptives emanating from one source over a discrete time interval. Rhyolitic ignimbrites originating from at least eight calderas during a period of intense explosive volcanism in the middle Quaternary dominate the mapped area around Taupo and Rotorua (Edbrooke 2005; Leonard & others 2010; Lee & others 2011). The maps record the impact of these super-volcanoes over large areas of the central North Island.

More than 20% of New Zealand's surface geology is "greywacke" – a loose yet useful term to describe the indurated, mostly Mesozoic sandstone and mudstone rocks forming much of the Southern Alps and the axial ranges of the North Island. These rocks are typically unfossiliferous, lack resolvable internal stratigraphy and are complexly deformed. In combination with parallel research that fingerprinted various constituent blocks of greywacke using innovative petrology, geochemistry and geochronology techniques, the QMAP project has achieved a much more coherent and detailed representation of these problematic rocks (e.g. Begg & Johnston 2000; Forsyth 2001; Rattenbury & others 2006; Cox & Barrell 2007).

International significance

The QMAP project is a world first example of national geological map series conceived and implemented using GIS technology. The high degree of logical consistency between the 21 individual map sheets and the early adoption of controlled terminology has facilitated production of the combined QMAP Seamless GIS dataset. This dataset is in turn well placed to adopt the emerging international geological mapping data model standard and controlled vocabularies as well as contribute to global interoperability initiatives such as the OneGeology project to produce a digital geological map of the world.

Measuring science quality and impact

Each geological map and accompanying explanatory text in the QMAP series underwent rigorous internal and external review as well as specialist editorial involvement. Yet the comparison of the quality and impact of fundamental science dataset resources, such as geological maps, against other science is fraught. The sector standard measure is the number of refereed science publications, particularly in so-called high-impact international journals. Geological maps are slow to produce (5–8 years), local (national) rather than international in their audience appeal, and are published outside mainstream journals. Established citation indexes such as Scopus and ISI Web of Science do not generally recognise geological map series. Many usages of geological maps in journal article figures are not even referenced, perhaps because these authors treat such map information as a fundamental resource. So at a superficial level, publishing a geological map is not a great career move for a geologist when numbers of publications and citations are all-important.

The Google Scholar search engine, however, has a less rigid view of what constitutes a citeable piece of scientific work and allows a crude comparison against mainstream journal articles. Many of the listed Google Scholar citations of QMAP geological maps are in "grey" literature such as reports, submissions and articles, demonstrating impact beyond the research science sphere. Even without the unacknowledged instances, the 21 QMAP series maps have been cited 564 times, averaging 3.8 per map per year which is a respectable level for a geoscience journal paper. More significant is the fact that geological maps are cited for decades. A geological map of Victoria Land, Antarctica, published as a New Zealand Geological Survey bulletin (Gunn & Warren 1962), is probably the most cited earth science publication on Antarctica (~350) and with 33 citations since 2007 is at a level equivalent to the top 20 of all Antarctic science publications.

The other important measure of geological map impact is map sales. Over 11 000 QMAP series maps have been sold ($35 each), averaging around 70 per map per year, and sales of their digital data equivalents on CD ($30) have exceeded 1000 copies. The sale volumes exceeded original estimates and many of the original print runs sold out, so 10 sheets have had to be reprinted. The effectiveness of steps towards free internet delivery of QMAP and other geological map data will need to be measured more in terms of data downloads in the future.

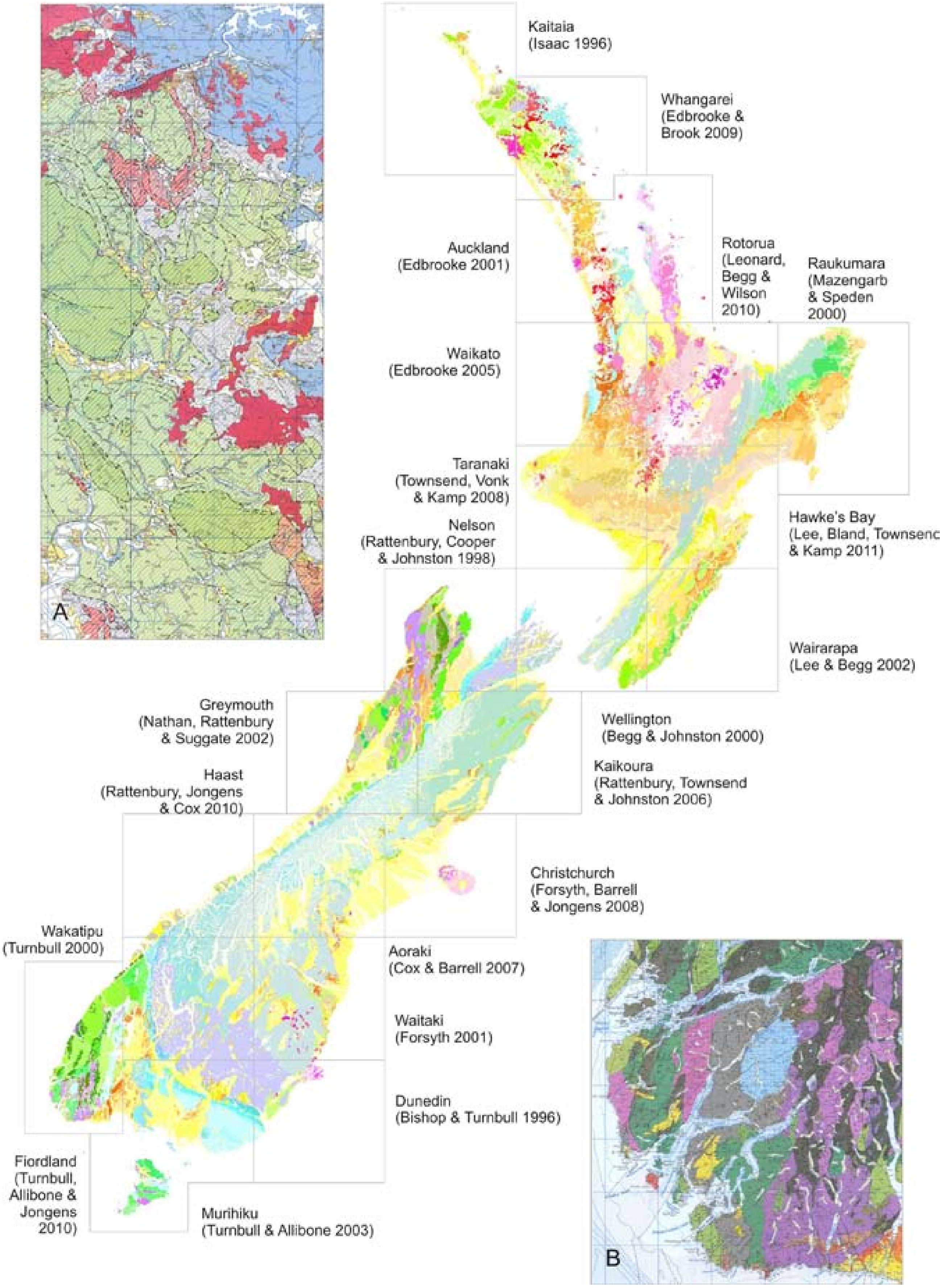
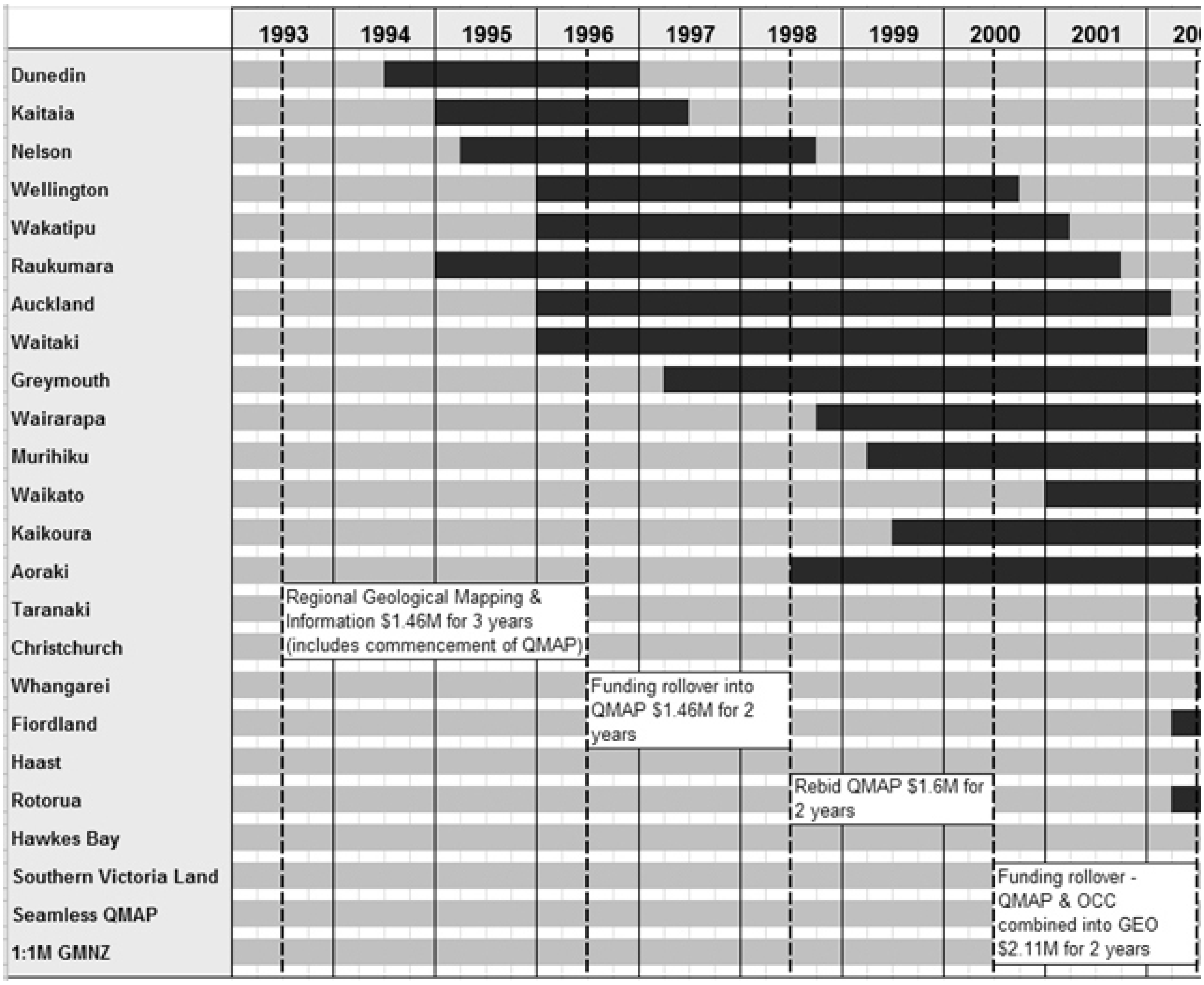


Figure 1. The QMAP 1:250 000 Geological Map of New Zealand series consists of 21 individual geological maps, which are now being merged into a seamless GIS dataset. Inset A shows geological detail of the Northland Peninsula, including the displaced Northland Allochthon rocks with the white diagonal overprint (after Edbrooke & Brook 2009). Inset B shows the complexity of igneous intrusions and Paleozoic metamorphosed sedimentary rocks in southwest Fiordland (after Turnbull & others 2010).

Funding

The QMAP project began early in the era of competitive Public Good Science Funding administered by FRST. Starting with the initial bid in 1993 and two periods of re-bidding in 1998 and 2004, with intervening funding roll-overs (requiring new contracting) in 1996, 2000 and 2002, the QMAP project had on-going financial support from FRST until 2010 (Fig. 2). The episodic bidding, reviews, contract drawing and negotiations were distractions from a highly focused and prescriptive long-term project, but the contract periods and intervals between bidding lengthened throughout the course of the project. The competitive funding model requirement for external and independent review at various stages through the project life contributed to the successful project outcome and completion. With the establishment of the Ministry of Science and Innovation and devolution of core funding to individual Crown Research Institutes the funding signals are less clear into the future. The QMAP project, as originally envisaged, was completed in this early stage of core funding management by GNS Science.

Figure 2 (below and opposite). Production schedule of the 21 geological maps in the QMAP series (with three additional projects) in the context of various FRST funding contracts.



Future directions

As mentioned in the introduction to this article, geological maps have a shelf life, and without new input the QMAP geological map sheets and their digital data equivalents would themselves become slowly obsolete. The use of GIS and the assembly of the QMAP Seamless GIS dataset have provided an opportunity to keep these geological map data current through regular and incremental updating. The future of printed hardcopy maps is less certain, as these are expensive to produce and require considerable resource commitment.

The QMAP project has resulted in high-quality regional geological map coverage of New Zealand. The data do not, however, meet the need for site-specific information for building construction, infrastructure and other property. Use of QMAP data at these detailed scales is inappropriate and strongly discouraged. New geological mapping projects at greater scales are under way to improve detail and knowledge of urban areas and some key resource-producing areas. These projects are also including 3D geological modelling as part of the suite of products. Mapping geologists think in 3D, and portraying geology as a map on a flat piece of paper under-sells their insight into the subsurface. Through 3D geological models they can convey their understanding more easily to the end user. The Canterbury earthquakes since late 2010 have resulted in re-prioritising of urban geological mapping, and a team of mapping geologists is synthesising a huge dataset of groundwater drill hole information and newly acquired results of geotechnical probe testing with the aim of creating a robust 3D model of Christchurch's near-surface geology. This model will then be made available to geotechnical specialists to assist in the evaluation of ground conditions for future construction work. Many other parts of New Zealand are vulnerable to earthquake-related damage and the Christchurch urban geology project will set the standard for geological mapping and data modelling in other cities in the future.

Acknowledgements

The QMAP series was achieved through early vision, sound implementation, geological nous and a lot of hard yet very rewarding work by the QMAP team. FRST provided continuous funding for most of the series through contracts C05303, C05X0003 and C05X0401 and GNS Science core funding the last two years. The support of GNS Science, New Zealand universities and the wider geoscience community has been greatly appreciated. Hamish Campbell, Steve Edbrooke and Ian Graham offered useful comments on drafts this article.

References

The references below include all 21 QMAP sheets. These are available in printed hardcopy and digital formats through Publication Sales, GNS Science, at http://www.gns.cri.nz/Home/Products/Maps/Geological-Maps

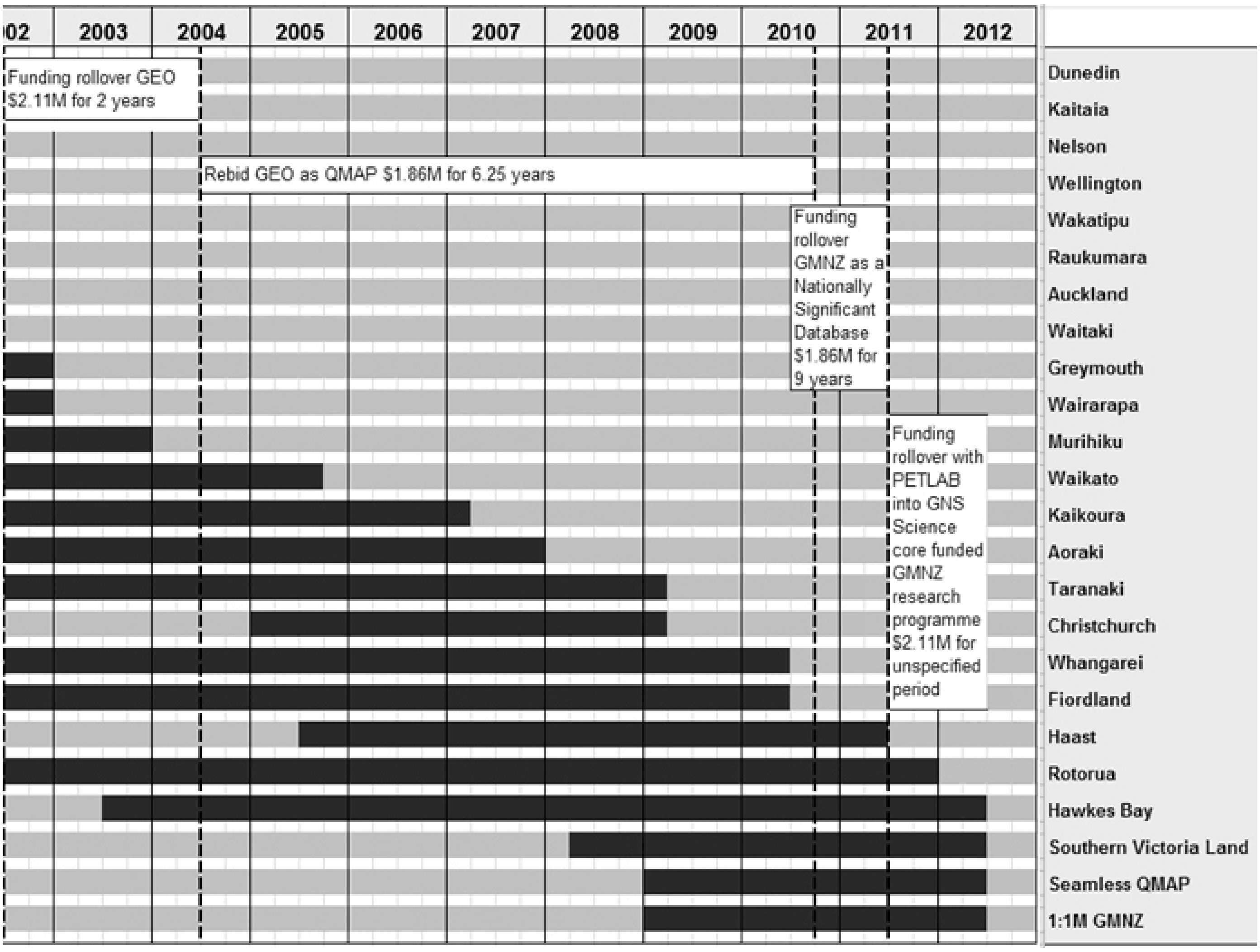
Begg, J.G.; Johnston, M.R. (compilers) 2000: Geology of the Wellington area: scale 1:250 000. Lower Hutt: Institute of Geological & Nuclear Sciences. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 10*. 64 p. + 1 folded map

Bishop, D.G.; Turnbull, I.M. (compilers) 1996: Geology of the Dunedin area: scale 1:250 000. Lower Hutt: Institute of Geological & Nuclear Sciences. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 21*. 52 p. + 1 folded map

Cox, S.C.; Barrell, D.J.A. (compilers) 2007: Geology of the Aoraki area: scale 1:250 000. Lower Hutt: GNS Science. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 15*. 71 p. + 1 folded map

Edbrooke, S.W. (compiler) 2001: Geology of the Auckland area: scale 1:250 000. Lower Hutt: Institute of Geological & Nuclear Sciences Limited. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 3*. 74 p. + 1 folded map

Edbrooke, S.W. (compiler) 2005: Geology of the Waikato area: scale 1:250 000. Lower Hutt: Institute of Geological & Nuclear Sciences. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 4*. 68 p. + 1 folded map



Edbrooke, S.W.; Brook, F.J. (compilers) 2009: Geology of the Whangarei area: scale 1:250 000. Lower Hutt: GNS Science. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 2*. 68 p. + 1 folded map

Forsyth, P.J. (compiler) 2001: Geology of the Waitaki area: scale 1:250 000. Lower Hutt: Institute of Geological & Nuclear Sciences Limited. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 19*. 64 p. + 1 folded map

Forsyth, P.J.; Barrell, D.J.A.; Jongens, R. (compilers) 2008: Geology of the Christchurch area: scale 1:250 000. Lower Hutt: GNS Science. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 16*. 67 p. + 1 folded map

Gunn, B.M.; Warren, G. 1962: Geology of Victoria Land between the Mawson and Mulock Glaciers, Antarctica. *New Zealand Geological Survey bulletin 71*. 156 p.

Isaac, M.J. (compiler) 1996: Geology of the Kaitaia area: scale 1:250 000. Lower Hutt: Institute of Geological & Nuclear Sciences. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 1*. 44 p. + 1 folded map

Lee, J.M.; Begg, J.G. (compilers) 2002: Geology of the Wairarapa area: scale 1:250 000. Lower Hutt: Institute of Geological & Nuclear Sciences Limited. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 11*. 66 p. + 1 folded map

Lee, J.M.; Bland, K.; Townsend, D.B.; Kamp, P.J.J. (compilers) 2011: Geology of the Hawke's Bay area: scale 1:250 000. Lower Hutt: Institute of Geological & Nuclear Sciences Limited. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 8*. 93 p. + 1 folded map

Leonard, G.S.; Begg, J.G.; Wilson, C.J.N. (compilers) 2010: Geology of the Rotorua area: scale 1:250 000. Lower Hutt: Institute of Geological & Nuclear Sciences Limited. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 5*. 102 p. + 1 folded map

Mazengarb, C.; Speden, I.G. (compilers) 2000: Geology of the Raukumara area: scale 1:250 000. Lower Hutt: Institute of Geological & Nuclear Sciences Limited. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 6*. 60 p. + 1 folded map

Ministry of Research, Science and Technology 1993. Review of geology and energy research. *MoRST Science Review 7*. Ministry of Research, Science and Technology, Wellington.

Nathan, S.; Rattenbury, M.S.; Suggate, R.P. (compilers) 2002: Geology of the Greymouth area: scale 1:250 000. Lower Hutt: Institute of Geological & Nuclear Sciences. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 12*. 58 p. + 1 folded map

Rattenbury, M.S.; Cooper, R.A.; Johnston, M.R. (compilers) 1998: Geology of the Nelson area: scale 1:250 000. Lower Hutt: Institute of Geological & Nuclear Sciences Limited. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 9*. 67 p. + 1 folded map

Rattenbury, M.S.; Jongens, R.; Cox, S.C. (compilers) 2010: Geology of the Haast area: scale 1:250 000. Lower Hutt: Institute of Geological & Nuclear Sciences Limited. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 14*. 67 p. + 1 folded map

Rattenbury, M.S.; Townsend, D.; Johnston, M.R. (compilers) 2006: Geology of the Kaikoura area: scale 1:250 000 geological map. Lower Hutt: GNS Science. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 13*. 70 p. + 1 folded map

Townsend, D.; Vonk, A.; Kamp, P.J.J. (compilers) 2008: Geology of the Taranaki area: scale 1:250 000. Lower Hutt: GNS Science. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 7*. 77 p. + 1 folded map

Turnbull, I.M. (compiler) 2000: Geology of the Wakatipu area: scale 1:250 000. Lower Hutt: Institute of Geological & Nuclear Sciences. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 18*. 72 p. + 1 folded map

Turnbull, I.M., Allibone, A.H. (compilers) 2003: Geology of the Murihiku area: scale 1:250 000. Lower Hutt: Institute of Geological & Nuclear Sciences Limited. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 20*. 74 p. + 1 fold. map

Turnbull, I.M.; Allibone, A.H.; Jongens, R. (compilers) 2010: Geology of the Fiordland area: scale 1:250 000. Lower Hutt: GNS Science. *Institute of Geological & Nuclear Sciences 1:250 000 geological map 17*. 97 p. + 1 folded map