Engagement and Impact 2018

Macquarie University

MQU04 (ST) - Impact

Overview

Title

(Title of the impact study)

TerraneChron® delivers a powerful tool to help the mineral exploration industry discover new gold, copper, nickel and other mineral deposits around the world.

Unit of Assessment

04 - Earth Sciences

Additional FoR codes

(Identify up to two additional two-digit FoRs that relate to the overall content of the impact study.)

11 - Medical and Health Sciences
21 - History and Archaeology

Socio-Economic Objective (SEO) Codes

(Choose from the list of two-digit SEO codes that are relevant to the impact study.)

84 - Mineral Resources (excl. Energy Resources)
85 - Energy
86 - Manufacturing
97 - Expanding Knowledge

Australian and New Zealand Standard Industrial Classification (ANZSIC) Codes

(Choose from the list of two-digit ANZSIC codes that are relevant to the impact study.)

10 - Exploration and Other Mining Support Services

Keywords

(List up to 10 keywords related to the impact described in Part A.)

Geochemical Remote Sensing

Mineral Exploration

Energy Exploration

Geological Mapping

Tectonic History

Crust Evolution

Isotopic Mapping

Radiometric Dating

Sensitivities

Commercially sensitive

No

Culturally sensitive

No

Sensitivities description

(Please describe any sensitivities in relation to the impact study that need to be considered, including any particular instructions for ARC staff or assessors, or for the impact study to be made publicly available after EI 2018.)

Aboriginal and Torres Strait Islander research flag

(Is this impact study associated with Aboriginal and Torres Strait Islander content?
NOTE - institutions may identify impact studies where the impact, associated research and/or approach to impact relates to Aboriginal and Torres Strait Islander peoples, nations, communities, language, place, culture and knowledges and/or is undertaken with Aboriginal and Torres Strait Islander peoples, nations, and/or communities.)

No

Science and Research Priorities

(Does this impact study fall within one or more of the Science and Research Priorities?)

Yes

Science and Research Priority	Practical Research Challenge
Resources	A fundamental understanding of the physical state of the Australian crust, its resource endowment and recovery.

Impact

Summary of the impact

(Briefly describe the specific impact in simple, clear English. This will enable the general community to understand the impact of the research.)

BHP Billiton, Rio Tinto, Vale, and many other companies use TerraneChron® to help them discover new mineral deposits.

The technique, invented and commercialised by Macquarie University, analyses grains of zircon collected from streams and riverbeds as a reconnaissance tool to rapidly identify rock systems of potential economic interest, without the time and expense of traditional mapping.

TerraneChron® has contributed to the discovery of mineral deposits worth many billions of dollars in Australia and around the world. It has been adopted by government survey organisations in Australia, Norway, Brazil, Argentina and other countries and is a key tool for UNCOVER Australia, a national collaboration launched in 2013. It has also transformed basic geological research.

Beneficiaries

(List up to 10 beneficiaries related to the impact study)

Minerals and Energy exploration sector

International, National and State Geological Surveys

Global Earth evolution research groups

Geochemical Technology Manufacturers (ICPMS Systems)

Countries in which the impact occurred

(Search the list of countries and add as many as relate to the location of the impact)

Australian Antarctic Territory
Argentina
Australia
Brazil
Canada
Chile
China (excludes SARs and Taiwan)
Congo, Republic of
France
Greenland
Iceland

India
Iran
Italy
Laos
Mongolia
New Caledonia
New Zealand
Norway
Russian Federation
South Africa
Turkey
United States of America
Colombia
Indonesia
Kyrgyzstan
Papua New Guinea
Mali
Namibia
Serbia
Spain
Ukraine
Zambia

Details of the impact

(Provide a narrative that clearly outlines the research impact. The narrative should explain the relationship between the associated research and the impact. It should also identify the contribution the research has made beyond academia, including:
- who or what has benefitted from the results of the research (this should identify relevant research end-users, or beneficiaries from industry, the community, government, wider public etc.)
- the nature or type of impact and how the research made a social, economic, cultural, and/or environmental impact
- the extent of the impact (with specific references to appropriate evidence, such as cost-benefit-analysis, quantity of those affected, reported benefits etc.)
- the dates and time period in which the impact occurred.

NOTE - the narrative must describe only impact that has occurred within the reference period, and must not make aspirational claims.)

Traditional mineral exploration relies on geological mapping, supported by geophysical surveys and remote sensing. Determining the age and origin of mapped rocks, key information in mineral exploration, is an expensive and time-consuming process. TerraneChron® has fundamentally changed this.

TerraneChron® is based on zircon, a common mineral in many igneous rocks, and so resistant that it survives well in river placer deposits. Using laser-based analysis of an individual zircon grain, we can measure its age, its trace-element pattern and the Hf-isotope signature, revealing a great deal about the type of rock it came from. The analysis of ca 100 grains from a stream sample (ca 4 days work) provides an overview of the ages and origins of rocks in the drainage basin. This information allows prospectors to evaluate the geological history of a drainage basin (from 1 to 1000 km across) and focus their search on areas with the most promising geology. The technique has also proven useful in petroleum exploration, because it helps evaluate the age and provenance of a sediment package.

GEOCHEMICAL REMOTE SENSING
Macquarie's Centre for Geochemical Evolution and Metallogeny of Continents (GEMOC, now part of the ARC Centre of Excellence for Core to Crust Fluid Systems), provides TerraneChron®'s geochemical remote sensing services to exploration companies on a commercial or commercial/collaborative basis. The companies send samples to GEMOC, where they are analysed. Over time GEMOC has developed both broad expertise in interpreting the results, and a large database with which new samples can be compared. When the data have been interpreted, a PowerPoint report is provided to the company describing the tectonic and rock-type history of the sampled area. Usually the companies will provide locations, so that GEMOC can integrate the new data into the database.

IMPACT ON TIME SAVED
The technical developments that led to TerraneChron®, in particular the in situ analysis of Hf isotopes in zircon, have made possible a volume of analyses and a level of interpretation that were not previously imaginable. In three months GEMOC can analyse more samples than was previously possible in a lifetime.

For the exploration industry, the ability to rapidly assess the geology of a given area means less time is wasted exploring in areas unlikely to be prospective for deposits; less time and less money spent on finding the next deposit increases its net present value.

MINERAL EXPLORATION
TerraneChron® has proved particularly useful in exploration for gold, copper and nickel deposits, and has been used to target many other resource types. One helicopter can now quickly sample the length of a river, and large areas of alluvial deposits can be surveyed in a few months. As an example, one company scanned the entire western side of the Andes for Cu-porphyry deposits, in one field season.

INTERNATIONALLY ACCESSIBLE SOFTWARE
To improve and speed up data-processing for laser-ablation analysis, GEMOC developed a sophisticated software package, commercialised as GLITTER. Over 300 copies of GLITTER have been sold internationally (including those bundled with instrument sales by Agilent), and this has helped both to standardise data protocols and to increase productivity in labs worldwide. GEMOC continues to update GLITTER, and to provide service to users.

GEOLOGICAL SURVEYS
The TerraneChron® or similar techniques are now used by national and state geological surveys around the world. All of the geological surveys in Australia use the techniques, as do e.g., the Norwegian, Brazilian and Argentinian surveys; other national surveys use techniques derived from Macquarie's research and innovations related to TerraneChron®. This has impacted on how governments understand and manage their geological endowment.

UNCOVER AUSTRALIA
"UNCOVER Australia" is national and state-based government collaboration drawing on universities, companies and geological surveys. Launched in 2013, it will explore the 70% of Australia's bedrock that lies beneath younger cover, and probably hosts many economic deposits. A major initiative in this effort will be the isotopic mapping of the entire continent, using the TerraneChron® approach. This illustrates the impact that TerraneChron® has had on geological thinking nationally.

ESTIMATING ECONOMIC IMPACT
It is difficult to estimate the economic value of the impact on resources companies and governments, because companies hold such information confidential. However, industry sources are glad to explain that TerraneChron® not only has greatly increased in exploration productivity, but has been essential to the discovery of major deposits. The economic impact therefore is in the billions of dollars for Australian and International companies.

INDUSTRY STEP CHANGE
TerraneChron® has fundamentally altered the strategies of the resources industry around the world. By working closely with industry and governments on the development and commercialisation of TerraneChron®, Macquarie has developed a virtuous cycle. Samples are sent by industry for analysis, and those analyses are then used to inform a database which is bringing together a deeper understanding of the evolution of the planet. Companies then use that database and the concepts arising from it to make probabilistic evaluations about where best to explore for new deposits. The training that Macquarie postgraduates receive in both the technology and the conceptual approaches is highly prized by industry; in particular, Rio Tinto heavily recruits from the Macquarie campus.

BASIC RESEARCH
TerraneChron® has impacted basic geological research, leading to the concept of isotopic mapping of large areas such as Yilgarn Craton (covering most of Western Australia) and SE Tibet to identify major Earth structures that control the localization of major mineral deposits.

Associated research

(Briefly describe the research that led to the impact presented for the UoA. The research must meet the definition of research in Section 1.9 of the EI 2018 Submission Guidelines. The description should include details of:
- what was researched
- when the research occurred
- who conducted the research and what is the association with the institution)

GEMOC's TerraneChron® methodology has delivered a powerful tool for geochemical remote sensing for the mineral exploration sector, allowing virtual geological mapping of rock types and tectonic events rapidly and cost-effectively, especially for inaccessible and difficult regions on regional (10-1000s km2) scales. Proof of concept was delivered by a series of peer-reviewed research papers (by O'Reilly, Griffin and Belousova) in international journals, many with industry co-authors. Detailed regional and global terrane studies led to a paradigm-changing reassessment of the mechanisms and timing of the formation and evolution of Earth's crust on which we live and from which we derive civilisation's resources. It has also has led to the concept of isotopic mapping of large areas (e.g. Yilgarn Craton, SE Tibet, E NSW) to identify major Earth structures that control the localisation of e.g. major copper, gold and nickel deposits. Thus TerraneChron® has accelerated and focussed exploration through applications of fundamental research advances that have serially expanded our understanding of Earth processes. This knowledge base is embodied and communicated in over 200 major publications (many highly cited) dominantly authored by O'Reilly, Griffin and Belousova from GEMOC, all 3 as academic staff at MQ from 2002-2016 (2002-2005 Griffin was seconded full-time at MQ before being appointed as Professor). 50 of these papers are co-authored with industry and geological survey end-users.

FoR of associated research

(Up to three two-digit FoRs that best describe the associated research)

04 - Earth Sciences
08 - Information and Computing Sciences

References (up to 10 references, 350 characters per reference)

(This section should include a list of up to 10 of the most relevant research outputs associated with the impact)

Xiong, Q., Griffin, W.L., Zheng, J-P., O'Reilly, S.Y., Pearson, N.J., Xu, B. and Belousova, E.A. 2016. Southward trench migration at 130-120 Ma caused accretion of the Neo-Tethyan forearc lithosphere in Tibetan ophiolites. Earth Planetary Science Letters 438, l57-65. DOI: 10.1016/j.epsl.2016.01.014

Griffin, W.L., Begg, G.K. and O'Reilly, S.Y. 2013. Continental-root control on the genesis of magmatic ore deposits. Nature Geoscience 6, 905-910.

Belousova, E.A., Kostitsyn, Y.A., Griffin, W.L., Begg, G.C., O'Reilly, S.Y. and Pearson, N.J. 2010. The growth of the continental crust: Constraints from zircon Hf-isotope data. Lithos, 119, 3-4, 457-466.

Wang, X.L., Zhou, J.C., Griffin, W.L., Wang, R.-C., Gui, J.-S., O'Reilly, S.Y., Xu, X., Liu, X.M. and Zhang, G.L. 2007. Detrital zircon geochronology of Precambrian basement sequences in the Jiangnan orogen: Dating the

assembly of the Yangtze and Cathaysia Blocks. Precambrian Research, 159, 1-2, 117-131.

Belousova, E.A., Griffin, W.L. and O'Reilly, S.Y. 2006. Zircon crystal morphology, trace element signatures and Hf isotope composition as a tool for petrogenetic modelling: Examples from Eastern Australian granitoids. Journal of Petrology, 47, 2, 329-353

Zheng, J., Griffin, W.L., O'Reilly, S.Y., Zhang, M., Pearson, N.J. and Pan, Y. 2006. Widespread Archean basement beneath the Yangtze craton. Geology, 34, 6, 417-420.

Griffin, W.L., Belousova, E.A., Shee, S.R., Pearson, N.J., O'Reilly, S.Y. 2004. Archean crustal evolution in the northern Yilgarn Craton: U-Pb and Hf-isotope evidence from detrital zircons. Precambrian Research, 131, 3-4, 231-282.

Jackson, S.E., Pearson, N.J., Griffin W.L. and Belousova, E.A. 2004. The application of laser ablation-inductively coupled plasma-mass spectrometry to in situ U–Pb zircon geochronology. Chemical Geology, 211, 1-2, 47-69.

Belousova, E.A., Griffin, W.L., O'Reilly, S.Y. and Fisher, N.I. 2002. Igneous zircon: Trace element composition as an indicator of source rock type. Contributions to Mineralogy and Petrology, 143, 5, 602-622.

Griffin, W.L., Wang, X., Jackson S.E., Pearson, N.J., O'Reilly, S.Y., Xu, X. and Zhou, X. 2002. Zircon chemistry and magma mixing, SE China: In-situ analysis of Hf isotopes, Tonglu and Pingtan igneous complexes, Lithos, 61, 3-4, 237-269.

Additional impact indicator information

Additional impact indicator information

(Provide information about any indicators not captured above that are relevant to the impact study, for example return on investment, jobs created, improvements in quality of life years (QALYs). Additional indicators should be quantitative in nature and include:
- name of indicator (100 characters)
- data for indicator (200 characters)
- brief description of indicator and how it is calculated (300 characters).)

Name

GLITTER Licenses Sold

Indicator Data

~270 new licences and 110 upgrades from 2002-2016. Licences in total (including pre-2002 sales = 287 full and 110 upgrades)

Indicator Description

The GLITTER software package has been a key enabler of global impact for TerraneChron®. The data is sourced internally from TerraneChron®.