Idealised numerical model of the Southern Ocean overturning, at 1/16th degree resolution.
Introduction

PRISE continued to operate as an externally funded research group within the Research School of Earth Sciences, providing access to the Research School’s specialised equipment and expertise in areas of geochronology, geochemistry and archaeometry. PRISE scientists also conducted their own research projects as supported by successful grant applications and supervised activities of both RSES and international postgraduate students.

During 2010 Dr Greg Yaxley moved to the Earth Materials and Processes group in order to take up an ARC Future Fellowship and Dr Marc Norman was transferred to the Earth Environment group. A/Prof Mark Fanning was made a Fellow of the Geological Society of America and both he and Dr Richard Armstrong were recognised by colleagues at the VII South American Symposium on Isotope Geology for their long-standing scientific collaborations in Argentina, Brazil and Chile. Dr Richard Armstrong was part of a successful ARC Discovery grant led by Prof Rainer Grün (Earth Environment) and also received a grant from AusAid to attend the 23rd Colloquium of African Geology in South Africa as an invited speaker.

PRISE staff members were again actively involved in wide-ranging collaborative research projects with academic colleagues throughout the world, as well as providing research and analytical skills to industry and Government agencies on a commercial basis. During 2010 PRISE hosted eighteen local and international visitors, most of whom were involved in ongoing collaborative projects using the SHRIMP, Laser ablation- and solution ICPMS and TIMS analytical facilities. PRISE staff also participated in field-orientated studies in Australia, Africa, SE Asia, Antarctica and North and South America.

Some areas of current research include:

- Multi-isotopic and trace element zircon studies to constrain magmatic evolution of plate margins and continental reconstructions; combined U-Th-Pb, Lu-Hf, Ti geothermometry, trace and REE chemistry, and oxygen isotope studies.
- Development of in situ sulphur isotope analytical protocols for the SHRIMP, including new protocols for the analysis of the minor isotopes $^{33}$S and $^{36}$S.
- Use of sulphur isotopes to aid in understanding the origin and conditions of formation of metal sulphides and sulphates. Developments and characterisation of new S sulphide and sulphate isotope standards.
- Chronology of the Archaean-Proterozoic transition and the rise of oxygen in the atmosphere
- Bioarchaeology in early Cambodian populations and in situ oxygen, carbon and strontium analysis of human teeth
- Geological connection between West Antarctica and Patagonia since the late Paleozoic: Tectonism, Palaeogeography, Biogeography and Paleoclimate
- Placing realistic constraints on the timing of world-wide Neoproterozoic glacial events: a critical examination of the "Snowball Earth" hypothesis
- The growth, geochronology, evolution and mineralisation of cratons
Rapid Emplacement Of The One Of The World’s Greatest Continental Magmatic Provinces

Precise Age Constraints On The Bushveld Complex

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The Bushveld Complex in southern Africa is one of the largest examples of continental magmatism on Earth. If the precursor felsic volcanic rocks of the Rooiberg Group are included, the volume of magma generated is estimated to be up to a staggering 1,000,000 km³. The timing and the origin of the various components of the complex are, however, poorly constrained with some work suggesting thermal activity could have continued for up to a billion years (McNaughton, et al., 1993). This research is aimed at determining a precise chronology of events covering the entire history of the Bushveld Complex, using combined zircon U-Pb dating, with the aim at establishing some constraints on the possible origin of this massive and economically important event.

In the broadest sense, the Bushveld Complex is generally considered to include the volcanic rocks of the Rooiberg Group, the basaltic layered rocks of the Rustenburg Layered Suite, the granitic intrusive rocks of the Lebowa Granite Suite, plus the enigmatic Rashoop Granophyres. Representatives of all these major components were sampled for dating. U-Pb zircon dating of felsites of the roofing Rooiberg Group show that these precursors to the main phase of the Bushveld Complex were emplaced 2059.9 ± 1 Ma ago. This is significantly prior to intrusion of the main phase of the complex – as shown by dates obtained on zircons from the famous PGE-bearing Merensky Reef, and from a late-stage basic pegmatoid. These gave statistically identical ages of 2055.3 ± 1.2 Ma and 2056.3 ± 0.7 Ma respectively. Dating of granites of the Lebowa Suite that demonstrably intrude and post-date the mafic rocks, shows they were intruded at 2054 ± 2 Ma (a mean of several dates obtained on a variety of granites from this suite). A date of 2054 ± 4 Ma recently published by Dorland et al., 2006 on a rhyolite within the overlying sedimentary sequence of the Waterberg Group shows that the Bushveld Complex had cooled and had undergone significant erosion short time after intrusion of the mafic phase.

This high-precision geochronological study established for the first time that the whole event occurred over a very short time interval of approximately 4 Ma. The emplacement of all the intrusive rocks took place over an even briefer period of just 1-2 Ma, a time interval similar to that measured for large igneous volcanic provinces such as the Karoo or Deccan. Extensive recent geochronological investigations of large parts of southern Africa have shown that Bushveld-aged igneous rocks occur over a vast region of the subcontinent. These are currently the focus of a larger study aimed at discovering the full areal extent of rocks of this age and to establishing a possible causal link between the Bushveld Complex and a larger regional event. It certainly seems probable that the Bushveld Complex, unique as it is, was a part of some larger “Bushveld event”, rather than an isolated igneous event of unknown origin. Certainly some origins can now be discounted – it is unlikely that an extraterrestrial (impact) origin can be reconciled with the distinctly different ages now established for the Rooiberg and Bushveld events. The origin of this enormous and economically important complex is still uncertain, but the rapid emplacement and erosion does provide some clues. Even though the Bushveld was born in an instant – in geological terms – it’s impact on the geology and economy of region has been enormous.

References:


Lu-Hf isotope evidence for the provenance of Permian detritus in accretionary complexes of Patagonia and the Antarctic Peninsula region

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Lu-Hf isotope data has been carried out for dated Permian zircon grains from six samples of the latest Palaeozoic to Jurassic low-grade metasedimentary rocks of western Patagonia and the Antarctic Peninsula, as well as from potential source rocks in the North Patagonian Massif. The results for the metasedimentary rocks yield $\varepsilon_{Hf}$ values mostly between -15 and +4 (130 analyses), with a dominant range (more than 85%) of -6 to +1, indicating provenance from Permian magmatic rocks that incorporated continental crust with a significant residence time. Other zircon grains record more negative $\varepsilon_{Hf}$ values indicating derivation from yet more mature crustal sources. Permian subvolcanic granites in the North Patagonian massif appear to be the closest large source area and dated zircon grains from eight samples of these granites yield initial of $\varepsilon_{Hf}$ values of -12 to +4 (45 measurements), 84% of which fall between -6 and +1, the range shown by the metasediments. However, the North Patagonian massif also contains some more juvenile Permian-Carboniferous components not seen in the metasediments, so that this may not be the primary or unique source. These granites are considered to represent the southernmost extension of the Choiyoi province, which consists predominantly of Permian rhyolites that crop out on the eastern side of the Andes in central Argentina, for which unpublished Hf isotope data yield a very similar range to that of the metasediments. The widespread nature of the Choiyoi volcanic rocks and the predominance of Permian zircon could make this a more favoured source for the detrital grains.

Hf isotope data reinforce the uniformity of the provenance of the turbidite detrital zircons and confirm the Choiyoi siliceous large igneous province and the Permian granitic rocks of the North Patagonian Massif as feasible sources. They further confirm the dominantly crustal origin of the Permian magmas. A source region involving mixing of, for example, crustal materials of Panafrican/Brasiliano and Grenvillian ages, together with a minor but significant subduction-related magmatic input, is an isotopically feasible explanation and is broadly consistent with the provenance of pre-Permian crust in this region, but the proportions of such a mixture must have remained relatively constant. This supports the proposal that recently recognised but widespread Permian magmatism in Patagonia represents voluminous crustal melting in response to subducted slab break-off. The results are also consistent with the premise that the Antarctic Peninsula and southern Patagonia were closely located from Permian to Jurassic times, receiving detritus from the same source.
Cosmic Time Machine

How Scientists are Able to Look Backon the early Solar System

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If we were able to travel back in time about four and a half billion years, we’d be able to see the early planets of the solar system beginning to form around an infant sun. This was a time of massive and enormously violent impacts as forming planets swept debris and each other out of their orbital paths. It was around this time that scientists believe that a body about the size of mars smashed into the Earth which such force that enough matter was ejected to create the Moon.

As time passed things settled down, planets established their modern orbits and most of the collisions that were going to take place had done so. Then around four billion years ago, just about the time life was beginning on Earth, something odd happened. The orbits of Jupiter and Saturn shifted slightly which in turn perturbed Uranus and Neptune. The gravitational effects of this reshuffle extended out into the Oort Cloud – a halo of comets in the outer solar system. This gravitational wobble was enough to induce a shower of comets to enter the inner solar system, impacting asteroids and catapulting them like billiard balls across the orbits of the inner planets. The result was a second period of massive bombardment which undoubtedly had a profound effect on life on Earth.

But perhaps equally as interesting as these events are in themselves, is the way humans living four billion years later have been able to figure out just what did happen in the distant past. By working with tiny quantities of lunar soil gathered by the Apollo astronauts and using the most modern of analytical techniques we are starting to unravel the forensics of those distant times.

Using advanced mass spectrometry, we measured concentrations of elements like platinum and gold that are very rare on the Moon but abundant in asteroids and meteorites. This fingerprints what type of asteroid hit the Moon and where in the Solar System the impactor came from, that is, was it a comet or from the asteroid belt? This tells us about – large-scale dynamics of the Solar System that stirred up the impators and sent them careening toward the Sun, with us in the way.

Of course the really interesting question is not just where the impacts occurred but when? To work that out, we took advantage of radioactive decay. Over very long periods an isotope of potassium (40K) decays into argon (40Ar). When an asteroid or comet impacts the moon the enormous energy that’s liberated tends to turn rock into a fine spray of molten glass. This cools into the form of tiny glass spherules a fraction of a millimetre across. These spherules contain small traces of potassium 40 but essentially no argon because the melting releases it. As the spherules age, the radioactive decay of potassium 40 begins to introduce argon again.

Although the samples were collected from the Moon almost 40 years ago, this is the first time it’s been possible to perform advanced chemical analysis and isotope dating on the exact same spherule. Our aim is to build up a history of the frequency of impacts in our part of the solar system. One of the interesting and perhaps alarming things to arise from these studies is that the number of lunar impact has risen significantly over the last 400 million years. This raises interesting questions about recent shifts in orbital mechanics that might be tossing planet-size boulders towards the Earth, and possible effects that this cosmic billiard game might have had on our planet’s climate and ecosystems.

ANU ScienceWise article with graphics
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