AUSGEO news ISSUE 81 March 2006

Australian Government
Geoscience Australia

A TIME MACHINE for Geoscience Australia

A new SHRIMP ion microprobe means improved geochronological support for mineral exploration in Australia.

Richard Stern

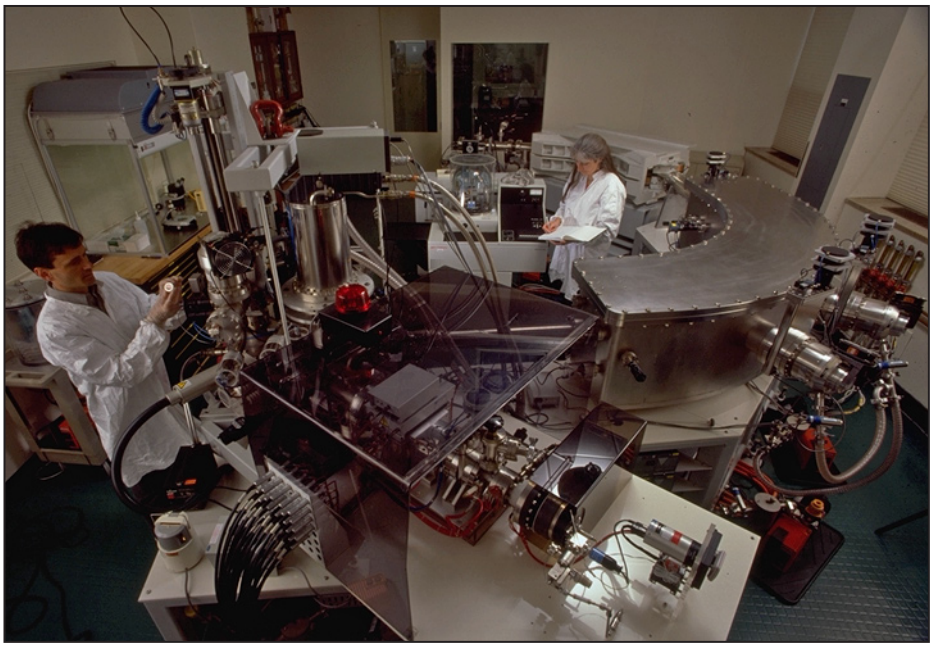
'Let's SHRIMP those zircons!' That kind of talk will become more common in Geoscience Australia when a new sensitive high resolution ion microprobe (SHRIMP) is installed in the basement of the Canberra headquarters next year. 'SHRIMP' has become part of the lexicon of geoscience, and now of Geoscience Australia.

Australian Scientific Instruments of the ACT was contracted in November 2005 to build and supply the specialised SHRIMP II. The signing of the contract by Dr Neil Williams, Geoscience Australia's CEO, and Ted Stapinski, ASI's Director (figure 1) was the culmination of a year-long effort by Geoscience Australia staff. In a novel partnership between government and industry, instrument time will be licensed back to ASI to conduct customer demonstrations and trial new hardware and software developments.

▲ **Figure 1.** Signing the SHRIMP purchase contract at Geoscience Australia. Seated are Ted Stapinski (Director, ASI) and Neil Williams (CEO, Geoscience Australia). At back (left to right) are Peter Southgate and Richard Stern (Geoscience Australia) and Ed Roberts (General Manager, ASI).

Smarter prospecting

It's getting harder to find new world-class mineral deposits in Australia, and mineral explorers need a comprehensive understanding of mineral systems within current and prospective terranes. One of Geoscience Australia's main roles is to provide key national-scale datasets, including geochronology, as a framework for exploration investment, particularly in greenfield regions and under cover. For example, Geoscience Australia and partners recently used SHRIMP geochronology to develop the geological event framework for the western Mount Isa Inlier (Neumann et al 2005). Geochronology, especially U–Pb (decay of uranium to lead) and targeted Ar–Ar (decay of potassium to argon) geochronology, provides the crucial time dimension of geological processes that form mineral deposits.



▲ **Figure 2.** A SHRIMP ion microprobe laboratory.

The purchase of a SHRIMP underlines the critical importance of geochronology in supporting mineral exploration investment in Australia. Geoscience Australia currently obtains all of its U–Pb geochronology data through SHRIMP instruments located in external labs, with Geoscience Australia staff visiting those facilities to make measurements. The in-house facility (figure 2) will enable better control over quality, quantity and timeliness of age data delivered to Geoscience Australia and its partners in the state and territory geological surveys. The new SHRIMP will revitalise the organisation's geochronology laboratory, enabling it to achieve world's best standards for Geoscience Australia and its clients. Geoscience Australia joins the Geological Survey of Canada, the United States Geological Survey, the Chinese Academy of Geological Sciences, the All Russian Geological Research Institute, and other major national research agencies throughout the world in recognising the importance of SHRIMP geochronology as a key resource in supporting mineral exploration.

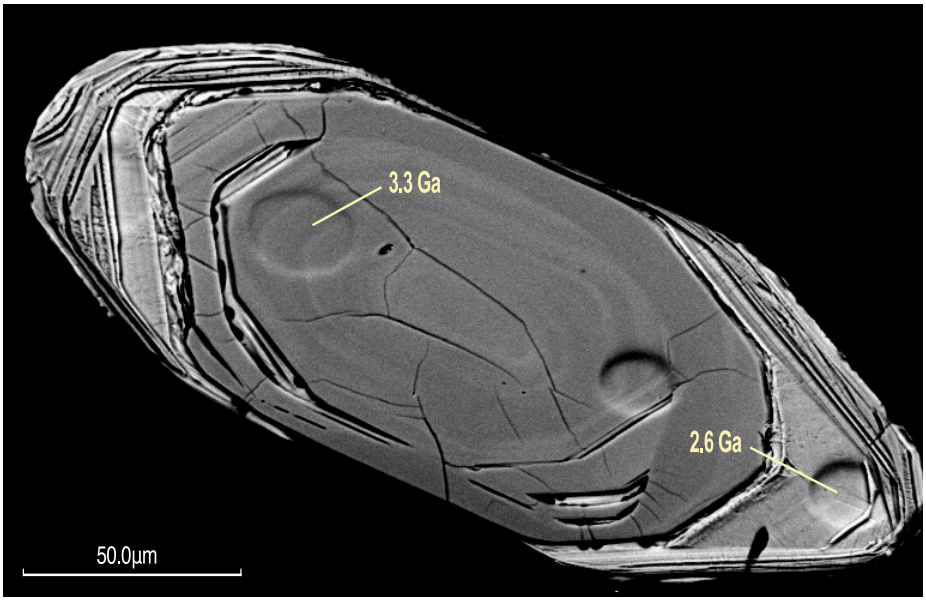


Figure 3. A sectioned zircon grain from a metamorphosed greywacke, imaged with backscattered electrons, subsequent to SHRIMP analysis (craters visible). A 3.3 Ga detrital core (dark grey) is mantled by a 2.6 Ga metamorphic overgrowth. From Böhm et al (2003).

Aussie excellence

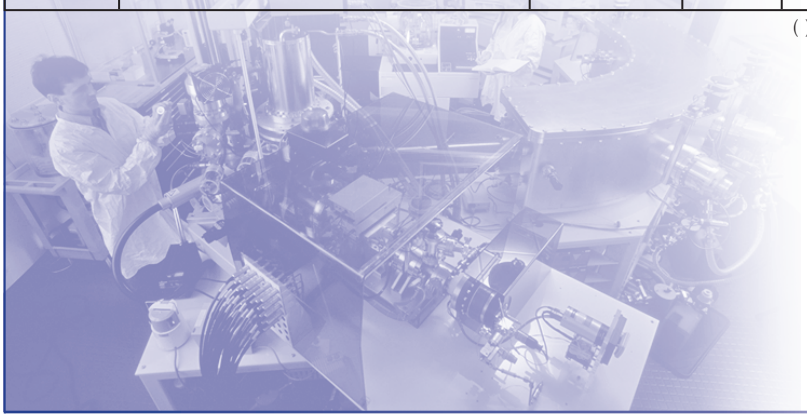
The SHRIMP is an internationally-recognized geochronology technology that was developed at the Australian National University in the late 1970's (Clement et al 1977). The prototype SHRIMP I became functional in 1980, and was followed in 1992 by a significantly improved version, SHRIMP II. Ion microprobes utilize a beam of charged particles to probe solids, such as individual mineral grains, for the purpose of elemental and isotopic analysis, and although these instruments were already used for geochemical purposes, none was tailored for geochronology until the introduction of the SHRIMP.

Commercial distribution of the SHRIMP II by ASI began in 1993 with the delivery of an instrument to Curtin University of Technology, and since then ASI has sold the SHRIMP II and an experimental design, SHRIMP-RG, to several research institutions around the world. The GA-SHRIMP II, expected to be delivered in the third quarter of 2007, will be the 14th instrument (Table 1). An international community of scientists that primarily use the SHRIMP and competitor technologies has emerged to become a major force in U–Pb geochronological research.

Table 1. SHRIMP ion microprobes around the world

Instrument number	Institution	Location	SHRIMP model	Year of commissioning
1	Australian National University	Canberra	I	1980
2	Australian National University	Canberra	II	1992
3	Curtin University of Technology	Perth	II	1993
4	Geological Survey of Canada	Ottawa	II	1995
5	Hiroshima University	Hiroshima	II	1996
6	Australian National University	Canberra	RG	1998
7	Stanford University	Stanford	RG	1998
8	National Institute of Polar Research	Tokyo	II	1999
9	Chinese Academy of Geological Sciences	Beijing	II	2001
10	All Russian Geological Research Institute	St. Petersburg	II	2003
11	Curtin University of Technology	Perth	II	2003
12	University of São Paulo	São Paulo	II	(2006)
13	Chinese Academy of Geological Sciences	Beijing	II	(2007)
14	Geoscience Australia	Canberra	II	(2007)

( ) projected



Using the time machine

U–Pb geochronology of accessory minerals is the dominant means of obtaining absolute and precise ages for ancient geological events recorded in rocks within the continental crust, the host of Earth's valuable mineral resources. Minerals such as zircon ($ZrSiO_4$), monazite ($CePO_4$), and titanite ($CaTiSiO_5$) incorporate trace quantities of uranium during crystallisation. The two isotopes of uranium (^{238}U, ^{235}U) radioactively decay to form two isotopes of lead (^{206}Pb, ^{207}Pb, respectively), along with several intermediate daughter elements. The isotopic ratios of lead to uranium, and the two lead isotopes, can be used to calculate the radiometric ages of the minerals. The half-lives of the uranium isotopes are known to high precision, and are long enough to permit dating of geological events that occurred a few million to billions of years ago.

The success of U–Pb geochronology lies partly in its wide applicability. Robust 'mineral chronometers' like zircon are found in almost all crustal rocks and can reveal the timing of magmatism, metamorphism, mineralisation and sedimentation. Other factors include the potential for very high analytical precision (for example, 0.1–1.0%), and the ability to determine whether the U to Pb radiometric clocks have remained undisturbed by comparing ages from the two decay series. There are several other useful and complementary methods of radiometric dating, such as the Ar-Ar method also used by Geoscience Australia, but none with the widespread utility of U–Pb geochronology.

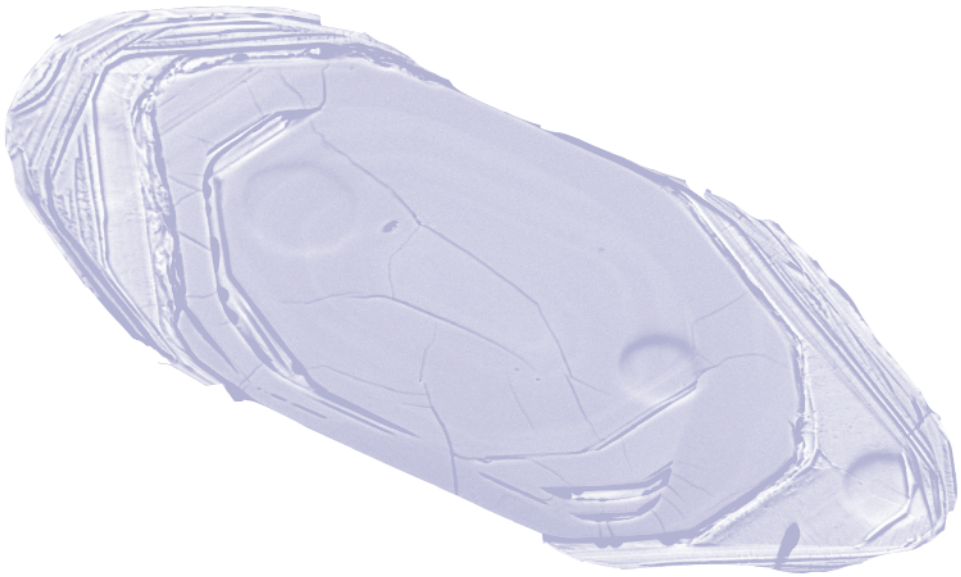
Conventional U–Pb geochronology by thermal ionisation (TIMS) is carried out on whole grains or parts of whole grains, requires careful chemical treatment to isolate the uranium and lead, and normally takes several days to generate age data. SHRIMP geochronology doesn't require chemical isolation of the uranium and lead in samples, so U–Pb ages can be obtained directly from the mineral chronometers at a spatial resolution of 5–30 µm without the need for a chemistry laboratory. Ages of individual growth zones within single crystals (figure 3) can be measured very rapidly, in about 15 minutes. And ages of minerals can be obtained in situ, allowing direct dating of minerals in thin sections. Applications of in situ geochronology are likely to have major impacts in many fields over the next decade.

A date for all

When SHRIMP U–Pb dating was introduced, it was viewed sceptically by a geochronological community accustomed to the rigours of TIMS, which produces results of unsurpassed precision and accuracy. Individual SHRIMP spot ages are significantly less precise, due to the much smaller amounts of mineral analysed (a few nanograms of sample per spot). Nevertheless, the 1983 discovery of the oldest (detrital) zircons on Earth (Froude et al 1983) focused attention on the value of SHRIMP technology and boosted its credibility as a viable technique.

Many subsequent SHRIMP studies have demonstrated that it's often valid to compromise precision if more ages can be acquired or the internal age complexities of a mineral can be understood (Williams 1998). SHRIMP addresses the two main weaknesses of TIMS—low data throughput and mixing of ages due to the relatively large samples analysed. Nevertheless, the TIMS method remains a powerful and relevant technique and is unlikely to be replaced by emergent technologies for certain critical applications (Parrish & Noble 2003).

Over the past two decades, SHRIMP geochronology has evolved and moved from the fringe to the mainstream. One of its biggest impacts is the enormous increase in the volume and scope of U–Pb geochronology, particularly in Australia but now increasingly on other continents. Our knowledge of the ages of ancient magmatism, tectonism, sedimentation and mineralisation would be significantly poorer if not for the advent of SHRIMP technology, which essentially allowed U–Pb geochronology to expand beyond a few highly skilled geochemists and into the hands (literally, by a click of the mouse) of many geologists interested in the ages of rocks.



References

1. Böhm CO, Heaman LM, Stern RA, Corkery MT & Creaser RA. 2003. Nature of Assean Lake ancient crust, Manitoba: a combined SHRIMP-ID-TIMS U–Pb geochronology and Sm–Nd isotope study. Precambrian Research 126:55–94.
2. Clement SWJ, Compston W & Newstead G. 1977. Design of a large, high resolution ion microprobe. Proceedings of the First International Conference on SIMS (abstract).
3. Froude DO, Ireland TR, Kinny PD, Williams IS, Compston W, Williams IR & Meyers JS. 1983. Ion microprobe identification of 4,100–4,200 Myr-old terrestrial zircons. Nature 304:616–618.
4. Neumann N, Southgate P, McIntyre A & Gibson G. 2005. New data on rock ages from Mt Isa Inlier. *AusGeo News 78*, 6–7.
5. Parrish RR & Noble SR. 2003. Zircon U–Th–Pb geochronology by isotope dilution-thermal ionization mass spectrometry (ID-TIMS). In: Hanchar JM & Hoskin PWO (eds), Zircon, Reviews in Mineralogy and Geochemistry 53, Mineralogical Society of America, 183–213.
6. Williams IS. 1998. U–Th–Pb geochronology by ion microprobe. In: McKibben MA, Shanks WCP & Ridley WI (eds), Applications of Microanalytical Techniques to Understanding Mineralizing Processes, Reviews in Economic Geology 7, Society of Economic Geologists, 1–35.

For more information on the Geoscience Australia SHRIMP and geochronology program, phone Richard Stern on +61 2 6249 9377 (email richard.stern@ga.gov.au)

Related website/articles
Ausgeo News 78
(new data on rock ages from Mt Isa Inlier)