THE NU ATTOM HIGH RESOLUTION ICP-MS: LASER ABLATION U-Pb GEOCHRONOLOGY

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INTRODUCTION

Modern high resolution ICP-MS (HR-ICP-MS) instruments offer a number of performance advantages compared to more widely used quadrupole ICP-MS instruments, including increased sensitivity, superior detection limits and faster scan speeds. For laser ablation acquisition, rapid peak scanning is a distinct advantage, as it allows for increased temporal resolution of time-resolved data. The advantage of single-collector ICP-MS over multi-collector ICP-MS, is that a wider mass range can be scanned in a single analysis. This means that a range of elemental concentrations can be determined, as well as precise isotope ratios.

Laser ablation sampling coupled to measurement via ICP-MS is an increasingly used tool within earth science, and can be used for determining quantitative trace element concentrations of materials, as well as for isotopic dating of minerals in particular within U-Pb geochronology. Here, we report the use of the Nu Attom for determining U-Th-Pb isotopes in zircon and monazite crystals, and demonstrate the ability to combine these isotope ratio measurements with other trace element concentrations using the wide mass range available in rapid peak-scanning mode.

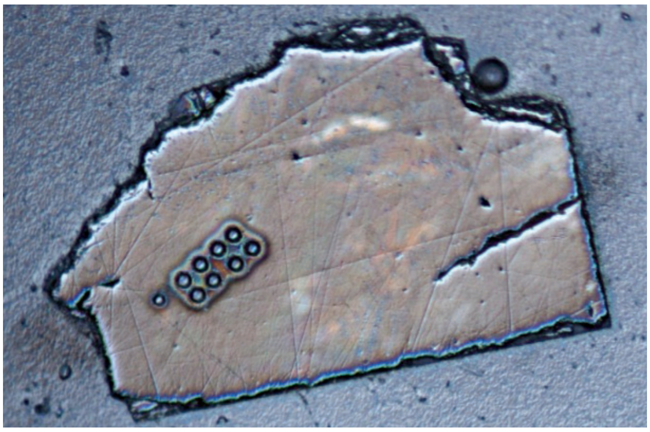

Figure 1: *20μm diameter ablation pits in Moacyr monazite.*

Instrumentation

The Nu Attom is a double-focusing, high-resolution magnetic sector mass spectrometer. The instrument is entirely purpose designed and built to provide the best performance and reliability coupled with flexibility and ease-of-use for precise and accurate elemental and isotope ratio analysis. A unique detector system gives the Nu AttoM a large dynamic range, and its electrostatic scanning capability has the widest range in its class (40%). Furthermore, the continuously variable high resolution means that sufficient resolution for isobaric separation can be achieved with minimum compromise in sensitivity.

For the laser ablation work presented here, a Nu Attom was coupled to a New Wave Research UP193FX excimer laser ablation system. Helium was used as a carrier gas, and mixed with argon before entering the ICP-MS. For some experiments a solution was simultaneously aspirated using the Nu Instruments DSN-100 that contained ^{203,205}Tl, ^{230}Th and ^{236}U; this allows for on-line correction of mass-bias and drift in the inter-element fractionation.

Experiment

Laser ablation analysis used a spot size of 20-35μm (figure 1), with a fluence of 1.8 to 2.2 j/cm^2, for 30 seconds of integration. An on-peak zero was measured every 5 to 10 analyses. The Pb-Pb, U-Pb and Th-Pb ratios were normalised to a bracketing primary standard, based on the average measured value of the standard compared to the 'true' value determined by ID-TIMS. The measured masses and dwell time for each of the four experiments are shown in Table 1; also shown are average count rates for the isotopes of interest for the standards shown in the figure. Trace element concentrations are semi-quantitative, and use repeat analyses of NIST 612 glass for normalisation.

The Attom can measure large signals by means of an attenuation mechanism; this was used for ^{232}Th which is particularly concentrated in monazite. To measure the degree of attenuation, ^{236}U is introduced via a spike solution and is measured with both a normal and an attenuated signal; the average value of the attenuation/normal signal is then applied to the ^{232}Th offline. Data were collected using the time-resolved-analysis function in the Nu Attolab software; with ratio calculations performed using the Nu calculations editor.

Discussion

Using typical ablation parameters (20 to 35 μm spot @ 1.5-2.5 j/cm^{-2}), the Nu Attom is capable of measuring ^{207}Pb/^{206}Pb, ^{208}Pb/^{232}Th ^{206}Pb/^{238}U ratios with an external reproducibility of <3% (2SD) after normalisation to a standard, these ratios are accurate to <2% (2SD) (figure 2). This makes the Attom ideal for U-Th-Pb geochronology of U-bearing accessory minerals such as zircon and monazite; although not shown, dating of other minerals such as titanite, allanite and apatite is feasible.

To gain the most from U-Th-Pb geochronology it is commonly useful to determine trace element concentrations of the dated minerals. For example, REE patterns in zircon can aid the determination of the co-precipitating mineralogy, and thus whether the dated growth-zone within the zircon represents a magmatic or metamorphic event. Ideally, trace element concentrations will relate to the individual growth zone that has been dated. This can be done using one ablation for a U-Th-Pb measurement, and a separate ablation for a trace element measurement; however, this assumes that the same zone has been analysed each time. For consumption of less material and allowing a greater spatial resolution, a preferred approach is to analyse U-Th-Pb isotopes and trace elements in one ablation. The large mass range of the Nu Attom allows for certain trace elements to be simultaneously determined along with precise U-Th-Pb isotopic ratios. Experiment 3 shows that ^{207}Pb/^{206}Pb and ^{206}Pb/^{238}U ratios can be precisely and accurately measured along with determination of the heavy REE content; whilst experiment 4 shows that a complete REE pattern can be determined along with precise and accurate ^{207}Pb/^{206}Pb age determinations (figure 2).

Conclusions

The Nu Attom ICP-MS allows for rapid peak-scanning across a wide mass range. The ability to determine precise and accurate U-Th-Pb isotope ratios, whilst at the same time determining concentrations of other trace elements makes it an ideal tool for geochronological dating of a range of natural materials.

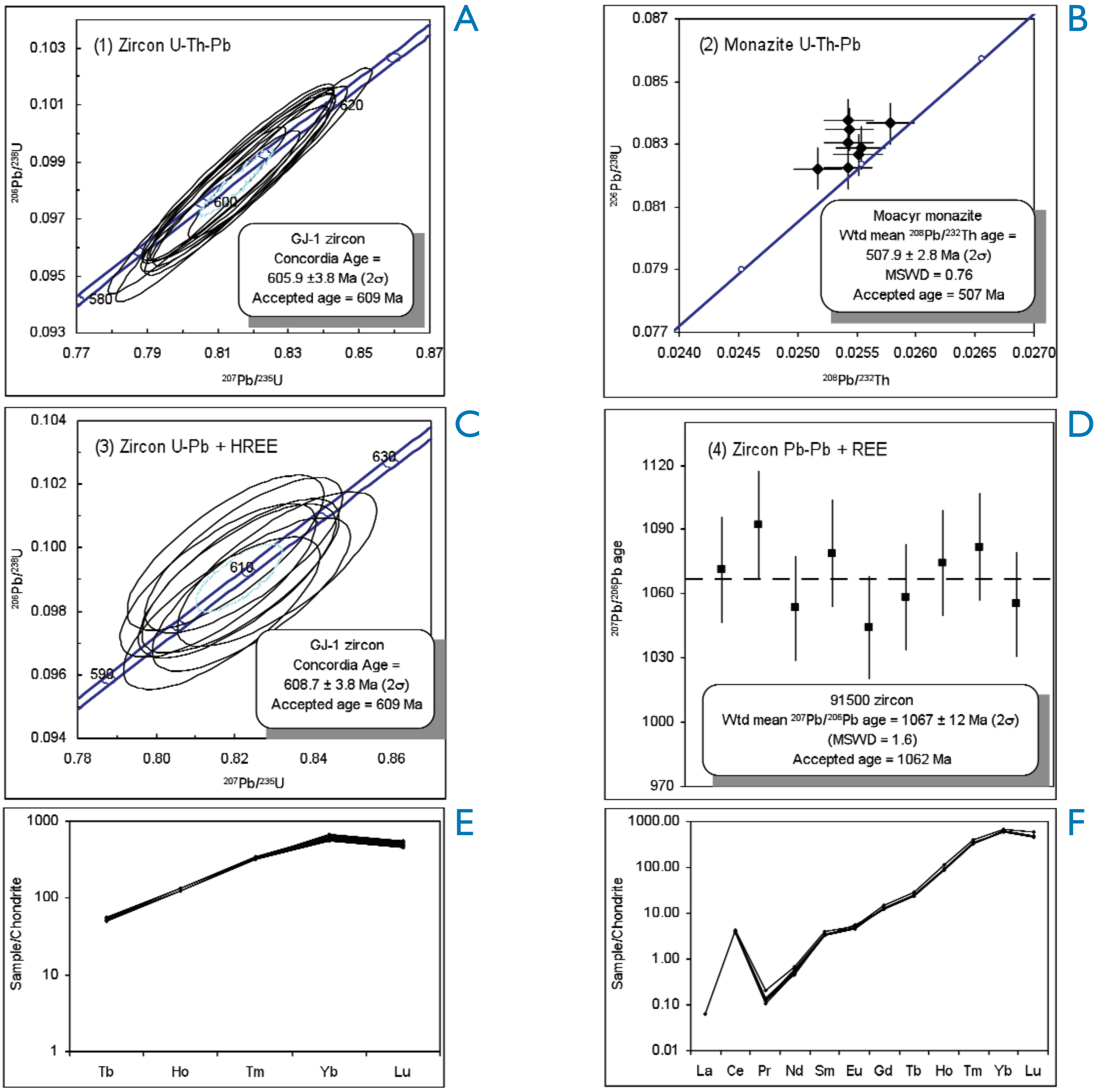

Figure 2: *(A) U-Pb concordia diagram for GJ-1 zircon normalised to 91500 (ellipses are 2σ). (B) Th/Pb vs. U/Pb isochron for Moacyr monazite normalised to Stern monazite (error bars are 2σ). (C) U-Pb Concordia for GJ-1 zircon normalised to 91500, and (D) weighted mean Pb-Pb age of 91500 zircon normalised to Plesovice. (E) Chondrite normalised HREE pattern, and (F) chondrite normalised REE pattern.*

Table 1: Measured masses and dwell times for each of the four experiments

(1) 35µm, ~2.2 j.cm^{-2}, 5Hz			(2) 20µm, ~1.8 j.cm^{-2}, 7Hz		
peak	dwell (µs)	cps	peak	dwell (µs)	cps
^{202}Hg	70		^{202}Hg	100	
^{203}Tl	100		^{203}Tl	100	
^{204}Hg,Pb	70		^{204}Hg,Pb	100	
^{205}Tl	100		^{205}Tl	100	
^{206}Pb	200	620000	^{206}Pb	200	650000
^{207}Pb	400	38000	^{207}Pb	200	41000
^{208}Pb	70		^{208}Pb	200	29000
^{230}Th	70		^{230}Th	100	
^{232}Th(att)	70		^{232}Th(att)	200	89000
^{235}U	400	47000	^{235}U	200	65000
^{236}U	70		^{236}U	100	
^{236}U(att)	70		^{236}U(att)	1000	

(3) 25µm, ~1.8 j.cm^{-2}, 7Hz			(4) 25µm, ~1.8 j.cm^{-2}, 7Hz		
peak	dwell (µs)	cps	peak	dwell (µs)	cps
^{159}Tb	100	16600	^{139}La	100	8
^{165}Ho	100	56000	^{140}Ce	100	157000
^{169}Tm	100	63000	^{141}Pr	100	350
^{172}Yb	100	164000	^{146}Nd	70	1300
^{175}Lu	100	85000	^{147}Sm	70	2600
^{206}Pb	200	308000	^{153}Eu	70	7000
^{207}Pb	400	19000	^{157}Gd	70	10500
^{235}U	400	26000	^{159}Tb	70	20000
			^{165}Ho	70	65000
			^{169}Tm	70	72000
			^{172}Yb	70	185000
			^{175}Lu	70	95000
			^{206}Pb	250	320000
			^{207}Pb	400	19500