Advantages and disadvantages of LA-ICP-MS and ID-TIMS U-Pb dating of complex zircons: a case study of Lutzkan and Ruy granitoids in W Bulgaria

Предимства и недостатъци на LA-ICP-MS и ID-TIMS U-Pb датиране на сложни циркони: изследване на примера на Люцканските и Руйските гранитоиди в Западна България

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Introduction

U-(Th)-Pb techniques is widely applied for dating of accessory minerals in magmatic, metamorphic and sedimentary rocks. Among the common accessory minerals the zircon is the favourite phase for dating because of its distribution in a wide variety of rocks, the relatively high U content combined with general lack of common lead and the remarkable resistance to high-temperature diffusive re-equilibration. The well-studied relation of the trace-element chemistry, Hf-isotope composition and morphology of the zircon with the composition and temperature of the parental magma made him a reliable tracer of magmatic processes.

The new LA-ICP-MS (Laser Ablation–Inductively Coupled Plasma–Mass Spectrometry) equipment at the Geological institute of the Bulgarian academy of Science (GI–BAS), owned by a consortium with the Sofia University (Faculty of geology and geography), the National archaeological institute with museum and the Institute of mineralogy and crystallography (BAS) offers an excellent opportunity for U-Pb zircon (also monazite/titanite) dating. It arises a question when is this techniques applicable for timing and tracing of geological processes and when we should prefer the “conventional” ID-TIMS (Isotope Dilution-Thermal Ionisation Mass Spectrometry). To answer this general question we present here some examples for zircons and titanites from granitoid rocks of the Lutzkan magmatic complex (Lutzkan and Ruy plutons) in Tran region, Western Bulgaria (Belev, 1960). These plutons consist of coarse- to medium-grained, porphyroid K-feldspar-bearing, amphibole-biotite monzogranite to granodiorite (i) and leucocratic, medium- to fine-grained, equigranular granites (Dyulgerov et al., 2006). Accessory phases are zircon, apatite, titanite, allanite, Fe-Ti oxides.

LA-ICP-MS and ID-TIMS – general comparison as dating/tracing techniques

Some important characteristics of the LA-ICP-MS and ID-TIMS U-Pb dating techniques are summarized in Table 1. They define the LA-ICP-MS as perfect tool for dating of rocks when the error uncertainties of 2–8% are acceptable for the researchers. This method is especially suitable for complex crystals (e.g. metamorphic zircons with cores and metamorphic rim(s)) because of the spatial resolution but also for zircon provenance analyses (when a minimum of 100 grains/analyses are required) due to the short time of the analyses. Additionally this method may provide data for

Table 1. General characteristics of LA-ICP-MS and ID-TIMS U-Pb zircon dating

Criteria	LA-ICP-MS	ID-TIMS
Spatial resolution	10–60 μm spot size, 5–20 μm depth	Dissolution of single grain or part of it
Sample preparation	Zircon mount of 1–10 samples with 20–40 grains; CL-BSE images (2–4 days)	Clean lab; chemical abrasion; dissolution, Pb-U separation (10–14 days for 2×6 zircons)
Time for isotope analyses	2–3 min, 5–10 min data reduction	3–4 h; 5 min data reduction
Precision and accuracy	2–8% precision per analysis (2σ); moderate accuracy	0.1–0.3% precision (2σ); high accuracy

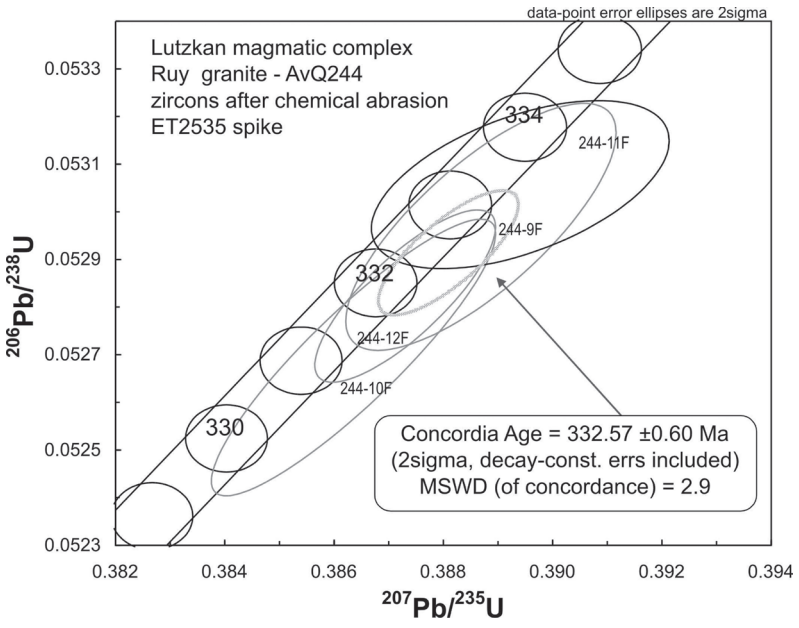

Fig. 1. Concordia diagram for chemically abraded zircons of Ruy granite

the zircon trace element content matching them with the age of the specific crystal zone. The ID-TIMS from the other side is unique for distinguishing of a succession of geological processes in a (geologically) short period of time: life times of magmatic-hydrothermal systems, volcanic/magmatic events, calibration of the stratigraphic time-scale. This method was actively improved in the last years and reached the unprecedental precision of <0.1% trough interlaboratory calibrated double-double spike (ET2535), extremely low blank, well defined decay constants, precise mass-spectrometers, development of the zircon chemical abrasion techniques.

U-Pb dating of zircons and titanites from Lutzkan and Ruy plutons

Zircons from Lutzkan and Ruy plutons are characterized with a high U-content and numerous inclusions. The ID-TIMS dating without special pre-treatment of the grains yielded discordant ages. LA-ICP-MS of the zircons are extremely discordant due to the high common-lead content that is possibly related with the inclusions. Only the $^{206}Pb/^{238}U$ ages can be used for estimation of the intrusion time. They spread in a wide interval between 220 and 380 Ma, whereas a mean age of 310 ± 26 Ma (8.3% error uncertainties at 95% confidential level) can be calculated. ID-TIMS analyses of chemically abraded zircons from the Ruy pluton (Fig. 1) are concordant at 332.57 ± 0.57 Ma (2σ uncertainties). This age coincides with the U-Pb concordia age of the titanites from the Lutzkan pluton of 334 ± 1.2 Ma (adding the error uncertainties). Zircons of a cross-cutting syenite-porphyry dyke reveal lead inheritance and lead loss (TIMS and LA-ICP-MS analyses). Consequently, their age is poorly defined, although the magmatic rims tend to a Carboniferous-Permian age. In the same sample titanites yield ID-TIMS age of 328.8 ± 1.2 Ma. LA-ICP-MS analyses of inherited cores in the granitoids argue for contamination of the Carboniferous magma with Lower Palaeozoic and Proterozoic materials.

Conclusions

Using the advantages of LA-ICP-MS and ID-TIMS U-Pb dating technics it was possible to define the age of the Lutzkan and Ruy plutons and their dykes in the interval between 334 ± 1.2 Ma and 328.8 ± 1.2 Ma and to infer granitic source (as primary magma or as a contaminant) with Proterozoic-Lower Palaeozoic age. The mean age of the LA-ICP-MS U-Pb zircon analyses should be used with caution and is better combined with the information about the real spread of the age data to provide geologically correct constraints (see also von Quadt et al., 2011).

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