Evaluation of Duluth Complex anorthositic series (AS3) zircon as a U-Pb geochronological standard: New high-precision isotope dilution thermal ionization mass spectrometry results

MARK D. SCHMITZ,†,‡ SAMUEL A. BOWING,§ and TREVOR R. IRELAND¶

1Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139, USA
2Research School of Earth Sciences, The Australian National University, 1 Mills Road, Canberra, ACT 0200, Australia

(Received August 12, 2002; accepted in revised form November 11, 2002)

Abstract—U-Pb zircon geochronology is increasingly called upon to achieve the resolution of absolute time at the 0.1% to 1% level for rocks of Phanerozoic to Hadean age. Doing so requires accurate calibration of the several methods (conventional isotope dilution thermal ionization mass spectrometry [ID-TIMS], Pb evaporation, high-resolution ion microprobe [e.g. SHRIMP], and laser ablation inductively coupled plasma mass spectrometry [LA-ICPMS]) currently in use, in numerous laboratories, for the analysis of U and Pb isotopes in accessory minerals. Toward this end, the geochronological community would benefit from the establishment, distribution and widespread analysis of one or more standard reference materials. Among the candidates is natural zircon from the Duluth Complex anorthositic series of the Midcontinent Rift system of North America. These zircons, first dated by conventional ID-TIMS at 1099 ± 0.5 Ma, have been subsequently adopted as a geochronological standard by a number of high resolution ion microprobe facilities. A new and independent analysis of the systematics of a large set of single zircons (n = 27) from the same mineral separate yields indistinguishable \(^{206}\)Pb/\(^{238}\)U, upper intercept, and U-Pb concordia dates for the AS3 zircons. The concordia date, based on a subset of 12 concordant and equivalent zircons, of 1099.1 ± 0.2 Ma (±1.2 Ma considering systematic uncertainties in Pb/U tracer calibration and U decay constants) is indistinguishable from previously published results. We further document the absence of inherited Pb in the AS3 zircons, and discuss strategies for avoiding certain domains within the AS3 zircons exhibiting small amounts of radiation-induced, surface and fracture-correlated, recent Pb loss. Although the AS3 zircons do not represent the ideal (and elusive) homogenous closed U-Pb system, we conclude that these and similar zircons from the Duluth Complex anorthositic series can provide a suitable geochronological reference standard for numerous U-Pb zircon analytical methods, given appropriate preparation guided by the results of this study. Our high precision data set also serves as a useful confirmatory test of the currently accepted U decay constants.

Copyright © 2003 Elsevier Ltd

1. INTRODUCTION

U-Pb zircon geochronology is firmly established as among the most precise and accurate means of resolving time throughout the geologic record. The available internal assessment of closed system behavior through the paired U-Pb chronometers, precisely measured U decay constants, high initial U/Pb ratios, and the geochemically robust and geologically common nature of zircon makes it a near ideal mineral for the radiometric measurement of time. The precision of concordant zircon U/Pb ages, for samples from a few millions years old to the age of the earth, can thus approach 0.1% by the ID-TIMS method, potentially accessing an intriguing array of problems regarding geologic histories, correlations, and rates of processes. However, excepting relative U/Pb zircon ages measured by identical methods in the same laboratory, systematic errors in mass spectrometry, tracer calibrations, and/or decay constants can introduce further, and perhaps larger, sources of uncertainty and bias into absolute U/Pb zircon ages.

Micronanalytical techniques (e.g., SHRIMP, LA-ICPMS) can unravel the geologic histories of single zircon domains but must rely on normalization to a standard zircon of known isotopic character. Current methodologies essentially limit U-Pb measurements to the 1% level and it is often unclear during any given analytical session whether the limitation is imposed from the technique or the geological behavior of the sample. In this regard, Pb loss and inheritance are undesirable attributes of a standard but U and Th heterogeneities can also cause difficulties in obtaining precise ion ratios. Ultimately, any source of uncertainty in the standard must be propagated onto the analyses of the unknowns whether they arise from the accumulated counting statistics, or from systematic effects contributing to uncertainty in the calibration. The minimization of geologic effects in the standard zircon would allow the assessment of instrumental artifacts, and in turn advance the analytical protocols used in microanalysis.

Recognizing the potential limitations of systematic error, Wiedenbeck et al. (1995) reported the results of a study of several large zircon crystals for possible use as standard materials for U/Pb and other isotopic and geochemical measurements. Of these zircons, only the 91500 (Koele Lake or Harvard Museum) zircon was found to have U/Pb systematics appropriate to its use as a standard material. Although used as a standard by some LA-ICPMS studies (Nesbitt et al., 1997; Horn et al., 2000), fragments of the zircon show an analytically resolvable scatter in \(^{206}\)Pb/\(^{238}\)U ratios, and as a single large