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Deciphering a multi-event in a non-complex set of detrital zircon U–Pb ages from Carboniferous graywackes of SW Iberia

A. Ferreira [a,*], C. Lopes [a], M. Chichorro [a], M.F. Pereira [b], A.R. Solá [c]

[a] GEOBIOTEC, FCT, Universidade Nova de Lisboa, Quinta da Torre, 2829-516 Caparica, Portugal
[b] Departamento de Geociências, ECT, Universidade de Évora, IDL, Portugal
[c] Unidade de Geologia, Hidrogeologia e Geologia Costeira, LNEG, Portugal

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ABSTRACT

The determination of U–Pb ages from detrital zircons of sedimentary rocks using LA-ICP-MS has been widely used for the purpose of provenance analysis. One problem that frequently arises is finding a population that appears to be non-complex despite several perceptible age peaks in its spectrum. These peaks are qualitatively defined by means of relative probability diagrams, or PDFs, but it is difficult to quantify their statistical significance relative to a zircon forming multi-event. Thus, can a multi-event in a non-complex set of detrital zircon U–Pb ages be deciphered and characterized?

The aim of this study is to attempt to provide an answer to this question by means of statistical analysis. Its objectives are: a) to determine the best minimum number of zircon age populations (peaks), *BmP*s, b) for the characterization of each peak in terms of age and event duration; c) to compare the results obtained from two datasets showing similar zircon ages; and d) to demonstrate the usefulness of deciphering these *BmP*s. First, cluster analysis is carried out, aimed at grouping zircon ages into a set of consistent clusters. A Gaussian Kernel function is then fitted to each cluster and summed to obtain a theoretical PDF_m (modeled probability density function). Finally, the selected modeled PDF_m (that built on the *BmP*s) is that which reports the lowest number of peaks for which the difference as compared with the original *gPDF* (global probability density function) is equal to or below 5%. Deciphered *BmP* peaks can be characterized and used for characterizing and providing an understanding of related event(s).

A geological interpretation, based on the results obtained, is attempted. This includes a robust measure for maximum age of deposition for both Cabrela and Mértola graywackes.

1. Introduction

The determination of U–Pb ages from the detrital zircons of sedimentary rocks using LA-ICP-MS has been widely used for the purpose of provenance analysis (Fedo et al., 2003). The discussion of potential sources for a single sample of sedimentary rock resulting from the analysis of detrital zircon populations allows for the recognition of different zircon-forming events. These events found in sedimentary rock mark important stages in the Earth's history in terms of crustal growth and recycling, while sources may or may not be currently exposed and subject to erosion (Fedo et al., 2003; Cawood et al., 2012).

The data resulting from isotopic analysis of U–Pb detrital zircons are commonly presented by means of relative probability diagrams (Hurford et al., 1984; Sircombe, 2004). Each sample of sedimentary rock presents a spectrum that identifies it, like a fingerprint, which allows comparisons with other spectra for other samples of sedimentary rocks with the same or a different age of deposition.

One problem that frequently arises in this type of study is finding a population that appears to be non-complex but whose spectrum allows for the definition of different age peaks (Vermeesch, 2012). The reliability of such peaks, defined by means of the qualitative description of the graphical representation of the results obtained (relative probability diagrams: PDFs) cannot be quantified, i.e. whether they represent statistically significant peaks related to a zircon forming multi-event or not. The question that arises is whether it is possible to quantify the statistical significance of these peaks and assign them a greater or lesser importance in the search for their geological significance.

The aim of this study is to decode and characterize zircon age populations (by deciphering distinct age peaks) in a zircon U–Pb non-complex age probability density distribution by means of: 1) a statistical analysis based on cluster analysis; 2) the construction of several

Abbreviations: n, number of zircon age spots in a dataset; *m*, number of clusters of zircon age spots obtained for a given level of merging cost after a cluster analysis; *gPDF*, global probability density function; Kf_i, Gaussian Kernel function for a U–Pb zircon age spot *i* (with $i = 1, \ldots, i, \ldots n$); p_jKf_j (or pKf_j), partial Gaussian Kernel function adjusted to a group *j* of zircon age spots (with $i = 1, \ldots, j, \ldots m$); *BmP*s, best minimum number of zircon age populations (peaks); PDF_m, modeled probability density function, after summing a set of *m* adjusted pKf_j.

* Corresponding author. Tel.: +351 212948300x10225; fax: +351 212948556.
E-mail addresses: amp.ferreira@fct.unl.pt, antonio@bgs.ac.uk (A. Ferreira).

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