minerals

Editorial

Editorial for Special Issue "Detrital Mineral U/Pb Age Dating and Geochemistry of magmatic Products in Basin Sequences: State of the Art and Progress"

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In general, provenance analysis has developed over the past 70 years into an enormously important tool in sediment investigations, both enabling solving earth science questions in basic research and practically applying it to mineral exploration. The mineral content of mainly siliciclastic sandstones reflects the geological situation of the basin-fringing supply areas. Likewise, associated conglomerates and pelites are used as supporting evidence. In modern times, thanks to methodological and technical advances, we have a variety of methods available to infer paleogeographic, orogenic and plate tectonic processes from the composition of sandstones and selected minerals. It is therefore both timely and interesting to briefly highlight these historical developments.

The first effort was to develop a useful classification scheme for sandstones according to their mineral content and rock fragments. Pioneers in this field were, e.g., Krynine [1] and Folk [2]. These sandstone classifications proved successful for that time but had the disadvantage of the measured mineral and grain content being influenced by the granulometry of the sandstone. A proliferation of classification schemes was the result [3]. However, with the restriction of the statistically point-counted grains to the sand size and the considered rock fragments with exclusively aphanitic texture (coarsely textured rock fragments are included in the classification with their individual mineral grains), the grain-size bias could be limited. This method, developed by Dickinson [4], also allowed an interpretation of the plate tectonic position of the supply areas with the restriction that the age of the volcanic/abyssal rock fragments remained unclear, especially in fossil sandstones. Research tools involving heavy minerals to describe delivery areas go back even further; however, they were definitely established as a recognized analytical method from the 1950s onwards [5]. The high input of the combined use of different analytical methods is emphasized, e.g., by Weltje and von Eynatten [6]. This is impressively manifested in the paper collection by Mange and Wright [7]. In the same volume, the concept of lag-time (in exhumation evaluation) was possibly applied for the first time in the northern Andes of Ecuador using fission-track analysis on detrital zircons [8].

Radiometric dating of detrital minerals represented something of a quantum jump in provenance analysis. Because of its abundance and robustness, zircon was the first choice. In an early study, detrital zircons were dated using the revolutionary SHRIMP (sensitive high resolution ion microprobe) method [9]. Soon thereafter, other researchers, e.g., Jackson [10], were able to prove the suitability of laser ablation ICP-MS (inductively coupled plasma mass spectrometry) techniques, which yielded comparably accurate U-Pb ages and carried the advantage of being far less time-consuming. In addition, geochemical signatures of detrital zircons, and especially the Lu-Hf isotope ratios, allow interpretation of the formation of magma zircons from melts in the Earth's crust, depleted mantle and mixtures thereof [11]. Thus, detrital zircons also provide arguments for the maximum age of the sandstone series, the chronostratigraphic and petrographic variability in the sourcing hinterlands, as well as the formation of magmas in the crust, the depleted mantle and the mixtures thereof, providing arguments for plate tectonic environment [11]. In the following, we present the articles in order of geological age, starting with the youngest.

Interesting evaluations of methods are provided by analyzing modern clastic systems because the relationships between source rocks and sediments are preserved. Three of the papers deal with these topics. Sun et al. [12] compare published muscovite Ar/Ar ages and detrital zircon age populations in modern sediments of the Yangtze River. Pooled age distributions show discrepancies in occurrence in the upper and lower reaches of the river with expected hinterland petrographic/age characteristics. They may be explained by combined effects of, e.g., lower reaches dilution and durability between muscovite and zircon. A very rich set of detrital zircons U-Pb age data from East China Sea, Yellow Sea and Bohai Sea surface samples is presented by Huang et al. [13]. Distinct detrital zircon age populations and mixing modeling support the supply from the framing orogenic belts and strong modification by tidal and ocean currents, which should also be considered in the analysis of fossil sediment series. Kanouo et al. [14] present a detailed study of Archean to Neoproterozoic zircons found in gold-bearing placers from the southern Meiganga area, Cameroon. Analysis of zircon cores by the laser ablation split stream technique (LASS) reveals their trace element composition and U-Pb ages within a single shot. Trace element data suggest that the majority of the zircons are derived from different magmatic sources, but very few mantle sourced or metamorphism-sourced examples are recognized. Supply from the Congo Craton, local Pan-African intrusions and the Cameroon Mobile Belt is interpreted. The latter could be used for tracking gold.

Based on their own original data and a reevaluation of published detrital zircon U-Pb ages and Hf-isotope ratios in early Miocene fine- to medium-grained sediments, Wang et al. [15] successfully reconstruct the sources of detritus in the northwestern South China Sea. The dominant contributor was the Red River system, with minor supply from central Vietnam and the Hainan uplift. This study again underscores the power of combined methods, U/Pb zircon ages and zircon Hf-isotopes, applied to provenance analysis which should be used more often in future. The Silante Formation of the western Cordillera of the North Andes has experienced very different interpretations over the course of more than 40 years of investigation, so that, e.g., its interpreted stratigraphic age was modified from Paleocene to Oligocene. The latest study by Vallejo et al. [16] combines stratigraphic bedding relationships, facies analysis, sandstone petrography, geochemistry of detrital clinopyroxenes, heavy minerals and detrital zircon U-Pb and muscovite Ar/Ar ages. A derivation of clastics from a continental margin arc, presumably the San Juan de Lachas unit, is concluded. The paper of Yin and Wu [17] contributes to understanding the complex sediment supply of the Paleogene Quaidam Basin in the Tibetan Plateau. Heavy minerals, detrital zircon U-Pb chronostratigraphy combined with detailed sediment distribution patterns recognize the Qilian Mountains as the main source area that formed a coeval large catchment area under the control of intensive tectonic activity.

Going backward in time, Di Giulio et al. [18] present a comparative study of the mid-Cretaceous transition from extensional to compressional tectonic settings in two very different plate tectonic settings: the Southern Andes (back-arc system) and the Western Alps (passive European continental margin). A rich data set of detrital zircons U-Pb geochronology, sandstone modal composition and apatite double-dating (in the Andes) supports the paleotectonic discrepancies and the related sediments. The first study of zircon from the Early Cretaceous Verkhneurmiysky granitoids in the Amur Badhzal tin ore district is reported by Machevariani et al. [19]. Raman spectroscopy, morphotype and internal impurities/alterations analysis of zircons allow the reconstruction of distinct stages during their evolution. According to the authors, zircons in Zinnwaldite granites show close affinities with such in Russia, Australia, Germany and the Czech Republic. Lee et al. [20] provide a combined study of the non-marine Late Cretaceous Neungju Basin (southwest Korea) formed in an active continental margin environment. The geochronological story of the basin fill is carried out by detrital zircon U-Pb dating from ash layers. However, the geochemistry and weathering of basin fill mudstones show a quite intriguing picture.

The authors warn that continental basin fill may show strong spatial contrasts in sediment supply because of limited mixing between the sources. The tectonic setting of the Anisian Gejiun alkaline basalts, part of the Eneishan Large Igneous Province, is controversially interpreted. Shang and Chen [21] present new laser ablation zircon U-Pb ages, whole-rock major, trace element and Sr-Nd-Pb isotopic data from outcrops and drill holes. The results imply that the basalts erupted in an extensional environment during the Gejiu-Napo rifting event in the southwestern margin of the South China Block.

Li et al. [22] investigated the Permian series of the west Bogda Shan range between the Junggar and Tarim blocks, the latter representing the southwestern margin of the Central Asian Orogenic Belt. Detrital zircon geochemistry and modal analysis of sandstone allow individualizing a middle Permian basin inversion from Carboniferous early Permian rift and post-rift to a continental arc environment supply. Hadimi et al. [23] analyze the Tiddas Souk Es-Sebt des Ait Ikko Basin, a continental trough in the Central Moroccan Meseta. Based on whole-rock geochemistry, pyroxene and biotite major and trace element data from the volcanic and sub-volcanic rocks calc-alkaline-series characteristics are derived from parental mafic magmas. Moreover, a four-stage basin evolution is recognized, showing, at first, an extension, followed by transpression and compression, respectively, and a final extensional event. The SHRIMP U-Pb dated zircons from a rhyolite dome (ca. 287 Ma) presumably formed during the third stage. Andesites and dacites show similarities with calc-alkaline series rocks, which are unrelated to active subduction. Miao et al. [24] present new research from the Central Asian Orogenic Belt (CAOB) in Mongolia. By means of detrital zircon U-Pb geochronology on Neoproterozoic early Paleozoic sandstones in the Ereendavaa terrane (the later southern margin of the Mongol-Okhotzk ocean), the authors define the earlier Kherlen ocean suture, which is an important new element for understanding the evolution of the CAOB. The existence of the new element is also reflected by Winkler et al. ([25], this volume). The authors investigate the plate tectonic history of the CAOB from Cambrian to Early Jurassic in central and southeastern Mongolia (Gobi). Detrital zircon U-Pb geochronology, Hf-isotope systematics and detrital mode of sandstones are applied. Including earlier results from the Mongoli-Okhotzk belt [26], a paleogeographical varying tectonic system of rifting, drifting and basin inversions (subduction) during the long timespan is reconstructed. For the plate tectonic reconstruction, integration of Hf-isotope systematics proved very efficient. The paper of Kim and Choi [27] deals with Pennsylvanian strata in the Sino-Korean Block. The work is mainly based on detrital zircon U-Pb age data that appear to be distinct from the coeval sediment series in China. A contemporaneous active continental margin setting to the east of the Sino Korean Block is inferred that relates to the westward subduction of the Paleo-Pacific plate.

Our present Special Issue contains a collection of articles that are exemplary for their application and combination of diverse diagnostic techniques. It is also pleasing to note that the case studies come from different parts of our globe, namely South America, Central Asia, Southeast Asia, Africa and Europe. We hope that our Special Issue will serve as a resource for knowledge and as a stimulus for further research and development in this field.

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