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Separate Lead Isotope Analyses of Whole Rock Leach and Residue Fractions to Characterize Formation Processes and Post-formation Evolutions of Magmatic and Metamorphic Lithologies

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Lead isotope analyses of whole rocks are used to trace sources of metals in ore deposits and to infer source reservoirs in petrogenetic studies, especially of magmatic rocks. Analyses are usually carried out on the bulk fraction of, when possible, unaltered rocks. Because rocks contain appreciable amounts of U and Th, the Pb isotopic values measured do not correspond to those at the moment of rock formation, unless rocks have recent or present-day ages or incorporated very high amounts of common lead at their formation. Additionally, the common Pb isotopic signature of the rock may be swamped by later fluid circulation carrying lead different from that of the rock. For petrogenetic and metallogenic studies the isotopic compositions of the lead at, respectively, the time of formation of the rock and of the mineralization are needed. If the rock system remained closed, these isotopic compositions can be obtained by U-Th corrections based on rock and mineralization ages. However, corrections for production of radiogenic isotopes require precise U, Th and Pb concentration measurements, knowledge of the rock age and that the rock system has remained closed since its formation. Element concentrations and rock age are not readily available whereas the closed-system condition cannot be verified on the basis of a bulk rock isotope analysis. Our aim is to discuss a method, based on the separate analyses of leach and residue fractions of the same rock sample, which: i) yields a fraction (usually the residue) with a signature as close as possible to that of common lead without adopting uncertain U-Th corrections, and ii) allows evaluation of the open or closed evolution of the rock system after its formation by comparing the compositions of the residual and leach fractions in the isotope space. We found that a >36 hours lasting leach attack with a mixture of 7M HCl and 14M HNO_3 removes most of the radiogenic and, if present, disequilibrium lead introduced into the rock after its formation. The isotopic response of rocks to this leach attack varies depending on mineralogical composition. Under this viewpoint, rocks can be subdivided into 2 main groups: 1) feldspar-rich rocks, like acid-intermediate magmatic and metamorphic rocks, have residual fractions with an isotopic signature close or identical to that of common lead and leach fractions variably more radiogenic, because such lithologies are characterized by low leachable/residual common lead ratios. This conclusion is supported by the comparison of results obtained by our method with compositions of K-feldspars and with age corrected isotopic ratios of bulk rocks for systems which apparently remained closed after their formation. The petrogenetic meaning of the isotopic compositions of the whole rock residues in feldspar-rich lithologies is an "averaging" of the isotopic compositions of feldspars. This is preferable to the analysis of single feldspars, whose isotopic compositions may not be representative of that of the bulk rock; 2) rocks that contain the majority of common lead in easily soluble phases (e.g., sulphides, oxides), in sheet or in chain silicates, from which common lead is also removed by our leach attack, and host at the same time U-rich refractory mineral phases (e.g. zircon), may have leaches less radiogenic than residues, and approaching the common lead signature. These rocks are exemplified by feldspar-poor basic and ultrabasic migmatites and by feldspar-poor, sheet silicate-rich metasediments. Due to the generally low content of zircon in basic and ultrabasic rocks, in most cases only slight deviations, if any, of the leach with respect to the residual fraction are obtained if the system was closed. If the system was open, the leach fraction will remove disequilibrium lead introduced after rock formation. This may be useful in the analysis of oceanic basic and ultrabasic magmatic rocks which are usually affected by seafloor hydrothermal activity. Significantly more radiogenic residues are obtained in feldspar-poor, sheet silicate-rich meta-sedimentary lithologies due to the presence of relatively large amounts of detrital zircons. Case studies have put in evidence a wide range of applications of this technique both in the petrogenetic and metallogenic fields.