MAGMATIC VERSUS METAMORPHIC U/TH/PB-ZIRCON AGES: IMPLICATIONS FROM U/TH-RATIOS AND ZIRCON EVAPORATION

KLÖTZLI, U. S.

Laboratory for Geochronology, University of Vienna, Franz Grill-Straße 9, A-1030 Vienna, Austria

When studying the geological evolution of mono- or polymetamorphic rock series the knowledge of the time of formation of the meta-igneous parts of the series is of utmost importance for palaeogeographic reconstructions, geochemical evolution, etc. U/Th/Pb-dating of zircons is often the only applicable geochronological method to establish sound age information for protolith formation and subsequent metamorphic overprinting of such meta-igneous rocks. But beside the well known problems posed on zircon dating by more or less complex U/Th/Pb inheritance, it is often difficult to distinguish between true magmatic ages and ages representing recrystallisation events during high-grade metamorphic overprinting.

When combining single zircon dating, zircon typology, cathode-luminescence, and electron-microprobe studies the problem of inheritance can partly be overcome and reliable age data for »geological events« can be provided. The single zircon evaporation analysis has proven to be a very useful tool to establish the geochronology of polymetamorphic rock series, especially of acidic to intermediate orthogneisses. But although most of the analysed zircons in such rocks exhibit »magmatic« typologies, the interpretation whether the determined $^{207}Pb/^{206}Pb$ ages represent magmatic or metamorphic ages is not always straight forward.

Fortunately, the existence of spatial variations in the $^{208}Pb/^{206}Pb$-ratios compared to $^{207}Pb/^{206}Pb$ provide some means to decipher the internal structure of the analysed zircon and thus allow some conclusions about magmatic versus metamorphic origin: Zircons normally reveal two distinct chemical zonation patterns. 1) An oscillatory zoning parallel the major prism faces (100, 110), and pyramidal faces (101, 211), respectively, either ordered, disordered or a combination thereof. This zonation is usually interpreted as representing a magmatic growth zonation characterised by changing relative proportions of Hf, U, Th, Y, HREE, Pb, ..., in the crystal lattice; 2) nebulitic, patchy zircon domains, usually interpreted as representing some sort of recrystallisation and redistribution of elements, most probable during metamorphic overprinting.

A fundamental prerequisite of absolute age determination is the assumption of closed system behaviour of mother and daughter elements and the absence of any internal isotope fractionation since the time of closure in respect to diffusion of the elements under consideration. Thus, if one assumes that no spatial fractionation between U, Th, and Pb has taken place in the crystal lattice since the time of closure the $^{207}Pb/^{206}Pb$-ratio can directly be recalculated to an apparent age and the $^{208}Pb/^{206}Pb$-ratio is directly proportional to the U/Th-ratio.

Theoretically, evaporation, i.e. mobilisation of SiO_2, U, Th, Pb, HREE, and Hf, of zircons normally proceeds shell like from the rim to the core of the crystal. So, with time, the evaporation process mobilises elements from more internal parts of the crystal. Therefore temporal variations in the $^{208}Pb/^{206}Pb$-ratio should correspond directly to spatial changes in the U/Th-ratios in different domains of the zircon lattice. Thus a complete evaporation analysis provides us with a spatial depth-profile of the apparent $^{207}Pb/^{206}Pb$-age and the corresponding U/Th-ratio.

Constant $^{207}Pb/^{206}Pb$ over a certain amount of time or evaporation steps are normally interpreted as representing intact U/Pb systematics with no unsupported U or Pb present in the analysed parts of the zircon crystal. If this is true variations in $^{208}Pb/^{206}Pb$ must directly reflect primary variations in U/Th as stated above. Evaporation analyses of a large number of magmatic zircons from granitoids of the Bohemian Massif have revealed, that variations in $^{208}Pb/^{206}Pb$ at constant $^{207}Pb/^{206}Pb$ are almost always present. The magnitude of the variations in $^{208}Pb/^{206}Pb$ can directly be correlated with the magnitude of variations in the U and Th concentrations within the zircon crystal. This is further corroborated by ion-microprobe analyses and partial dissolution experiments. Therefore, the observed variations in $^{208}Pb/^{206}Pb$ at constant $^{207}Pb/^{206}Pb$ are interpreted as representing the magmatic growth zonation and directly support the model of shell like element mobilisation during evaporation. Constant $^{208}Pb/^{206}Pb$ at constant $^{207}Pb/^{206}Pb$ is then interpreted as representing homogeneous domains, in respect to U/Th, or as representing recrystallised zircon domains where complete Pb homogenisation, and probably also U and Th homogenisation has occurred. Using this argumentation, evaporation ages from zircons of unknown provenience exhibiting large variations in $^{208}Pb/^{206}Pb$ at constant $^{207}Pb/^{206}Pb$ can be interpreted as probably representing magmatic ages and not metamorphic recrystallisation ages. Vice versa, evaporation ages from zircons showing no or only very little variations in $^{208}Pb/^{206}Pb$ can tentatively be interpreted as probably representing metamorphic recrystallisation ages. Also the method even allows, in certain cases, to distinguish between inherited zircon cores of magmatic or metamorphic origin.