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Rapid uplift of Late Cretaceous acidic magma from northern Croatia deciphered by studying inclusions in zircon using Raman spectroscopy

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The Late Cretaceous igneous rocks within the south-western part of the Pannonian Basin basement (Croatia) occur in two areas: at the north-western part of Mt. Papuk (Pp; covering the area of ~10km^2) and at Mt. Požeška Gora (Pg; area of ~30 km^2). The predominant rocks are rhyolites and basalts, with pyroclastic material to a lesser extent. Additionally, smaller granite body crops out on Pg. The specific magma geochemistry (A-type signature) and age (~82 Ma) recently refined on acidic varieties (granite and rhyolite) indicate the beginning of the tectonic transition in this area from compression to extension.

In the reconstruction of magma evolution, inclusions captured in zircon grains represent valuable material that provides additional information. Zircon grains extracted from the samples of acidic rocks (rhyolites and granites) are quite small, usually less than 100 μm in the longer axis, with an average aspect ratio of 2.1:1. The grains are euhedral, with an external morphology defined by {100} prisms and {101}>{211} bipyramids. Such a primitive external zircon morphology suggests a magma source in the lower crust or upper mantle. The high Zr-saturation temperature and Ti-in-zircon temperature (~780 °C for Pp, ~910 °C for Pg) also suggest a deep source processes and material. The zircon grains are colourless and highly transparent, comprising solid inclusions suitable for analysis with the Raman spectrometer. The inclusions are euhedral-subhedral, mostly less than 10–15 μm in diameter. They are randomly oriented with the respect to the host zircon crystal growth structure. The following inclusions in zircons were detected by Raman spectrometer: anatase, kokchetavite, kumdykolite, apatite and hematite. In respect to characteristics of magma crystallisation, we have found important that anatase represents a TiO_2 polymorph formed at lower igneous temperatures, but its crystallisation compared to rutile is favoured by rapid crystallisation. The kokchetavite and kumdykolite are polymorphs of $KAlSi_3O_8$ and $NaAlSi_3O_8$, respectively. Recent research show that they represent metastable phases in melt inclusions as a consequence of rapid crystallisation. Apatite detected in zircon dominantly resembles F-apatite. A high F content is indicative of magma formed by partial melting of upper mantle material, while hematite inclusions indicate an oxidising environment for the magma at the time of hematite crystallisation. In addition to the inclusions, the rapid uplift of the Late Cretaceous acidic magma is supported by the occurrence of hematite with crystallographically oriented ilmenite exsolutions and perthite found in Pg granite as well as zircon aspect ratios.

In conclusion, the inclusions found in the zircon, which were protected from later equilibration with the melt or alteration by fluids, confirm a deep magma source (upper mantle/lower crust) and represent independent mineralogical evidence indicating rapid uplift and emplacement of a hot mantle/crust transition level magma with early-crystallised zircon into the upper crustal level. The rapid uplift was possible due to the formation of accompanying extensional deep-rifts in the course of the tectonic transition from compression to extension.