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Geochronology - a suitable tool to discern causality from temporal coincidence?

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Geoscientists tend to subdivide the system Earth into different subsystems (geosphere, hydrosphere, atmosphere, biosphere), which are interacting with each other in a non-linear way. The quantitative understanding of this interaction is essential to make reconstructions of the geological past. This is mostly done by a linear approach of establishing time-series of chemical and physical proxies, calibrating their contemporaneity through geochronology, and eventually invoke causality. A good example is the comparison of carbon or oxygen isotope time series to the paleo-biodiversity in ancient sedimentary sections, temporally correlated using astrochronology or high-precision U-Pb dating of volcanic zircon in interlayered ash beds. While highly accurate and precise data are necessary to form the basis for linear and non-linear models, we have to be aware that any analysis is the result of an experiment – an isotope-chemical analysis in the U-Pb example - introducing random and non-random noise, which can mimic, disturb, distort or mask non-linear system behavior. High-precision/high-accuracy U-Pb age determination using the mineral zircon (ZrSiO4) and application of the techniques of isotope dilution, thermal ionization mass spectrometry is a good example of such an experiment we apply to the geological history of our planet.

Two examples where precise U-Pb dating methods are used to link disparate processes are (1) using the duration and the tempo of zircon growth in a magmatic system as a measure for modeling magma flux in space and time, and apply these to infer potential eruptibility and volcanic hazard of a plutonic-volcanic plumbing system; (2) establish absolute age and duration of magma emplacement in large igneous provinces, feed these data into models of volatile injection into and residence of volatile species in the atmosphere, estimate their influence on the inherent parameters of Earth's climate, and infer causality with climatic, environmental and biotic crises. Both of these are outstanding scientific questions that attract and deserve significant attention by a general as well as academic public. However, insufficient attention is drawn onto the questions of the nature and importance of the noise we add through isotopic age determination.

There are two prominent issues to be discussed in this context, (1) to what extent (at what precision) can we distinguish natural age variation among zircon grains from random scatter produced by analytical techniques and the complexity of the U-Pb isotopic system in zircon, and (2) how can we correlate the U-Pb dates established for crystallization of zircon in residual and/or assimilated melt portions of mafic magmatic rocks from large igneous provinces to the release and injection of magmatic and contact-metamorphic volatiles into the atmosphere? This contribution intends to demonstrate that analytical scatter and complex system behavior are often confounded with age variation (and vice versa) and will outline new approaches and insights how to quantify their respective contributions.