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Taking geoscience to the IMAX: 3D and 4D insight into geological processes using micro-CT

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Geology is inherently dynamic, and full understanding of any geological system can only be achieved by considering the processes by which change occurs. Analytical limitations mean understanding has largely developed from ex situ analyses of the products of geological change, rather than of the processes themselves. Most methods essentially utilise “snap shot” sampling: and from thin section petrography to high resolution crystal chemical stratigraphy and field volcanology, we capture an incomplete view of a spatially and temporally variable system. Even with detailed experimental work, we can usually only analyse samples before and after we perform an experiment, as routine analysis methods are destructive. Serial sectioning and quenched experiments stopped at different stages can give some insight into the third and fourth dimension, but the true scaling of the processes from the laboratory to the 4D (3D + time) geosphere is still poorly understood.

Micro computed tomography (XMT) can visualise the internal structures and spatial associations within geological samples non-destructively. With image resolutions of between 200 microns and 50 nanometres, tomography has the ability to provide a detailed sample assessment in 3D, and quantification of mineral associations, porosity, grain orientations, fracture alignments and many other features. This allows better understanding of the role of the complex geometries and associations within the samples, but the challenge of capturing the processes that generate and modify these structures remains. To capture processes, recent work has focused on developing experimental capability for in situ experiments on geological materials. Data presented will showcase examples from recent experiments where high speed synchrotron x-ray tomography has been used to acquire each 3D image in under 2 seconds. We present a suite of studies that showcase how it is now possible to take quantification of many geological processed into 3D and 4D. This will include tracking the interactions between bubbles and crystals in a deforming magma, the dissolution of individual mineral grains from low grade ores, and quantification of three phase flow in sediments and soils. Our aim is to demonstrate how XMT can provide new insight into dynamic processes in all geoscience disciplines, and give you some insight into where 4D geoscience could take us next.