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Activation SPECT for 3D elemental mapping of a neutron-irradiated ore sample

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Non-destructive mapping of elemental distribution in bulk samples is hard to achieve with standard analytical tools: neutron activation analysis (NAA) allows for elemental identification but provides no spatial localisation, while X-ray or neutron computed tomography (CT) can provide structural information but often fall short in confidently extrapolating elemental distributions. We demonstrate that single photon emission computed tomography (SPECT) performed after thermal neutron activation ("Activation SPECT") can address this gap, that is, to localise activated nuclides in 3D and thus identify their parent element.
A successful proof-of-concept study has been conducted at the Australian Nuclear Science and Technology Organisation (ANSTO). Samples with known distributions of copper (Cu) and gold (Au) were irradiated at ANSTO's Dingo thermal neutron beamline to produce Cu-64 and Au-198 through neutron capture. The characteristic gamma emissions from the decay of these radionuclides can be used to identify the parent isotope. Through SPECT imaging of the neutron-activated samples, list-mode data was then acquired and used to reconstruct separate 3D activity maps using isotope specific energy and timing windows.
This workflow was applied to a 1 x 1 x 8 cm drill-core from Cobar, NSW with unknown spatial distribution and composition. Following neutron irradiation at Dingo's tertiary shutter position and subsequent SPECT imaging, the spatial distribution attributable to Cu-64 and Au-198 was determined. An unexpected component in the list-mode spectra was identified later as Mn-56 from matrix activation and reconstructed.
Activation-SPECT adds isotope-specific volumetric information to conventional NAA/CT workflows for mining, mineral exploration and cultural heritage. Combined with structural imaging modalities, this approach enhances our capacity to estimate elemental distributions in bulk samples of unknown compositions. Simulation modelling is also employed to assess the feasibility of Activation SPECT for other elements and sample geometries, and guide future experimental set-ups using this technique.

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