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Seeing through old mining wastes with secondary cosmic rays

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Tailing sand is almost only gangue-minerals-containing mining waste formed during the ore enrichment process. This waste material is deposited as a slurry in tailings storage facilities. Waste rock is defined as a rock material removed around the ore and typically piled near the quarries and mines.

Back in the days when the ore processing methods were poorly developed and ore deposits were located just below the Earth's surface, there were relatively large amounts of valuable materials left in the mining wastes. The heritage mining waste storage facilities, such as tailings ponds and waste rock stockpiles, are today considered significant secondary raw material resources by the EU. Moreover, due to the global trend of sustainable development and the EU's vision of economic autonomy, especially those mining waste storage facilities that contain critical raw materials (such as battery metal-bearing minerals) are expected to play a significant role in the future. These factors drive exploration and beneficiation not only towards new ore deposits but also to the wastes of those deposits that were exploited in the past.

One of the methods that hold promise as a characterization method of heritage tailings and waste rocks in terms of the ore potential estimation is cosmic-ray muography. Muography is based on muons that are electron-like elementary particles formed by the collision of cosmic rays and substances of the atmosphere. All the time and everywhere on our planet, the surface of the Earth is bombarded by high-energy muons. Due to the high energy and the fact that a muon is much heavier than an electron, muons have a high penetrating power to dense materials. The idea of muography is to measure the attenuation of muons after they have travelled through the object and subsequently translate the recorded muon statistics into meaningful density information such as 2D or 3D images. As the highest-energy muons can pass through even kilometres of rock, muography can be applied in many applications within the uppermost kilometres or so of the Earth's subsurface. The attenuation of muon flux depends on the mass density of the material: the denser the material is on average, the more it reduces the muon's energy (muons that have lost enough energy become non-relativistic and rapidly cease to exist).

We tentatively propose that there is a major opportunity to utilize muography in the estimations of the ore potential of old mining waste facilities. For example, one application of muography

could be the usage of a cylindrical detector placed in a borehole bored in a tailings pond. The measurements could be made at different depths and with several detectors. The measurements could tell if there are density differences in tailings and how they are distributed. Muography could be a considerable method of targeting further estimation studies of the resource potential of the old tailings. Muography measurements could also be a possible way to target the exploration of old waste rock stockpiles. Such an endeavour could be carried out from the sides of the stockpiles with one or more muon telescopes.