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Examples of applications of neutron imaging methods for the study of properties and phenomena in the earth sciences

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Non-destructive and non-invasive investigations of stones, minerals and soil assemblies are possible with neutrons. Whereas the methods of neutron diffraction can deliver structural information on the atomic level, the neutron imaging techniques deal with macroscopic properties and processes.

Although neutrons transmit samples and arrangements with dimensions up to about ten centimetres, the limitation in spatial resolution is given mainly by the detector performance and the scattering of neutrons inside the structure. Presently, a typical resolution is given with about 0.1 mm.

Unlike X-ray methods, neutrons strongly interact (and give contrast) with light elements as hydrogen, boron, lithium or carbon. This property of thermal and cold neutrons provide a high potential for the detection and visualisation of organic inclusions, oil distribution or water diffusion properties in porous media.

At PSI, neutron imaging techniques are established on a routine base at the NEUTRA station of the spallation neutron source SINQ. There are several detection systems available, which provide different performance in respect to spatial and temporal resolution. With the help of the tomography setup, the full three-dimensional information of the object under investigation can be obtained. Time dependent two-dimensional investigations can be performed with up to 15 frames per second, considering a reduction in image quality compared to the standard radiography system requiring about 20 seconds per frame.

Neutron imaging systems have been used in the recent years for several different investigations in the fields of geology, soil physics and the study of building materials. The talk will explain the different examples, including the boundary conditions, the aims of the investigations and the obtained qualitative and quantitative results.

The following studies have been of special interest and importance:

- Transport of water through a water saturated soil assembly; in this case, profit has been taken from the fact that light water (H_2O) has higher attenuation for thermal neutrons than heavy water (D_2O) with the same hydrodynamic properties.
- Water migration through granite and sandstone by capillary forces and under external pressure (two-dimensional, time-dependent).
- The behaviour of the penetration of moisture near fractures in granite (three-dimensional, time-dependent)
- Non-invasive determination of the water content in excavated soil structures by referencing between the wet and dry status.
- Determination of size and distribution of organic inclusions in stony matrixes.

As the method of neutron imaging is a universal tool for such kind of investigations, much more studies will be possible on request if the problem to solve fits into the boundary conditions of the experimental setup. Structural materials (preferably made of aluminium, zircon or titanium) around the sample for preparing pressure, heat or other conditions are easily penetrated by neutrons.