EPOS-NL: the Netherlands contribution to EPOS

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EPOS-NL is the Dutch National research infrastructure (NRI) contribution to EPOS (Figure 1). This NRI is financed by the Netherlands Organisation for Scientific Research (NWO) as part of the national roadmap for large-scale research infrastructure. Dutch Universities and knowledge institutions have a long history of operating advanced facilities. However, these facilities are often fragmented, incomplete and less than optimally accessible. With the 12.2 M€ recently granted from this national roadmap scheme (4th April 2018), EPOS-NL (Co-PIs Martyn Drury, Kees Wapenaar, Chris Spiers and Jeannot Trampert) will integrate all major national solid Earth sciences facilities into a coherent infrastructure that will develop innovative new facilities and open access data services within the EPOS framework.

EPOS-NL facilities is open for scientists in the Netherlands and Europe to undertake research that serves societal needs regarding supply of natural resources, and protection and warning against geo-hazards. The EPOS-NL consortium integrates world-class university groups from Utrecht University (UU) and Delft University of Technology (TU Delft) with the Royal Netherlands Meteorological Institute (KNMI), the national institute for weather, climate and seismology.

The new facilities developed by EPOS-NL will allow novel ground-breaking research in the field of geo-resources, in particular in the domains of:

- Geo-energy: exploration and exploitation of new, low carbon
geo-energy resources in the Netherlands and Europe, in particular geothermal energy.

- **Geo-storage**: geological storage of CO₂, fuels like natural gas and renewably generated hydrogen, and wastes related to energy production.
- **Geo-hazards**: such as induced earthquakes and subsidence caused by human activities in the subsurface.

EPOS-NL facilities will contribute to a new, multi-scale experimental, observational and modelling approach that provides understanding, from the molecular to the basin and even crustal scales, of the coupled processes of fluid flow and deformation in complex porous and fractured media. The new cluster of experimental facilities will allow research on centimetre to decimetre scale rock samples, addressing the micro to nanoscale processes active within them, but also features massively instrumented analogue scale-modelling approaches addressing the metre to kilometre and basin scales. At the reservoir and field scale, EPOS-NL intends to deliver first-time active monitoring of subsurface test-bed facilities and reservoir systems, providing validation of process models and upscaling procedures and substantially increasing both our understanding and ability to control and predict subsurface system behaviour.

The EPOS-NL facilities cluster will include:

- The Earth Simulation Laboratory (ESL) at Utrecht University, for multi-scale rock physics and analogue experiments;
- The Groningen gas field seismological network and the ORFEUS Data Centre (ODC) at KNMI;
- The deep geothermal well (DAPWELL) and Petrophysics Lab (DPL) at TU Delft and;
- Distributed facilities for multi-scale imaging and tomography (MINT) of geo-materials at Utrecht University and TU Delft.

**ESL - Earth Simulation Laboratory (UU)**

The ESL (Figure 2) will integrate the existing world-class multi-scale, multi-physics experimental facilities at UU (HPT Laboratory; TecLab) with existing numerical modelling and imaging facilities for seismological research. New facilities will include a high-resolution imaging of the 4D internal deformation of analogue models and an ultra-high resolution HPT testing machine able to deform rock samples and simulate fault slip under geothermal, flow-through conditions.

**The Groningen gas field seismological network and the ORFEUS Data Centre (KNMI)**

The Groningen gas field is a unique natural observatory for induced seismicity (Figure 3). Big data from the dense seismic network of borehole stations in Groningen will be integrated in the ORFEUS Data Centre and made openly available to the geoscientific community through the EPOS Thematic Core Service Seismology.

**DAPWELL geothermal well and Petrophysics Lab (TU Delft)**
A deep geothermal doublet, built with new materials (composite casing) and extensive monitoring and testing instrumentation, will be installed on the TU Delft campus (Figure 4). Cores will be analysed in the laboratory to determine the petrophysical properties of the reservoir rocks and a seismic network at the surface will monitor fluid flow between injector and producer well.

**MINT - Multi-scale imaging and tomography (UU & TU Delft)**
MINT is a cluster of instruments enabling visualization and correlation of 3D and 2D structures within rock samples at all scales ranging from meters to nanometres (Figure 5). It will include X-ray tomography systems with a range of resolutions and sample size capabilities and cutting-edge automated electron microscopes. MINT will be able to image rocks at all scales and allow notoriously difficult sub-micron pore and fracture networks to be analysed and scaled to larger rock structures.

**Connection with EPOS TCS**
Incorporation of EPOS-NL within the pan-European EPOS research infrastructure facilitates transnational access to physical facilities, as well as optimal exploitation of research results via open access data services that will be fully compatible and interoperable with the EPOS e-infrastructure.

The unique KNMI dense seismic network of borehole stations in the Groningen gas field will be integrated into EPOS TCS Seismology through ORFEUS Data Centre, one of the large data archives in the federated structure of EIDA (European Integrated Data Archive), following the technical requirements, data management plan (DMP), policies and metadata models of EIDA. Services that will be provided by TCS Seismology, covering novel access tools, will provide new opportunities for innovative, multidisciplinary research. The vast amount of seismic data from the KNMI networks for monitoring induced seismicity in the Groningen gas field will provide a unique dataset for a nationally important episode of human induced earthquakes.

Multi-scale microscopy, rock physics and analogue modelling data generated in the ESL and MINT facilities will be available to users thanks to the data services provided by the EPOS TCS Multi-scale laboratories. Moreover, the ESL and MINT facilities will participate to the TCS Multi-scale laboratories Trans-national Access program.

DAPwell will function as a service provider in the Geo-energy test beds TCS.

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