



HAL
open science

Geophysical inversion and machine learning of dense 3D seismic and resistivity models for imaging deep landslide structures

Myriam Lajaunie, Céleste Broucke, Jean-Philippe Malet, Julien Gance, Clément Hibert, Catherine Bertrand, G. Sénéchal, Dominique Rousset, Cathy Truffert, Claire Bataillès, et al.

► **To cite this version:**

Myriam Lajaunie, Céleste Broucke, Jean-Philippe Malet, Julien Gance, Clément Hibert, et al.. Geophysical inversion and machine learning of dense 3D seismic and resistivity models for imaging deep landslide structures. 5èmes Rencontres Scientifiques et Techniques Résif, Nov 2021, Obernai (67210), France. hal-03481172

HAL Id: hal-03481172

<https://hal.science/hal-03481172v1>

Submitted on 15 Dec 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Geophysical inversion and machine learning of dense 3D seismic and resistivity models for imaging deep landslide structures.

Myriam Lajaunie¹, Céleste Broucke², Jean-Philippe Malet^{1,2}, Julien Gance³, Clément Hibert^{1,2}, Catherine Bertrand⁴, Guy Sénéchal⁵, Dominique Rousset⁵, Cathy Truffert³, Claire Bataillès⁶, Laurent Lespine⁶

- 1 : Institut Terre et Environnement de Strasbourg (ITES), CNRS UMR 7063, Strasbourg, France
- 2 : Ecole et Observatoire des Sciences de la Terre (EOST), CNRS UMS 830, Strasbourg, France
- 3 : IRIS-Instruments, Orléans, France
- 4 : Laboratoire Chrono-Environnement (LCE), CNRS UMR 6249, Besançon, France
- 5 : Laboratoire des Fluides Complexes et de leurs Réservoirs, Université de Pau et des Pays de l'Adour (LFCR), UMR 5150, Pau
- 6 : Office National des Forêts – Service de Restauration des Terrains en Montagne 64/65, Tarbes

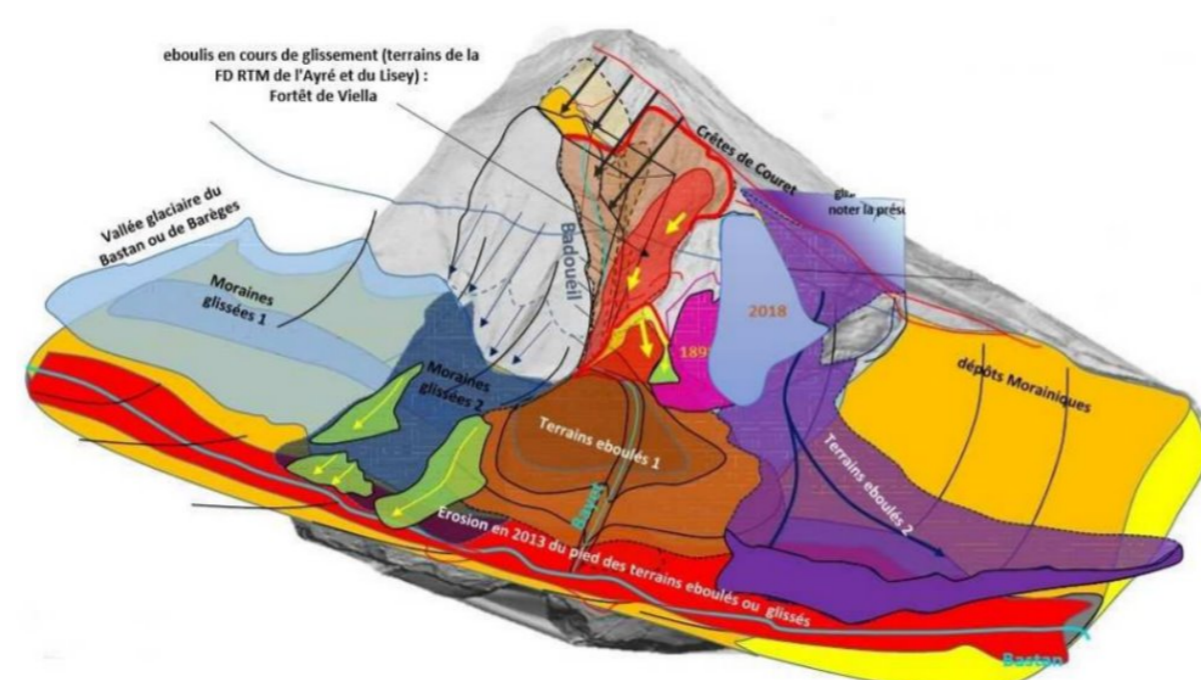


Objective

- Joint interpretation of resistivity and seismic travel time dataset using 3D geophysical inversion and machine learning
- Better representation of the spatial variation of structures, heterogeneities and water pathways
- 3D geometrical models as input for landslide hydro-mechanical modelling

The Viella landslide, Central Pyrénées

- Large landslide affecting unconsolidated sediments (moraine, rockslide deposits, alluviums)
- Estimated depth > 80 m, reactivation in 2018
- Surface velocity up to several cm.yr⁻¹ with damage to buildings and infrastructures



3D conceptual representation of the slope material (Bataillès et al., 2019)

The Viella landslide: geomorphology, region of interest for the geophysical survey and geological sketch

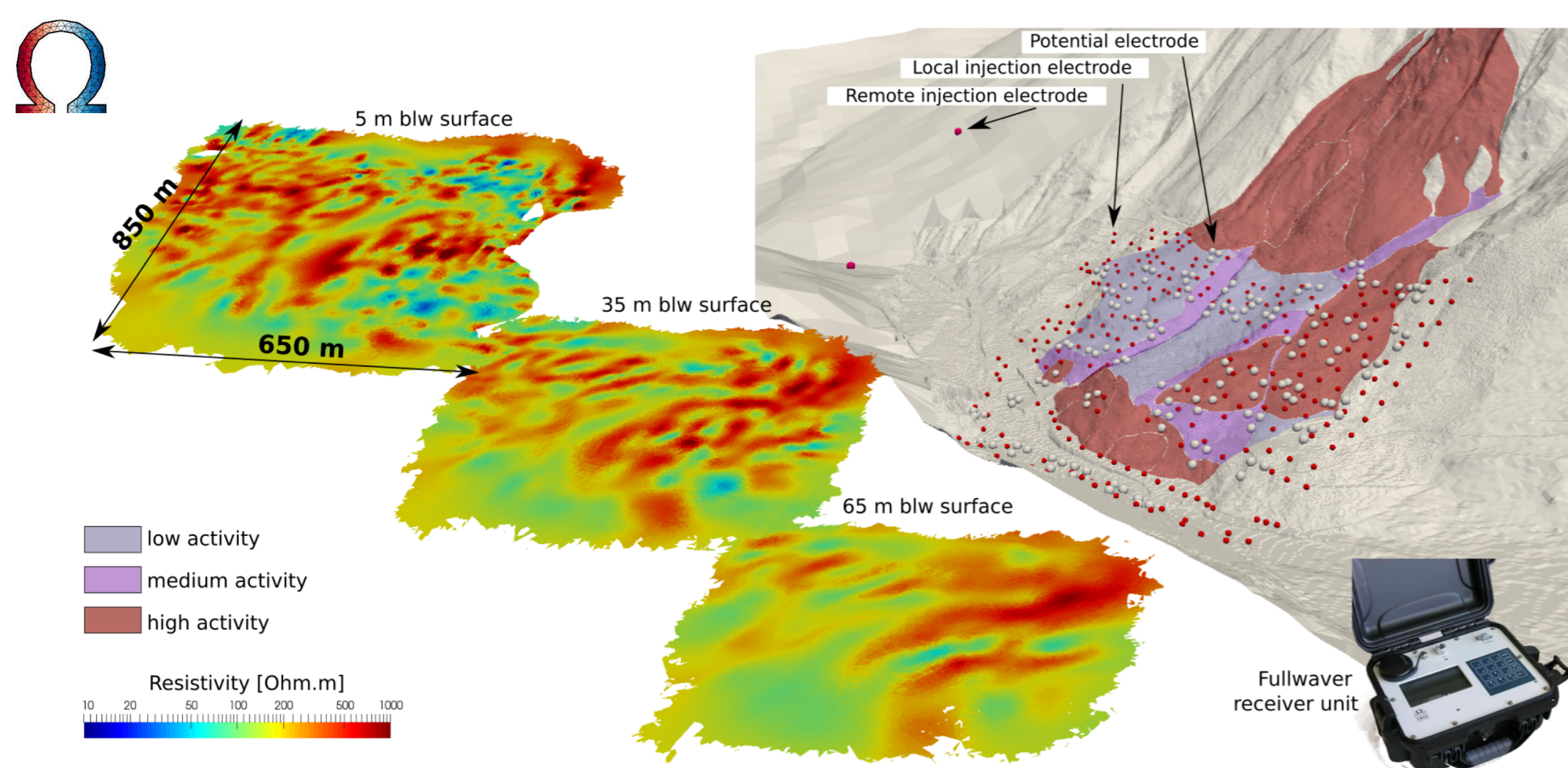
Survey

- > 15 boreholes, inclinometers and piezometers and hydrogeological tracing
- 3D resistivity survey (153 electrodes, 235 injection points, TDIP and Fullwaver system)
- 3D seismic survey (72 geophones / DENSAR; > 200 seismic sources – vibroseis, PEG-90kg, Sissy-shots)
- Geophysical acquisition carried out in June/July 2020

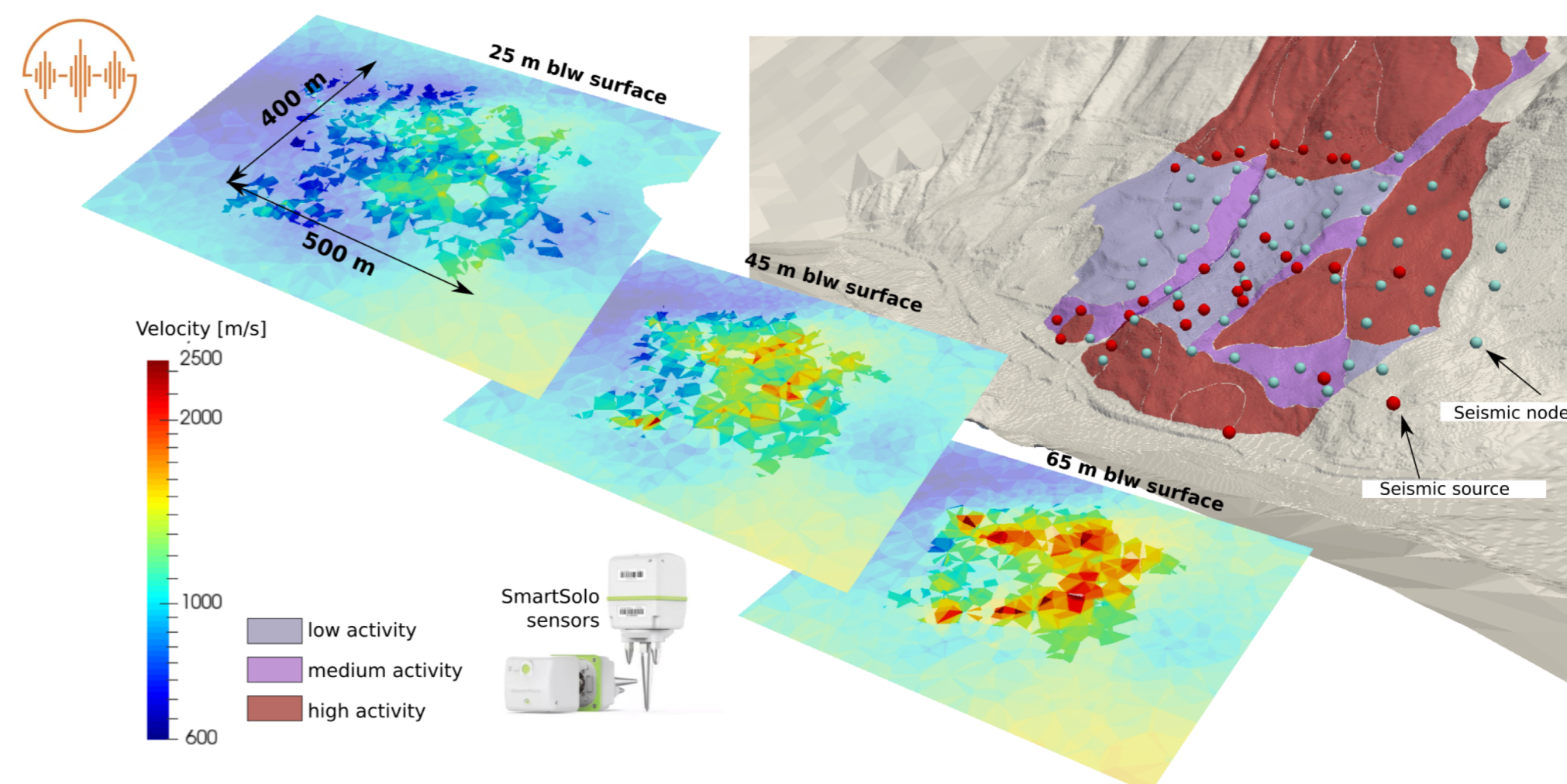


3D ERT injection control

3D ERT model (BERT inversion) and 2D resistivity slices at several depths



3D P-wave travel-time model (PyGimly inversion) and 2D velocity field at several depths



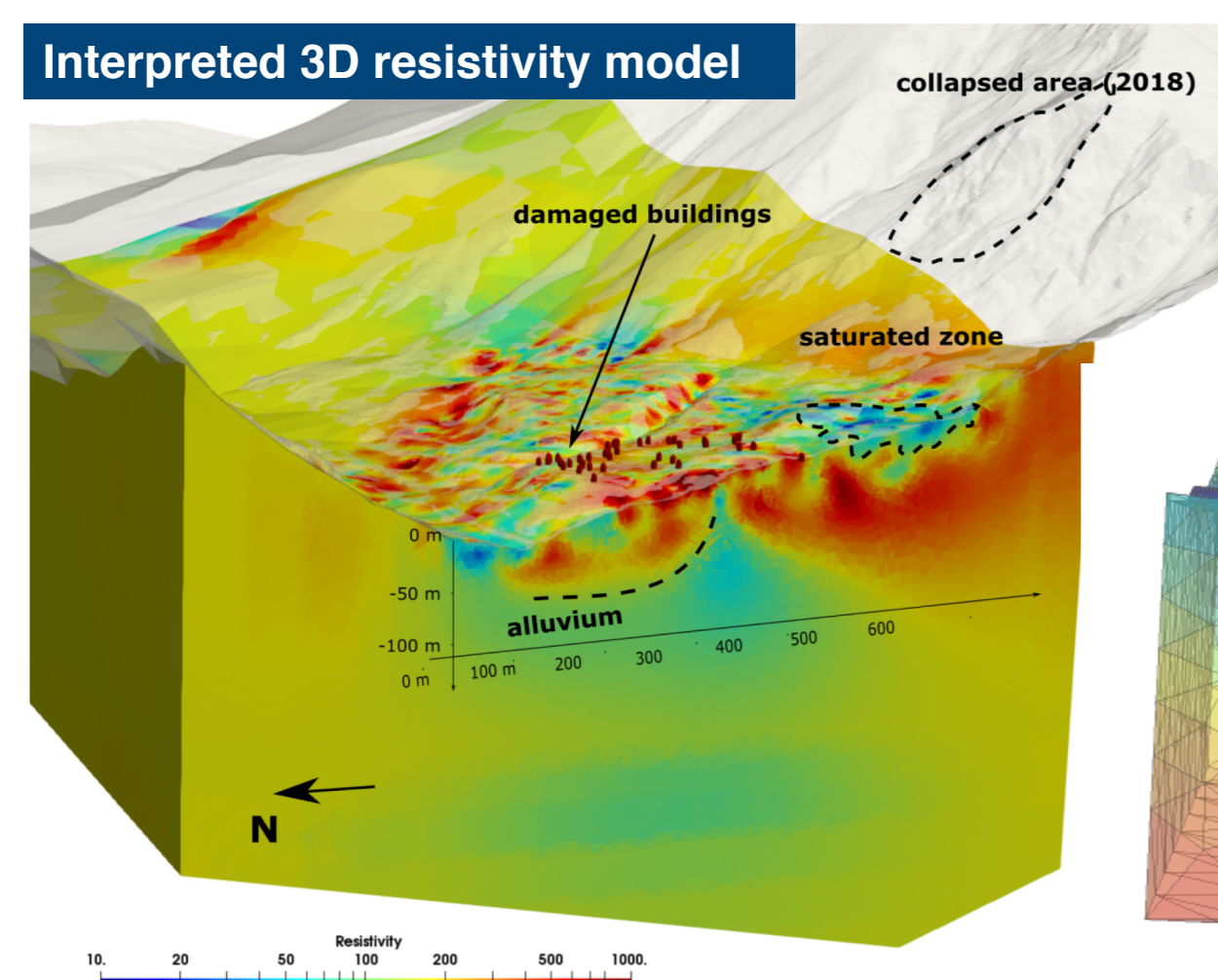
Geophysical inversion

- 3D models allow documenting the complex structures of the slope at several spatial scales
- Relation between resistivity and lithological / hydrogeological units
- Relation between seismic velocity and compacity of the slope sediments

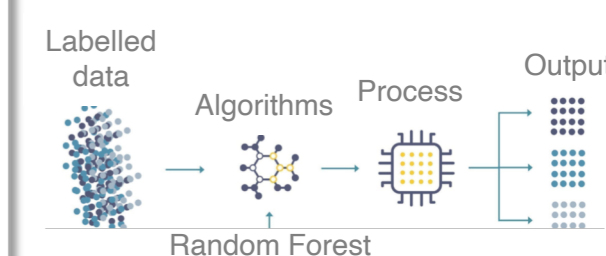
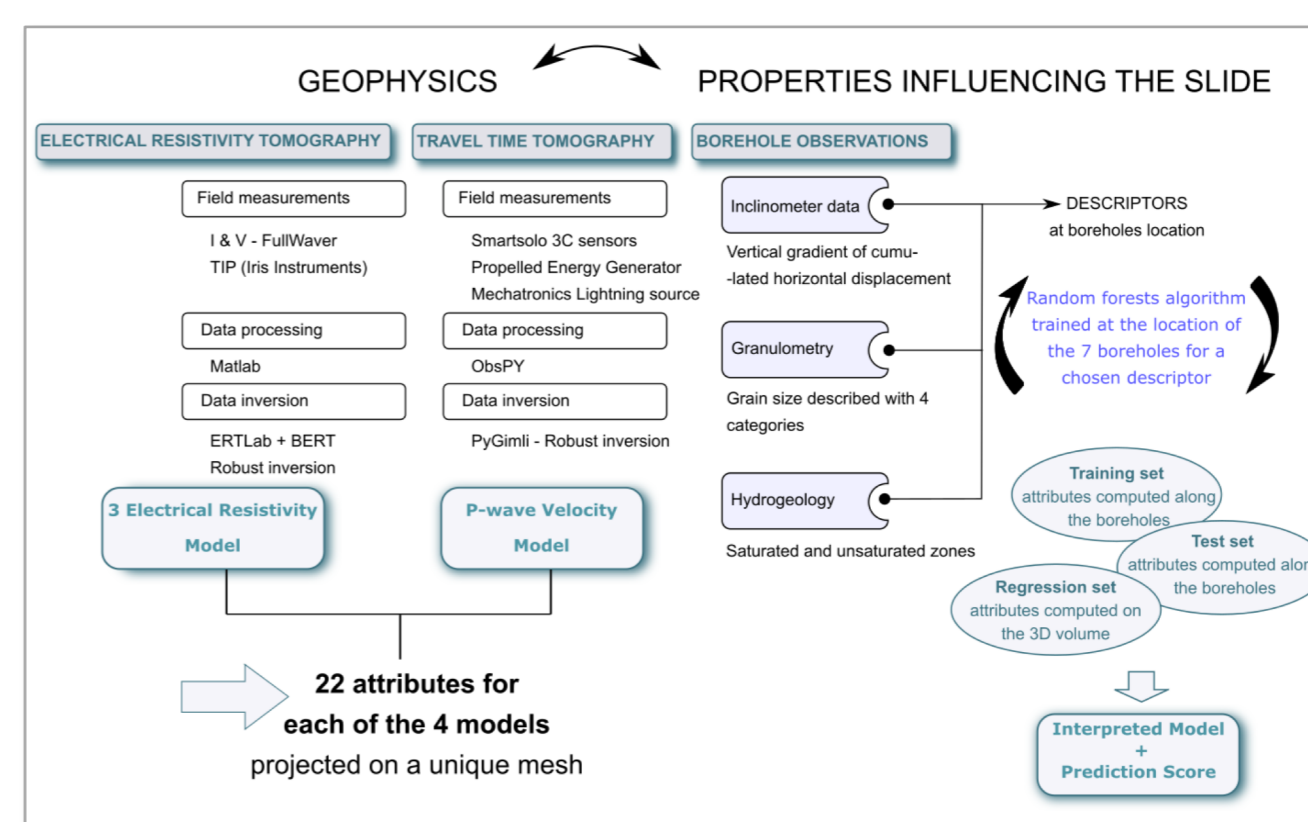
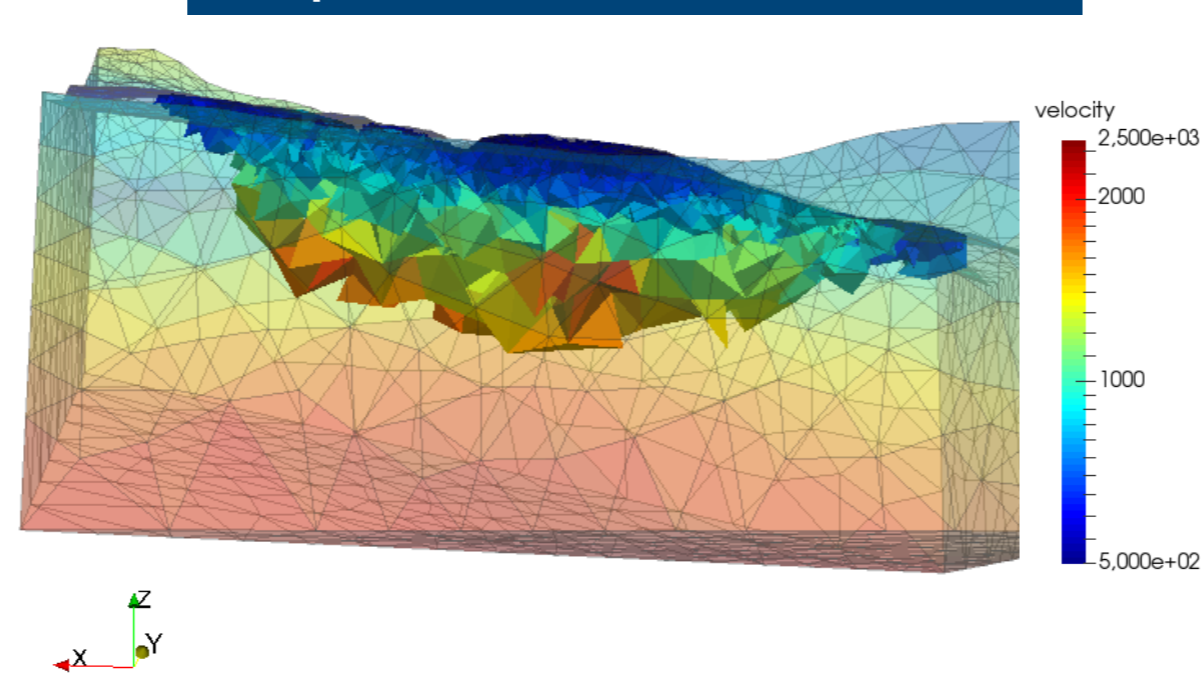
Multi-data fusion with machine learning

- Geophysical attributes derived from the models
- Hydrogeological (water saturation) and lithological (material compacity and granulometry) information from boreholes
- Regression using a Random Forest classifier

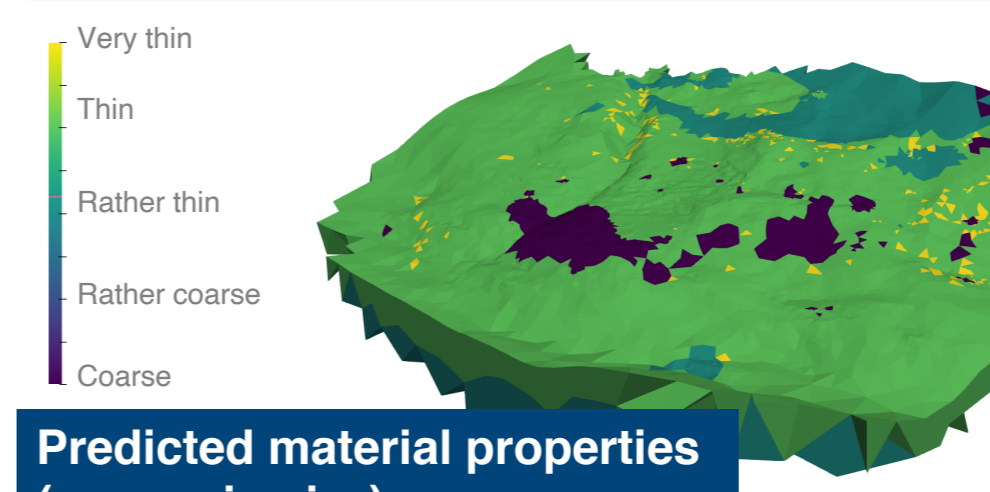
Interpreted 3D resistivity model



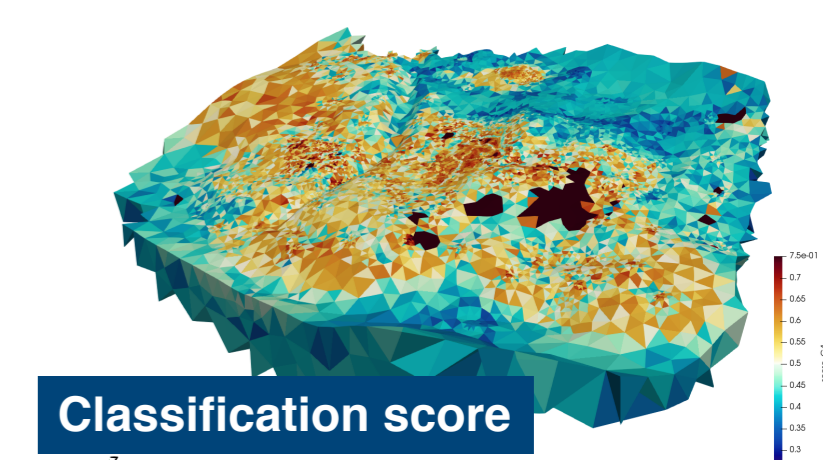
Interpreted 3D P-wave seismic model



- Computation of 88 geophysical attributes
- Extraction of lithological and hydrogeological attributes at borehole locations
- Machine learning algorithm: training - 75% of obs. validation - 25% of obs.



Predicted material properties (e.g. grain size)



Classification score