With this project we aim on the seismic investigations of the petit-spot volcanism – recently discovered phenomenon that shed a new light on our understanding of the intraplate volcanism. Petit-spot volcanoes (or petit-spots) are small volcanoes that erupt along lithospheric fractures in response to plate flexure during subduction. Their discovery was of great significance, as it demonstrated, that tectonic processes have potential to cause intraplate volcanism and supported the existence of small-degree melts at the base of the lithosphere.

Shortly after discovery of petit-spots, the debate emerged that the wide distribution of those volcanoes over relatively small area significantly alternate the composition of the sedimentary cover of the incoming oceanic crust. Moreover, in the larger scale they affect the geochemical cycle of arc magmatism and the global volatile cycle. Therefore, petit-spots bring significant impact on the subduction system in terms of megathrust rupture nucleation and slip propagation. In particular, it has been proposed that the difference in the thickness and composition of the sedimentary cover influenced the spread of the giant co-seismic slip during the 2011 Tohoku (Mw) 9.1 earthquake – the most powerful earthquake that have ever occurred in Japan triggering deadly tsunami wave and taking a catastrophic toll of nearly 20 000 fatalities. The need of detail insight into the shallow structure of incoming sediments in this area has already been noticed by the group of international scientists, who recently submitted a drilling proposal with the aim to assess the nature of the sedimentary cover affected by the petit-spot magmatism. Detailed seismic imaging of those structures will therefore further support the drilling program and will provide complementary information about the studied area. On the other hand, the petit-spots are just a small-scale surface evidences of the volcanic processes that take place in the deep lithosphere. Those processes are still not fully understood and have yet to be investigated. From the proposed mechanism of development of petit-spot volcanoes, we presume that their formation shall introduce the lateral variations of the physical parameters of the oceanic crust and uppermost mantle. As for today, the high-resolution crustal-scale inversion and migration methods are the only robust techniques to image those variations.

Therefore, our fundamental goal here is to couple leading-edge full-waveform based inversion and depth-migration techniques with different types of unique seismic data to retrieve the high-resolution models of subsurface in the outer-rise region of the Japan Trench – the area where the petit-spot volcanoes were discovered for the first time 15 years ago. In particular, we plan to reconstruct high-resolution P and S wave velocity models (Vp and Vs) using full-waveform inversion (FWI) of the ocean-bottom seismometer (OBS) data, as well as reflectivity image using least squares reverse-time migration (LSRTM) of the multi-channel streamer (MCS) data. On the methodological side of this proposal we firstly want to tackle the long standing problem of moving the velocity model reconstruction with FWI of OBS data beyond the acoustic approximation. In particular reconstruction Vs remains challenging both on the methodological and computing side, and therefore, establishing robust workflow for this type of FWI is now one of the technical challenges. Access to the high resolution Vp/Vs ratio models would significantly increase the amount of geological information that might be inferred from the final imaging results. Secondly, owing the fact that we will have access to the detailed FWI Vp model, we would like to adopt the LSRTM technique to fully exploit the potential of the academic MCS data for the purpose of reflectivity imaging.

We want to obtain a detailed image of the changes in the sedimentary cover caused by petit-spot volcanism to understand how they alternate the inputs to the subduction zone and how it may affect the geodynamic system during nucleation and propagation of the megathrust earthquakes. On the other hand, we aim on the building the high-resolution crustal-scale models of the underlying structures. We want to recover variations of physical parameters associated with petit-spot volcanism down to the uppermost mantle. Those variations shall be seismically visible and their precise reconstruction is key factor to understand the way lava migrates from the deep lithosphere through the oceanic crust to erupt and form petit-spots.

Interpretation of the results derived with the proposed seismic imaging approach will help to answer intriguing scientific questions related to the petit-spot volcanism and in broader sense the inputs to subduction zones. This will bring a new insight on the subduction inputs and determine the genesis and global role of petit-spot magmatism. Simultaneously, the lessons learnt from this project will support optimisation and design of the future academic seismic data acquisitions and processing with the leading-edge wave-based seismic imaging techniques.