

## **Development of joint gravity–magnetotelluric inversion software and its application to data from the Howley Basin, NL.**

### **Project Deliverables:**

- A 3D joint gravity–magnetotelluric (MT) inversion program.
- Access to this 3D joint gravity–MT inversion program, and the individual gravity and MT inversion programs, for use in other locations in NL; positioned for development of joint inversion software for gravity and controlled-source EM (CSEM) data, which could be applied to data-sets from offshore NL.
- An improved model of the Howley Basin constructed from the joint and constrained inversion of the gravity and MT data-sets recently collected in the Basin, in particular, a more accurate, reliable density model guided by the MT data.

### **Project Description:**

This project will investigate and develop methodology and software for jointly inverting magnetotelluric (MT) and gravity data. The software that is developed will be applied to the gravity and MT data-sets that have recently been acquired for the Howley Basin, NL. The project will commence in September 2017 and will have a duration of four years.

Inversion is the process of automatically constructing a computer model of the Earth's subsurface from geophysical survey data. This enables quantitative interpretation of the geophysical data, such as estimation of the horizontal position, depth and size of features of interest in the subsurface, to be carried out. Inversion techniques for single data-types are fairly mature and well understood. Recently, attention has moved to trying to invert multiple different data-types at the same time to produce a single Earth model that is consistent with all the different data-types. The expectation is that an Earth model that reproduces observations from two (or more) data-types will better represent the subsurface than any of the two (or more) Earth models that are constructed individually from each single data-type. For example, surface gravity data, which has good horizontal resolution but poor vertical resolution, and cross borehole seismic tomography data, which has good vertical resolution but moderate lateral resolution, can complement each other in a joint inversion to give an Earth model that is significantly more accurate than either of the models obtained from the individual inversions of the gravity and seismic data-sets (Carter-McAuslan et al., 2015).

The applicant's research group is at the forefront of development of joint inversion methodology (e.g., Lelièvre et al., 2012; Carter-McAuslan et al., 2015; Lelièvre and Farquharson, 2016). At present there are two different approaches to the "joint" in joint inversion. One approach is based on the "cross-gradient" measure. This measure attempts to quantify whether or not the two physical properties (e.g., density and seismic velocity, or density and electrical conductivity) in the joint Earth model are varying spatially in the same way, exploiting the assumption that a change in one physical property when moving from one geological unit to another will be accompanied by a change in the other physical property. This approach has been implemented by a number of research groups (e.g., Gallardo & Meju, 2004; Jegen et al., 2009; Moorkamp et al., 2011). In principle, this is a promising approach. However, in practice, the

cross-gradient method is plagued by significant non-uniqueness in the optimization problem that is used as the means of implementing this approach, making the cross-gradient method not very practical.

The second approach to joint inversion, and the one we favour, uses physical property information to couple together in the model the physical properties of the different geological units known or anticipated to occur in the subsurface under investigation (e.g., Lelièvre et al., 2012). The known or estimated values of the physical properties of the different geological units are provided to the inversion. The inversion then attempts to construct a model in each cell of which the physical properties match those provided. Each cell in the model therefore corresponds to one of the known or anticipated units. This is in addition to the model reproducing each of the multiple geophysical data-sets being inverted. We have found that this physical-property approach to joint inversion, although not easy, does result in an inversion algorithm that is not as beset with non-uniqueness and local minima issues as the cross-gradient approach, and thus provides a more practical means of effecting joint inversion.

We have so far developed joint inversion software for combinations of gravity, gravity gradiometry, magnetic and travel-time seismic data (Lelièvre et al., 2012; Carter-McAuslan et al., 2015). The proposed research project will extend this to include the combination of gravity and MT data. We already have in place the algorithms and software components for joint inversion and for 3D gravity forward modelling and inversion. Also, we have recently developed 3D MT forward modelling and inversion methodology and software (Jahandari & Farquharson, 2016). We therefore have all the components we need in order to develop and test joint gravity–MT inversion methodology and software, and are confident of the success of this part of the project.

Recently, a line of MT data was acquired across the Howley Basin, NL, as part of a PEEP funded project (Livada, 2014). Seismic data were also acquired during this same project, and a substantial amount of gravity data were collected in the Basin as part of a partner project. These gravity data significantly expanded upon previously collected gravity data for the area. The line of MT data was modelled and inverted using typical 2D MT inversion methods. The Basin is comprised of presumably more electrically conductive sedimentary rocks overlying a more electrically resistive basement. The 2D MT inversion results suggest the Basin is roughly wedge-shaped in cross-section tapering to the east with a depth of approximately 2km in the west (Livada, 2014). The structure of the Basin is predominantly 2D, but there are features in the MT data (and the magnetic data for the area) that hint at possible 3D effects, especially at the eastern end of the MT survey line where it rises out of the Basin and crosses the Green Bay Fault. The application of joint gravity–MT modelling and inversion, and for 3D Earth models, has very real potential, therefore, for aiding in the interpretation and understanding of the Howley Basin. Joint inversion in particular shows promise as the sedimentary rocks of the Basin are both less dense and more conductive than the basement rocks. In addition, MT data have an inherent depth sensitivity, albeit limited, which is not the case for gravity data. Joint inversion of the gravity and MT data from the Basin therefore has the very real potential of the MT data guiding the gravity part of the inversion in terms of the depth of the Basin, and hence of producing a more reliable and corroborated density model of the Howley Basin.