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Synthetic modelling and joint inversion of seismic and gravity data for overburden stripping in the Athabasca Basin

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Introduction

Gravity signatures from components of the footprints of Uranium deposits in the Athabasca Basin are masked by the contribution to the measured gravity coming from glacial sediments (overburden). In the research illustrated here, the joint inversion of seismic refraction and gravity data is assessed as a means to estimate the depth of overburden. Once the thickness of the overburden is determined, the contribution of the overburden to gravity measurements can be accounted for and the gravity data used to look for density anomalies in the sedimentary and basement rocks (Juhoiuntti et al., 2012).

Forward modelling

Two models, one with modest topography and one drumlin-shaped, with the same physical properties were made, in which the upper layer is the overburden (v=1600m/s and d=2g/cc) and the lower layer is sandstone (v=4000m/s and d=2.42g/cc). Models were discretized using a triangular mesh. Seismic first arrival travel time and gravity data were synthesized.

Seismic refraction inversion

Inversions were performed of seismic data using both L2-norm and L1-norm methods (Fig. 1) (Lelievre et al., 2012). Vertical sections have more than 40,000 small triangular cells. Although small cells increase computer run-time, they increase resolution and accuracy. The L2-norm vertical section illustrates a good agreement with the original model. However, the interface between the two layers is not sharp. In contrast, the L1-norm section shows a sharper interface. Fitting between observed and calculated data is good.

Joint inversion

Figure 2 shows a model with representative topography for the Athabasca Basin, and the results of independent inversions. Figure 3 shows the joint inversion results. In comparison to the independent inversions, not only the density model is much improved, but also the interface has been clearly reproduced for both density and seismic velocity vertical sections using L2-norm method. For the joint inversion, two clusters can be seen in Figure 4 which represent the physical properties of upper (S=0.000625s/m and d=2g/cc) and lower (S=0.00025s/m and d=2.42g/cc) layers.

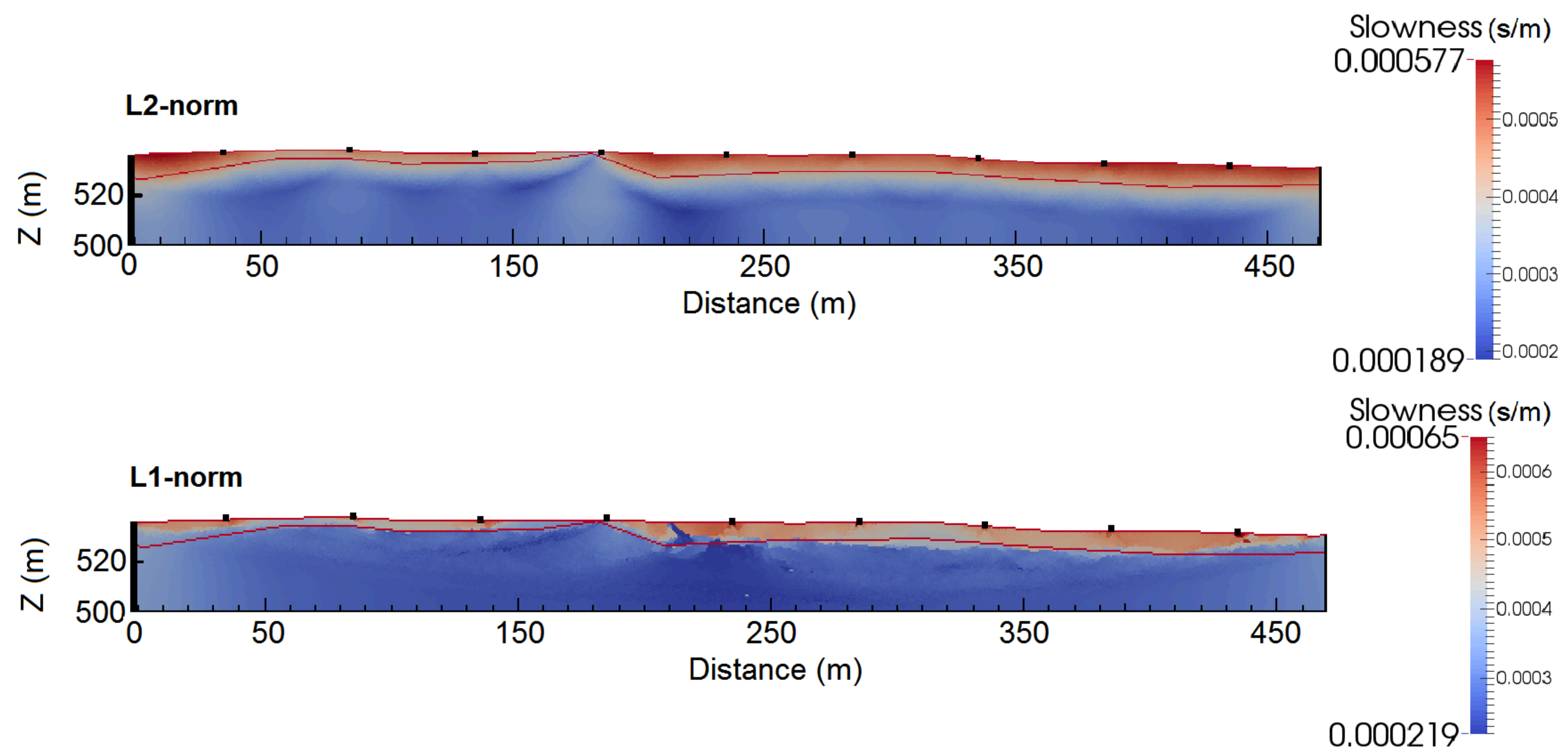

Fig. 1. Earth models constructed from inversion of synthetic seismic data generated from a model with modest topography using L2- and L1-norm methods. Locations of sources indicated by squares. Red line indicates the glacial sediments-sandstone contact in the model used to synthesize the data. Run-time for L2: 1hour; Run-time for L1: more than 5 hours.

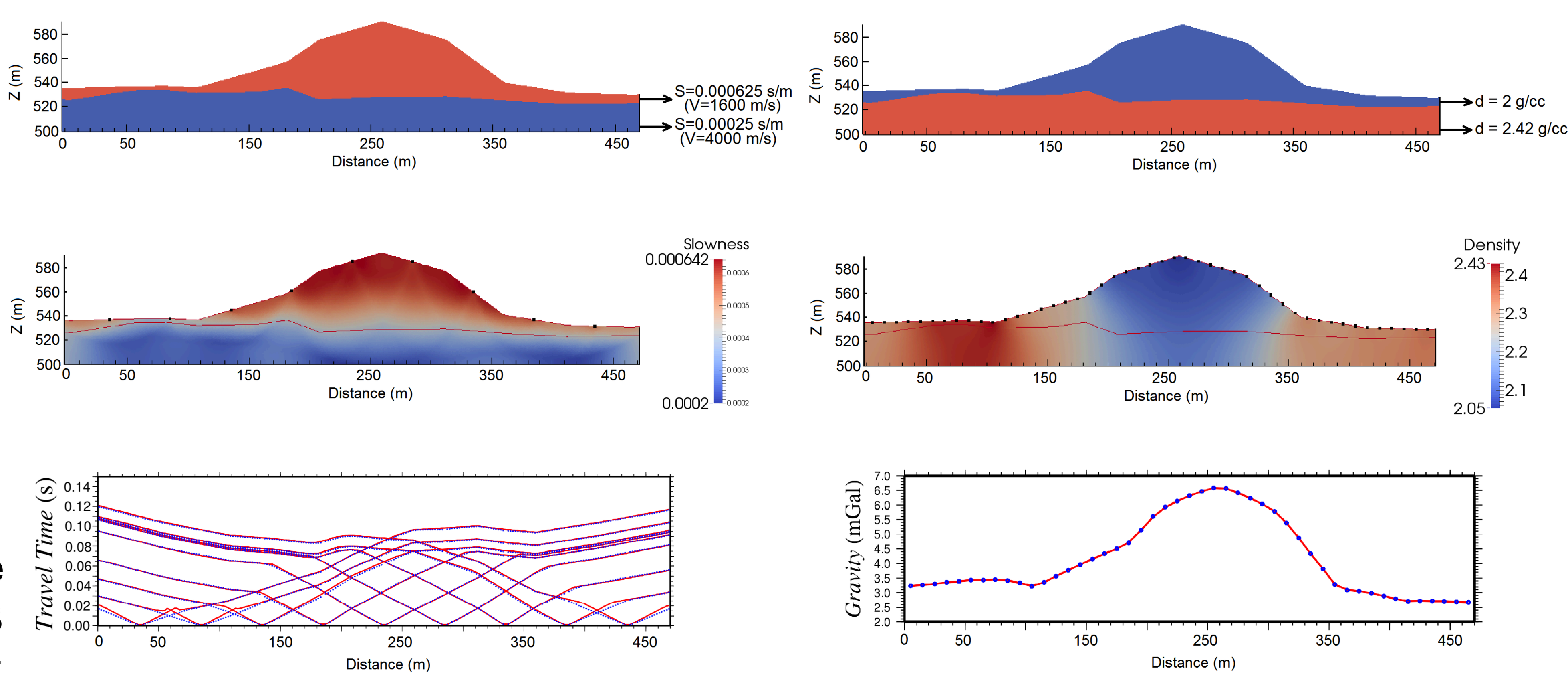

Fig. 2. Top: model of glacial sediments (v=1600m/s and d=2g/cc) over sandstone (v=4000m/s and d=2.42g/cc) based on conceptual topography (drumlin). Middle: Earth models constructed from independent inversions of synthetic seismic and gravity data along this line (L2-norm). Bottom: Refraction data (left) and gravity data (right) for the true model (red) and data calculated from the inversion result (blue).

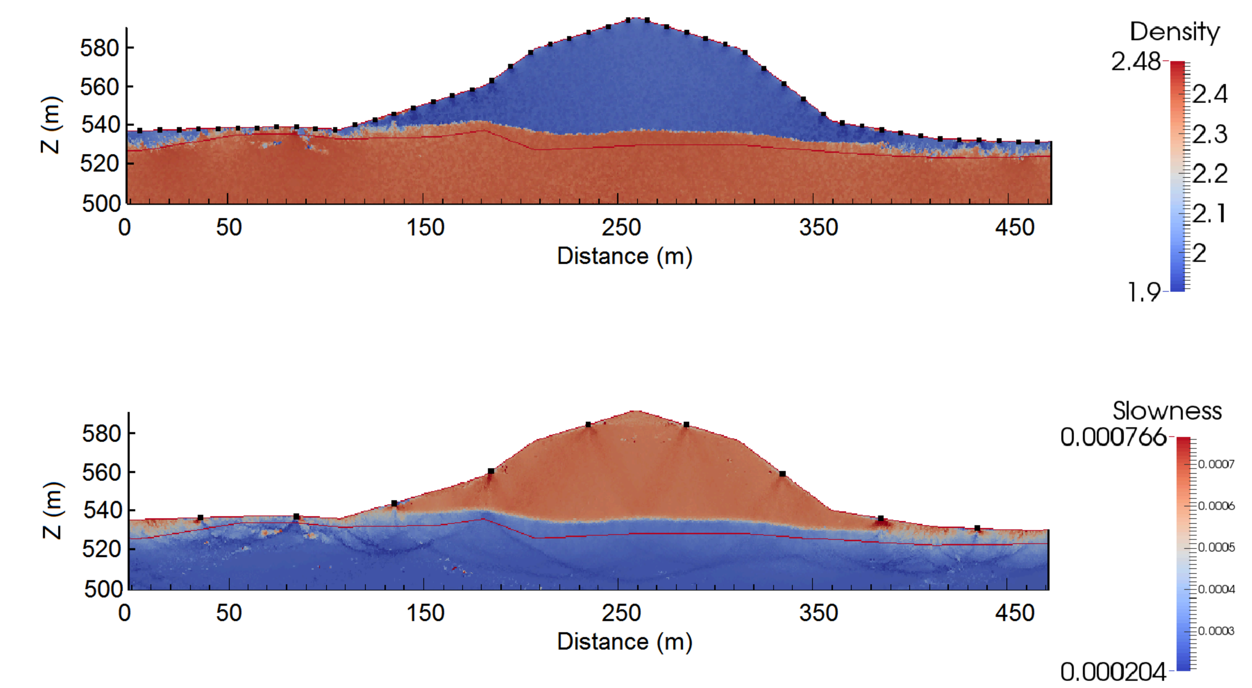

Fig. 3. Density and slowness models constructed from joint inversion of seismic and gravity data (L2-norm).

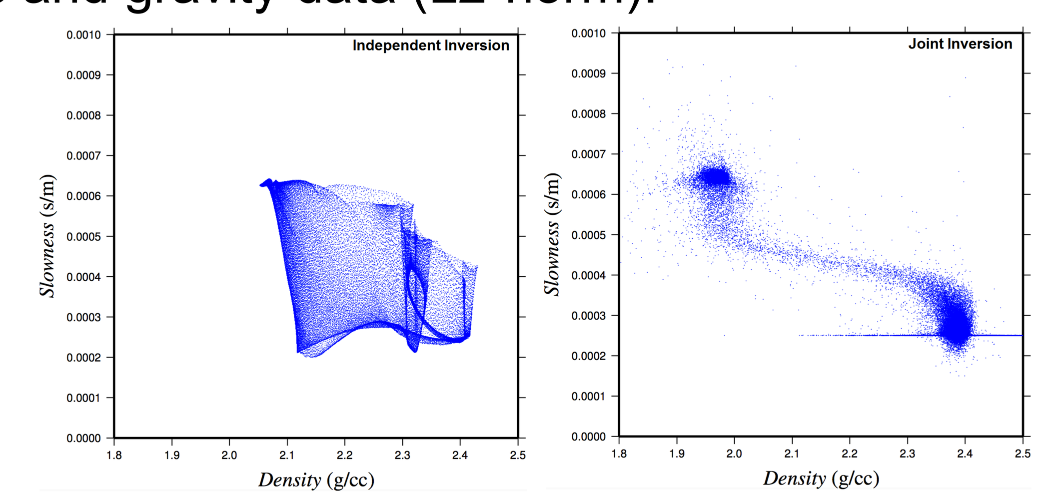

Fig. 4. Physical properties (slowness versus density) obtained after the independent and joint inversions for drumlin-shaped model.

Conclusion

Seismic first arrival travel time and gravity data were synthesized for two models. After inverting the data, results show that the joint inversion of seismic refraction and gravity data can estimate the depth of overburden better than the independent inversions.

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