The Role of Tectonic Evolution, Crustal Structure and Multiphase Magmatism in the Evolution of the Hatton Rifted Continental Margin, Offshore Ireland, Using Seismic Reflection and Potential Field Methods

Laura Bérdi*[1,2,3], Manel Prada[1,2], Brian M. O'Reilly[1,2], Peter Haughton[2,3], Patrick M. Shannon[2,3] & Sara Martínez-Loriente[2,3]

1) Dublin Institute for Advanced Studies, Geophysics Section, 5 Merrion square, Dublin, Ireland, 2) Irish Centre for Research in Applied Geosciences (iCRAG), University College Dublin, Belfield, Dublin 4, Ireland, 3) School of Earth Sciences, University College Dublin, Belfield, Dublin 4, Ireland, 4) Institut de Ciencies del Mar, Barcelona, Spain, *laura.berdi@icrag-centre.org

1. INTRODUCTION

The Hatton Basin is located at the western European Atlantic Margin, approximately 600 km west of Scotland and Ireland (Fig. 1a). It is bounded by the Rockall Bank to the east and by the Hatton High to the west. The sediments in the Hatton Basin can be divided into eight main stratigraphic sequences (Fig. 2), spanning from Jurassic and/or older to Holocene on the basis of seismic reflection interpretation (this study, Fig. 1b), shallow borehole data (Hitchen, 2004 and DSDP data), seismic refraction studies (Jacob et al., 1995; Shannon et al., 1995; Vogt et al., 1998) and analogues from neighbouring offshore basins (e.g. McDonnell & Shannon, 2001). Due to the lack of deep borehole data in the study area, the Mesozoic evolution of the basin is not fully understood. On the basis of recent seismic reflection data interpretation, the project provides previously unkown seismic stratigraphic control on the presumed Mesozoic succession and sedimentary transport routes through time. Moreover, new constraints on the nature and timing of igneous processes and their influence on sedimentation are also recorded.

The results of this project will provide an in depth understanding of the nature and timing of geological processes in the area and thus, contribute to two main themes: **(1) Energy security** and **(2) Climate change.** Understanding the sedimentary and thermal evolution of the Hatton Basin plays a major role in defining whether there is a working petroleum system with possible hydrocarbon accumulations in the area **(1)**. Furthermore, the study of the igneous evolution of the basin could form the basis for further research on the effects of volcanic activity on the Paleocene-Eocene Thermal Maximum (PETM) global warming event **(2).**

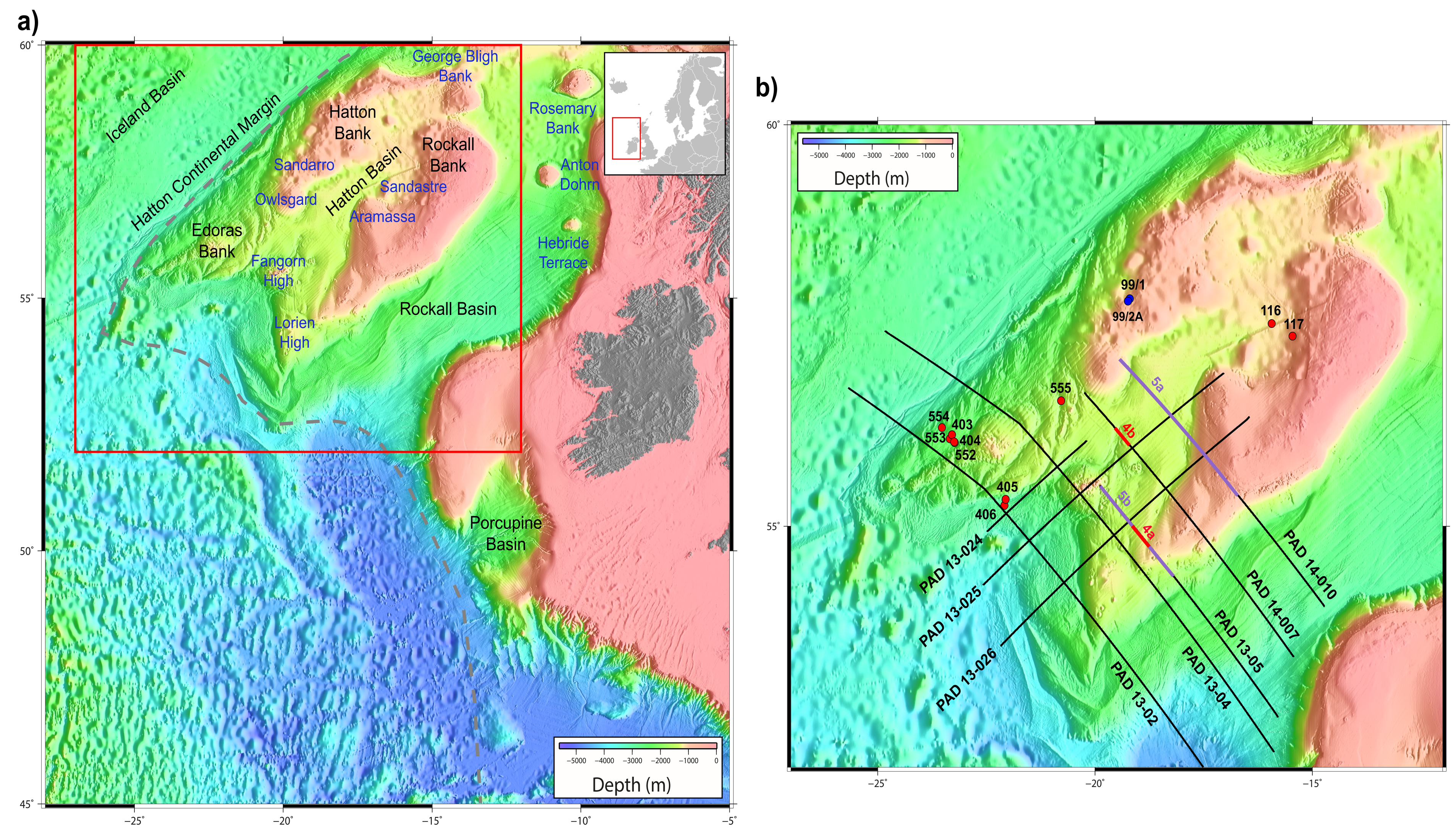

Figure 1. a) Bathymetry map of the Hatton Basin showing the main tectonic structures (black) and igneous features (blue) in the area. The red rectangle highlights the study area. The well and seismic data used in this study are shown on fig. 1b). The red circles represent DSDP boreholes, the BGS boreholes are highlighted in blue and the ODP borehole is shown in green. The grey dashed line represents the continent-ocean boundary.

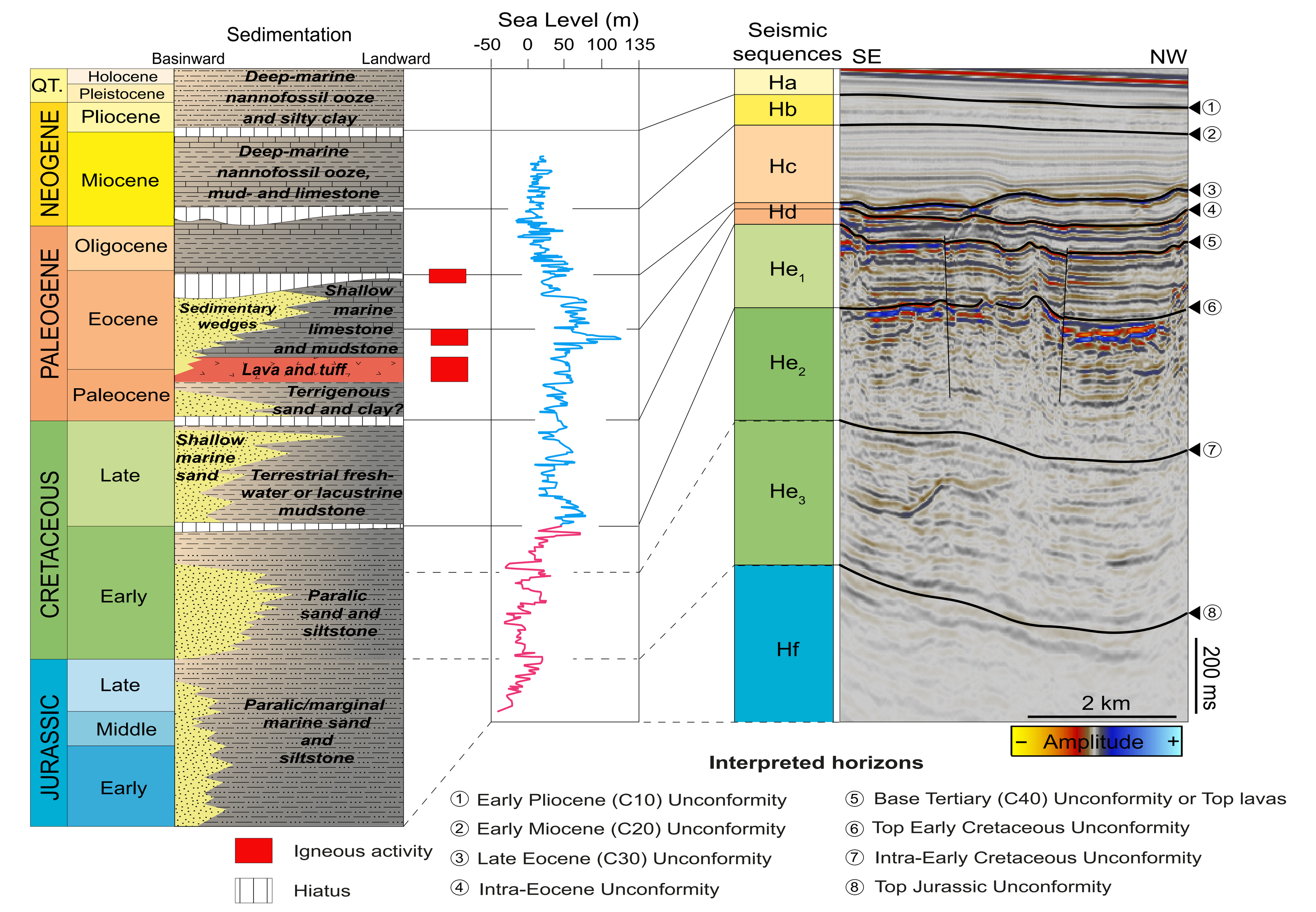

Figure 2. General stratigraphic column of the Hatton Basin showing the mapped regional unconformities and sedimentary megasequences (after Laughton et al., 1972, Hitchen, 2004, Stoker et al., 2001) and the changes in sedimentation style and igneous activity during basin evolution (based on DSDP data, McDonnell & Shannon, 2001 and this study). Sea level curves are from Miller et al., 2005 (blue) and Sahagian & Jones, 1993 (pink).

2. CORRELATION BETWEEN SEISMIC AND FIELD DATA

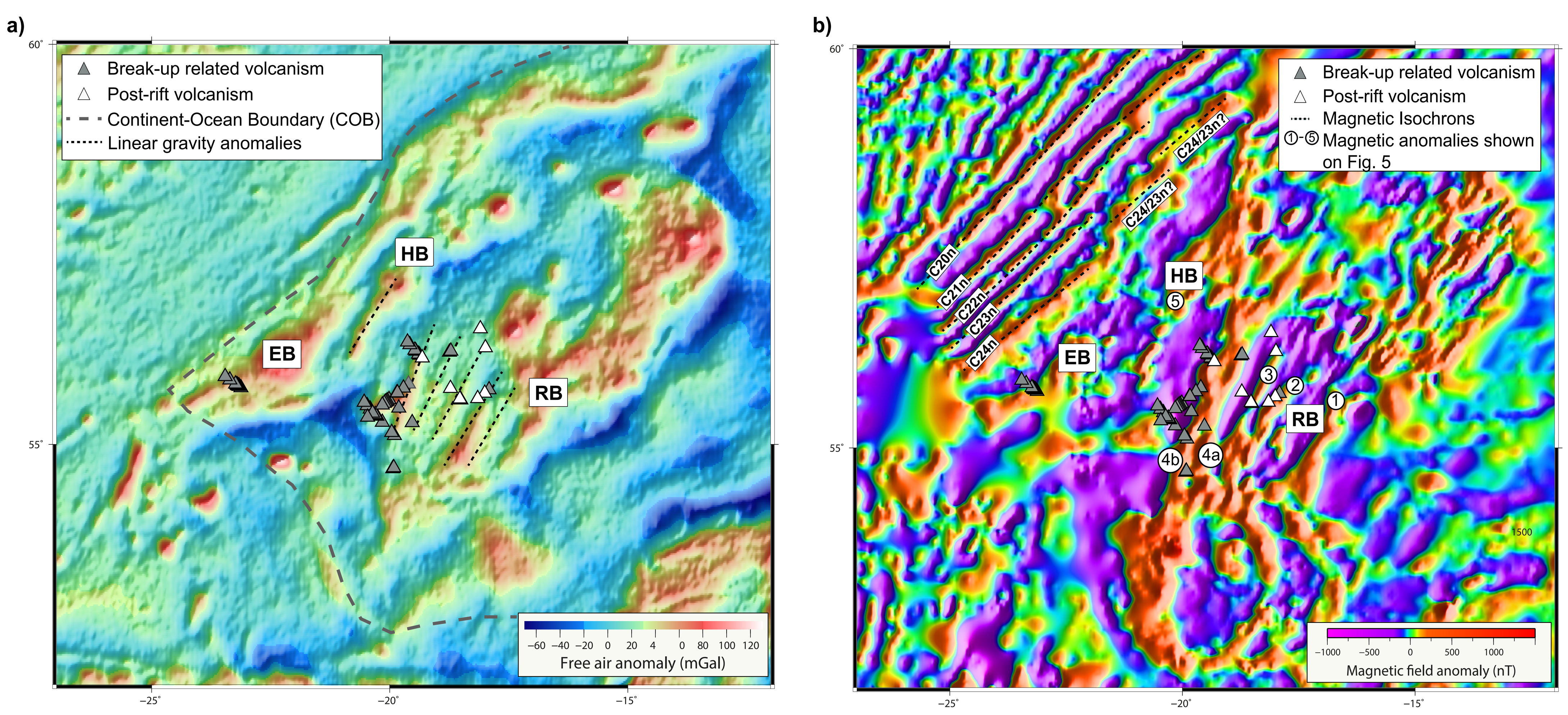

Figure 3. Gravity (a) and magnetic map (b) of the Hatton Basin (Sandwell et al., 2014; Verhoef et al., 1996). The numbered, NNE-SSW oriented anomalies in the basin correlate to increases in the potential field (more pronounced in the magnetic field) when extracted in 2D view (see Fig. 5). Most of the paleo-volcanic cones in the basin are located along these anomalies, which indicates areas with inherited zones of weaknesses in the crust. Combined with results from geophysical modeling, magma is thought to have used these zones - interpreted as major normal faults - as pathways to enter the Hatton Basin through deep-seated dike intrusions. EB - Edoras Bank, HB - Hatton Bank, RB - Rockall Bank.

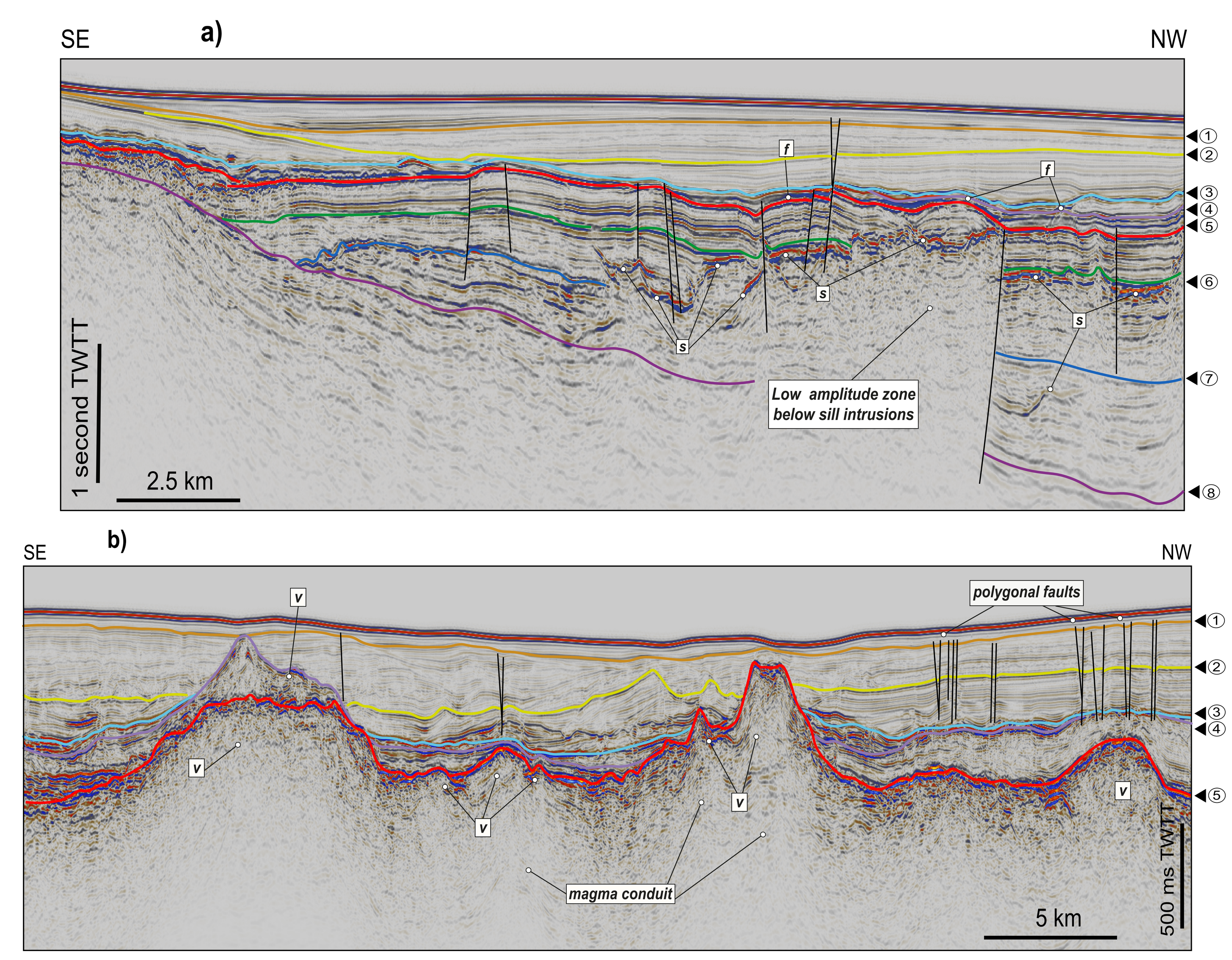

Figure 4. Examples of high-resolution seismic data showing the sedimentary architecture of the Hatton Basin at the basin margin (a) and multiple phases of magmatism (b). The volcanoes shown of Fig. 4b formed during the regional Late Paleocene-Early Eocene magmatic period (around PETM time), while the volcanic cone on the southeastern end of the profile post-dates the breakup along the North Atlantic margin. Other magmatic products, such as sills and dykes are also observed in the dataset intruding host rocks. f - forced fold, s - sill, v - volcano. For horizon legend, refer to Fig. 2.

3. GRAVITY AND MAGNETIC MODELING

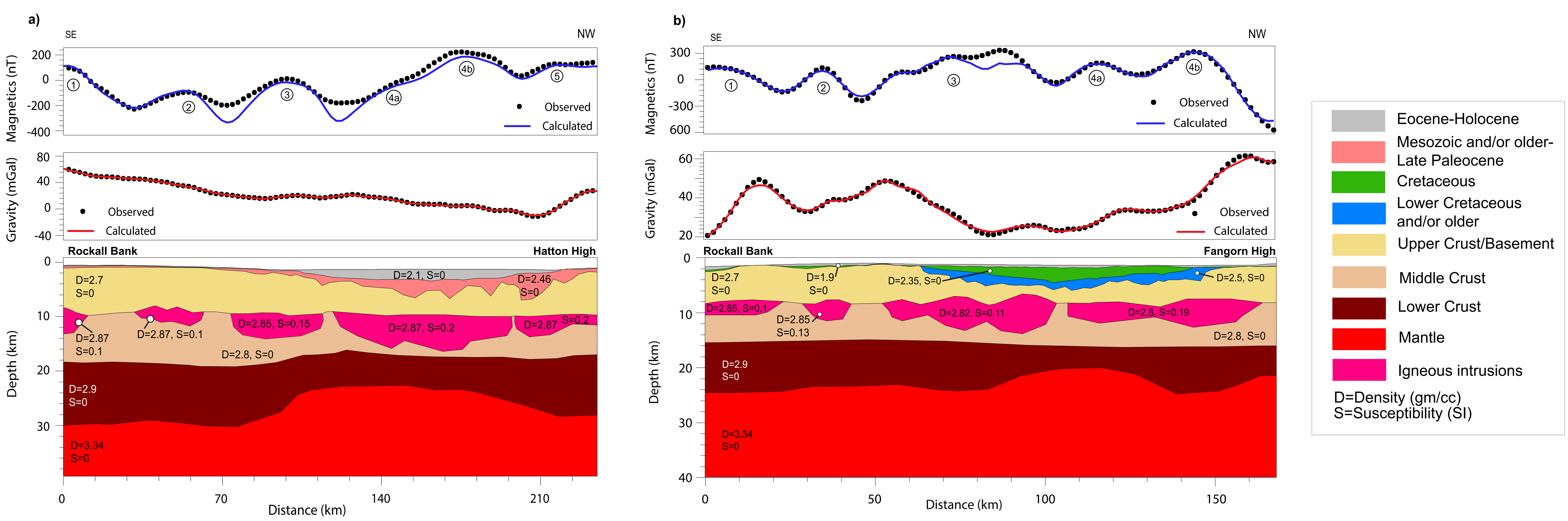

Figure 5. Potential field models of PAD seismic profiles 14-010 (a) and 13-005 (b). The shape and extent of sedimentary blocks between the basement and seabed are based on seismic picks. The horizons were depth converted into the model and - with the exception of the top basement pick - were not modified during modeling. On Fig. 5a, the Paleocene block includes the Mesozoic and/or older sediments beneath (which could not be picked along the whole profile).The top basement was interpreted at the bottom of reflectivity on each seismic line and was then modified according to the gravity response during modeling. The models show a basement with highs, horsts and half grabens, accomodating the deposition of thick Mesozoic and/or older sediments. The magnetic anomalies represent igneous intrusions at the top of the middle crust/bottom of the upper crust, located in a parallel, linear pattern in 3D view (Fig. 3) with localised volcanism along them. These intrusions are likely to had reached the basin through reactivated basement faults. Gravity grid is from Sandwell et al. (2014), magnetic data is from Verhoef et al. (1996), modeling was performed in Geosoft.

This publication has emanated from research supported in part by a research grant from Science Foundation Ireland (SFI) under Grant Number 13/RC/2092 and co-funded under the European Regional Development Fund and by PIPCO RSG and its member companies. Seismic data provided by the Petroleum Affairs Division of the Department of Communications, Climate Action & Environment.

Hitchen, K. 2004. The geology of the UK Hatton-Rockall margin. Marine and Petroleum Geology, 21, 993-1012.
Jacob, A. W. B. , Shannon, P. M., Makris, J., Hauser, F., Vogt, U. & B. M. O'Reilly. 1995. An overview of the results of the RAPIDS seismic project, North Atlantic. Geological Society, London, Special Publications, 93, 429-431.
Laughton, A. S., Berggren, W. A., Benson, R., Davies T. A., Franz, U., Musich, L., Perch-Nielsen, K., Ruffman, A., van Hinte, J. E. And Whitmarsh, R. B. 1972. Initial reports of the Deep Sea Drilling Project, vol. 12. Technical report, U.S. Government printing Office, Washington D.C.
Miller, K. G. et al. 2005. The Phanerozoic Record of Global Sea-Level Change. Science, 310, 1293-1298.
Sahagian, D. & Jones, M. 1993. Quantified Middle Jurassic to Paleocene eustaic variations based on Russian Platform stratigraphy: Stage level resolution. Geol. Soc. of Am. Bull., 105, 1109-1118.
Sandwell, D.T., Müller, R.D., Smith, W.H.F., Garcia, E. & R. Francis. 2014. New global marine gravity model from CryoSat-2 and Jason-1 reveals buried tectonic structure. Science, 346, 65-67.
Shannon, P. M. , Jacob, A. W. B. , Makris, J. , O'Reilly, B. , Hauser, F. & U. Vogt. 1995. Basin development and petroleum prospectivity of the Rockall and Hatton region. Geological Society, London, Special Publications, 93, 435-457.
Stoker, M. S., van Weering, T. C. E., and Svaerdborg, T. (2001). A mid- to late Cenozoic tectonostratigraphic framework for the Rockall Trough. In P. M. Shannon, P. H. And Corcoran, D., editors, The Petroleum Exploration of Ireland's Offshore Basins, vol. 188, 411-438. Geological Society, London, Special Publications.
Verhoef, J., Roest, W.R., Macnab, R., Arkani-Hamed, J. (1996). Magnetic anomalies of the Arctic and North Atlantic Oceans and adjacent land areas; GSC Open File 3125, Parts a and b (CD-ROM and project report). Geological Survey of Canada, Dartmouth NS.
Vogt, U., Makris, J., O'Reilly, B.M., Hauser, F., Readman, P.W., Jacob, A.W.B. & P.M. Shannon. 1998. The Hatton Basin and continental margin: Crustal structure from wide-angle seismic and gravity data. Journal of Geophysical Research, 103, 12545–12566.