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**Geological Survey of Ireland Research Programme
- Short Call 2015, Final Report -**

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Organisation name	PGW Europe
Organisation type:	☐ HEI ☐ Public Sector (other) ☒ Private Sector
Department/section	

Project Title	Integrated geological-geophysical model for stratiform Zn-Pb exploration
Contract No.	2015-sc-014



2. Project information:

Title of project	Integrated geological-geophysical model for stratiform Pb-Zn exploration
Keywords	Mineral exploration, geophysics, geology
Duration	10 months

Abstract/short description:

This projects aims to provide better insight into the localization of stratabound and fault-controlled Zn-Pb deposits in Ireland, by creating a 3D litho-structural model, based on geophysical data obtained from the Tellus (and related) surveys. Geology modelling using geophysical data is the ideal tool for understanding the 3D geometry of units, structures and contacts at depth. We aim to create new regional integrated litho-structural interpretation, 2D section-based models of magnetic and EM datasets, as well as obtain physical rock property measurements. All of these provide the basis for the construction of a geological and geophysical 3D model. The model will help characterize the geophysical signature of known zinc-lead deposits and use the obtained characteristics to delineate new exploration targets.

Project Description:

- (i) Strategic context and rationale (relating to Tellus, INFOMAR, national strategy etc. as applicable)

Ireland is host to Europe's largest zinc-lead deposit in current production at Navan (70 Mt, Figure 1). The known deposits contain some 14 Mt of zinc metal, approximately 1.5% of world zinc found to date, and additionally to the Navan deposit comprise the 18.9 Mt Lisheen deposit and Galmoy (6.2 Mt) (Department of Communications, Marine and Natural Resources, 2006). Ireland has a widespread carbonate succession that has proved a favourable host for stratabound (Irish-type; Figure 2) or cross-cutting (Mississippi-Valley-type, MVT) zinc-lead mineral deposits. The bulk of these carbonates occur in Central Ireland, where a number of thick Lower Carboniferous limestone basins occur. The known deposits are stratigraphically and structurally controlled.

Recent exploration has identified four key targets, especially in the Central Ireland Basin (Department of Communications, Marine and Natural Resources, 2006). (1) The lowest non-argillaceous carbonates of the Waulsortian Group (central and southern Basin) and Navan Group (northern Basin). (2) Major NE or ENE trending fault structures that displace the Navan Group or Waulsortian Limestones, in areas of maximum displacement. (3) At major fault structures and within thick Lower Carboniferous fine-grained clastics in the Munster Basin. (4) In the Carboniferous cover rocks overlying the Dalradian metamorphic rocks of the Northwestern Basement.

All the known zinc-lead deposits in central Ireland are shallow (<200 m depth) (Department of Communications, Marine and Natural Resources, 2006), opening the possibility of undiscovered deposits at depth. Geology modelling using geophysical data is the ideal tool for understanding the 3D geometry of units, structures and contacts at depth.

The Tellus geophysical survey data provides new aeromagnetic, gamma spectrometry and electromagnetic data (Figure 3). This data provides not only a better and more coherent insight into the near-surface geology, but also allows for an improved understanding of the lithology distribution at depth.

A new regional integrated litho-structural interpretation is proposed as a starting point, which then provides the structural skeleton for the subsequent modelling and interpretation at more detailed scales.

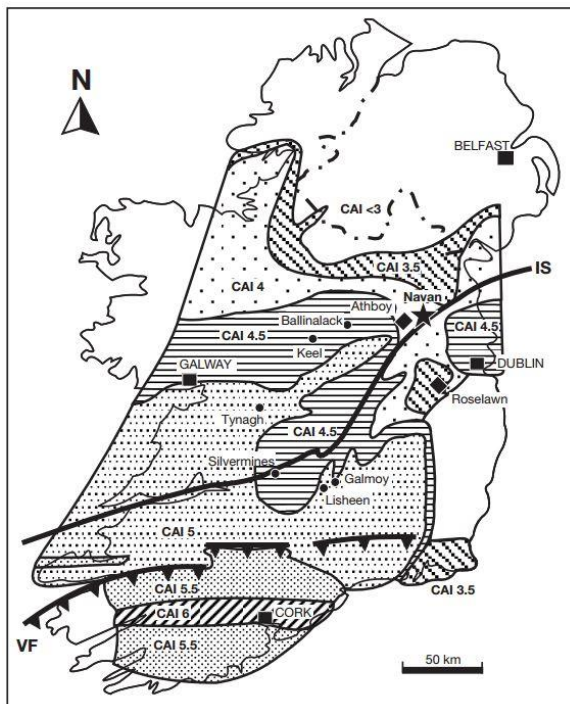


Figure 1: Location of the Navan zinc-lead deposit along the Iapetus Suture (IS) (Anderson et al., 2006).

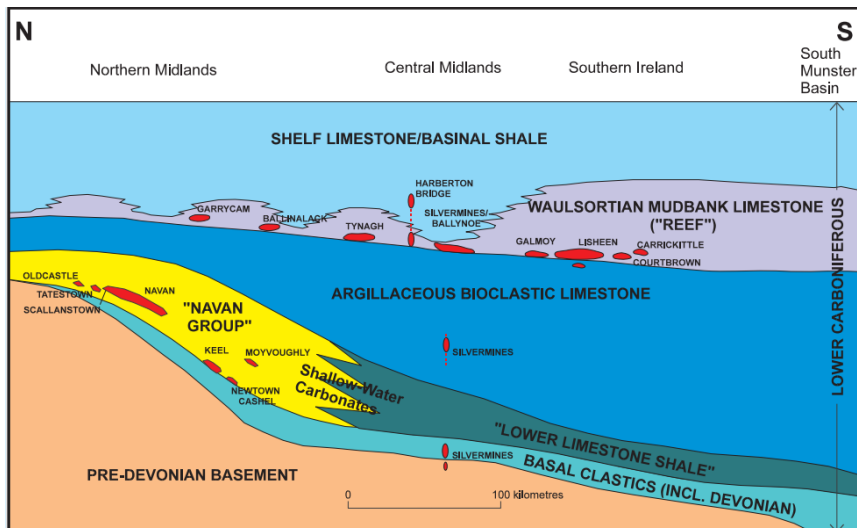


Figure 2: Schematic section showing the stratigraphic extent of Zn-Pb mineralization in the Lower Carboniferous (Department of Communications, Marine and Natural Resources, 2006).

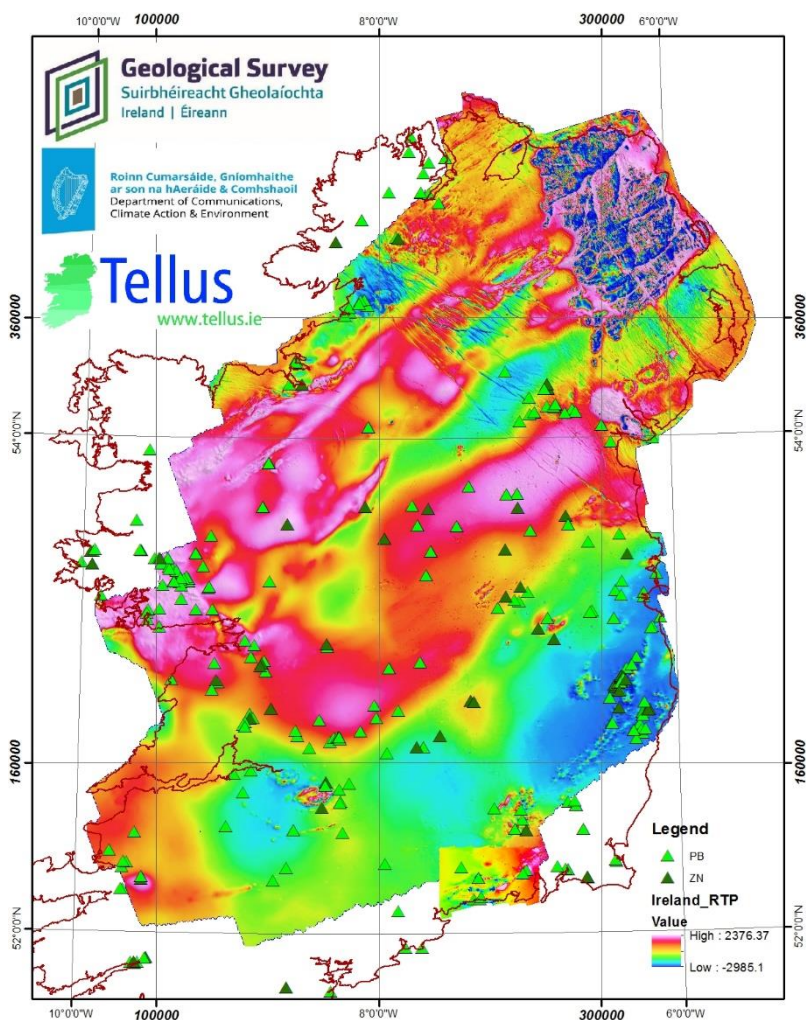


Figure 3: Aeromagnetic compilation of Tellus data with existing data from the EMD. Mineral deposit locations are shown as green triangles.

(ii) Objectives and scientific/engineering targets beyond the state of the art

The project goal was a geophysical characterization of known zinc-lead deposits in Ireland and then use those obtained characteristics to delineate exploration targets. We selected three areas with good geologic control to focus the geophysical modeling and interpretation. This was necessary due to the variability in the local geology, especially in the basement underlying the Carboniferous sediments. Additionally, the scale of basement structures required detailed data for the model to have enough sensitivity to resolve target features. Due to the variable thickness of the Carboniferous sedimentary cover, a limited number of boreholes are deep enough to reach the lower Paleozoic basement. Areas suitable for geophysical modeling were constrained by the availability of rock property data. Especially in the Navan and the Keel-Ballinalack areas the breadth of data, including from magnetic, gravity, EM, seismic and rock property measurements, integrated interpretation were successful.

We formed a new methodology that would allow us to use the existing data and obtain new useful information on the geometry and structure of the basement, location and characteristics of faults both in the Carboniferous sediments and the underlying Paleozoic basements. These features are critical for exploration of structurally hosted Pb-Zn deposits. Main project outcomes are:

- a) A new aeromagnetic compilation for Ireland, including all the Tellus data from Tellus Northern Ireland (2007), Tellus Border (2011-2012), Tellus North Midlands (2014-2015) and 2016 area A1, as well as EMD data to complete the gaps. The higher resolution of Tellus data was preserved in our 40m grid cell size compilation.
- b) A new methodology of structural interpretation of airborne electromagnetic (EM) data was established. Rather than mapping structures at different time gates, we interpreted structures at different depth slices from the conductivity depth data. Tracing a single structure through varying vertical positions results in the strike and dip of the near-surface faults.
- c) The Dublin Institute for Advanced Studies (DIAS) provided us with their ground gravity database. This data was reprocessed and modeled on sections to provide additional structural insights into the basement geometry.
- d) Overall, a detailed structural analysis shows the distribution and geometry of faults over three main areas of interest: Navan, Keele/Ballinalack and Silvermines.

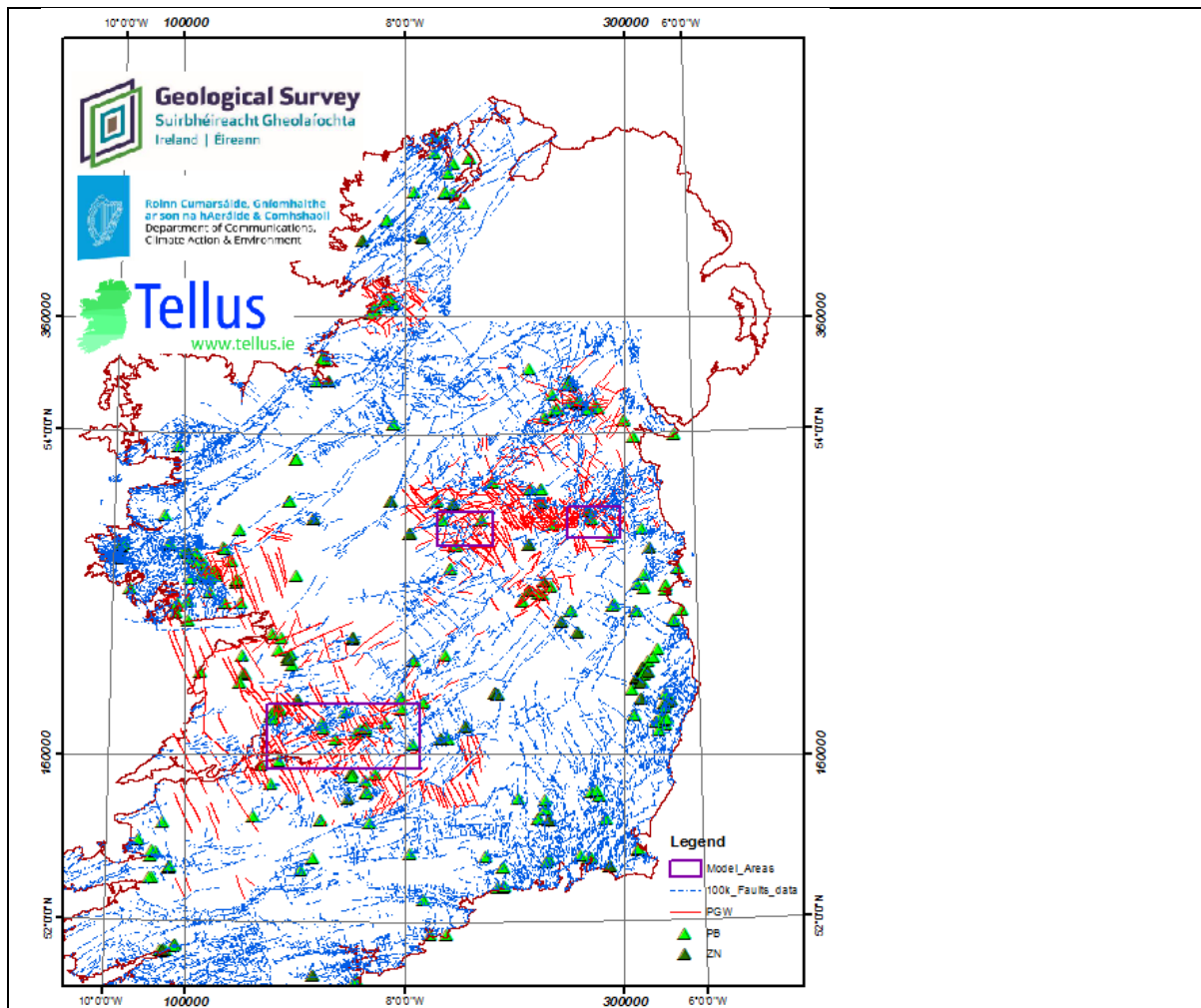


Figure 4: General overview of PGW's structural interpretation (red lines) over GSI's 1:100k scale fault database (blue lines). The three areas of detailed interpretation are marked in purple. Top left: Keele/Ballinalack; top-right: Navan; bottom: Silvermines.

(iii) Implementation (including timelines, milestones, management)

The data processing took definitely longer than anticipated. Part of it was securing access to all the available data. After a successful meeting in Toronto during the PDAC convention in March 2016, the Exploration Mining Department sent us additional aeromagnetic surveys in April 2016. For the gravity data, we only managed to obtain it through the DIAS on late October 2016. Tellus data was readily available for Tellus Northern Ireland, Border and North Midlands. The 2016 A1 block was only made available in early November, so we did manage to incorporate it into our compilation, but due to time constraints the EM data from this block was not added to our interpretation in the Navan area.

We also tried to establish a counterpart at the GSI who we could work with, but were unsuccessful at that. GSI's Director, Mr. Koen Verbruggen was quite helpful in providing contact information with iCRAG, DIAS and mining companies that would be interested on our results.

The revised timeline and project milestones were the following:

- a) Reprocessing of EMD historical aeromagnetic surveys and compilation with the new Tellus surveys: May-June 2016

- b) Presentation of preliminary results at Tellus stakeholder's meeting at the Royal Irish Academy, Dublin: October 5th, 2016
- c) Extended presentation of results and meetings with interested parties (iCrag, DIAS, Tara Mines, Teck Resources and Group Eleven Resources): October 24-28, 2016.
- d) Incorporation of feedback and new information from all the parties met in late October; finalization of models and drafting of extended report, as well as presentations out of the project: November 2016.

(iv) Outputs

- Reprocessing (levelling, microlevelling and computation of interpretation products) for 22 aeromagnetic surveys over 12 blocks delivered by EMD in April 2016 (Haberton, Midlands, Oldtown, Clonmel, Lisheen, Tullamore, Galmoy, Tullamore B, Tullamore test, Inishannon, Limerick, Gort, Newbridge south, Tara Wexford, Ballinalack, Fermoy East, Fermoy West, Clahir, Slieve Dart, North Cork and higher resolution Galmoy).
- Compilation of all the above with historical EMD data and Tellus surveys (Tellus Northern Ireland, Tellus Border, Tellus North Midlands, and 2016 A1). The main output is a unified grid for all Ireland comprising all the above mentioned data in total magnetic intensity (TMI) as well as other interpretation subproducts from the TMI (reduction to the pole (RTP), tilt derivative of the RTP (RTP_Tilt), First vertical derivative of the RTP (RTP1VD), and amplitude of the analytic signal of the TMI (ASIG). All these grids are available in Geosoft .grd format.
- Interpreted structures from airborne geophysical data (fault sets and generations, cross-cutting relationships and relative age of fault sets) over the main Pb-Zn provinces, and in accordance with GIS's 1:100k structural database.
- Detailed structural interpretation over three main areas: Navan, Keel-Ballinalack and Silvermines;
- Voxel of apparent conductivity for the Keel-Ballinalack area (as geosoft_voxel and UBC mesh format) and 25 m depth slices (saved as a .ers multilayer grid).
- 3D structural interpretation over the Keel deposit, derived from the above apparent conductivity data.
- DIAS gravity data gridded at 500m and corrected for Terrain effects (as geosoft .grd grid)
- Summary of rock property data over Navan and Ballinalack.
- Magnetic and gravity modelled sections over Navan and Keel areas
- Extended presentation/report including all the main findings, as well as recommendations for follow-up.

Impact/value of the project:

The main value for this project is on the data compilation and the 3D interpretation and modelling methodology implemented from the EM data, which can be used to determine the geometry of structures in other area. The gravity modelling workflow represents the starting points for further in-depth analysis of the basement geometry.

The work completed in this project has generated a substantial amount of interest from exploration companies active in the Irish Midlands. For one, the new magnetic compilation is a great tool to identify regional structures and at the same time highlighted distribution of aeromagnetic data of varying resolution. The structural interpretation can be further utilized to determine which areas might seem favourable under a specific exploration model. The advances made in the interpretation of the basement geometry is also an active interest within the research and exploration community.

Follow-up & Recommendations:

- One of the main geological complexities of this project is the heterogeneity of the basement in the midlands. For example, 2 density datasets around Navan and Ballinalack (company data derived from boreholes) gave contradictory information in relation to the density contrast between basement and Carboniferous sediments. It would be worthwhile to extend this project to analyse this particular matter in more detail.
- During the technical discussions held with one of the companies (Oct. 2016), they mentioned the importance of Grangegeeth terrain (recognized on Ashton et al., 2015), representing a small sliver of crust originating from the north and displaced during the Caledonian. Identifying more features like these beneath the Carboniferous sediments would be useful for exploration.
- The main advantage of the EM data is the capability of providing with structural information at different depth-levels. However, this depends on a good conductivity model vs depth derived from the data. For the TNM and Tellus A1 block (2016) the contractors delivered conductivity depth transforms (CDTs). The one from A1 looks rather noisy and should be improved upon. The computation of actual 2.5D inversions on the EM data would be advantageous for any subsequent litho-structural analysis out of the EM data collected.
- Application of the methodology derived through this project should be extended over other areas covered by Tellus data, in order to resolve some of the questions raised above.

References:

Department of Communications, Marine and Natural Resources, 2006. Exploration and Mining Division Ireland: Zinc and Lead in Ireland.

Anderson, I.K., Ashton, J.H., Boyce, A.J., Fallick, A.E., and Russell, M.J., 2006. Ore depositional process in the Navan Zn-Pb deposit, Ireland. *Economic Geology* 93, 5, 535-563.

Ashton, J.H., R.J. Blakeman, J.M. Geraghty, A. Beach, D. Collier, M.E. Philcox, A.J. Boyce, J.J. Wilkinson, 2015, The Giant Navan Carbonate-Hosted Zn-Pb Deposit – A Review, in *Current Perspectives on Zinc Deposits*, Irish Association for Economic Geology, p.85-122.

Appendix 1 – Publications & Presentations:

[Conference Publication] Ugalde, H., Lenauer, I., Davitt, T. (2017) Structural modelling from EM data: case studies from Ireland *SAGA (South African Geophysical Association) 2017 – Expanding Frontiers, To be submitted December 2017* (to be presented in October 2017, Cape Town, South Africa).

[Journal Paper] Ugalde, H., Lenauer, I., Davitt, T. (2017) Structural modelling from EM data: case studies from Ireland *in Preparation*. To be submitted to Exploration Geophysics.

[Presentation] Ugalde, H., Davitt, T. (2016) “Integrated geological-geophysical model for stratiform Pb-Zn exploration”. Presented at iCRAG, October 25th 2016, Dublin.

[Presentation] Ugalde, H., Davitt, T. (2016) “Integrated geological-geophysical model for stratiform Pb-Zn exploration”. Presented at DIAS, October 25th 2016, Dublin.

[Presentation] Ugalde, H., Davitt, T. (2016) “Integrated geological-geophysical model for stratiform Pb-Zn exploration”. Presented for Group Eleven Resources, October 26th 2016, Mullingar, Co. Westmeath.

[Presentation] Ugalde, H., Davitt, T. (2016) “Integrated geological-geophysical model for stratiform Pb-Zn exploration”. Presented at Tara Mines/Boliden, October 27th 2016, Navan.

[Presentation] Ugalde, H., Davitt, T. (2016) “Integrated geological-geophysical model for stratiform Pb-Zn exploration”. Presented at Teck Resources, October 28th 2016, Mullingar, Co. Westmeath.

[Presentation] Ugalde, H., Lenauer, I. (2016) “Beyond the Purple Blob: Geophysical and Structural Geology Integration”. Presented at Association of Professional Geoscientists of Ontario (APGO) Networking event, November 15th 2016, Toronto, ON.

[Presentation] Ugalde, H., Lenauer, I. (2016) “Geophysical and Structural Geology Integration: cases from Ireland and Bathurst, NB Canada”. Presented at Brock University, November 23rd 2016, St. Catharines, Ontario, Canada.

Appendix 2 – Any additional information not included above:

Extended presentation given at iCRAG, DIAS, Tara Mines/Boliden, Teck Resources and Group Eleven Resources on October 2016: the presentation has been updated and includes the feedback from those meetings, as well as new modelling results. We include the complete presentation for proper project dissemination.