Quantitative basin-scale predictive models of volcano-sedimentary architecture: implications for resources and hazards (Ref IAP2-18-36)

University of Glasgow, School of Geographical and Earth Sciences
In partnership with Durham University and Siccar Point Energy (CASE Partner)

Supervisory Team
- Amanda Owen, University of Glasgow
- David Brown, University of Glasgow
- Richard Brown, Durham University

Key Words
1. Sedimentology
2. Volcanology
3. Resources
4. Hazards
5. Basins

Overview

Sedimentary basins are important archives of past environments that allow geoscientists to gain insights into how major geological processes such as tectonics, climate and base level (sea level) variations can influence our environment. Due to the complex interaction of these processes, the resultant deposits vary significantly in time and space and have a multitude of different characteristics. Predictive depositional models are essential to the interpretation of ancient sedimentary successions as they enable us to identify common facies and depositional architectures that ultimately allow us to predict how major processes will affect the characteristics of the deposits in time and space.

In addition to being important archives to the past, deposits within sedimentary basins contain societally important resources such as ground water, petroleum and minerals (e.g. copper and uranium). For such deposits, it is essential to understand how the reservoirs (commonly sandstone-rich deposits) are distributed and connected in three-dimensions. In order to successfully exploit and extract these resources, predictive models are essential in reducing uncertainty in exploration efforts, which often operate with sparse datasets that are spatially limited.

Fig. 1: Example of a quantified systems scale predictive model of fluvial systems (Owen et al., 2015)

However, to date many traditional predictive models are qualitative in nature. It is essential that geoscientists move towards using quantitative approaches if we are to truly understand the variation, and controls, on depositional sequences.

Predictive models for individual fluvial systems within a basin are reasonably well-established from both modern and ancient examples, with well-documented downstream trends (e.g. Fig 1; Owen at al., 2015). Quantitative basin-scale predictive models however,
are in their relative infancy in continental sedimentary successions (e.g. Owen at al., 2018), but they have successfully provided a predictive framework that can now be applied to other basins. These models use a ‘systems-based’ approach whereby palaeogeographic models of the basin are developed based on statistical information on key characteristics such as palaeocurrent trends, grain size, channel-body and storey thickness. These quantitative observations provide powerful information on downstream trends compared to more traditional lithostratigraphic approaches.

Research in this area has inevitably focused on continental sedimentary basins. However, there are numerous examples worldwide of modern and ancient basins where sediments compete for space with volcanic units (lavas and pyroclastic rocks) and reworked volcanlastic units (Fig. 2) (Heimdal et al., 2018). These complex mixed successions are relatively poorly studied, with only some examples that have been mapped and a lithostratigraphic scheme developed (Passey and Bell 2007; Brown et al., 2009; Williamson and Bell, 2012), and some offshore seismic studies (e.g. Hardman et al., 2018). However, such basins are of increasing importance societally as they too contain resources, and are now targeted for exploration as extraction in more traditional basins is exhausted.

Methodology

This project will use novel quantitative field-based studies to develop basin/system-scale models of volcano-sedimentary architecture. Potential areas to develop these models include the Neuquen Basin (Argentina) (Fig. 2) and the Absaroka Volcanic Field (Wyoming, USA). Data can also be developed from more local examples in southern Iceland (Fig. 3) and the Mull and Skye lava fields, NW Scotland. Over two field seasons extensive quantitative data will be collected using logs and architectural panels. These data will include measurements of key characteristics such as palaeocurrent trends, grain size, channel body thickness, and channel percentage. These methods will be applied to clastic units and lavas. Stratigraphical correlations will be determined where possible. These data will be statistically analysed to determine relationships between the different field criteria and to identify spatial and temporal trends. Field data will be supported by outcrop models collected using unpiloted aerial vehicle (UAV) to aid quantitative observations, but also to develop models of deposit architecture. Some petrographic and geochemical analyses will also be undertaken to aid correlations.

The project will involve a placement with the CASE partner, Siccar Point Energy in Aberdeen. The placement will allow comparison of field data with offshore seismic data, and help to refine exploration models.
## Timeline

Year 1: Literature review; field data collection; outcrop model development; preliminary data analysis; petrographic and geochemical analyses; one month internship with Siccar Point Energy

Year 2: Field data collection; outcrop model refinement; advanced data and statistical analysis; paper 1 on architecture of volcano-sedimentary systems

Year 3: Two month internship with Siccar Point Energy; final data and statistical analysis; paper 2 on basin-scale predictive models; thesis writing

Year 3-3.5 (6 months only): Thesis completion; further papers if relevant.

## Training & Skills

The student will receive expert training, from leaders in the field, in:

1. The identification of a variety of lavas, volcaniclastic rocks (pyroclastic and reworked materials) and siliciclastic sedimentary rocks in the field, using a rigorous lithofacies approach.
2. Quantification of lithofacies architecture of depositional bodies through detailed logging and outcrop measurements.
3. Flying of a UAV and developing outcrop models.
4. Statistical analysis of quantitative data.
5. Optical microscopy and geochemical analysis (XRF), including sample preparation.
6. Seismic interpretation and processing.
7. Presentation and writing skills.
8. Expedition skills (working in extreme environments).

The student will be joining an innovative and multidisciplinary geology group at the University of Glasgow, which form part of the Solid Earth and Quantitative Geomorphology Research Themes in the School of Geographical and Earth Sciences.

Excellent employability skill training will be provided by IAPETUS2 and the University of Glasgow College of Science and Engineering Graduate School. The project will also be of interest to those considering careers in the resource or hazards industries.

## References & Further Reading


Hardman et al. (2018): [http://pg.lyellcollection.org/content/early/2018/01/08/petgeo2017-061](http://pg.lyellcollection.org/content/early/2018/01/08/petgeo2017-061)

Heimdal et al. (2018): [https://www.nature.com/articles/s41598-017-18629-8](https://www.nature.com/articles/s41598-017-18629-8)


Williamson and Bell (2012): [http://sjg.lyellcollection.org/content/48/1/1/tab-article-info](http://sjg.lyellcollection.org/content/48/1/1/tab-article-info)

## Further Information

Amanda Owen: [amanda.owen@glasgow.ac.uk](mailto:amanda.owen@glasgow.ac.uk)

David Brown: [david.brown@glasgow.ac.uk](mailto:david.brown@glasgow.ac.uk)

Richard Brown: [richard.brown3@durham.ac.uk](mailto:richard.brown3@durham.ac.uk)