Institution: University of Aberdeen

Unit of Assessment: 7 (Earth Systems & Environmental Sciences)

Title of case study: Stratigraphic techniques to develop untapped oil & gas reserves

1. Summary of the impact

Research by the University of Aberdeen's research group on Stratigraphic Evolution of large Igneous Provinces (StratLIP) has guided the successful development of new oil-producing fields in the North East Atlantic that were previously not in production, aided by an improved understanding of the geological context within which the reserves were discovered. The research has informed every phase of exploration and development by several of the UK's leading energy companies, in one project saving the partners £600m and proving the financial viability of a major oilfield development deemed important to the UK's oil supply. The findings have contributed to an increase in the UK's energy security and the strength of the UK's oil and gas industry, especially in the context of the local economy of Aberdeen, the energy capital of Europe.

2. Underpinning research

The Faroe-Shetland Basin, located in the North East Atlantic, is one of the world's largest lava fields and constitutes a major new frontier for oil and gas exploration. However the natural resources that lie beneath the sea in this Large Igneous Province (LIP) remain largely untapped. Unlike in purely sedimentary basins, traditional techniques employed for oil exploration, such as seismic imaging, are adversely affected in volcanic terrains due to layers of lava up to three kilometres thick. It is these lavas that seal off the oil and gas reservoirs.

Since 2006, multidisciplinary research by the University of Aberdeen's StratLIP (Stratigraphic Evolution of Large Igneous Provinces) research group has formulated predictive models of reservoir development and distribution in order to facilitate hydrocarbon exploration and exploitation of LIPs. Led by Professor David Jolley, Chair in Geology (at Aberdeen since 2005), the academics have studied environmental system processes in large lava fields and mapped sediments between the lava flows to identify the location of oil and gas reservoirs. Through extensive fieldwork, the team mapped the stratigraphy of the North Atlantic Igneous Province (NAIP) and carried out subsea vulcanological, lithological and palynological analysis (1,2) to identify stratigraphical hydrocarbon traps, informing applications by oil and gas companies for drilling licences within Faroese waters.

Interdisciplinary research demonstrated the impact of large-scale volcanism on atmospheric forcing, plant ecosystem dynamics and eutrophication events (2, 3). By building a comprehensive picture of previous climate change in LIPs, Jolley and colleagues were able to identify the different climatic events that had occurred within specific regions of the lava field; for example, by studying the effects of a hypothermal event on plants within the ecosystem. This work allowed the research team to devise a predictive model of intra-volcanic reservoir distribution and contributed to greater understanding of the location of oil and gas reservoirs in the Rosebank field, located offshore northwest of the Shetland Islands, and Corona Ridge in the Faroe-Shetland Channel.

Further research into spatial recognition and mapping of plant ecosystems within LIPs (2), allied to more traditional geophysics-based flowfield mapping techniques, underpinned major reinterpretations of the distribution of oil and gas reservoirs within the Rosebank and Cambo oil fields. Stratigraphical analysis revealed that the reservoir sands had come from the south, not the

east as previously thought, and that reservoirs could be found within river valleys in the lava field itself. Jolley's analysis of the Cambo oil field showed that the site was higher in the drainage system than initially predicted. This led to the repositioning of the drilling well and fundamental changes to the mapping models used by Chevron, the energy company leading the exploitation of the field, to improve their accuracy. Studies of changing vegetation patterns identified the location of reservoir sands and where they are likely to extend to, thus guiding exploration companies in their future drilling activities and reducing the risk of costly but unproductive drilling.

3. References to the research

Key Publications in Refereed Journals:

1. Passey, S. & **Jolley**, D.W. 2009: "*A revised lithostratigraphic nomenclature for the Faroe Islands Basalt Group, NE Atlantic Ocean*." Transaction of the Royal Society of Edinburgh, Earth and Environmental Science 99, 127-158.
   This reference contains a fundamental shift in the understanding of the eruptive and depositional history of the lava fields which host the hydrocarbon source rocks.

2. **Jolley**, D.W., Passey, S.R., Hole, M.J. & Millett, J. 2012. "*Large scale magmatic pulses drive plant ecosystem dynamics."* Journal of the Geological Society, London, 169, 703-711.
   This breakthrough paper establishes the link between magma pulsing, sedimentary (reservoir) systems and spatial ecology.

3. **Jolley**, D.W., Widdowson, M., & Self, S. M. 2008. *Volcanogenic nutrient fluxes and plant ecosystems in Large Igneous Provinces. "An example from the Columbia River Basalt Group."* Journal of the Geological Society, London 165, 955-966.
   A breakthrough paper demonstrating the range of, and links between ecological and geochemical trends in a lava field, providing an analogy for Rosebank/Camo reservoir modelling.

4. **Jolley**, D.W. Bell, B.R., Williamson, I.T. & Prince, I. 2009. "*Syn-eruption vegetation dynamics, palaeosurfaces and structural controls on lava field vegetation: An example from the Palaeogene Staffa Formation, Mull Lava Field, Scotland*." Review of Palaeobotany and Palynology 153, 19-33.
   The principal publication defining the range of ecological gradients in a lava field defining some of the parameters used to constrain Rosebank and Cambo reservoirs.

Grant examples

1. Jolley D.W. & Passey S. Sediment transfer and drainage systems in the Late Paleocene – Early Eocene of the Faroe – Shetland Basin (2009-11, Sindri £246,556)

2. Jolley D.W. & Huuse, M. Lava sediment interaction in a nearshore environment: an analogue for offshore exploration (2009-11, Sindri £226,169).

4. Details of the impact

The StratLIP group's role in advancing the understanding of the stratigraphy of the north-east Atlantic has been integral to the exploration of oil and gas fields in the north-east Atlantic Ocean. The findings have informed every phase of the development process: licensing applications, planning of drilling programmes, drilling of wells and post-drill evaluation.

Leading energy companies Chevron and Statoil confirm (1, 2) that without Aberdeen's research, their joint development of the Rosebank oil and gas field – heralded by Chevron as "*one of the last great resource areas for the UK*" at 240 million barrels of oil equivalent – would not have been

possible. The Rosebank project, a joint venture between Chevron North Sea Ltd, Statoil (UK) Ltd, OMV (UK) Ltd and DONG Exploration and Production (UK) Ltd was approved for development by Chevron in July 2012. UK Energy Minister at the time, Charles Hendry, described the project as a "pioneer development" with the potential to substantially increase the UK's proven oil reserves, and create more than a thousand jobs (3). Chevron's own reservoir mapping model originally showed that the development of Rosebank was not economically viable. According to the Leading Geoscientist at Statoil, new data from Aberdeen suggested greater intra-reservoir sand connectivity than previously calculated, effectively reducing the element of risk in drilling for oil. They reran the reservoir model by inputting Aberdeen's data and found that the number of producer wells required to commence production had fallen to nine from 15 at a saving of £600m (£100m per well). Ellis says: "*The greater confidence in reservoir connectivity … increased the recovery factor from 25 per cent to 40 per cent, again having a significant increase on the reserve base and project profitability.*" In effect this 15 per cent increase proved the difference between the continuation and abandonment of the Rosebank exploration.

Aberdeen's work on the Rosebank field had a direct impact on the development of neighbouring field Cambo, jointly operated by Chevron and Hess. The stratigraphic framework devised by StratLIP was applied during the drilling of an appraisal well and as a Chevron Geologist confirms (2), "*the decision to continue (with the project) was greatly influenced by the application of the framework". Ablard says an ecosystem model developed by Aberdeen for Cambo has been "instrumental in informing reservoir models giving a clearer understanding of potential recoverable volumes*". In other words StratLIP's input has enabled Chevron to better identify the location of oil and gas deposits in the Cambo field, which contributed to a decision in November 2012 to drill the Cambo-5 oil well (4).

In the wider Northeast Atlantic, StratLIP has greatly increased the regional understanding of the relationship of the dominantly volcanic Flett Formation to that of the underlying marine sedimentary rocks of the Lamba and Vaila formations. This has given energy companies much greater confidence in pursuing deeper exploration targets than would be possible if they relied on seismic data alone. In particular, the stratigraphical and palaeoenvironmental context provided by StratLIP's research has, according to Statoil (1), given the oil industry the confidence to drill deeper in areas of thick basalt lava cover. Statoil, with partners ExxonMobil and Atlantic Petroleum, began drilling its Brugdan II Well into a sub-basalt section offshore the Faroe Islands in June 2012. As the Leading Geoscientist at Statoil put it: "*The cost of a typical well drilled in thick basalt areas can be in excess of £100 million and therefore not undertaken lightly*."

An example of the risk involved in deep-water drilling in frontier provinces came with the abandonment in 2011 of Chevron's Lagavulin well, west of the Shetland Islands, which cost £170m to drill. Findings by Jolley regarding the geology of the wider region are informing Chevron's explorations further afield, including more effective planning, to reduce the risk of a similar outcome in the future.

As well as benefitting the UK government's efforts to revive the UK's oil and gas industry, StratLIP's research has enabled the Faroese government to maximise the economic potential of the oil and gas resources situated within its maritime boundaries. The SINDRI Group (5), set up by the Faroese government, comprises oil companies operating in the Faroese region. Its main objective is to carry out joint projects to explore oil and gas reservoirs in the Faroese continental shelf. Oil companies pay the Faroese government substantial fees for each well drilled. Reflecting Aberdeen's influence in driving forward development of the NAIP, Sindri granted StratLIP a total of £792,579 in funding between 2008 and July 2013 (Grant examples 1, 2 above). The funding

decision in 2008 was covered by the Press and Journal and BBC Scotland News.

5. Sources to corroborate the impact

1. A Lead Geoscientist, Statoil UK Ltd, will corroborate the benefits and economic impact to Statoil with regard to their Rosebank North Atlantic field development, and the value of the underpinning research.

2. A Geologist at Chevron North Sea Ltd can corroborate the benefits and economic impact to Chevron with regard to their Cambo North Atlantic field development, and the value of the underpinning research.

3. *Article in Wall Street Journal dated 9th July 2012:*
   http://online.wsj.com/article/SB10001424052702304022004577516800838931944.html
   This is an independent media source verifying the economic value of Chevron's development, demonstrating the significance of the impact beyond the UK.

4. Article in Shetland Times, dated 7th July 2012
   http://www.shetlandtimes.co.uk/2012/11/07/chevron-given-go-ahead-for-west-of-shetland-drilling
   This is an independent media source verifying the economic value of Chevron's development, demonstrating the significance of the impact within the UK.

5. An Administration Coordinator at Sindri Group, can corroborate the impact of the underpinning research for international oil & gas exploration in fields beyond the UK.