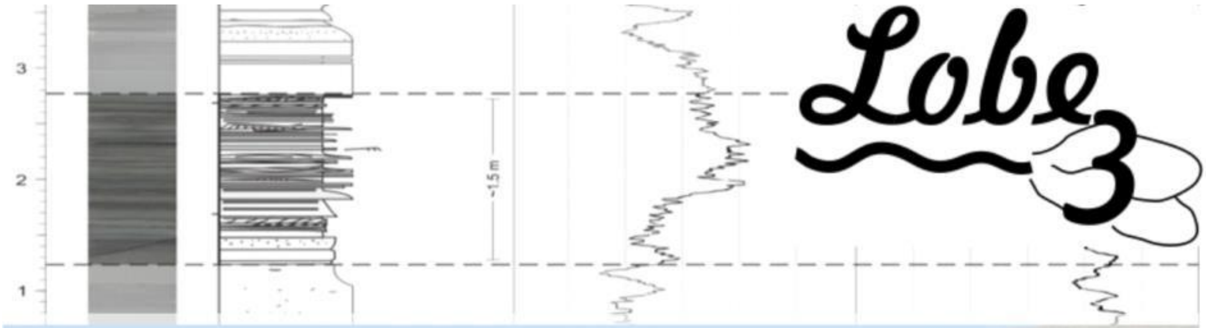


David Hodgson (Uni. of Leeds),
Ian Kane and Stephen Flint (Uni. of Manchester)
Christopher Jackson (Imperial College)

Jan 2018-Dec 2021 (4 years)

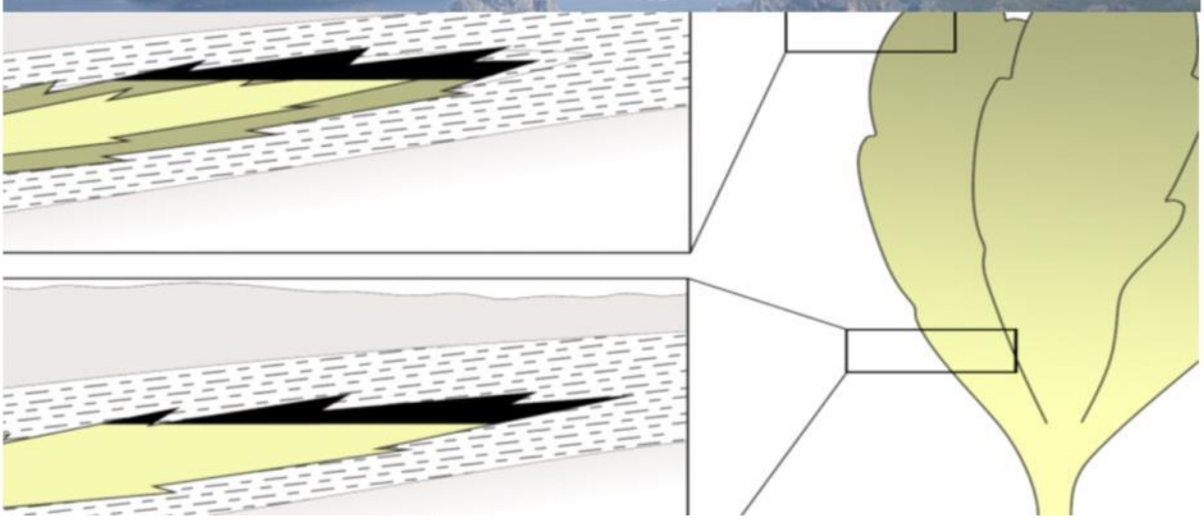
Cost: £33,000/year for 3 years
(~$42k, €39k, 344kNOK, 55kAUD, 131kBRL)

WP1: Lobes and stratigraphic traps

WP2: Extracting value from the Lobe JIP core database

WP3: Exportability to subsurface and confined lobe systems

WP4: 3D-Lobe - virtual outcrops and geomodels



Executive summary:

Lobe3 establishes a new collaboration between Hodgson, Kane and Jackson across three institutions, and continues a long-standing and successful collaboration with Flint. We will extract additional value from the existing Karoo core database collected during Lobe2, and undertake further data collection in the Neuquén Basin (Argentina), the Central North Sea, the Jaca Basin (Spain), and the Basque Basin (Spain) in order to:

i) reduce uncertainties in the geometry and distribution of base-of-slope to basin-floor **stratigraphic traps** associated with lobes (WP1)

ii) investigate impact of **salt diapirism** on submarine lobe deposit architecture (WP1)

iii) improve our ability to interpret **3D stacking patterns** of basin-floor systems from 1D well log data (WP2)

iv) quantify the **degree of confinement** of lobe systems (WP2)

v) test **exportability and applicability** of outcrop-derived concepts to data-rich post-rift subsurface systems and salt-influenced systems (WP3)

vi) construct **geomodels and virtual outcrops** to support cost-efficient, non-field-based and blended training programmes, and archive Lobe JIP data in 3D (WP4)

Lobe3 will comprise four integrated Work Packages that will run concurrently, with the investigators forming a co-supervisory team for three associated PhD studentships. The Lobe3 JIP will require a minimum of 5 sponsor companies (with 3 PhDs); additional sponsors will permit appointment of a postdoctoral researcher.

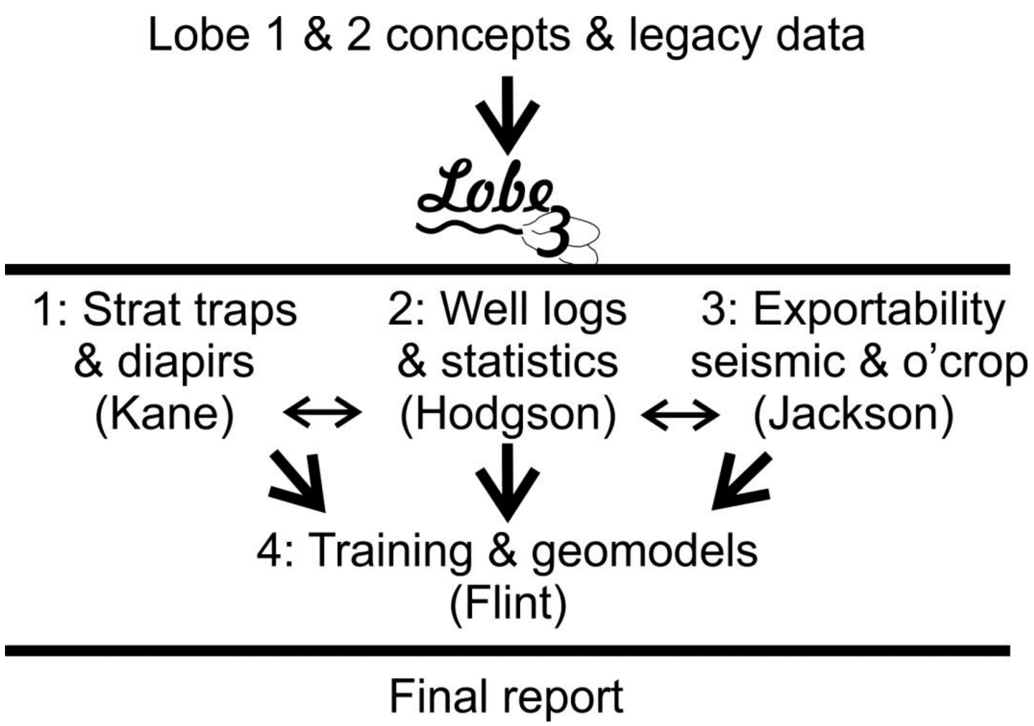


Figure 1: Structure of Lobe3 work programme as four Work Packages with a different PI responsible

Lobe2 (2012-2016) highlights:

- **Seven fully cored research boreholes** with a full suite of well logs have allowed reliable direct calibration of core with borehole image log datasets, and comparison to adjacent outcrop 3-D geometry and architecture.
- Sedimentological and stratigraphic recognition criteria for **intraslope or perched lobes and lobe complexes** (Spychala et al. 2015).
- Recognition criteria to distinguish between basin-floor channel fills and **scour-fills**.
- Recognition and analysis of the suite of components that characterise **channel-lobe transition zones**, such as sediment waves, scour-fills, and base-of-slope lobes, to aid identification of the stratigraphic expression (Hofstra et al. 2015).
- A matrix of **key characteristics of lobes and lobe complexes** in different palaeogeographic positions to aid subsurface interpretation.
- Documented analysis of the effect of subtle (<1 degree) slopes on flow behaviour and stacking patterns in the construction of **thick aggradational lobe fringes** (Spychala 2017a).
- An assessment of the **stratigraphic relationship between sand-rich channel-fills, and underlying lobe deposits**, and how this can be used to infer avulsion dynamics, and the impact on reservoir quality and sandbody connectivity.
- For the first time, an assessment and process explanation for the differences in sedimentology between **frontal and lateral lobe fringes** (Spychala et al. 2017b).
- **Quantification of lobe thickness and facies proportions** by EoD.
- Reliable observation-based criteria have been established in core and well logs to distinguish between superficially similar **thin bed types**, including lateral, frontal, and aggradational lobe fringes.
- The integrated outcrop, core and well log results and interpretations from LOBE 2 represent a unique dataset and housed in a new Statoil-funded core store for **training future generations** of geoscientists and petroleum engineers.

Figure 2: New Lobe2 and Slope4 core store, Inverdoorn, South Africa

Lobe3 programme summary:

***WP0:* Advances in submarine lobe sedimentology and stratigraphy** *(Lead: David Hodgson)*: The last decade, since the Lobe JIP began, has seen a huge increase in the number of studies of exhumed, modern, and ancient subsurface basin-floor systems. A comprehensive review of submarine lobe deposits is timely. We will compare facies proportions and distributions, dimensions, and stacking patterns across systems to identify controls on commonalities and differences.

***WP1*: Lobes and stratigraphic traps** (*Lead: Ian Kane*): Stratigraphic traps form at pinchouts of lobes, and are plays in mature (e.g. North Sea) and frontier (e.g. Palaeogene GoM) hydrocarbon basins. Using outcrop and subsurface analogues, we can reduce the risks associated with targeting basin-floor and base-of-slope stratigraphic traps. Subsurface datasets lack the resolution to constrain the rates and styles of lateral facies changes, or the architectural relationships that impact reservoir quality at sand pinchouts. Outcrop analogues can help to constrain this. The interplay between structurally induced seabed relief and sediment gravity current flow processes are key to predicting, for example, the rate of thinning and changes in lithofacies (and hence reservoir quality) towards pinchout.

1.1 Investigation of the relationship between **salt diapirism and lobe deposition** will result allow us to build architectural panels from outcrop (Bakio, N Spain) and subsurface (Central North Sea) datasets; we will construct numerical models of growth (and collapse) with different sedimentation rates.

1.2 **Facies and seismic forward models** of the terminations of lobe complexes, with rates and styles of facies change constraining the 3D architecture of stratigraphic traps. This will use sandbody pinchouts from well-constrained basins, such as the Neuquén and Jaca Basins, where the architecture of dip sections through pinchouts crop out.

***WP2*: Extracting value from the Lobe JIP core database** (*Lead: David Hodgson*): The Lobe JIP heritage database comprises 14 research boreholes, and several kilometres of core, and is the world's best-integrated dataset of its type. The core and well logs were calibrated in Lobe2, with an atlas of element types compiled. However, a huge amount of potential remains in this database. This will be extracted and applied quantitatively to subsurface systems where the geometry of sandbodies, and the distribution of reservoir quality sand and heterogeneities in basin-floor systems are poorly constrained.

2.1 Detailed well-log analysis to characterise facies and different lobe elements identified in core, and to develop **electrofacies methodologies**, with a focus on thin-bedded successions. We will also investigate the use of machine-learning techniques to automatically pick elements based on well log character and shape.

2.2 Novel integration of the lobe dimension database to **numerically model lobe stacking patterns** in synthetic basins with different geometries and degrees of confinement. This will require stacking pattern and facies distribution data from confined lobe systems (e.g. Jaca Basin, Neuquén Basin) to condition the models.

***WP3*: Exportability to subsurface and confined lobe systems** (Lead: Christopher Jackson)

Lobe systems are documented from many different basin types. The Karoo lobe deposits share characteristics with many other systems in terms of dimensions, facies distributions, and stacking patterns. However, the exportability of concepts and models to systems with wider grain-size ranges, and more (active or static) seabed topography remains poorly constrained. A common subsurface setting is post-rift systems that can form volumetrically important reservoirs in several basins (e.g. Outer Moray Firth, Agat, offshore eastern Canada).

3.1 Publically available datasets from NW Shelf of Australia will allow testing of outcrop-derived predictive models. In this location, an early post-rift, Upper Jurassic deep-water succession, the Angel Fm., is penetrated by numerous wells and imaged by newly released 3D seismic reflection data. The tectonic setting also complements ongoing work in the exhumed post-rift system in the Neuquén Basin, Argentina.

***WP4:* 3D-Lobe - virtual outcrops and geomodels** (Lead: Steve Flint):

Recent technological advances permit the construction of geomodels and virtual outcrops. Digital outcrop models of key Lobe JIP locations will support cost-efficient, non-field-based and blended training programmes (Fig. 2), and all Lobe data digitally archived

4.1 **Virtual outcrops** using UAV and photogrammetry (Fig. 3) to build geomodels of key outcrops tied to research boreholes. These can complement outcrop-based learning, allowing integration with in-house training modules, e.g., tied to seismic interpretation workshops, or in advance of targeted outcrop-based learning.

4.2 3D Lobe, housing the existing Lobe database in ArcGIS, GoogleEarth and Petrel, together with isopachs, correlation panels etc., to provide easy company-wide access to all the available Lobe JIP data. This approach was a successful outcome from Slope.

Figure 3: UAV-based photograph of Unit A near the town of Laingsburg. The stratigraphic thickness of succession of stack lobe complexes in this view is ~130m.

Summary of Lobe3 deliverables

WP1 - Lobes and stratigraphic traps

- Architectural panels from the outcrop and subsurface cases with measured sections showing the rate of facies change, bed thinning and the effects of active topographic development on lobe growth, facies and stacking patterns, and resultant reservoir and reservoir quality distribution.

- Computational geometrical models for case studies to examine architectural response to variable boundary conditions, e.g., structural growth, sediment supply; these will result in more generically applicable models.

- Detailed quantified architecture and facies panels from the outcrop and subsurface cases with measured sections showing the rate of facies change,% sandstone, bed thinning and the effects of active topographic development on lobe growth, facies and stacking patterns, and resultant reservoir and reservoir quality distribution.

- Seismic forward models tied to facies patterns observed in outcrop and compared directly to the salt-affected cases from strike and dip sections.

WP2 - Maximising value and application of the Lobe well database

- Refined down-hole recognition criteria in core and wireline log datasets for lobe elements, lobes and lobe complexes in different positions (axis to fringe).

- Statistical analysis of thickness trends in lobe tied to outcrop constrained hierarchy.

- numerical modelling of lobe and lobe complex stacking patterns from 1D data to support interpretation of the degree (and style) of system confinement.

WP3 – Subsurface analysis of lobes

- Refined down-hole recognition criteria in core and well-log datasets for lobe elements, lobes and lobe complexes, thereby complimenting outcrop-derived deliverables from WP2.

- A suite of stratigraphic and architectural panels for lobe systems in late syn-rift to early post-rift deep-water successions

- An atlas-style compilation illustrating the seismic, core and well-log expression of deep-water depositional elements

WP4 - 3D-Lobe - virtual outcrops and geomodels

- Support to WP1 and WP2 by extending the analysis of pinch-out styles for lobes in different settings into 3D and near-3D to better understand local variability

- Support to WP3 by comparing seismic scale geometries with equivalent outcrop geometries, while embedding the sub-seismic detail within the models.

- Training images of different lobe types for use in MPS geological modelling

For more details about Lobe3 please contact:

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