The development of lake margins, their interactions with contemporaneous continental environments and the implications for their reservoir potential

Keele University in collaboration with the British Geological Survey

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Overview

The interiors of continental sedimentary basins are typically characterised by enclosed lakes, and associated lacustrine depositional systems, that provide the ultimate sink for sediment transported through the basin. Lacustrine sediments have the potential to form excellent hydrocarbon source rocks, and lacustrine margins may develop significant deposits of sand-grade sediment with good reservoir potential. However, despite this well-recognised hydrocarbon potential, the characteristics of lacustrine shoreline sediments, their relationships to lake type and development, their interactions with lake-marginal continental sedimentary environments, and the relations between their reservoir potential and their evolution remain somewhat equivocal.

Using a combination of outcrop, seismic and core data, this project will examine a range of lakes of different sizes and styles, developed in icehouse and greenhouse climatic settings, and in a range of tectonically and non-tectonically-controlled basins, in order to develop a suite of models that typify the range of lake-shoreline sediments, their reservoir potential and their relations to the depositions of lacustrine source rocks. The project will relate these models to the controls of sediment supply, water level, accommodation and climate upon lake evolution, and provide field-based analogue models to aid future petroleum exploration in lacustrine depositional systems.

Background and methodology

Some 20% or more of worldwide hydrocarbon production can be attributed in some way to lacustrine sediments (Bohacs et al., 2000) and consequently numerous individual studies have attempted to produce models of lake sediment development. Models for lacustrine shorelines have commonly drawn upon scientific understanding of the development of their marine equivalents, but lakes do not typically share similar responses to allo-controls with marine systems. In particular:

- lake water levels vary much more rapidly and over greater orders of magnitude than those of marine systems;
- lake water level and sediment supply are more directly connected than they are in the marine realm;
- basin type (under and overfilled lake basins) along with climate have a strong control on lake-margin environment, facies and architecture;
- tectonic changes in the hinterland can produce rapid, expansive and significant changes in facies types and architecture, both at basin margins and extending far out into basin centres.

Models for lacustrine systems have been developed that relate the sediments deposited to basin type, and these models provide a basis for assessing likely source rock potential, but no such equivalents are recognised that depict source to reservoir relationships in settings where lacustrine shorelines develop with significant reservoir potential.

This work will draw upon a number of well-exposed modern and ancient lake successions from continental basins of the Western USA, including the arid Moenave lacustrine system of Arizona, the ice-house Lake Bonnevile system in Utah and the hot-house Green River system of Wyoming. From these studies, a series of potential facies models for lacustrine shoreline development (potential reservoir rocks) and inter-relationships with deeper lake sediments (potential source rocks) will be developed. The models will be extended using further field studies to assess the influence of the contemporaneous continental environments that surround the lake upon shoreline development and sedimentology, and to examine interactions between environments. These models will be generalised based upon their relations to the allo-controls of basin type, sediment supply,

climate and accommodation space to provide sequence and cyclo-stratigraphical guiding models that can be applied at the larger core and seismic scale.

Developed models will be applied first to the analysis of core from lacustrine examples of the Leman Sandstone of the Southern North Sea and the early Cretaceous lacustrine deposits of the North Falkland Basin, in order to construct source to reservoir models that might be applicable across a range of settings.

Timeline

Year 1: PhD Training; literature review (lacustrine systems, modelling and field data capture; geology of field sites); major fieldwork in the western USA to determine the nature and relationships of lake sediments between lake centre and lake shoreline; development of initial models.

Year 2: PhD Training; initial examination of core to compare and contrast with field data; fieldwork to determine interactions with lake marginal contemporaneous sedimentary environments; development of facies models of interactions, and distillation of summary models for different lake systems responding to different allo-controls; presentation at major international conference and development of first paper on interactions and controls.

Year 3: Further development of allo-forced evolutionary models for a range of different lake settings; application of evolutionary allo-forced models to core interpretation, development of cyclo-stratigraphical models and application to seismic-scale interpretation and petroleum geology; minor fieldwork to 'mop up'; final distillation of models; presentations at major international conference and development of paper 2 – cyclo-stratigraphy and lake type models.

Year 4: Preparation and submission of thesis; development of papers and presentations at major conferences.

Skills training and experience

This project will provide the student with high-end industry training in a variety of industry-standard sedimentary modelling techniques, seismic interpretation using Landmark and/or Kingdom software, well log analysis and interpretation using ODM software, along with industry standard software packages including Petrel™. Fieldwork forms an extensive part of this project and the student will gain good experience in field techniques for sedimentary data collection and analysis, including modern digital methods of field data capture, as well as experience in fieldwork planning, logistics and execution.

The project is advertised under the inter-university Oil and Gas Consortium scheme – a collaboration of 14 UK universities and the British Geological Survey. The scheme provides four-year PhDs with accompanying high-end industry training courses in years 1 and 2.

The *Basin Dynamics Research Group* at Keele has a background of experience in sedimentology in a variety of continental settings. Past members of the group have looked at alluvial fan and fluvial environments and their interactions. Current members of the group work on aeolian, arid ephemeral fluvial, evaporitic environments and sequence stratigraphical applications in the continental realm The proposed project provides a natural extension of past and current work within the group, and the group's expertise provide a good grounding for the work.

Staff supporting the project at the *British Geological Survey* (BGS) have significant experience in researching sub-surface lake to margin settings and the petroleum aspects thereof, as well as significant hydrocarbon exploration experience and field experience in the Western USA and beyond. BGS will provide opportunities for the student to work with them on industry seismic datasets in their offices in Edinburgh and Nottingham, as well as academic support in the field.

Funding

This project is funded under the inter-university Oil and Gas consortium. Funding includes RCUK level stipend for four years, fees bursary (UK/EU fee level only) for four years, and yearly travel and subsistence grant for four years.

Start Date: September / October 2018

Further information and application

For further information on the project please feel free to contact the lead supervisor, Stuart Clarke: s.m.clarke@keele.ac.uk +44 (0)1782 733171
www.keele.ac.uk/bdrg/

For further information on applying to study at Keele please see:
http://www.keele.ac.uk/pgresearch/howtoapply/

Applications are handled centrally through Keele University's central admissions system:
https://www.keele.ac.uk/researchsubjects/geologygeoscience/