Summary
The objective of this workshop is to explore the petroleum engineering and reservoir modelling aspects of deepwater clastic reservoirs. The discussion highlights the linkage from depositional processes to geological architecture and flow heterogeneity in development planning.

Learning Outcomes
Participants will learn how to:

1. Assess the genetic processes which produce slumps, slides, debrites and high/low density turbidites, and explain why the concept of confinement underpins the description of heterogeneity in deepwater clastic systems.
2. Evaluate the extent to which pay is under/over-estimated in mud-rich/sand-rich systems, respectively, and the resulting errors in STOIIP and PI estimation.
3. Organise a detailed sedimentological description into key reservoir elements and build an architectural model using those elements.
4. Assess the basic principle of flow in porous media (Darcy) and describe how flow heterogeneity varies in layered and amalgamated clastic systems (Stiles, stable/unstable displacement, critical heterogeneity for flow bypassing).
5. Appraise the contrasting heterogeneities in sand- and mud-rich systems and determine how much detail is required in a reservoir description based on a consideration of fluid type and production mechanism.
6. Evaluate how kv/kh impacts recovery in typical deepwater clastic architectures; understanding of transmissibility, determination of bottom water vs. edge water sweep and linkage to depositional confinement in order to optimally locate a well to optimise sweep for a range of architectural cases.
7. Judge length scale variations for a typical deepwater clastic system on an REV plot, and discuss how this would be handled in a reservoir modelling and simulation context.

Duration and Training Method
This is a five-day field course which comprises fieldwork and associated exercises, supported by classroom presentations and discussions. The proportion of field to classroom time is approximately 80/20. The fieldwork is supported by reservoir models of key outcrops.

Physical Demand
The physical demands for this class are MODERATE according to the Nautilus Training Alliance field course grading system. The longest walk on the class is approximately 2 km (1 mile), with an ascent (and descent) of 75 m (245 feet). There will be walks of up to 1 km (0.5 miles) most days. The field area is in the Europe’s only desert region and participants should expect high temperatures and an arid working environment.
Who Should Attend

The outcrops dictate that the course is of maximum interest to staff dealing with the management of turbidite reservoirs but the intention is that the primary focus is on the reservoir management and not sedimentology. The class is designed for and runs best with a multidisciplinary audience including geologists, geophysicists and reservoir engineers.

Prerequisites and Linking Courses

A basic understanding of deepwater sedimentology in addition to reservoir appraisal and development would be useful skills.

Those interested in expanding their understanding of deepwater clastic systems may wish to attend (predominantly at Skilled Application Competence Level) N009 (Sedimentology, Stratigraphy and Reservoir Geology of Deepwater Clastic Systems - County Clare, Ireland). Whilst those interested in enhancing their seismic interpretation of deepwater systems should consider N483 (Geological Seismic Interpretation of Deepwater Systems: Depositional Environments, Reservoir Architecture and Stratigraphy).

Classes dealing with the themes of modeling and reservoir management are also available and include N012 (Reservoir Modelling Field Class, Utah), N412 (A Critical Guide to Reservoir Appraisal and Development) and N058 (Reservoir Characterisation and Geostatistical Modelling in Field Development).

This course also links with N386 (Reservoir Model Design, Pembrokeshire, UK).

Course Content

This course is presented by a production geologist and reservoir engineer involved in deepwater reservoir development, and is presented as a practical reservoir discussion rather than purely a traditional geological field trip.

The Tabernas outcrops are very well exposed and offer examples of sand-rich and debris flow-dominated reservoirs, high net:gross fan systems and classic mud-dominated facies. The variety in the outcrops make them good analogues for many deepwater clastic reservoirs. In particular, they give excellent insights into the reservoir heterogeneities occurring within apparently continuous ‘sand lobes’ and major channels.

Deepwater clastic architecture is the key thread but content is geared towards the themes of reservoir modeling and development planning. Additional quantitative input to the discussion is available in the form of pre-built Petrel and Eclipse models of ‘sandy fan’ and ‘isolated channel’ models of the outcrops visited. The outcrop discussion and exercises will be related to oilfield case studies.

This course covers the following issues:
N033: Characterisation, Modelling, Simulation and Development Planning in Deepwater Clastic Reservoirs
(*Tabernas, Spain*)
Tutor(s): Mark Bentley and Ed Stephens

- Types of submarine fan systems
- Influence of topography on reservoir distribution and quality
- Reservoir heterogeneity
- Reservoir modelling and simulation
- Upscaling from core to simulation scale
- Well selection and placement
- Development planning for submarine fan reservoirs

**Itinerary**

**Day 0:**
Arrival in Almeria and transfer to hotel.
Evening course safety brief and introductory lecture followed by group dinner in the hotel.

**Day 1: Overview of the Tabernas Basin.**
The class begins with overviews, orientation and scale of the Tabernas Basin. Visit to the basin margin to view coarse non-marine and shallow marine clastics which mark the initiation of sedimentation in the basin.

Visits to the deepwater basin-fill succession to see the types of depositional environments in the basin – slumps, slides, debris flows, unconfined and confined turbidites – and a general introduction to deepwater clastic sedimentology and terminology.

**Day 2: Muddy Fan**
We visit a series of outcrop sections within a low net:gross submarine fan and typical geometries of those environments – thin-bedded turbidite sheet sands.

We visit a series of outcrop sections within a low net:gross submarine fan and typical geometries of those environments - thin-bedded turbidite sheet sands in confined and unconfined settings.

We discuss thresholds of net:gross and the particular issue of thin bed pay. We will use an outcrop-based model example to explore the concept of effective net from an engineering rather than a purely geological perspective.

**Day 3: Feeder Systems**
We visit a series of outcrop sections to analyse the muddy feeder system and the sandy feeder system. Here we will study the individual architectures of the channelised units and discuss the facies, stacking patterns and evidence for their interpretation as feeder systems.

Thin-skin sliding and soft sedimentary tectonics are also viewed in deeper, more distal sediments.
Day 4: Sandy Fan
We visit a series of outcrop sections within a high net:gross submarine fan; high concentration, amalgamated sands in the lower fan, sheet-like tabular sands in the upper fan and visits to the onlap margin of the body to view the overall geometries.

Here we will conceive an overall sedimentological model for the outcrops and take a reservoir engineering perspective on the observed heterogeneity - does any of it matter? The outcome of this discussion will link through to a well design exercise. Outcrop-based permeability data will be used to support the observations on heterogeneity and to discuss how small scale heterogeneity can be reasonably scaled in to a simulation model.

Day 5: Isolated Channel
We visit a series of outcrop sections to view Tabernas’ famous isolated channel and take the opportunity to describe and discuss intra-channel architectures and likely morphologies.

Participants will carry out a modelling exercise on the channel based on their observations. A model developed for the class will be used as a basis for discussion of development planning in submarine fan systems. End of week cultural highlight in the evening.

Day 6:
Transfer and depart Almeria.