Summary

This course provides an in-depth understanding of the controls on the development of carbonate successions using a process-product oriented approach. The dominant influences of biota and sea level change on the facies, architecture and reservoir characteristics of ramp and reef systems are examined. Participants develop an understanding of the processes driving carbonate systems that help reduce uncertainties in the prediction of subsurface facies and porosity distribution.

Learning Outcomes

Participants will learn how to:

1. Sketch the stratigraphy and evolution of Upper Miocene carbonate ramp to reef sequences in the Balearic Islands (at Basic Application level).
2. Evaluate the underlying biological and hydrological controls that determine carbonate deposition in reef and ramp settings.
3. Compare and contrast the controls on carbonate versus siliciclastic deposition.
4. Evaluate the effects of sea level change on the architecture and geometry of carbonate platforms.
5. Assess the relationship between the carbonate factory and accommodation space - in particular examine the effects of the location and volume of sediment production, biological binding and early cementation.
6. Characterise the key sedimentological aspects and facies belt distributions in ramp and rimmed shelf carbonate systems and assess likely primary porosity distributions.
7. Appraise interpretations of carbonate platforms from seismic data and likely facies distribution.

Duration and Training Method

This is a five-day course, comprising observation, discussion and exercises in the field with some classroom lectures. This course will also make use of Digital Outcrop Imagery (DOI).

Physical Demand

This course is graded MODERATE on the Nautilus Training Alliance field grading system. Fieldwork is conducted primarily on coastal sections, which often involves walking and scrambling over deeply weathered, highly uneven, and sharp carbonates. Many outcrops are adjacent to precipitous sea cliffs, which could cause concern for people who suffer from vertigo. Hikes are typically less than 3 km long. Weather conditions are generally warm, but high heat, high humidity, rain, and cool conditions are possible.

Who Should Attend

This course is structured to appeal to all subsurface geoscientists who wish to broaden and deepen their
knowledge of carbonate plays. In particular, the class will benefit those with some experience of carbonate reservoirs and issues relating to facies and porosity prediction in ramp or reef systems.

Prerequisites and Linking Courses

There are no prerequisites for this class although some experience of carbonate systems is an advantage and attendance on Nautilus Training Alliance course N020 (Carbonate Depositional Systems) is suggested for those with little or no knowledge of carbonate rocks and reservoirs.

Geoscientists working carbonate systems onshore North America may find the Nautilus Training Alliance field class N091 (Carbonate Reservoir Architecture and Applied Carbonate Sequence Stratigraphy, West Texas & New Mexico) directly relevant. The new (as of 2019) N494 (Oligo-Miocene Carbonate Systems: Examples from Southern Italy, Apulia, Italy) field course is also relevant for geoscientists working on carbonate systems. Carbonate sequence stratigraphy is addressed in classroom courses N073 (Workshop in Geological Seismic Interpretation: Carbonate Systems) and N091 (Carbonate Reservoir Architecture and Applied Carbonate Sequence Stratigraphy).

Course Content

Predictive models for inter-well scale variations in heterogeneous carbonate rocks are best made from outcrop studies of well-exposed examples. The predictive accuracy of these models is dependent on a detailed understanding of the genetic factors controlling facies architecture and diagenetic processes. The distinction between different types of carbonate platforms is clearly important for exploration and development programs, in order to accurately interpret the seismic imaging of facies geometry and the potential for stratigraphic traps. In carbonate platforms, the depositional profile and facies-belts distribution show greater diversity than in siliciclastic shelves because major differences exist in the genetic factors.

Unlike siliciclastic systems, carbonate production (sediment supply) occurs within the depositional system. The type and amount of sediment input mainly depends on biological systems, and consequently on intrabasinal conditions (nutrient availability, temperature, salinity, water energy, etc.) and it is affected by biological evolution. Location of sediment input occurs throughout the shelf and the areal distribution of different types of biota determines the net production of carbonate.

Additionally, accommodation and carbonate-production are interdependent factors. The size and efficiency of the carbonate factory depends of the type of dominant carbonate-producing biota and of the interaction between sea-floor bathymetry and relative sea-level changes. The amount and type of sediment being produced and the production loci, as well as biological binding, and early cementation, influence the base level for sediment to accumulate, which determines the accommodation.

Excellent exposures of the Upper Miocene platforms along continuous outcrops on the sea cliffs of the
Balearic Islands, as well as water-well data, reveal in detail the 3-D facies belts distribution in two types of carbonate platforms - a distally-steepened ramp and a reef-rimmed platform. In these examples, most of the detailed stratigraphic heterogeneities are below the resolution of seismic and well-log analyses. Thus, they could aid in constructing realistic models for distribution, geometry, and volume of porous and permeable units of some shallow-water carbonate reservoirs, as well as models for fluid flow.

The genetic analysis of carbonate platforms presented here has a greater potential for prediction of the properties than descriptive models, because it allows the key features and the associated facies to be determined more accurately, which prevents quick and easy, but inaccurate, interpretations. Unfortunately, genetic classifications often fail because of the difficulties in deciphering evidence from ancient rocks. In spite of these difficulties, genetic approaches provide insights into the factors that must be identified in producing a genetic model and are essential to accurately predicted rock-property distributions in carbonates.

Course Itinerary

Day 0 (Menorca Island)

Arrival of participants

CLASSROOM (late evening):

- Meeting and introduction: why we look at Menorca and Mallorca rocks?
- Overview of the Menorca distally steepened ramp

Day 1 (Menorca Island).

CLASSROOM:

- Safety brief

FIELD: The Lower Tortonian ramp system

Observation of inner- and middle ramp lithofacies, including:

- Examination of the transition from continental to marine conditions and inner to middle ramp facies.
- Grain size and textures distribution
- Dune bedforms and palaeocurrent directions
- Diagenesis: Fluid flow pathways evidenced by preferential cementation

CLASSROOM:
Overview on the Llucmajor reef rimmed Platform.

Day 2 (Menorca Island)
FIELD: The Lower Tortonian ramp system
Observation of ramp-slope and outer-ramp lithofacies, including:
- Rhodolith facies composition and arrangement. Loci of carbonate production
- Toe of slope facies and subaqueous dunes: types and transport direction
- Mass-flow- and turbidity-flow deposits on the ramp slope; channel and levee structures
- Slump scars and backsets and density flows
- Discussion on implications for reservoir potential

Fly to Mallorca and Hotel check-in

Day 3 (Mallorca Island)
FIELD: The upper Tortonian reef rimmed shelf
Observation of a complete set of representative facies, including:
- Open platform and reef slope lithofacies. Changing style of sediment production
- Reef core lithofacies, with representative corel ecological-bathymetric zones, porosity types and diagenesis
- Outer lagoonal lithofacies. Grainy and bioconstructed facies interrelationships

CLASSROOM: (if time permits):

Day 4 (Mallorca Island)
FIELD: The Upper Tortonian reef rimmed shelf
Analysis of the architecture of the Llucmajor shelf and exercises, including:
- Boat trip to view the shelf to basin transition, from Vallgornera - Cala pi to Cap Blanc (9 - 20 stops) (It may change day, depending on sea conditions)
- General architecture, statal geometries and sequence development from the large- to the meso-scale

EXERCISES (in the field):
• Core description exercise on cores drilled from the Miocene platform
• 2D core correlation exercise
• Discussion on 3D core correlation: applications to seismic interpretations

CLASSROOM: (if time permits)

Day 5 (Mallorca Island)

FIELD: Upper Tortonian-Messinian capping series and paleokarst

Analysis of the Santanyi Limestone outcrops and facies succession, including:

• Observation of mangrove deposits, tidal grainstones, thrombolites and stromatolites
• Karst collapse structures, implications for porosity development
• Sequence stratigraphic features and their influence on hydrocarbon exploration and development in carbonate systems

CLASSROOM: (if time permits)

Day 6

Participants depart Mallorca