Editorial Introduction to the Special Issue on "Stratigraphy, structure and evolution of the European continental margins"

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Stratigraphy, structure and evolution of the European continental margins

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In the course of the last three decades fundamental marine geological research in Europe has grown to full maturity and has been thriving thanks to significant European financial support via collaborative research projects on a variety of topics, such as slope stability (e.g. COSTA, EUROMARGINS), gas hydrates (e.g. HYDRATECH, ANAXIMANDER), fluid flow (e.g. MEDIFLUX, CRIMEA), cold-water corals and deep biosphere (e.g. GEOMOUND, ECOMOUND, HERMES, HERMIONE, MiCROSYSTEMS), paleoceanography (e.g. MOCCHA), delta's (e.g. EURODELTA), source-to-sink studies (e.g. EUROSTRATAFORM), continental margin processes (e.g. OMARC, EURODOM, PROMESS), and the deep ocean floor (e.g. GEOSTAR, BIODEEP, MIDAS). Through these projects major progress was made in our understanding of fundamental processes governing the stratigraphy, structure and evolution of the European continental margins and surrounding ocean floors, including the interactions between geosphere, hydrosphere and biosphere. Moreover, most of these projects included a significant capacity-building component, with as prime example the IOC-UNESCO Training Through Research initiative, focusing on nearly all of the above topics. Most of the participating graduate students have now become leading scientists. An additional major support initiative consisted of the EuroFLEETS program, combining cutting-edge marine science with access to research infrastructure and capacity building. In terms of research infrastructure, the creation of ECORD in 2003 as European representative within IODP has also significantly contributed to ground-truthing –by ocean drilling– the European continental margins.

Over these three decades, European funding mechanisms have changed significantly, but marine geological research of the European continental margins and adjacent deep ocean floors has continued. While the early studies set the scene for a better insight in the geological processes shaping our continental margins, present-day research is increasingly focusing on the relationship of margin geology with oceanography and biology in an integrated Earth System Science approach.

With this thematic issue, we wish to provide an overview of the current state of the science regarding the stratigraphy, structure and evolution of the European continental margins and surrounding ocean floors (Figure 1). Contributions are either in the form of (solicited) review papers or of original research papers. They cover the following themes: slope stability and mass-wasting processes, bottom-water circulation, cold-water coral mounds, subsurface fluid flow, polygonal fault systems and sediment/seafloor dynamics.

INSERT FIGURE 1 HERE

1. **Slope stability and mass-wasting processes**

   Dennielou et al. (this issue) discuss how a large submarine mass-transport deposit, the Rhône Western Mass Transport Deposit (RWMTD), has led to a radical modification of the sediment routing pathways on the continental slope and rise in the Gulf of Lions (Western Mediterranean). The Rhône Western Mass Transport Deposit was only one of several mass wasting events in the Gulf of Lions that occurred more or less contemporaneously at the end of the Last Glacial Maximum lowstand, between 19.5 and 21.7 ka cal BP.

2. **Bottom-water circulation**

Uenzelmann-Neben & Gruetzner (this issue) provide a review of the existing data on and the current understanding of the evolution of the height of the Greenland-Scotland Ridge and the chronology of Greenland-Scotland Ridge overflow. Their discussion focuses on the earliest traces of the overflow as recorded in the formation of sediment drifts in the eastern North Atlantic. These drifts indicate that until the late Oligocene/early Miocene a deep water circulation appears to have been present only in the eastern North Atlantic, the Rockall Trough. Subsequent deepening and widening of the Greenland-Scotland Ridge allowed overflow of the Iceland-Faroe Ridge and later the Denmark Strait, from the early and middle Miocene onwards, respectively, resulting in sediment drift formation in the Iceland and Irminger basins and on the southern Greenland continental slope.

Rovere et al. (this issue) discuss the origin of large-scale bedforms on the southern microtidal Adriatic shelf and shelf edge. These bedforms formed under marine conditions, and their age of deposition was inferred from radiocarbon dating and seismic stratigraphy. Their orientations are compatible with unidirectional flows and they are attributed to bottom currents, associated to the flow of dense shelf waters, which may locally undergo acceleration by bathymetric highs and shelf edge curvature. These currents control the cessation or continuation of bedform-forming processes and contribute to the erosive sculpting of the shelf and localized sand bodies. This study highlights the importance of shelf parameters, such shelf width and shelf edge curvature, for the prediction of sand bodies, which are potentially exploitable.

3. **Cold-water coral mounds**

An area of 1440 km^2 along the Atlantic continental margin offshore Morocco hosts ~16,000 exposed and buried cold-water coral mounds. Hebbeln et al. (this issue) discuss their distribution and morphology and find that the exposed coral mounds are predominantly arranged in two slope-parallel belts – a peculiar feature that is also observed in other coral mound provinces. The exposed mounds are characterized by an almost complete lack of living cold-water corals. Their morphology and direction of elongation point to internal waves as important forcing factors. The skeletal coral carbonate preserved in these mounds may play a very important role in the regional carbonate budget.

Two other studies involving cold-water coral mounds, use them as sedimentary archives of variations in ocean circulation.

Dubois-Dauphin et al. (this issue) produce the first combined εNd and $\Delta^{14}C$ record of the North-East Atlantic subsurface water for the late Holocene, based on two sediment cores from

the Mingulay Reef Complex located on the Western British continental shelf. This record allows identifying abrupt variations in the subpolar gyre dynamics during the last 4500 yr, which are linked to the climatic conditions in Northern Europe.
Elliot et al. (this issue) show that the onset of cold-water coral reef growth on the Wyville Thomson Ridge occurred around 9 cal ka BP and was associated with a shift in flow patterns of surface currents in this area. This change of circulation patterns induced favourable sedimentological and hydrological conditions for corals to grow, and is associated with large-scale modifications of North Atlantic circulation patterns at the end of the deglaciation.

4. Subsurface fluid flow

López-Rodríguez et al. (this issue) use pore-water chemistry profiles from sediment cores retrieved from the Carmen mud volcano (West Alboran Basin) to determine the age of the recentmost expulsion of mud breccia at the mud volcano summit, as well as the likely source of the deep fluids. Using a quantitative transport and reaction model, the timing of the mud breccia expulsion event could be determined to have taken place very recently, in the year 2000 CE ± 5 yrs. Analysis of clay minerals and the elemental and isotope ratios of the deep-sourced pore waters suggest a fluid source driven by smectite dehydration at ca. 5 ± 1 km depth, which corresponds to the depth interval of overpressured shales and megabreccias of Early to Middle Miocene age.

Nuzzo et al. (this issue) analyze the composition of hydrocarbon gases and helium isotopes ($^3He/^4He$) in fluids from mud volcanoes on and outside of the active accretionary wedge of the Gulf of Cadiz to obtain information on fluid sources and fluid migration history in deeply buried sediments. The large excess of radiogenic helium (^4He) in the fluids agrees with a clay mineral dehydration source of water. The isotopic signature of hydrocarbon gases and helium isotopes in the fluids across the region highlight the strong relationship between generation/expulsion of fluids and tectonic activity, and offer a unique view into processes taking place within deeply buried sediments undergoing deformation at this complex convergent plate boundary.

5. Polygonal fault systems

Polygonal faulting was observed for the first time on shallow high-resolution reflection seismic profiles from the southern North Sea Basin (Henriet et al., 1991), offshore Belgium. The geological formation that is affected by these polygonal faults extends onshore and crops out in Flanders, and several of these faults are exposed in clay quarries. Verschuren (this issue) performs a detailed multi-scale analysis of these outcropping faults and proposes a new model for their origin. In this model, gravity, shallow overpressure and syneresis, together, drove the deformation and faults nucleated periodically, grew rapidly and were locked by viscoplastic flow.

6. Sediment/seafloor dynamics

Predicting seabed mobility is hampered by the limited accuracy of sediment transport models when the bed is composed of mixed sediments. The hiding-exposure effect modifies the threshold of motion of individual grain classes in sediment mixtures and its strength is dependent on the grain-size distribution. McCarron et al. (this issue) conducted a comprehensive series of laboratory experiments to quantify the hiding-exposure effect for a full range of sand-gravel mixtures from pure sand to pure gravel. The hiding-exposure effect was found to be dependent on the percentage of the coarse mode present in the bimodal mixture, whereby the effect for the mixture is the weighted sum of the hiding-exposure effect for the fine and coarse modes.

7. Tribute to Jean-Pierre Henriet

The Guest Editors of this Special Issue would like to dedicate this volume to the memory of Jean-Pierre Henriet (1945-2017).

Jean-Pierre was a visionary marine geologist and geophysicist. He was based at Ghent University (Belgium), where he founded the Renard Centre of Marine Geology (RCMG). RCMG was named after Alphonse-François Renard (1842-1903), who produced the first map of the distribution of deep-sea sediments, and who studied the first manganese nodules that were acquired during the legendary H.M.S. Challenger expedition from 1872 to 1876. Jean-Pierre was also the architect of a major reorganization of Ifremer's Marine Geoscience Department, of which he was Director between 1990 and 1995. He was a leading scientist in many of the above-mentioned research projects. He was deeply respected in the scientific community, i) for working for decades at initiating and stimulating international/European research programs aimed at exploring and improving our understanding of our oceans and continental margins, ii) for relentlessly creating opportunities for young scientists that allowed them to grow, to excel and eventually to become leaders in the marine geological community, and iii) for tearing down boundaries between East and West, North and South and paving the way towards a large, single and collaborative research space.

He will be remembered for his pioneering work on what now has become known as polygonal fault systems, and for his work on the cold-water coral mounds offshore Ireland and Morocco. The 10 papers making up this special issue address several of the topics on which Jean-Pierre worked during his career: i.e. polygonal fault systems, cold-water coral mounds, subsurface fluid-flow processes, slope stability, bottom-water currents and sediment dynamics. He would have been delighted with the new scientific insights they provide.

Acknowledgements

We thank all authors for their contribution to this special issue. We also want to thank those authors whose contributions (among which one dealing with a mud volcano named after Jean-Pierre Henriet!) unfortunately could not meet the deadlines of this special issue. Our sincere thanks go also to the reviewers for their dedication and for providing constructive and helpful feedback. Finally, we also wish to acknowledge the support and help from Editor-in-Chief, Dr. Gert de Lange, in preparing this special issue.

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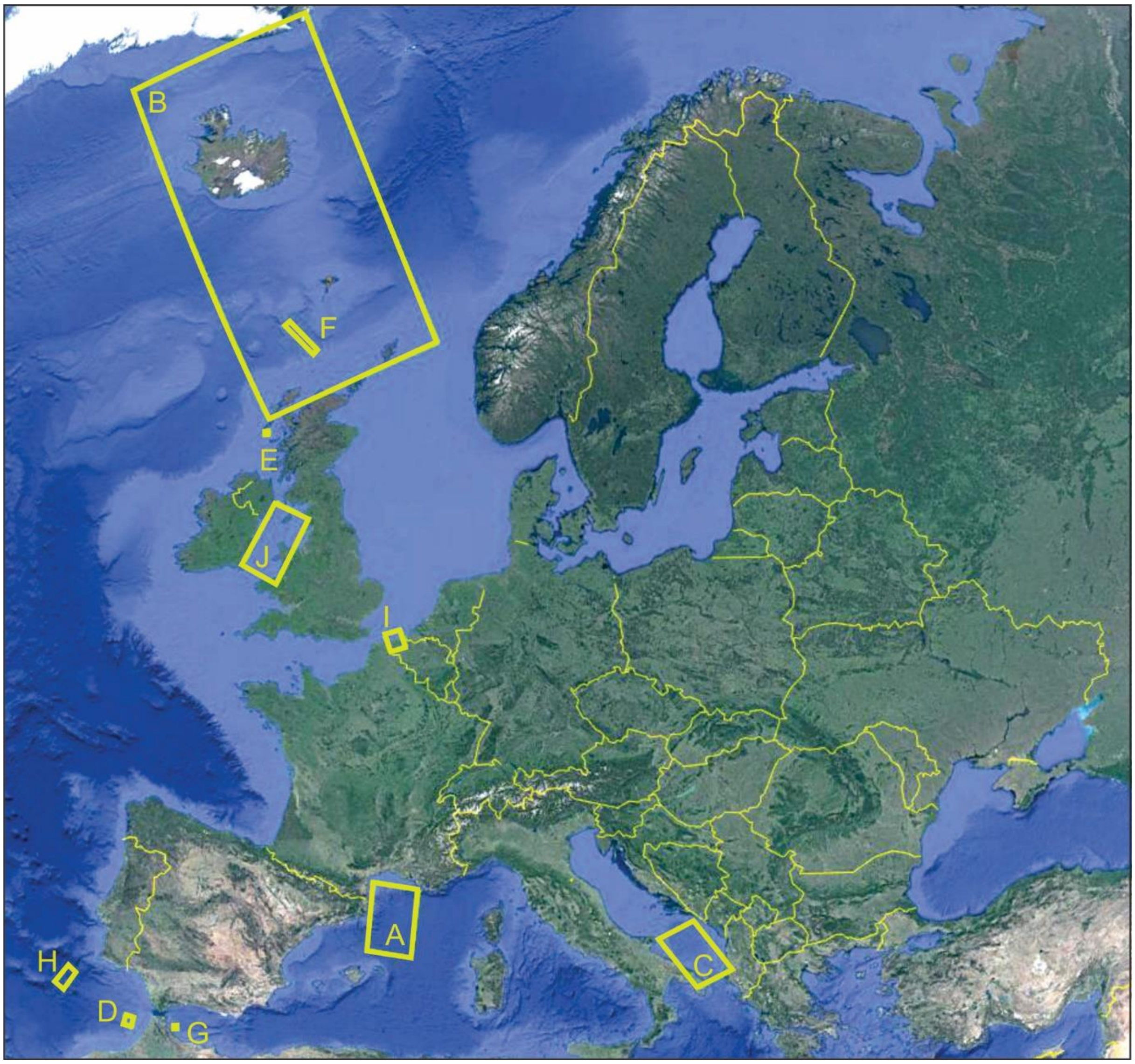

Figure 1: Overview map (GoogleEarth) showing the location of the study areas discussed in this special issue. A. Gulf of Lions (Dennielou et al., this issue), B. Greenland-Scotland Ridge (Uenzelmann-Neben & Gruetzner, this issue), C. Adriatic Sea (Rovere et al., this issue), D. Atlantic Moroccan Coral Mound Province on the Moroccan continental margin (Hebbeln et al., this issue), E. Mingulay Reef Complex on the Western British continental shelf (Dubois-Dauphin et al., this issue), F. Wyville Thomson Ridge (Elliot et al., this issue), G. Carmen mud volcano in the West Alboran Basin (López-Rodríguez et al., this issue), H. Gulf of Cadiz (Nuzzo et al., this issue), southern North Sea basin (Verschuren, this volume), Irish Sea (McCarron et al., this volume).