

Impact case study (REF3)

Institution: Royal Holloway, University of London		
Unit of Assessment: 7 Earth Systems and Environmental Sciences		
Title of case study: Researching Deep Marine Environments: Informing national and international policymakers and transforming the development strategies of Energy Industries worldwide		
Period when the underpinning research was undertaken: 2001-2019		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s): F Javier Hernandez-Molina	Role(s) (e.g. job title): Professor in Sedimentary Geology	Period(s) employed by submitting HEI: 2014-date
Period when the claimed impact occurred: 2017-2020		
Is this case study continued from a case study submitted in 2014? N		
1. Summary of the impact		
<p>Research led by Professor Hernandez-Molina at Royal Holloway improved understanding of the processes affecting deep marine environments. It showed the influence of bottom-current circulation along continental margins and its relationship to contourite depositional systems. This research was used by energy industries and informed environmental policymakers in two distinct areas. First, energy companies were able to undertake more precise resource evaluation and exploration, and telecommunication companies used the expert mapping to better plan telecommunication cabling. Second, environmental policymakers and international lawyers drew on their research to help define and delimit national sovereign rights and co-ordinate infrastructural planning on the seabed.</p>		
2. Underpinning research		
<p>Sedimentary deposits produced by thermohaline-induced deep water bottom currents (contourites), are important for three reasons. Contourites are used by marine geologists to generate insights into past ocean circulation with implications for better understanding climate change. Second, energy companies consider sand-rich contourites to be potential reservoir rocks in deep water environments with potential for oil and gas deposits and carbon dioxide (CO₂) sequestration. Finally, contourites are prone to slope instability carries with it risks to seafloor installations such as pipelines and submarine telecommunication cabling. The research is vital to ensure that deep marine environments are well understood in order to ensure that risk of environmental disaster and expensive damage to critical infrastructure are mitigated.</p> <p>Research conducted at Royal Holloway pioneered the location and identification of deep-water sedimentary deposit systems and the role of bottom currents on the sedimentation process. Led by Hernandez-Molina and <i>The Drifters</i> group (established in 2016, and composed of 21 researchers, including staff, PhD students alongside a global network of researchers) recognised that research on contourites, despite ongoing for over the last 50 years, was still in need of further refinement because their worldwide important role in marine sedimentation (R1). The spatial and temporal evolution of contourites and the oceanographic processes that make and form them need to be better understood. Contourite processes are proving to be more complex than previously thought with implications for modelling and nomenclature, and enhanced collaboration as pioneered by our group between geologists, benthic biologists and oceanographers is necessary to improve further our understanding of how these extreme environments are shaped by bottom-current dynamics and deposits (R2).</p> <p>The Drifters group has two strands of research. First it addresses the role and purpose of deep marine sedimentation. The group investigates the modern marine seafloor in a variety of</p>		

geographical locations, as well as interrogating the long-term geological past. Evidence for ancient ocean dynamics is used to inform studies on the future evolution of oceans. We analysed samples that we collected during the *Integrated Ocean Drilling Programme Expedition (IODP) 339* in 2012 to establish that there was an abundance of sand contourites with potential to act as good quality reservoirs in deep marine environments **(R3, R4)**. The group investigated how submarine processes such as internal waves, eddies and deep-sea storms affect deep water assemblages. Second, the research is strongly aligned to professional stakeholders such as the oil and gas industries and telecommunication sector. Working with companies such as Total, ENI, BP, Wintershall Dea and ExxonMobil, the underpinning research considers explicitly the economic potential of deep-water deposits and the operational challenges they pose to underwater infrastructure. Specifically, the group identified an extensive distribution of contourite sands around the Atlantic and Indian Oceans and posited that they are likely to act as reservoir units and seals for unconventional oil and gas potential. As a joint industrial project (2017-2020), the group's underpinning research on contourites attracted commercial sponsorship and produced both assessments of energy potential as well as CO₂ sequestration **(R5, R6)**.

3. References to the research

The following articles are all published in highly regarded peer-reviewed international journals, which showcase the internationalization of our research. The research was supported by funding from the European Union, Royal Society and an industry-led Joint Industrial Project (2017-2020) and renewed in 2020 for 2021-2024.

(R1) Rebesco, M., **Hernández-Molina**, F.J., Van Rooij, D., Wåhlin, A., 2014. Contourites and associated sediments controlled by deep-water circulation processes: state of the art and future considerations. *Marine Geology*, 352: 111-154. <https://doi.org/10.1016/j.margeo.2014.03.011> . *Impact Factor: 3.349 (Source: Scopus)*

(R2) **Hernández-Molina**, F.J., Llave, E., Ercilla, G.; Maestro, A., Medialdea, T., Ferrin, A., Somoza, L., Gracia, E., Masson, D.G., García, M., Vizcaino, A., León, R., 2008. Recent sedimentary processes in the Galicia Bank (NW Iberian Margin): An integrated study using high-resolution marine geophysical methods. *Marine Geology*, 249 (1-2): 21-45. <https://doi.org/10.1016/j.margeo.2007.09.011> *Impact Factor: 3.349 (Source: Scopus)*

(R3) **Hernández-Molina**, F.J., Stow, D.A.V., et al., 2014. Onset of Mediterranean Outflow into the North Atlantic. *Science*, 344: 1244- 1250. DOI: [10.1126/science.1251306](https://doi.org/10.1126/science.1251306) *Impact Factor: 41.063 (2018) (Source: Science journal)*

(R4) **Hernández-Molina**, F.J., Sierro, F.J., Llave, E., Roque, C., et al. 2016. Evolution of the Gulf of Cadiz margin and southwest Portugal contourite depositional system: Tectonic, sedimentary and paleoceanographic implications from IODP expedition 339, *Marine Geology*, 377: 7-39. <https://doi.org/10.1016/j.margeo.2015.09.013>. *Impact Factor: 3.349 (Source: Scopus)*

(R5) de Castro, S., **Hernández-Molina**, F.J., Rodríguez-Tovar, F.J., Llave, E., NG, Z.L., Nishida, N., Mena, A, 2020. Contourites and bottom current reworked sands. *Marine Geology*. <https://doi.org/10.1016/j.margeo.2020.106267> . *Impact Factor: 3.349 (Source: Scopus)*

(R6) Miramontes, E., Eggenhuisen, J.T., Silva Jacinto, R., Poneti, G., Pohl, F., Normandeau, A., Campbell, D.C., **Hernández-Molina**, F.J., 2020. Reply. Channel-levee evolution in combined contour current–turbidity current flows from flume-tank experiments. *Geology*. 48. <https://doi.org/10.1130/G47111.1> . *Impact Factor: 5.406 #1 in "geology" category for 13 years in a row (Source: The Geological Society of America)*

4. Details of the impact

Industry, policy-making communities and legal experts depend on a clear understanding of deep-water environments. Currently, there is over 1.500.000km of underwater cabling (vital for the

global internet) lying on the world's seabed and identifying safe-zone locations is a matter of global security. Deep-water environments, including contourites, are highly dynamic and subject to rapid change in erosional and depositional rates. Professor Hernández-Molina's long-standing relationships with stakeholders in the energy and telecommunications sectors around the world have enabled industrial and policy-relevant impact.

Changing Working Practices in the Energy Industry. Oil and gas companies, and the countries that fund, licence and support such activities, are interested and invested in deep-water prospecting, evaluation and development (E1). The findings of The Drifters group informed the resource development planning of companies, including Petrobras (Brazil), ENI (Italy), BG/Shell group (Netherlands), Total (France), BP (UK), ExxonMobil (USA), Wintershall Dea (Germany), Spectrum/TGS (UK) and Searcher (UK). Working with technical teams attached to these companies, Professor Hernández-Molina and his team shared their expert knowledge about contourites, and the identification of sandy deposits (reservoir rocks) and organic matter rich sediment (source rocks) within those deposits. Francois Raison (TOTAL) acknowledge that this work have *“important implications for exploration and appraisal undertakings in a number of sedimentary basins”* (E4, E2).

As a consequence of research led by Hernández-Molina, Total and ExxonMobil changed their exploration approaches to deep-sea sediments by redesigning their appraisal process. [text removed for publication] of ENI (E7) and Adriano Viana (researcher from PETROBRAS E1) state that the research has helped with their exploration along the Brazilian margin, the Santos Basin. Further collaborative work with ENI identified 'the Mamba Complex', an estimated 85,000,000,000,000, feet reservoir of natural gas located in offshore Mozambique. Neil Hodgson (Director, Searcher Geodata Ltd) states that

“Professor F. Javier Hernandez-Molina and his research team “The Drifters” Research Group have been working in collaboration with staff at Searcher on contourite deposits for a number of years. Guided and influenced by our interaction with Professor Hernandez-Molina and his team, we have re-evaluated, and reconsidered every deepwater seismic line that we have interpreted over the last 3 years” (E6).

[text removed for publication] from Wintersahll Dea) recognises that the revaluation of some reservoirs in different marine basins are possible because the collaboration with The Drifters group research group (E3). The research on contourite sands reveals evidences their potential as prolific hydrocarbon reservoirs and contributed to the detection of contourites along the South African, Uruguayan, and Brazilian margins. Since their identification, an oil field with oil reserves of up to 2,700,000,000,000 bbl was discovered in the Brazilian Margin; and the discovery of a gas field offshore in Mozambique both in 2014 (E5, E6).

Improving Risk Management and the Resilience of Underwater Cabling. Hernández-Molina and The Drifters research team worked with representatives of the telecommunications industry. Operating in deep-water environments, prone of underwater hazards such as landslides and deep-water storms, is an expensive proposition. The laying and maintenance of underwater cabling is crucial to the functioning of the world's internet. Following expert guidance from Professor Hernández-Molina's team, telecommunications companies changed how and where they laid underwater cabling. [text removed for publication] from Alcatel Submarine Network, USA) states

“[text removed for publication]” (E8).

The cost implications are very high since the repair of an underwater cable costs millions of pounds because of the difficulty reaching remote locations and accessing underwater cabling systems. The company acknowledged the work of the group in terms of cost mitigation, an example of this includes the *“[text removed for publication].”* (E8)

Technical Advice to Expert Groups and Policy Makers. The research of The Drifters group informed the implementation of the formal legal and geophysical criteria used to determine the limits of the continental shelf. Hernández-Molina's expertise was sought by the body charged

with interpreting the formal criteria, namely the UN Commission on the Limits of the Continental Shelf (CLCS). The criteria governing the outer continental shelf are highly technical, and the underpinning research of The Drifters research group has been adopted by the CLCS (E9). Marcelo Parterlini (Argentina), a member of the CLCS, noted that

“the important research that you and your team are making in relation to contourite deposit systems... its research work is especially important in connection with the delineation of the outer limits of the continental shelf beyond 200 nautical-miles in the context of the application of article 76 of the United Nations Convention on the Law of the Sea-UNCLOS... In addition, this research that you and your team carry out in a continuous way over time, allow both the geo-marine scientific community and also the States to have access to up-to-date knowledge on these topics. This certainly has a great impact on the application of article 76 and also on the economic-such as new energy sources-, social and environmental protection policies on the extended continental shelf” (E9).

Hernandez-Molina was asked to provide technical advice over a period of six years, between 2012 and 2018, as the CLCS received and evaluated submissions from coastal states around the world. Research at Royal Holloway was used by the CLCS to consider new types of margins affected by bottom currents for evaluating the proposal of the coastal states. Coastal states seek ‘recommendations’ from the CLCS because that then forms the basis for establishing their sovereign rights to resources that lie on and beneath the seabed.

5. Sources to corroborate the impact

E1. Testimonial from *Dr Adriano Viana* researcher from **PETROBRAS** (Brazil) ‘Letter of support for Prof. Javier Hernandez-Molina- contourite deposits in industry’, June 2020.

E2. Testimonial from *[text removed for publication]*, Process Stratigraphy, **ExxonMobil** Upstream Research (USA) ‘Letter of support for Prof. Javier Hernandez-Molina- contourite deposits in industry’, June 2020.

E3. Testimonial from *[text removed for publication]* from **Wintershall Dea** (Germany) ‘Letter of support for Prof. Javier Hernandez-Molina- contourite deposits in industry’, June 2020.

E4. Testimonial from *Dr Francois Raison* researcher from **TOTAL, SA** (France) ‘Letter of support for Prof. Javier Hernandez-Molina- contourite deposits in industry’, June 2020.

E5. Testimonial from *Dr David J Went*, Director of Geoscience AME, **TGS** (UK) ‘Letter of support for Prof. Javier Hernandez-Molina- contourite deposits in industry’, June 2020.

E6. Testimonial from *Dr Neil Hodgson*, VP Geoscience Searcher Director, **Searcher Geodata Ltd** (UK) ‘Letter of support for Prof. Javier Hernandez-Molina- contourite deposits in industry’, June 2020.

E7. Testimonial from *[text removed for publication]* from **ENI** (Italy) ‘Letter of support for Prof. Javier Hernandez-Molina- Bottom current deposits in marine deep-water setting in industry’, 2018.

E8. Testimonial from *[text removed for publication]* from **Alcatel Submarine Networks UK Ltd** ‘Letter of support for Prof. Javier Hernandez-Molina- contourite deposits in industry’, June 2020.

E9. Testimonial from *Dr. Marcelo Paterlini*, Member of the **Commission on the Limits of the Continental Shelf (CLCS)** by **UNCLOS (United Nations Law of the Sea Convention)** ‘Letter of support for Prof. Javier Hernandez-Molina- contourite deposits in industry’, June 2020.