# Exploring and understanding the resources of the seafloor

The ocean covers slightly more than 70% of the surface of planet Earth and the better part of it has never been explored. The economic downturn we've been experiencing since 2008 has not weakened the environmental demands and expectations for controlling the exploitation of mineral and energy resources in the deep sea. On the contrary, the context of climate change rather urges us to take advantage of this slowdown to step up research efforts to learn more about this environment, develop tools to measure the impacts of industrial activity under these extreme conditions and to limit the related risks. In terms of resources, against a backdrop of transitioning energy sources, this also means developing the technologies which will enable us to best utilise the sources of renewable energy that the ocean can supply.

To meet these requirements, Ifremer is conducting research and innovation studies with four orientations:

- **deepen knowledge about geology, geophysics and geochemistry of the deep ocean, especially on the margins and mid-Atlantic ridges;**
- discover the mechanisms which maintain biodiversity in these environments and identify the related ecosystem services;
- develop appropriate tools to measure physical, chemical and biological parameters in harsh environments which are demanding on equipment;
- and contribute to innovations for marine renewable energy sources.

From performing geochemical assessments on the Congo River deep-sea fan to supporting the tidal energy development of a small-to-medium-sized enterprise, as well as studying the hazards associated with destabilised gas hydrates in the Black Sea, Ifremer's studies in this field are varied. The 2015 milestones presented in this chapter also offer a brief overview of the various forms of funding mobilised for these research studies (public funds, H2020, public/private partnerships) and typical forms of cooperation engaged to complete them successfully.

## *Millennial-scale fluctuations of the European Ice Sheet at the end of the last glacial and global impacts*

Understanding the mechanisms of past climates provides a sound basis for understanding climate changes underway and for modelling their future trends. Using deep-sea sediment cores, collected in the northern Bay of Biscay on several research cruises, the fluctuations of the European ice sheet during its last major advance (between 35,000 and 22,000 years ago) then during its retreat and disappearance (over the past 22,000 years) were recently inventoried with previously unmatched accuracy.

This paleoclimate reconstruction is based on three major points: **fine-scale surveying of the geochemical fingerprint of sedimentary deposits at the mouth of the Channel river, which no longer exists today**, linking the ice sheet, extending from the north of Ireland to the north of Russia, to the Bay of Biscay over the last million years**; identifying sources around the Baltic Sea and the British Isles**, where some of the products from glacial erosion are still visible; and **building a high resolution stratigraphic framework**. As well as proposing an entirely new and continuous reconstruction of European glacial oscillations, these results have made it possible for the first time to compare highly detailed (millennial resolution) marine paleoclimate knowledge with very patchy terrestrial knowledge. Paradoxically, major ice

recessions have been described during extreme cold peaks (Heinrich events), and this profoundly challenges our previous understanding of past atmosphere-ocean-cryosphere* interactions.

**surface area of the Earth where water is present in solid form (ice caps, etc.).*

***Toucanne S.* et al.*, 2015. Quaternary Science Reviews***

## *An amazing ecosystem 5,000 metres deep, fed by Congo River inflow*

**In the tropical South Atlantic, the terminal lobes of the Congo deep-sea fan,located at a depth of 5,000 m and a distance of 800 km from African shores, have the specificity of receiving frequent deposits which are rich in fresh organic matter**. These deposits are generated by sediments directly discharged by the Congo River into the submarine canyon linked to its mouth and which are then carried to the lobes by turbidity currents. Thus, in spite of its abyssal depths, this area of lobes has characteristics which are similar to those in coastal delta zones, for instance in terms of organic carbon content and the frequency of sedimentary inputs. These conditions are exceptional at such depths, and foster the development of special microbial and fauna communities, in particular, based on chemosynthesis comparable to that of cold seeps or hydrothermal vents, creating a zone of high biodiversity in the deep sea. The ANR's multidisciplinary "Congolobe" project bringing together geologists, geochemists, microbiologists and benthic ecologists from the laboratory of climate and environmental sciences (UMR-CNRS, CEA, University of Versailles), from Pierre & Marie Curie University (UPMC) and from Ifremer is aiming to make the connection between the type and magnitude of organic matter inputs from the Congo river and these exceptional ecosystems discovered in 2000 and then explored and studied in 2011 during two cruises with the remote-operated *Victor 6000* vehicle.

**The entire zone shows sedimentary macrofauna densities which are six to seven times higher than expected and an abnormally high oxygen demand at these depths.** All the conditions are met for the development of biological communities like those in pockmark zones of fluid and methane-rich gas emissions located further downstream on the margin. Habitats formed by microbial mats or bivalves living in symbiosis with bacteria sporadically develop due to the presence of sulphides in concentrations which are favourable for their growth. These sulphides come from the high inputs of iron oxides coming from the Congo River. A microbiological study of the communities revealed that not only archaebacteria and various anaerobic bacteria were present, but there were also specific bacterial communities oxidizing methane under aerobic conditions. Lastly, the presence of microbial lines which are characteristic of the terrestrial environment found at a depth of 5,000 m raises questions about the functioning of the ecosystem mainly controlled by the availability of methane, sulphide and iron.

Thanks to a joint analysis of geochemical and biological data, hypotheses have been put forward about how chemosynthetic habitats evolve. However, questions remain about the conditions under which these habitats are established and persist in an extremely unstable sedimentary environment, with **sedimentation rates reaching 10 cm/year.**

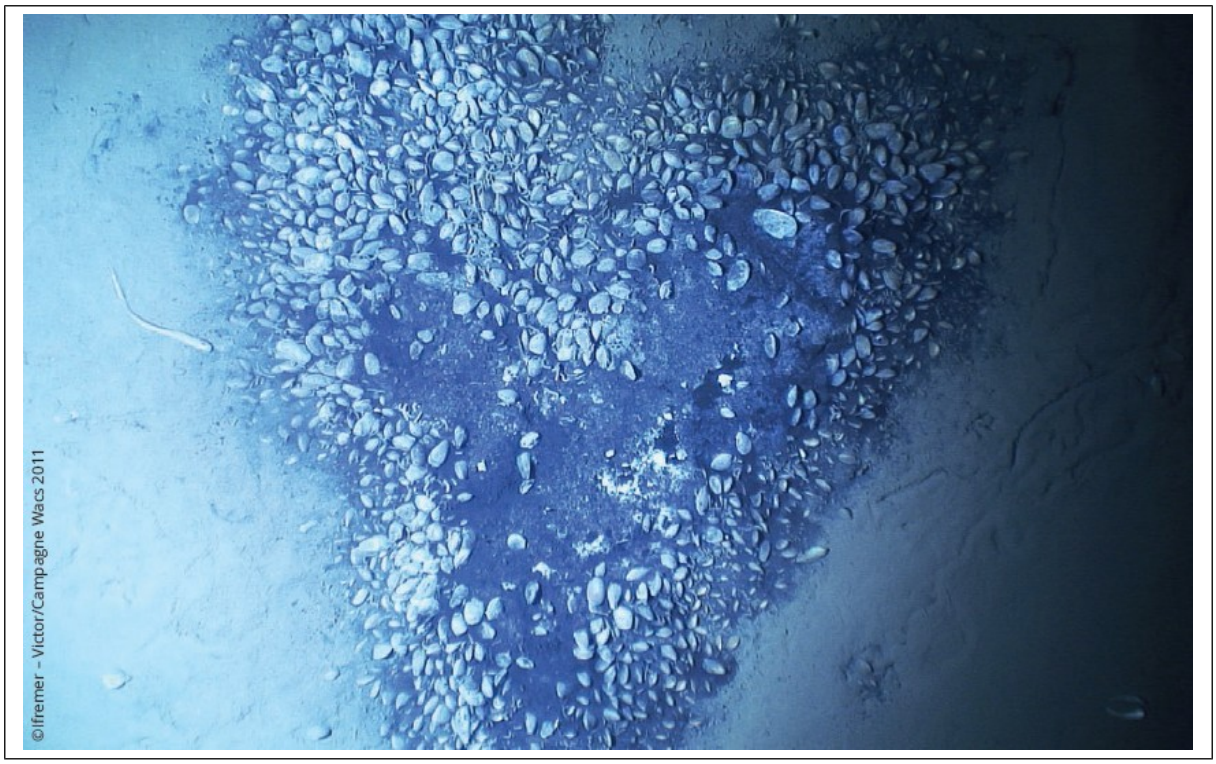


**Figure 1: Clusters of vesicomyid bivalves on the site of the Congo River deep-sea fan's terminal lobes in the Gulf of Guinea (Atlantic Ocean)**

## *Gas hydrates and seafloors in the Black Sea*

Gas hydrates are water molecules which form a cage around molecules of gases, like methane. In nature, they are stable under certain conditions of temperature and pressure and have the particularity of storing gas in a highly concentrated form. Warming of the water and/or a drop in pressure can cause the hydrates to be destabilised and thus release methane. This makes the sediment fragile and under some conditions causes submarine landslides. Methane is also a powerful greenhouse gas and its discharge into the atmosphere contributes to raising the global temperature.

In September 2015, the Ghass oceanographic cruise studied gas hydrates and free gas and the role they play in sedimentary deformations and destabilisation of seafloors in the Black Sea. The cruise was conducted by Ifremer and associated with the European Midas project, rallying German (Geomar), Romanian (GeoEcoMar), Norwegian (NGI) and Spanish (University of Barcelona) research scientists. It made acoustic acquisitions in the water column and seismic acquisitions of the seabed and then took samples in them, aboard RV *Pourquoi pas?*. **Some sites showed the presence of methane hydrates in marine surface sediments,** which was a first in this zone located offshore from the city of Constanta, Romania. Specific analyses are underway to analyse the chronostratigraphic context of the study zone in order to address the chronology of the processes involved: sedimentary destabilisation, expelling of gas, formation of gas hydrates.

Quantifying the saturation in gas and in hydrates and the dynamics of gas/hydrate systems are also being studied. Integrating the data should establish whether there is a proven

link between their presence and the gravity instabilities and deformations observed during the cruise.

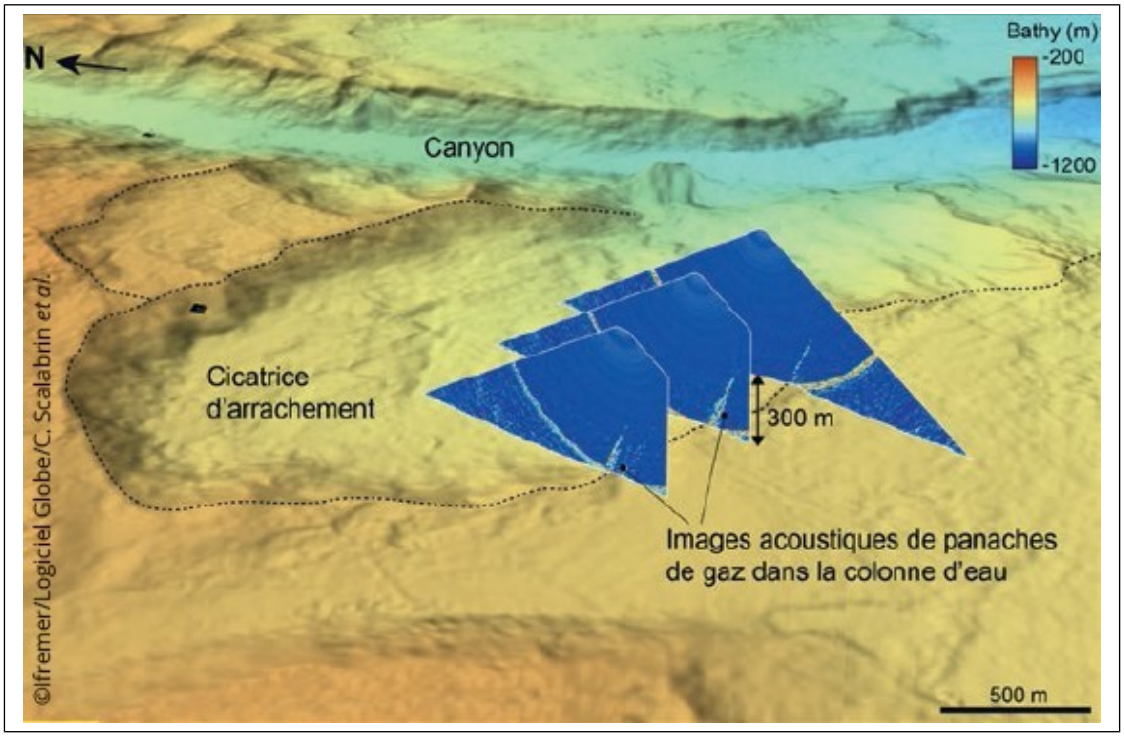


**Figure 2: 3D image of seafloor, of part of the zone prospected during the Ghass cruise, showing landslide scars around an underwater canyon. Acoustic images of the water column reveal gas seep activity around the edges of one of the landslide scars.**

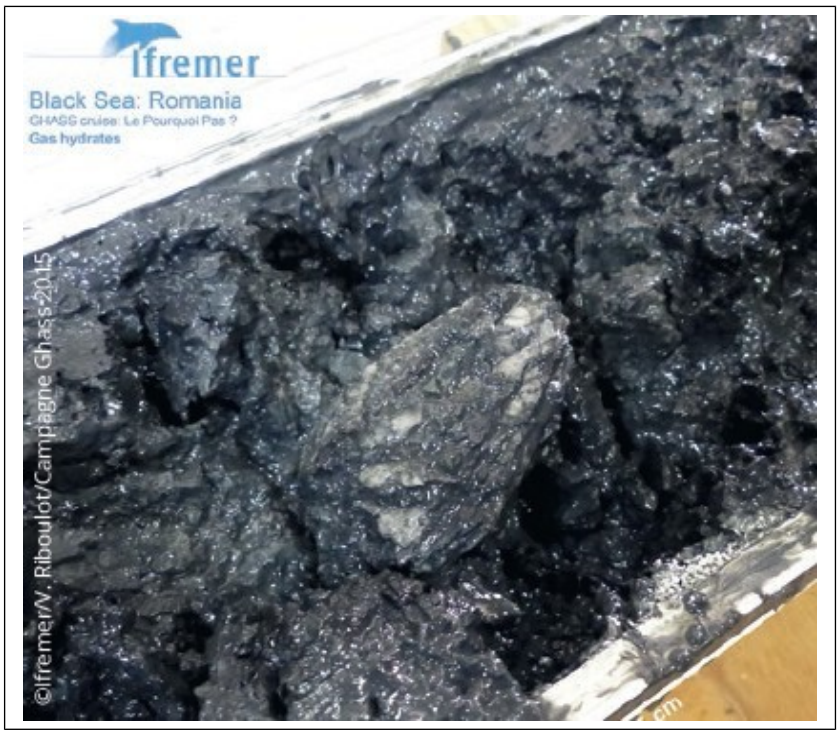


**Figure 3: A core sample taken in the Romanian sector of the Black Sea during the Ghass mission, showing the presence of gas hydrates for the first time (at centre).**

## ***Modelling the effects of tsunamis in the Atlantic and the English Channel***

Financed in the framework of the Investments for the future programme (PIA) and sponsored by the CEA in cooperation with Ifremer, EDF, BRGM and SHOM, the Tandem project (ANR project, 2014-2017) is devoted to assessing the effects of tsunamis around the French coasts of the Atlantic and the Western English Channel. In order to assess the coastal impact, this project is performing numerical modelling to generate and propagate tsunamis and identifying and characterising the sources or causes of tsunamis due to either earthquakes or submarine landslides. **A key point of the project lies in identifying past and potential slides and quantifying the mechanical behaviour of the geological layers involved.** How the slipped volume evolves in the seconds or minutes after the landslide is triggered will effectively determine the risk of a tsunami occurring. With this objective, the Gitan cruise was organised aboard RV *Pourquoi pas?* In the Bay of Biscay. The mapping, seismic and coring results will make it possible to quantify sub-sea gravity flows, model tsunamigenic waves on the French Atlantic coasts and evaluate the possible impact close to coastal civilian nuclear facilities

## ***Discovery of a vast biogenic methane fluid system on the Aquitaine shelf***

The Pamela project is a partnership-based multidisciplinary research project with the Total company, several universities (Rennes, UBO, UPMC), CNRS and Ifpen focusing on the evolution of passive margins (transitional zones between the continental crust and the ocean crust where there is no subduction).

In this framework, two oceanographic cruises, Gazcogne1 aboard ocean research vessel *Le Suroît* and Gazcogne2 aboard RV *Pourquoi pas?* were conducted on the Aquitaine continental margin. **They discovered a fluid system associated with biogenic methane emissions which extends over 200 km2 on the edge of the Aquitaine shelf.** This gaseous venting is associated on the seabed with authigenic (formed in sediment on site) carbonate seamounts created by anaerobic oxidation of methane. Scientists are investigating how this special and unique fluid system came into being, has evolved and been preserved over time.

# 2015 Ocean Research Cruises

| Cruise name | Position | Dates |
|---|---|---|
| **Storm** | Indian Ocean | 01/01/2015 to 04/02/2015 |
| **Polyplac2** | Pacific Ocean | 21/04/2015 to 05/05/2015 |
| **Vespa** | Western Pacific Ocean | 22/05/2015 to 18/06/2015 |
| **Gitan** | Bay of Biscay | 05/08/2015 to 15/08/2015 |
| **Ghass** | Black Sea | 31/08/2015 to 30/09/2015 |
| **Tecta** | Western Pacific Ocean | 02/09/2015 to 10/10/2015 |
| **Nodule 2015** | Pacific Ocean | 31/10/2015 to 01/12/2015 |

Find all these research cruises on the Marine Geoscience website, in the tab Cruises and data, 2015 Cruises.

# PROVIDING SUPPORT FOR PUBLIC POLICIES

## *France's undersea domain grows by over 500,000 km2: Extraplac programme*

In 2015, France extended its undersea territorial domain by 579,000 km2, i.e. approximately the surface area of metropolitan France. Four orders published in the Official journal on 25 September 2015 officially set the **new limits of the continental shelf off Martinique, Guadeloupe, French Guiana, New Caledonia and the Kerguelen islands**. This extension increases France's rights to seafloor and sub-seafloor resources beyond the 200 nautical mile zone. **The applications for extension of the continental shelf are submitted to the special UN Commission on the Limits of the Continental Shelf (CLPC).** An extension can be claimed providing that the seabed meets the criteria of natural extension and geological and morphological continuity from the land-mass. To draw up extension claim applications in compliance with these criteria, in 2002 France set up a dedicated national programme for the French continental shelf called Extraplac, coordinated by an interministerial steering committee reporting to the Secretariat general for the Sea. Ifremer led the scientific project group, in close collaboration with SHOM, Ifpen and IPEV. **The claims currently being examined concern French Polynesia in the Pacific Ocean and the Crozet archipelago, Reunion Island and Saint-Paul and Amsterdam islands in the Indian Ocean.** All the steps taken are based on studies previously carried out at sea in order to specify the geological characteristics of the sub-sea environments in question.

## *Sustainable management of marine granulates*

After the strategy was drawn up for the sustainable management of terrestrial and marine granulates and quarry substances and materials, the Ministry of the Environment, Energy and the Sea mobilised a marine granulate working group (GTGM) to define a methodological guide for the sustainable management of marine granulates on the scale of seafronts.
The working group (made up of representatives from various marine granulate extraction stakeholders, maritime social-professional stakeholders, representatives of elected officials from coastal areas, scientific institutions, NGOs, state administration managers and devolved State services) was set up around a plenary group steering the work and four technical groups.
In the framework of its mission to inform public policy making, **Ifremer has worked in two of the technical groups:**

- **the "criterion" group to take inventory of the state of knowledge about pressures and impacts from marine granulate extraction on the environment;**
- **the "resource" group to draw up a summary of knowledge about mineral resources and the stakes for exploiting them.** The group relied in great part on the results from the Ifremer/Ministry of the Environment-marine granulates study (2005-2012).

A methodological guide was drafted for the drawing up of guidance documents for the sustainable management of marine granulates (DOGGM), whose publication is slated for 2016.

# Interview : Stéphanie DUPRÉ, Ifremer, Geological hazards and sedimentary dynamics laboratory, chief scientist on the Gazcogne2 oceanographic cruise.

**Hadn't the continental shelf of the Bay of Biscay already been "scrutinized" before your cruise?**

*Yes indeed, but in spite of numerous studies in the zone, no fluid indicator had been detected up until then. It is only very recently, thanks to acoustic surveys acquired on fisheries resource cruises that the first fluid emissions in the water column had been discovered.*

**What means were used to make these observations?**

*It was acoustic imaging of the seafloor and the water column, acquired with a multibeam echosounder that enabled us to identify more than 3,000 fluid seeps. Gas bubbles from the seabed, which sometimes reach the water-atmosphere interface, were sampled under* in situ *conditions with the* Pegaz *system deployed by the* Victor 6000 *underwater vehicle.*

**Are these fluid and gas emissions associated with a particular ecosystem?**

*In spite of the favourable chemical conditions, the fauna directly linked to microbial chemosynthesis is very limited there. However, microbial activity is clearly present with microbial assemblages which are characteristic of so-called cold seeps. The abundance of sessile and mobile fauna (sponges, fish, etc.) is most certainly favoured by the substrates and available nutrients.*

**Are these fluid emissions due to seismic movements?**

*No, not at all, these emissions are linked to the tectonic-sedimentary architecture of the Aquitaine margin. However, the spatial-temporal variability of the fluid expelled at the seabed depending on seismic cycles is a subject that we are studying in the framework of the Marmara Sea study site.*