# [PS]The Power of Scientific Drilling Data in Frontier Exploration*

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Search and Discovery Article #70314 (2018)**
Posted January 15, 2018

*Adapted from poster presentation given at AAPG International Conference and Exhibition, London, England, October 15-18, 2017


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## Abstract

The International Ocean Discovery Program (IODP) and its predecessors form a global collaborative research and exploration effort with a 50-year history that has facilitated ocean research drilling and in so doing, helped explore Earth's history and dynamics. In this time, the program has collected a broad range of data types ranging from petrology to paleomagnetism, from paleontology to petrophysics, and beyond. An equally wide variety of geological environments have been sampled by the international consortium across the world's oceans, including sequences familiar to the hydrocarbon industry, such as siliciclastic sedimentary deposits, but also those which are perhaps more unfamiliar, including ocean crust formations. This presentation will explore how industry and the scientific community can better engage in order to prevent duplication of data acquisition and research, and forge new productive collaborations. The main IODP legacy datasets that may be relevant to industry include petrophysical, biostratigraphic and stratigraphic data, and novel applications of these and other data will be discussed. Case studies of existing industry uses of the databank will be presented as well as details of how researchers and industry can access the various publicly available databases generated by the program. As the energy and extractive industries move into more marginal environments, the program's breadth in geography, geology and data, in combination with the scientific expertise of the ocean drilling research community, makes an unrivalled resource for industry as they push the frontiers.

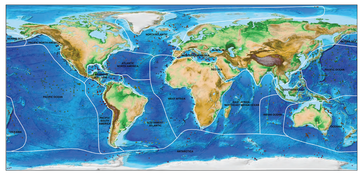
# The Power of Scientific Drilling Data in Frontier Exploration

## DEEPWATER BOREHOLE DATA ATLAS

Making deep ocean sediment data more accessible could aid the exploration and discovery of new hydrocarbon resources

*TGS, 1 The Crescent, Surbiton KT6 4BN; 020 8339 4200*

Publicly-available data, acquired through over 50 years of international ocean drilling programmes, have been made more accessible to the petroleum industry by the global geoscientific data product and service provider, TGS. The database is helping to increase understanding of earth processes and of the subsurface beneath our seas and oceans. It could also be of broader benefit in the future, leading to the discovery and exploitation of new hydrocarbon resources.



*Global distribution of well data available in the Deepwater Borehole Data Atlas (source: TGS)*

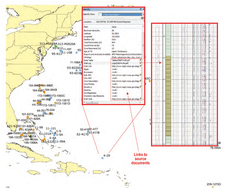
The data gathered through scientific ocean drilling research programmes are released into the public domain. There is a considerable amount of useful information within these data that would benefit oil and gas exploration, but it is largely buried within inaccessible and varied formats hosted on many websites.

In 2014, TGS developed a web scraping tool to automatically seek-out, download and compile the open-source data for the 3,499 boreholes available through the IODP and its predecessors. The compiled data were then analysed, standardised and presented in a way that would make them useful both internally within TGS and to its extensive client database. The result was the Deepwater Borehole Data Atlas.

The Atlas includes a database describing each well chronologically, with a focus on data that are essential to the petroleum industry. Composite logs were created for the 1,722 boreholes that recovered core data dating from the Pliocene (5.3 - 2.6 Ma) or older.

The product gives the oil and gas industry easy access to subsurface data collected by academics in places where the commercial sector might not have gone, and where there is commonly a paucity of data. This can help the industry improve their understanding of these frontier regions, which can ultimately lead to the discovery of new hydrocarbon resources. In short, the Atlas provides a useful starting point in areas where industry wells do not exist and can be invaluable in informing seismic survey planning and interpretation.

Internally, the Atlas has proven invaluable to TGS. For example, through dating sediments in Orphan Knoll (Newfoundland), 175 km from the nearest exploration well, which is a critical step in de-risking prospects in the region. TGS has also tied the data to deepwater seismic data they acquired in order to get information, such as total organic content (TOC), about Cenomanian-Turonian source rock. These data were for offshore Senegal, 250 km from exploration wells, and showed one of the highest TOC values in the West Atlantic margins (more than 20%).



*GIS interace with hyperlinks to deliverables, including PDF plot, LAS files and associated source document s (source: TGS)*

***Features:***
- Time-saving
- User-friendly
- GIS-based application
- Quality-controlled, consistent dataset
- Accessible log plot summaries
- Lithology and stratigraphic columns

*Contributors:*
Steve Allen (TGS)
Nicola Temple

## GLOBAL EARTH MODEL

Deep sea science enhances capabilities of industrial geoscientists and hydrocarbon sector

*Landmark Exploration Insights, 97 Jubilee Avenue, Milton Park, Abingdon OX14 4RW; 01235 442 699*

Landmark Exploration Insights, a product family within Landmark, a Halliburton business line, specialise in synthesising published geological information relevant to the subsurface of the Earth. This information has been used to develop the Global Earth Model, a product that supplies the hydrocarbon industry with access to an integrated database that is both informative and predictive, aiding in exploration and exploitation activities and providing a resource for analysing geological risks. The model draws on publicly available data including data from IODP and its forerunners.

The Global Earth Model is a prime example of how IODP data has been used to facilitate the hydrocarbon sector's efforts to extract and analyse geological information so as to determine which areas of the world's oceans are ripe for exploration. The database provides an invaluable resource for analysing geological risks, with the hydrocarbon industry benefitting from access to datasets and geological interpretations, including sequence stratigraphy, biostratigraphy and organic geochemistry.

*Global Earth Model (source: Landmark)*

The product aims to piece together a picture of how the Earth has evolved through geological time contributing to our overall geological understanding and to the global search for hydrocarbon resources. Specifically, IODP data provides a valuable constraint on subsurface geological risk for exploration, especially in frontier regions.

*Screenshot of the Global Earth Model interface (source: Landmark)*

The use of IODP data in this way is testament to the symbiotic relationship between industry and scientific ocean drilling research.

The IODP-related data and information utilised by Exploration Insights' clients and the hydrocarbon industry more generally is vital as oil and gas companies respond to ever-increasing demand to identify resources. A full understanding of the geological mechanisms controlling the resource distribution of the Earth is only possible thanks to an aggregate approach to collating and sharing data. In turn, this enables geologists working for the hydrocarbon industry to advise their clients about exploration opportunities across the globe. As such, the IODP databases contribute to providing critically unique data-points in certain geographic regions. This helps open up possibilities to meet the demands of the industry in ways that might not otherwise be contemplated.

The existing relationship between Landmark and IODP is primarily a passive one, with the Landmark Exploration Insights team utilising the open-source data via the programme's databases and associated publications. In keeping with the philosophy of IODP, the contribution of the data to the Global Earth Model product facilitates improved understanding of the earth. In doing this it maximises the use of the programme's data for purposes over and above the original projects for which the data were originally acquired. Realising the potential of IODP and the science arising from expeditions through utilisation of various datasets and through referencing of publications is essential to help secure the future of this international scientific programme.


*GEOExPro article about the Global Earth Model and IODP (volume 12, number 6; source: GEOExPro)*

***Features:***
- Global sequence stratigraphic model
- Continual integration of new data
- Globally consistent
- Precise temporal context
- Efficient collaborative workflows

*Contributors:*
Mike Simmons (Halliburton)
Aliya Mughal

The **INTERNATIONAL OCEAN DISCOVERY PROGRAM** (IODP) is the fourth evolution of a global collaborative research and exploration effort that has drilled, sampled and measured the Earth beneath the sea over the last nearly 50 years. IODP has collected a broad range of data types from a huge variety of geological environments, often using tools and technologies originally developed by the hydrocarbon industry. Over the decades there has been an increasing emphasis placed on scientific outputs that are societally relevant, with the current IODP having core themes that centre on: sea-level rise and climate change; the deep biosphere; and the processes and products of earthquakes, landslides and tsunamis. The programme continues to diversify through continued operation with 3 platforms to ensure maximum flexibility, and also via increased collaboration with industry by enhanced cooperation and co-funded ventures.

Owing to the diverse range of places the programme has drilled (see map), the open-access IODP database offers an unrivalled resource for helping improve interpretation in frontier areas. Often the information provided by IODP will be the only data available in a geographic area.

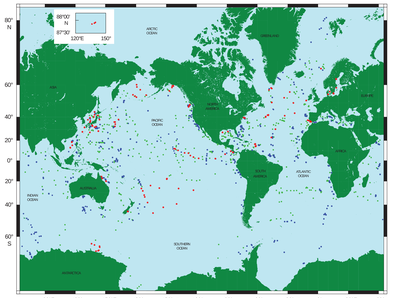
A legacy programme, IODP acquires a set of standard measurements on all expeditions, including:
- Core description
- Petrology
- Structural geology
- Paleontology
- Stratigraphy
- Biostratigraphy
- Geochemistry
- Physical properties
- Downhole logging
- Paleomagnetics
- Microbiology

In terms of collaboration with industry, the UK has always led the way within IODP, setting up the original Industry Liaison Panel during IODP1. The UK IODP continues to influence the way in which the wider programme interacts with end-users and stakeholders, and is always looking for innovative ways in which to engage and interact.

DRILLING COLLABORATIONS
- **Complementary Project Proposals:** acceptance of third party (government, industry etc) funding to subsidise IODP expeditions
- **Contracting IODP drilling platforms:** IODP platforms do not operate 12 months per year and are available for non-IODP projects
- **Contracting commercial vessels for IODP:** mission-specific platform projects commonly contract commercial vessels and technology for project implementation

UTILISING IODP DATA
- **Global Earth Model, Landmark Exploration Insights:** an interactive globally consistent product (GEOExPro v12 n6)
- **Deepwater Borehole Data Atlas, TGS:** collated, analysed, standardised and properly presented database, composite logs with interactive viewing platform (presented at APPEX 2016)
- **www.Mikrotax.org:** online universal taxonomic database of nannos and planktonic forams (GEOExPro v13 n6)

TRAINING THE NEXT GENERATION
- **Industry-supported PhDs and research:** for example, studentships partly-funded by BG Group, Neftex , Chevron etc
- **Biostratigraphers**: for example UCL, including collaborations with Chevron, RPS Energy and Shell
- **Petrophysicists:** for example, Petrophysics Summer Schools in 2016 and 2017, ww.le.ac.uk/epc




DSDP Legs 1–96 (♦), ODP Legs 100–210 (♦), IODP Expeditions 301–352 (♦)

SHARED SITE SURVEY
- **Industry site survey data:** certain data has been made available to support IODP drilling proposals
- **Academic site survey data:** non-proprietary site survey data relating to IODP drilling proposals is usually made publicly available

TECHNOLOGICAL DEVELOPMENTS
- **Seabed rock drill technology:** IODP projects have encouraged development of *in situ* measurement and monitoring capability from these cost-effective systems
- **Novel measurements:** for example, magnetic susceptibility, which is gaining popularity in the hydrocarbon industry

PROMOTING COLLABORATION
- **Industry panel members:** to advise IODP on site survey and environmental protection and safety related to drilling proposals
- **Co-hosting meetings/seminars:** for example, London Petrophysical Society "Old Data, New Tricks"" seminar, Sept 2015
- **UK IODP funded Travel Awards:** to support development of collaborations with industry

DATA ACCESS

Following a one-year post-cruise moratorium, data and samples are made publicly available.
- **Data** from IODP expeditions can be accessed via the expedition's implementing organisation site.
- Certain **site survey data** is also available online via the programme's Site Survey Data Bank (SSDB).
- **Core samples** can be requested from one of the 3 core repositories.
- Information on accessing these data is available on **www.iodp.rocks** ('Sample & Data Access' tab).

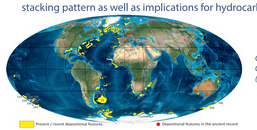
## CONTOURITES Joint Industry Project (JIP):

Seismic recognition and sediment characterisation of deep-water contourite depositional systems and implications for the oil industry

*Hernández-Molina[1], Stow[2], Creaser[2], Thieblemont[1], Jones[1], Suklap[1], Docherty[1], Sasamura[1], Beagle[1], Hyslop[1],*
*[1]Royal Holloway Univ. London, [2]Heriot-Watt University*

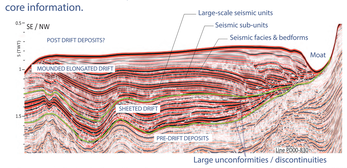
Over the last decade, studies across a number of continental margins have recorded the almost ubiquitous presence of contourites across a wide variety of water depths and geological settings. "Contourite depositional system" refers to large contourite deposits (drifts) and associated erosional features in an environment dominated by along-slope processes, due to the interaction of water masses with continental margins.

The present work has the main aims:
- to summarise the main depositional and erosive features associated with bottom-currents;
- and to evaluate their role in determining the morphology and sedimentary stacking pattern as well as implications for hydrocarbon exploration.




*Global occurrence of large Contourite Depositional Systems (Rebesco et al., 2014)*

Bathymetric data and multichannel 2D and 3D seismic reflection profiles show an impressive array of present and ancient large erosive (moats, channels), depositional (drifts) and mixed (terrace) features, which have been generated by bottom currents. They are clearly identifiable on seismic reflection profiles, analogous in scale and with superficially similar characteristics to channels, lobes and fans of turbidite origin. The sediments that make up such drifts may be very thick, sorted sands of wide lateral extent and considerable vertical thickness which provide an important and very attractive new reservoir play in deep-water systems. For example, sandy deposits are common on contourite terraces, which have been described at different depths along the continental slopes and rises. Contourite mud-rich deposits act as ideal caprock seals and, where they are relatively rich in organic matter, may also act as hydrocarbon source rocks or, on deeper burial, as potential shale-gas reservoirs. In addition, there is an increasing catalogue of turbidite reservoirs worldwide hosting anomalous reservoir qualities, with turbidity-contourite systems being more common on continental margins than previously thought. These along-slope considerations are often omitted from models, mainly due to the many unknowns regarding mixed-drift systems. This can lead to significant differences between reservoir models and core information.




*Example of a Contourite Depositional System along the slope of the Gulf of Cadiz (Courtesy of REPSOL)*

Although contourite and mixed-drift depositional systems are hugely significant to the oil industry engaged in deep-water exploration, reservoir evaluation and development, contourites are still relatively little known by this sector. There is particularly limited information available on sandy contourites and mixed-drift systems, despite promising results from several IODP expeditions and industrial wells. Significant work is still required to develop new conceptual models for contourites and mixed-drift systems.

A new JIP will bring existing knowledge and relevance of contourite and mixed-drift depositional systems firmly into the industrial domain, as well as bridge gaps in our scientific understanding. As oil and gas exploration moves into more frontier environments, the importance of furthering our understanding of this type of reservoir facies through research becomes increasingly significant. This advanced understanding of bottom-current deposits and the oceanographic processes that form them, will assist in global hydrocarbon exploration.

***When:*** 2017 - 2020
***Sponsors:*** TOTAL, BP, ENI, Spectrum
***Outputs:*** Contourite Atlas; research projects

*Contributors:*
Javier Molina Hernández (RHUL)
Zeinab Adeyemi

## www.MIKROTAX.org

An online taxonomy database of nannofossils and planktonic foraminifera for industrial and academic biostratigraphers

*Bown[1], Young[1], Wade[1] [1]University College London*

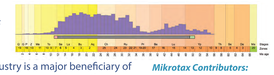
Paleontologists have sailed as scientific participants in the the International Ocean Discovery Program (IODP) and its predecessors, since the 1960s, cataloguing microfossils found within sediments extracted from the seafloor. The availability of rigorously maintained taxonomic and stratigraphic information is key to their efforts to use microfossils as an age-dating tool that can help chart past geological changes and predict the impact of future environmental change. In 2007, UCL scientists facilitated the development of Nannotax, an online taxonomy resource for nannoplankton research. Building on the success of the Nannotax database, the UCL group secured funding (2016-2018) to extend it to include planktonic foraminifera using the exisiting modular software structure. The 2 databases available via www.mikrotax.org, draw on publicly available microfossil occurrence records (including those from IODP), and are relied on by paleoceanographers, industrial biostratigraphers and other specialists for training and reference. It is the most comprehensive taxonomic resource for these groups of organisms, and enables a more rigorous approach to biostratigraphy across the hydrocarbon industry and academia.


The variety and volume of taxonomic classification systems on which paleontologists rely, many of which exist in paper form, pose a significant challenge when it comes to extracting and analysing data with the requisite degree of accuracy. In a bid to collate these taxonomic records into one universally available, standardised system, Mikrotax offers comprehensive relational databases of microfossil occurrence records.


*GEOExPro article about the Nannotax (volume 13, number 6; source: GEOExPro)*

Each microfossil group (nannos/forams) is collated and curated by expert advisory boards, with the databases remaining live documents to ensure inclusion of new samples and data as they are made available. The degree of rigour and detail applied to all Mikrotax entries means that practitioners, including those in the consultancy sector, can use microfossils more effectively as stratigraphic indicators. This allows them to achieve higher temporal precision, and provides resources that have improved the overall level of expertise in the field.

*Example of biostratigraphic distribution graphic*



The hydrocarbon industry is a major beneficiary of the data and insights garnered by biostratigraphy. The degree of specificity with which biostratigraphers can date fossils, using tools such as Mikrotax, means that commercial companies are able to identify specific stratigraphic horizons in order to locate and exploit oil and gas reservoirs. The time-saving benefits of Nannotax readily translate into monetary savings for companies because it can provide answers in seconds rather than hours or days. This means that the efficiency of biostratigraphic work is optimised and the interpretations can inform operational decisions in a more timely and cost-effective way.

In terms of frontier regions, with a large portion of the data in Mikrotax originating from IODP expeditions, the databases offer insight into the stratigraphy of areas not classicly explored by industry.

***Mikrotax Contributors:***
UCL, Network Stratigraphic; Smithsonian Institute; Museum fur Naturkunde, petrostrat, Morgan Goodall Paleo.

***Features:***
high resolution images; collated/curated by an expert advisory board; biostratigraphic distribution; range charts

***Future:***
extend content; enhance functionality; include other taxonomic groups; include more paleoinformatic data (occurrence, biostrat event calibrations); distribution maps (?)

*Contributors:*
Jeremy Young, Paul Bown (UCL)
Aliya Mughal



Sally Morgan