

**IRELAND'S DEEPWATER FRONTIER:
RESULTS FROM THE PETROLEUM
INFRASTRUCTURE PROGRAMME (PIP)**

EXTENDED ABSTRACTS

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PIP – Meeting the Challenge of New Frontiers

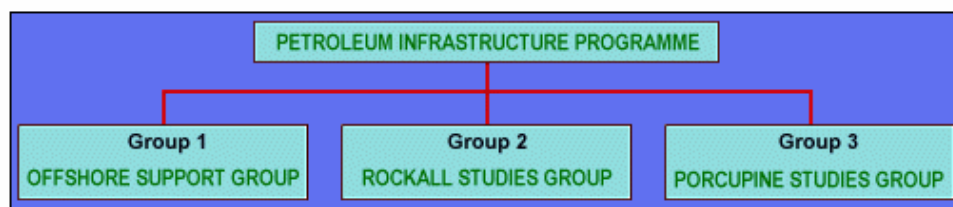
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The Petroleum Infrastructure Programme (PIP) was set up by the PAD in 1997. Initially there were 2 groups, the Rockall Studies Group (RSG) and the Offshore Support Group (OSG). Then in 1999 a further group was added - the Porcupine Studies Group (PSG). The overall aim of PIP is to promote hydrocarbon exploration and development activities in Ireland by:

- strengthening of local support structures
- funding of research data gathering and 'land-based' research in Irish frontier areas
- providing a forum for co-operation amongst explorationists and researchers.

PIP Organisation



Research under the programme goes beyond normal licence area-specific work and is designed so as not to duplicate the efforts of other groups or of commercial contractors. It is also considered essential that local researchers should be given an opportunity to participate in the research projects. PIP is funded by oil companies with licences in the Rockall and Porcupine Basins, and the PAD presently contributes to the funding of the PSG.

It was recognised at an early stage that exploration of Irish frontier areas presented a host of complex problems ranging from geological uncertainties to the many unknowns of the natural and physical environment. It was also recognised that for these to be tackled effectively a concerted joint effort involving Industry and Government would be required and that it would be necessary to have access to several specialist disciplines.

Group 1 (OSG)

The OSG addresses Ireland's overall support structure for hydrocarbon exploration and development through:

- industry-related training
- equipment purchase
- data acquisition
- research support.

The OSG is administered by the PAD in consultation with advisory committees which comprise representatives from academic institutions, contractors, government agencies and exploration companies. The final decisions on project selection and funding levels are made by the PAD.

The total budget for the OSG now stands at £860,000 of which more than a third (38%) remains uncommitted. So far, 28 projects are being supported with contributions ranging from £3000 to £33,000. Further details on the OSG are contained in this volume.

Group 2 (RSG) and Group 3 (PSG)

The study groups each have the same specific objectives, only the areas differ. Both groups were set up to address common exploration/development-related uncertainties through:

- regional data gathering - G&G / geotechnical / environmental / metocean
- research projects, both applied and academic
- scholarships associated with the research
- research cruise sponsorship.

Practical organisational models were developed for the study groups, defining committee structures, decision making processes, voting rights (varied to compensate for different levels of financial participation), financial arrangements, contractual issues, project management, insurance and indemnity provisions, data confidentiality (5 years under present Licensing Terms) and various other operational and administrative matters. The groups are run by management committees comprising the licence holders and are chaired by the PAD. In the case of the RSG, a number of executive functions were held by company members and one member, in particular, agreed to act as agent for the group on contractual matters.

Management committees agree outline work programmes, which are then either put to technical committees (5 in the case of the RSG) or directly to project mentors (volunteers from amongst the members) for detailed project definition and costings. In arriving at a detailed work programme, important gaps in data/knowledge as well as the potential for co-operation with others (e.g. JIPs, EU programmes, vessels of opportunity) are thoroughly assessed. Specialist advice is frequently sought from within members' own organisations as well as the academic community. The most qualified researchers available are selected to perform the work and in many cases this involved linkages between overseas and local research organisations. Cost considerations have also to be assessed in the selection process. In this way work programmes are refined to ensure that all projects are carried out on the research areas most requiring attention and that the groups' limited funds were used in a prudent way.

A Company 'limited by guarantee', PIPCo RSG Ltd, was established in Ireland to handle the study groups' finances – holding bank accounts, overseeing payments, inspecting data inventories, commissioning regular audits etc. This was essential to ensure that the groups' support for research was conducted in a cost effective and transparent manner. PIPCo RSG Ltd takes its instructions from the management committees and in the case of the PSG also acts as agent for the group.

An independent Dublin-based geological consultancy firm, CSA Group Ltd, was selected to provide Secretariat services for the RSG and PSG - administrative support including contract preparation, financial tracking and cash-flow projections, project scheduling (to match cash-flows and inter-project data dependence), project management, status reporting, communications and databasing, data management, sample storage, scheduling of meetings, record keeping etc. The professional services provided by the Secretariat assisted in finding solutions to many of the operational challenges facing the study groups - not least in IT-related communications and databasing, as described later in this volume. The Secretariat has also become a vital focal point for the study groups.

Group 2 (RSG)

The RSG is the largest of the PIP groups and focuses on the Rockall Basin. Over the 4 years to 2001, a total budget of £4.8 million (less than half the cost of an exploration well) was used to execute a work programme agreed between the members. The RSG completed its term in June 2001. In all 55 projects received funding and of these 15 projects, mostly PhDs, are still underway. While a large part of the budget was required for vital research data acquisition (cruises, requiring the use of foreign vessels for the most part), £1.8 million was spent on actual land-based research with some 61% of this going to local universities and institutions. The balance was used for specialised services provided by outside organisations, mostly in the EU. Administrative overheads were kept to a minimum - about 10%.

In 1997 there were 17 members:- Agip, Anadarko, Arco, BG, BP, British-Borneo, Elf, Enterprise Oil, Mobil, Murphy, PAD, Phillips, Saga, Shell, Statoil, Total, Union Texas. By the end of the RSG's term, the number of companies had dwindled to 13 through corporate mergers and takeovers. A caretaker group (RSG Caretaker Group – 'RCG') is now in place to oversee the completion of the groups work.

Group 3 (PSG)

The PSG focus is on the Porcupine Basin and has a total budget of £680,000, including a contribution of £50,000 from the RSG. The PSG is scheduled to complete its term in March 2002. Contracts have been approved for 19 projects and of these 10 have been completed, 7 are underway and 2 have contracts pending. There is close to a 50:50 split between data acquisition and land-based research i.e. less acquisition than the RSG on account of a smaller budget. Local universities and institutions are getting about 50% of the research budget with the balance being used to obtain specialised services from abroad. Administrative overheads are again running at about 10%.

There are presently 8 members in the PSG:- Agip, Chevron, Elf (TFE), Enterprise Oil, Marathon, PAD, Phillips and Statoil.

Results

In carrying out their work, the RSG and PSG had to overcome several challenges and some of their more important achievements are as follows:

- large number and variety of projects conducted, mentored and QC'ed by experts
- identification and use, where possible, of local research specialists
- nearly 90% of budgets spent on projects; overheads kept to a minimum
- most tax-efficient treatment obtained for expenditure on research programmes
- cost reductions achieved through co-operation with other JIPs and the use of vessels of opportunity
- development of 'commonality of purpose' within large groups (up to 16 companies and the PAD)
- development of workable systems for decision making, communications, databasing etc.
- all work performed in a safe and environmentally sound manner.

Of course the main achievement is the delivery of high quality projects. The work of the study groups has led to a significant improvement in our understanding of the geology, climatology, environment, seabed processes and the potential for geohazards. Several 'landmark' data acquisition projects have been carried out and are described in this volume; these are:

- RSG, TRIM (TOBI Rockall Irish Margin) environmental survey, 1998 - providing new insights into sedimentary processes and seabed habitats in the Rockall Trough
- RSG, RAPIDS 3 wideangle reflection/refraction seismic profiling, 1999 - detailing crustal structure under the Rockall Basin at a higher resolution than previously achieved
- RSG, Shallow Drilling Programme, 1999 - revealing the sedimentary fill of basins flanking the Rockall Basin for the first time
- RSG/PSG, Cetaceans & Seabirds at Sea survey, 1999-2001 - recording the distribution and concentrations of these fauna in deep water areas west of Ireland for much of the year.

Important regional framework and baseline studies have been produced based on the new and pre-existing data. These are all referred to in the present volume and include: structural nomenclature studies, shallow stratigraphy and geohazard studies, climatology studies and integrated environmental studies.

Effective co-operation has been established with other groups (e.g. UNESCO TTR programme, UK Rockall Consortium, EU programmes such as STRATAGEM). This has allowed the acquisition of data that could not, otherwise, have been afforded.

Local research capabilities have been identified and, in some cases, helped to develop with PIP support (e.g. in areas of geophysical research, oceanographic research and geotechnical studies). Where the required competencies existed locally and were competitively priced, these were used, as is reflected in the statistics.

The Future

The PIP study groups and researchers have identified many areas where further geological and environmental data gathering are required. Some of these areas will be highlighted during the present conference.

There still remains a considerable untapped potential for cost effective data acquisition through co-operation with other JIPs and EU programmes.

The PSG continues to be an active JIP in the Irish offshore area. This year it is to contribute to the acquisition of a deep seismic transect across the Porcupine Basin while further data acquisition is planned for 2002.

Conclusions

PIP projects are providing a legacy of data, samples, analytical results and equipment that will contribute to further research. Member companies have consistently promoted the early release of data as illustrated by numerous papers presented at international meetings and of course by the present conference.

The RSG and PSG have become effective JIPs capable of executing large-scale work programmes on time, within budget and in a cost-effective manner. These work programmes, which are beyond the capability of any one licence group, have been designed to provide an essential basis for exploration west of Ireland.

The study groups have also developed excellent contact networks and have become well known to the international research community. They are therefore well positioned to maximise co-operation with other JIPs and international programmes.

Successful JIP models, involving Industry and Government, have been developed to promote hydrocarbon exploration/development-oriented research in frontier areas offshore Ireland. The close involvement of the company members in executive, agent and mentorship roles, and the professional services provided by the Secretariat have been crucial to the development of these models.

Acknowledgements

The success of the Petroleum Infrastructure Programme is attributed to the contribution of the members and the many research / data acquisition teams associated with the programme. The important contribution of the Secretariat is acknowledged. Local and overseas providers of 'vessels of opportunity' are also acknowledged as are the commercial contractors who assisted the research through the provision of data.

Structural Nomenclature of Ireland's Atlantic Margin

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The Rockall structural nomenclature project, carried out for the Rockall Studies Group, was completed in December 1999 and published as Special Publication 1/99 Petroleum Affairs Division, Department of the Marine and Natural Resources (Naylor *et al.* 1999). The Porcupine structural nomenclature project, under the aegis of the Porcupine Studies Group, is nearing completion.

The aims of both projects were:

- to establish a regional structural framework for the Irish Atlantic offshore region (Fig. 1), and
- to identify and give formal names to regional structural elements for petroleum industry and academic use, and thus avoid confusing and conflicting nomenclature.

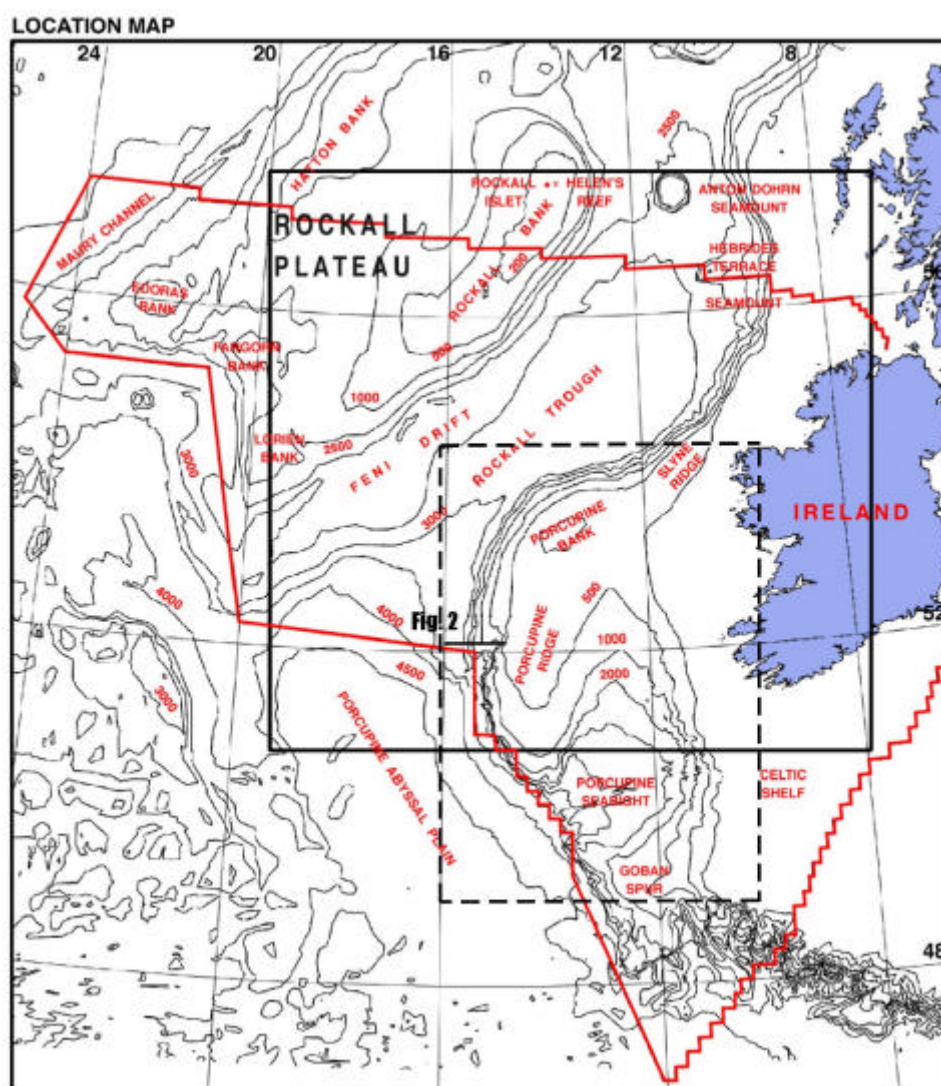


Figure 1. Bathymetric map of the Rockall and Porcupine region showing the location of the geoseismic section shown in Figure 2.

The projects began with a review and synthesis of the existing published literature and maps to produce a regional map of known structural features. The researchers then reviewed in excess of 40,000 line km of reflection seismic data made available by the Petroleum Affairs Division and individual exploration companies. This has included almost all the available non-exclusive seismic data within the Rockall and Porcupine regions. Structural features and zones have been traced from line to line and plotted on 1:1,000,000 scale maps. Workshop sessions with industry and PAD representatives then further refined the interpretations. A selection of seismic lines which best illustrate the identified features were interpreted to produce coloured geoseismic sections. Fourteen of these accompanied the 1999 Rockall publication, and a further thirteen will accompany the final Porcupine project report.

A formal system for naming of structural features was established which provides guidance regarding the names to be used in naming new features (feature name e.g. Rockall, Porcupine, Slyne) and defines the structural terms to be applied as the second, or category (e.g. Basin, High), name.

The projects have identified new structural elements and have confirmed or re-defined previously known features. A series of Late Palaeozoic-Tertiary basins have been outlined along both margins of the Rockall Basin. These segmented but structurally linked basins are onlapped and buried beneath a Cretaceous and Tertiary cover. Several Cretaceous and Tertiary basin depocentres lie on the flanks of the Rockall Basin. A number of major structural features have been identified and mapped within the Porcupine Basin and the Goban Spur area, and these reflect the complex history of Late Palaeozoic to Tertiary development of the region.

To avoid misunderstanding, a clear distinction has been made between the names for bathymetric and geological features. Where possible, established feature names have been retained, although the category of the feature has been changed in some cases. However, inappropriate names - as when the name of a coastal feature or town hundreds of kilometres distant have been used - have been discarded and a new name has been applied. The names of Irish saints, well established in the literature, have been used in naming or re-naming offshore basins. Structural highs or prominent igneous features have been named after mystical islands and related features which have been documented in Celtic mythology. An example of the structures named and defined is shown on Figure 2.

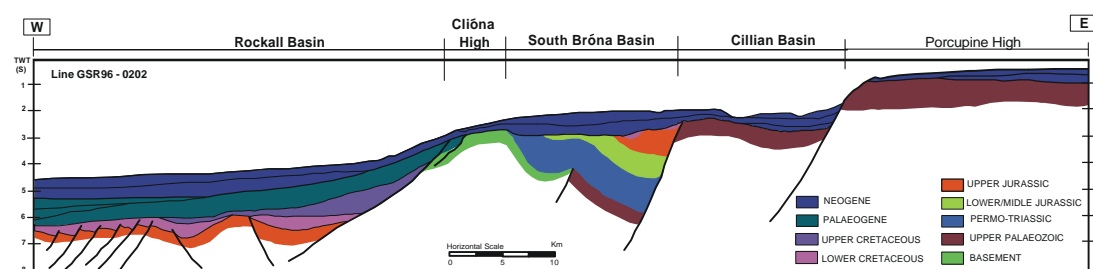


Figure 2. Geoseismic section across the eastern margin of the Rockall Basin and the South Bróna and Cillian basins, illustrating a series of basins and highs of various ages.

The results of the projects will provide for the first time structural elements maps covering the entire Irish designated Atlantic margin area. These, together with the accompanying nomenclature and geoseismic sections, should provide a sound framework on which future detailed appraisals can build.

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme.

Reference

NAYLOR, D., SHANNON, P. & MURPHY, N. 1999. Irish Rockall region – a standard structural nomenclature system. *Petroleum Affairs Division. Special Publication 1/99*.

The role of gravity and magnetic anomaly data in assessing regional structure within the Irish Rockall Basin and surrounding areas

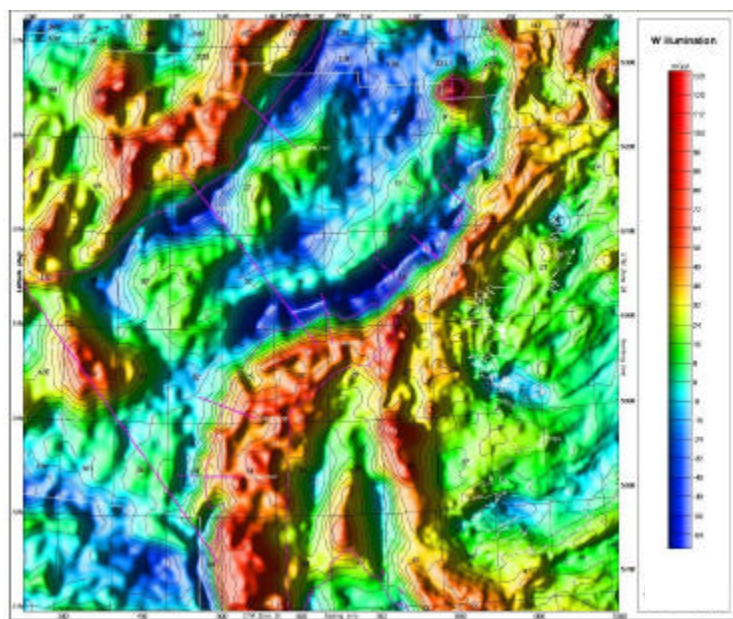
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A study based on the potential field (i.e. gravity and magnetic) data from the Rockall area west of Ireland was undertaken jointly by the British Geological Survey (BGS) and ARK Geophysics Ltd for the Rockall Studies Group. Data were available from a range of surveys of varying quality and with different acquisition parameters. 25,000 line kilometres of marine gravity and 44,000 line km of marine magnetic data and 97,000 line km of airborne magnetic data were included in the network adjustment. Onshore gravity observations and airborne magnetic data from the Irish mainland were also incorporated. In general, the coverage deteriorates significantly towards the west, resulting in a decrease in information content distinct from the effects of increasing water depths beyond the Irish shelf. Grids from pre-existing compilations were used to fill in the remaining gaps, with the western half of the area relying mainly on gravity anomaly values derived from satellite altimetry. A grid node spacing of 2 km and map production scale of 1:1M were adopted for display purposes.

A variety of techniques were applied in generating the images including the use of colour, shaded relief, upward continuation and derivatives. The marked change in resolution of gravity data across the area was accommodated by use of a variable upward continuation operator that effectively increased the observation height from 300 m above sea level in the east to 2 km in the west. The resulting images provide a valuable insight into the structural pattern of the region with evidence of extensive features cutting across the northeasterly trend of the Rockall Basin itself (Fig. 1). This information is important in evaluating overall basin architecture and the broader aspects of hydrocarbon prospectivity. It is important to recognise that there is no simple correlation between the geology and the anomalies as such.



For example, the characteristic high-low free-air gravity anomaly signature over the margins of the Rockall Basin is evidence of isostatic compensation, with marked crustal thinning beneath the deeper waters. Modelling helps in understanding the nature of these relationships. The images are particularly useful for understanding the regional context in which to set more local studies with higher resolution survey data. They also provide information in areas with little or no seismic data and greatly assist in correlating between the existing seismic lines.

Figure 1. Free-air gravity anomaly image offshore with Bouguer gravity anomaly values on land

Two-dimensional (2D) gravity modelling of basin structure was carried out along six seismic profiles near the shelf breaks. These illustrated that the response is dominated by effects related directly to the marked changes in bathymetry and highlighted the importance of establishing the contribution to the gravity response from crustal thinning in these areas. Nevertheless, the modelling provided an indication of underlying basement structure along the margins of the Rockall Basin and pointed to inconsistencies with the seismic interpretations in relation to the thickness of sedimentary strata.

Two-dimensional combined gravity/magnetic modelling was carried out along two regional profiles crossing the full width of the Rockall Basin to address the broader issues of crustal structure. There was little seismic information from beneath the Tertiary within the Rockall Basin on the profiles used and interpretation of the potential field data provides the only available evidence of underlying structural controls and for the overall thickness of the sedimentary succession. The model along profile WI-32 (Fig. 2) illustrates the structural complexity within the basement beneath the Rockall Basin and its margins, together with an indication of internal basin structure.

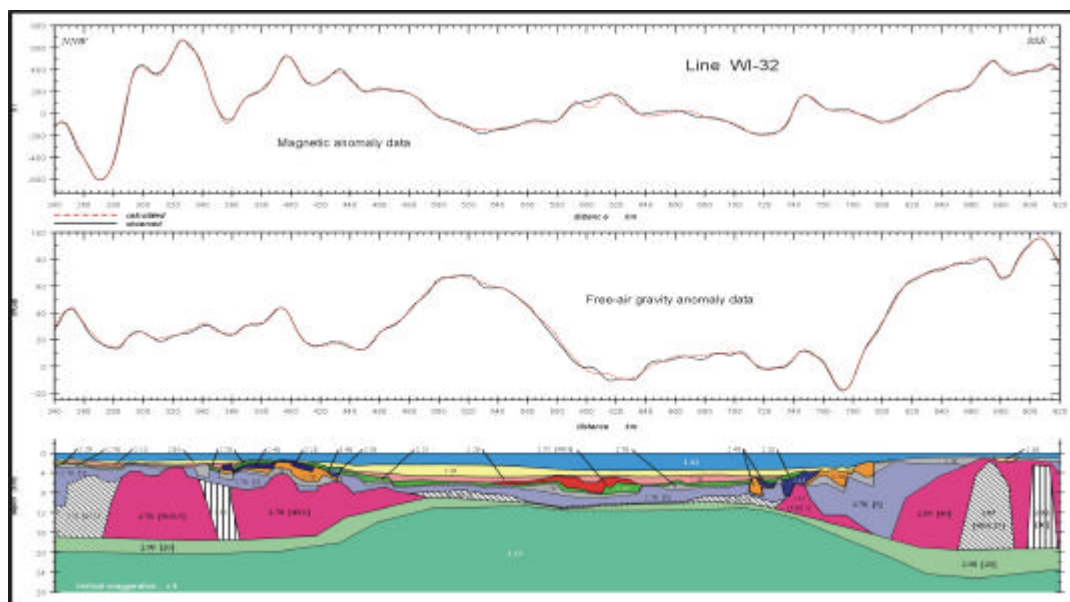


Figure 2. Crustal structure and sediment thickness derived from potential field data along regional seismic profile WI-32

In principle, it is preferable to work in a 3D rather than a 2D environment for developing reliable models. For this study a preliminary three-dimensional (3D), full-crustal model was constructed for the whole area and the thickness of the cover sequence was then optimised to minimise the residual anomalies between calculated and observed free-air gravity responses. The principal output was an 'Apparent Basin Thickness Map' that shows computed variations in the thickness of the sedimentary strata over the entire study area and provides a framework for developing more sophisticated models where there is better data/control. Variations in magnetisation within the upper crust (taken as the base of the cover sequence derived from the 3D gravity optimisation) were calculated separately. The 3D magnetic model helps define variations in basement type, areas of normally and reversely magnetised volcanic rocks and major igneous centres.

This type of study should be regarded as part of an on-going process, with new data being incorporated as they become available so that the images and models can be refined and developed. Integration with the results of other studies, especially from seismic experiments, is essential to ensuring that the data are used effectively, and that a coherent structural model is developed for the region as a whole.

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme. Gravity and magnetic data displayed for onshore Ireland were supplied by the Dublin Institute of Advanced Studies (DIAS) and the Geological Survey of Ireland (GSI) respectively.

Deep seismic investigation of the Rockall Basin: the RAPIDS 3 project

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The Rockall Basin is the largest of the basins in the Irish offshore and lies in deep water to the west of Ireland. During the past few years it has become the focus of oil and gas exploration interest. While analysis of the significant amount of new and good quality reflection seismic data acquired during the past five or six years has provided information on the structure in the younger part of the sedimentary succession, the deep structure of the Rockall region remained poorly constrained. The RAPIDS 3 (Rockall And Porcupine Irish Deep Seismic) project, funded by the Irish Petroleum Infrastructure Programme (Rockall Studies Group), acquired four wide-angle deep seismic profiles in April-June 2000 (Fig. 1).

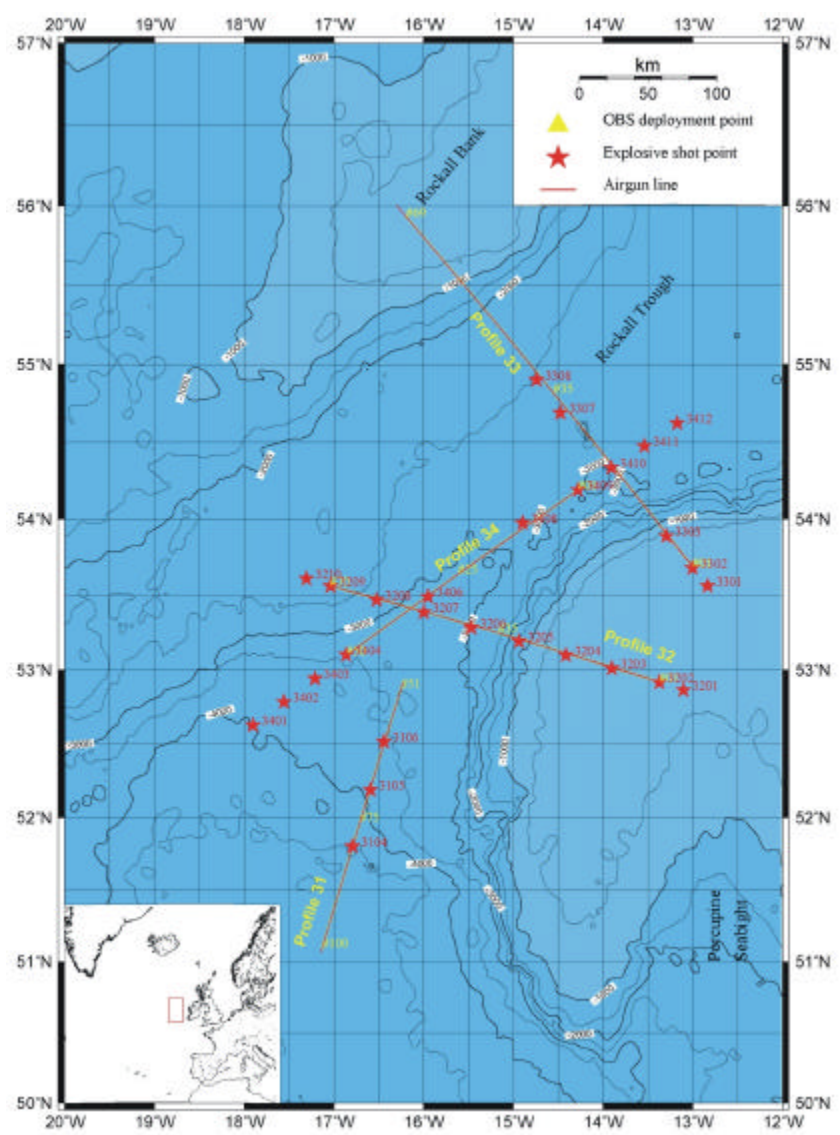


Figure 1. Location of the RAPIDS 3 profiles.

The overall objectives of RAPIDS 3 were to provide a three-dimensional constraint on general crustal sedimentary geometries, and to test the differential crustal stretching model which has been developed on the basis of RAPIDS 1 and RAPIDS 2 (Hauser *et al.* 1995; Jacob *et al.* 1995; O'Reilly *et al.* 1996; Shannon *et al.* 1999). Specific aims of the project were as follows:

- To examine the sedimentary succession and crustal structure along the eastern margin of the Rockall Basin in an area where the main basin edge abuts a series of buried ?Early Mesozoic basins. This region may correspond to a major change in basement crustal style, or to a deep-seated inherited Caledonian or older structural fabric.
- To constrain the precise location, nature and structural style of the western margin of the Rockall Basin south of the RAPIDS 1 profile.
- To investigate the nature of the deep mantle reflectors identified along the RAPIDS 2 axial profile and which may reflect the presence of a fossil lithosphere/asthenosphere boundary. This would provide critical evidence to support the differential stretching model which has significant implications regarding heat flow, number, age and nature of extensional episodes in regions of attenuated crust.

The survey commenced on 14th April and was completed on 1st June 1999. The R/V Akademik Boris Petrov, a 75 m research vessel, was employed for airgun profiling and for deployment and retrieval of Ocean Bottom Seismometers (OBS), with the R/V Celtic Voyager, a 31 m vessel, used to fire a number of explosive shots. Two axial (34 and 31) and two transverse (32 and 33) profiles were recorded using an airgun array as a primary source and explosive shots as an additional source for deeper energy penetration. Data were recorded on a closely spaced set of OBS with a spacing of 4.67 km to 5.75 km between OBSs. The shot spacing was 120 m. Data quality was generally excellent with a good signal to noise ratio and energy propagation of >100 km providing clear arrivals from boundaries within the crust and occasionally the upper mantle.

Whole crustal P-wave velocity models have been produced on profiles 32, 33 and 34 from 2-D travel-time modelling of these arrivals. The velocity models typically indicate a 4–5 km thick sedimentary succession within the central part of the Rockall Basin, although depocentres up to 7.5 km thick occur locally, e.g. the Macdara Basin (Mackenzie *et al.* 2000a, b). Up to eight layers, grouped into three main seismic packages, are defined. These are generally flat lying in the centre of the basin pinching out to the basin margins where significant structural complexities are observed. The succession is interpreted to be of Late Palaeozoic to Recent age, with some of the units interpreted as igneous layers (sills or lavas). A Tertiary succession, up to 2 km thick, is relatively flat-lying in the centre of the basin and pinches out onto the basin margins. A Mesozoic succession, 2–6 km thick, is structurally complex, with significant thickness variations, and is generally confined to the basinal areas. A Late Palaeozoic succession, up to 2 km thick, has minor thickness variations and is regionally extensive, occurring both in the basins and on the basement highs. Significant topography is observed on the crystalline basement possibly representing a series of rotational fault blocks. The model for profile 33 is shown in Figure 2. The independently-derived wide-angle layers correspond closely to major seismic packages identified on seismic reflection profiles, and are consistent with results from borehole extrapolation, thereby providing a degree of confidence in the robust nature of the modelling.

Beneath the Porcupine and Rockall highs a 3-layer crust of 25–30 km thickness is modelled. The crust thins beneath the basin to 6–8 km. A maximum thinning occurs beneath the edges of the basin with the crust beneath the centre of the basin being slightly thicker. The three intra-crustal layers also thin and merge together to a 2-layer, or sometimes 1-layer, crust beneath the centre of the basin. The Moho shows a degree of asymmetry with a steeper Moho dip beneath the eastern margin of the basin.

On several seismic sections an upper mantle reflector is seen beneath the centre of the Rockall Basin. Sub-Moho velocities are lower where this phase is observed, suggesting that serpentinisation of the upper mantle may have occurred. This supports the model of O'Reilly *et al.* (1996) of the RAPIDS 1 profile

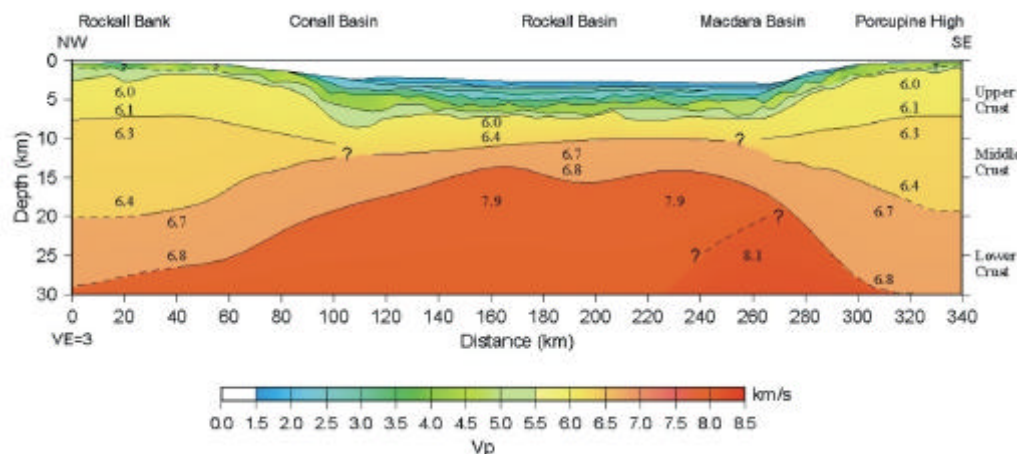


Figure 2. P-wave model for RAPIDS 3 profile 33 (see Fig. 1 for location).

The wide-angle models and interpretations provide a number of pointers of interest from an exploration viewpoint. They indicate (a) the full thickness of the sedimentary succession, (b) suggest the presence of an extensive relatively low velocity layer (Upper Palaeozoic and/or fractured basement) beneath the basin and across the highs, (c) demonstrate the presence of a number of sedimentary depocentres at different levels in the succession, and (d) indicate a number of regions of major tilted fault block at different levels within the basin. The asymmetry of the Moho may point to the presence of an inherited deep-seated fabric controlling basin location and formation, while the thickness patterns in the crust, together with the possible central zone of mantle serpentinisation, has implications for heat flow and subsidence patterns in the sedimentary succession.

Acknowledgements

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The tectonic development of the Irish Rockall and Porcupine Basins: a comparison

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The adjacent Porcupine and Rockall Basins show a similar tectonic history. WSW-ENE trending Caledonian structures, particularly splays of the Great Glen Fault, had an important control on the Late Palaeozoic and Mesozoic development of the two basins. Although the controls on Carboniferous basin formation are unclear they probably relate to dextral transtension along reactivated Caledonian structures such as the Iapetus Suture. The effects of the Late Carboniferous Variscan Orogeny are seen on the eastern flank of the Porcupine Basin with the development of a north-facing, thin-skinned thrust system with associated W-E trending ramp anticlines and fault propagation folds. This zone has not been detected on the western flank of the Porcupine and is expected to pass south of the Rockall.

The Permo-Triassic to Early Jurassic period saw the first stages in the break-up of Pangea that would eventually lead to the formation of the North Atlantic. The widespread development of basins of this age, proven in the North Porcupine, Slyne and Erris Basins, has been proposed in the Porcupine to Rockall region (e.g. Shannon 1991), and is supported in this study on the grounds of geometry and seismic character. The amount of crustal stretching at this time, calculated on the basis of fault throws, was relatively low ($\beta \leq 1.5$).

The formation of the Porcupine and Rockall Basins in their current configuration was a result of Mid to Late Jurassic rifting (e.g. Croker & Shannon 1987; Shannon et al. 1999). In many cases the polarity of the extensional faults formed at this time is opposite to that for basin margin faults formed during Permian to Early Jurassic rifting, leading to complex geometries. Rifting in the Rockall Basin continued into the Early Cretaceous, up to the end of the Barremian. In the Porcupine Basin the Early Cretaceous has an early post-rift geometry. The crustal stretching during this period increases southwards in both basins (from $\beta = 2.5$ to 4.5 in the Rockall and from $\beta = 1$ to ca. 4 in the Porcupine Basin). This variation in the amount of stretching suggests that the Hatton, Rockall and Porcupine Highs underwent small clockwise rotations during this main rifting event.

Within the Rockall Basin, early syn-rift packages show evidence of erosion beneath an unconformity of possible Base Aptian age. This is supported by the borehole drilled into the North Bróna Basin where a thin ?Aptian to Upper Cretaceous sequence sits unconformably on Upper Jurassic syn-rift sediments. In the Porcupine Basin at this time a major irregular downcutting unconformity was formed. The Early Cretaceous was also the period in which the Porcupine Median Volcanic Ridge was formed, similar structures developed within the southern Rockall and volcanic sediments appear in sequences drilled in the Porcupine Basin. It is proposed that these observations can be explained by uplift and volcanism associated with a short-lived mantle plume developed at the rift triple junction at the southern end of the Rockall Basin.

Post-rift sedimentation continued throughout the Late Cretaceous, although minor rifting is observed in the North Porcupine Basin probably related to a local pull-apart structure caused by oblique reactivation of the northern boundary of Finnian's Spur, which is interpreted to coincide with a major Caledonian structure. Minor extension continued into the Palaeocene in the North Porcupine Basin. During the Late Palaeocene to Eocene the Rockall was affected by compression related to ridge push forces from the newly formed Atlantic spreading centre west of the Hatton Bank. Simultaneously on the eastern margin of the Porcupine Basin there was minor extensional reactivation of many of the Late Jurassic extensional faults although the relationship between these two sets of structures remains unclear.

The Late Eocene to Present history of both basins is one of subsidence progressively outstripping sediment supply. The origin of this subsidence has not been successfully explained and is matched along most of the Atlantic Margin.

Acknowledgements

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First shallow drilling on the eastern flank of the Irish Rockall Basin – operations review, drilling history and preview of results

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In 1998 the Seabed Technical Committee (STC) of the Rockall Studies Group (RSG) canvassed all sixteen members of the Petroleum Infrastructure Programme (PIP) for locations for a shallow drilling programme in the Irish sector of the Rockall Basin. The objective of the programme was to penetrate the sedimentary fill of isolated, presumed Mesozoic, basins bordering the Rockall Basin (e.g. Cornfield *et al.* 1999, Naylor *et al.* 1999 and Walsh *et al.* 1999). Eventually seven locations were chosen based on water depth (a maximum of 1700 metres), operational suitability and geological interest. In 1998 the NERC research vessel RRS Challenger was used by the British Geological Survey (BGS) to site survey these locations by acquiring shallow seismic data and gravity cores for geotechnical analysis. From the site surveys four locations were chosen for drilling by the drillship Norskald later in the same year. The final locations were chosen to acquire as much geological information as possible within operational and budget constraints (Fig. 1). Due to mechanical problems, the Norskald was unable to start the programme and instead the drillship MV Bucentaur was used the following year (1999). Prior to mobilisation extensive contingency planning was undertaken by the STC and BGS to optimise the decision making process under operational conditions. This was aided by a secure 24 hour Petrolink drilling website, installed on the drillship, with a mirror site onshore that allowed all interested members instant access to the latest drilling data. Onboard biostratigraphy was undertaken for initial dating and to ensure that important seismic reflectors were cored and TD objectives met. This information was entered into a constantly updated well log and report for the end of the cruise.

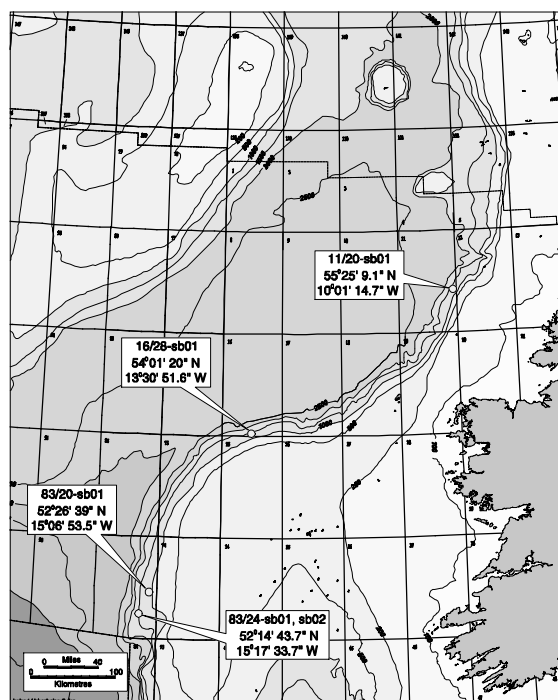


Figure 1. Location of RSG boreholes.

In the summer of 1999 the first borehole (11/20-sb01) was spudded on the Erris High but was forced to terminate after 21 metres due to extremely slow drilling, in a hard tuffaceous section, and incoming heavy weather. The borehole did however yield valuable geological information and drilling experience for the later boreholes.

The second borehole (16/28-sb01) drilled 148 metres in the Macdara Basin and reached its objective unconformity before stopping due to poor weather in basalt of unknown age. This borehole is an important calibration point for this part of the Rockall margin.

Borehole 83/20-sb01 was spudded in the North Bróna Basin and achieved the greatest penetration at 177 metres. Comparison of the borehole results with seismic profiles, and TD penetration of Mesozoic sediments, reveals that this borehole is extremely important in understanding the history of the Rockall Basin.

The final location in the South Bróna Basin was re-spudded after the first attempt (83/24-sb01) was curtailed due to poor weather. The 83/24-sb02 borehole was terminated at 71 metres after reaching its objective unconformity and was drilled in a BGS record water depth of 1566 metres. The top hole results of this borehole can be correlated to 83/20-sb01 on seismic data, however TD was reached in Palaeozoic sediments.

Although not all borehole objectives were met, the cruise was extremely successful in acquiring the first core from the Irish Rockall Basin margin. While the data remains confidential to the RSG, some of the key results will be presented at this conference. In addition to the penetration of extensive Tertiary sections, three out of five boreholes achieved their objective of recovering Mesozoic sediments (Jurassic and Cretaceous) and this will prove extremely important for understanding the geological evolution and hydrocarbon prospectivity of the area. This result was achieved by extensive pre-planning and effective teamwork between the BGS, drill-crew and STC combined with some unexpected good to occasionally marginal weather in the Rockall.

Acknowledgements

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Application of fluid inclusion studies to basin histories and hydrocarbon exploration, Atlantic Margin offshore Ireland.

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Fluid inclusions are microscopic cavities in crystals that are filled with liquid \pm gas \pm solid phases. In sedimentary rocks they can provide samples of fluids (e.g. waters, petroleum and gases) present during the evolution of the basin. Secondly, they can provide an estimate of the temperature at which the fluid became trapped in the host mineral. In sedimentary rocks the host minerals commonly include quartz, calcite and dolomite formed during cementation. In addition detrital quartz and calcite can also yield useful fluid inclusion data. Sedimentary basins contain crosscutting hydrothermal mineral veins (quartz \pm calcite) which are also a target for fluid inclusion studies yielding information on fluids which passed through the basin after lithification. Finally, fluid inclusions can provide estimates of fluid density. Fluid inclusion petrography combined with estimates of trapping temperature, composition and density can provide important information to the petroleum exploration and development industry e.g. a) temperature of mineral cement growth and composition of fluid present, b) temperature, composition and timing of fluid migration (i.e. water, petroleum and gas) and, c) temperature and composition of hydrothermal fluids in late crosscutting veins.

Because fluid inclusions are seldom greater than 50 microns (1 micron = 0.001 mm) their internal detail is only resolvable using a microscope with transmitted light. Thus microscopic examination can be carried out routinely and is a necessary prerequisite before further analysis. During this study phase it is possible to recognise the presence of mixed carbonic and aqueous fluids and petroleum bearing inclusions. The salt content of single fluid inclusions is usually determined by observing phase changes which occur within each inclusion upon cooling and subsequently heating the sample. This non-destructive procedure called microthermometry is carried out on doubly polished wafers of sample (<100 microns thick) placed within the chamber of a microscope mounted heating/freezing stage. The recorded phase transition temperatures are then used to model fluid compositions by applying the microthermometric data to experimentally determined phase diagrams.

The recognition of oil inclusions, detected by their fluorescence under ultra-violet light, is a very valuable indication of migrating hydrocarbons, and in frontier basins can be the first direct evidence for an active hydrocarbon system. The distribution of oil inclusions is a good guide to those levels that have functioned as reservoir or carrier beds.

It is possible to undertake more sophisticated analyses of the oil trapped in fluid inclusions, including assessment of API° gravity and bulk geochemistry. This data is important in establishing oil-source correlations, and the history of oil charge. A major challenge is the determination of detailed compositions of hydrocarbons trapped in fluid inclusions. R&D studies (Parnell et al in this volume) have successfully used laser technology to determine the API gravity and aromatic concentration of crude oils by measuring fluorescence lifetimes. This technology is being adapted to determine these characteristics in hydrocarbon bearing fluid inclusions.

The results of fluid inclusion studies on samples from the Irish Rockall will be used to demonstrate how fluid inclusion studies are used to model the fluid composition and the P T conditions of fluid trapping. In addition reference will be made to ongoing fluid inclusion studies of sandstone chippings and vein minerals from the Porcupine Basin. Comparisons will be made with fluid inclusion studies carried out elsewhere on the Atlantic margins (e.g. in the West of Shetland region and the Jeanne d'Arc Basin offshore Newfoundland) and in the Celtic Sea and Fastnet Basins. All combine to demonstrate that fluid inclusion studies form an integral part of basin history studies and frontier oil exploration.

Acknowledgements

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A deep-towed sidescan sonar (TOBI) survey of the margins of the Rockall Trough: environmental aspects

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The margins of the Rockall Trough, currently the focus of oil and gas exploration interest, incorporate an environmentally-important and lightly studied shelf region. This valuable natural laboratory contains information on slope stability, sediment transport, nutrient upwelling, current and biological activity at a shelf/slope/basin-floor transition. An extensive high-resolution sidescan sonar survey was carried out in the Irish sector of the Rockall Trough in June/July 1998. The TRIM (TOBI Rockall Irish Margins) project, funded by the Irish Petroleum Infrastructure Programme (Rockall Studies Group), acquired 3100 line km of TOBI (30 kHz) sidescan sonar and 3700 km of 3.5 kHz profiler data along the margins of the Rockall Trough (Fig. 1).

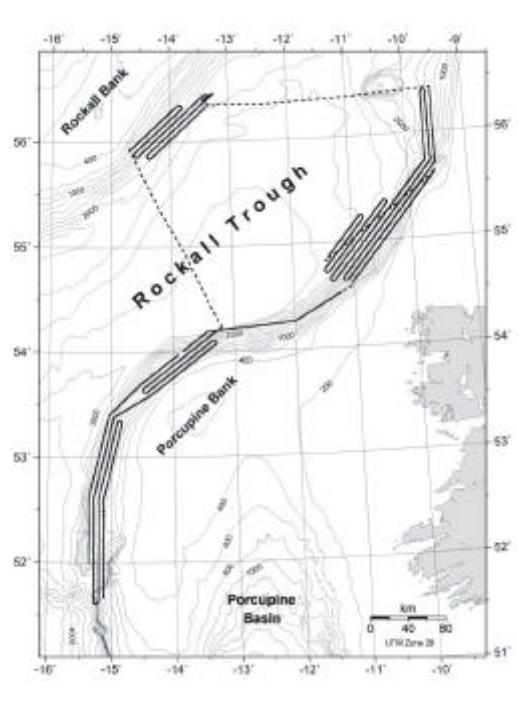


Figure 1. Track chart for TOBI and 3.5 kHz survey (dashed lines are 3.5 kHz data only) with 200 m isobath contours.

The main overall aim of the project was to provide geological and environmental data which could be used in a baseline environmental study of the region. Particular scientific targets were:

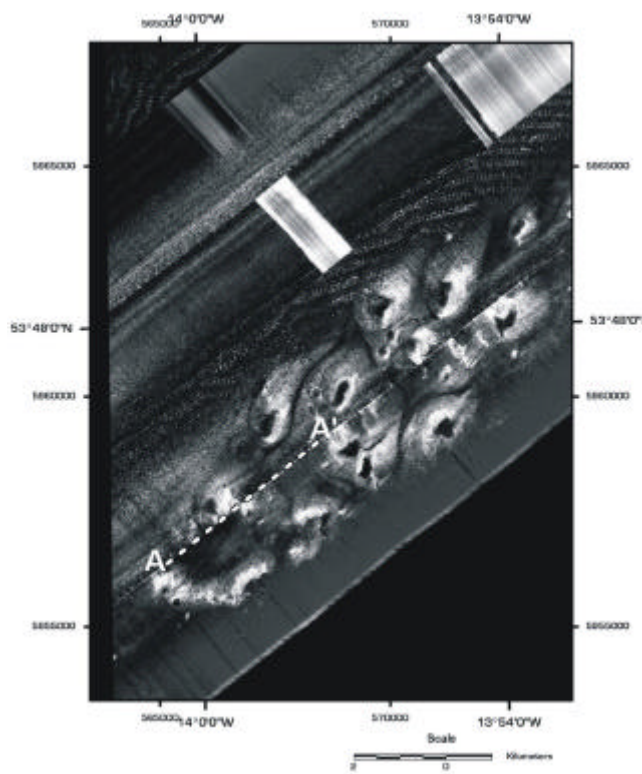
- The regions of steep slopes, which host a variety of mass wasting and slope instability features. Sudden movement of such large features have the potential to generate tsunamis. They also affect the sediment budget and the environmental balance of the basin.
- The Recent cold water carbonate mounds on the eastern margin of the Rockall Trough. These have important environmental implications and their origin and growth may be related to the escape of thermogenic gas along basin-edge faults, to the release of hydrate methane under conditions that may be driven by global temperature changes, or to deep water current-driven nutrient upwelling onto the shelf.
- The large canyon features on the eastern flank of the Rockall Trough. They may represent major sediment pathways for submarine fan systems and, as modern analogues for sandstone reservoirs, can provide valuable information on likely sand distribution systematics in deep basin systems. They show significant topographic relief, and probably host a range of ecological niches.

The sidescan sonar mosaics, together with 3.5 kHz profiler information, were integrated with available gravity core data to provide information on the nature of the seabed and the shallow sub-bottom structure. The images obtained are a snapshot of the present physical and environmental state of the seabed, which is a point of reference for monitoring natural and anthropogenic environmental change.

A number of dramatic slope failure features, of different types, are identified on both the western and eastern margins of the Rockall Trough (Shannon *et al.* 1999a,b, 2001, Readman *et al.* 2000). Assessing the hazards to the environment and to seabed installations requires knowledge of the frequency and magnitude of slope failure events on different parts of the slope. These are determined by slope gradients, the geotechnical properties of the seabed sediments/rocks and possible triggering mechanisms such as pressure fluctuations due to storms or ground acceleration caused by tectonic earthquakes.

The steepest gradients occur along the walls of V-shaped channels along most of the eastern margin of the Rockall Trough where the slope can exceed 12° . Slope escarpments along both the surveyed margins of the Rockall Trough are produced predominantly by translational sliding of rafts away from the headwall of the slide zone. Evidence for rotational sliding and failure of the slope is very rare. The sutured patterns of escarpments on the sonar sidescan mosaics (particularly on the Rockall Bank where the lithologies are more mud-prone) are probably produced by multiple failure events. The relative sharpness of these structures, despite the presence of erosive bottom currents, suggests that many are very (historically) recent. Recently-detected (1999 and 2000) earthquakes exceeding magnitude 2, in the Rockall Trough may be related to slope failure.

Sedimentary bedforms associated with contourite sands and carbonate mound populations define a counter-clockwise bottom current circulation pattern within the Rockall Trough. Evidence for particularly strong currents is present along the upper slope down to 1000 m water depth and at the base of the slope. Strong bottom currents seem to be associated with the biologically-productive parts of the continental slope. For example, bedform patterns around the individual mounds of a large population on the eastern margin of the Rockall Trough (Fig. 2) suggest active NE-directed currents. Mobile, high porosity contourite sand sheets (with a high retention capacity for hydrocarbons) are extensively developed along the Porcupine Bank region of the slope. These could have an important effect on the environmental impact of pollution.



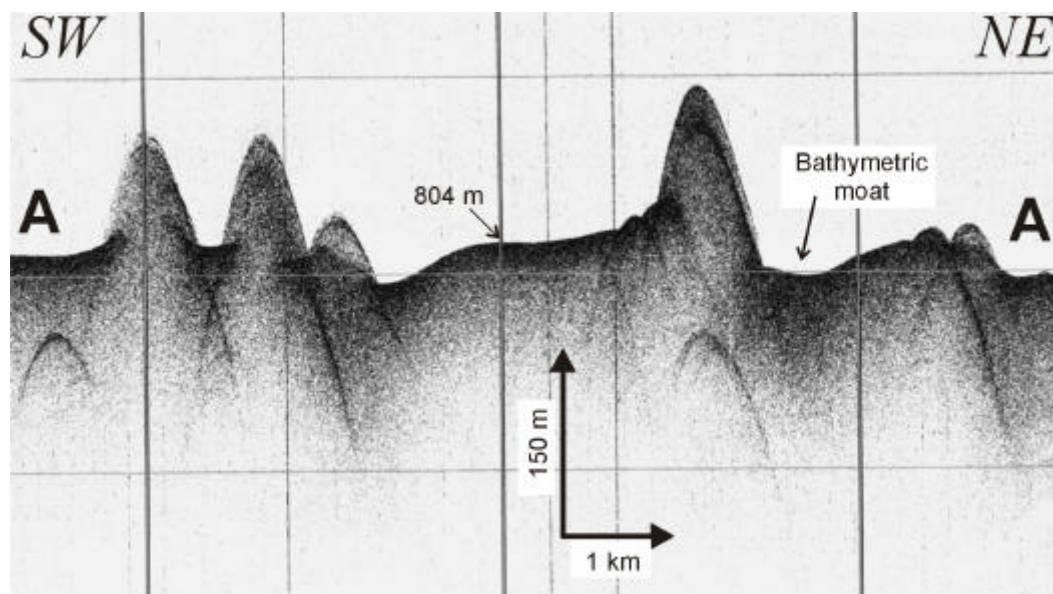


Figure 2. (a) TOBI mosaic showing a cluster of carbonate mounds on the eastern margin of the Rockall Trough. Note the elongation of sediment tails in the lee of the mounds. They indicate southwest to northeast current flow. (b) 3.5 kHz profile across a carbonate mound cluster (see location on Figure 2a).

Hard seabed (with moderate to high backscatter) composed of bedrock and/or consolidated sediments have a lower capacity to bind hydrocarbon pollutants, as the porosity of these sediments/rocks is less. Significant contamination of the water column in the event of a major oil leak or spillage would result with immediate and local biological impact, since this seabed type often forms a suitable substrate for biologically diverse carbonate mounds. More mud-prone shallow lithologies are present across the Donegal Fan and the canyon systems further south as well as along the slope of the Rockall Bank. These clay-rich sediments can bind hydrocarbon compounds in the form of colloids. A diffuse sediment-water interface would enhance this capacity and possibly limit the distance of oil discharges in the event of a spillage.

Regions of high backscatter, interpreted as consolidated sediments and/or bedrock exposed by multiple slope failure events, define a second type of slope failure zone. Several of these areas have been ground-truthed by gravity cores as either rock (bedrock) or chalk (Cretaceous?). Pairs and clusters of carbonate mounds are rooted upon some of these regions in water depths of 1200 m, and up to 2500 m, suggesting that they are older than these modern mound structures. They therefore are interpreted as relatively stable regions of the slope with a lower probability of failure.

The environmental inventory provided by the TRIM project will help to build an understanding of the behaviour and development of such regions and the hazard assessment of the steep basin slopes. In addition to the sedimentological and environmental data, the project has provided information useful in planning installation of seabed facilities and in fisheries research. The results from the survey will provide valuable information on the sedimentology, slope stability, geological development and environmental setting of the Rockall Trough.

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Cetaceans and seabirds at sea of western Ireland

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Since July 1999, a major offshore survey of cetaceans and seabirds has been in progress off southwestern and western Ireland. This survey is a 2½ year project undertaken on behalf of the Rockall Studies Group (RSG) and Porcupine Studies Group (PSG) of the Petroleum Infrastructure Programme. This programme was set up by the Petroleum Affairs Division (PAD) of the Department of the Marine and Natural Resources in 1997. The overall scientific research programme has been allocated a total of £300,000 by the RSG/PSG and PAD, making it the most significant offshore study of whales, dolphins and seabirds ever conducted in Irish waters. The limited amount of research west of Ireland has indicated that the continental shelf and slope, as well as the deep abyssal plain provide important habitats for many cetaceans and seabirds, including species that are highly vulnerable or rare. The study area for the current project includes all three habitat types and encompasses the offshore waters to the southwest and west of Ireland, stretching south from the Goban Spur to the Porcupine Seabight, Rockall Trough and west to the Hatton and Rockall Troughs. The primary objective of the study was to identify major concentrations of cetaceans and seabirds in these waters and evaluate seasonal trends in their abundance and distribution using standard visual and acoustic monitoring techniques. Ship-based surveys were conducted, primarily on vessels of opportunity (e.g. research vessels, fishery protection vessels, ferries). A total of 284 person-days were spent at sea, most of which (181 person-days) were during the summer/autumn months (May–October). A total of 1,253 individual cetaceans of 15 species have been recorded on effort during the project's first 19 months. Four species of mysticetes (baleen whales) and 11 odontocete (toothed whale) species have been identified in 167 encounters to date. Limited habitat-association patterns were noted for certain cetacean species, including long-finned pilot whales (Fig. 1), harbour porpoises, and minke whales.



Figure 1. Surfacing fin whale (*Balaenoptera physalus*) recorded during the SIAR survey, August 2000.

A total of 68,295 birds of 62 species were recorded during the first 19 months of the study. There is emerging evidence that the deep waters of the Rockall Trough are utilised by a range of seabird species, including all the shearwaters, gannet (Fig. 2), kittiwake, lesser black-backed gull, great skua

and puffin (Fig. 3). The Rockall Trough appears to act as conduit through which some seabird species migrate – especially in autumn.



Figure 2. Juvenile Gannet (*Morus bassanus*) observed with fishing-line trailing from the beak.



Figure 3. Adult Puffin (*Fratercula arctica*) photographed on Grimsey Island, Iceland.

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme.

A descriptive climatology for the Atlantic fringe

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Fugro GEOS and Amergen developed a descriptive climatology on behalf of the Rockall Studies Group (RSG) and the Porcupine Studies Group (PSG), following work by Leggett and Cahill (1999) under RSG Project 97/29. The RSG summary covers the area 51°N to 57°N, 18°W to 8°W. The PSG summary extends further southward and covers the area 48°N to 54°N, 16°W to 9°W. The two regions are illustrated in Figure 1, together with the locations of the principal data sources.

The climatology provides preliminary metocean criteria in support of offshore operations west of Ireland and specifically concentrates on the deep water continental shelf concession areas. The following parameters are addressed within the report

- Winds
- Waves
- Currents
- Water levels
- Seawater Temperature

Wind and wave data were acquired from the UK Meteorological Office European Shelf Model, and these were compared to buoy measurements to provide confidence in the results. The data were analysed to derive wind roses and exceedence tables on a monthly basis to provide a tool for operational planning. The locations of the wave model data are marked on Figure 1 as red circles and annotated as Global Wave Model (GWM) or European Waters Wave Model (EWM). The locations of the wave buoys are marked as blue circles.

A detailed overview of the oceanographic processes driving the currents through the two areas is provided, and magnitudes and time/length scales discussed in order to relate these to potential impact on offshore operations.

Current data were obtained from the Proudman Oceanographic Laboratory's Continental Shelf (CS3) model and the North East Atlantic (NEA) Model. The locations of these data are illustrated in Figure 1 as green circles. The CS3 model includes a surge component whereas the NEA model is purely tidal. Neither model adequately represent the dynamics of the dominant slope flow, or other processes.

Historical current data were acquired for Porcupine Studies Group region. Although the historical data provide information on the magnitudes of currents that might be encountered, the spatial and temporal resolution is relatively poor, particularly in the vertical. All available data were subjected to preliminary QC prior to standard presentations as joint frequency of occurrence tables. Exceedence profiles at 10% and 50% were derived by fitting a curve to a composite profile of all available data within sub-regions of the area of interest to the Porcupine Studies Group.

Seawater temperature and salinity were extracted from the NODC database of profiles. These were analysed to provide mean sea surface temperature in thirteen $2^\circ \times 2^\circ$ blocks on a monthly basis. Additionally tabulated temperature data associated with each of these blocks are presented on a monthly basis.

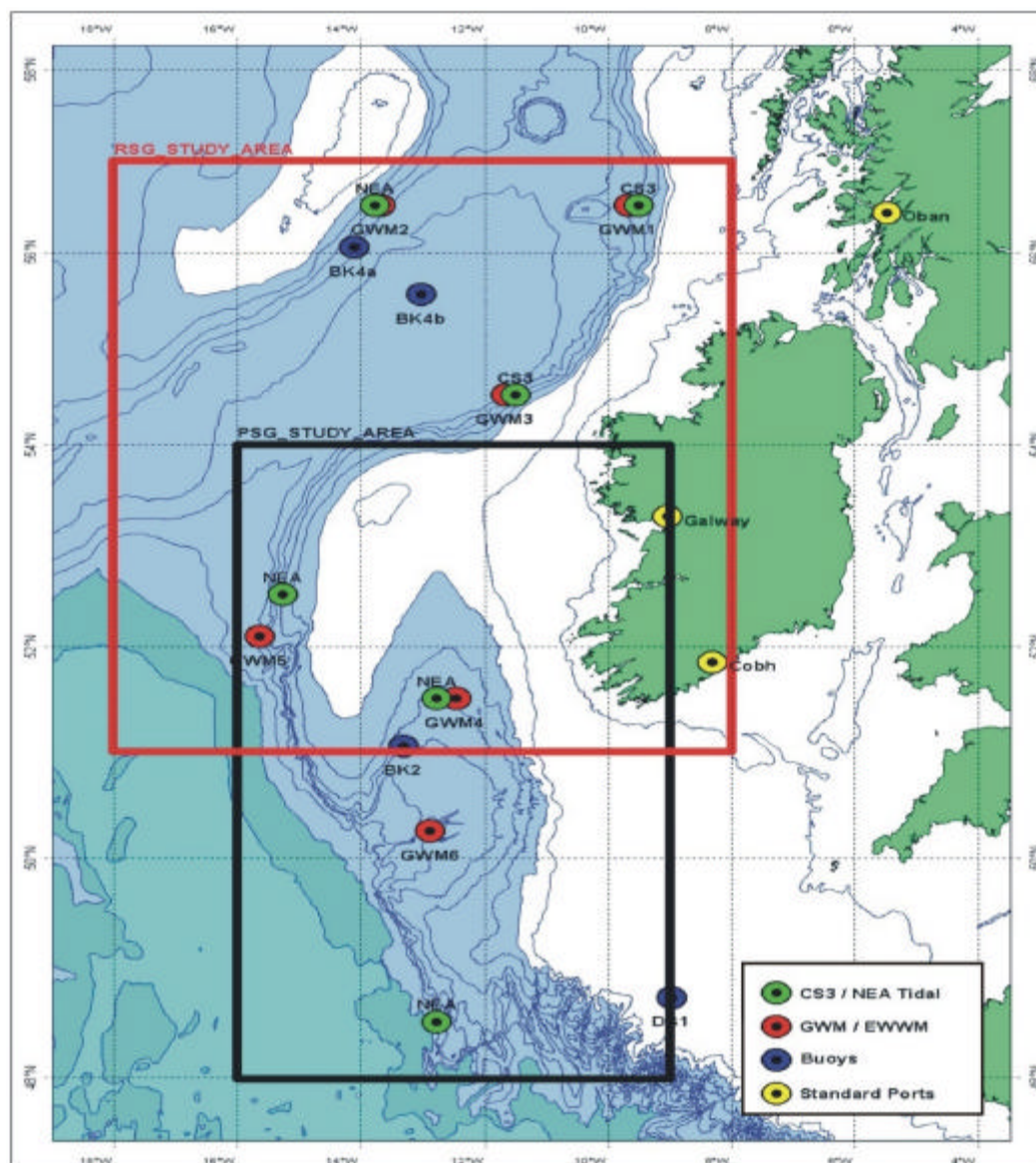


Figure 1. West of Ireland Regional Climatology study – data sources and standard ports.

The results of the analyses provided a preliminary quantitative description of the climatology. The wind data indicated typical seasonal trends with worst conditions being experienced in February and the most benign conditions in July (see Figure 2). Generally westerly winds are experienced throughout the year with the exception of May, during which north to northeast winds are experienced.

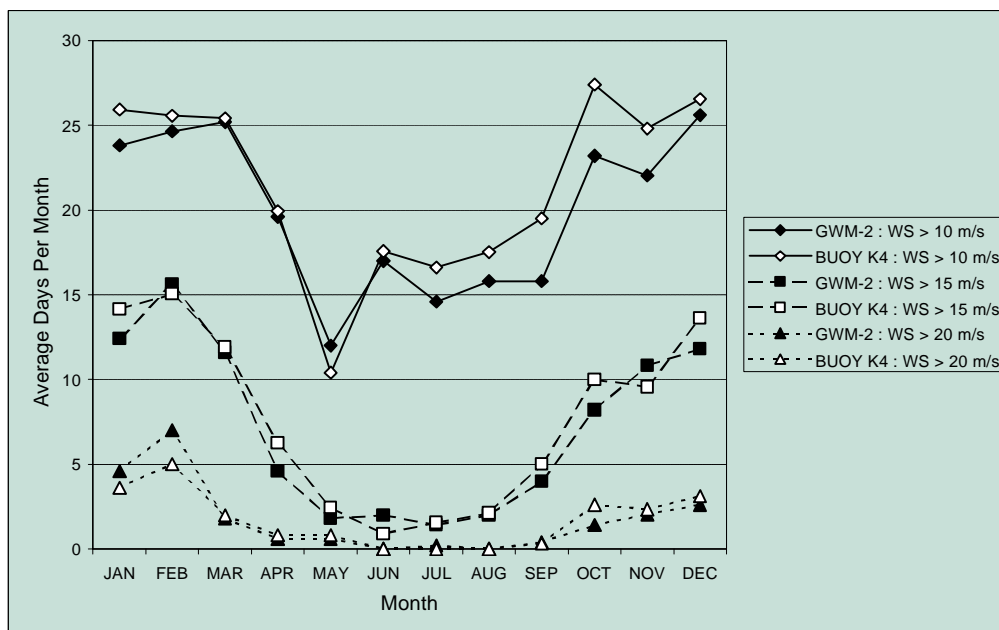


Figure 2 - Monthly Wind Speed Exceedences at GWM2 and K4 Buoy

The wave data provided similar results to the wind data in terms of seasonality. However the May direction reversal was not evident in the dominant wave direction, although often seen in the second dominant direction. December to February experience an average of 9-10 days with wave heights in excess of 6m, as illustrated in Figure 3, whereas July to August experience only 1 or 2 days when the significant wave height exceeds 2m.

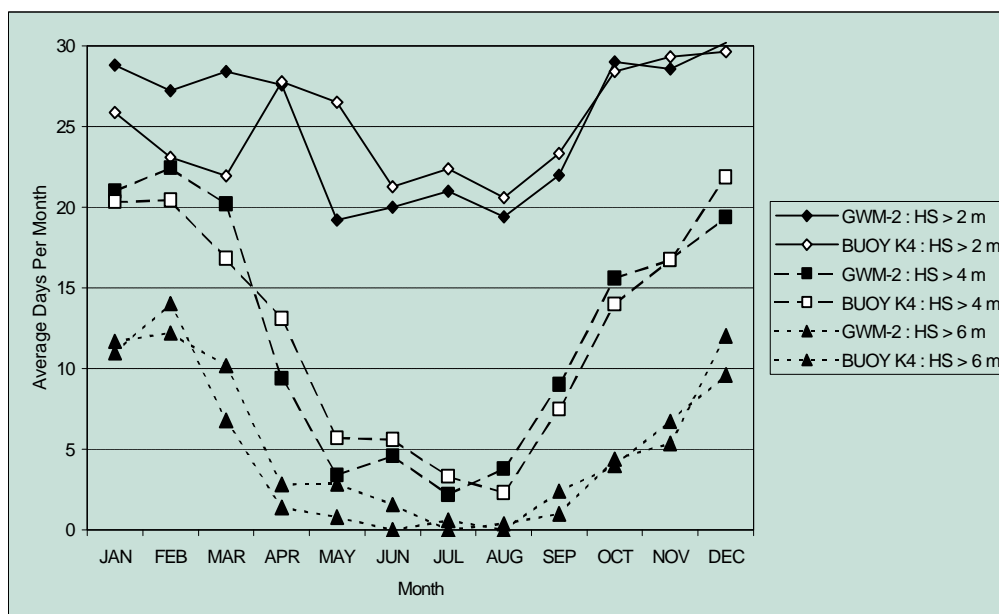


Figure 3 - Monthly Wave Height exceedences at GWM2 and K4 Buoy

The current regime in the RSG and PSG areas is very complex. The dominant feature is the slope current, however many other processes occur including mesoscale variability, internal waves and cascading. Table 1 provides a brief summary of the typical and maximum currents from the literature

and analysis of the data. It is anticipated that the maximum measured currents have not captured some of the more energetic events such as eddies propagating along the shelf.

LOCATION	Mean Speed	Max. Speed	Tidal Currents on slope	Slope current characteristics
Hebrides& Malin	0.10 to 0.20 m/s Mostly associated with slope current.	≥ 0.60 m/s	0.10 to 0.25 m/s M2 and diurnal Internal tides& solitons.	Highly barotropic and increasing Northwards. Minimal seasonality. Weaker, more variable deep flow. Interannual variation in slope transport. 2-10 day modulation by low frequency waves.
Rockall Bank	0.05 m/s upper 0.10 m/s deep	0.50 m/s	0.10 to 0.20 m/s increased diurnal tides.	Southerly boundary flow below surface layer. Trapped diurnal waves present.
Porcupine Bank	0-200 m : No Data 200-500 m : 0.11 m/s 500-1000 m : 0.13 m/s 1000-2000 m : 0.08 m/s >2000 m : 0.07 m/s	0-200 m : No Data 200-500 m : 0.34 m/s 500-1000 m : 0.38 m/s 1000-2000 m : 0.32 m/s >2000 m : 0.23 m/s	0.05 to 0.15 m/s. Diurnal (trapped) waves. Internal waves.	Broader slope current at all depths. Part seasonal response termed SOMA. (Sep-Oct-Mar-Apr) Discontinuity at northern end? 2-10 day Modulation by low frequency trapped slope waves.
Porcupine Sea Bight	0-200 m : 0.15 m/s 200-500 m : 0.09 m/s 500-1000 m : 0.08 m/s	0-200 m : 0.65 m/s 200-500 m : 0.41 m/s 500-1000 m : 0.25 m/s	0.05 to 0.20 m/s Increase near sea bed at diurnal frequency.	Strong seasonal slope current along eastern margin, with weaker flow at northern end.
Goban Spur Celtic Sea OMEX Region	0-200 m : 0.26 m/s 200-500 m : 0.11 m/s 500-1000 m : 0.12 m/s 1000-2000 m : 0.10 m/s >2000 m : 0.08 m/s	0-200 m : 0.60 m/s 200-500 m : 0.46 m/s 500-1000 m : 0.56 m/s 1000-2000 m : 0.55 m/s >2000 m : 0.26 m/s	Relatively low energy at Spur. Higher to south. Internal tides.	Slope current increasing poleward. Seasonal (SOMA). Inertial overshoot at Goban Spur.
Deep Ocean Upper layer	0.01 to 0.02 m/s	0.50 m/s	Small.	Currents dominated by mesoscale variability (Eddies). Wind driven maximums.
Deep Ocean Lower layer	0.01 to 0.02 m/s	0.30 m/s	Small some local increased currents	Cyclonic in Trough and Biscay / Porcupine basins. Penetration of eddy kinetic energy to depths. Overflows from the Wyville-Thomson Ridge.

Table 1 Summary of Typical and maximum currents

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme.

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PIP and the Information Highway

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The PIP Rockall Studies Group (RSG) had to overcome the significant challenges of efficiently conducting PIP business, managing data acquired by the PIP projects, managing budgets and delivering interim results in a timely manner. All this required that people at different locations be connected, sometimes day or night. CSA Group Ltd was contracted as Secretariat by the group to assist in meeting these challenges. The solutions developed for the RSG are described. These same solutions were subsequently applied to the PIP Porcupine Studies Group (PSG) with little or no modifications being required.

The RSG organisation comprises an executive, a management committee, five technical committees and more than 50 projects some with up to five partners and subcontractors. Over 150 people are involved in more than 60 different office locations in Ireland, UK, Netherlands, Germany and beyond. The decision making process involved consultation, sometimes at short notice, between several individuals representing RSG members and contractors. Early project and finance planning was conducted through face to face meetings of the management and technical committees in Dublin. A solution would have to be found to allow quick operational decisions on expensive marine projects to be made at short notice and provide an ability to quickly assess new data acquisition opportunities and obtain the necessary consent of members to commit funds and approve contracts.

The technologies adopted included conference calls, e-mail, websites and online searchable databases. Committee meetings were daylong affairs involving long discussions and exchange of ideas. Conference calls were used where clarifications were required e.g. budget sanction or equipment specifications. In 1997 when PIP was initiated internal e-mail was widely used but universal access by employees to the internet was still restricted by many companies. In time e-mail became the backbone of communication for PIP members. However the volume of documents and the file size of some maps and images made an alternative route necessary.

The secretariat specified a website design to act as a business tool (Fig. 1).

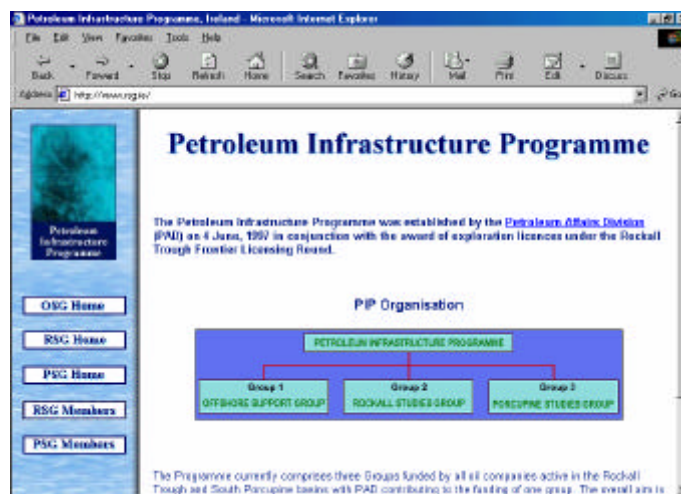


Figure 1. PIP website (created by Solomon Solutions Ltd)

It allows members password access beyond the public page to a secure area where minutes of meetings, project progress reports and financial information can be viewed and downloaded at any time. This meant that members did not need to maintain a separate filing system for key documents and they could view large map files. The RSG website is updated monthly or more frequently if committee meetings have taken place. A secure operations website was rented from Petrolink Services Ltd during the Atlantic Margin Drilling Project. This deep coring project with the MV Bucentaur had the capacity

to devour a large part of the RSG budget with little return on investment if not tightly managed. Each morning daily progress reports and results were posted on the secure website to which all members had access. When operational decisions dictated by weather and downhole conditions were necessary the RSG member mentoring the project could quickly consult other management committee members, already well informed by the website, for their approval. This resulted in significant savings in time and money.

The challenge of managing the data collected by PIP was recognised at an early stage and provision was made in the budget to address the issue. The projects produced a diversity of deliverables i.e. reports, maps, side scan sonar images, deep and shallow seismic data in hard and digital copy, core samples, micropaleo slides, software products and licence access to seismic and other data. This material is stored in different locations and can be accessed by all the members. The solution is the online searchable metadata database inventory known as the PIP Data Inventory (Fig. 2). The database, accessible to all members, gives information on the nature and location of all the deliverables from more than 50 projects funded by PIP. It also provides a comprehensive bibliography on all significant publications and research cruises that relate to the Rockall and Porcupine Basins.

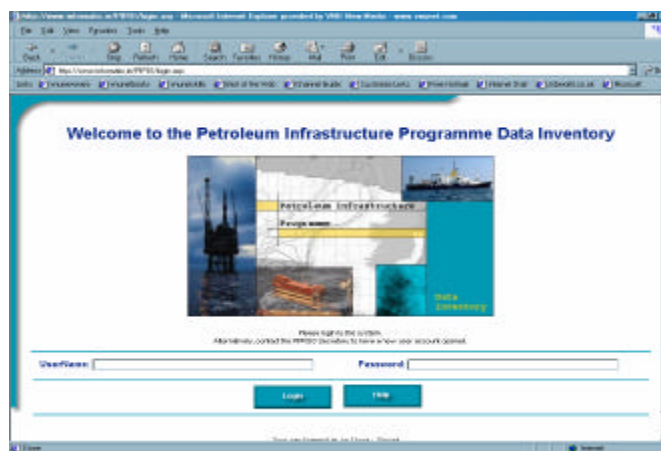


Figure 2. PIP Data Inventory: online searchable meta database (created by Informatic Software Ltd and CSA Computing Services Ltd)

The establishment of this system of communication and data management was a learning process. It is important to allow for communications and databasing in the budget and establish a cost ceiling of about 10% of the overall cost of the projects in the programme. Where possible off the shelf solutions should be found. This was the case with the Petrolink website and to some extent the RSG website. There was no existing database solution on the market in 1998 and consultation with our colleagues in the Faeroes PIP equivalent called GEMS indicated to us that they were no further advanced at the time than we were in solving this issue. It is important to get the specifications right from the beginning. With the need to consult 17 members this is not always easy. In practice, once a prototype was available to manipulate, the definition of requirements by members was easier. The issue of confidentiality and security, with many layers of access required, added to the complexity and cost. During the database construction regular scheduled progress meetings with the software engineers is useful to identify bugs and design faults early on. The entire database development process was time consuming. Much of the RSG database population was performed by the PAD and secretariat, with the researchers then verifying content.

In conclusion the use of the internet for e-mail, website and database provided cost savings in high value projects, allowed windows of opportunity to be successfully exploited, created a ready to use model for other joint research projects e.g. the PSG and provided a legacy for future research.

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme.

Shallow stratigraphy and geohazards in the Rockall Basin

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In October 1999 the RSG Seabed Technical Subcommittee commissioned a study aimed at increasing our understanding of shallow stratigraphy, Neogene tectonic history, geohazards and the links between them. The study used c. 13,000 line km of seismic data, plus geological and geotechnical data accessible to the RSG including results from Shallow Drilling sites situated along the eastern margin of the Rockall Basin. Good progress was made through an integrated interpretation approach in: a) developing a stratigraphic framework across the basin, b) identifying and mapping geohazards of many kinds, and c) understanding controls on seabed condition.

Objectives and Scope:

Objectives were specified as follows:

- To establish a regional late Cenozoic – Holocene stratigraphic framework on an area of c. 300,000 sq km of the Rockall Basin.
- To identify, interpret and map regionally all significant geohazards and integrate with the results of other relevant datasets.
- Recommend additional work, where necessary, and identify specific areas of study to maximize the value of this Study (Austin 2000).

Methodologies:

The work progressed by:

- Analysing recently sampled core and geological results from the four important 1999 RSG Shallow Drilling Sites (BGS 1999) and by integrating with and verifying the regional stratigraphic framework proposed by the BGS (Stoker et al. 2001).
- Addressing the work of the most active research players in the basin. This generally meant academics given the under-explored Frontier nature of the region, i.e. UCD - Praeg & Shannon 2000, DIAS – Readman et al 1999, BGS, NIOZ, and RCMG.
- Assembling geophysical and geological databases and QA/QC on navigation to load digital portions of databases into Interpretation Workstation (LMK) using UTM, ED50, Zone 28N, CM 15 degrees W.
- Building database maps (Petrosys) and key sections to compare with other researchers.
- Commencing interpretation with integration and feedback to other workers whenever feasible, e.g. structural framework used was that of Naylor et al 1999.

Challenges:

The lack of strike geological control in the seismic database became apparent and much reliance had to be made on linking interpreted seabed slope profiles by jump correlation. As the interpretation progressed profiles and maps were generated and ideas and concepts fed back and iterated until a working model was reached.

Given the scale and scope of the study it was hardly surprising that based upon the crucial biostratigraphic dating of one section of borehole core (at the 16/28 location), a further re-iteration of the interpretation was required in the vicinity of the Porcupine Bank slope. This resulted in a slightly more robust and regionally meaningful set of results.

Furthermore the arrival of the TOBI interpretations in map and then digital map form (RSG Project 97/14) greatly enhanced the definition and understanding of many of the geohazards existing in the Rockall Basin. As time ran out excitement increased as several massive pieces of the puzzle slid (quite literally) into place and the power of successful integration of the datasets proved its worth.

Results:

With a study of this scale and proportion there have been several significant results, many aspects that look good but require more work; many questions have been answered and still more questions now need to be answered. Perhaps the recommendations following below also provide one of the major results of the Study.

- The concise, single volume Report, presents the shallow geological succession and unified Cenozoic stratigraphic framework across the Rockall Basin area. It was distributed to RSG members in August 2000. It contains 13 annotated figures and 51 data examples. Regional and area specific maps are presented as 8 time and 22 depth surfaces and isopachs of the major events.
- The developed stratigraphic framework (Figures 1-3) is in agreement with the most recent published by BGS, NIOZ and UCD. It extends these concepts across the complete basin and its margins and identifies those areas where the stratigraphy remains unclear. The Study forms a large, accepted input into STRATAGEM the EC funded Late Cenozoic project running from the Porcupine Basin up to Northern Norway.
- As elsewhere along the NE Atlantic Margin new insights have been made following the truly regional approach to geological interpretation and mapping. These refer to some fundamental aspects of geological history and tectonism such as:-Meso/Cenozoic – Recent stratigraphy, the younger Neogene age of some faulting, relationship of slope canyon and valley systems to basin formation, plus development of carbonate growth around the basin.
- Geohazards such as major landslide features have been identified and mapped. They are observed in true regional geological context that not only aids explanation and prediction but also has helped prepare the way for more in depth detailed site-specific investigation. This must be a crucial step in any advancement towards coherent assessment of stability of seabed slopes in and around the Rockall Basin.

Study Recommendations as part of the overall research strategy:

- Full integration of seismic and TRIM datasets. Out of five recommended study areas, this is currently being done in a part of NE Rockall as a starting point.
- Investigation of slope stratigraphy and mass wasting processes. NE Rockall region has been selected for further study allowing local feedback and synergy with the above.
- Additional carefully selected Shallow Drilling Sites – several sites have been recommended to test newly identified and accessible Tertiary or Mesozoic subcrops.
- More study of canyon incision, infilling and tectono-stratigraphic history. This appears to be a key piece in the progression of our understanding of many issues in the Rockall and Porcupine.
- Continued integration between industry and academic institutions.

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme.

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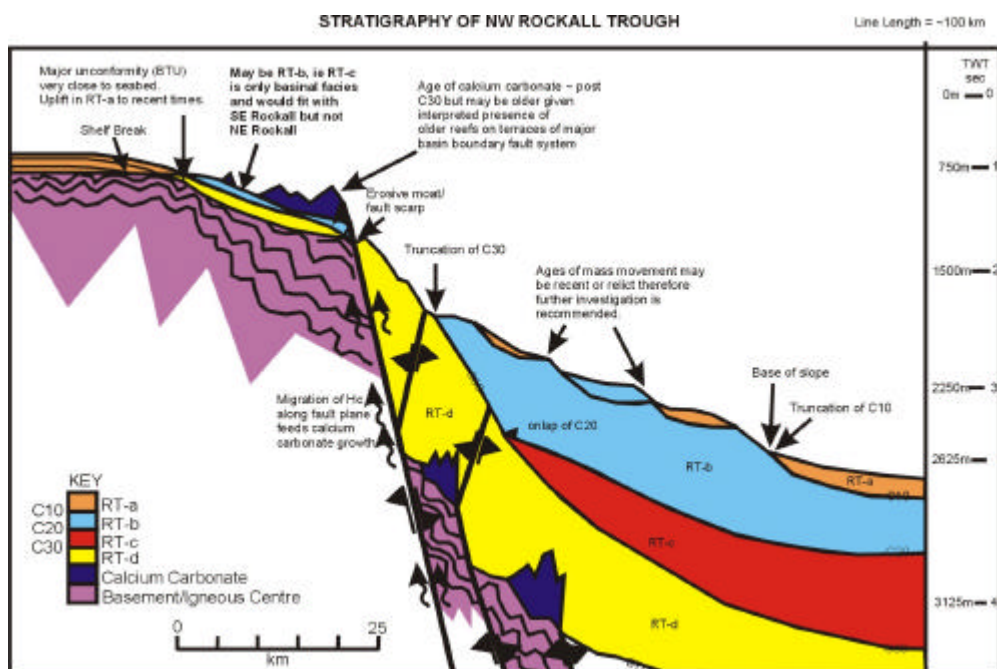


Figure 1. Stratigraphic framework of the NW Rockall Basin

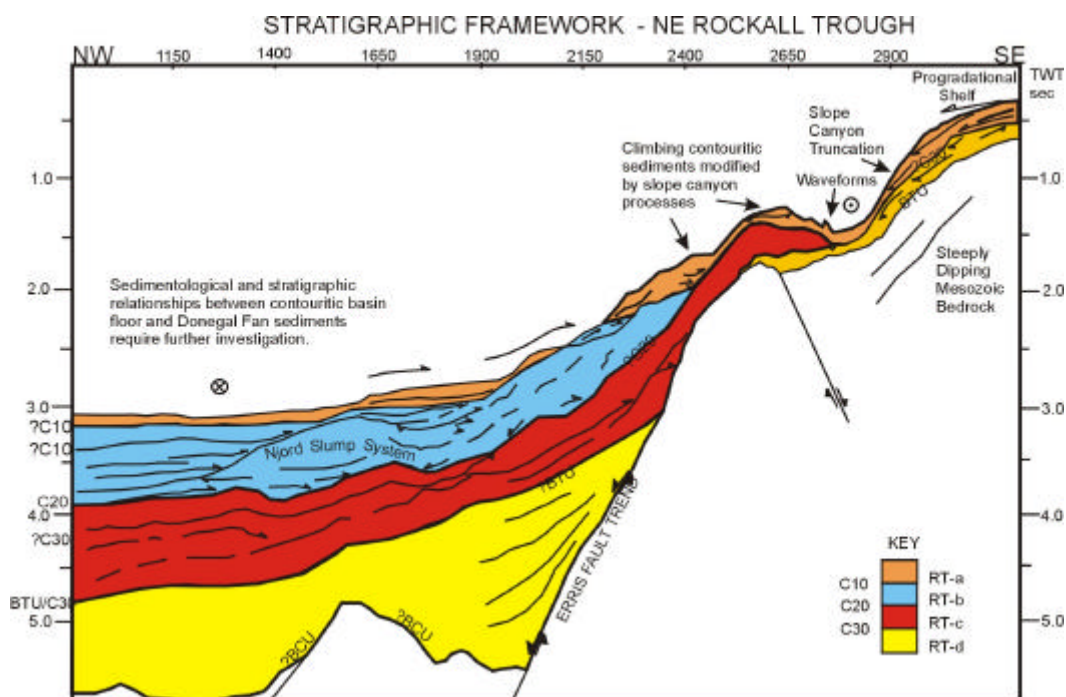


Figure 2. Stratigraphic framework of the NE Rockall Basin

STRATIGRAPHIC FRAMEWORK - SE ROCKALL TROUGH

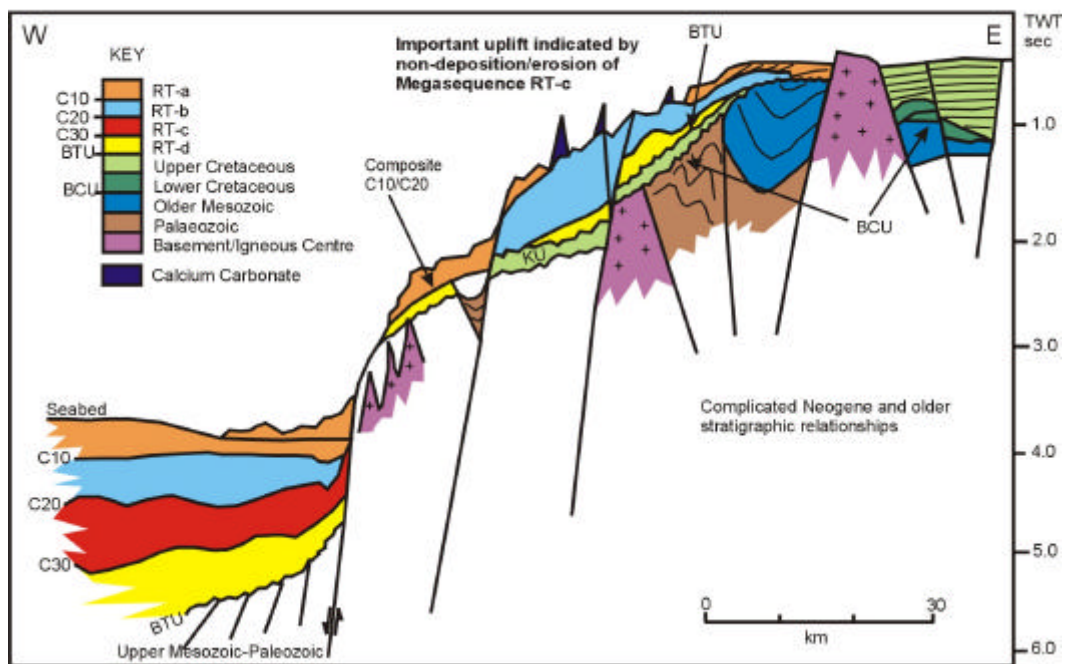


Figure 3. Stratigraphic framework of the SE Rockall Basin

Seabed images from the margins of the Irish Rockall Trough

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The TRIM (TOBI Rockall Irish Margins) survey investigated slope related sedimentological processes along the margins of the Rockall Trough, using the deep towed TOBI (Towed Ocean Bottom Instrument) sidescan instrument (Shannon *et al.* 2001). Due to consistently moderate weather conditions 3100 line km of sidescan sonar data were gathered during the survey (see Fig. 1). This information was supplemented by a further 3600 km of 3.5 kHz profile data, from a hull mounted (ORETECH) echo sounder system aboard the NIOZ research vessel PELAGIA. The TOBI sidescan system is of higher resolution than sea-surface towed sidescan instruments such as GLORIA (a 5 m pixel size as opposed to 50 m). It transmits at a frequency of 32 kHz and samples the acoustic response of the seabed and shallow sedimentary structure at a centimetre to metre scale. This acoustic response therefore reflects not only the backscattering properties of the seabed but also the shallow detailed structure of sediments formed by recent sedimentological processes along the margins of the Trough.

The interpretative methodology involved the detailed correlation of the deep-towed sidescan sonar backscatter with the character of the more deeply penetrating (50 to 100 m) 3.5 kHz profile data. This approach was used to map in detail the morphology of important canyon systems and the geometry of slope failure features associated with these systems, such as large sediment aprons (associated with anelastic flow) and regions of elastic slope failure, defined by slope escarpments.

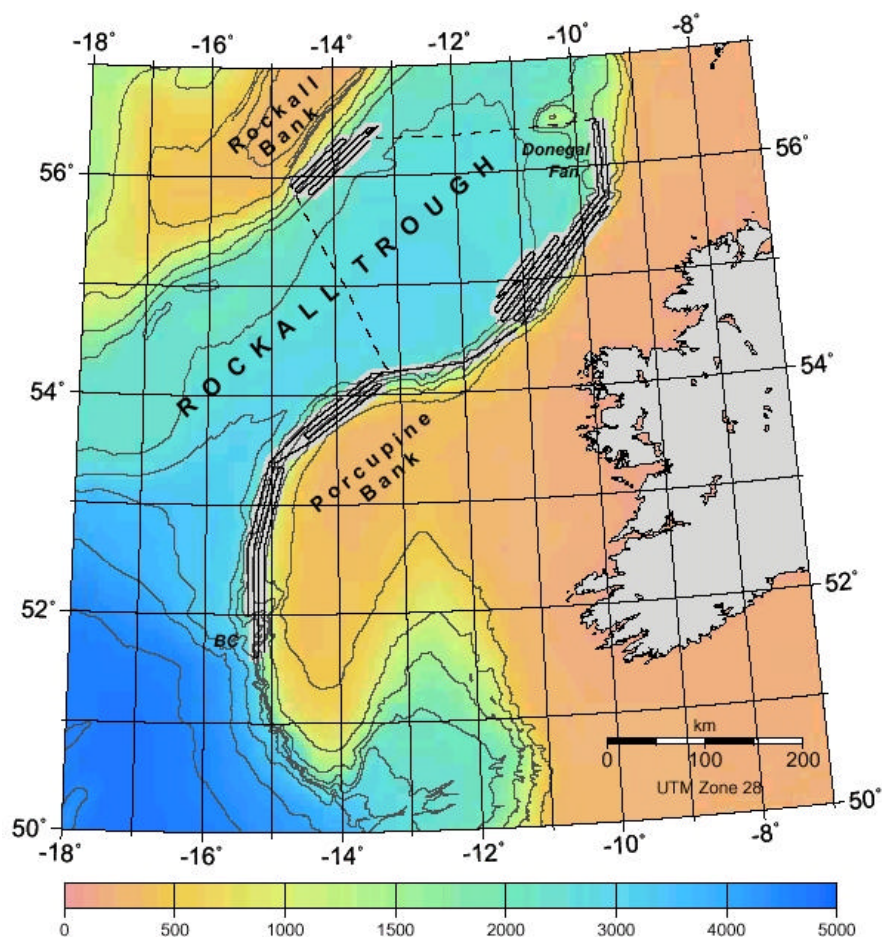


Figure 1 Location map showing the TOBI coverage (black lines and grey shading) over the Irish sector of the Rockall Trough. BC stands for Bróna Canyon. Bathymetry contours (GEBCO97) are at 500 m intervals.

In addition, it was possible to establish a broad chronology for the sequence of recent slope failure and sedimentological events, which led to the sonar imagery patterns observed today. The results of the survey provide an insight into geologically recent (Pleistocene-Holocene) processes along both margins of the Trough, including the influence of slope parallel contour currents in sculpturing the margins morphology. The data are of particular use in guiding the interpretation of the shallow seismic stratigraphy along the margins of the Rockall Trough, as many of the slope failure features encountered in the TRIM sidescan data have a deeper seismic response and signature.

The geomorphology of the slope along the eastern margin of the Rockall Trough reflects a southward reduction in the influence of glacio-marine processes. This reduction in glacial influence is inferred from changes in the style of slope failure (both elastic and anelastic), particularly along the eastern margin which becomes progressively starved of sediments southwards. Several key observations have been made and used to infer variations in processes along the eastern and western margin of the Trough and a tentative broad chronology of events. These are summarised below, sequentially from north to south.

Northwest of Co. Donegal (c. 56° N, along the glaciomarine Donegal Fan) where the bathymetric slope gradients are lowest canyon systems and large slope escarpments produced by elastic failure are absent. Finger-like forms apparent on the sidescan mosaics define complex “flow slides” which shows little or no correlation with the deeper 3.5 kHz echo character. This lack of correlation suggests that sediment flow directions varied erratically with time (Readman *et al.* 2000).

Further south, due west of Co. Donegal (c. 55° N) an intricate series of submarine canyons is present that probably have a strong glaciogenic control on their formation. Slope parallel escarpments produced by elastic failure are more common here (Fig. 2). The canyon complexes are comprised of a cauliform pattern of U-shaped gullies along the upper slope, which connect to singular V-shaped channels along the upper to mid-slope (Fig. 3). They feed a complex series of stacked sedimentary aprons toward the lower part of the slope (where the data covers this region). Distinct isolated acoustically transparent bodies, interpreted as late Pleistocene/Holocene debris flow deposits, cover these. The correlation between the sonar backscatter and the 3.5 kHz echo character in this region is exact. This suggests that the sediment flow and slope failure processes, which formed these patterns, were much more stable than further to the north. The region is an important part of the transition zone where glacial controls become less significant in shaping the morphology of the Trough's eastern margin (Readman *et al.* 2000).

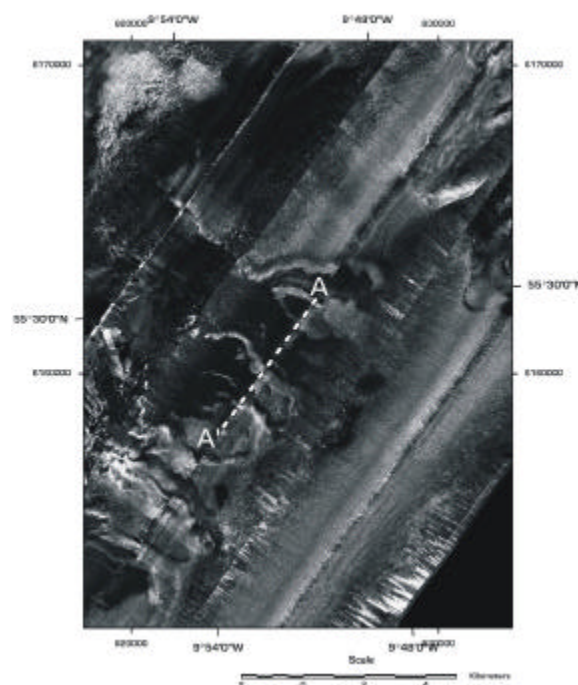


Figure 2 TOBI image of canyon system comprising a U-shaped gully complex feeding a V-shaped channel which is deeply incised into the slope. Profile A-A' is the 3.5 kHz profile shown in Figure 3.

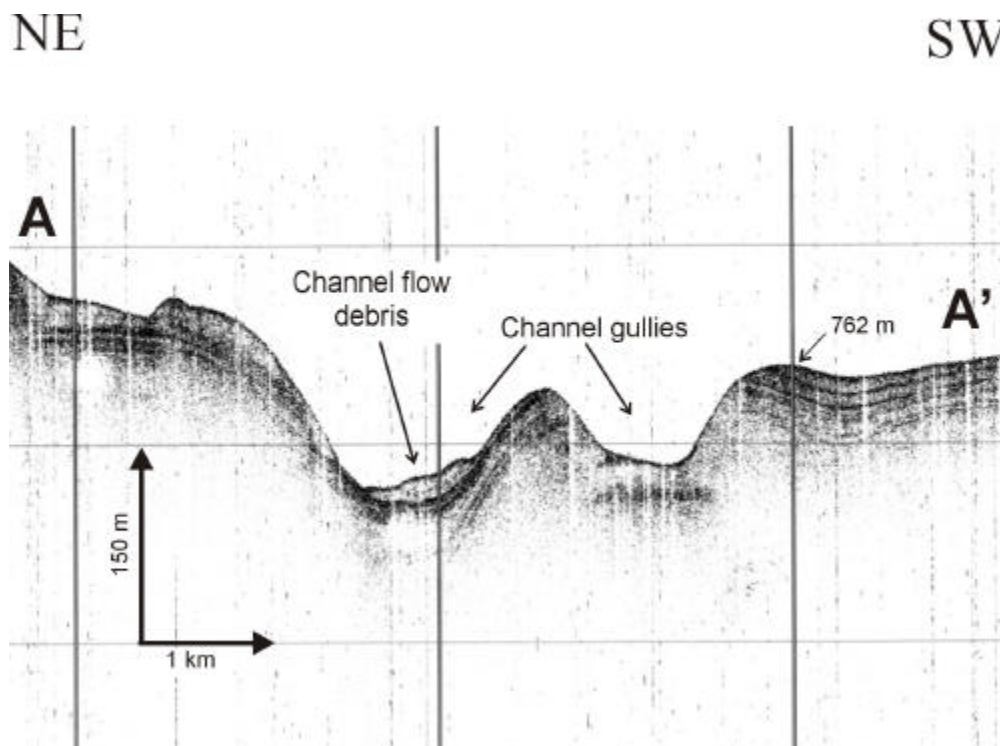


Figure 3 A 3.5 kHz profile showing U-shaped gullies incised into a laminated sub-bottom structure. The boundaries of the individual gullies are defined by cusped slump scarps. Note the incision and truncation of the sub-bottom structure. Figure 2 shows location of the profile on TOBI imagery.

In the south, along the shoulder of the western Porcupine Bank (c. 54° N) the canyon systems are morphologically less complicated. The cauliflower systems of U-shaped gullies along the upper slope region are no longer present. Instead, deeply incised V-shaped channels are present which converge or join together toward the lower slope, defining V-shaped patterns of mapped backscatter on the TOBI imagery. These deeply incised channels either become buried and/or their axes change to slope parallel orientations toward the upper slope. The change in the direction of channel axes produces a “dog-leg” planform shape and may be controlled by geologically old basin margin faults. Depositional lobes of sediment are fed from these “dog-leg channels” and they are associated with regions of high acoustic backscatter across the mid to lower slope.

These high backscattering regions are suggestive of multiple slope failure events that expose consolidated sediments of possible pre-Neogene or older age. They sometimes form a suitable substrate for carbonate mounds, indicating that the events are older than the mound structures and are overlapped by a classical turbidite sequence, which extends westward across the basin floor. The eastern margin is most starved of sediment in the south where a large canyon system (herein named the Bróna Canyon, and labelled BC in Fig. 1) is deeply engraved into bedrock. Recent (late Pleistocene/Holocene) sediment input into this canyon system is very small. A low sinuosity channel on the seabed is defined by subtle tonal variations in backscatter with no evidence of significant seafloor incision and was probably produced by low-density turbidity currents, flowing into the Bróna Canyon.

Canyons are absent along the margins of the Rockall Bank. Slope failure escarpments were produced by piecemeal detachment of mud-prone sediment rafts from the headwalls of several regions of detachment along the slope (Fig. 4). Translational motion of coherent blocks of sediment rather than rotational failure was the main failure mechanism. This style of elastic failure, with similar backscattering attributes, is also prominent along the eastern margin of the Rockall Trough, but particularly along the Porcupine Bank. The lack of evidence for any current-modification of the escarpments, despite the presence of strong bottom currents on both margins of the Trough, suggests that many of these structures are historically recent.

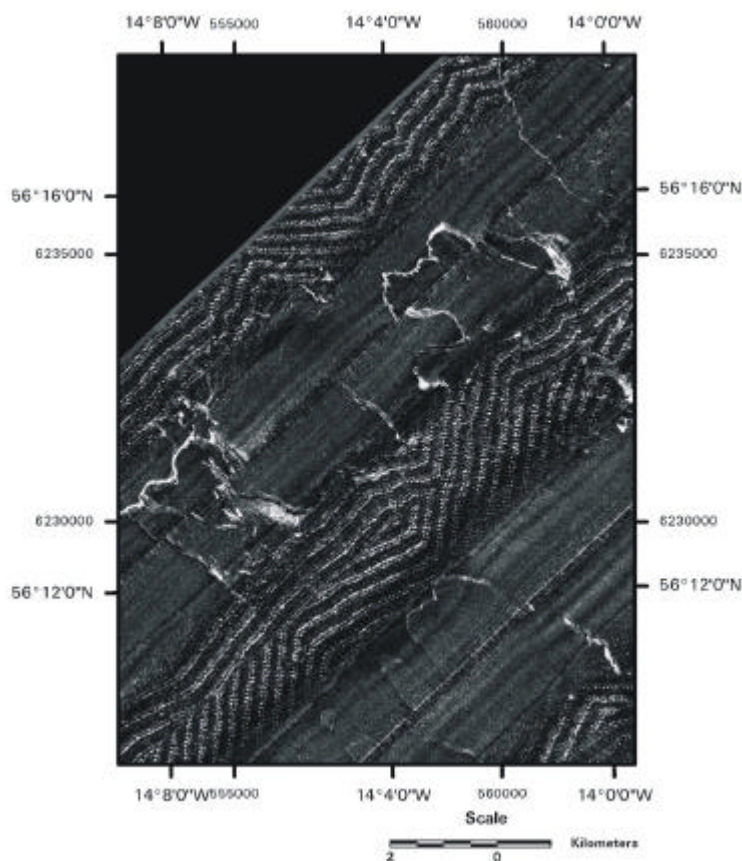


Figure 4 TOBI imagery showing a tabular slab failure scarp on the eastern side of the Rockall Bank. The suture pattern of very bright backscatter defines the headwall region of the escarpment.

Evidence for a strong counter clockwise current circulation pattern is present especially along the upper and lower slope of the Trough. On the eastern margin a carbonate mound population disturbs a strong poleward flowing contour current. The pattern of sedimentary bedforms, defined by sonar backscatter variations, suggests current velocities of the order of 1 ms^{-1} (O'Reilly *et al.* 2000). Longitudinal bedforms and current lineations define a similar current regime elsewhere along the upper and middle slope of the Trough margins.

The entire TRIM dataset provides an example of how shallow sedimentary facies architecture and slope morphology evolve together in a deep-water basin which straddles the broad transition region from a glaciated to a non-glaciated margin. In the north, glacial influences were overwhelming across the Donegal Fan. West of Co. Donegal, where the regional margin slope is steeper, the cauliform gully systems are likely to have been produced by gravitational collapse of stacked glaciomarine debris, periodically shed by advancing and retreating glaciers. The input of glacial sediment was probably pulsed and forced by palaeoclimatic variations in the North Atlantic during the Pleistocene epoch.

The very different morphology of the canyons systems along the Porcupine Bank margin may mark an important change in the processes, which formed them. Their component channels are deeply incised into consolidated sediments or rock along the lower part of the slope, and they commonly have “dog-leg” geometries with their axes swinging from SE toward E, as they become buried upslope. This may suggest a possible tectonic control from basin margin faults and a Cenozoic or older age for their inception. They may perhaps represent geologically ancient canyon systems, which were active during a period of basin margin uplift and later were drowned by rapid Tertiary basin subsidence. Subsequently they acted as a transport pathway for late Tertiary and Quaternary glaciomarine sediments, for those borne by rivers, and for sediments remobilised by strong Holocene contour currents.

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme.

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History of a Slippery Slope: Neogene to Quaternary Sedimentary Processes on the Eastern Rockall Margin

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The Rockall Trough has steep margins (2-15°) and the importance of sediment transfer across them is apparent from seabed imagery (GLORIA, TOBI) showing widespread slide scars, as well as canyons along the eastern margin (Unnithan et al., 2001; Shannon et al., 2001). Here we present evidence that many of the seabed features are of Plio-Pleistocene age, but that mass failure has interacted with current deposition since the Miocene. The study draws on several datasets collected for RSG along the eastern margin, in water depths of about 1000-2000 m: seabed features seen on TOBI imagery (O'Reilly et al. 1999) are integrated with a Cenozoic stratigraphy established from shallow seismic-borehole correlations at several sites (Fig. 1), each about 30 km² (Praeg & Shannon 2000; Haughton & Amy 2000).

The seismic-borehole stratigraphy shows that Plio-Pleistocene deposits of variable character, a few 10s of metres thick, overlie a regional unconformity (C10 reflection - Stoker 1999), beneath which Miocene marine deposits 100s of metres thick are preserved in two locations (83/20 and 11/20; Fig. 1). At survey area 83/20, a buried canyon is recognised within the Miocene unit. At survey area 11/20 (Figs 2, 3), multiple unconformities within the (inferred) Miocene unit are interpreted as buried slide scars, recording repeated interruption of marine deposition by failure down adjacent steep slopes (currently 10-15°). The most recent failure in the area has resulted in a seabed scarp in places over 100 m high (Fig. 2), which extends higher up the margin than any subsurface feature. At survey area 83/24, upslope-thickening Plio-Pleistocene deposits contain a smaller slide scar with seabed expression (Figs 4, 5) that remains unresolved by TOBI imagery. Gravity cores across the feature indicate a mantle of marine deposits and, along with cores from other sites, are currently being analysed to determine the age of the 'seabed' scars.

TOBI imagery shows slide scars to be ubiquitous along the margin north of survey area 83/20 (Fig. 1) and seismic data show that failure has resulted in truncation of Palaeogene strata at or near seabed over wide areas (e.g. survey areas 16/28 and 75/10). The seismic-borehole stratigraphy shows that the observed dissection of the margin dates back to the Miocene and that the area affected by failure may have expanded since the ?Mio/Pliocene episode of uplift and erosion (C10 reflection). Such an expansion could be a response to a number of factors, including a steepening of slopes during the Neogene or the increasing amplitude of glacial/interglacial climate cycles in the last million years. Future work will include examination of sedimentary geometries over wider areas using both bathymetric and industry seismic data, and could usefully include correlation to stratigraphic units on the floor of the Rockall Basin.

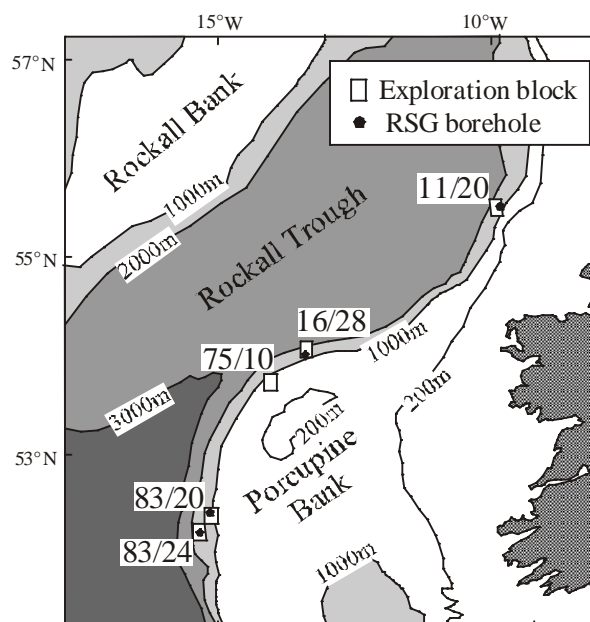


Figure 1 – Location of shallow seismic survey areas.
Block 11/20 includes two adjacent surveys.

Acknowledgement

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme.

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Figure 2 -Survey area 11/20 seismic line locations, derived bathymetric contours and seabed features. A slide scarp, in places >100 m in height, truncates Neogene strata across the area (see Fig. 3). Modified from Praeg & Shannon (2000).

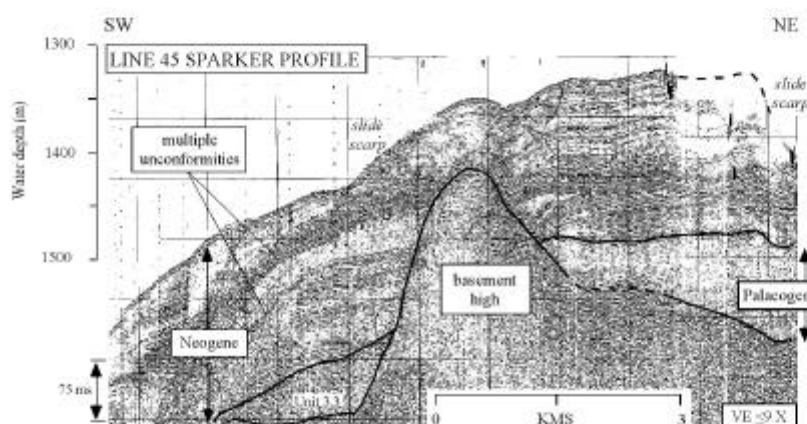
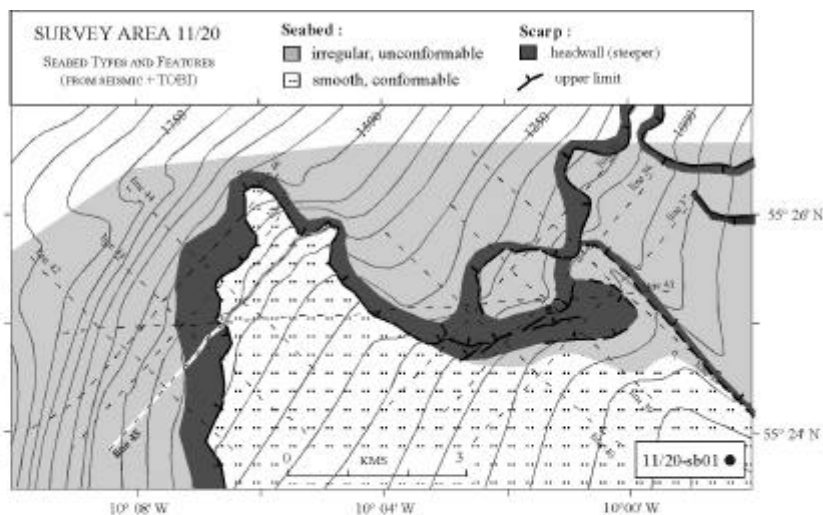


Figure 3 -Sparker profile across the seabed slide scarp shown in Fig. 2, with multiple high-angle unconformities interpreted as buried slide scars. Modified from Praeg & Shannon (2000).

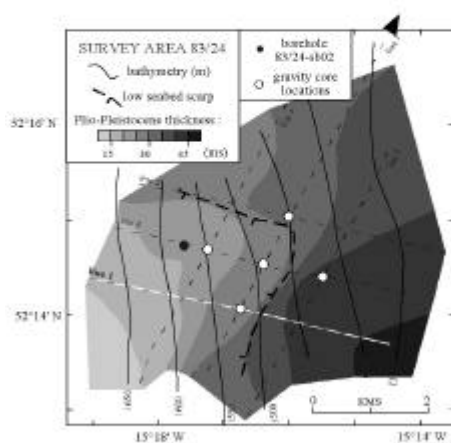


Figure 4 -Survey area 83/24 seismic line locations and derived bathymetry, with thickness of Plio-Pleistocene unit superimposed. Modified from Praeg & Shannon, 2000.

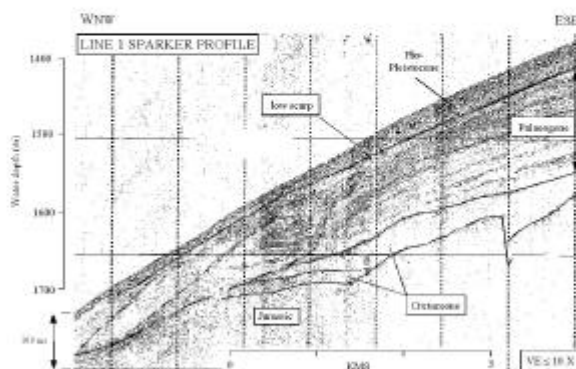


Figure 5 -Sparker profile showing abrupt downslope thinning across a low scarp, the arcuate plan-form of which (Fig. 4) is indicative of a slide scar. Modified from Praeg & Shannon, 2000.

Sedimentological analysis of gravity cores from the Rockall Trough

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Shallow gravity coring during 1998 on the slopes flanking the Rockall Trough has provided a suite of 45 gravity cores. Most of the gravity cores are clustered in areas targeted for deeper drilling, but there were also isolated cores acquired on seabed features identified on the basis of regional sonar work. These cores are being studied in order to achieve a better understanding of the history of slope instability and the importance of bottom current processes on the flanks of the Rockall Trough. A particular strength of the dataset is the closely spaced clusters of gravity cores which are tied and linked by shallow seismic profiles and sea bed TOBI imagery. This allows the lateral variability and structure of the deposits to be assessed at a km length scale on different parts of the slope.

All the cores at Sites 1 and 1A (blocks 83/24 and 83/20 respectively) on the flank of the Porcupine Bank (Figure 1) show good internal detail in terms of compositional and textural variations, and physical and biogenic structures. The cores show alternations of carbonate mud and unsorted quartz and foraminiferal sand occasionally with scattered pebbles. Carbonate profiles have been created for two of the cores, showing a varying carbonate content down core. There are clear parallels between a number of the units at Sites 1 and 1A, suggesting a coherent stratigraphy over large parts of the slope along this part of the trough margin. The two sites differ at shallow levels when the 1A Site became the location of pervasive glass sponge deposits. The depositional history of the area can be mostly explained by Quaternary climatic changes and changing sediment supply, with high carbonate production during warm periods and low carbonate production during cold periods.

For Site 2 (Block 16/28; Figure 1) on the east flank of the Rockall Trough a number of the coring attempts failed due to hard sea floor and recent slope failure. Only two short cores were recovered. Both the recovered cores are very sandy (foraminiferal sand) with only a small number of clay units.

Sites 3 and 3A (Block 11/20) are located on the rugose and failed NE Rockall Trough slopes (Figure 1). The stratigraphy is less complex compared to 1 and 1A with only one or two units identified in each of the cores. The lower unit is a grey, well compacted clay. X-rays of selected cores show that the clay is laminated. The upper unit is a lithic, foraminiferal sand. This unit varies in thickness between cores and in some cores it is absent. Although the data are still to be analysed in detail, it appears that the sea bed lithology varies according to the local sea bed bathymetry, with sandier sediment preserved within depressions.

A number of gravity cores have also been recovered from the eastern flank of the Rockall Bank, Site 4 (block 78/28; Figure 1). One of the cores at this site contains corals in a sandy matrix. This core is interpreted to represent a coral mound which is visible on seismic profiles. The other cores are located off the carbonate mound where mainly pelagic deposition of foraminiferal sand occurred, but with some local variations between the cores.

Five of the cores had a major debris flow complex on the northwest flank of the trough as the target: Sites 4.4, 4.5, 4.7 and 4.8 (Figure 1). The sediments in all the cores are mainly well compacted clay, but in the downslope cores in Sites 4.7 and 4.8 a well sorted, cross-laminated and rippled sand unit with a sharp erosive base is identified. This unit is interpreted as a turbidite sand derived from slope failure events further up slope.

The detailed stratigraphic archive revealed by the cores show that a variety of depositional processes work along the flanks of the Rockall Trough. To fully understand these processes and the bottom conditions in the Rockall Trough, more work is required. The cores and the sediments need to be studied in more detail (point counting of the siliciclastic and bioclastic grains, additional carbonate profiles, oxygen isotope analyses, XRD of the clay minerals, etc.). Dating is required to achieve an absolute chronology of the mass movement events and changing sediment supply. The cores need to be fully integrated with the seismic lines and the TOBI images available for the area. It would also be useful to tie the core records to longer piston cores in the area to see how the stratigraphy and the processes recognised might extend to greater depth.

Acknowledgements

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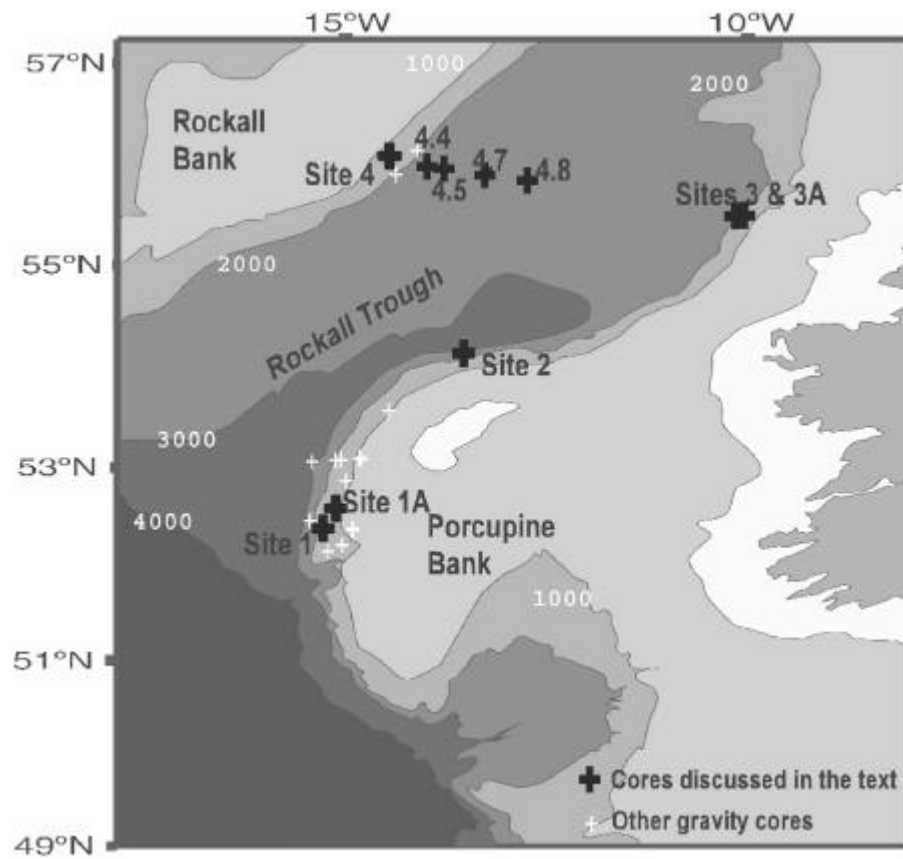


Figure 1. Map showing the location of the Challenger gravity coring sites along the flanks of the Rockall Trough. Bathymetric depths are in metres.

Poster Presentations

(by order of programme)

Imaging below highly heterogeneous layers

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Introduction

Highly heterogeneous materials such as basalt make it difficult to seismically image the underlying sedimentary sequences. This is a problem in petroleum exploration as many structures of interest lie beneath lava flows. Conventional techniques have failed to improve sub-basalt imagery. In this work we apply unconventional seismic processing techniques on synthetic and real seismic data.

Use of Converted waves

P-to-S converted waves show good penetration of high velocity layers. One solution to the sub-basalt imaging problem is to try to exploit those waves during the processing in an effort to improve imagery.

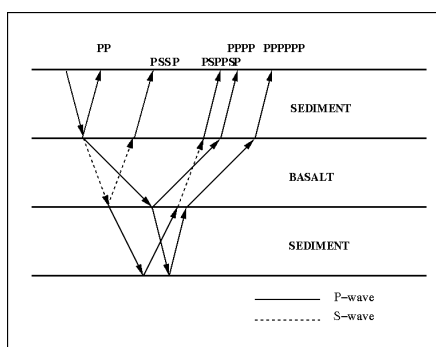


Figure 1. Ray tracing to track wave conversion.

In our modelling we consider wavetrains containing S wave segments within the basalt only (Fig. 1). Analysis of the data has shown that S waves have larger amplitudes than P waves for long offsets, having also the potential benefit of arriving at larger offsets such that they would be free of multiple contamination.

Far-offset arrivals

A 2-D conventional streamer seismic line over basalt was reprocessed using the information obtained from far offset arrivals (Fig. 2). These arrivals are not affected by multiple reflections.

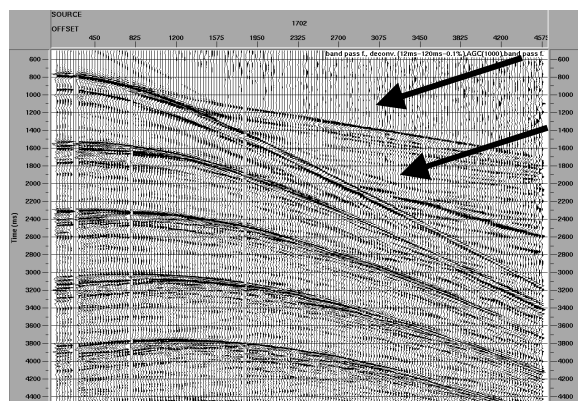


Figure 2. Raw shot gather. During the processing we preserved the long offset arrivals highlighted by arrows.

During conventional processing, these arrivals are usually cut with a top mute that follows the sea bottom. As result of stacking the far-offset arrivals, a reflector has been identified as the bottom of the basalt. This event cannot be identified in a previous conventionally processed section. However, the

data were still of poor quality and the identification of converted waves was almost impossible. Why is the data quality so poor when good conversions are expected?

Body wave scattering

One fundamental problem is the body wave scattering coming from the intrinsically heterogeneous nature of basalt. The scattered wavefield in a highly heterogeneous layer influences the image quality and the reliability of the structural interpretation below the scattering layer. A very detailed knowledge of the velocity field and pre-stack migration could correct this effect. However in highly heterogeneous materials such as basalt, sufficient resolution on the velocity field may be difficult to achieve. In addition there remains contamination, caused by multiple scattering, which cannot be corrected completely because of the single scattering assumption inherent to all the migration techniques.

Interface scattering

Scattering from rough interfaces such as top basalt also severely affects deeper image quality. A pre-stack wave equation datuming technique has been tested, on synthetic data, to remove the effects of interface scattering from a rough top basalt surface. Wave equation datuming is the name given to upward or downward continuation of seismic time data when the purpose is to redefine the reference surface on which the sources and the receivers appear to be located. The "normal" application for this technique is to remove near surface velocity variations or topography effects that adversely affect the continuity and time structure of subsurface reflectors. Here we apply the wave equation datuming to resolve problems in imaging below layers with irregular interfaces, even if the interface lies at depth. An example of the application of this technique on synthetic data is shown in Figure 3. Comparing Figure 3(a) and (b) we see a marked improvement in our imaging of bottom basalt.

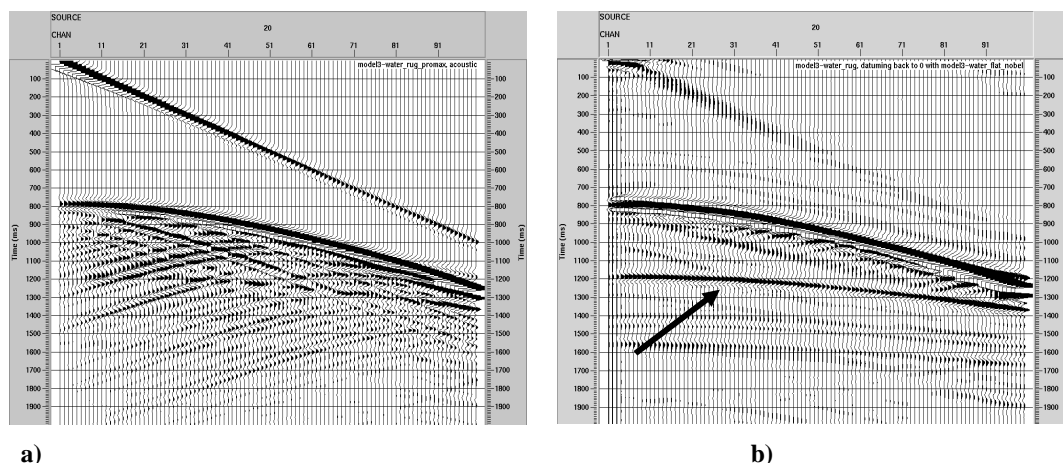


Figure 3. Synthetic shot gather (a) before and (b) after the pre-stack wave equation datuming. Bottom basalt is arrowed.

The technique has been also successfully tested on real field data from the Northeast Atlantic margin, in an area where there is a thin basalt layer that changes abruptly from smooth to rugose, with very evident effects on the sub-basalt image quality. Where the basalt is smooth, clear reflections are visible below the basalt layer; where the layer has irregular topography, a large amount of scattering is generated and this completely contaminates any sub-basalt arrival. For this reason, this represents the perfect dataset to test the technique, giving a form of control on the results, that is, reflections should be correlatable across the entire section. The results confirm the reliability of the technique. A few reflectors appeared in the final re-datumed stack section, and they can be quite confidently related to other arrivals as they show good continuity throughout the section.

Acknowledgements

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Statistical characterisation of reflectivity patterns in deep seismic profiles - application to Southern Rockall Basin

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The deeper parts of vertical incidence seismic sections are difficult to interpret, as they do not display simple reflectivity patterns. In order to extract as much information as possible from these profiles, algorithms have been developed for the statistical characterisation of these reflectivity patterns, which will allow regions such as basement and igneous complexes to be statistically compared and distinguished. The algorithms used are VECSTAT, which extracts reflector length, vector mean, and variance data, and ITOGRAM, which measures reflector spacing, with and orientation along time or depth slices. These algorithms use data in a simple rastified format that can be derived from any media. These methods are being applied to seismic profiles in the Rockall Basin region using both, the BIRPS WIRELINE and WESTLINE deep seismic data sets, and a network of commercial lines (Fig. 1). The commercial lines, mainly shot as exploratory surveys in the 1970s and all available in the public domain, show varying degrees of penetration of the basement. Most of the data is on the basin itself, mainly in the Northern Irish sector. Data for the western margin is limited to four lines, which traverse the entire basin.

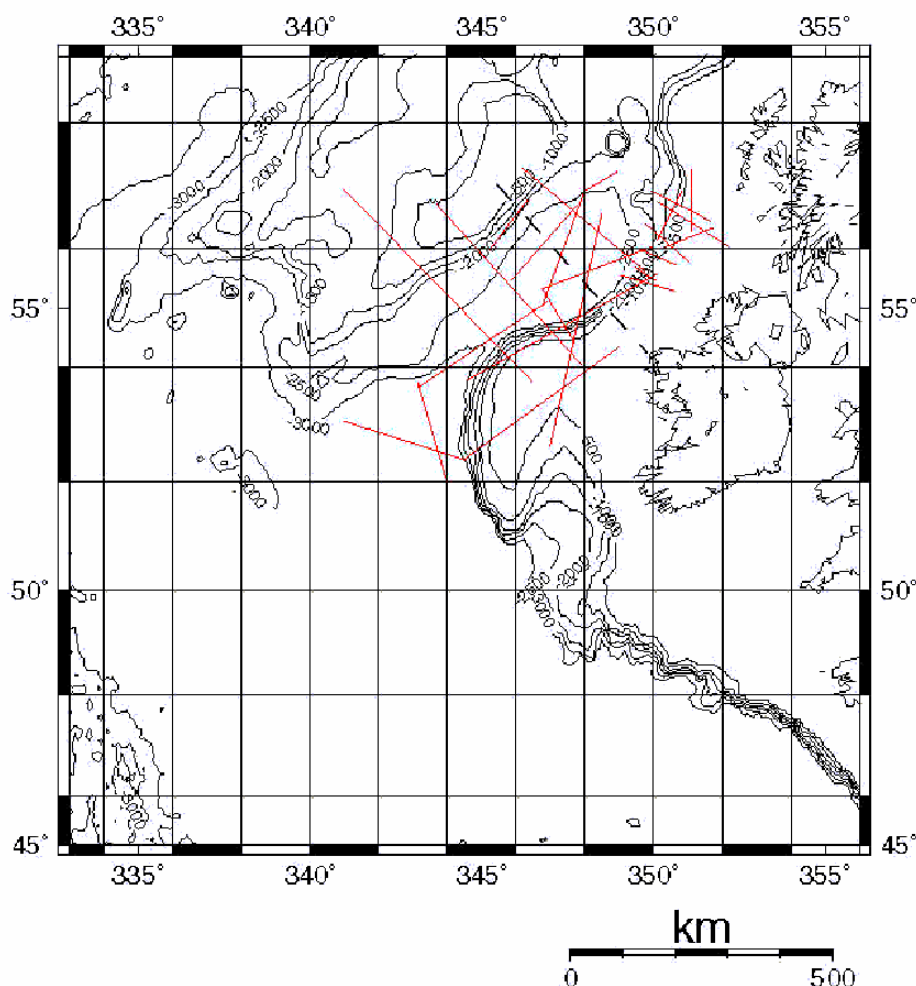


Figure 1. Overview of the density of lines currently been used in the project.
WESTLINE in dashed black

The reflectivity patterns of these lines are characterised in terms of mean orientation, spacing, length, and circular variance in order to statistically distinguish various geological basement types. The unstretched basement to the east and west of the basin, the fault margins, and the thinned rifted basin floor, all exhibit different statistical characteristics. Figure 2 shows the vector mean plot for a section of unstretched basement taken from the eastern end of the WESTLINE deep seismic profile (see Fig. 1). The random scatter of the vector orientations is due to the massive undifferentiated nature of this seismically transparent basement geology type. This can be contrasted with Figure 3, a vector mean plot from a section of WESTLINE in the centre of the basin. The thinned rifted crust (140-260 grid depth) shows subhorizontal (green) vectors as reflectors of this orientation have developed in the basement. Even outside the areas of the main reflectors the range of vector orientations has been focused from ± 45 from the horizontal in the unstretched crust to ± 20 in the stretched crust.

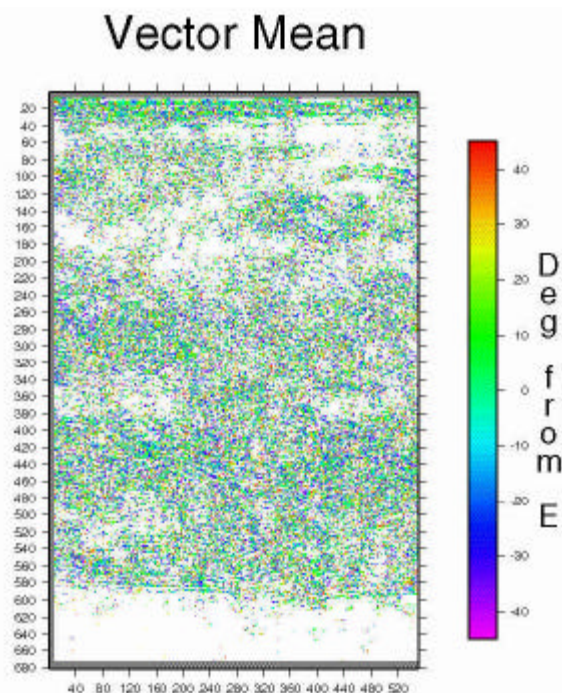


Figure 2 The vector mean plot for unstretched basement. Compare the random vector orientation resulting from the reflectorless transparent basement with Figure 3.

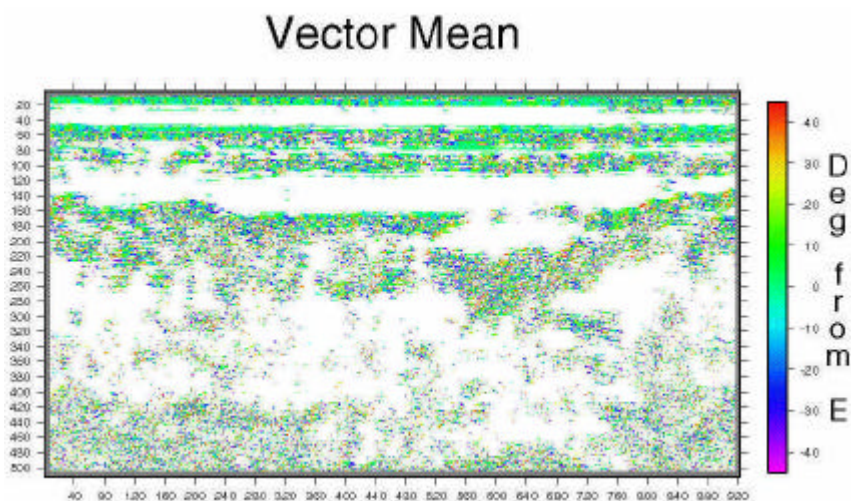


Figure 3 The vector mean plot for stretched basement. Compare the subhorizontal (green) vectors of the sedimentary layers (top) and the stretched basement (140-260 grid dept) with Figure 2.

Further statistical variation can be seen in subgroups such as igneous complexes. The network of analysed lines are then connected, fence diagram style and used to map the spatial extent of the various basement geology types and hence build up a basement geology map.

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme.

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Flexural rigidity and crustal structure across the Irish Atlantic Margin using satellite gravity and bathymetry data

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Variations in extensional strain can result in variations in the spacing of individual rift basins, the size and shape of rift basins and the length of their bounding faults. The particular rifting style is sensitive to lithospheric rheology which can be characterized by yield stress envelopes. Recent studies have shown that estimates of lithospheric yield stress envelopes may be used to infer a theoretical effective elastic thickness T_e (flexural rigidity) of the lithosphere. The spatial variability of T_e within a single province is therefore a good indicator of the spatial variability of lithosphere rheology, though it must be combined with other information (e.g. crustal thickness and composition, heat flow) before it can be used to make inferences upon the styles of rifting.

Effective elastic thickness estimates of lithosphere can be obtained from the statistical coherence in the wavenumber domain between gravity and bathymetry/topography, Forsyth(1985). Traditionally this has been done using Fourier transforms which because of their sinusoidal base functions have very poor spatial resolution. This is the reason why we cannot make T_e estimates at each grid point and must instead make do with effectively an average value across some region. A new mathematical technique called multi-resolution analysis employs wavelets to improve spatial resolution has been developed over the last decade or so, Grossmann and Morlet (1984). The use of wavelets allow the analysis of the local properties of a signal and therefore proves quite useful in coherence technique to obtain increased resolution in the space domain, Stark et al.(2001).

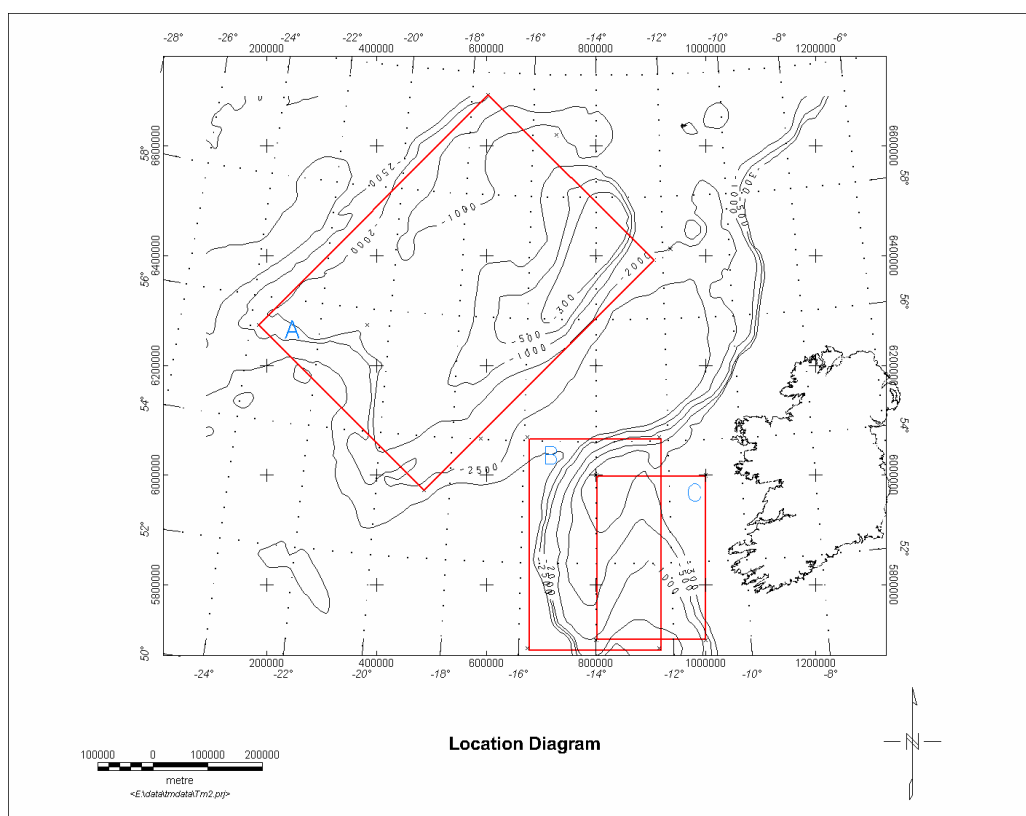


Figure 1. Area of study.

The primary study area for this project has centred on the Irish Atlantic margin containing the Rockall and Porcupine regions (Fig. 1). Grids at 5km intervals of Bouguer gravity and bathymetry were prepared from the Sandwell and Smith 2 minute (public domain) satellite dataset since the RSG datasets did not cover a large enough area for the analysis. Results were obtained with both the standard Fourier transform methods using Multitaper (MT) spectral analysis and the wavelets. The MT method gave T_e values of 13 km on the Rockall Bank (Fig. 1, box A) and 5 to 6 km on the Porcupine basin and bank (Fig. 1, boxes B, C).

The actual coherence results from the 3 areas along with their associated error curves is shown in Figure 2. The wavelet technique was used to obtain a T_e map over the entire area.

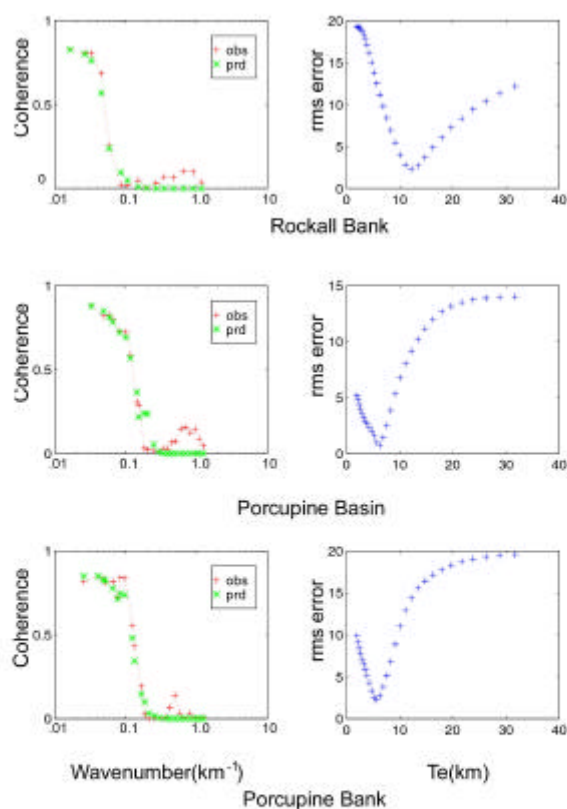


Figure 2. Coherence results from the 3 areas along with their associated error curves.

The Variation in apparent T_e across the study area is illustrated in Figure 3. This assumes that the load ratio f (i.e. the ratio of initial subsurface to surface loads) is one. This is a provisional result and work is currently underway to investigate the T_e variation when the load ratio is allowed to vary. The apparent T_e map shows two robust features. A T_e minimum on the eastern margin of the Rockall Trough and a T_e maximum along the Hatton margin. Final f and T_e maps will be presented at the PIP conference.

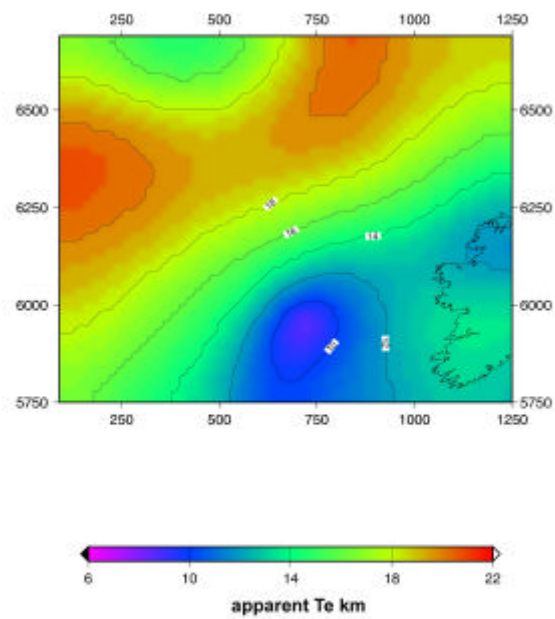


Figure 3. Variation in T_e across the study area.

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme.

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The crystalline basement of the Rockall Basin and its influence on petroleum basin evolution

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Crystalline basement samples from both flanks of the Rockall Basin are being examined petrographically, geochemically and isotopically to determine crustal boundaries which cannot be determined by other methods (e.g. seismic, potential field etc.). These boundaries may have been reactivated during basin development and hence can influence petroleum basin siting and development.

Major and trace element analyses have been obtained by XRF from four new samples from the Rockall High and eight new samples from the Stanton Banks (Fig. 1). Whole-rock Sm-Nd isotopic analyses have been obtained for all samples while seven samples have been analysed for whole rock Rb-Sr.

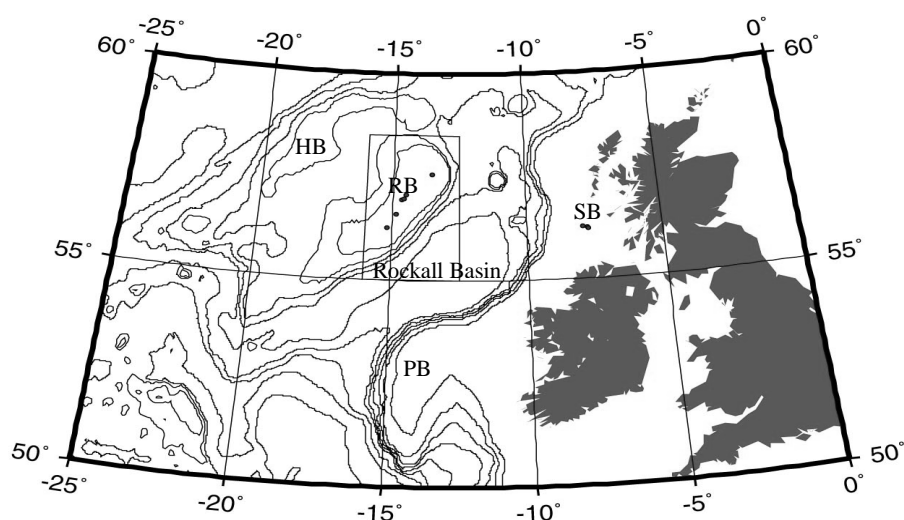


Fig 1. Bathymetry (500m intervals) of the Rockall Bank (RB) and the Rockall Basin. Locations of samples from the Rockall Bank are marked, as is the Stanton Banks (SB) region. Hatton Bank (HB) and the Porcupine Bank (PB) are also shown.

These data from the Rockall High along with published data (Morton & Taylor 1991; Daly *et al.* 1995; Scanlon *et al.* 2000) show that there is a continuous crustal block through the northern and central area of the Bank, which seems to have experienced a similar metamorphic history. A crustal break may be present in the south of the Rockall High as suggested by Miller *et al.* (1973), but the lack of new samples from this area limits further investigation.

Data from the Stanton Banks region show that this region is a previously unrecognised Proterozoic terrane to the north of the Great Glen Fault. Sm-Nd isotopic analyses show that the region does not directly correlate with known basement types to the south of the Great Glen Fault but that some similarities do exist. Dating of the metamorphic and igneous events is underway and will try to correlate events with these other basement regions, in order to produce a revised basement map of the continental shelf region.

These data, along with previous maps (Roberts 1975; Fyfe *et al.* 1993), have been used to construct revised geological maps of both these areas, and a preliminary pre-Atlantic opening basement map has been constructed (Fig. 2).

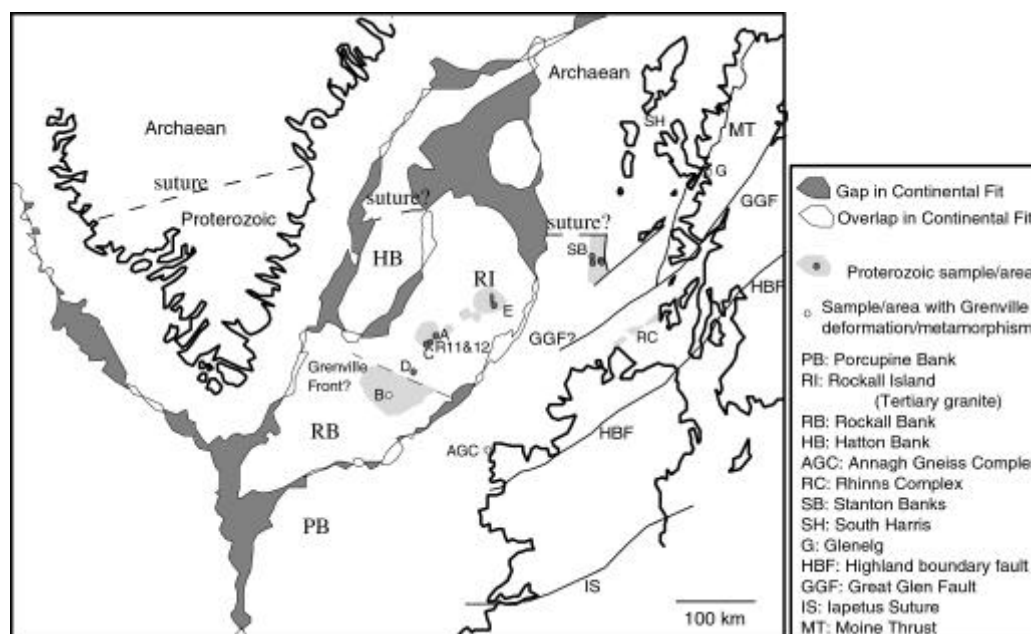


Fig. 2. Schematic reconstruction of the North Atlantic region (after Dickin 1992) showing locations and extent of outcropping Proterozoic basement regions. Dashed line labelled suture indicates known and postulated position of suture between Proterozoic crust to the south and Archaean crust to the north

Rb-Sr mineral dating of all available basement samples from both sides of the Rockall Basin is proceeding and will be combined with *in-situ* laser probe Ar-Ar dating of polished rock slices and small batch bulk-mineral (biotite and hornblende) Ar-Ar dating. This will provide a powerful method of determining crustal boundaries in the Rockall Basin region. Apatite fission-track data is being obtained and it is hoped that these will show whether crustal blocks delineated by isotopic methods have been reactivated and will also provide information on the low temperature thermal history and Phanerozoic denudation of the Rockall High and continental shelf.

Future work will include high pressure-temperature petrophysical measurements (e.g. sonic velocities etc.) of some of the crystalline basement samples, and it is hoped that these data will be integrated with regional potential field and seismic data to help constrain geophysical models.

Acknowledgements

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The application of Fluid Inclusion studies to oil and gas exploration

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Fluid inclusions occur in natural crystals and can be simply considered as sealed microscopic (usually < 50 microns in longest dimension) vacuum flasks that contain a sample of fluid trapped during (or after) formation of the host crystal. Solid, liquid and vapour phases are commonly observed in fluid inclusions under the petrological microscope. Fluid inclusion studies can provide geological information of fundamental importance to the petroleum exploration industry.

When specially prepared translucent wafers (0.2 to 0.5 mm thick) of a mineral or rock sample are mounted on the stage of a transmitted light microscope, the internal details of fluid inclusions are resolvable using high powered objective lenses (x40 to x100). Thus microscopic examination can be carried out routinely and is a necessary first step in all fluid inclusion studies. A first approximation of the chemistry of fluid inclusions is then obtained by microthermometry. This is a non destructive analytical method which depends upon the accurate interpretation of phase changes which occur with varying temperature. The method involves the use of a special heating/freezing stage, capable of achieving temperatures ranging from -190° to +600° C, mounted on a transmitted light microscope. The temperature at which phase changes occur in the inclusion, upon controlled freezing and subsequent heating of the wafer, are recorded. This information is then used to model fluid compositions by applying the microthermometric data to experimentally determined phase diagrams. In this way chemical and physical characteristics of the trapped fluid can be ascertained e.g. gaseous species present (e.g. CO₂ and CH₄), fluid salinity and the minimum pressure and temperature of fluid entrapment. This method is primarily used for estimating compositions of aqueous fluid inclusions.

Hydrocarbon-bearing fluid inclusions are commonly detected by their fluorescence under ultra-violet light (see Figure 1). They are a very valuable indication of migrating hydrocarbons, and in frontier basins can be the first direct evidence for an active hydrocarbon system. The distribution of oil inclusions is a good guide to those levels that have functioned as reservoir or carrier beds.

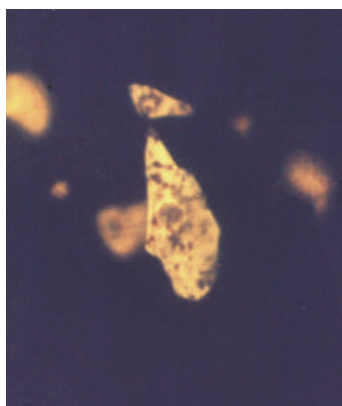


Figure 1. Fluorescent hydrocarbon-bearing fluid inclusions containing solid waxes.

A major challenge today however, is the determination of accurate compositions of hydrocarbons trapped in fluid inclusions. Compositional data is essential for the determination of the density and trapping temperature of the hydrocarbon fluid. Conventional microthermometry described above cannot yield the compositional data required for modelling the conditions of fluid trapping. To this end R&D studies are underway into the application of laser technology to determine the compositions of hydrocarbon fluids trapped in inclusions. These range from the detection of methane to the measurement of fluorescence lifetimes in hydrocarbon-bearing inclusions. However, there is much potential in utilising the simplest data from such inclusions, i.e.

their microthermometric behaviour, fluorescence properties and the fundamental existence of hydrocarbons during fluid entrapment.

Studies of the distribution of hydrocarbon inclusions can help to understand:

- (i) mechanisms of hydrocarbon migration,
- (ii) filling history of reservoirs,
- (iii) fluid compartmentation in reservoirs,
- (iv) relationships between hydrocarbon migration and deformation,
- (v) relationships between hydrocarbon emplacement and reservoir diagenesis.

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Thermal maturity of samples from Rockall Basin shallow boreholes

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Vitrinite reflectance has been measured in several core samples from the 1999 Rockall Basin shallow boreholes (A, B and C) acquired on the eastern margin of the Rockall Basin by the RSG (Jones et al. 2001) to determine thermal maturity, together with other methods including spore colour/fluorescence, microforaminiferal lining colour/fluorescence, clay crystallinity and clay crystallite size estimation. The maturity results have been integrated with the palynological data to aid interpretation.

Cretaceous greensands from borehole A have yielded very little organic matter and reliable vitrinite reflectance determinations were almost impossible. The reflectance of three particles measured was c. 1.3% R_r and presumably reworked. The organic content of the samples is dominated by marine organic matter and microforaminiferal linings were found to be abundant. These could prove to be a viable alternative maturation indicator in similar lithologies in the future. However, colour changes and the fluorescence threshold first need to be calibrated against the 'standard' vitrinite reflectance and spore colour/fluorescence scales.

Jurassic samples from the same borehole yielded three populations of vitrinite. Non-fluorescent and fluorescent Carboniferous spores (Figure 1) suggest at least two separate Carboniferous sources. These may be correlated with reworked vitrinite populations of 0.85% R_r and 1.27% R_r .

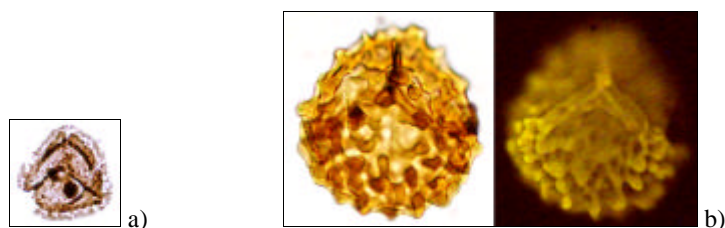


Figure 2. a) *Lycospora pusilla*, Carboniferous, non-fluorescent; b) *Raistrickia* sp., Carboniferous, fluorescent. (x500)

The indigenous vitrinite population has a low mean random reflectance, c. 0.3% R_r . However, Jurassic spore populations show various colours and could also suggest several Jurassic sources of vitrinite below the fluorescence threshold of 1.3% R_r . (Figure 2)

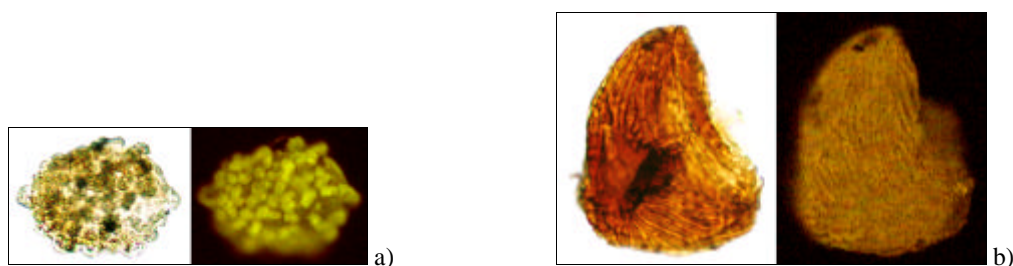


Figure 3. a) *Cerebropollenites* sp., Jurassic, fluorescent; b) *Cicatricosisporites* sp., Jurassic, fluorescent. (x500)

Siltstones from borehole B yielded mean random vitrinite reflectance values of *c.* 2.4% R_r . Carboniferous spores have been observed to be relatively dark in colour and non-fluorescent. (Fig. 5) Additionally, illite crystallinity values support the relatively high maturation level in comparison with the other boreholes.

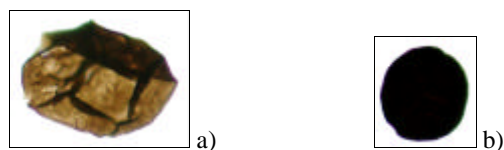


Figure 4. a) *Calamospora* sp, Carboniferous, non-fluorescent; b) *Punctatisporites* sp, Carboniferous, non-fluorescent. (x500)

Tertiary mudstones from borehole C yielded at least two populations of vitrinite with mean random reflectances of *c.* 0.8% R_r and *c.* 1.2% R_r . Both populations are unlikely to be Tertiary in age, considering the low reflectance of the Jurassic material encountered in another borehole in the region. Carboniferous spore colours and fluorescence suggest both vitrinite populations may be associated with different Carboniferous sources.

The clays, which were present in nearly all of the samples collected for this study provided limited information on the thermal maturity. Overlapping peaks in the XRD traces hindered the measurement of clay crystallinity using the Kübler Index in most cases. However, illite crystallite sizes were measured, revealing an increase in size with stratigraphic age. The occurrence of chlorite rather than kaolinite in the samples of borehole B may support the interpretation of indigenous vitrinite in this borehole as the substitution of kaolinite by chlorite has been found to correlate with $R_r = c.$ 1.9-2.1%.

Acknowledgements

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Application of potential field data to interpretation of the Porcupine Basin, Offshore Ireland

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A compilation of magnetic and gravity data (ARK Geophysics Ltd. 2000) covering the Porcupine Basin, located offshore west of Ireland, was carried out as a prelude to an interpretation study. The purpose of the study was to highlight deep and shallow crustal structure and provide a regional structural framework, incorporating the adjacent shelf and onshore areas. The aeromagnetic data incorporated a compilation of high-resolution surveys onshore, and a high-resolution survey offshore over the centre of the basin surrounded by surveys with widely spaced flightlines. The gravity compilation combined land data onshore, with offshore marine data in the east and satellite altimetry data in the west.

Thirty-one map products were generated from the magnetic, gravity and bathymetry data to prepare the interpretation (PGW Europe Ltd. 2001). Magnetic products included: total magnetic intensity, reduction-to-the-pole, first vertical derivative, pseudo-gravity, upward continuation, residual field, analytic signal, Compu-drape to the seafloor, Euler deconvolution, source edge detection and Source Parameter Imaging. Gravity products included: free-air gravity, isostatically-corrected Bouguer gravity, horizontal gradients, upward continuation, residual field, Euler deconvolution and source edge detection.

Figures 1 and 2 show the basic gravity and magnetic data respectively, along with the sources and distribution of the original surveys. The Porcupine Basin is outlined quite well by both sets of data. Numerous sub-basins and smaller adjacent basins are evident. The magnetic data delineate the intra-sedimentary volcanics and several igneous centres, the roots of which can be seen in the gravity data. Basin structures (e.g. horsts, grabens, ridges, highs) have been interpreted. Faults that control or cut these structures, as well as tectonic features, are also evident. The interpretation of the potential field data will provide significant input to the local interpretation of seismic lines, and the tying of the seismic interpretation into the regional framework. Coincident modelling of the potential field data will lend further credence to the seismic results.

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme. Gravity and magnetic data displayed for onshore Ireland were supplied by the Dublin Institute of Advanced Studies (DIAS) and the Geological Survey of Ireland (GSI) respectively.

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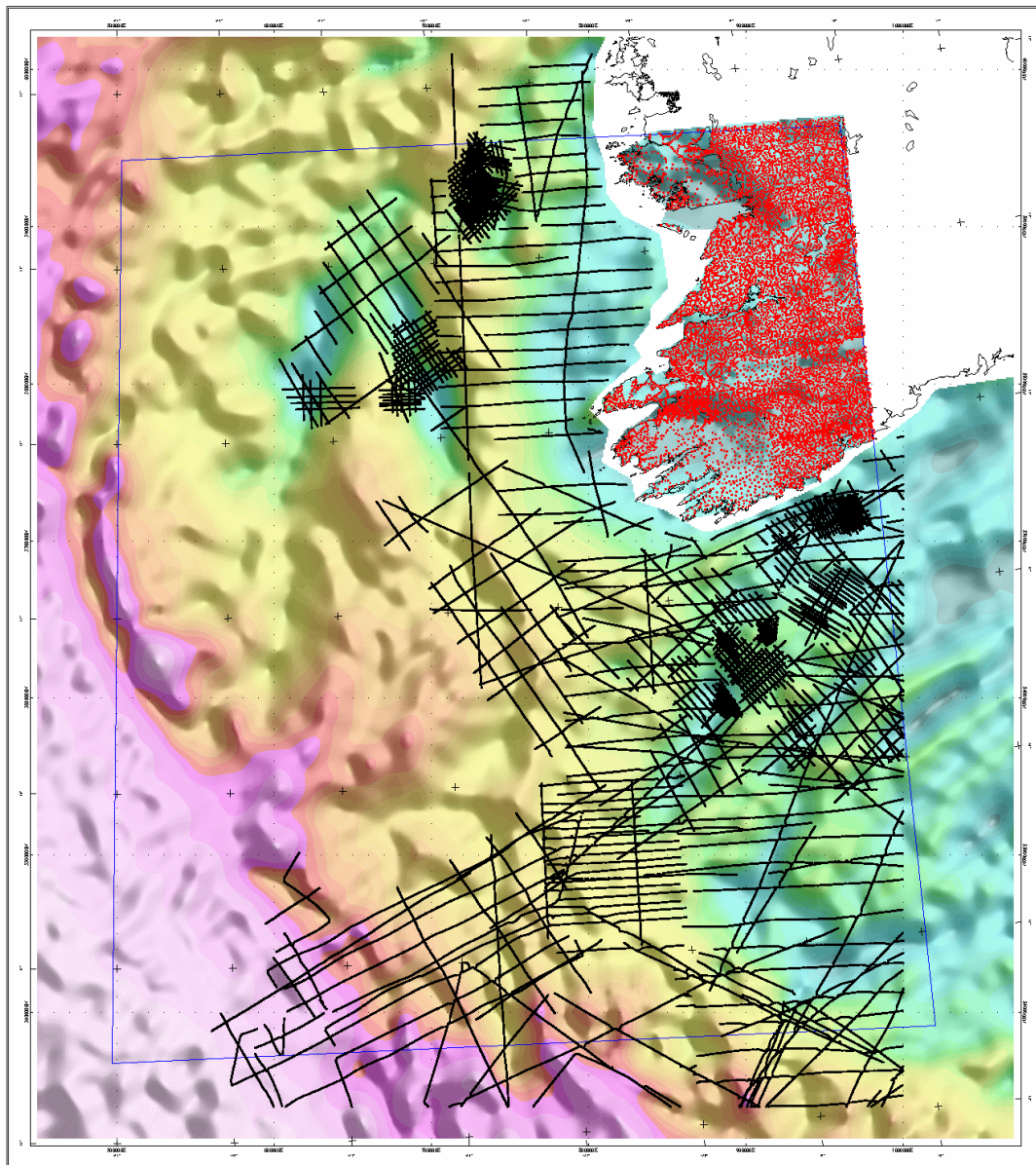


Figure 1. Gravity data coverage superimposed on Bouguer gravity image shaded from the northeast.
Land gravity stations (DIAS) shown in red. Gravity ship tracks (PAD) shown in black.
Area to west lacking coverage utilizes the satellite altimeter data (Sandwell).

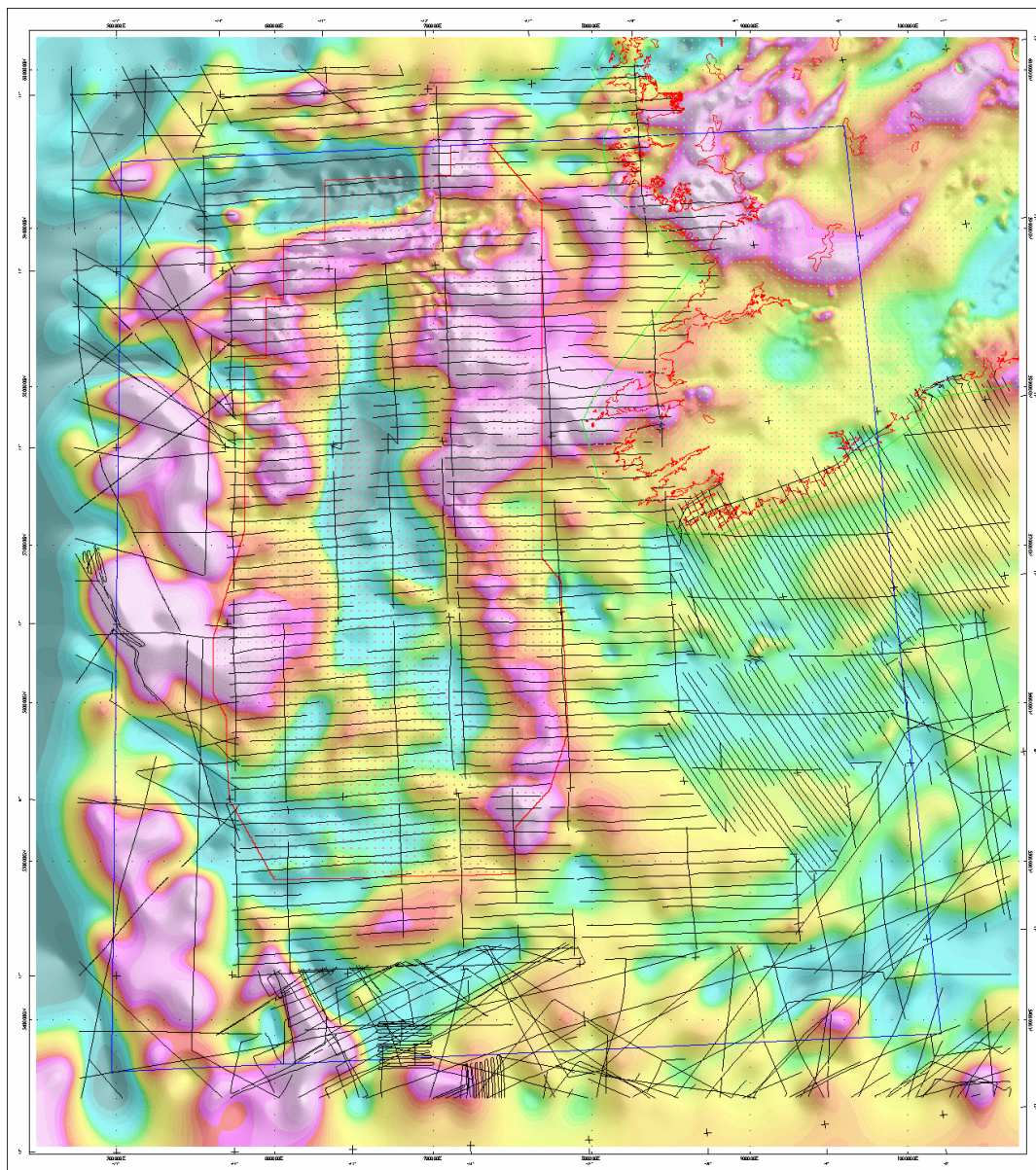


Figure 2. Magnetic data coverage superimposed on magnetic anomaly image (excluding Nopec's high-resolution offshore survey) shaded from the northeast.

Offshore aeromagnetic flightlines (PAD) shown in black.

Offshore high-resolution aeromagnetic grid shown in red (Nopec 97).

Onshore aeromagnetic grid (GSI) shown in green.

Integrated Structural Nomenclature and Features Map of Ireland's Atlantic Margin

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During the course of academic research and exploration over the past 30 years a large number of structural features have been identified in the Atlantic Margin region west of Ireland. Some of these have been named, while others were partly described and unnamed. In many cases the names used were of obscure or inappropriate derivation. Until recently no unified systematic nomenclature, or system of nomenclature, existed for the increasing number of structural features identified in the region. Two linked structural projects have now been completed and the results of these projects have been merged to provide an integrated structural nomenclature for the Irish Atlantic Margin. The region encompassed is shown on Figure 1. It includes the basins and highs in the Rockall, Hatton, Slyne, Erris, Porcupine and Goban Spur areas.

The Rockall structural nomenclature project, carried out for the Rockall Studies Group, was completed in December 1999 and published as Special Publication 1/99 by the Petroleum Affairs Division, Department of the Marine and Natural Resources (Naylor *et al.* 1999). The Porcupine structural nomenclature project, under the aegis of the Porcupine Studies Group, was recently completed (August 2001) and is expected to be published shortly.

The overall aims of both projects were:

- to establish a nomenclature methodology and a regional structural framework for the Irish Atlantic offshore region (Fig. 1), and
- to identify and give formal names to regional structural elements for petroleum industry and academic use, and thus avoid confusing and conflicting nomenclature.

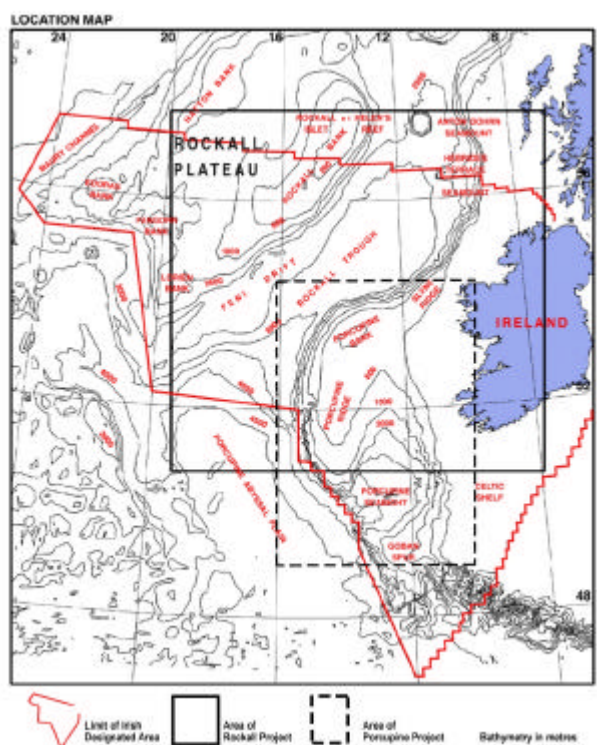


Figure 1. Bathymetric map of the Rockall and Porcupine region showing the location of the areas involved in the structural nomenclature projects.

Both projects began with a review and synthesis of the published literature and maps to produce a regional map of known structural features. The researchers then reviewed all available seismic reflection data in the areas. This centred initially on the regional speculative seismic surveys and was followed up by more detailed surveys involving proprietary data. More than 30,000 line km of reflection seismic data, made available by the Petroleum Affairs Division and individual exploration companies, were examined in the Rockall and Porcupine regions. Structural features and zones were plotted on 1:1,000,000 scale maps. Workshops with industry and PAD representatives then further refined the interpretations. A selection of seismic lines, which best illustrate the identified features, were interpreted to produce coloured geoseismic sections. Fourteen of these accompanied the 1999 Rockall publication, while a further twelve accompanied the final Porcupine project report.

The projects have identified a number of significant new structural elements and have confirmed or re-defined previously known features. A series of Late Palaeozoic-Tertiary basins have been outlined along both margins of the Rockall Basin. These segmented but structurally linked basins are overlapped and buried beneath a Cretaceous and Tertiary cover. Several Cretaceous and Tertiary basin depocentres lie on the flanks of the Rockall Basin. Within the Porcupine Basin and Goban Spur regions the location of major Jurassic and Cretaceous depocentres have been delineated. A number of previously unknown, or poorly delineated igneous centres, have been identified within the region. The Porcupine Median Volcanic Ridge System has been remapped and is shown to have a significantly different distribution to previous publications. A number of pronounced deep features (e.g. Porcupine Arch and Fionn High) have been delineated. E-W and NW-SE oriented major structural features have been identified and mapped within the Goban Spur area, and these reflect the complex history of Late Palaeozoic to Tertiary development of the region.

A formal system for naming of structural features was established which provides guidance regarding the methodology and names to be used in naming new features and structures. Within both projects, a clear distinction has been made between the names for bathymetric and geological features. Where possible, established feature names have been retained, although the category of the feature has been changed in some cases. However, inappropriate names - such as the names of golf courses or the names of coastal features hundreds of kilometres distant - have been discarded and a new name has been applied. The names of Irish saints, well established in the literature, have been used in naming or re-naming offshore basins. Structural highs or prominent igneous features have been named after characters, mystical islands and related features which have been well documented in Celtic mythology.

The maps produced in the two projects were merged and unified into a single map encompassing Ireland's Atlantic margin. The results of the projects have provided, for the first time, detailed structural elements maps and linked geoseismic sections covering the entire Irish designated Atlantic margin area. These, together with the accompanying nomenclature, should provide a sound framework on which future detailed appraisal of the region can be developed.

Acknowledgements

The projects have been undertaken on behalf of the Irish Petroleum Infrastructure Programme.

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Gravity modelling across the Porcupine Basin: insights into crustal structure

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The Porcupine Basin developed during the Mesozoic Era in response to multiple continental rifting episodes that also controlled basin subsidence in the neighbouring Rockall Basin and the sedimentary basins along the shelf and slope regions of the Rockall Trough's eastern margin (Corefield *et al.* 1999). However, unlike the Rockall Basin, the seismic properties of the crust and upper mantle across the axial region of the Porcupine Basin have not been investigated using wide-angle seismic techniques. Vertical seismic reflection profiles exist, processed to beyond 10 s, but these have failed to clearly image the Moho reflection below the basin-fill sequence (England & Hobbs 1997). Previous investigations using wide-angle-seismic methods were centred on the continent-ocean transition at the mouth of the Porcupine Basin and part of the eastern basin margin across the Irish Mainland Platform (Makris *et al.* 1988).

The geographical and structural position of the Porcupine Basin between the highly stretched crust of the Rockall Basin (where $\beta = 5$ to 6) and the Irish mainland and shelf, where the crust is about 30 km thick (O'Reilly *et al.* 1996), suggests that there is a structural relationship between the two basins at a whole crustal or possibly lithospheric scale. Knowledge of the gross geometry of the crust, particularly the depth to the Moho, is important towards understanding the tectonic relationship between both basins. Information about the crustal structure can be obtained by modelling potential field data (especially gravity) if the gravity effects the basin sediment fill and the water column are known and can be successfully removed. The vertical seismic velocity structure of the dominantly Mesozoic and Tertiary basin-fill sediments of the basin is known from conventional vertical seismic profiles which are stratigraphically constrained by exploration wells (Shannon *et al.* 1995).

This information is used to remove the gravitational effects of the basin syn-rift and post-rift sequences and to isolate the free air gravity anomaly due predominantly to the depth and shape of the Moho below the Porcupine Basin. Five seismic reflection profiles extending from one margin of the basin to the other are used to model both the gravity and magnetic fields in the region using a 2-D modelling approach. Complete and independent interpretations of the selected seismic profiles, based on regional borehole stratigraphic correlations have been provided by other members of the Porcupine Studies Group (PSG). The modelling of the gravity field across the basin is further constrained by the regional wide-angle and vertical incidence seismic structure of the crust in the Celtic Sea Basins, the Rockall Basin and the Irish mainland (O'Reilly *et al.* 1991; Klemperer & Hobbs 1991; Hauser *et al.* 1995).

Preliminary results will be presented based on a compilation of the free air gravity and magnetic data for the region provided by the PSG. Discussion of the results will be largely focused on variations in crustal thickness and geometry along the axis of the basin and the role of cross-basin faults in segmenting crustal structure. Shorter wavelength variations in the gravity and magnetic fields will be correlated with specific features independently interpreted from the seismic profiles that were used to isolate the gravity signature of the deep crustal structure. One initial result of the study suggests that NW trending cross-basin faults inferred from a set of similarly trending gravity lineaments seem to mark an important change in the structure of the crust south of the previously interpreted Porcupine Median Volcanic Ridge (Naylor *et al.* 1999). This trend appears also to be important for basin structuring in the Irish and Celtic Seas (Readman *et al.* 1995).

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme.

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Integrated science to help overcome the challenge of overpressure

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The industry trend is to explore and develop deeper targets and in deeper water - Gulf of Mexico, offshore Brazil, Northwest Europe, Southeast Asia, North and West Africa. Frontier areas lack well data particularly in the top-hole section where shallow water flows occur.

This paper presents a methodology that uses changes in seismic velocities to infer the formation pore pressure. Velocities increase during compaction because porosity reduces and grain-to-grain contact increases. During rapid burial of low permeability sediments, fluid escape may not be in equilibrium. The pore fluid begins to support the overburden and becomes overpressured. In these zones the seismic velocities are lower because the porosities are higher.

3D assessment of the structural styles and depositional systems enhances interpretation. Using co-kriging, an initial velocity model is constructed from seismic stacking velocities and sonic logs. The optimum seismic image in depth is obtained by several iterations of pre-stack depth migration using tomography. By creating litho-facies associations a model is built up by analysis of sedimentary processes and use of sequence stratigraphy. Well petrophysical properties and global analogue rock properties data aid synthetic seismic modelling. These are used to generate and analyse seismic attributes. Pre- and post-stack acoustic impedance inversion, amplitude variation with offset and rock properties from seismic (λ μ - ρ) will help isolate lithology and pore fluid. Velocity is transformed to pore pressure as a function of effective stress.

Emphasis is given to a focused cross-disciplinary team to unlock the valuable information held within the available data. This allows a rapid and accurate assessment of abnormal pressures that can be incorporated into bidding, prospectivity, drilling and field development strategies, thus reducing risk.

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The seismic structure of the Southern Rockall Trough from wide-angle profiling

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The Rockall And Porcupine Irish Deep Seismic (RAPIDS 3) project was conducted in early 1999 and involved the acquisition of four wide-angle reflection/refraction seismic profiles in the region of the Rockall Trough (Fig. 1). Two axial (profiles 34 and 31) and two transverse profiles (profiles 32 and 33) were recorded using an airgun array as a primary source and explosive shots as an additional source for deeper energy penetration.

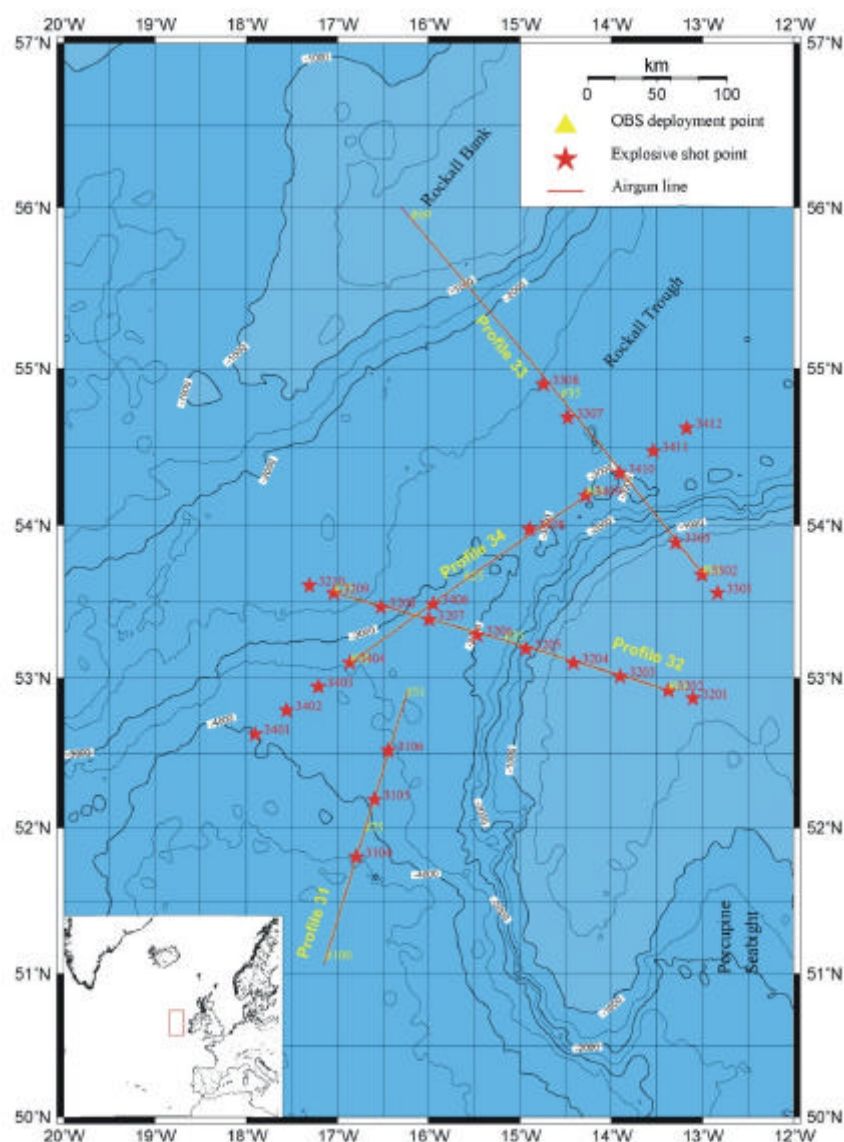


Figure 1: Location of the RAPIDS 3 seismic profiles

The project builds upon the work of the two previous RAPIDS projects (e.g., Jacob et al, 1995) and is aimed at furthering our knowledge of the sedimentary sequence and the tectonic evolution of the trough.

Data quality was in general excellent with a good signal to noise ratio and energy propagation of > 100 km providing clear arrivals from boundaries within the crust and occasionally the upper mantle. Preliminary whole crustal P-wave velocity models have been produced on 3 of the 4 profiles (profiles 32, 33 and 34) from 2-D travel-time modelling of these arrivals utilising the code of Zelt & Smith (1992).

The velocity models typically indicate a 4 – 5 km thick sedimentary succession within the central part of the basin although local thicker depocentres occur e.g., the Macdara Basin. Three main seismic packages are identified within the sedimentary succession with a number of local units within each. The sedimentary packages are generally flat lying in the centre of the basin pinching out to the basin margins where significant structural complexities are observed. The succession is thought to be of Late Palaeozoic to Recent age. Significant topography is observed on the crystalline basement possibly representing a series of rotational fault blocks or strike-slip transtensional movement.

Beneath the Porcupine and Rockall Highs a 3-layer crust of 25 – 30 km thickness is modelled. This structure and velocities are similar to that observed beneath continental Ireland and Great Britain (Lowe & Jacob, 1989). The crust thins beneath the trough to 6 – 8 km thickness with maximum thinning occurring beneath the edges of the trough with the centre of the trough slightly thicker. The three intra-crustal layers also thin and merge together such that beneath the centre of the trough a 1 or in some places a 2-layer crust is observed. The exact nature of this transition from a 3-layer crust as well as the location and implications of the location of 2-layers as opposed to 1 requires further research.

The Moho appears to show some degree of asymmetry with the crustal thickening occurring more gradually beneath the western edge of the trough (from the beneath the trough to beneath the Rockall High) than on the eastern edge (to beneath the Porcupine High).

On several seismic sections a later phase is observed at critical distances greater than that of the Moho (PmP) phase. This P_LP phase is a reflector from an upper mantle interface that, preliminary modelling indicates, is present beneath the centre of the trough. Sub Moho velocities are lower where this phase is observed suggesting that some form of alteration of the upper mantle has occurred.

At this time the models are in a preliminary stage but indicate several aspects that once fully modelled will have important implications for the tectonic development of the Rockall Trough.

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme.

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Interpretation and modelling of Line SPB97-103, Porcupine Basin, offshore Ireland

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The poster presentation represents the results of the report detailing the interpretation and forward modelling of the gravity and magnetic data which has been integrated along seismic line SPB97-103, Porcupine Basin, offshore Ireland. The seismic line was 130km in length, running east-west, located at the northern end of the Porcupine Basin at a latitude of 51° 50' N (Fig. 1). The seismic line was provided by Phillips Petroleum, courtesy of Fugro-Geoteam A.S. The main objectives of the study were to review the regional stratigraphy, determine the nature and extent of volcanics and to delineate basement related features. The project was completed for Porcupine Studies Group.

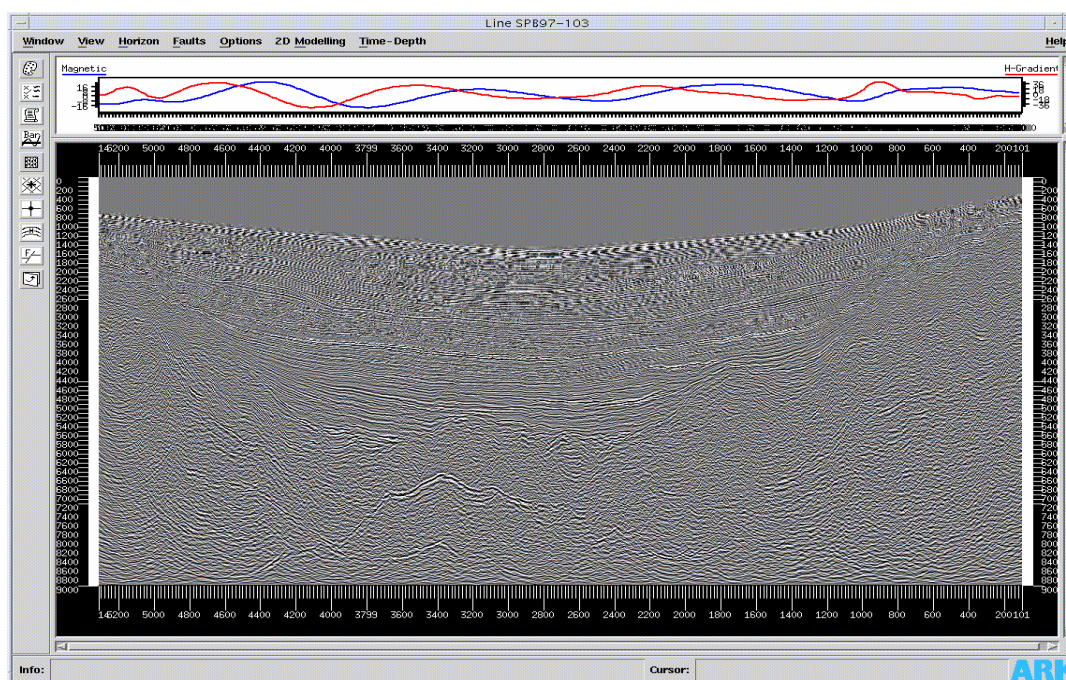


Figure 1. Seismic line SPB97-103

The main feature noticeable in the gravity data is the large north-south trending gravity high under the centre of the Porcupine Basin. The magnetic data shows a large magnetic low associated with the Porcupine Basin.

The dominant character of the gravity and magnetic field is consistent with a sedimentary basin, bounded by basement blocks on the west and east, underpinned by reversely magnetised mantle material towards the centre axis of the basin. The gravity and magnetic data available for the study were taken from the 2000 data compilation produced by ARK that included Petroleum Affairs Division (PAD) dataset, D.T. Sandwell's Geosat and ERS-1 satellite altimeter profiles and Dublin Institute for Advanced Studies (DIAS) datasets.

The methodology used was to generate models built directly on the seismic data. Their forward calculated gravity and magnetic responses were compared with the measured gravity and magnetic data. The models are then changed until a satisfactory match between the observed and measured data

is achieved (Figs 2 & 3). The link between the seismic data, in time, and the potential field modelling, in depth, is provided by the velocity information.

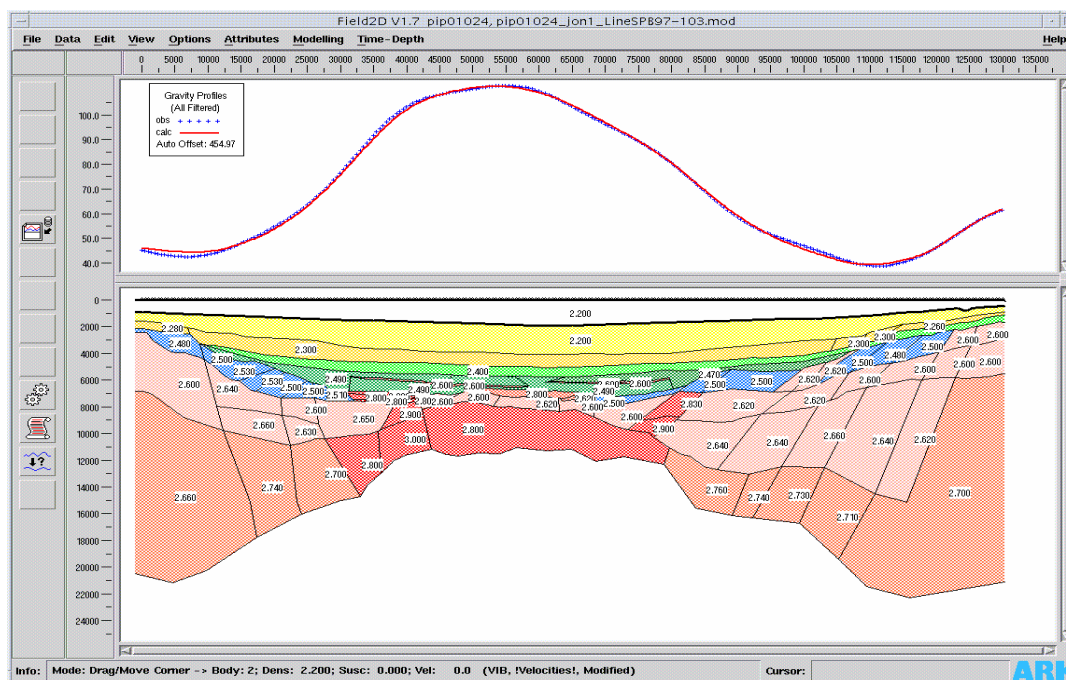


Figure 2. Result of gravity modelling on SPB97-103

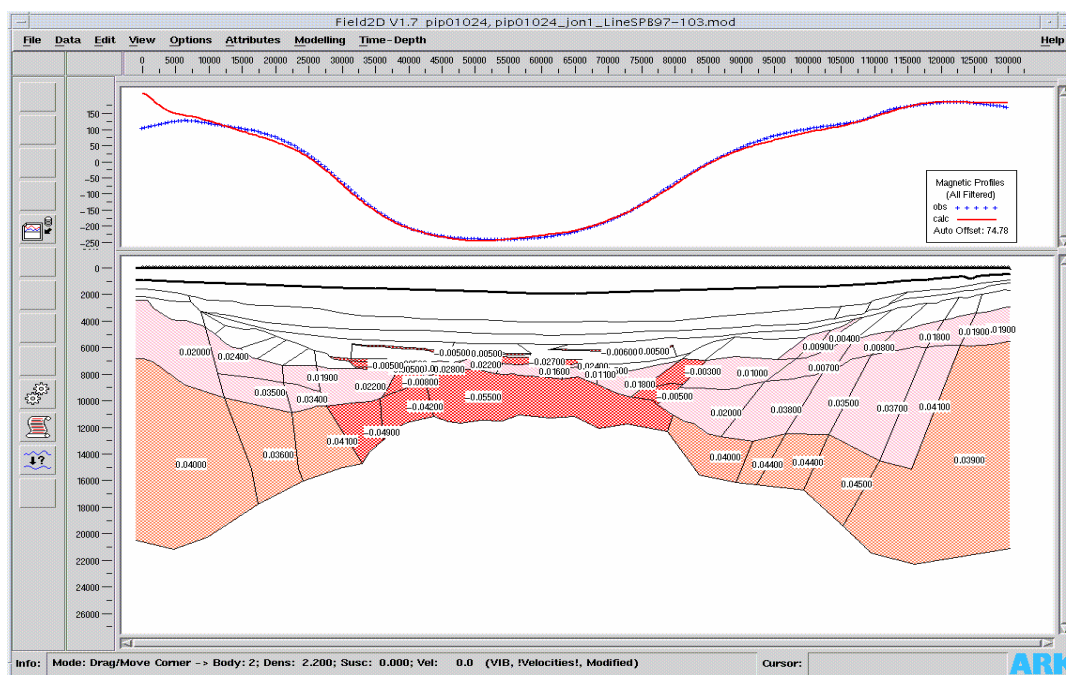


Figure 3. Result of magnetic modelling on SPB97-103

The main conclusion that can be made from the modelling of line SPB97-103 is that the regional trend in both the gravity and magnetic data are dominated by a large intrusive body located within the basement. This appears at a depth of around 8km and is just visible within the seismic profile. This feature and the basement to either side of the basin continue down to depths of up to 20km. Overlying the basement is a relatively simple sedimentary basin structure. Within this basin there was also

evidence of further intrusive material and the presence of the “Median Volcanic Ridge”, a thin layer of volcanic material located in between the Cretaceous and Permian-Jurassic layers.

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme. Phillips Petroleum and Fugro-Geoteam A.S. are also acknowledged for the provision of seismic line SPB97-103.

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Maintenance and Collapse of a Cretaceous High on the SE Rockall Slope: Evidence from Shallow Seismic-Borehole Correlations in the Bróna Basins

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The tectono-sedimentary development of the Rockall Basin and environs during North Atlantic opening remains poorly constrained, in part due to limited sample control on the age or lithology of strata seen on seismic reflection data. Here we present an integrated analysis of borehole and shallow seismic data (Haughton & Amy 2000; Praeg & Shannon 2000) from two sites on the SE Rockall slope (Fig. 1), collected for RSG in 1988-89. The results provide evidence for deposition in a Cretaceous to Palaeogene shallow marine (i.e. shelfal) setting, punctuated by a Late Cretaceous episode of fault-controlled deposition. The two sites, each about 30 km², currently lie in water depths of 1000-1700 m above the South and North Bróna Basins (blocks 83/24 and 83/20, respectively).

At both sites, Upper Jurassic strata of the Bróna Basins are unconformably overlain by an onlapping seismic unit (Figs 2, 3) that corresponds to a condensed interval of Lower Cretaceous shallow-marine sandy limestones and lean ironstones. These record the development of a persistent clastic-starved shallow marine setting, following inversion of the Jurassic basins. The limited clastic supply included a contribution from granitic basement exposed in local (remnant fault crest) highs. At the northern site, the shallow water deposits (Turonian to Cenomanian) are sharply overlain by fine-grained and micritic 'greensands' (Cenomanian-Campanian) that formed in a low energy outer shelf setting, suggesting abrupt deepening of the former shelf high. Seismic reflection geometries record the growth and contraction of a fault-controlled greensand wedge up to 50 m thick, onlapped by Late Campanian-Maastrichtian pelagic micrite (Fig. 2). The latter imply reduced clastic supply to passively deepening (but still shelfal?) basins. At the southern site, correlative units are developed entirely in the shallow water sandy limestone and lean ironstone facies and seismic data show that faulting did not result in a distinctive seismic faces (Fig. 3). The Cretaceous units are onlapped by Palaeogene micritic limestones (Eocene in the borehole) that locally include evidence of early fault growth or reactivation but otherwise thicken passively S to SE across the Late Cretaceous basin-bounding faults (Fig. 3).

The extent of Late Cretaceous fault growth at either site is small in comparison to the underlying Jurassic successions, which contain fault-controlled wedges >1 km thick (Naylor et al. 1999). However, there are two remarkable features of the observed record. The first is that the area persisted as a shallow water platform through the Cretaceous, despite the Jurassic extension. The second is that, in the South Bróna Basin, Late Cretaceous to Palaeogene subsidence patterns are almost opposite in trend to that recorded by the present bathymetric slope of the Rockall Basin (Fig. 3), implying the latter to have developed since the Eocene. The maintenance of a Cretaceous high may be due to a) lateral offset of Jurassic fault-controlled subsidence from the ensuing thermal subsidence, b) Cretaceous flexural arching between the proto-Rockall and Porcupine Basins to the west and east, or c) thermal perturbation of 'normal' subsidence patterns by Cretaceous heat input to the lithosphere. Future work to test these hypotheses will include the extension of the shallow seismic stratigraphy to a grid of industry seismic data from the area to better constrain the evolution of subsidence patterns in relation to fault growth and basin development.

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme.

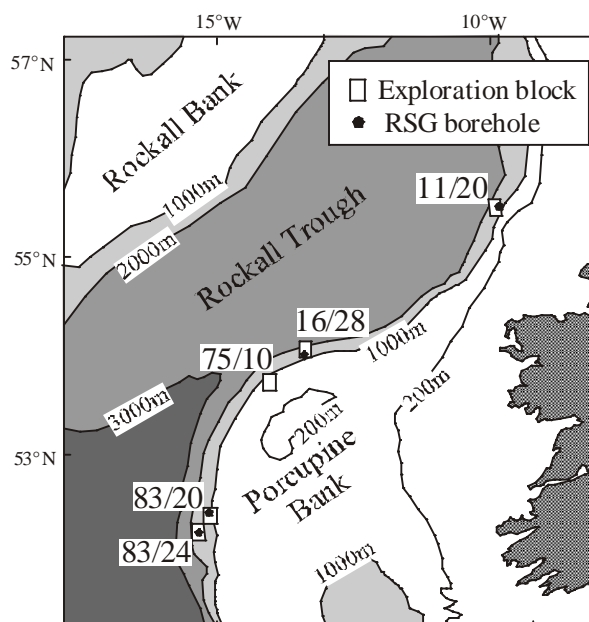


Figure 1 – Location of shallow seismic survey areas.
Block 11/20 includes two adjacent surveys.

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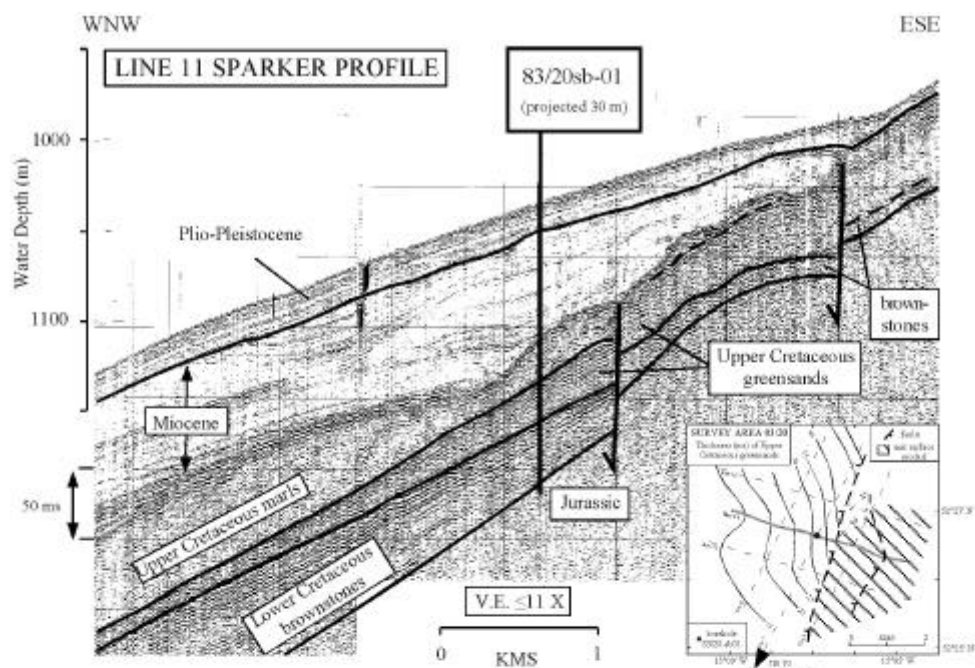


Figure 2 - Sparker profile across the 83/20 survey area, showing the results of seismic-borehole correlation. Note thickening of Upper Cretaceous greensands toward the lower of the pair of faults. Inset shows seismic line locations with superimposed greensand isochores. Modified from Praeg & Shannon (2000).

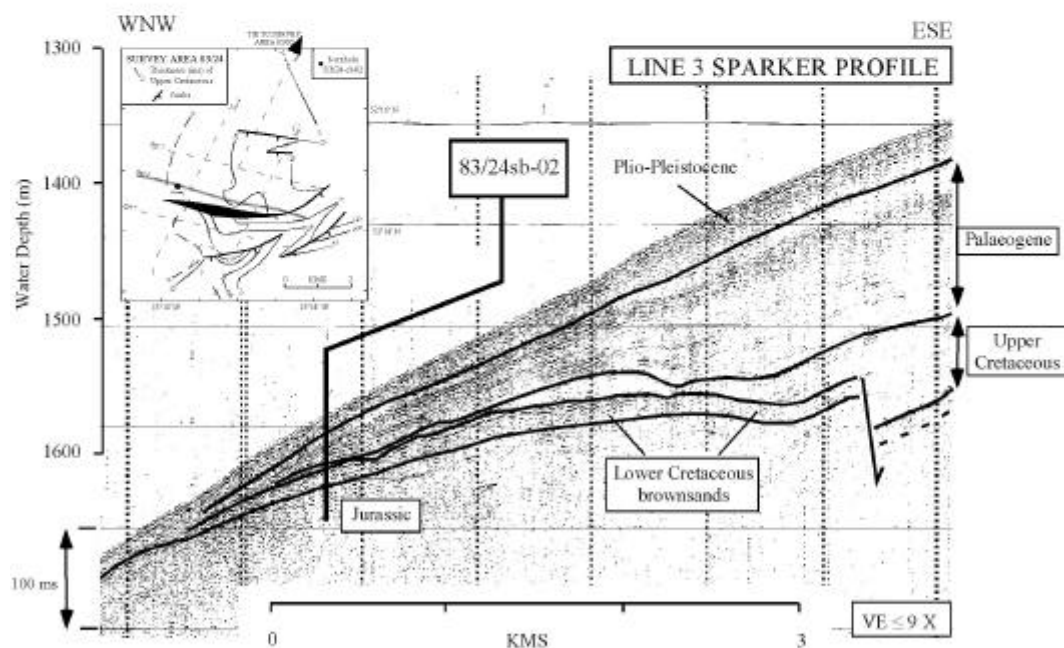


Figure 3 - Sparker profile across the 83/24 survey area, showing integrated seismic-borehole stratigraphy. Note easterly thickening of the fault-controlled Upper Cretaceous and onlapping Palaeogene units towards the South Bróna Basin, oblique to seabed trends. Inset shows seismic line locations with superimposed fault distribution and Upper Cretaceous isochores. Modified from Praeg & Shannon (2000).

Volcanoes on the Edge : New Insight from Shallow Drilling on the Margins of the Rockall Trough

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Shallow drilling on behalf of RSG in 1999 (Stoker 1999) resulted in the recovery of volcanic material from two sites on the eastern margin of the Rockall Trough (Fig. 1): in block 11/20, a short cored section from the Erris High is dominated by volcanoclastic deposits, while in block 16/28, a borehole from the northern margin of the Porcupine Bank terminated in basaltic rock. Petrographic and geochemical analyses of the cored material, supported by interpretation of shallow seismic profiles across the sites, provides evidence that raises some fundamental questions concerning the relationships between the volcanic materials and associated sedimentary successions and adds to our understanding of magmatism associated with development of deep bathymetry in the region.

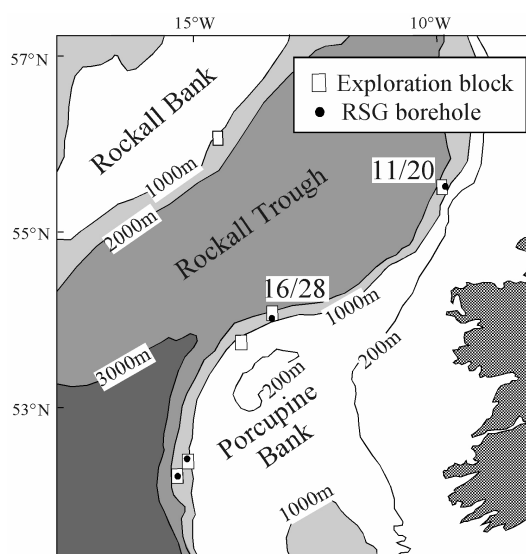


Figure 1: Location of RSG shallow seismic survey areas and coring sites

Borehole 11/20sb-01 on the Erris High (Fig. 1) recovered a short section of soft Pliocene mud sitting on an indurated succession of basaltic lapilli tuffs containing a number of cross-cutting ('intrusive') limestone bodies (Fig. 2). The material is largely unsuitable for biostratigraphy, but an Eocene or younger age is suspected (Haughton & Amy 2000). The volcanoclastics comprise two distinct facies: (1) poorly sorted, polymict, bioclast-rich, lapilli tuff in which there are both angular and rounded vesicular lapilli, and (2) a relatively well-sorted, open packed, monomict lapilli tuff without bioclasts and with angular grain shapes. Petrographically, the lapilli fragments comprise variably altered, highly vesicular basaltic rock types with common olivine phenocryst pseudomorphs. The lapilli are surrounded by palgonitised rims, isopachous zeolite cement fringes (phillipsite) and a later pore-occluding sparry calcite cement (Fig. 2). Micritic limestone dykes and sills cross-cut the lapilli and intergranular cements, although micrite has locally spilled into pores within the volcanoclastic deposits, producing geopetal fills overlying earlier zeolite cement rims. The limestone veinlets thus both pre-date and post-date the sparry calcite cement.

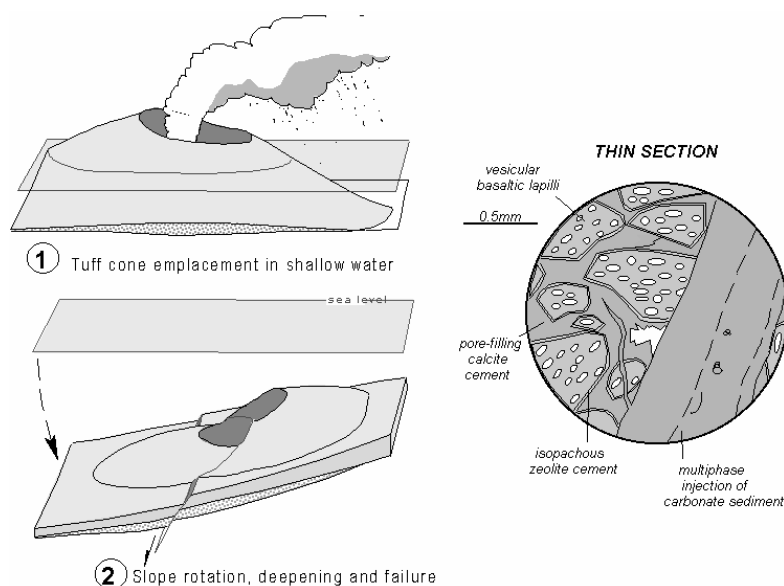


Figure 2: Model of tuff cone formation and subsequent deformation during slope development, to account for the features observed at microscopic scales (right) and supported by seismic-scale observations (see Fig. 3).

The volcanoclastic section is interpreted as the unstable subaqueous portion of a monogenetic, Curtsey-type, hydrovolcanic tuff-cone (Fig. 2), subject to inter-eruption marine reworking (accounting for the bioclastic lapilli tuffs) and periods of syn-eruption flushing with monomict volcanoclastic particles. This interpretation is supported by seismic data showing the core to come from an acoustically-opaque, cone-like feature at least 200 m high and 2-3 km across, one of two such features on this part of the Erris High (Fig. 3). The eruption involved a primitive magma with the range and abundance of phenocryst types closely comparable to that of material recently dredged from the flanks of Anton Dohrn, Rosemary Bank and Hebrides Terrace seamounts to the north. The tuff-cone deposits were subsequently forcefully injected (rather than passively infilled) by soft micritic carbonates, some of pelagic aspect (with abundant planktonic foraminifera), but elsewhere containing a shallow-water fauna (including echinoderms and bryozoans and evidence for minor siliciclastic input). The remobilised carbonate exploited fracture systems in the already partly cemented tuffs. Multiphase hydraulic pumping of soft carbonate sediment and 'hot' carbonate-charged water is envisaged, possibly due to gravity-driven destabilisation and fracturing of the tuff cone as it partly 'broke-away' during slope rotation following volcanism and cone growth (Fig. 2). The area was shallow water to emergent at the time of volcanism (based on the fauna and evidence for hydrovolcanic activity) but deepened with time. A seismic unit that onlaps the cone and displays upslope thickening (Fig. 3) indicates a subsequent reversal of slope, from easterly to the present westerly orientation. Failure of the cone during the rotation may have caused the carbonate to be remobilised and intruded, so that the inferred evolution reflects the onset of the main trough deepening phase.

On the northern margin of Porcupine Bank, borehole 16/28-sb01 (Fig. 1) encountered basalt beneath a thin Maastrichtian or older shallow-water sandy limestone, the latter unconformably overlain by a Lower to mid-Eocene deepening-upwards succession. The basalt is hydrothermally altered, comprising olivine and plagioclase phenocrysts within a matrix of needle-shaped plagioclase and fine-grained pyroxene. It is extensively veined by calcite-chlorite-zeolite-oxide filled fractures. REE, major and trace element abundances in the least-altered material indicate that it is an alkali basalt enriched in incompatible and light REE's. It closely resembles extrusive basalts dredged from the Hebrides Terrace Seamount. The origin of the basalt is equivocal but there is circumstantial evidence to suggest that it might be extrusive rather than a sill. If this is the case, it implies that there was Maastrichtian or older volcanism in the area north of Porcupine Bank. The volcanism would also have occurred prior to the main phase of deepening, which is recorded in the overlying Eocene succession.

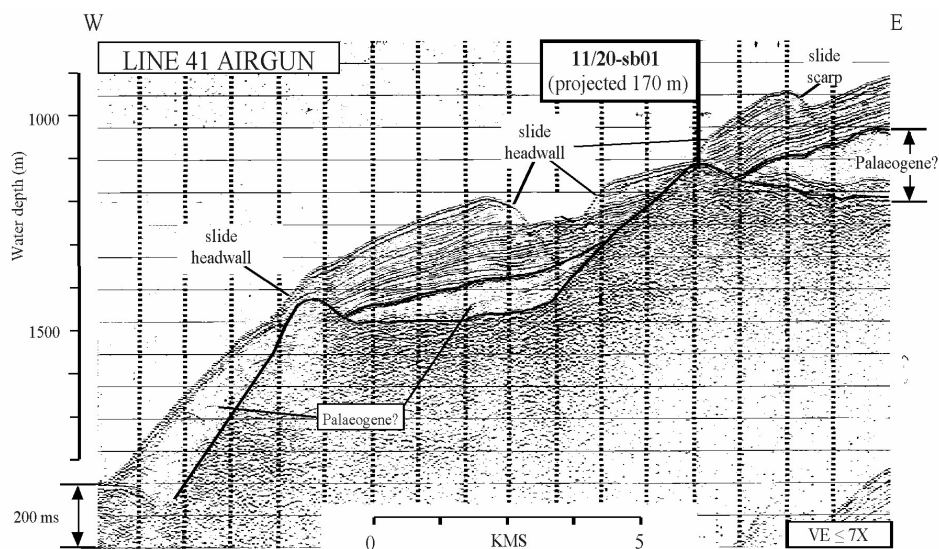


Figure 3: Airgun seismic profile across the 11/20 survey area, intersecting two conical subsurface highs at the top of acoustic 'basement'. Note the upslope thickening of the probable Palaeogene unit onlapping the cone at right, indicating slope rotation. Modified from Praeg & Shannon (2000).

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme.

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Images of slope failure along the glaciated eastern margin of the Rockall Trough from TOBI sidescan sonar

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The eastern margin of the Rockall Trough straddles the transition region between the heavily glaciated margins of the NE Atlantic at high latitudes, and the starved non-glaciated margins present in the south towards Iberia. To investigate this transition region, a deep towed sidescan sonar (TOBI) survey was carried out along the eastern margin of the Rockall Trough, between 52° and 56° 25' N. Interpretation of the sidescan data was complimented by 3.5 kHz profile data, which was also gathered during the survey. The examples in this poster demonstrate how acoustic properties gradually change over a relatively small distance (c. 80 km) from north to south between 54° and 56° 25' N (Fig. 1) along the margin due to decreasing importance of glacial processes (Readman *et al.* 2001, Shannon *et al.* 2001).

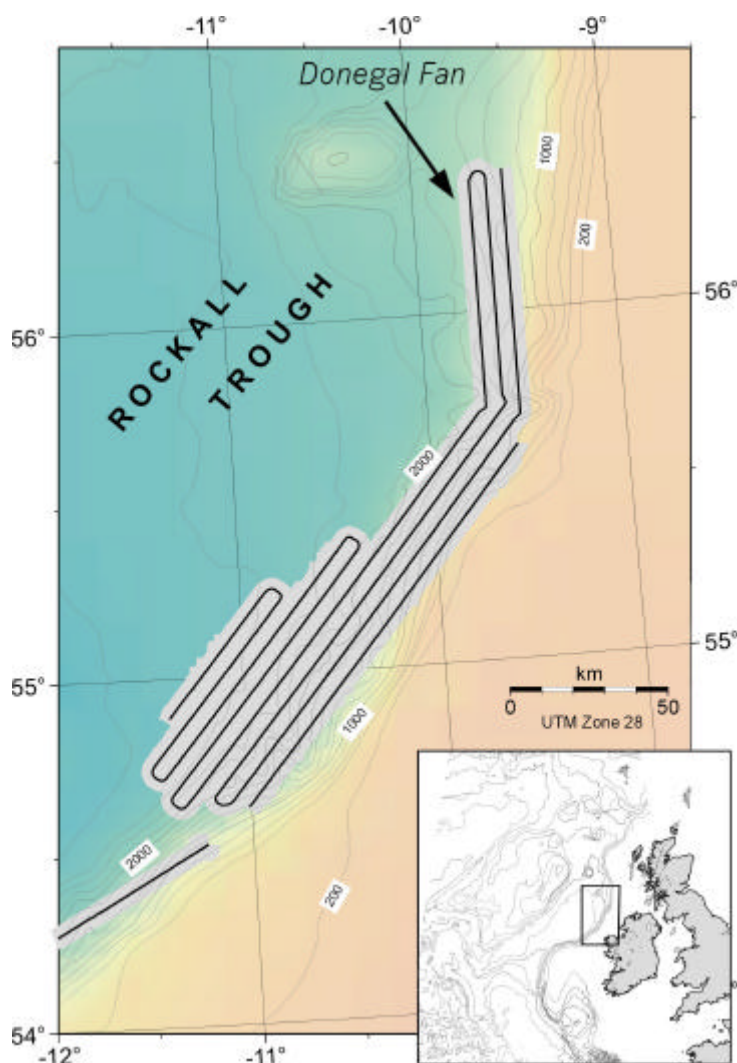


Figure 1. Location map showing the TOBI coverage (black lines and grey shading) between 54° and 56° 25' N in the Irish sector of the Rockall Trough. Bathymetry (GEBCO97) contours are at 200 m intervals.

The region north of 55° 39' N is notable for the absence of submarine canyons, and slope gradients are lowest in this region. Bottom topography is smooth to undulating and the 3.5 kHz echo character is very poorly correlated with acoustic backscatter. For example complex streaky tongues of high backscatter extending across the entire slope are not related to changes in echo character. Slope failure escarpments (due to elastic failure) are rare or absent in the region largely because the slope gradient is low. The deposits are interpreted as a stacked sequence of sheet-like anelastic flow deposits in the proximal region of a glacio-marine submarine fan (the Donegal Fan).

An extensive complex of submarine canyons are resolved south of the Donegal Fan, deeply incised into the upper and middle slope region. The best example is developed between 55° 20' and 55° 40' N. Each system consists of an extensive U-shaped cauliform tributary gully system produced by multiple elastic failures of the upper slope and terrace. These feed a series of incised V-shaped channels in the mid-slope region (Figs 2 and 3). The change from U-shaped gullies to V-shaped channels marks the transition from elastic slope failure to anelastic flow and slope incision.

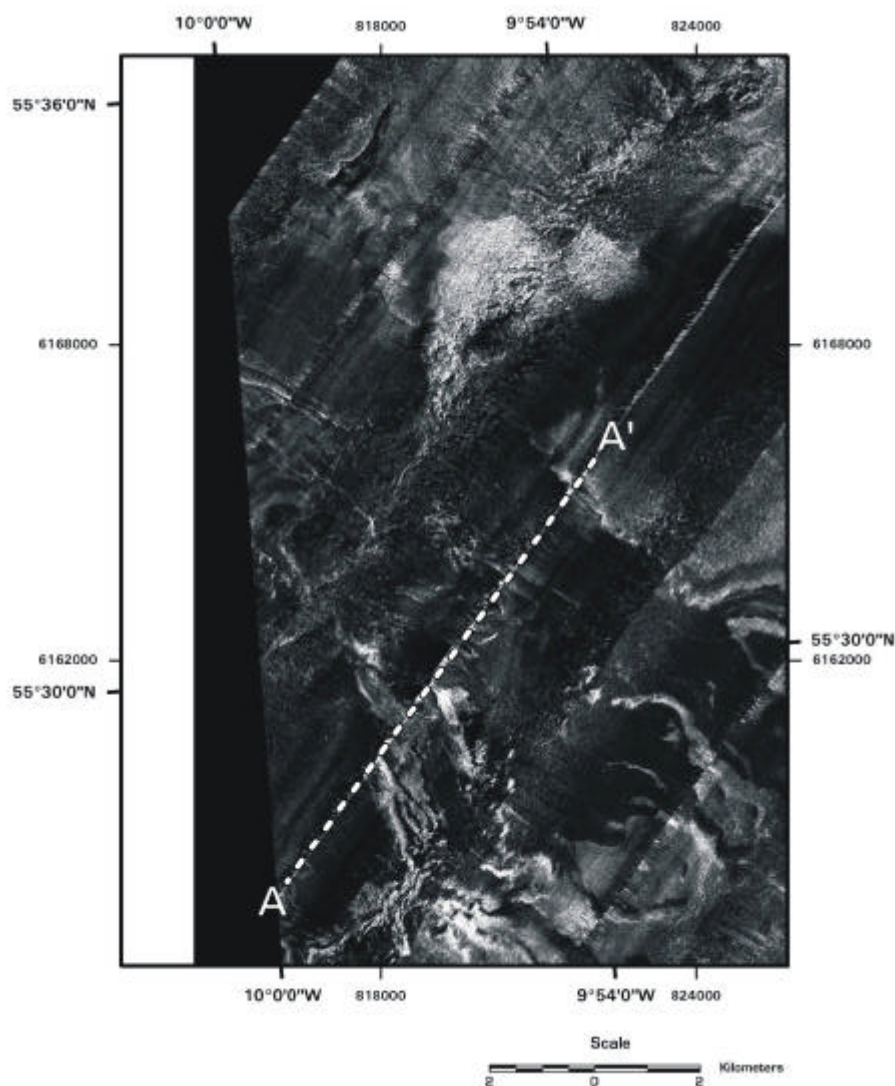


Figure 2. TOBI image across a V-shaped channel along the upper to mid-slope region of the eastern margin of the Rockall Trough. The channel connects up-slope to a U-shaped gully system defined by finger-shaped regions of low backscatter towards the southeast corner of the image. The location of the 3.5 kHz profile shown in Fig. 3 is indicated by the dashed line A-A'.

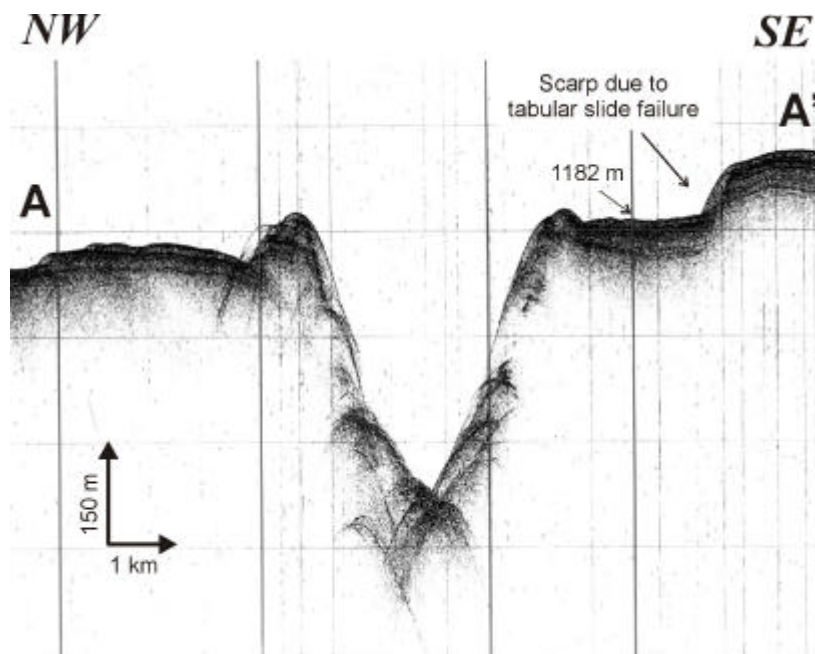


Figure 3. Large V-shaped canyon incised 400 m below the layered sediments on its flanks at c. 1200 m water depth. Slump scarps along the walls cause diffraction trails. Layered sediments on the shoulders may be eroded hemipelagites or turbidite sediments. The location of the profile is shown in Fig. 2.

On the mid to lower slope large regions with a speckled character of high and low backscatter trending E-W to NW-SE are highly correlated with echo character (Fig. 4). These are interpreted as a flow fabric within large sedimentary megaturbidite aprons fed through the canyon systems further upslope. Several coherent flow aprons are recognized. These are sometimes buried by acoustically transparent debris flow deposits (Fig. 5).

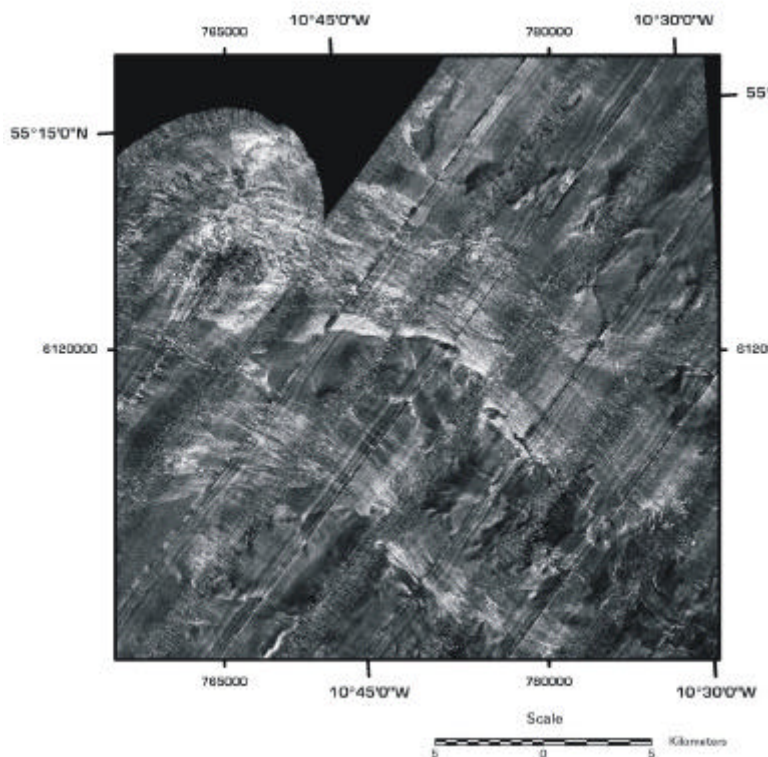


Figure 4. TOBI image of sediment flow aprons defined by areas of high speckled backscatter. These were probably deposited by high density turbidity currents or debris flows.

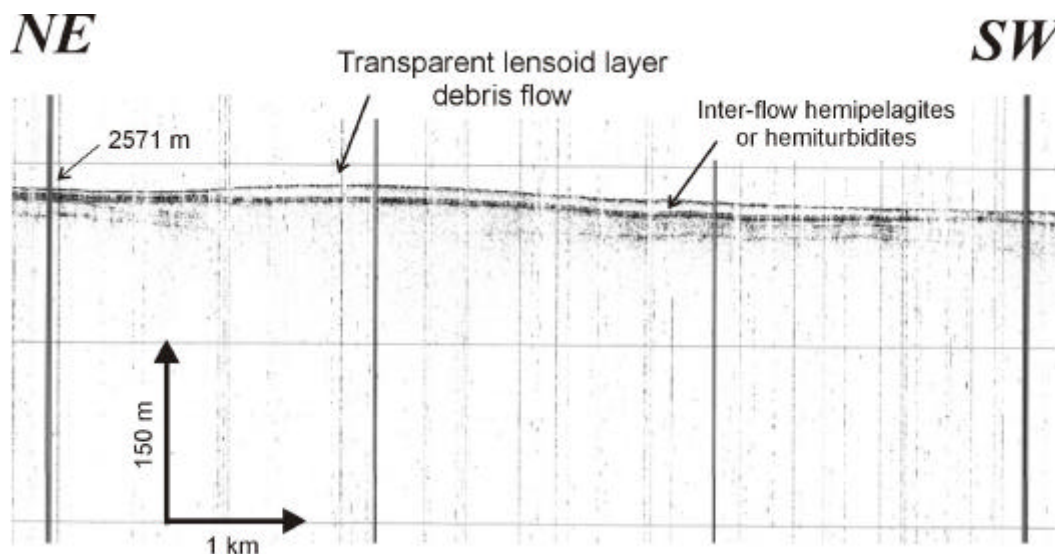


Figure 5. Lensoid debris flow. The sediment sheet is transparent with no indication of an internal structure. This suggests that it represents a distinct flow event. The sediment deposit overlies a very thin but discernable laminated (hemipelagite/turbidite) layer.

A clear variation in sedimentary processes is evident from north to south across both sectors of the margin. This reflects a diminishment in glacial influence southwards from the prograding Donegal Fan during the Pleistocene epoch. The formation of sediment aprons and canyon complexes is linked to the advance of glaciers during glacial stadials. They are probably controlled by the high debris input from Quaternary glaciers at the mouths of broad troughs, which cross the shelf region west of Donegal. The flux of ice rafted debris is likely to be highest and the frequency and magnitude of slope failure events largest, when glacial ice crosses the continental shelf and sea level is low. Strong NE flowing bottom contour currents as indicated by longitudinal bedforms dominated post glacial slope processes (O'Reilly *et al.* 2000).

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme.

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Geological and geotechnical analysis of gravity cores from the Rockall Trough

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A suite of 45 gravity cores was obtained in 1998 on the slopes flanking the Rockall Trough. Most of these are clustered in areas targeted for deeper drilling, with some isolated cores acquired on seabed features identified on the basis of regional sonar work. This poster presents the geotechnical and geological methods and techniques used in two related projects. Project 99/01 is concerned with investigating the history of slope instability and the importance of bottom current processes on the flanks of the Rockall Trough. Project 00/17 is involved with a geotechnical analysis of the cores and will quantify some of the seabed and near surface lithologies in various slope settings along the Rockall Trough. Site 1 (Block 83/24), located on the northwest flank of the Porcupine Bank, will be used as an example to illustrate the work.

Each core, which is approximately 2-3m long, is divided up into boxes, varying in length from 20 cm to 1 m and all have a diameter of c. 87.5mm. Prior to opening the cores two opposing longitudinal grooves were cut with a mechanical saw to a depth of approximately 90% of the thickness of the perspex casing. A blade was used to manually cut through the remaining perspex casing along the groove. A guitar string was drawn through the core dividing it into two halves. A digital camera was used to take photographs of the split core immediately after opening. Figure 1 shows an example of a core photo from block 83/24. One half was used for sampling and the other half was preserved for reference and logging. The half core kept for sampling was further divided longitudinally by using glass plates, with half the core reserved for geotechnical sampling and the other half being used for geological sampling. Samples were chosen so as to capture all the key lithologies in each core, and spaced so as to avoid sampling across lithological boundaries. All cores were logged graphically at a scale of 1:10.

Geotechnical tests were carried out according to the guidelines set out in BS1377 (parts 1 and 2). Specific gravity tests were carried out using the small pycnometer method described in BS1377 (part 2). This involves placing a known weight of the sample into a small vessel of known weight and volume. The bottle is filled with distilled water and all air is removed. The specific gravity of the sample is determined by contrasting this weight with the weight of a bottle full of water. The liquid limit is determined by using a small cone penetrometer, again as specified in BS1377 (part 2). Particle size analyses were carried out in two phases. The material was initially passed through a full suite of sieves from 2 mm down to 63 µm. The fraction passing the 63 µm sieve was then transferred to a sedimentation cylinder. From both of these Grading curves were obtained from both methods using the hydrometer technique described in BS1377 (part 2).

Selected cores were X-rayed prior to and after opening. This was done in order to reveal any cryptic structures in the cores (subtle laminations, bioturbation, dropstones). A pilot programme of grain size analyses was performed by laser grain size analyses at the University of Leeds. High-resolution carbonate profiles have been generated for the most complete cores. The carbonate content was measured using a Scheibler Calcimeter acquired for the purpose. A small sample (0.1 - 0.2 mg) was dried, crushed and weighed. The sample was then dissolved in HCl. The Scheibler Gasometer measures the amount of CO₂ liberated in the reaction between the carbonate and the HCl. The percentage carbonate content can then be calculated from the amount of CO₂ released. Point counting of the bioclastic and siliciclastic grains has started for core 83/24sc005. The objective is to assess temporal variations in the nature, amount and provenance of the ice-rafted material. Representative samples were dried, weighed and then sieved through a 125 µm sieve. The material collected on the sieve was weighed in order to calculate the percent of sample above 125 µm, and ultimately to quantify the volumes of different lithics. A thin section was prepared of the sieved fraction and standard point counting was performed.

A number of basic trends have been observed in the geotechnical characteristics of the sediments. Moisture contents, while varying from site to site, overall showed a drying out with depth. They did,

however, show a significant scatter with a range of 20% to 80%, with values varying as much as 34% over a 97cm depth range. Particle densities had a mean value of 2.54 g/m^3 with a standard deviation of 0.15 g/m^3 . Overall the values were approximately constant with depth, with a possibility of an increase with increasing depth. The average value obtained was within the values for a non-organic siliceous soil (2.65 g/m^3), which corresponds with the geological results.

In the geological part of the study 11 units (Units 1.A – 1.L from base to top), based on lithology, colour and grain size, have been identified in Block 83/24. The cores show good internal detail in terms of compositional and textural variations, and physical and biogenic structures. See Figure 1 for a picture of core 83/24 sc005. The cores show alternations of carbonate mud and unsorted quartz and foraminiferal sand, occasionally with scattered pebbles. The depositional history of the area can be mostly explained by Quaternary climatic changes and changing sediment supply, with high carbonate production during warm periods and low carbonate production during cold periods. The climatic interpretations are based on lithology, sedimentary structures and carbonate content.

The detailed stratigraphic archive revealed by the cores show that a variety of depositional processes work along the flanks of the Rockall Trough. More work is required in order to fully understand these processes and the bottom conditions in the Rockall Trough. The cores and the sediments need to be studied in more detail (more point counting, additional carbonate profiles, oxygen isotope analyses, XRD of the clay minerals, etc.). Dating is required to achieve an absolute chronology of the mass movement events and changing sediment supply. The cores need to be fully integrated with the seismic lines and with the TOBI images available for the area. It would also be useful to tie the core records to longer piston cores in the area to see how the stratigraphy and the processes recognized might extend to greater depth.

The geotechnical work for Block 83/24 is now nearing completion. Future work will focus mainly on Sites 3 and 3A, Block 11/20, on the northeast flank of the Rockall Trough. This is an area which has undergone relatively recent slope failure. This is in contrast to Site 1, which is an area which seems relatively stable. It is hoped to perform consolidation tests and shear strength tests in order to establish the consolidation history of some of the sites and to ascertain the susceptibility of the material to slumping. More grain size analyses are planned in order to estimate the susceptibility of the sediments to slumping. Correlations between the laser sizing method of particle size analysis and the hydrometer method are also planned.

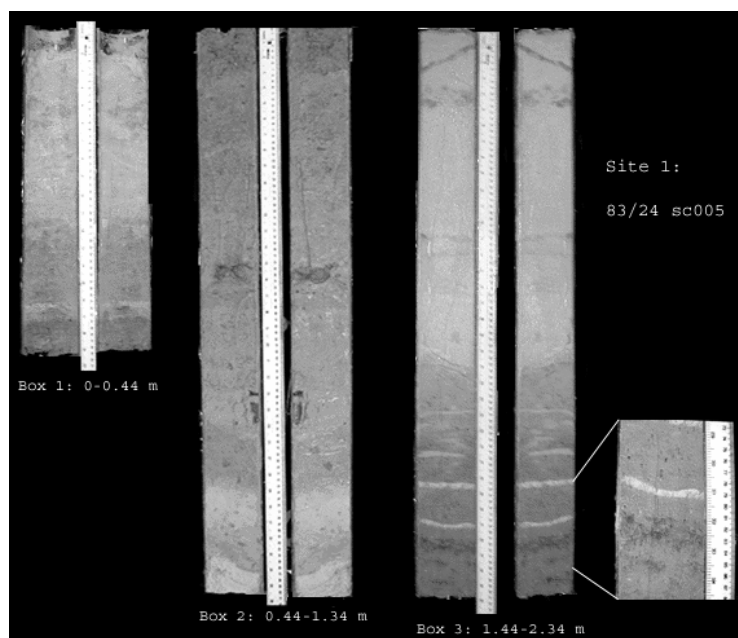


Figure 1. Digital photograph of core 83/24 sc005 located on the northwest flank of the Porcupine Bank.

Acknowledgements

These projects have been undertaken on behalf of the Irish Petroleum Infrastructure Programme.

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Metal analyses of surface sediment samples collected for the RSG in the Rockall Trough

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As the technology for deepwater drilling develops, areas previously considered inaccessible are being explored. With this in mind, this project aimed to establish background levels for a wide range of metals from an area around the Rockall Trough where exploration is possible in the future. Limited data is currently available for marine sediments for this area and water depth. During 1998, surface sediment samples were collected in the Rockall Trough for the Rockall Studies Group (Fig. 1). The work was carried out under contract by the vessel RRS Challenger, operated by the British Geological Survey.

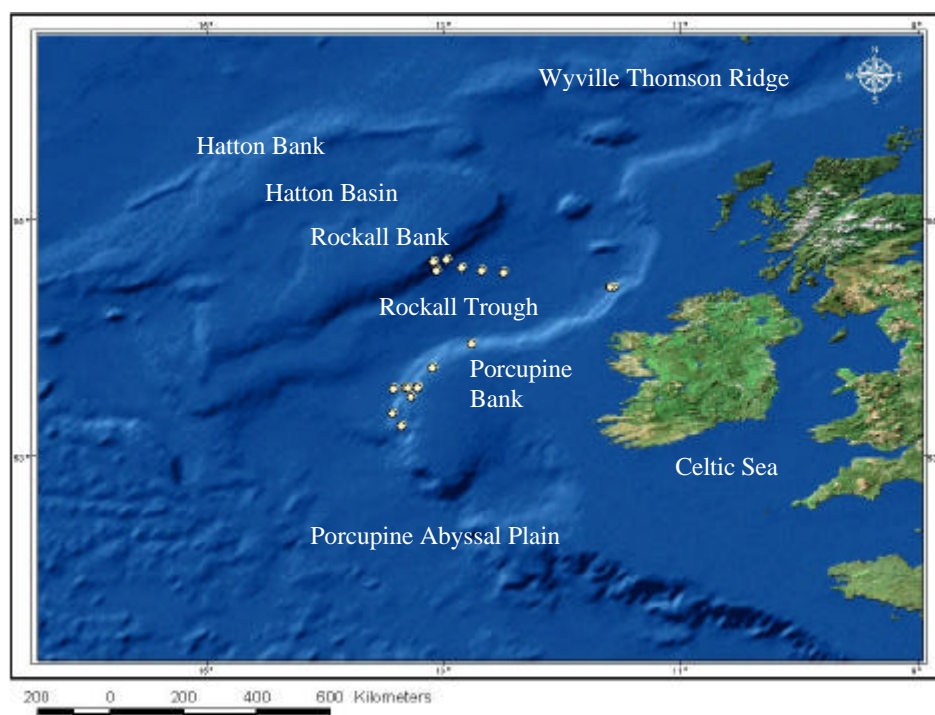


Figure 1. Locations of samples collected for the RSG in 1998

The principle objectives of this study were:

- to develop and validate methods for the analysis of a range of metals of environmental interest in 32 surface sediment samples from the area in and around the Rockall Trough
- to compare the results obtained with literature data
- to determine the spatial distribution and establish baseline concentration ranges of the metals in surface sediments samples collected from the area around the Rockall Trough.

The samples were collected from gravity cores taken at water depths ranging from 700 to 2774 metres and generally consisted of muds and sands. Sediments were freeze-dried and large aggregates broken up. Stones and large shell or coral fragments were discarded and material that passed through a 1 mm stainless steel mesh was retained for analysis.

Samples were analysed for lead, cadmium, chromium, copper, nickel, zinc, vanadium, strontium, barium, lithium and aluminium by Atomic Absorption Spectroscopy (Flame and Graphite Furnace) following total microwave digestion (0.1 g freeze-dried sample, hydrofluoric acid (6 mls), reverse aqua

regia (1 ml, 3:1; nitric acid: hydrochloric acid). Mercury was analysed by Cold Vapour Atomic Fluorescence Spectroscopy following partial microwave digestion (0.2 g freeze-dried sample, nitric acid (4 mls)).

Table 1: Summarised results (mg kg⁻¹, unless stated otherwise) dry weight of metals in total sediments from 32 surface sediment samples taken from Rockall Trough. Agreed ecotoxicological assessment criteria (EAC) for trace metals in sediments taken from the Oslo Paris Conventions for the Prevention of Marine Pollution Joint Meeting of the Oslo Paris Commissions (OSPARCOM) Brussels: 2-5 September 1997 (Anon, 1997).

Determinand	Mean	Median	Std. Deviation	Range	Ecotoxicological Assessment Criteria	ICES 1990/91 North Sea	ICES 1993 Baltic Sea
Mercury	0.069	0.045	0.071	0.025 – 0.353	0.05 – 0.5 (p)	0.057 – 0.08	0.013 – 0.406
Lead	8.51	8.45	2.40	3.43 – 16.2	5 – 50 (p)	1.7 – 288 (mean=21)	20.7 – 200
Cadmium	0.251	0.144	0.442	0.027 – 2.57	0.1 – 1 (p)	0.01 – 0.38 (mean=0.05)	0.085 – 10.95
Chromium	28.7	27.4	8.18	15.1 – 54.2	10 – 100 (p)	3 – 117 (mean=30)	47.7 – 130
Copper	17.1	14.6	8.78	5.89 – 42.7	5 – 50 (p)	0.1 – 87 (mean=14)	20.5 – 211
Nickel	18.3	15.5	7.33	8.83 – 38.9	5 – 50 (p)	1.5 – 113 (mean=23)	27.1 – 517
Zinc	41.4	32.9	26.6	18.0 – 149	50 – 500 (p)	3 – 510 (mean=39)	59.7 – 1021
Vanadium	45.4	40.3	25.9	16.4 – 139	-	-	57.6 – 193
Strontium	950	939	440	214 – 2089	-	-	-
Barium	324	316	106	115 – 543	-	-	-
Lithium	19.7	17.4	10.6	4.51 – 55.7	-	-	33.3 – 140
Aluminium (%)	2.70	2.60	1.19	0.860 – 6.23	-	0.1 – 9.29	3.5 – 10.3

For meaningful temporal and spatial comparisons of the contaminant concentrations in sediment monitoring, it is essential to normalise for the influence of natural variability in sediment composition.

Data interpretation includes geochemical normalisation, which involves the use of elements such as aluminium and lithium as tracers to normalise for grain size effects. Total (bulk) sediments are analysed in this approach, eliminating the problems associated with sieving (handling of aggregates, possible contamination, leaching and enrichment). Lithium was chosen as the preferred normaliser during this study.

This present study shows that the majority of trace metal concentrations detected in the samples collected were at background levels. Deeper water regions are rarely exposed to the same levels of anthropogenic inputs as coastal regions and as a result, lower concentrations are to be expected. All levels detected were below or within the provisional ecotoxicological assessment criteria for each metal where available.

The analytical quality assurance programme included the use of a number of Certified Reference Materials (CRMs) to validate the accuracy and precision of the analytical methods developed and to provide ongoing quality control. Participation in QUASIMEME (Quality Assurance of Information in Marine Environmental Monitoring) proficiency testing scheme also underpins analytical quality.

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme

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Acoustic surveys of Cetaceans in Irish waters

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Cetaceans rely on sound as their main sense for communication, navigation and prey capture. Acoustic surveys of cetaceans have been conducted by the University College, Cork from several vessels of opportunity and one dedicated vessel (Fig. 1) since August 2000.



Figure 1. The SIAR survey vessel, MV Emerald Dawn.

The equipment consists of a 300 m-long towed hydrophone array linked directly to an on-board PC with specialised software for the automatic detection and analysis of cetacean vocalisations (Fig. 2). Tonal and pulsed sounds of toothed whales and dolphins included in the 200Hz-22kHz range are monitored, allowing the detection of animals up to several kilometres away from the survey vessel.

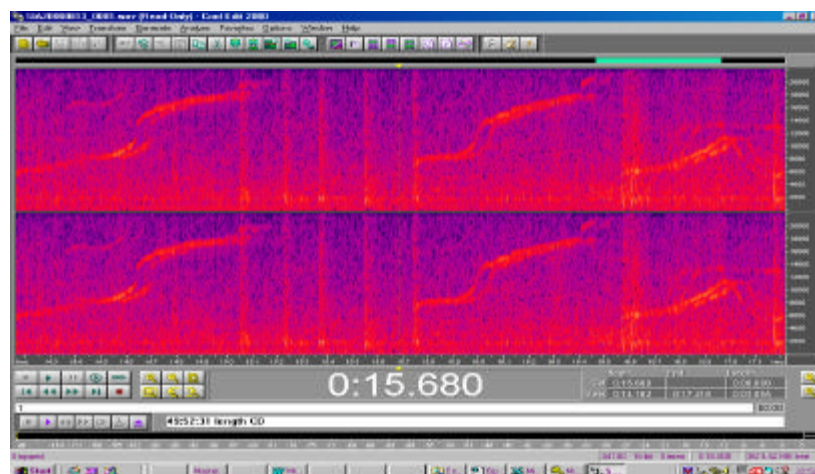


Figure 2. Software used for cetacean tonal sound detection and spectral analysis.

As such, the research team can identify the vocalising species (Fig. 3) with a view to providing species distribution maps and abundance indices over the study area. This area encompasses the offshore waters to the southwest and west of Ireland, stretching from the Goban Spur to the Porcupine Seabight, Rockall Trough and including adjoining continental shelf areas. More than 5,590 km have been monitored acoustically to date, through a variety of environmental conditions and over 24-hour periods.

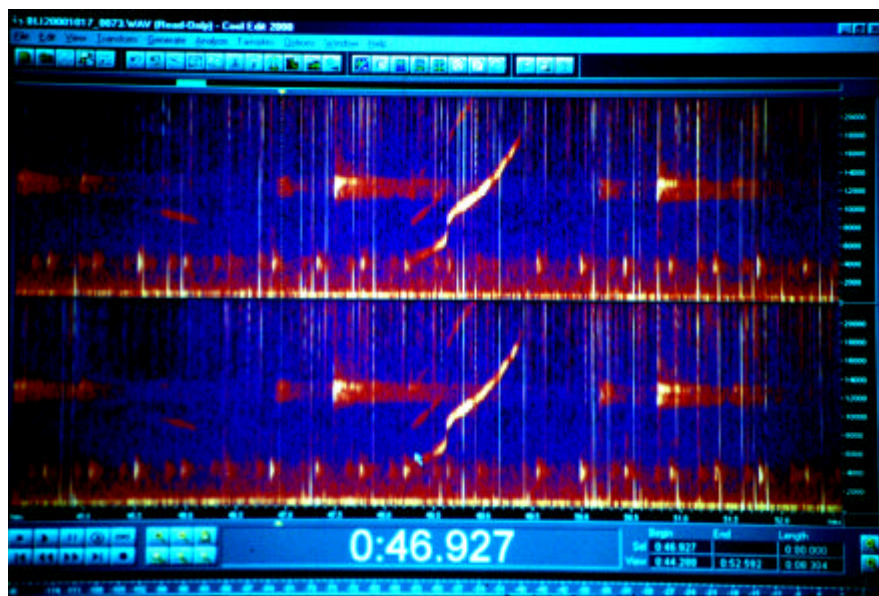


Figure 3. A PC monitor display of dolphin whistle detection software in operation, showing a distinct whistle detection in the centre of the screen.

The hydrophone array has also recorded airgun echoes from a source distance over 150 km away. Seismic airguns, drilling operations and increased shipping traffic increase background noise both in low and high frequency components. There has been little research so far into the effects of marine industrial activities on cetaceans, and some aberrant behaviour of the animals influenced by them may be less important than potential exclusion of cetaceans from important habitats. Acoustic monitoring, such as that employed here, provide an effective research tool for the determination and minimisation of real and potential impacts of such human activities on cetaceans.

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Regional habitat mapping in the Irish Rockall Trough using geological and geophysical data

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What is a regional habitat map?

A regional habitat map is a map indicating the extent and distribution of the main biological habitats that may be expected in an area, based upon knowledge of: bathymetry, seabed hardness, current activity, other physical and chemical oceanographic data and existing biological information from other sources (usually academic). It is produced to enable interested parties to understand regional seafloor types and processes, and from these to obtain an overview of the likely biological environment.

Have such maps been produced before?

Over the past decade, tools such as side-scan sonar and multi-beam sonar have come of age and become available to a much wider community. Projects in both deep and shallow water have been using these techniques as regional mapping tools in order to investigate the general context and lay of the seabed. In the UK, for example, there is an increasing use of side-scan sonar for coastal habitat mapping projects, and the AFEN consortium of oil companies have been at the forefront in the introduction of these techniques for environmental research.

Imagine that, instead of a seafloor map, we were producing a "vegetation" map of a remote land area from satellites and some varied local information. This is what is being done here but for the marine environment. While it has never been done in exactly this way before, the AFEN work and the work of the DTI in their Strategic Environmental Assessments has used all of the techniques to be employed.

Emphasis on processes

While the principal characteristic affecting the nature of deep sea benthic biological communities is undoubtedly water depth, a wide range of other features can have very significant affects on the biological environment. These include: water quality (e.g. Arctic vs Atlantic), food supply, near-bed currents, substrate type and gas/oil seepage. Such processes modify the simple bathymetric distribution of habitats in both time and space. This type of map attempts to reveal processes as much as possible in order to understand the natural stability of the seafloor environment.

Natural changes

Data from Porcupine Abyssal Plain have shown that even at abyssal depths and over relatively short periods of time (<5 years) dramatic changes in the biological community can occur without any obvious anthropogenic influence. At the local scale dealt with in many Environmental Impact Statements, such changes could completely negate the value of environmental data collected for the EIS. However, a regional view may reveal broad-scale variability and possibly some of the processes potentially responsible for natural changes. It is important to note that these processes may not be revealed when the regional habitat map is drawn but at a later date when the map is compared to anomalous observations made at a specific site.

What types of data are used?

Regional - geophysical

At the regional scale (10-100km) the most commonly available data are: 3-D seismic, GLORIA (long-range side-scan sonar), Multibeam and TOBI (medium range side-scan sonar).

Local - geological

At the more local scale (1-10km) the most commonly available data are high resolution multi-beam and side-scan sonar, towed camera surveys and observations such as currents. These are collected routinely by cable and oil companies looking for information on the physical nature of the seabed; at the same time, the techniques provide valuable data on the potential biological environments.

Detailed - biological

Sampling techniques range from the use of towed gears (e.g. trawls, dredges and epibenthic sledges) sampling collecting large animals (megafauna) from hundreds or thousands of square metres of the seafloor, to corers designed to take undisturbed samples of the sediments and the overlying water, together with the enclosed macro- and meiofaunal organisms. Such core samples can also be used to investigate the sediment physics and chemistry.

Photographic techniques, time-lapse, survey and sediment profiling, can also be powerful and labour saving tools, particularly where some knowledge of the broad area is already available.

How may regional habitat maps be used?**Scientific research**

These types of maps enable planning of scientific research. The carbonate mounds in Irish waters and the sandy Darwin Mounds in UK waters were all identified using regional survey tools. Their discovery and location enabled preparation for detailed and well organised studies so enabling scientists to focus their resources on the critical areas of interest.

Environmental protection

Identification of sensitive areas is possible once an entire region has been mapped. Increasing concerns over the need to identify potential special areas of conservation under the EU habitats directive make this type of map extremely useful.

Oil & Gas E&P activities

Regional context enables operators to understand processes that may affect their area of operations but are controlled from further away. A large contourite deposit for example would indicate that fine sediment transport will occur in a region and may be episodic. Local studies in the area of a rig may not reveal that.

Human vs naturally forced changes are difficult to determine in a small area. The context of a regional map may indicate the existence of natural processes that could be blamed upon the industry.

Design and development issues are greatly enhanced by regional information. On the Irish margin for example, regional environmental information may reveal the presence of submarine landslides that are not detectable within the operations area (usually a 5km square box).

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Central Rockall Basin 1:500,000 Solid Geology Map – British Geological Survey and Petroleum Affairs Division, Ireland.

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The solid geology map of the Central Rockall Basin, located in Fig. 1, has been compiled by the British Geological Survey (BGS) in collaboration with the Petroleum Affairs Division (PAD) of the Department of the Marine and Natural Resources, Ireland. This map is a draft copy of the final approved (BGS and PAD peer review) compilation, which is shortly to enter the BGS drawing office leading eventually to external publication.

This mapping exercise was undertaken as part of the BGS's continuing commitment to offshore reconnaissance mapping of the UK Atlantic frontier margin. The decision to include the northern part of the Irish Rockall Trough (to 56°N) also reflects PAD's involvement in promoting a better understanding of the Irish offshore region, and their desire to work with the BGS to further this goal. Consequently, an extensive and varied geological and geophysical dataset was available for this study. In addition to the BGS high-resolution seismic reflection data and borehole information collected east of 10°W, the dataset also included the following:

- BGS / Rockall Consortium high-resolution and deep-seismic profiles, and shallow borehole and core information.
- Mobil deep-seismic data purchased by the BGS / Rockall Consortium.
- Various commercial deep-seismic data and well information provided by the PAD for the northern Irish sector.
- Deep seismic data, well information and reports supplied by BP from their study of 'The Hydrocarbon Potential of Licence P548 and the Hebridean Margin'.
- The Fugro-Geoteam WRM96 dataset.

All of these data have helped to build upon the preliminary mapping in the Central Rockall Basin previously reported by Stoker & Gillespie (1996) and Stoker *et al.* (1999). Due to the large area covered by the mapping project, the map has been drafted at a scale of 1:500,000. The development of the structural framework benefited greatly from the Irish Petroleum Infrastructure Programme's (PIP) Rockall Studies Group structural nomenclature project (Naylor *et al.* 1999), which was made available to this study prior to its publication. A partial revision of some of the structural terminology, e.g. Rockall Trough and Bank become Rockall Basin and High, follow recommendations made by Naylor *et al.* (1999). These structural elements are summarized in Fig. 1. The reappraisal of this region has also resulted in a partial revision of the geology of the Hebridean margin, between 8° and 10°W, as currently depicted on the published BGS 1:250,000 solid geology maps of St Kilda and Peach.

Acknowledgements

This map could not have been compiled without the considerable help and encouragement of the following companies, institutes and individuals:

- Between 1992 and 1995, when the UK Central Rockall Basin dataset in this area was acquired, the BGS was supported in a consortium – the Rockall Consortium – by 8 exploration companies consisting of BP, British Gas, Conoco, EE Caledonia, Elf, Enterprise, Esso and Mobil.
- Noel Murphy and Peter Croker of the PAD provided data for the compilation phase, constructive comments during the review process, and encouragement throughout the project.
- Brian Mitchener of BP supplied the reports covering 'The Hydrocarbon Potential of Licence P548 and the Hebridean Margin'.
- Pat Shannon (University College Dublin) and David Naylor (ERA-Maptec Ltd, Dublin) helped to clarify aspects of the structural framework in the northern Irish Rockall Basin.
- Peter Broad of Fugro-Geoteam granted access to the WRM96 dataset.
- BGS colleagues, Ken Hitchen, Dan Evans, Derek Ritchie and Howard Johnson all provided various kinds of input (data and comment), and Richard Carruthers compiled the gravity image.

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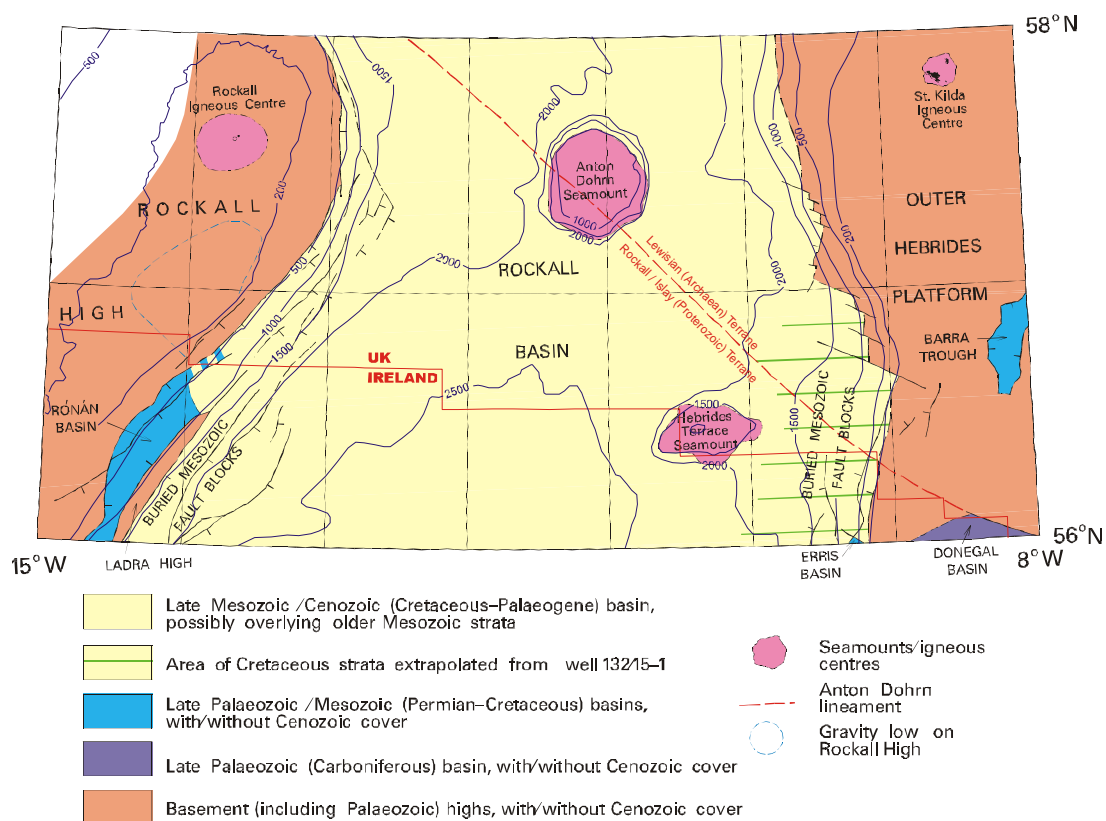


Fig. 1 Map showing area of study together with main structural elements, which summarize several key phases of basin development. Structural information from the Irish sector is based on Naylor *et al.* (1999). Bathymetric contours in metres.

Middle to Upper Cenozoic Stratigraphy, Rockall Trough

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The montage of seismic profiles presented on this poster has been compiled as part of a preliminary Landmark interpretation of the middle to upper Cenozoic stratigraphy of the central Rockall Trough. This project utilised the high-resolution seismic reflection (airgun) profiles – cruise 92/01 – which was acquired by the BGS Rockall Consortium in 1992. These data were acquired digitally in the form of six trace shot gathers; thus it was necessary for them to be processed using ProMAX to create final seismic sections. Further details of the processing sequence can be found in Bulat (1993).

The fundamental objective of this short project was to instigate a Landmark-based interpretation of the 92/01 data, utilising a recent seismic-sequence stratigraphy established in the central and southern Rockall Trough by Stoker *et al.* (2001) (Fig. 1). Three key reflectors and megasequences have been identified for the middle to upper Cenozoic succession. Although the 92/01 database was included in the establishment of this stratigraphic framework, reflector identification across the entire survey area, and local mis-ties between profiles, remained a problem. Moreover, all of the interpretation prior to this study had been undertaken on paper copies of the seismic profiles. Thus, the interpreted data was not easily updated in the light of more recent studies and had a very limited client accessibility. Consequently, in a bid to improve the quality of the seismic interpretation, as well as the database management and archiving, this landmark project was initiated. The funding made available by the BGS Rockall Consortium enabled an initial data-loading phase followed by a preliminary interpretation and reporting phase to be completed. The poster presents five examples of the 92/01 airgun data interpreted in terms of the key middle to upper Cenozoic reflectors, a brief summary of the age and origin of the reflectors, and some specific descriptions of features associated with each profile.

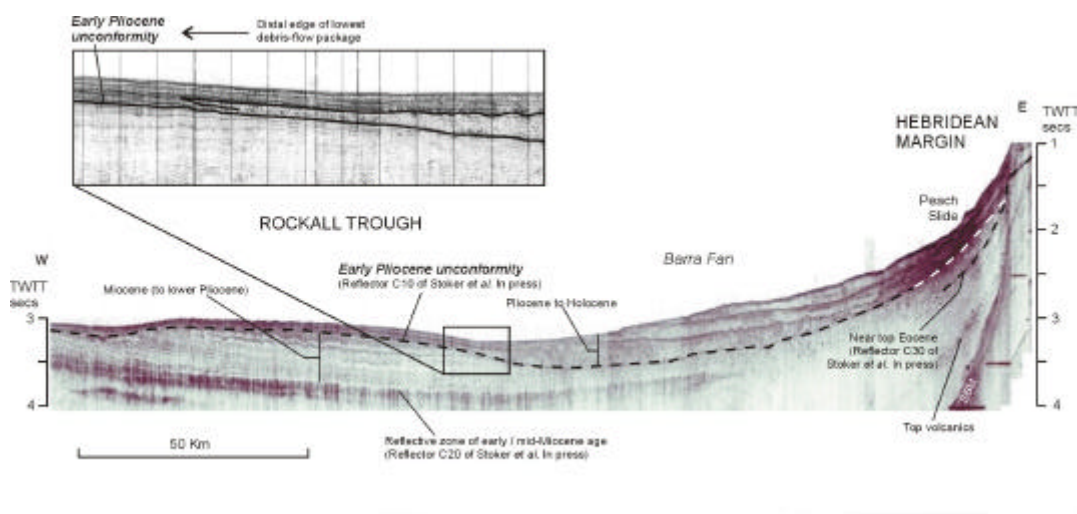


Fig. 1 BGS airgun profile 92/01-56 from the eastern part of the Rockall Trough (UK sector) showing the mid- to late Cenozoic stratigraphy of Stoker *et al.* (2001). Note especially the onlap of the basinal C10 reflector (early Pliocene unconformity) onto the C30 reflector (near top Eocene) in the mid-slope area of the Hebridean margin. The C10 reflector forms the base of the shelf-margin, Plio-Pleistocene prograding wedge of the Barra Fan as well as a regionally mappable, deep-water, angular unconformity.

The inset shows the interdigitating nature of the shelf-margin debris-flow deposits with the basinal turbidites and contourites.

The timing of this study has fitted very well with recent developments concerned with improving our understanding of the mid- to late Cenozoic evolution of the continental margin west of Britain and Ireland. This wider impact includes:

1. Future integration with the seismic data collected by the BGS Rockall consortium from the Rockall Plateau in 2000.
2. Linkage with the PIP/RSG¹ shallow stratigraphy project in the Irish Rockall Trough (Austin 2000).
3. Linkage with the EU Stratagem² project – a 3-year project that started in March 2000 – that is designed to establish a unified mid- to late Cenozoic stratigraphy for the NW European Atlantic margin between Ireland and mid-Norway (Evans 2000).

The next stage in the development of the database is to revise and integrate the existing seismic-stratigraphic interpretation in the light of these recent developments. Consequently, it will now be much easier to update the Landmark-based 92/01 dataset, therefore providing an interpretation for members of the BGS Rockall Consortium that will reflect the current state of knowledge of the shallow stratigraphy. One example of the importance of this knowledge is illustrated by the widespread recognition of reflector C10 – the intra-early Pliocene angular unconformity – both on the shelf-margin and in basinal environments (Fig. 1). This implies a significant margin-wide event in the late Neogene that includes uplift of the Hebridean margin, which may have major implications for the petroleum system along the Atlantic margin west of Britain and Ireland.

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¹ Petroleum Infrastructure Programme / Rockall Studies Group

² Stratigraphical Development of the Glaciated European Margin – STRATAGEM (www.stratagem-europe.org)

The Geology of Hatton Bank (UK sector)

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Hatton Bank is a large, elongate, irregularly-shaped underwater bank situated in the NE Atlantic Ocean 800-1000 km west of Scotland (Fig. 1). However during the Mesozoic the area was only 800 km NE of Newfoundland and it remained close to SE Greenland until continental break-up started west of the bank at about 55Ma. Interpretation of deep seismic lines shot in 1987 suggested that at least part of Hatton Bank comprises large-scale, highly tilted, rotated fault blocks with associated half grabens infilled with dipping sediments, some of which have a resolved interval velocity of 5.1 – 5.3 km/s (Keser Neish 1993).



Figure 1. BGS Rockall Consortium seismic data coverage across Hatton Bank (black lines). Location of BGS line 98/01-73 is highlighted in orange. Lyonesse and Sandarro are (?Tertiary) igneous centres which have extruded lavas in a radial pattern (shown diagrammatically). Bathymetry contours in blue (depths in metres).

On behalf of the UK Rockall Consortium, the BGS has undertaken geophysical surveys (1998 and 2000) and shallow drilling (1999) on Hatton Bank in the UK sector adjacent to the UK/Irish median line. These data, combined with potential field studies and 1987 DTI and 1990 GEUS seismic data, have allowed further understanding of the bank.

The Tertiary succession in the Hatton Bank area can be divided into three mega-sequences separated by two marked unconformities. Although not yet dated by drilling on Hatton, similar regional unconformities, which have been identified on the Atlantic Margin from Norway to SW Ireland, have been dated (in the Rockall Basin) as Late Eocene and Early Pliocene (Stoker *et al.* 2001).

Early Tertiary (presumed) subcropping lavas are widespread on Hatton Bank. These have been extruded from large central igneous complexes (with associated near-circular positive gravity anomalies) and fissure eruptions. The juxtaposition and variations in the seismic character and magnetic response of the lavas has allowed the extent and relative differences in age to be mapped.

Where the lavas are absent, seismic data image pre-Tertiary sediments which, in places, are faulted and folded (Fig. 2). Regional considerations suggest an age range of ?Carboniferous to Cretaceous for these sediments. Similar, mainly Mesozoic, sedimentary successions offshore Newfoundland and Labrador have yielded numerous hydrocarbon discoveries (DeSilva 1999) including the producing

Hibernia oilfield in the Jeanne d'Arc Basin. Hence, the geology of Hatton Bank has significant implications for the prospectivity west of the UK and Ireland. Although Hatton Bank is a present day bathymetric high, seismic and gravity data suggest that much of the bank is not just a large pre-Cambrian block but that it has a more complicated geological history.

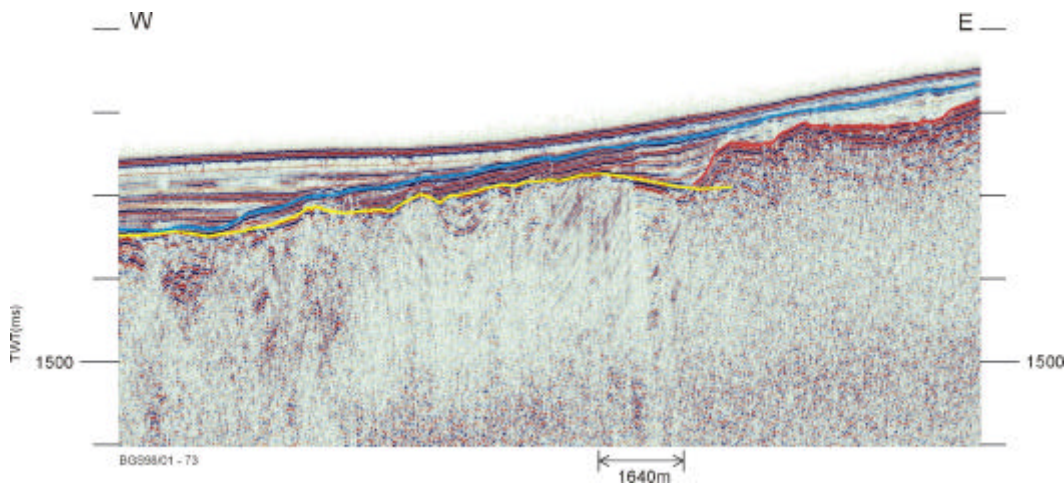


Figure 2. Example of seismic data from Hatton Bank (part of BGS seismic line 98/01-73). The lavas (red horizon, extreme right), derived from the Sandarro igneous centre, rest directly on folded 'Mesozoic' rocks. The eroded, fossil landscape surface of the 'Mesozoic' is highlighted in yellow. The unconformity (blue horizon) within the well-bedded Tertiary strata is probably Early Pliocene age.

In 2001 and 2002 BGS will collect short, sea-bed cores from Hatton and Rockall Banks as part of its non-commissioned Science Budget work programme. A full suite of descriptions and analyses will be undertaken on the material including geochemical, isotopic and age determinations on the basement and lava samples collected. In future years BGS plans more geophysical surveying and shallow drilling in the Hatton-Rockall area.

Acknowledgements

The 1998-2000 data acquisition on Hatton Bank was largely funded by members of the UK Rockall Consortium which comprised BGS and Agip, Amerada Hess, Arco, BG, BP-Amoco, Conoco, Elf, ExxonMobil, Phillips, Shell, Statoil and Texaco.

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Bathymetry map of the Irish Rockall Trough

Mike Postle-Hacon

*Hydrossearch Associates Ltd, Goldsworth House, Denton Way, Goldsworth Park, Woking, Surrey,
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This work is concentrated primarily in the Irish sector of the Rockall Trough concentrating upon licensed acreage in the SE, NE and NW Rockall regions. The overall objective was to provide both regional and more detailed industry standard contoured bathymetric maps to be fit for purpose in most aspects of hydrocarbon exploration activities. This task would involve communication with academic and other organisations in conjunction with the RSG's project mentor to access useable digital terrain model (DTM) information or regular x,y,z ASCII files of seabed picks throughout the Study Area. The following datasets would be considered for inclusion, with emphasis on digital data:

- PGS 3D Seismic (regional, NE Rockall)
- PGS 3D Seismic (local, NE Rockall)
- Proprietary 2D Exploration Seismic data from Rockall Basin
- PIP/RSG commercial 2D Exploration seismic database
- NIOZ 2D seismic and/or pinger data
- Dept of the Marine and Natural Resources (regional 2D Seismic & PAD96 bathymetric data)
- IFREMER Swathe Bathymetry data
- GEBCO Bathymetry, GEODAS trackline bathymetry
- US Navy 5 arc minute grid bathymetry data

Navigation QC/QA would include conversion of datasets where appropriate to the following geodetic parameters:

Projection:	Universal Transverse Mercator
Zone:	28 North
Spheroid:	WGS 84
Central Meridian:	15.0° West
Datum:	WGS 84

Seismic, including the PIP 2D commercial exploration data, or other data, was to be loaded into workstation interpretation systems to allow picking of seabed horizon where not already completed. The picked seabed horizons from the various datasets would then be loaded into one unifying system e.g. ER-Mapper v6 and Petrosys for subsequent processing and interpretation. The following will be applied in an iterative manner to ensure integrity of the final product:

- Merging of the various datasets, editing and filtering or other manipulations.
- Decision on data class ordering
- Gridding procedures (minimum grid likely to be 100m x 100m) utilising minimum curvature algorithms.
- T/D conversion, (suggested oceanic water layer velocity will be 1490m/sec unless otherwise advised).
- Editing, QC/QA and contouring prior to final map construction.

Finally, regional and detailed bathymetry maps would be constructed at scales and projections to be defined, e.g. regional map (UTM Zone 28) at 1:1,000,000 scale with isobaths every 500m or 250m (1:2,500,000, A3 version for final report); detailed area specific maps (UTM Zone 28) at 1:500,000 scale (1:1,500,000, A3 version for final report). Where appropriate a grid interval of 100 x 100m was envisaged for the detailed mapping.

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme.

Compilation Map – PIP database and other relevant datasets

Martin Davies¹ and Eilis Vaughan²

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² *ERA-Maptec Ltd, 36 Dame Street, Dublin 2, Ireland.*

The PIP Database map was initially prepared to help members locate the many Rockall Studies Group (RSG) related datasets visually. The datasets shown include data acquired directly by the Rockall Studies Group (Challenger 1998, TOBI 1999, RAPIDS 1999, Bucentaur 1999, SIAR 2000), licenced by the RSG (Logachev 1997, Pelagia 2000) or datasets of particular relevance to certain RSG projects (seabed imagery, seismic and coring datasets).

The map was then updated to include datasets of interest to the Porcupine Studies Group (PSG), such as WARR seismic data. The map was renamed as the PIP Database map.

The map has been developed by ERA-Maptec using Arc-Info, using data supplied by the RSG and PSG Secretariats. The version shown is at 1:1,000,000 scale and covers the Rockall and Porcupine Basins. As each dataset is stored as an Arc-Info coverage, maps can be produced at any scale for any part of the Irish Offshore.

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme.

Demo Presentations

(by order of programme)

PIPDI - PIP Online Data Inventory

Brian McNamara¹, Martin Davies², Michael Hanrahan³ and John Gowen²

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²*CSA Group Ltd, 7 Dundrum Business Park, Windy Arbour, Dublin 14, Ireland.*

³*Petroleum Affairs Division, Dept. of the Marine and Natural Resources, Beggars Bush, Haddington Road, Dublin 4, Ireland.*

The PIP Data Inventory (PIPDI) was developed by ISL and CSA, with input from the PAD, in order to collate meta-data which describe the datasets collected by the various RSG and PSG funded research projects. Population of the database with RSG meta-data was carried out by the PAD with assistance from CSA. Population of PSG meta-data will be performed by respective project teams.

The meta-data are divided into four categories:

- Cruises
- Datasets
- Documents
- Projects

All meta-data can be searched by free-text searching, keywords, geo-location and other search criteria and each record contains links to any related meta-data as well a link to the contact details of relevant organisations or institutions. In the case of datasets and documents the storage location is recorded.

In addition, the 'Other Datasets' module can be accessed via the PIPDI. This module was populated by CSA and contains metadata from the following PIP projects:

- 97/51 - Data Review for the RSG Seabed Committee
- 97/52 - Environmental data gathering and preliminary assessment for the RSG Environmental Committee
- P00/14 - An inventory of geological and environmental data in the Porcupine Seabight and adjacent areas.

And, it is planned to populate the Other Datasets module with further meta-data in the future.

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme and a financial contribution was made by the Geological Survey of Ireland.

An inventory of geological and environmental data in the Porcupine Seabight and adjacent areas, including an update for the Rockall Trough inventory

Andy Wheeler¹, Martin Davies² and Patrick Shannon³

¹*Coastal Resources Centre, University College Cork, Western Road, Cork, Ireland.*

²*CSA Oil & Gas Services Ltd, 7 Dundrum Business Park, Windy Arbour, Dublin 14, Ireland.*

³*Department of Geology, University College Dublin, Belfield, Dublin 4, Ireland.*

Geological and biological sampling of surficial sediments (shallow cores, surface samples, dredges and benthic trawls) and geophysical data collection (seismic, side-scan sonar, multibeam sonar, sub-bottom profiler, magnetic and gravity) in the Porcupine Seabight and Rockall Trough has been ongoing for several decades. There has been an appreciable increase in this activity in recent years partially stimulated by hydrocarbon exploration activities. Sampling activities have been undertaken by a number of institutions, academic and commercial, for a variety of purposes. Consequently, there is variation in sampling/surveying procedures, sample/survey types, storage, analyses and metadata documentation. This is exacerbated by the fact that many samples were collected by non-indigenous institutions with analysis and storage occurring outside the country. There is a need to provide an up-to-date inventory of samples and geophysical data including details of sample status and usability to best facilitate ongoing examinations of surficial sediment properties in the Porcupine Seabight and Rockall Trough.

The present authors participated in an earlier inventory of sample data, survey data and bibliography for the Rockall Trough (with some coverage in the Porcupine Seabight) for the Rockall Studies Group (1998).

However, there is now a need for:

- up-dating the inventory to 2000 for the Irish Rockall Trough
- provision of a comprehensive inventory for the Porcupine Seabight
- attention to be drawn to derived datasets where possible for collected data
- an assessment, where practical, of seabed sample storage and longevity
- an assessment of sample and survey data usefulness for future work.

The database is being constructed to document the extent of surficial sampling activity (geological cores, geological dredges, biological samples, benthic trawls) and geophysical survey data (non-commercial seismic, side-scan sonar, multibeam sonar, sub-bottom profiler, magnetic and gravity) in the Porcupine Seabight. An update from 1997 to 2000 of the existing RSG data inventory for the Rockall Trough following a comparable format will be made. The information collected will be fed into the PIP online Data Inventory (PIPDI) application which will be tailored to fit the data.

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme.

References

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PIP 1, Offshore Support Group – activities and future plans

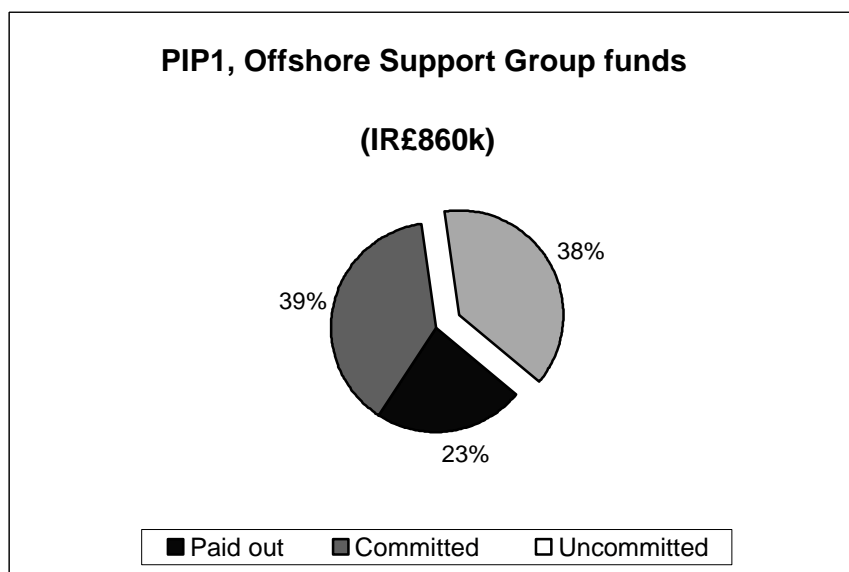
Noel Murphy, Rory Boyd and Michael Hanrahan

Petroleum Affairs Division, Dept of the Marine and Natural Resources, Beggars Bush, Haddington Road, Dublin 4, Ireland.

The Offshore Support Group (OSG) or Group 1 of the Petroleum Infrastructure Programme (PIP) was established in June 1997 to assist in developing local support structures for hydrocarbon exploration and development offshore Ireland. The OSG aims to concentrate on training, equipment purchase, research support and limited data acquisition.

The group is managed by the Petroleum Affairs Division (PAD) which, in turn, receives recommendations from two advisory committees on proposals to be supported and the levels of funding considered appropriate. The advisory committees are made up of representatives from the E & P industry, Government agencies and academic organisations. Partial funding is the norm and proposals must conform to strict guidelines if they are to receive serious consideration. The selection process is based on a marking system which ranks the quality of proposals according to a number of parameters, the most important of which are the relevance to PIP1 objectives, originality, cost and the availability of other sources of funding, if required.

The total funding available to the OSG is IR£860,000 of which IR£197,693 has been dispersed to-date. Not all successful applicants decide to proceed with their projects which can mean that it is possible to fund additional work from time to time. So far, there have been two invitations to submit proposals, one in 1998 and the other in 1999. Both resulted in applications for funding far in excess of available finances.

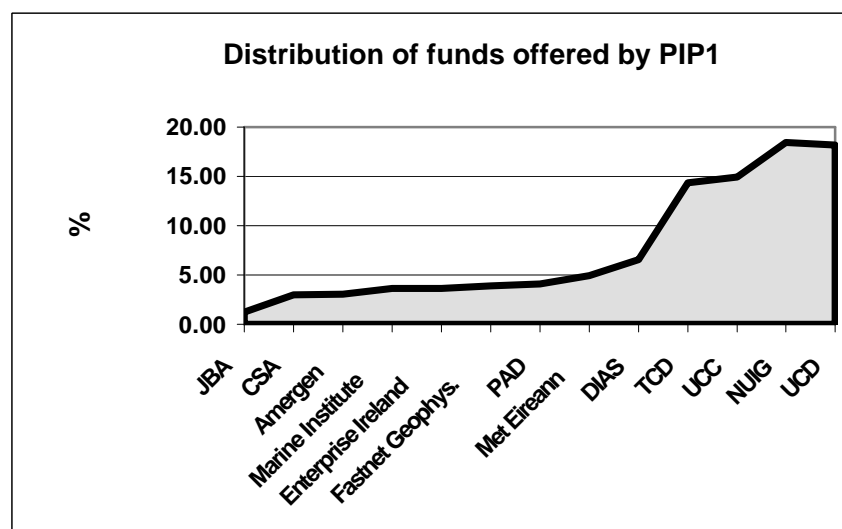


A wide variety of proposals have been offered OSG support and the main items for funding are as follows:

- acquisition systems e.g. sidescan sonar and boomer seismic; acoustic monitoring equipment for cetaceans, contributions to the purchase of OBS's, multi-beam sonar and an automated weather station;
- analytical equipment e.g. laser particle size analyser, magnetic susceptibility meter and cathodeluminescence equipment;
- diverse software including packages for processing of seismic and sidescan sonar data;

- contributions to the setting up of 'marine geotechnics' and 'offshore structures testing' facilities;
- training in data acquisition and feasibility studies such as the investigation of distance learning techniques;
- applied research e.g. lithofacies extrapolation from well logs and investigation of slope processes in the Rockall Trough;
- limited geological sample acquisition;
- the provision of microscopes, PC's, Unix workstations, plotters & various software products to upgrade facilities at Irish institutions.

In terms of who has benefited from PIP1 support, the academic/research institutions with offshore research interests have received the lion's share. Included as recipients are University departments (e.g. Geology, Zoology, Civil Engineering); the Coastal Resources Centre in Cork and the Applied Geophysics Unit in Galway are included together with UCC and NUIG respectively.



The OSG has also proved particularly effective in complementing the work of PIP2, Rockall Studies Group (RSG) – e.g. the provision of equipment for fluid inclusion analysis and cetacean monitoring as well as the funding of research staff to investigate seabed slope process using samples and other data acquired by that group. PIP1 has assisted the PAD with the publication costs of its structural nomenclature system for the Rockall Trough, which was founded on RSG work and is available at this conference.

In terms of the future of PIP1, it is clear that in order to derive the most benefit from limited funds, special consideration will have to be paid to supporting strategic work and emerging centres of excellence.

Opportunities for co-operation with other groups will also be investigated and it is envisaged that another call for proposals will be issued during 2001.

Acknowledgements

This project has been undertaken on behalf of the Irish Petroleum Infrastructure Programme.

Faroes Oil Industry Group - FOÍB

Halvor Snarvold

c/o Atlanticon Sp/f, Bryggjubakki 4, Postboks 263, FO-110 Tórshavn, Faroe Islands

FOÍB's scope and objectives are to:

- provide a forum to discuss and agree common policies on Faroese participation, HSE, operational and related issues
- provide a forum for industry communication with the Faroese Authorities and other interested parties
- collaborate in acquiring data where this is of benefit to all Licensees
- identify areas for the efficient use of resources in relation to operations in Faroese waters
- coordinate joint projects funded under the terms of individual licences
- act as caretaker for the conclusion of outstanding GEM activities

FOÍB's organisation – voting arrangements, secretariat, committee structures etc. – will be presented.

Contact details are as follows:

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Operators presently in FOÍB are: Statoil, BP-Amoco, Amerada Hess, Agip and Anadarko.

SINDRI – the Future Exploration Issues Programme of the Faroes Islands

Martin Heinesen

Jarðfrøðisavnið, Brekkutun 1, Postboks 3169, FO-188 Tórshavn, Faroe Islands.

Introduction

The Minister of Petroleum officially established the Sindri Programme – the Future Exploration Issues Programme of the Faroese Continental Shelf - on 17 August 2001 as part of the stipulated work programmes for licensees within the Faroese area. At the same time the Programme's objectives, steering mechanisms and funding were defined.

Participating companies are: Amerada Hess, Agip, Anadarko, Atlantic Petroleum, BP, British Gas, DONG, Enterprise, Føroya Kolvetni, Phillips, Shell, Statoil, and Veba.

SINDRI Objectives

The main objective for the Sindri Programme is to carry out joint project(s) of relevance to the future investigation of the Faroese continental shelf. The primary topics for investigation are:

- Relevant technologies for imaging within basalt-covered areas
- Regional geology and evolution of the entire Faroese area
- Definition of the hydrocarbon system of the entire Faroese area

Group Management

The Management Committee is composed of senior exploration representatives from the funding companies and Jarðfrøðisavnið (JFS), the Geological Survey of the Faroe Islands.

The role of the Management Committee is to provide the Management/Steering Function for joint industry projects.

The Technical Coordinator is provided by JFS to assist the Chairman in the day-to-day management of the Programme.

Atlanticon and JFS provide the additional support functions of administration and archive, respectively.

Data in the Faroese Area

Data previously acquired by various companies in the Faroese area includes:

- >50,000 km 2D Seismic
- >10,000 sq. km. 3D Seismic
- Experimental Seismic Data (WAR/OBS/OBC/VCS)
- >60,000 km Aeromagnetics
- Gravimetric Data
- Marine MMT
- Full Tensor Gradient Surveys
- Airborne Laserfluorescence
- Seabed Sampling

SINDRI Projects

Projects currently being funded by the Sindri Group include:

- Faroes Region: A Standard Structural Nomenclature System (JFS)
- Characterization and Architecture of Basalt in the Faroes Region (JFS)
- SINDRI Website Development (JFS)
- Sub-Basalt Imaging Expert Review

- Workshop on the Petroleum System of the Faroese Area (Sindri Group)

Contacts

For more information concerning the Sindri Group and its projects, please contact:

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E-mail: tdj@geus.dk

Attn: Trine Dahl-Jensen

The SINDRI Story

In Norse mythology, Sindri was the very gifted blacksmith who amongst many masterpieces made the magic Hammer of Thor.

He was a creative dwarf who excelled at taking on new and magical ventures, particularly bets initiated by the Gods.

The word cinders is derived from the name Sindri. Our symbol for Sindri is created by the Faroese artist Anker Eli Petersen.

The BGS (UK) Rockall Continental Margin Consortium

Ken Hitchen

British Geological Survey, Murchison House, Edinburgh EH9 3LA, Scotland, UK.

Background

The consortium was established in January 1992 as the result of a British Geological Survey (BGS) initiative. Originally eight oil companies signed up to a three-year work programme which concentrated in the area from the UK/Irish median line to 59°N and from about 10°W to 14°W (i.e. the central UK part of the deep-water Rockall Trough).

The principal aims were to:

- (1) improve our understanding of the geology and geological history of the area
- (2) extend the coverage of the BGS offshore regional mapping programme
- (3) gain regional geological knowledge which may prove useful in the search for hydrocarbons in the area.

After the initial three-year period the decision was taken to continue the work on a year-by-year basis. New members were encouraged to join the consortium and the area of interest was extended to include the whole of the UK designated area west of Scotland. Current membership in 2001 comprises BGS, Agip, Amerada Hess, BG, BP-Amoco, Conoco, Enterprise, ExxonMobil, Statoil, Texaco, TotalFinaElf and the DTI. By the end of 2001 the consortium will have been active on the Rockall Margin for 10 years and turnover will have exceeded UK£8m.

Organization

The consortium is administered by a Management Steering Committee. This is chaired by BGS and meets four times per year in BGS Edinburgh. Each company member has a single representative. The committee determines the work programme and hence the annual level of contribution required from each company. BGS acts as operator and secretariat for the consortium and hence undertakes most of the work including planning, new data acquisition, interpretation and analysis, desk studies, reporting and contractual matters.

New Data

Since 1992 the consortium has acquired over 16000km of seismic data. This varies from BGS-style high-resolution data to 'crustal' 2D data using a 9390 ins³ source and recorded to 18s TWT. An experimental 140km two-ship (synthetic aperture) profile has also been recorded in the Rockall Trough. Most seismic data have coincident gravity, magnetic and bathymetry data.

Over 200 gravity, vibrocore or rockdrill cores have been collected and 14 continuously-cored shallow boreholes have been drilled including the first ever such boreholes on Rockall Bank and Hatton Bank.

Over 80 reports have been produced. Topics covered include operational details, drilling results and analyses, seismic interpretation, organic and inorganic geochemistry, gravity and magnetic atlas production and modelling, sub-basalt imaging and stratigraphic compilations.

Confidentiality

New data remains confidential for specific periods of time depending on the data type. Data ownership reverts to BGS at the end of the confidentiality period. Reports remain confidential indefinitely. Some of the results from the early work are now being incorporated into BGS products and BGS-authored technical papers.

Selected Geological Highlights

1. Recognition of a NW-SE terrane boundary across the Rockall Trough.
2. Discovery of folded, faulted and eroded ?pre-Cenozoic sedimentary rocks at a high structural level on Hatton Bank. This contrasts with Rockall Bank where metamorphic basement is at, or close to, the sea bed over large areas.
3. Mapping the subcrop of the Early Cenozoic lavas. Discovery of several new central igneous complexes. Analysis of the lavas for major, trace and REE geochemistry (not all basalts) and

- selected isotopes. Determination of age and N/R polarity of selected samples. Elucidation of the volcanic history.
4. Improved sub-basalt imaging using long offset synthetic aperture seismic data and converted shear wave techniques.
 5. Recognition that the Rockall Margin does not have a simple history of subsidence throughout the Cenozoic but has undergone periods of uplift, erosion and compression, both on a local and a regional scale, causing asymmetry of some of the principal stratigraphic units (especially in the Rockall Trough).
 6. Establishment of a well-dated Cenozoic mega-stratigraphy for the Rockall Trough with the identification of major unconformity surfaces formed during the late Eocene and the early Pliocene. Recognition of similar surfaces across the Rockall Plateau (ages yet to be confirmed by sampling and drilling). The later unconformity is a response to margin-wide exhumation. Both unconformities have significant implications for hydrocarbon exploration.
 7. Recognition that sediment drifts and contourites form a major component of mid to late Cenozoic continental margin development, not only off NW Britain, but along the whole Atlantic Margin from Norway to SW Ireland.
 8. Recognition that the Rockall Trough has been, and continues to be, a dynamic deep-water basin influenced by the interaction of both downslope and alongslope processes.
 9. Mapping the sea-bed solid geology of the central Rockall Trough as a start towards mapping the whole of the UK designated area west of Scotland and the production of offshore regional geological reports.

Plans for the future

The consortium is funded up to the end of 2001. The work programme for next year is currently under discussion. However, in 2002, BGS will acquire more short sea-bed cores from Rockall and Hatton Banks and will conduct the full range of relevant analyses on the material collected.

The National Seabed Survey, offshore Ireland

Geological Survey of Ireland

GSI, Beggars Bush, Haddington Road, Dublin 4, Ireland.

In April 1999 the Irish Government sanctioned a seven-year £21 million project to map the Irish seabed. It is the largest project of its kind ever undertaken by the Irish government, indeed by any country in the world. The project envisages a survey of some 525,000 sq. km. of the Irish marine territory. The project is being managed by the Geological Survey of Ireland.

The primary objective of the survey is to provide baseline information. This information will encourage and promote research in marine science. It will also benefit various elements in the public sector as well as the private sector in unravelling potentially huge natural resources in the Irish seabed. It will benefit policy and decision makers in government in relation to management and sustainable development of Ireland's marine resources.

The data acquisition phase was begun in 2000 by awarding the contract to Global Ocean Technologies Limited (GOTECH), an Irish company at the forefront of marine survey works. GOTECH was awarded a contract to survey Zone 3 (Figure 1), in water depths ranging from 200m to 4,500m in the Atlantic. By the end of August 2001 they have managed to complete 85% of the Zone 3 and they expect to complete the remainder before the end of November 2001.

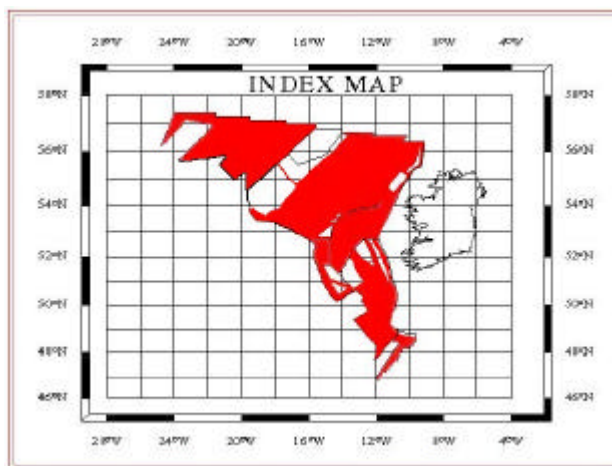


Figure 1: Coverage of Zone 3 to end Aug '01

Data Acquisition

The primary data to be collected are multibeam sonar data. This dataset will provide much-needed basemaps with accurate bathymetry. Inherent in the dataset will be backscatter information, which will provide an insight into the nature of the seabed and the overlying sediments. Along with the multibeam data we are also collecting magnetic and gravity data which will enable understanding of deeper geology and structures. To further our knowledge of near surface geology we are also using sub-bottom profiling techniques (Figure 2). In addition to these, other complementary datasets being collected include:

- Single beam echo sounder
- Salinity, conductivity, temperature and sound velocity profiles

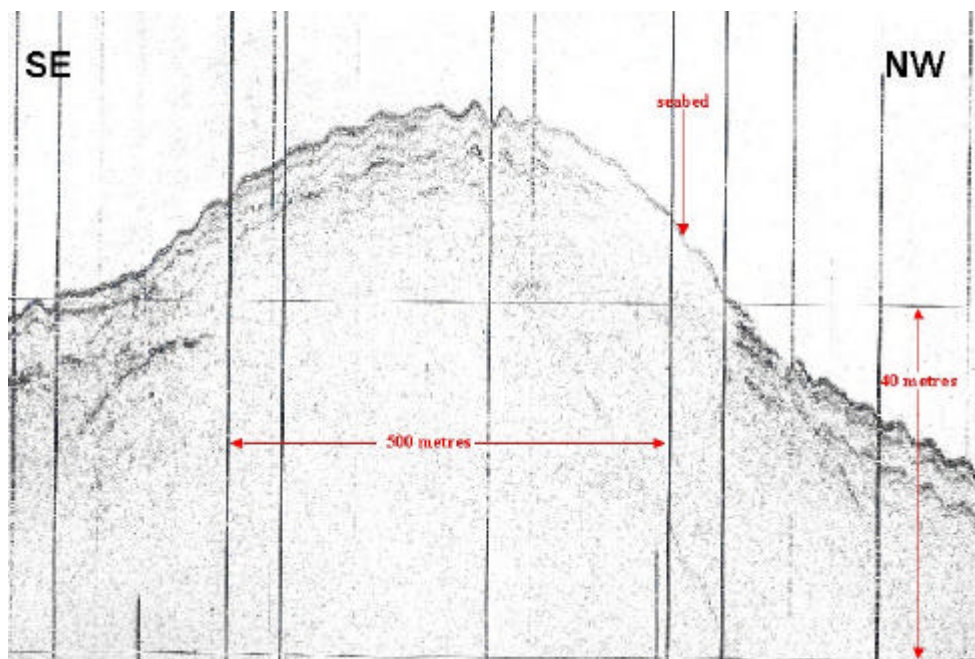


Figure 2: Example of a sub-bottom profile chart (shallow seismic line)

Products

The primary deliverable from the survey will be paper maps based on datasets collected through multibeam sonar, magnetic and gravity techniques. These will be regional maps covering 2° longitude X 1° latitude area at scale of 1:250,000. Also available will be sub-bottom profiles along the survey lines.

Subsequent to in-house reprocessing of the survey results maps of seabed geology and morphology will be available.

While initially GSI will be concentrating making data available in hard copy, it is also preparing itself to make data available in digital format. GSI is open to discuss specific requirements in terms of format and scale.

Preliminary Results

From the 2000 season preliminary maps it is already clear that lots of exciting and interesting results are being produced. There have been indications of the existence of hydrocarbons in the form of gas escape features and mounds. Interpretation of the backscatter maps clearly identifies both active and inactive deep-water channel complexes (Figure 3). Areas of catastrophic slope failure have also been identified. A substantial number of carbonate mounds and bioherms (reefs) of *Lophelia pertusa* (a deep-sea cold water coral), not previously identified, have been observed in the multibeam and sub bottom profile records. Many other low relief features such as sedimentary bedforms have also been successfully resolved.

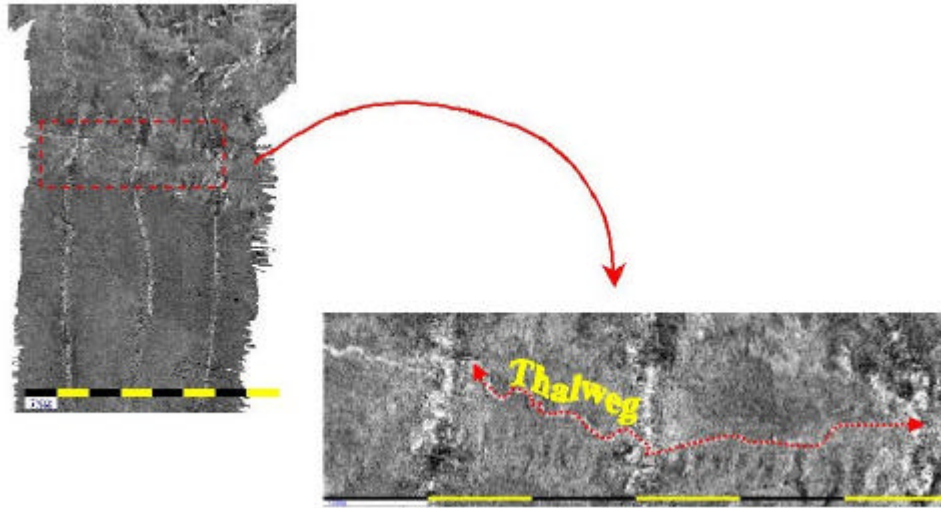


Figure 3: Active Channel deposition, backscatter data

The gravity and magnetic data will assist in understanding deeper geology and in identifying potential hydrocarbon prospects. The data will complement the already existing information and may even further enhance interpretation of seismic data.

As the second survey season progresses many more interesting features and possibilities are continuing to unfold...

Activities of the Marine Institute 2001 – Seabed Surveys

Marine Institute

Marine Institute, 80 Harcourt Street, Dublin 2, Ireland.

The National Seabed Survey is a major marine project, which was sanctioned by the Irish Government in 1999 and which will involve detailed mapping of the continental shelf utilising multibeam sonar, sub bottom and potential field data acquisition. The project managers are the Geological Survey of Ireland (GSI), with the Marine Institute as a strategic partner. The Marine Institute will be undertaking data acquisition and processing within Zone 2 (from 50 to 200 metre contour) during the period 2002- 2005 inclusive.

In addition to preparations for 2002 onwards the Marine Institute is co-ordinating an ancillary research programme to the National Seabed Survey. In this context the Marine Institute is keen to make every effort to ensure that any useful marine research/marine monitoring that can be done in parallel with the seabed survey, will be done, without undermining the progress of the survey itself.

In a dedicated effort towards streamlining our capacity for acquisition of Zone 2 of the National Seabed Survey the Marine Institute has been involved in a range of activities in 2001, with the following highlights.

Galway Bay Survey

A key step in the preparations for the Marine Institute's involvement in Zone 2 of the National Seabed Survey has been the operation of a mini-survey in Galway Bay using the R.V. Celtic Voyager in August-September 2001.

The survey involves the acquisition of multibeam sonar, magnetics and sub-bottom profiler data. It provides the opportunity for a rigorous shake down of the R.V. Celtic Voyager in the context of seabed surveying, the results of which will benefit development of the new National Research Vessel, Celtic Explorer. The survey also provides a platform for the development of protocols for the planning, operation and management of seabed surveys and to explore potential value added products.

To operate the survey itself the Marine Institute has appointed a private contractor with demonstrated expertise in survey management and data acquisition. Following public tender the contract was awarded to Global Ocean Technologies (GOTECH) Ltd. who are presently also engaged by GSI as contractors for data acquisition in Zone 3 of the National Seabed Survey. GOTECH will work closely with the Marine Institute for the duration of the project.

Newfoundland Labrador Business Partnership

In June 2001 the Marine Institute received support for the Newfoundland Labrador Business Partnership to engage in a collaborative project with the Canadian Centre for Marine Communications, Newfoundland. The 2001 project will focus on practical outputs, which will achieve a direct transfer of expertise to Ireland from Canada, and on the identification of specific future initiatives, which can achieve mutual benefits. The project will run from August through October 2001, during which time the Marine Institute has engaged two experts from CCMC. One, who will be present for the Galway Bay Survey, will focus on the transfer of expertise in hydrographic surveying including survey planning and logistics, data acquisition, data processing and interpretation and product development. The second will focus on the assessment of data management and data dissemination options for Seabed Survey data and on the identification of business and research opportunities for the development of data products and services arising from the seabed survey.

Seabed Survey Workshop

In early October 2001 the Marine Institute will be hosting a workshop focusing on recent developments in seafloor survey technologies and data applications.

The Marine Institute looks forward to continuing involvement in these and other future initiatives.

STRATAGEM, the Stratigraphical Development of the Glaciated European Margin - the Rockall-Porcupine Workpackage

Dan Evans and the STRATAGEM Partners

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- A Data Exchange Agreement between PIPCo /RSG and STRATAGEM has been signed.
- Following a data compilation exercise, key seismic lines were successfully collected during cruise RV Pelagia 64 PE 166 in 2000. The data are of a high quality, and proved to be very important for linking existing BGS, ENAM and commercial datasets in this region, including commercial wells.
- A correlation between WP2 and WP3 shows that the early Pliocene (C10/INU/CN-040) boundary and the Oligo-Miocene boundary (including the LOEMU and CN-010) are clearly identifiable on the seismic profiles.
- Schematic line drawings of profiles STRAT00/02 00/05 are illustrated. On the basis of these profiles, the Cenozoic succession in the northern Rockall Trough has been successfully linked to that established for the central and southern Rockall Trough: namely the correlation and relationships of the C10 (early Pliocene), C20 (early/mid-Miocene) and C30 (late Eocene) reflectors of Stoker et al. (2001). Two key points to note from these profiles are:
 - The C20 reflector clearly onlaps C30 as the Rockall Trough becomes shallower to the north. Consequently, megasequence RTc of Stoker et al. (2001) is absent from the north Rockall Trough.
 - The Cenozoic succession, including the Neogene section, is structurally more complex in the northern Rockall Trough compared to the central and southern Rockall Trough. This zone of increased complexity correlates to the area between Rosemary Bank and the Wyville-Thomson/Ymir Ridge, and is influenced both by buried igneous centres and more-recently active tectonics. An anticlinal feature is clearly evident on seismic data and appears to continue to influence the seabed at the present-day.
- In the Porcupine Basin, three regionally correlateable sequence boundaries have been identified in the Oligocene to Recent succession, and preliminary maps of these have been produced. The C30 (late Eocene), C20 (early/mid Miocene) and C10 (early Pliocene) sequence boundaries Stoker et al. (2001) are present throughout the basin. C30 is tied to well data (e.g. 35/13-1), from the north of the basin, but no cuttings or cores were available to date the C20-C10 section.
- Integration of the results from PIP/RSG site survey seismics, shallow boreholes and TOBI data (obtained by trade agreement with PIP RSG) in the Rockall Basin has been carried out. These are currently being integrated with the regional industry profiles and interpretations.
- Work is in progress to integrate all of these data throughout the Rockall Trough in terms of the stratigraphic framework and the various distribution and isopach maps. A well correlation panel has been produced.
- Backstripping modelling is currently in progress along two lines: BGS profile 84/06-53 is from the north central Rockall Trough and commercial profile DHG9510 is from the northern Rockall Trough.
- Work is continuing, with a project workshop to be held in Trieste on 19-22nd September. A major stratigraphic report will be produced in august 2002.

GEOMOUND – The Internal Mound Factory

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The European Northeast Atlantic margin is a relatively unexplored, spectacular natural laboratory which offers huge potential in terms of studying and understanding deep sea processes. Recent discoveries of large carbonate mound provinces on the slope and shelf margins to the west of Ireland (Fig. 1), coupled with an increase in petroleum exploration and fisheries activity in this area, has contributed to the inclusion of 'sustainable marine ecosystems' as a key objective in the EU Fifth Framework Programme. A cluster of six projects (GEOMOUND, ECOMOUND, STRATAGEM, ACES, COSTA and DEEP-BUG), funded under the Fifth Framework Programme, are involved in linked research on the deep-water mineral and biological resources of the region.

The carbonate mounds in the Porcupine Seabight, the Rockall Trough and their flanking banks typically lie in water depths of 500 – 1000m (Hovland *et al.* 1994, Henri² *et al.* 1998, 2001). They are up to 300 m high and individual structures cover an area extending from 100 m to 3 km. Mounds occur both as seabed and as buried structures. Four distinct types of mound types have been identified on the basis of their morphology, internal geometry and geographic location.

The GEOMOUND project brings together 8 scientific research groups from 6 European countries. The 3-year project started in early 2000. It is involved in carrying out a comprehensive assessment of the sedimentary systems associated with the carbonate mound provinces in the Porcupine and Rockall region off western Ireland. The overall objective is to improve the understanding of the geological controls on the initiation and development of the mounds. In particular, the GEOMOUND project will:

- Produce a systematic inventory of recorded Neogene to Recent mound occurrences in the Porcupine and Rockall region, documenting morphologies, structural associations, patterns and temporal associations,
- Critically evaluate hypotheses and test the diagnostic value of carbonate mounds as potential indicators for hydrocarbons and for fluid expulsion events,
- Develop a model for fluid migration pathways and processes which might have fuelled the instigation and development of mound provinces,
- Define possible targets for a future Ocean Drilling Project.

Very little is known to date about the origin and genesis of the cold water carbonate mounds. Various development models have been suggested (e.g. Hovland *et al.* 1994, Henri² *et al.* 1998, 2001) but remain, until now, largely untested. GEOMOUND will provide the first comprehensive step towards understanding the link between carbonate mounds and

- Climatic changes (e.g. Quaternary glaciations),
- Ocean currents (e.g. ocean bottom currents),
- Slope stability linked to possible dissociation of gas hydrates,
- Hydrocarbon and fluid migration patterns in the basins.

In addition to the evaluation of existing seismic and well datasets, the GEOMOUND partners are involved in acquiring new scientific data in a number of targeted sites (Fig. 1) within the Porcupine and Rockall region. A number of GEOMOUND-funded research cruises took place in 2000 and in 2001. These have resulted in the acquisition of a significant amount of new data. These have included swath bathymetry, high-resolution seismic, gravity core, box core, geochemical and current data. GEOMOUND partners have also participated in a number of additional research cruises. These include the recent (August 2001) CARACOLE (CARbonate mounds And COLd coral Exploration) cruise which provided spectacular video footage, as well as geological, geophysical and geochemical data on selected mounds within a number of the targeted GEOMOUND sites. Some of these sites were also targeted for PIP-funded projects (e.g. TRIM (TOBI) project).

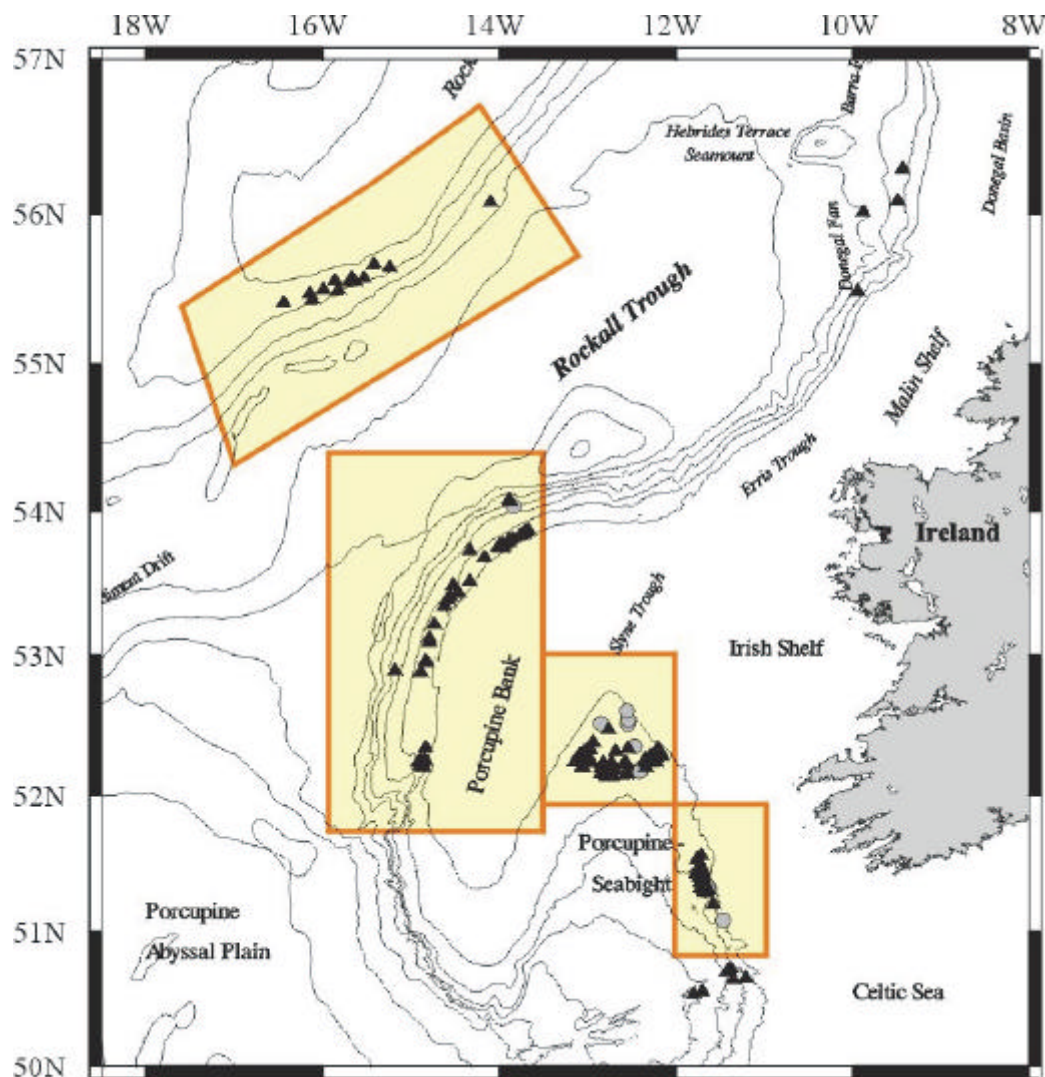


Figure 1. Map showing the location of known carbonate mounds (based on Croker & O'Loughlin, 1999). The areas of special interest, being targeted by GEOMOUND research cruises, are highlighted.

Acknowledgements

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The Atlantic Coral Ecosystem Study (ACES) - a European, margin scale, multi-disciplinary, EU Fifth Framework research project.

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The ACES project has recently been funded by the EU Fifth Framework Programme and involves researchers from 6 countries and 11 laboratories. The multi-disciplinary team of geologists, sedimentologists, physical oceanographers and biogeochemists will provide essential information in support of biologists to further our understanding of the deep water coral ecosystem. In a truly pan-European margin study, five coral inhabiting locations will be studied, i.e. on the Galicia Bank (43° N), the Porcupine Slope (51° N), the Rockall Trough (59° N), Kosterfjord (59° N) and the Norwegian Shelf (64° N). The principal objectives of the project are to:

- 1) Map the structural and genetic variability, the framework-constructing potential, and the longevity of deep-water coral (DWC) ecosystems over the latitudinal gradient of the European NE-Atlantic.
- 2) Assess hydrographic and other local physical forcing factors affecting benthic boundary layer particle dynamics and particulate organic carbon supply.
- 3) Describe biodiversity, dynamics and functioning of the DWC ecosystem, coral biology, behaviour and sensitivity to both natural and anthropogenic stress.
- 4) Designate an ecosystem sensitivity coding, highlight major conservation issues, and make practical recommendations for the sustainable use of the DWC ecosystem.

The final product will be a list of recommendations concerning sustainable development in the vicinity of the coral ecosystem which will be both informative and practical.

The Coastal Resources Centre, Cork

CRC, University College Cork, Lee Maltings, Prospect Row, Cork, Ireland

Background

The Coastal Resources Centre (CRC) represents an interdisciplinary research group within University College Cork (UCC). The various elements which contribute to the Centre, from within the Departments of Zoology and Animal Ecology, Geography and Geology have evolved into an integrated research group dedicated to coastal and marine resources studies. The Coastal Resources Centre now forms an integral part of the overall Environment Research Institute (ERI), established in 2000. Within the ERI, the Coastal Resources Centre serves as a critical mass of expertise, with 20 researchers dedicated to coastal and marine research, currently working on 24 contracted research projects.

Objectives

The overall objective of the Coastal Resources Centre is to investigate the interactions between biological and physical coastal and marine resources and human populations, with a view to establishing the level of sustainable utilisation, and thereafter, stimulating the adoption of scientifically-based integrated coastal and marine management plans. The objectives can be summarised as follows:

- To provide information in a manageable form by the evaluation and mapping of physical and biological resources, including societal features, in coastal and marine areas;
- To investigate the physical and biological processes operating in coastal and marine areas, including monitoring the impacts of change in coastal and marine use;
- To formulate and promote integrated coastal and marine management strategies with due attention to the risks to, and potential of, coastal and marine resources and processes;
- To increase awareness and develop expertise in integrated coastal and marine resource management by education and training of coastal and marine resources students, managers and users.

Research

The Coastal Resources Centre provides a focus within UCC for research on coastal and marine resources, their status and potential for sustainable development. The Centre actively seeks out funding programmes to which it submits research proposals, developing a work programme incorporating research, consultancy and training initiatives, based on existing expertise and projects within UCC. This ensures the maintenance of a corpus of expertise in these areas, enhancing the training opportunities for future researchers.

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