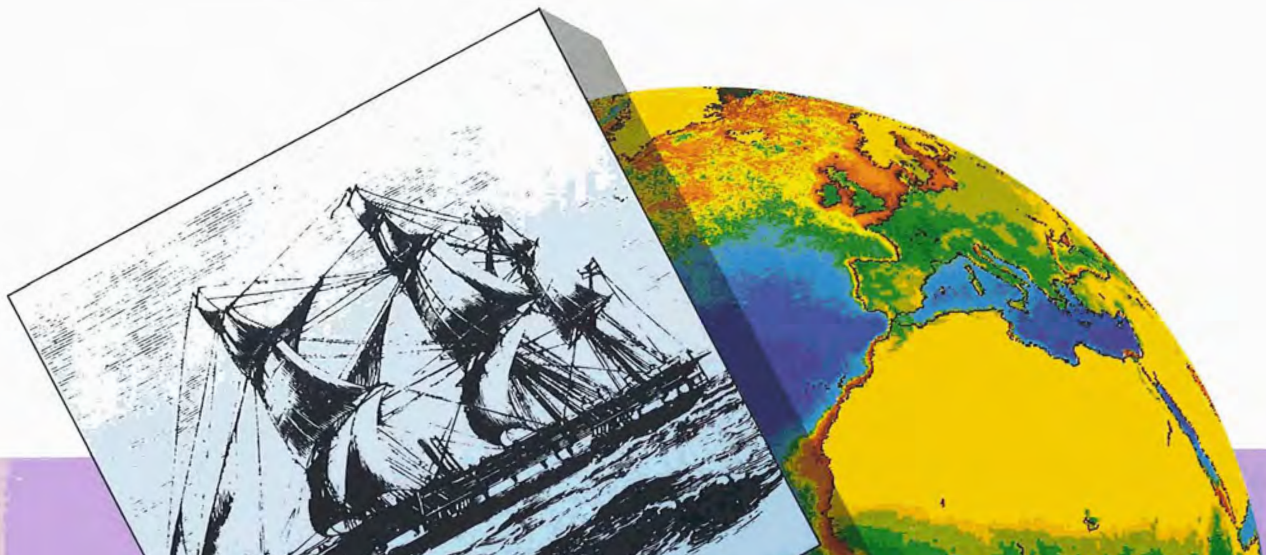
OCEAN Challenge



The Challenger Society for Marine Science

Volume 6, No.2

Volume 6, No.2, 1996

OCEAN Challenge

The Magazine of the Challenger Society for Marine Science

SCOPE AND AIMS

Ocean Challenge aims to keep its readers up to date with what is happening in oceanography in the UK and Europe. By covering the whole range of marine-related sciences in an accessible style it should be valuable both to specialist oceanographers who wish to broaden their knowledge of marine sciences, and to informed lay persons who are concerned about the oceanic environment.

The views expressed in *Ocean Challenge* are those of the authors and do not necessarily reflect those of the Challenger Society or the Editor.

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***Ocean Challenge* is sent automatically to members of the Challenger Society for Marine Science.**
For more information about the Society, see inside back cover.

DATA PROTECTION ACT, 1984 (UK)

Under the terms of this Act, you are informed that this magazine is sent to you through the use of a computer-based mailing list.

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The cover image shows the global phytoplankton distribution. Phytoplankton concentrations are low in the central gyres (purple, deep blue), and tend to be high along coasts (yellow, orange and red). The images, which were made by processing thousands of individual scenes from the Coastal Zone Color Scanner, have been used by courtesy of Gene Feldmann, NASA/Goddard Flight Center, Space Data and Computing Division, Greenbelt, Maryland 20771, USA.

The cover was designed by Ann Aldred Associates.

Forthcoming Events

Events in 1996

ECSA Workshop: Sediment Sampling Protocols and Techniques May/June or August/September, Bangor. This workshop will deal mainly with soft-sediment sampling from boats. *Contact* Ivor Rees, University College of North Wales.

Inauguration of the Marine Forum Information and Documentation Centre (by the Earl of Cranbrook). 2 June, University College, Scarborough. *Contact* Dr Jean-Paul Ducrotoy, The Marine Forum, c/o University College of Scarborough, The University of York, Filey Rd, Scarborough, YO11 3AZ, UK; Tel. 01723-362392; Fax: 01732-370815; Email: marforum@ucscarb.ac.uk

Oceanography from Aircraft (Challenger Society Meeting). 18 June, Southampton. *Contact* Simon Boxall, Dept of Oceanography, University of Southampton, Southampton Oceanography Centre, European Way, Southampton SO14 3ZH.

Marine Communities: Measurement and Management (Conference of CERCI, the Centre for European Research into Coastal Issues). 1–3 July, University College, Scarborough. The conference aims to present current research on various aspects of marine communities, and to bring together scientists and managers in a workshop on the collection and use of data. There will be an excursion to Bempton Ciffs and Flamborough Heritage Coast. The conference will also incorporate a meeting of the Marine Forum Steering Committee. *Contact* Dr Jean-Paul Ducrotoy, The Marine Forum, c/o University College of Scarborough, The University of York, Filey Rd, Scarborough, YO11 3AZ, UK; Tel. 01723-362392; Fax: 01732-370815; Email: marforum@ ucscarb.ac.uk

Atmospheric Chemistry of Sulphur in Relation to Aerosols, Cloud and Climate (Royal Society Discussion Meeting). 3–4 July, London. Organized by Dr R.A. Cox, Dr C. Hewitt, Prof. P.S. Liss, Dr J.E. Lovelock, Dr K. Shine and Prof. B.A. Thrush. *Contact* The Scientific Meetings Secretary, The Royal Society, 6 Carlton House Terrace, London SW1Y 5AG. Tel. 0171-839-5561, extn 278; Fax: 0171-839-2170.

The Role of the Ocean in Global Change Research (The Oceanography Society's 1996 Scientific Meeting, in cooperation with IGBP, WCRP, HDP and SCOR)). 8–11 July, Amsterdam, The Netherlands. Topics to include: the tropical oceans; mid-latitudes, physics and fish; the role of the polar oceans; shelf systems and environmental change. *Contact* Pechan & Associates, Inc., Attention: TOS Meeting, 5537 Hempstead Way, Springfield, VA 22151, USA, Fax 703-642-1258.

ECSA Workshop: Properties and Behaviour of Mud 9–10 July, School of Environmental Sciences, University of East Anglia. This workshop is intended as an introduction for multidisciplinary study. *Contact* Reg Parker, Blackdown Consultants Ltd, Tel. +44-(0)1823-667065; Fax: +44-(0)1823-660243.

Scientific Priorities in Irish Sea Research (Challenger Society Meeting). 16 July, Liverpool. *Contact* Dr H. Davies or Dr M. Preston, Dept of Earth Sciences, University of Liverpool, PO Box 147, Liverpool L69 3BX; Tel. +44-(0)151-794-4093; Fax:+44-(0)151-794-4099.

Joint Symposium of ECSA and the Estuarine Research Federation Sept. *Further details* will be available from D.S. McLusky, Dept of Biology and Molecular Science, University of Stirling, Stirling FK9 4LA. Tel. 01786-467755; Fax: +44-(0)1786-464994.

Impact of Oil and Gas Exploitation (Marine Forum/Nature Conservancy Council in conjunction with the Centre for European Research into Coastal Issues). September (*date to be confirmed*), Edinburgh. *Contact* Dr Jean-Paul Ducrotoy, The Marine Forum, c/o University College of Scarborough, The University of York, Filey Rd, Scarborough, YO11 3AZ, UK; Tel. 01723-362392; Fax: +44-(0)1732-370815; Email: marforum@ ucscarb.ac.uk

UK Oceanography '96 2–6 September, Bangor. *For more details see p.17*

The 25th General Assembly of the European Seismological Commission (ESC) September 9 –14, Reykjavik, Iceland. In addition to the standard subcommission open symposia, several sessions of special interest to the mid-oceanic ridge research community are foreseen, such as: seismology and faulting at ridges; The Iceland hot spot; crust/mantle structure and processes; seismology, deformation, and structure of volcanoes. Field trips to the plate boundary areas, e.g. the rift zones and transform zone of South Iceland will be arranged. *For further information contact*: LOC XXV General Assembly ESC, Attn: Mr. Bardi Thorkelsson, The Icelandic Meteorological Office, Bustadavegur 9, 150 Reykjavik, Iceland. Fax: +354 552 8121; Email: esc96@vedur.is

Animal and Sediment Interactions in the Marine Environment (Joint Meeting of the Marine Studies Group and Porcupine Society). 14–15 September, Geology Dept of Royal Holloway College, Egham, Surrey. This weekend meeting aims to bring together biologists and geoscientists to exchange ideas about processes occurring in sediments at or near the sea-bed, from Recent and fossil perspectives. Accommodation will be available on campus; the conference dinner will be on Saturday evening. *For further information or offer contributions, contact* Garry Reid (MSG convenor), School of Ocean Sciences, University of Wales Marine Sciences Lab, Menai Bridge, Gwynedd, LL59 5EY; Tel. +44-(0)1248-382602; Email: oss018@bangor.ac.uk *or* Jan Light/John Wilson (Porcupine/RHUL convenors) Geology Dept, Royal Holloway, University of London, Egham, Surrey, TW20 0EX Tel. +44 (0)1784-443581; Fax: +44-(0)1784-471780; Email: j.wilson@gl.rhbnc.ac.uk

ECSA Workshop: Marine and Estuarine Algae Dates to be confirmed.. Heriot–Watt University , Edinburgh, Scotland. *Contact* Martin Wilkinson, Tel. +44-(0)131-451-3468; Fax: +44-(0)131-451-3009.

ECSA Workshop: Estuarine Habitat Reconstruction September (just before or just after ECSA 26, see below), Brussels, Belgium. *Contact* Patrick Meire, Tel. +32-(0)2558-1820; Fax: +32-(0)2558-1805.

ECSA-26: Transport, Retention and Transformation Processes and their Biological Control in Estuarine and Coastal Systems (Joint ECSA and ERF Meeting) 16–20 September, Middelburg, The Netherlands. *Local organizers:* Carlo Heip, Victor de Jonge and Ken Tenmore.

Exploration and Exploitation of Deep-water Minerals (Joint Meeting of Challenger Society and Geological Society). 29–30 October. *Contact* Dr T. Minshull, Bullard Laboratory, Dept of Earth Sciences, University of Cambridge, Madingley Rd, Cambridge CB3 0EZ.

The Life and Oceanographic Times of John Young Buchanan, 1844–1925 (Challenger Society Meeting). 23 November, Lecture Theatre, Southampton Oceanography Centre. It is hoped to use the occasion to discuss the formation of a specialist history group within the Challenger Society, but non-members are welcome at the meeting. *For programme and registration details contact* Margaret Deacon, Dept of Oceanography, University of Southampton, Southampton Oceanography Centre, European Way, Southampton SO14 3ZH, UK; Fax: +44-(0)1703-593059; or Neil Wells, at the same address, or via Email: n.c.wells@soc.soton.ac.uk

Events in 1997

Chemosynthesis (Challenger Society Meeting). Date and location t.b.a. *Convenor* Prof. Paul Dando, Bangor.

Extreme Environments (Challenger Society Meeting). Details t.b.a.

WOCE (Challenger Society Meeting). Details t.b.a. *Convenor* Trevor Guymer, Southampton Oceanography Centre.

Shelf-edge Oceanography (Challenger Society Meeting at UKGA). 2–4 April, Southampton. *Contact* John Huthnance, Proudman Oceanographic Laboratory, Birkenhead, Merseyside LA3 7RA; Tel. 0151-653-8633; Fax: +44-(0)151-653-6269.

Oceanology International 97: Pacific Rim incorporating **OI Pacific Rim 97, COSU 97 (Coastal Open Space Utilisation) and IOA 97 (Meeting of the International OTEC/DOWA Association)** 12–14 May, World Trade Centre, Singapore. This will be the first of the OI meetings to move outside the UK in response to the rapidly expanding opportunities in the Asian Pacific market. *Contact:* Lesley Ann Sandbach, Project Director, OI Pacific Rim, Ocean Honuse, 50 Kingston Rd, New Malden, Surrey KT3 3LZ; Tel. +44 (0)181-949-9222; Fax: +44-(0)181-949-8186; Email: oiasia@spearhead.co.uk; see also worldwide web: http://www.acrso.ns/ca~spearhead/

Vegetation/Climate/Atmosphere Feedbacks: Past, Present and Future (Royal Society Discussion Meeting). 21–22 May, London. Organized by Dr D.J. Beerling, Prof. W.G. Chaloner and Prof. F.I. Woodward. *Contact* The Scientific Meetings Secretary, The Royal Society, 6 Carlton House Terrace, London SW1Y 5AG. Tel. +44-(0)171-839-5561, extn 278; Fax: +44-(0)171-839-2170.

Earth–Ocean–Atmosphere: Forces for Change (Joint Assemblies of IAMAS and IAPSO). 1–9 July, World Congress Centre, Melbourne, Australia. Will also include a meeting of the IUGG Tsunami Commission. *Contact* IAMAS/IAPSO Secretariat Convention Network, 224 Rouse St, Port Melbourne, VIctoria 3207, Australia; Tel. 61-3-9646-4122; Fax: 61-3-9646-7737; Email: mscarlett@peg.apc.org

The Evolution of Biological Diversity: From Population Diversity to Speciation (Royal Society Discussion Meeting). 9–10 July, London. Organized by Professor R.M. May and Dr A.E. Magurran. *Contact* The Scientific Meetings Secretary (details as for 21–22 May).

Suffolk and Essex Estuaries (Estuarine and Coastal Sciences Association Meeting). *Local organisers* D. Nedwell and S.J. Malcolm. Details to be arranged.

ECSA Workshop: Estuarine and Coastal Chemistry Easter, venue to be confirmed. *Contact* Geoff Millward, University of Plymouth; Tel. +44-(0)1752-233000; Fax: +44-(0)1752-233035.

ECSA-27: Comparison of Enclosed and Semi-enclosed Systems (Joint Meeting of Baltic Marine Biologists (BMB) and ECSA). Mid-June (during the 15th BMB Symposium) Mariehamn; Island of Åland, Finland. *Likely organisers* E.M. Blomqvist, E. Bonsdorff and I. Vitasalo.

ECSA-28: Remote Sensing in Estuaries (Joint Meeting of ECSA and the Remote-Sensing Society). 1–6 September, University of St Andrews, Scotland. *Organisers*: John McManus and J. Anderson.

Carbon Dioxide and the Oceans (Challenger Society Meeting) Probably to be held in October; details to be finalized.

BES Welcomes Oceanographers

The British Ecological Society will be holding its 1996 winter meeting from 17 to 19 December at Durham. As usual, the Society's Aquatic Group will be holding its own sessions, which are intended to appeal to marine as well as freshwater biologists. The various session titles have therefore been deliberately chosen to encompass all of aquatic ecology, and will include:

- Scale effects in aquatic systems
- Trophic interactions in aquatic systems
- The ecological basis for aquatic management
- Fish ecology

There will also be a presentation by Professor Robert T. Paine from the University of Washington, who will be giving two lectures covering his work on food web dynamics and competition in coastal systems. There is no registration fee for the conference. The deadline for submission of abstracts will be in early September. Submissions from PhD students are strongly encouraged.

Further details about the meeting or the BES can be obtained from:

The British Ecological Society,
26 Blades Court, Putney,
London SW15 2NU
Tel: +44-(0)181-871-9797
Fax: +44-(0)181-871-9779
Email: general@ecology.demon.co.uk

More information about the Aquatic Ecology Group is available from:

Mike Dobson
Dept of Environmental and Geographical Sciences
Manchester Metropolitan University
Chester St., Manchester, M1 5GD
Tel. 0161-247-1587
Fax.: 0161-247 6318;
Email: m.dobson@mmu,ac.uk

Remember: If you are organizing a conference or meeting on any aspect of oceanography, you can publicize it through *Ocean Challenge*. Details should be sent to the Editor at:
The Dept of Earth Sciences
The Open University
Milton Keynes, Bucks
MK7 6AA, UK
Email: A.M.Colling@open.ac.uk

Fort Tourgis – a Marine Centre of Excellence for Alderney, the UK and Europe?

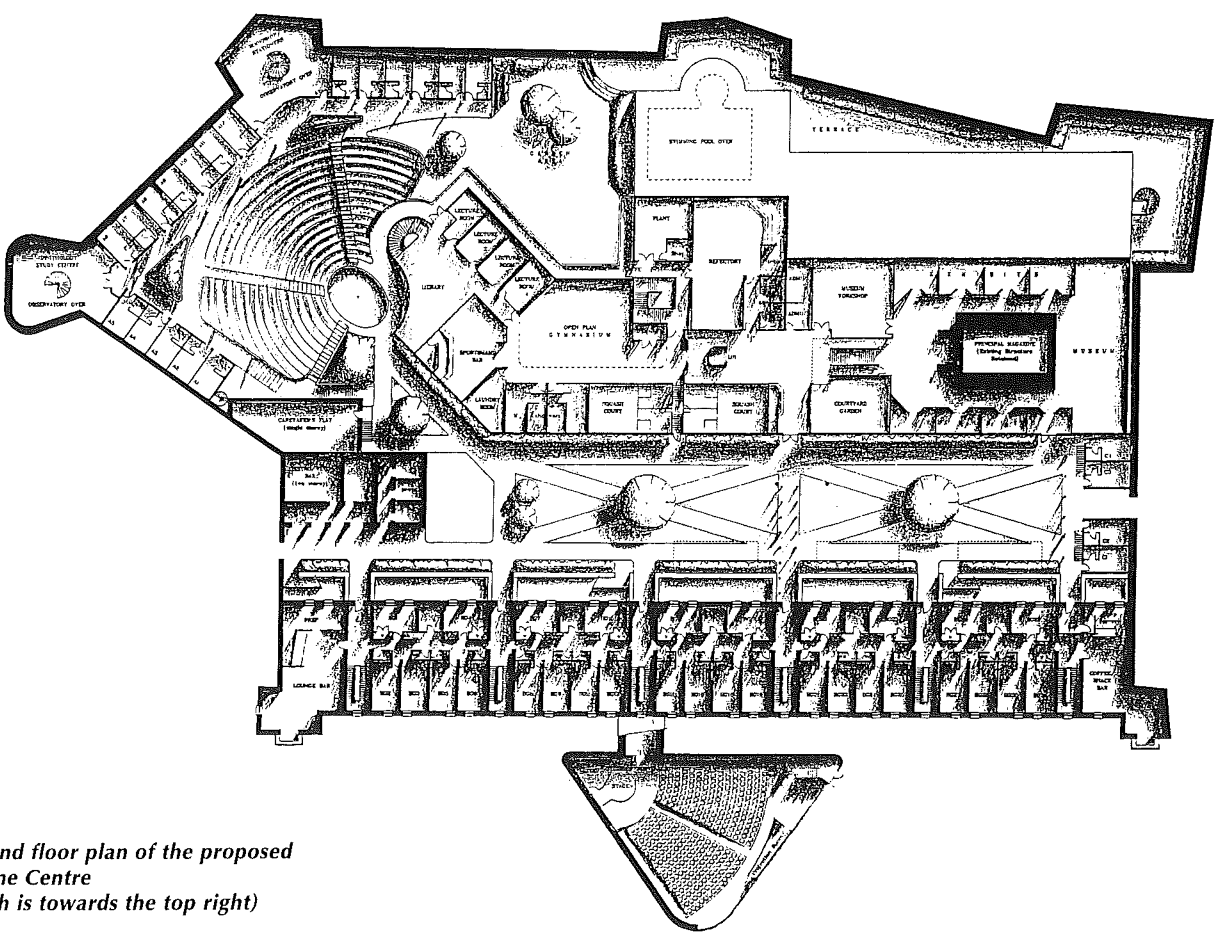
In 1204, King John of England lost mainland Normandy to King Philip of France, and the Channel Islands became the only part of the Duchy of Normandy left to the English Crown. The Islands have continued to owe allegiance to the English Sovereign (as a successor to the Duchy of Normandy) and are dependencies of the Crown. They are therefore unique – neither colonies nor independent, owing allegience to the Sovereign but not incorporated within the UK, inside the European Union for customs purposes but outside the Community as far as fiscal matters and immigration control are concerned.

The Fort

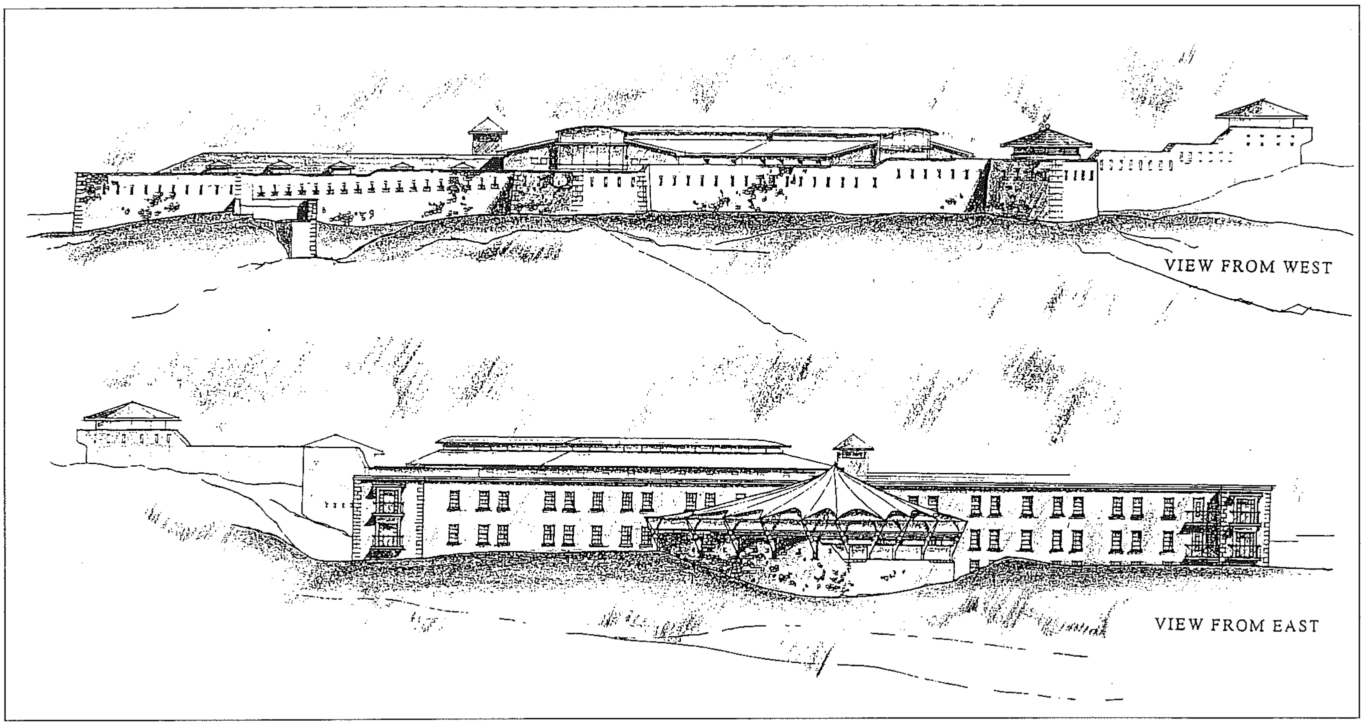
By the end of the French Revolution and Napoleonic struggles in 1815, Alderney and the other Channel Islands were surrounded by coastal forts, most of which were abandoned soon after the ending of hostilities. In 1840, however, the French decided to enlarge their strongly fortified naval base at Cherbourg, and the Admirality recognised that this posed a threat to the security of the naval dockyards at Plymouth and Portsmouth. Alderney was considered to have great strategic potential as a look-out station, and so in 1844 it was decided to abandon Longis and build a new harbour on the other side of the island at Braye for the use of the Royal Navy. It was also decided to defend the whole island with a series of forts around the coast.

Fort Tourgis was completed in 1855 and, like all the other forts ringing the island, was designed by William Jervois. It is the second largest after Fort Albert, eventually boasting five batteries with mounting for 33 guns, and provided accommodation for 12 officers and 247 men. Its position at the north-west corner of the island on the low headland known as Rocque Tourgie was such that the batteries covered both Clonque Bay and Platte Saline, creating an angle of defence of some 180 degrees.

Recognising that it is one of the most important landmarks of the island, in 1993 the States of Alderney decided to regenerate and restore the Fort. An International Design Bid Competition was launched, the aim being to select a project centred around a prestigious building with facilities that could be made available to Alderney residents, provide economic enhancement for Alderney, and at the same time preserve the essential features of the Fort. In February of 1995, the States of Alderney announced that Christopher Fitton and John Mitchell of ASM Properties, Bristol, had won the competition with their proposal to develop this historic site into a Centre of Excellence for Marine Studies.



Ground floor plan of the proposed Marine Centre (north is towards the top right)



The Proposal

The Centre's prime function will be to offer taught MSc postgraduate courses within the three related disciplines of Marine Archaeology, Marine Biology and Oceanography. Students will be given the opportunity to attend lectures in the other two disciplines, so enabling them to become more aware of the importance of inter-disciplinary activities and be more attractive to employers in the various water-based industries. It is also hoped that this arrangement will inspire interdisciplinary research.

During the autumn and winter months, the Centre's programme will attract full-time students seeking experience in marine studies. Over summer vacations, the facilities of the Centre will be used to provide short general courses for both students and non-academic visitors to Alderney. It is envisaged that the facilities at the Centre, and the courses it offers, will be a major attraction for summer visitors.

It is likely that many of the visiting experts and the permanent tutors will come from the participating universities themselves. So far, the relevant departments at the universities of Oxford, Bangor and Southampton have expressed interest in the curriculum to be offered.

Fees and Staffing

At present, planning is based on the following figures:

Full Time Staff
Director, Administrative Assistants, technical and support staff

Visiting Staff
Eight international experts for each of the three terms.

Course Fees

Main Courses	£6,500 p.a.
Short Courses	£125 per wk

Course Numbers

Winter Courses	210 (full-time equiv. students)
Summer Courses	210 (13-wk equiv. students)

Accommodation Fees

Main Courses	£65 per wk
Short Courses	£75 per wk

Financial Strategy

The fiscal basis of the Fort Tourgis Marine Centre had to satisfy the remit of a commercial development (this was a fundamental requirement of the competition conditions). The original funding strategy was based upon the take-up of a lease of the Fort Tourgis complex once it had been developed. The Centre's main source of income will be from the 210 study bedrooms. This method of funding student accommodation has been adopted elsewhere in the UK.

Since ASM won the competition the financial planning has been the subject of close scrutiny by the financial departments of universities interested in becoming involved in the Centre. The capital funding equation has been amended to include a stronger emphasis on reducing the cost of the capital required and the year-to-year running expenses. The reduction in this cost will create much lower break-even points than the original 65% occupancy requirement stated in the original competition, and this will, it is hoped, increase the profit to well over one million pounds should full occupancy be achieved. Any such profit will be invested back into the Marine Centre thus helping to maintain its status as a Centre of Excellence.

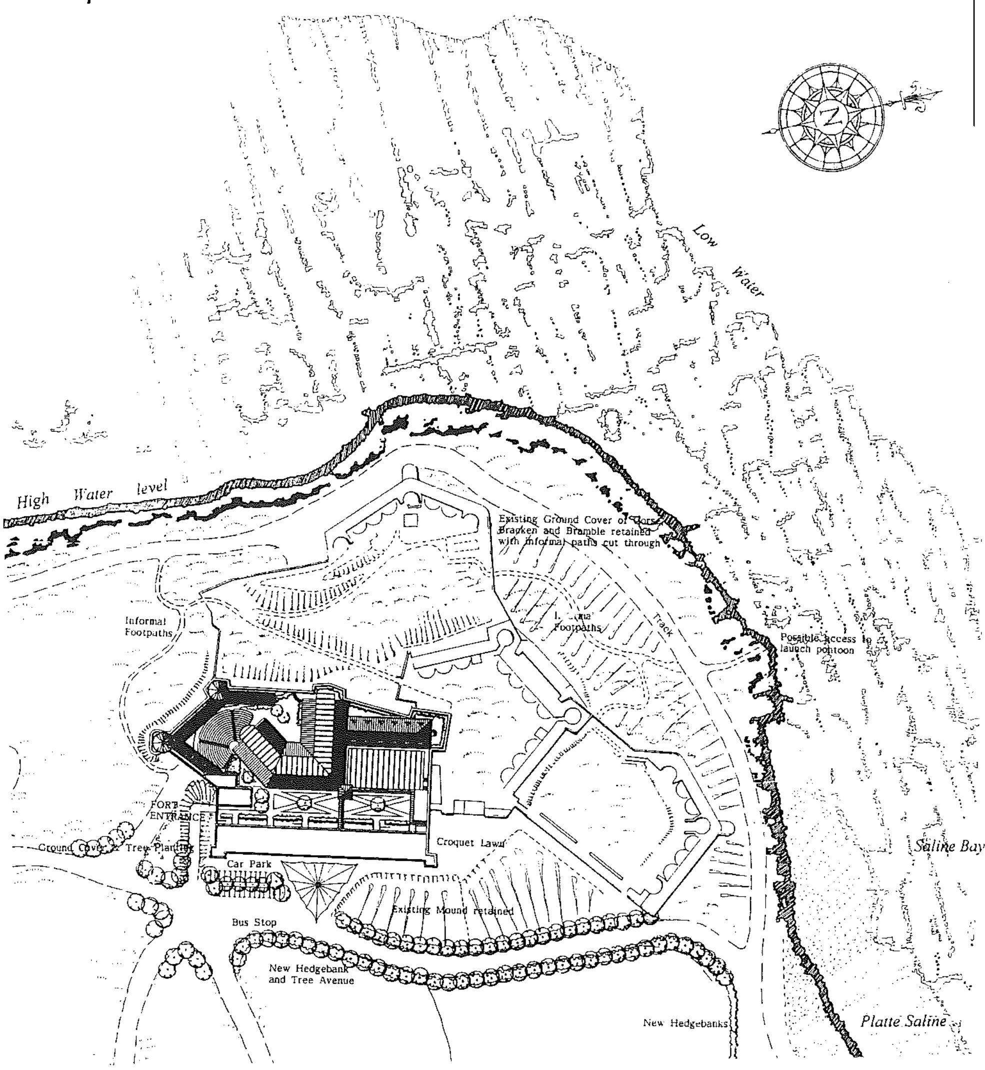
The overall financial model will be designed to ensure the long-term viability of the centre. Funds will be drawn from a variety of sources which include government and company sponsorships, educational and historic grants, private individuals and venture capital. Pledges of scholarships have already been offered and it is hoped that 20% of the total places will be filled in this way.

continued >>

Current Status of Plans

The increasing involvement of universities and the development of course requirements has now enabled the design team to begin work in more detail. The idea that won the competition indicated that the development of Fort Tourgis as a Centre of Excellence for Marine Study could work within the confines of its Napoleonic Citadel, but it is inevitable that the the physical shape and appearance of the complex will change and evolve. Further scope has arisen with the States of Alderney giving permission for additional (but discreet) development beyond the Citadel walls towards the sea. This will allow, for example, the construction of marine laboratories with steady state environments and/or other special facilities. The aim is to provide a high quality Centre within budget that will offer the best facilities and student environment without detracting from, or overpowering, the setting of this historic fort and landmark for Alderney and the Channel Islands.

Landscape plan, showing the proximity of the Fort to the coast and the rocks exposed at low tide



There's Money in It!

Share your views of UK Oceanography 96 with readers of *Ocean Challenge* in a unique opportunity to practise your communication skills and perhaps earn a cash prize at the same time!

We are offering £50 for the best account of the meeting. Accounts should be lively and interesting, well-written and well structured, and about a thousand words long. They do not have to cover all the talks, but should give a flavour of at least some of the science. In the best tradition of science journalism (e.g. Radio 4's 'Science Now'), they should aim to inform and engage all readers, whether specialist oceanographers or interested non-professionals.

Entries should arrive with the Editor within two weeks of the end of the conference. They may be sent as manuscripts or electronically (see addresses on p.3).

The winning account will be published in *Ocean Challenge* in the issue following the conference.

Plans for Educational Trust

The Fort Tourgis Team are now formulating an Educational Trust which is to be registered in the United Kingdom. The Trust will take up the 99-year lease offered by the States of Alderney and be responsible for the management of the Centre. It is envisaged that full academic and financial committees will be set up to organise and administer the centre from within the Trust.

In formulating the Trust, the Fort Tourgis Team would like to hear from any readers with an interest in the Fort Tourgis Educational Trust or the use of the Centre.

If you are interested in this project, or have any queries, you should contact:

Christopher Fitton
Special Projects Director
ASM Properties Ltd,
Trafalgar House
The Promenade
Clifton Down
Bristol, BS8 3NG, UK

Tel. +44-(0)117-923-8218
Fax: +44-(0)117-923-8103.

NOW There's a FUNNY THING...

A Diet of Worms ...

Ocean Challenge readers might be forgiven for being fed up with reading yet more about the *Brent Spar*. But whether we like it or not, the Greenpeace–Shell battle raised the deep sea higher on the public agenda than it has ever been before. We should milk it for all it is worth – and also learn any lessons we can from it. Here is another little gem that you might find interesting. It starts long before *Brent Spar* impinged on the public consciousness, so please bear with me.

On August 23 1993 *The Times* carried an article describing the plans of a US-based British engineer, Graham Hawkes, to build high-speed submersibles that would 'fly' to the bottom of the deep ocean. Like the much longer article on the project in *Time* magazine in August 1995, the *Times* piece was justifiably enthusiastic about the contribution that the proposed vehicle might make to our understanding of the depths of the oceans. However, it also contained two glaring errors of fact. First, it intimated that scientists had only recently realised that living organisms were to be found at the bottom of the oceans, whereas this was well-known in the 1870s. Second, it suggested that the radical new vehicle might lead to the discovery on the bottom of the deep ocean of previously unknown animals (which it almost certainly would) and plants (which it equally emphatically wouldn't; plants need light to enable them to photosynthesise, a process quite impossible in the depths of the oceans).

I was so incensed by this demonstration of fundamental ignorance of the environment that covers two-thirds of the Earth's surface that I wrote a letter to *The Times* in an effort to correct any misconceptions. Apart from one or two minor, but irritating, editorial changes, *The Times* accepted the bulk of the letter and published it on 3 September 1993. But they refused to accept the following final paragraph:

"This is all very esoteric and probably doesn't matter very much to most readers. But it is my experience and, I suspect, that of most other people, that whenever one knows anything about a subject reported in the media, even a newspaper as widely respected as *The Times*, the report will be fundamentally flawed. A worrying corollary must be that our knowledge and opinions of most other matters are probably based on inadequate, outdated and erroneous information."

In arguing for the removal of this paragraph, far from claiming that newspapers generally get things right, the Letters Editor said "But everybody could write that," implying that the expressed sentiments were correct, but that there was nothing that they could, or perhaps should, do about it.

Although the ultimate outcome – the misinformation of the public – is the same, I would argue that it is one thing for a journalist to reveal his or her ignorance of a topic in a published piece, and quite another to misquote a so-called expert and therefore apparently to reveal their ignorance also. It is as a warning about this second-hand attribution of ignorance that this article is directed, based on my own '*Brent Spar* experience'. I imagine that similar stories could be told about other current news items with a scientific background such as BSE, female contraceptives, and the European fisheries policy.

The end of the story in my case, and the spur which led me to write this article, followed a lecture at the Royal Society of Arts on 6 December 1995 by Chris Rose, Greenpeace's campaign director. The short lecture itself was well-delivered and quite informative, but not nearly as revealing as the hour plus question-and-answer session that followed it. This was dominated by a number of Shell employees who clearly had decided to use the opportunity to put over their own point of view, that Shell had been a wonderfully green and socially conscious organisation, particularly in its activities in Nigeria. As the last questioner in the session, I was able to express my own concern at the amount of erroneous information that had been fed to Joe Public during the *Brent Spar* debate and to ask if Chris Rose, or Greenpeace, had any suggestions about how we, all of us, should deal with the media in order to ensure that the correct message gets across.

Understandably, Chris Rose had no real answer, but in the bar afterwards his Greenpeace boss, Lord Melchett, accused me (and the Natural Environment Research Council) of being the source of at least one piece of erroneous information – that the proposed dump site for the *Spar* was a low biodiversity environment. When I protested that I had never said any such thing, Peter Melchett pointed out that I had been quoted widely, and in the most 'exalted' of circles, as maintaining that deep sea disposal of the structure would result in "the death of a few worms". He was quite right, of course. Since the story of how this misquotation came about is at the same time both amusing and vaguely sinister, I share it now with you as I did then with him.

It began one day in late May last year when Charles Clover, the *Daily Telegraph* environment editor, phoned me because, he said, he understood that I believed that dumping the *Brent Spar* in the deep sea would do no harm. I countered by saying that I had never suggested anything of the kind, but that of the two alternatives apparently available – deep sea dumping or dragging the *Spar* through the North Sea for land-based disposal – I believed the former carried with it considerably less environmental risk than the latter. "Then what will happen if the *Spar* is dumped?" asked Clover.

"Well for a start," I said, "it will disturb the muddy sediment over a large area, equivalent to at least a couple of football pitches, and will kill millions of animals." Clover's response indicated that this was neither what he expected, or perhaps wanted, to hear. So I calmed him down a bit.

I pointed out that only a few hundreds of the immediate fatalities would be of the types of animals that most people would think of: starfishes, sea-urchins and their relatives; crabs, shrimps and lobsters; clams and snails; fishes and so on. Instead, the vast majority of the mortalities would be among the myriads of little beasts that live within the sediments and form the basis of the sea-floor community.

"What sorts of animals are they?" asked Clover. Avoiding the difficult concept of bacteria and forams, I said that they would include a number of groups such as small crustaceans, polychaetes and molluscs, but above all would be nematodes. You've guessed it. Next question: "What are nematodes?"

Well, I said, foolishly warming to my task, they are little worm-like creatures and are probably the most abundant group of multicellular animals on Earth, found in all environments on land, in water and even in the air. In fact, I rushed on, it is nematodes, though different species from those found in the ocean of course, that are killed in their millions whenever we undertake major earthworks. For example, I guessed that a similar number of nematodes would be destroyed by the *Brent Spar* as are killed each time we build a quarter of a mile of motorway – or, for that matter, a large hospital.

On 31 May the *Telegraph* carried a long piece by Charles Clover in anticipation of the North Sea Conference due to take place in Esbjerg, Denmark, the following week. The main thrust of the article was the environmental damage caused by intensive fishing in the North Sea, much of it by just those nations that had been most vocal in criticising the UK Government's decision to licence the dumping of the *Brent Spar*. But in a tailpiece under the title 'Dump the rig – and be damned' Clover referred to our conversation reasonably accurately and misquoting me only in a relatively minor way.

"It [*Brent Spar*] is a large structure", he had me say, "which will undoubtedly cause some changes in water flows and local disturbance of sediments ... Some animals [but not millions] – mostly worms and bivalves – will be killed," he had me continue, "But people don't seem to ask how many millions of creatures – worms and so on – are killed when you build a mile of motorway or a hospital."

The original conversation had been for the best part of half an hour, so this distillation seemed a bit drastic. But I was already used to such media filleting; after all, twenty minutes of recording for television or radio is frequently cut to as many seconds. I was also a bit peeved by Clover's cavalier treatment of my numbers, and my taxonomy. But since the main message seemed to have come across, I did nothing about it. In any case, anyone who has ever dealt with the media knows that no-one reads retractions or corrections.

Anyway, nobody seemed to pick up on what I might or might not have said and other issues hit the headlines – arguments about just how much oil was in the *Spar*, and leaked MAFF internal memos, for example. Then, on 20 June, as the *Spar* approached the proposed dump site, Charles Clover again used our conversation in a short piece under the headline 'Storm in Atlantic teacup'.

This time he had me saying, though not within quotes, that the most likely impact was the death of *a number of worms* on the sea bed [my italics]. This would be equivalent to the number killed by the building of a hospital or a quarter of mile of road.

That same evening Shell capitulated and the Greenpeace victory had wall-to-wall news coverage around the world. Two days later John Major resigned and the *Brent Spar* was largely pushed out of the headlines by the Major–Redwood battle. But this time my "worm" remarks had been taken up by no less an organ than *Private Eye*. Although the *Eye* was more concerned with trying, unsuccessfully, to demonstrate that my lab was in Shell's pocket, they repeated part of the *Telegraph* article almost, but not quite, word for word. According to the *Eye* on 30 June, I had told the *Daily Telegraph* "that the most likely impact of rig-dumping would be the death of some worms – equivalent in number to worms killed by the building of a hospital or road." Please note, we are now talking about "some worms" [how many is "some"?] and no longer about the *Brent Spar*, but about "rig-dumping" [how many and what sort?].

When we were done over by *Private Eye* my group thought we had reached the citation zenith of any scientific career, but the best was yet to come. Once the Conservative leadership election brouhaha had died down, the *Brent Spar* again became a hot political issue. In the Prime Minister's re-shuffle Tim Eggar had become the President of the Board of Trade, and on 12 July he faced questions in the House on the *Brent Spar* which, along with the answers, were faithfully reported in *Hansard*. Tony Banks asked if the Minister could "assure the House that environmental considerations are uppermost in his mind and that dumping something at sea is more environmentally advantageous than bringing it ashore?"

In his answer, Mr Eggar included the following statement, presumably provided by one of his minions in the DTI (now, incidentally, with the move of the Office for Science and Technology, the Department from which my salary ultimately comes!)

"As for the environmental damage that the hon. Gentleman claims will be done to the deep sea and the Atlantic, I shall quote Dr Tony Rice, an independent scientist and probably the leading independent deep sea biologist in the country [wow!], who said that the most likely impact of deep-sea disposal of the *Brent Spar* was "the death of a number of worms on the sea bed". It is no good the hon. Gentleman shaking his head. The leading independent deep-sea biologist said that, and that it was equivalent to the number of worms that would die on the ground during construction of a quarter of a mile of motorway."

Since I have never spoken to Mr. Eggar nor, as far as I am aware, to his Civil Servant advisers, I can only assume that the "quote" was taken from a newspaper article. Indeed, it must have been, because I would have been careful to emphasize the millions of animals that would be killed by a dumped *Brent Spar*, or by a comparable impact on land. In fact, except for the organisms directly concerned (on which the impact would be rather dramatic), I have said publicly, and reiterate here, that I believe that neither a dumped *Brent Spar* nor a quarter mile of motorway construction would be, on their own, environmentally disastrous. But this is not the point. My grouse is that via a couple of simple intermediate steps a perfectly reasonable statement by a so-called expert can be totally misquoted by a Minister of the Crown and, at least in some eyes, therefore achieve a degree of credibility.

Lest you believe that in these cynical days no-one takes any notice of what a politician says, let me end with a final little twist in the tail of this story. A few weeks after the *Hansard* account was published, a German colleague sent me a cutting from a small local newspaper, the *Flensburger Nachrichten*. Here, Mr Eggar's quotation of the effect of dumping the *Spar*, firmly attributed to me (den britischen Tiefsee-biologen Tony Rice), becomes "Der Tod von ein paar Würmern auf dem Meeresgrund". My initial assumption was that my "millions" had now become "two"! But my German friends assure me that it is not quite as bad as that. Ein paar with a small 'p' apparently means 'a few', but definitely no more than about ten.

So there we are. In four easy stages, from a telephone conversation to a *Daily Telegraph* article to a *Hansard* report and finally to the *Flensburger Nachrichten* my original estimate has been reduced by at least six orders of magnitude, but is still attributed to me! No wonder Peter Melchett, and goodness knows how many others, have a jaundiced, not to say totally wrong, view of what I, and presumably others, have said. So the *Times* Letters Editor was in a curiously twisted way quite right not to accept my warning paragraph; everyone probably could write that.

But what should we, as scientists, do about it? Well, we could refuse to have any dealings with the media on the grounds that they always garble what we say. We could, but I don't think that is a satisfactory answer. For one thing, many of us would find it very difficult. No matter how hard we protest, most of us are flattered, naturally, to be considered worthy of media attention. Moreover, if we are worth our salt as scientists we are, indeed, expert (perhaps *the* expert) in our particular area, no matter how small and specialised that area may be. And if our expertise impinges on some important decision, no matter how peripherally, we should be not only willing but anxious to make our knowledge available to the decision-makers and the public at large. As long as we do not step outside our area of expertise, or exploit our expertise to make value judgements in areas for which our knowledge does not qualify us, this is a responsibility that we should not shirk, particularly if we are independent of the vested interests involved, political, commercial or environmental.

So if we are not to shun the media, what are we to do? I can only offer you my personal solution. First, be philosophical; whatever you do the media are likely to misrepresent your statements and opinions. Don't despair when this happens; instead, try to learn from their mistakes, and yours, and aim to do better next time. If you have something to say that you think is newsworthy, be pro-active instead of reactive. Take the initiative and contact the media instead of waiting for them to contact you. And if you have stumbled across a journalist who seems to get it right more often than wrong, give the story to him or her first and tell them why you are doing so. It will work wonders; journalists are no more immune to flattery than we are. If all else fails and you are caught on the hop by a 'phone call and an urgent request for an on-the-record interview, don't be rushed or bullied. If the story is that important they will wait. If it is for a newspaper or magazine, ask them what they want to know and tell them you will let them have a couple of hundred words in writing. But be reasonable; get it to them quickly by fax or Email rather than by second-class post! If it is for radio or television, go for a live interview rather than a recorded one if you have the choice. This may sound terrifying, but at least it will be your words that go out, warts and all, and not what some editor thinks you said or wants you to have said.

Finally, if all of these strategies fail or are inappropriate, think carefully of the three or four important points that you would like to make – and make them, repeatedly if necessary, to drive them home. Don't allow yourself to be side-tracked into less important issues; given the choice, journalists seem to have a highly developed propensity to highlight trivia and to throw away the gold dust. Don't give them the chance.

Having given you chapter and verse about just one of the many ways in which I have been misrepresented over the last few months, it may seem a little pretentious to advise you on how to avoid the same fate. But I hope that I am rather more media-wise now than I was a year ago and that I won't fall into quite the same traps in the future.

Above all, don't let me put you off dealing with the media. Though I wouldn't go so far as to claim that no publicity is bad publicity, good science needs all the exposure it can get. Anyway, despite the obvious frustrations, becoming involved with the media can be very rewarding – and it can be fun!

Tony (A.L.) Rice
Southampton Oceanography Centre

The Grape Vine

• Many members will have been saddened by the recent death of Ron Currie, whose steady work as Challenger Society Secretary (effectively chief executive, in those days) did much to sustain the Society for over 30 years, until its reconstitution in 1988. An obituary will appear in the next issue.

• Professor John Pethick has moved from the University of Hull to Cambridge, where he is in charge of the Department of Coastal Research.

• Dr Graham Shimmield, formerly at the Dept of Geology and Geophysics, University of Edinburgh is now Director of the Dunstaffnage Marine Laboratory, Oban, where he succeeds Professor J.B.L. Mathews, who remains Secretary of SAMS.

• Your Associate Editor was fortunate to meet Dr Alice Newton who works at the University of Algarve in Portugal. She was recently on a research visit to Menai Bridge, in connection with a joint project on the Faro lagoons with Steve Mudge. She hopes to recruit some members for the Challenger Society in Portugal, and we have been promised an article on the research she and her colleagues are doing.

• Dr Paul Tett has moved from the School of Ocean Sciences, Bangor, to Napier University, Edinburgh.

A message to readers

The items of news above are the result of our spies being in the right place at the right time. If you would like to contribute any news about people or projects, or indeed longer items for the News and Views pages, please write to the Editor at the Open University (for full address, see inside back cover) or send a message by Email: A.M.Colling@open.ac.uk

News and Views

Water Mass Changes in the Eastern Mediterranean – Anthropogenic or Natural?

In Volume 5, No.3, we published an article by Michael Krom on the Oceanography of the Eastern Mediterranean. It focussed principally on some unusual aspects of the surface circulation and biological production, after summarising the main water masses and their formation (see also below). This item is about the deepest of these water masses.

Since the early decades of the century, the Adriatic Sea has been identified as the dominant source region for water below about 1 200 m over the whole of the eastern Mediterranean. Cooling and evaporation by strong winds, especially in winter, increase the density of surface waters and they sink. Another potential source area for sub-surface water masses is the Aegean Sea, but water from this region has previously been identified only at depths of less than 1 000 m.

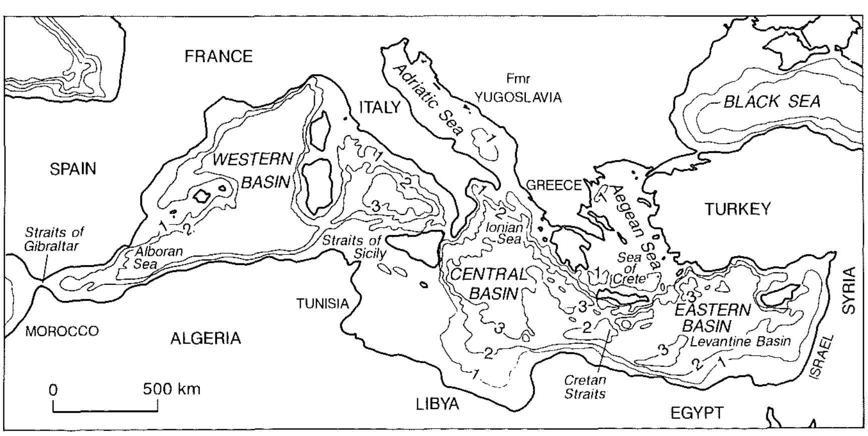
The last comprehehsive hydrographic survey, made in 1987, confirmed this general picture of the thermohaline circulation in the Eastern Mediterranean. A 1995 survey found some interesting changes, however. Deep water salinities had previously been rather similar all the way from the Central Basin to the Levantine Basin (see map): 38.65–38.70 between 1 200–1 500 m and the bottom at 2.5–4 km, depending on location. The new survey found that salinities in the lower part of the water column in the vicinity of Crete were now significantly greater, but that values actually decrease *upwards*, from >38.80 at ~3 km to <38.75 at ~1 km, above which salinities increase again towards the surface – in short, there is now a salinity 'inversion' at ~1 km in the water column around Crete.

CFC tracer data suggest that this inversion is a recent phenomenon, and the researchers propose that the 'new' high-salinity deep water started flowing out of the Aegean in 1988. The intrusion of this Aegean water has displaced older lower salinity deep water upwards, and may have brought nutrient-rich waters nearer to the surface, which could enhance primary production in the region.

These changes in the pattern of deep water formation may have been triggered in some way by the general increases in both temperature and salinity of Mediterranean waters observed in recent decades. This has been ascribed by some authorities to the damming of rivers for agricultural purposes. Are we looking at the first example of how human activities can affect thermohaline circulation in the oceans?

Postscript and Correction: Readers may have gathered a false impression from Figure 3 of Michael Krom's article that Levantine Deep Water wells up to the surface between Crete and Cyprus. The 'bubbles' on the diagram were intended to indicate sub-surface mixing of this deep water with the intermediate waters flowing westward out of the basin. Our schematic diagram also implied that formation of Levantine Intermediate Water occurs only east of Cyprus. In fact, it mainly occurs south of the Turkish coast (as stated in the article).

The basins of the Mediterranean Sea



There may previously also have been a contribution from the Aegean to intermediate waters in the Eastern Basin, though the data summarised above indicate that Aegean water now descends to greater depths.

Sound Bites

The idea of monitoring the progress of global warming in the oceans by measuring small increases in the speed of sound in seawater requires a mega-scale experiment, because small changes in sound velocity can only be detected over very large distances. Readers will no doubt have read or heard of the proposal to propagate low-frequency sound pulses along the sound channel throughout the oceans, and record travel times at distant locations. Heard Island in the Southern Ocean seems to be the favoured point of origin (sound can radiate from there into all three main ocean basins), with receiving stations as far apart as Bermuda and San Francisco.

Environmentalists and marine mammal watchers are not keen on the idea, because for sound to travel those great distances, you have to make fairly loud bangs, which could seriously damage – so the story goes – the animals' sensitive auditory organs. This concern is presently being tested at the Scripps Institution: 195 decibel 'rumbles' are being broadcast for twenty minutes every four hours. So far there have been no observable behavioural changes in any marine mammals in the vicinity. That's fairly amazing, because 120 decibels is roughly what a jet engine puts out, and 195 decibels is several orders of magnitude louder than that.

The testing programme will continue until near the end of 1996, and if results continue 'promising', the Big One will presumably go ahead. Imagine: the Millenium may yet be marked by huge drumbeats echoing through the oceans.

Environmental Management – Soviet-Style

The sad saga of the dessicating Aral Sea has been told many times in recent years, by environmental magazines and newspaper colour supplements. It is cited as a classic and obvious example of the former Soviet regime's complete disregard for the principles of sustainability and conservation of natural resources. It was partly a matter of ignorance, but political dogma played a major part, as in: "Nature is there to be tamed by the people for the good of the State."

The much larger (~1 000 km long) Caspian Sea, 500 km west of the Aral Sea, seems to be no better off environmentally, though its level has actually been *rising* since 1978. Before that, the sea had been receding from its shores for several decades, allegedly as a consequence of dam construction along the Volga, which supplies some 80% of the river inflow to the Caspian (though it seems the recession actually predated the dams). Again because of the Soviet obsession with economic growth and total disregard for the environment, the Caspian is heavily polluted with wastes from the petroleum production (especially the vast oil installations round Baku in the western Caspian), mining and nuclear industries.

Effects on the biota have not been beneficial. The Caspian is a relatively small remnant of the ancient Tethys Ocean (the Mediterranean is the largest), and it became freshened during the Pleistocene (~1 million years ago) and evolved around 400 endemic species, including sturgeon, and other commercially exploited fish. Pollution and damming of rivers have caused drastic reductions in fish stocks, and the sturgeon fishery was almost extinct by 1995. Shipping can easily reach the Caspian from the Black Sea (via the Don and Volga Rivers and the Lenin Canal which links them), and so can aquatic organisms. A current matter of concern is the possibility that *Mnemopsis leidyi*, described as "a voracious West Atlantic ctenophore" may reach the Caspian. It arrived in the Black Sea in the 1980s, destroying the local pelagic food chain and causing collapse of fisheries; it could easily be introduced into the Caspian via ships' ballast water.

That the Caspian Sea rises and falls on a cyclical pattern has been known since ancient times, but although climatic change and tectonic factors are the favoured causes, the precise mechanism remains elusive. As the level continues to rise, the waters will presumably flood installations constructed before and during the 1960s and 1970s, mobilising and dispersing the various toxic substances that impregnate the land surrounding those installations. An interesting twist to the tale is a proposal to build a 500 km canal linking the Caspian and Aral Seas, partly to ameliorate the rise in the Caspian, partly to try and refill the Aral Sea. As it happens, however, the Aral Sea is actually higher than the Caspian (a matter of 80 m or so) which means water would have to be pumped between the two. Plus all of which, the Caspian may well have started on the downward part of its cycle by the time the canal is built.

Manned Submersibles 'Nautile' and 'Cyana'

As part of the framework of the European programme 'Training and mobility of researchers – access to large-scale facilities', Ifremer offers one place on each of ten scientific cruises of *Nautile* and *Cyana* in the years 1996–1997–1998 for young European scientists who do not normally have access to such equipment.

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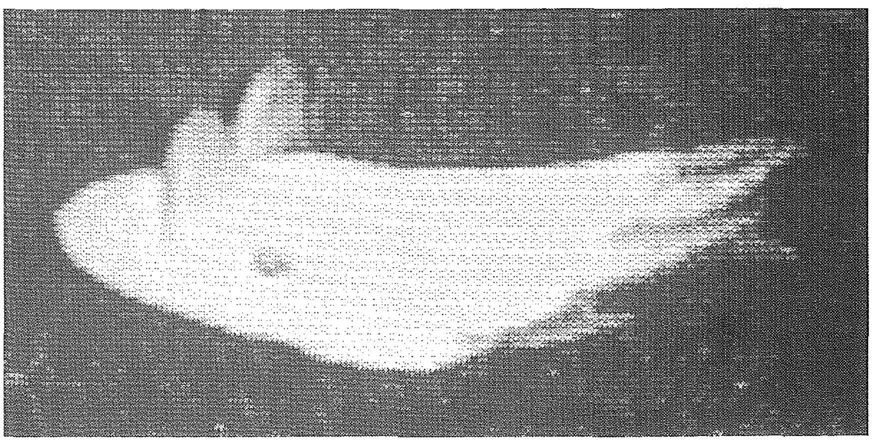
The White 'Sea Bat' of the Antarctic Pack Ice

This extraordinary 'sea bat' octopus is named *Opisthotenthis weddelli* and is found only under the pack ice of the Weddell Sea in the Antarctic. The only white sea bat in the world, it is the subject of intensive research by the French Ifremer Antarctic Research Base, director Dr Yves Toumalin. The white sea bat does not live near the bottom like other sea bats but lives right near the sea surface among the jagged 'keels' of the pack ice.

By night, the white sea bats descend from the ice and somehow detect and eat krill, *Euphausia superba*, which is their only food. By day, in sunny weather, an even more extraordinary behaviour occurs: the sea bats locate openings to the surface – seal breathing holes or natural cracks between ice floes, etc. – and somehow crawl up and out of the pack ice fissures and spread themselves on the surface of the ice. Dr Toumalin believes that this species may have some special requirement for UV radiation, and that this is how they expose themselves to UV rays.

Whether lying spread out on the ice UV-bathing, or swimming about the underside of the pack ice, the whiteness of these sea bats presumably camouflages the animals and helps reduce predation by penguins and seals. How the sea bats do not freeze solid when spread out on the ice is another mystery. The French are also studying this, in the hope of discovering some new antifreeze chemical.



White sea bat below the pack ice. It is swimming using its fins, with its arms held together for streamlining.

Photo and news from French Antarctic base, 1.4.96. Photo from diver's video film, reproduced by courtesy of Ifremer.

Overfishing and Extinction – The Continuing Story

What is depensation? It is the inability of a natural population of animals to recover when it has been so depleted by predation that survivors are unable to reproduce efficiently. It is also called the Allee effect or inverse density dependence. Extinction follows, because even if predation ceases, the population cannot recover. Depensation occurs because the ratio of recruits to total population decreases as population declines, and it has apparently been documented for some insects and marine mammals, including whales (though one of the more striking examples must have been the North American passenger pigeon).

It seems obvious, doesn't it? And when applied to fisheries, depensation would imply that you might as well fish your stocks right out (i.e. to extinction) rather than close the fishery when numbers get low, to enable them to recover – because they won't (this view could have some adherents among participants in the recent discussions on EU fisheries policy, and we return to it later).

As usual, things are not so simple. A comprehensive investigation of over 100 severely depleted fish stocks, recently reported in *Science* (August 1995) showed evidence of depensatory behaviour in only a minority of them – and that evidence was not conclusive. In all other cases, it seems that the ratio of recruits to population appeared actually to *increase* at low population levels. These included stocks of cod, plaice, hake and most other commercially valuable fish examined.

The conclusion is that if fisheries collapse, it is because of overfishing alone, not because overfishing has been compounded by depensation. The implication is that if you stop fishing for a while, stocks will recover unless environmental or ecosystem-level changes alter the underlying dynamics of the stock (e.g. through global warming) or if survivors succumb disproportionately to natural predation. That seems by no means impossible: relatively abrupt removal of a major part of a food web by overfishing could alter the dynamics of the ecosystem to the detriment of survivors.

But assuming this doesn't happen, at what point in the decline of the population is fishing to be stopped? And then for how long must the fishery remain closed? For example, it was reported that stocks of Newfoundland cod were in rapid decline during the second half of the 1980s, but only in 1992, when the stock was estimated to be 1/100th of its original size, was the fishery closed. 35 000 jobs were lost, and three years later there was still no sign of recovery. On human time-scales, closing a fishery can have long-term effects.

Although the research summarised above was for North American fish stocks, we might presume the results are generally applicable. So what implications might they have for Atlantic waters round Europe? We are constantly being told that too many fishermen are chasing too few fish and that too many young and immature fish are being caught, i.e. there is both growth and recruitment overfishing. Even allowing for the considerable natural fluctuations that fish stocks experience, varying by as much as an order of magnitude between one year and the next (so that measurements must be made against a very 'noisy' background), there is now enough evidence to convince even the most hardened sceptic that European fish stocks are in serious decline.

At the end of 1995, the total allowable EU catch for the six main fish varieties (plaice, sole, mackerel, herring, cod and haddock) was reduced from 1.4 million tonnes to a little over 1 million tonnes. But the cut was applied differentially; indeed, the quotas for cod and haddock actually went *up* slightly. This seems bizarre in the light of headlines in the press throughout 1995, carrying messages like: 'Crisis for cod and haddock threaten fish and chips', and 'Scientists say North Sea cod is facing extinction'. What's more, Britain's Fisheries Minister was actually able to negotiate an *increase* of 50 000 tonnes in the total allowable catch (to be shared *pro rata* among the fishing nations).

The quota reduction means that more fishermen will go out of business, but this seems also to have differential effects: It is said that that UK fishermen are receiving EU money to *compensate* them for decommissioning and breaking up their boats, while at the same time Spanish fishermen receive EU money to *subsidise* them to improve the fishing efficiency of their vessels. 'Quota-swapping' also seems to be rife: boats owned in one country are registered in another, so that they can fish its waters and then take their catch home. It is difficult to see who benefits from such arrangements in the long term – certainly not the fish.

In the light of the widespread acknowledgement that too many boats are chasing too few fish, it seems manifest folly to make what can only have been a political decision to allow up to 40 boats from Spain and Portugal to fish in the Irish Box, hitherto the exclusive preserve of British and Irish vessels. All very well to say that 'foreigners' will be rigorously prosecuted if they are caught fishing there without permission, but would they be caught? And what guarantee is there that those fishing *with* permission would stick to their quotas? What's more, the quotas allocated to these additional vessels must mean drastic reductions in those allocated to UK and Ireland. In the context of a decreasing butter ration, it is not helpful to have to spread the butter even thinner.

For years, scientists and fishermen have inveighed against a quota system which encourages dumping or illegal landing and selling. About 25 million tonnes of dead and dying fish are thrown back into the sea every year, a huge amount in the context of a total world marine catch of some 80 million tonnes. Dumping occurs because quotas are exceeded – usually inadvertently – and/or because the fish are undersized. It is better to dump than risk penalties that put you out of business. Not every country has rules that encourage dumping. Namibia for example, expressly forbids it, even though it imposes catch quotas, and systems have been evolved to enforce both the ban and the quotas and to deal harshly with illegal fishing in Namibian waters. The system is not perfect and is open to abuse, but it must have lessons for the nations of the EU who should surely also be persuaded to insist on the use of nets that allow young fish to escape. Such nets have been designed, and have a mesh that keeps its size and shape in operation and so allows small fish out, instead of closing up into a bag and entrapping all within.

There is a real prospect that some fish stocks may be harvested to extinction if the economics of the free market are left to dominate. The reader is referred to a somewhat chilling analysis of this issue by Robert M. May (now Chief Scientific Adviser to HM Government), in *Nature* for 3 November 1994 (pp.42–3). His article does not rule out the possibility that a political decision could be (perhaps even has been?) made to permit 'fishing to extinction' of selected stocks in some areas, in order to maximise the economic returns – though it is not likely such a decision would be widely publicised. That is not so far-fetched as it seems; after all it may already have happened to the Newfoundland cod.

It does not seem too implausible that extinction of many commercial fish stocks could occur within decades (or less). It is likely, in consequence, that the media will increasingly be reporting unedifying variants (or repeats) of the Spanish–British tuna war of 1994 or the Spanish (+EU) Canadian halibut (turbot) war of 1995.

It is strange how another EU member can see this fishing business from a quite different perspective. In late-1995/early 1996 Portugal was battered by storms and gales, and flooded by torrential rain. It broke the drought of the last few years and at least ensured that there may not be too many water shortages and (hydro-electric) power cuts this summer – but it played hell with the fishing industry.

The national and local papers were full of stories about the shortage of fish and the impending bankruptcy of fishermen who could no longer afford to maintain their boats, because of lack of income. This may sound familiar, but the reason had nothing to do with wicked foreigners fishing inside Portugal's 200 n.m. limit; it had everything to do with the fact that they couldn't go to sea because the winds and waves were too fierce. Indeed, while we read and hear a lot about Portuguese fishing boats operating in our waters (under licence of course), and 'taking our fish and our livelihoods', there seems to be little or no traffic the other way. Is this possibly because Portugal's shelf is narrow, and while the upwelling does provide a rich coastal fishery, stocks are simply not large enough to justify 'invasion' by larger foreign vessels? Up until the 1960s, one of the big annual events in Portugal was the departure of the cod-fishing fleet for the Newfoundland banks; the sailing ships and dories were blessed by the bishop of Lisbon as they set off from Belêm, and the dried salt cod (bacalhau) with which they returned was a cheap staple food. (Interested readers are referred to the books by Alan Villiers, who immortalised the cod fleet and its crews.) So even then, the Portuguese were relying on fish from distant waters. With the Newfoundland fisheries now subject to potential depensation (for which the Portuguese cannot be held more than partly responsible – and a small part at that), it is perhaps small wonder that Portugal has sought access to the Irish Box. This may only feature in the Portuguese press when/if there is a run-in with the locals.

Brent Spar ... again

It won't go away, you know. Those fetching pictures of *Brent Spar* posed attractively against the mountainous backdrop of a Norwegian fjord do not imply a permanent resting place for the rig – even though it has already become a tourist attraction. Now that it has been established that the rig is nothing like as toxically disadvantaged as Greenpeace had originally claimed, the way is open once more for serious consideration of the deep-sea disposal option. Press reports have suggested that there has been some divergence of opinion among the senior heirarchy of Shell. Some say the deep-sea option remains definitely ruled out, some say the contrary. The fetching pictures mentioned above don't show the iceberg-like four-fifths of its total length beneath the water surface – something like 80 m, deeper than much of the North Sea. The problems of getting the rig ashore for the land-dismantling option remain just as formidable as they always were. Who will wager against the eventual resting place for *Brent Spar* being the deep Atlantic, at or near the site originally proposed?

Another reason why this issue won't go away is that the oldest North Sea rigs must be nearing the end of their useful lives, and as we go to press there is news that the Leman gas rig about to be dismantled. It's only a 6000-tonne structure (that's the amount of *ballast* there is in *Brent Spar*), and it was always intended that it would be dismantled on land. We understand that another four North Sea structures are scheduled for decomissioning shortly. Some of them are *huge*, up to 250000 tonnes. After a few years the *Brent Spar* controversy may come to be seen as a minor storm in a historically trivial teacup.

Incidentally, many people have pointed out that hundreds of millions of tonnes of shipping were sunk in the Atlantic during two World Wars. Hundreds of thousands or perhaps even millions of tonnes of fuel oil must have gone down too (not all of it floated and/or burned on the surface), along with no doubt very substantial quantities of toxic metals. And what about the millions of tonnes of munitions dumped at sea after the War (see item overleaf)? *Brent Spar* is a pygmy by comparison with all that, and even the most ardent conservationist would have to admit that the *rate* of accumulation of large objects in the deep sea in the last five decades is a fraction of that which prevailed in the 1940s. Would there have been so much fuss about *Brent Spar* if somebody had stood up publicly and said these things? Or did somebody say so, and it was never reported because it would have spoiled a good public row?

Cynicism apart, is there a psychological angle to all this. The huge tonnages of shipping lost in wartime were sunk at a time when nobody knew much about currents in the deep sea. Insofar as anyone thought about it at all, was not the deep sea envisaged to be a region of very slow (or even no) water movements? Because all those sunken ships disappeared into this 'quiet' environment, have we come to think of them as still resting undisturbed on the ocean floor? We now know about mesoscale eddies and abyssal storms. Is that why nowadays we see any *new* anthropogenic additions to the deep oceans as subject to much more rapid dispersal through the water column than was previously realised?

Fisheries Review

A recent MAFF publication (see below*) provides a fascinating review of fisheries around the coast of the UK and Wales. It contains diagrams and descriptions of fishing techniques, and deals systematically with each stretch of coastline. For each region there is a summary of the various species caught and the number and type of vessels involved (as of 1995). Finally, there are maps showing the distribution of commercial fisheries, including those for crustaceans and molluscs. The review is strictly factual, with little evaluation or discussion (of, for example, changes in fishing practice or in catch sizes) but no less interesting for that.

**The coastal fisheries of England and Wales, Part III: A review of their status 1992–1994* (Fisheries Research Technical Report No.100) (1995) by M.J. Gray. ISSN 0308-55589, available from MAFF, Directorate of Fisheries Research, Fisheries Laboratory, Lowestoft, Suffolk, NR33 0HT, UK

Out of Sight, Out of Mind – Almost

Readers with a geological bent might have been puzzled by reports of the discovery (re-discovery actually) of an arms dump in the Beaufort Dyke on the bed of the Irish Sea. Isn't a dyke something you find as part of the ocean crust, a vertical sheet of basalt? How can you dump anything *inside* one? Well, of course a dyke (dike) is a ditch, especially if you are in East Anglia or Holland (though it can also be a wall or rampart). Be all that as it may, the Beaufort Dyke is a 40-km long NNE-trending furrow about 200 m deep in the North Channel of the Irish Sea. Hundreds of thousands of tonnes of surplus munitions were dumped between 1945 and the mid-1970s (there are rumours that dumping even goes back to the First World War).

All sorts of interesting things are down there, not only explosives and ammunition, but also incendiaries and poison gas and smoke bombs. The story hit the headlines only because British Gas were surveying the route for a new gas pipeline across the strait, between Stranraer and Larne. The cache of weaponry would never have been publicised if the surveying operations hadn't disturbed it. Numerous items have been snared in fishing nets or washed up on shore over the years, but occasional incidents like that don't make more than the local news (if that).

The Beaufort Dyke is continually scoured by strong tidal currents (up to $1–2\ m\ s^{-1}$), so it seems a bit surprising that it would be selected for dumping anyway, because the currents would surely prevent burial by sediment – is it possible that the strength of these bottom currents was not known at the time dumping was started? Not that it matters much, apparently, because most of the stuff ended up scattered over the surrounding sea bed, not in the actual furrow at all. The Irish Sea may not be the most radioactive sea in the world, but it may well be the best armed!

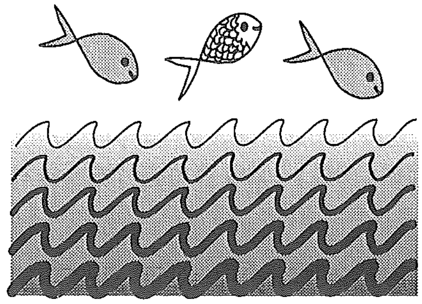
Another interesting twist to this story for *Brent Spar*-watchers is that the amount of toxic substances in these weapons must surely dwarf anything in the *Spar*. It seems plain that if you dump a lot of nasties in small bits instead of one big chunk, it's easier to avoid publicity, perhaps even detection – long enough for those responsible to be retired or dead anyway. What is more, the effect of this potentially toxic material on marine life seems to have been minimal – or has it just not been documented? Yet this is in water a few hundred metres deep in a recognised fishing area. Shell and Greenpeace, take note.

Goodbye to the Coble

How many of our readers have heard of the coble? Probably not many. Perhaps it doesn't matter, because the coble will soon be but a footnote to the history of British inshore fishing, if present trends continue. They are small (~30 foot/10 m) open boats with a high prow, low stern and flat bottom, enabling them to work off beaches. They have been a feature of inshore fishing along Britain's north-east coast for more than a thousand years, catching chiefly (but not exclusively) lobster, crab and cod. With newly imposed EC fishing regulations and quotas, no new licences are being issued and coble fishermen are being compensated *only* if they have their boats destroyed. There used to be 400 cobles in the Yorkshire fishing village of Staithes alone, now there are fewer than 150 along the entire coast, and that total is declining at more than 15 boats a year.

Those who mourn the passing of this part of Britain's fishing industry claim that cobles did no harm, because the fishing is selective, nothing is wasted because everything is sold, young fish are not taken, and fishing grounds are not harmed – until, that is, trawlers come along and scrape them flat.

Meanwhile, we continue to read press reports like the one describing the presence of 20 Russian factory ships moored in Weymouth harbour for the winter and being supplied by British trawlers with fish from British waters. Is not the Force of the Market a wondrous thing?



What Price Rio?

Press reports in late 1995 related how one Mark Votier – a freelance journalist – had just become liable for around £250 000 in fines and legal costs in an action brought by the Japanese Institute for Cetacean Research (partly-funded by the Japanese Government). It seems that before going on a five-month voyage with the Institute's research vessels in 1993–94 he had signed an undertaking that required him to submit for censorship any material he proposed to publish, and prohibited him from releasing film of 'unsightly tasks'. In the event, he published photographs and video footage which showed whales being harpooned and then slowly killed by electrocution, using electric lances. Average dying time was 8 minutes, the longest was 23 minutes, and there was no evidence that death was painless. The lances were restricted to 220 volts, partly it seems to avoid damaging tissue and organs for research and partly 'to protect whaling crews'.

Although there is a moratorium on commercial whaling, it appears that IWC regulations allow member states to grant themselves permits to catch whales for research. Japan gave itself a 'research quota' of 440 minke whales in 1995, and it is alleged by some critics that this 'research whaling' is a front for the supply of whalemeat to the commercial market (see *Ocean Challenge* 5, No.2, p.19). Mark Votier is quoted as saying that he couldn't have lived with himself if he hadn't published what he saw. But he signed a contract and then violated the terms of that contract – so legally he got what he deserved.

I think it's surreal. I recall something called the Rio Summit a few years back, a huge international gathering accompanied by great fanfare, the purpose of which was to persuade people to take more care of their environment and of their fellow creatures. Now here we have a bunch of people publicly shown to be subjecting large numbers of marine mammals to a slow and painful death. Their response to this bad publicity is to sue for breach of contract. Am I alone in thinking their world-view is excessively anthropocentric? And what is the point of international environmental agreements if individual governments can legislate to nullify them?

John Wright

How Microcontinents Form – A New Theory?

In a single dreadful day and a single dreadful night of rain ... the island of Atlantis disappeared and was sunk beneath the sea.
From *Timaeus* by Plato

The myth of Atlantis is with us still, not the story of Santorini, but "the story of a minor continent disappearing beneath the waves of the Atlantic". No kidding, I read those words in an article called 'Atlantis, secret of the ancient world', published in January 1996. And there's more, lots more. You will be interested to learn that: "Oceanographers have mapped the floor of the Atlantic Ocean. Apart from some lava that had obviously weathered in air rather than under water, some algae that definitely belong to a fresh water species, suggesting former freshwater lakes now on the ocean floor, and some remnants of sunken ancient port walls in the vicinity of Bimini [in the Caribbean], little pointed in the direction of a sunken landmass". Wow. Follow that. All right, I will. "The Flood reported in Genesis, in the Sumerian epic of Gilgamesh, and in pre-Columbian American myths is a scientific fact. And so is the story put forward by the finest of Greek philosophers, Plato's tale of Atlantis. They all speak of the same event in prehistory which scientific calculations have placed in the eighth millenium before our era."

We have the writings of an Austrian geologist, one Alexander Tollmann, for corroboration. In his book *Und die Sinflut gab es Doch*, or *The Flood did Happen*, he tells us that shortly before the autumn equinox (*sic*) about 9545 years ago a gigantic comet approached planet Earth from the south-east (*sic* again), at a speed of 100–140 $km\,min^{-1}$, described as a cosmic velocity. Well, no. That's between 1.6 and 2 $m\,s^{-1}$, an order of magnitude slower than your run-of-the-mill Earth-crossing comet or asteroid. It had a diameter of several kilometres, and broke up into seven large fragments and innumerable smaller ones. Interestingly, the seven major impacts were all in the sea (see map). The bombardment caused the usual havoc we associate with such events: earthquakes, tsunamis, acid rain, wildfires, prolonged winter, and so on, a catalogue which suggests that some of the impacts on land may have been quite major ones too. But we shall never know, because comets consist largely of ice and tend not to make craters anyway – if the evidence from the Tunguska (Siberia) impact of 1908 is reliable.

So how does Tollmann (the name means Magnificant Man, by the way, not gate-keeper) know the impact sites of those fragments? Search me. At all events, the map shows one of them is near the Azores, and the article says that according to the Egyptians, Atlantis was a large island empire in the Atlantic Ocean which sank in a volcanic catastrophe some nine thousand years ago. Well, the dates are consistent, but how could the Egyptians know that? I have only the most rudimentary grasp of Middle Eastern chronology, but this is around 7 000 BC, and I reckon even the Egyptians had little idea of the world outside the eastern Mediterranean at that time.

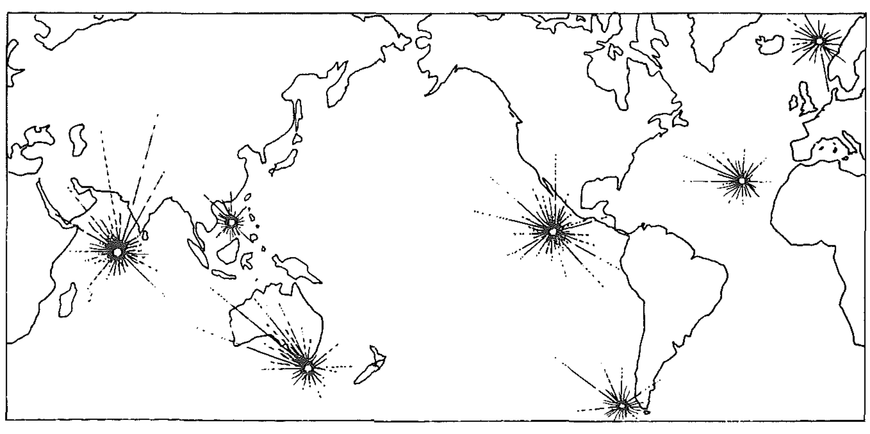
At all events, there seem to have been more witnesses to these celestial happenings than you might suppose, considering their antiquity. Thus, in the Book of Enoch (described as a "talmudic commentary on *Genesis*") we are told that "Enoch saw seven stars at the end of the horizon and they were as great as burning mountains." By this stage of the story our comet has been designated as Asteroid A, which I find unsettling, because asteroids are rocky and make much bigger holes than comets do. Leaving that aside, the "impactor" which fell in the Indian Ocean and sent flood waves as far as the Middle East is here interpreted as giving rise to the biblical story of Noah. The rich tektite field of southern Australia is linked by implication to the Tasman Sea "impact", because there is a legend about "a rain of glowing tektites (*sic*) which tormented the Aborigines to the point of killing their own children to save them from being burnt to death". Did you know that we get the term 'tektite' from the Aborigines? Nor did I.

I find that nearly all those who attempt to dress up ancient myths with pseudo-science, in the hope that it will give them credibility, share an irritating propensity to ignore the Arrow of Time. For example: "Whether the impact of Asteroid A also caused an oscillation of the Earth's axis and a changing of the poles we do not know – yet. But it may well be that the icing over of Antarctica and sudden asphyxiation of enormous mammoth herds in Siberia are connected with it. The constant advance and retreat of the polar ice and the glaciers are a geophysical conundrum which is far from being solved."

But here's the best one. It seems that one Professor Charles H. Hapgood, an American cartographer, "discovered and studied a number of ancient maps of astounding accuracy – in particular one which shows Antarctica before its glaciation". See what I mean about an inability to understand time-scales? Could it be that Professor Hapgood is not a deluded antiquarian, and that his maps are satellite images, processed to show the continent beneath the ice cover?

It seems that contemporary opinion identified all these happenings as divine retribution for humanity's shortcomings, and in particular for the "hubris, arrogance and will to dominate of which the ancient Atlanteans [so it seems] stood accused". Well, if that's all it takes to bring on a comet/asteroid impact, I reckon that in countries all round the world people should be preparing for annihilation any day now.

John Wright



WOCE snippets from WOCE snippets from WOCE snippets from WOCE

Remarkable RAFOS Results

A two-year programme of deployment of neutrally buoyant acoustically tracked RAFOS floats (= SOFAR spelt backwards) in the western Pacific between about 20° N and 40° N at around 1 000 m depth, has recently been completed. Results show the flow at this depth to be predominantly eastward from about the longitude of Japan to at least several hundred kilometres beyond the Date Line (180° longitude), a total distance of over 5 000 km. The flow is slow (1–4 cm s^{-1}) and complicated by small meanders and several eddies, but its zonal persistence is stated to be 'remarkable and quite unexpected'.

More on NAC Meanders

A similar experiment in the north-western Atlantic used acoustic floats to explore part of the downstream continuation of the Gulf Stream, the North Atlantic Current (NAC, also called the North Atlantic Drift). The segment which travels north for about 1000 km (between ~40° N and 50° N) after rounding the Grand Banks (see Figure 3, p.28 of *Ocean Challenge* Volume 6, No.1) is difficult to monitor by satellite because of persistent cloud cover, hence the decision to use a lagrangian approach.

Figure 1 (below) shows how the overall pattern of the flow is characterised by meanders of short wavelength and large amplitude, associated with the generation of eddies. It seems that while the amplitude of the meanders can change to the point where they can disappear (when they are cut off and form eddies), they are stationary features, i.e. they do not propagate along the flow. Even though they are not always present (e.g. the cyclonic 'trough' at 44° N is there only about 20 per cent of the time), they are believed to be linked to specific topographic features: "the weaving of the current results from inertial overshoots responding to the topographic relief: the South-East Newfoundland Rise (or Newfoundland Ridge), the Newfoundland Sea-mounts, and Flemish Cap". In other words, the current is topographically 'steered' by the requirement to conserve potential vorticity as it flows over a changing bathymetric relief.

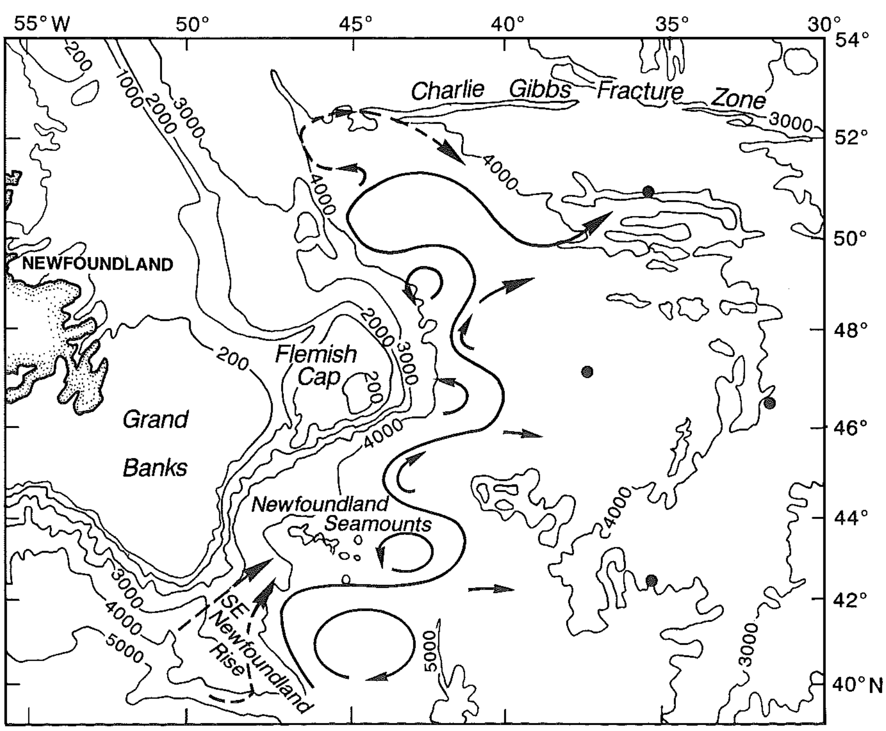


Figure 1 *Generalised path of the North Atlantic Current, showing the meanders that give rise to eddies, and their relationship to the sea-bed topography. The four black dots mark the positions of the sound sources used to provide acoustic navigation for the floats*

There is a strong retroflection (called the Loop Current) at about 52° N, where the NAC begins its eastward flow to cross the mid-Atlantic Ridge at the latitude of the Charlie Gibbs Fracture Zone. The NAC is a boundary between warm subtropical waters of the Newfoundland Basin and cold sub-polar water flowing south in the Labrador Current, and its path can wander up to 200 km or so either side of the approximate average position shown in Figure 1, as the size of its meanders continually changes.

The Kuroshio in the East Taiwan Channel

Back in the western Pacific, the Kuroshio is being investigated by a current meter array in the East Taiwan Channel, where the current enters the East China Sea. The objective is to monitor the structure and transport of the Kuroshio for a two-year period (commencing late 1994) and document its variability. Results from geostrophic computations and modelling suggest that the current is strongest in the spring and weakest in the autumn, the seasonal variation in volume transport averaging around 4–5 Sv (the mean transport is about 40 Sv).

The core of the current tends to meander from side to side of the East Taiwan Channel, which is about 200 km across. Model results suggest a strong seasonal correlation between transport and sea-level difference across the channel (from ~35 to ~45 cm), suggesting that sea-level measurements could be used for long-term monitoring of the current.

These items have been abstracted from articles in *WOCE Notes* (the publication of US WOCE), Vol. 7, No.3 by: Stephen C. Riser; Mary-Elena Carr, Edward J. Kearns, Mark D. Prater and Thomas Rossby; and William E. Johns, Thomas N. Lee, Cho-Teng Liu and Dongxiao Zhang.

If you would like to know more about US WOCE, contact US WOCE Office, Department of Oceanography, Texas A&M University, College Station, TX 77843-3146; Tel. 409/845-1443; Fax: 409/845-0888; Email: uswoce@astra.tamu.edu

WOCE and Law of the Sea

Ocean and atmosphere pay no heed to international boundaries, currents flow and winds blow whither they will, heedless of demarcation lines drawn by mere mortals – but the mortals must abide by them, and that goes for oceanographers too. We recently heard that a UK WOCE cruise in the southern Atlantic was prevented by the Brazilian authorities from working within the 200 n.m. limit. Shortly afterwards came news of a similar happening in the south-east Indian Ocean. It seems that US and Australian research cruises to investigate the South Java Current were refused permission to enter Indonesian waters no less than four times during 1995. The Java Current is the principal conduit for the passage of warm surface water from the western Pacific into the Indian Ocean, and probably plays a major role in ENSO events. The refusal to allow scientists to have a closer look at it does not help anyone's under-standing of a phenomenon which must surely affect the Indonesian region as much as (indeed probably more than) it does many other parts of the world. You'd think they'd be keen to cooperate, but perhaps there are understandable reasons for a mindset that favours the answer 'No'. In other words, it may not be enough to blame the official myopia and paranoia that characterise totalitarian regimes.

Thus, although Indonesia's military rulers are well known to be suspi-cious of foreigners, for reasons upon which this column cannot possibly comment, the Brazilians have at least some semblance of democratic government. On the other hand, rich countries have a not altogether unjustified reputation for ripping off poorer ones – and while colonialism may be officially dead, neo-colonial-ism, especially economic neo-colonialism, is alive and well. So perhaps it is not surprising that foreign scientists in research ships are often perceived to be secretly obtain-ing data and information about natural resources in or beneath the EEZ, which their countries might then be able to exploit.

Unfortunately, even though scientists and/or officials of the coastal state are nowadays invariably invited to participate in the research, it is not always possible to show that the science is 'neutral' – and it's espe-cially difficult to do so when the invited guests fail to turn up – which seemed to be what happened in the Indonesian case! One obvious solution to the problem lies in education, to produce more informed scientists with access to the higher echelons of bureaucracy, where they can influence decisions on issues of this kind.

Not Many People Know That ...

Ocean Challenge readers may be surprised by the revolutionary discovery that metals are fraction-ated by gravity in the oceans: the denser the metal, the greater its concentration in deep water.

We are indebted to the inspiration of *New Scientist*'s Dædalus and his DREADCO team for this exciting new development. It is based upon the startling premise that as alcohol is lighter than water, the top half of your pint should be more potent than the bottom half. It follows that as salt is denser than water there should be more at the bottom of the ocean than at the surface. It follows further that concentrations of high-density precious metals (gold, platinum, palladium, iridium), not to mention others such as mercury and tungsten, should be orders of magnitude greater than near the surface. It would be neces-sary only to lower a pipe into an ocean trench, pump out the bottom water and extract the metals.

Few would fail to admire the genius of Dædalus, but is there a misconcep-tion here? To be sure, some of the precious metals (notably platinum and palladium) *are* relatively enriched in bottom water, but only because they are so-called recycled elements, which means they are incorporated into organic tissue and then returned to solution by remineralisation when the organisms die and sink into deep water. Heavy elements (e.g. mercury) are also among those that are adsorbed and scavenged by sinking particles, whence they could be released into bottom waters by desorption. Neither of these processes seems likely to increase heavy metal concentrations in bottom waters sufficiently to make them economically attractive targets for mining companies.

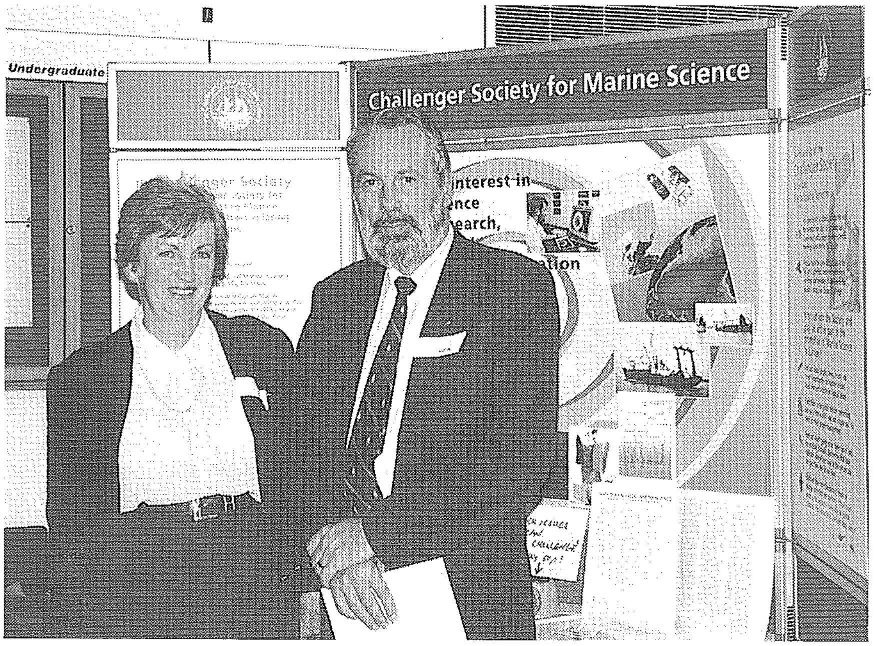
But there is more: we can forget mercury scavenging. It seems that mercury in the deep oceans occurs in liquid form, interbedded within deep-sea sediments, and can be extracted by a method akin to the froth flotation used to separate metal ores: it can be ground up with fats to make low-density globules which could readily be pumped to the surface.

That's a nice final touch. Your editors would be pleased to learn of liquid mercury layers (microlayers?) found in ODP (or DSDP) cores. This could add a whole new dimension to the issue of oil platform disposal.

The Challenger Legacy

On 17–18 September of last year, a symposium was held to mark the opening of the Southampton Oceanography Centre. A goodly number of members attended this two-day meeting, organised by Margaret Deacon and Tony Rice. We were comfortably lodged and boarded in the Glen Eyre halls of residence and treated to a wide-ranging series of lectures and presentations. The majority were historical reviews, and there were four main sessions. The first of these, The Historical Context was in some respects the most unusual, because several of the speakers focussed on the history of the science in the prevailing social and intellectual climate of the 19th century, rather than upon the science itself.

Various topics from this session have stuck somewhat eclectically in the memory of your correspondent. One is the account of Luigi Marsigli, who is generally credited with the first published scientific account of the sea (1725), but who may be remembered more for his initial identification of corals as the flowers of marine plants. The second half of the nineteenth century saw the birth of Big Science as it might now be recognised (the most famous example in this context being, of course, the voyage of the *Challenger*). This was also a relatively short-lived era when science benefitted from the enthusiasm of rich and often noble (even royal) patrons: 'gentlement of leisure'



One of the successes of the conference was the diversity of people it attracted. Here standing by the Challenger Society display are Dr Alexandru Bologa, from the Romanian Marine Research Institute, Constanta, and Helen Craggs, who studied oceanography with the Open University.

(alas, few ladies in those days) who were themselves active researchers at a time when the wealthy amateur could make a major contiribution to the science. Some of the most important of those contributions were made by Monaco's Prince Albert and Portugal's Dom Carlos. Whoever ran the 'big science', though, whether it was government committees or the rich private operator, it seems that there was already plenty of petty bureaucracy, obfuscation, and even obstruction, not to say internecine strife, to overcome on the way to getting worthwhile results. It is strange how often the phrase *plus ça change* crops up these days, isn't it?

The other three sessions dealt with Ocean Basins, Ocean Circulation, and Ocean Ecosystems, and reviewed the development of understanding in the various marine science disciplines more conventionally – though no less interestingly. The time-scales were inevitably different: after all, satellite oceanography, hydrothermal vents, or artificial. tracers, were barely heard of two decades ago; while people have been speculating for centuries about ocean currents, the saltiness of seawater, and the amount and diversity of life forms in the oceans.

The Challenger Society AGM, held during the course of the Conference, was the occasion for two 'thankyou's. Sylvia Harvey, the Society's long-standing Executive Secretary, has not moved to Southampton from Wormley. Sylvia was warmly thanked for her hard work over many years, and presented with gifts and flowers by John Simpson, the Challenger Society

Retiring Executive Secretary Sylvia Harvey receiving tokens of appreciation from Challenger Society President, John Simpson (inside the parcels are an atlas and a vase)
(Photos courtesy of Malcolm Walker)

President. The other 'thankyou' was to David Carter, for acting as Treasurer for the Society for longer than he can care to remember – as anyone who has ever acted as an Hon. Treasurer for any society will know, 'treasuring' is a thankless task.

Another duty that the President had to perform was to announce the winner of the Challenger Society Prize for the best Open University student of Oceanography in the previous year This time the prize went to Anne Banks: the prize was a cheque for £50 and five years' free membership of the Society.

The evening reception and buffet at the SOC was most interesting: if the grandeur of the new building is to be matched by the research that will be done there, we may expect major advances in oceanography to be a frequent occurrence in UK. A display of stands and models and stands was much admired (see above right), there was an abundance of food and drink, and for landlubbers the novelty of a guided tour of the refitted *Discovery.* It was very interesting to listen to comments of the veterans of two and three decades ago, as they compared the cramped and often primitive conditions of how the ship was 'in my day' with the more spacious and efficient working environment provided by modern design and new technology.

A major emphasis of the new Centre will be a multidisciplinary approach to understanding how the Earth and its oceans function as a physical, biological, geological and chemical system on a global scale; and to achieve this, SOC will become a 'centre of excellence in research and education'. All very laudable, but I am an old cynic. Perusal of the literature, conversations with practising researchers, and my own experience of academic attitudes, together

"All my own work!" Ann Aldred poses before two of the panels of the **Challenger** ***Expedition display that she designed for the conference. The panels, which were conceived by Tony Rice, are still on display at the new Southampton Centre.***

lead me to conclude that scientific specialism remains alive and well, and that the great majority of scientists active in research display a profound ignorance of matters outside their own field – in which they often have an international reputation. You cannot blame them, after all, when careers depends on publication lists, why dissipate energy trying to understand what goes on outside your own sub-discipline? It might help students to understand the meaning of multi- and interdisciplinary science, but there are no brownie points for teaching, even now, as we approach the Millenium.

John Wright

Presidents' Photographic Competition

At UK Oceanography '96, there will be a competition, sponsored by past and present Presidents of the Challenger Society, for the best photograph on an oceanographic theme. Photographs on any oceanographic theme will be welcome but the judges will be looking particularly for pictures of oceanographers in action.

Photos should not be bigger than A3, and should be submitted by 12.00 noon on Monday, 2 September, to Carol Robinson. Please do not send pictures in advance by post.

Entries will be displayed for judging on Tuesday and prizes will be presented at the Conference Dinner on Thursday, 5 September.

There will be two prizes of £50 and £25

Interested in the History of Oceanography?

- The papers given at the conference are being published in book form by UCL Press, under the title *The Challenger Legacy*. The only exception, Anita McConnell's talk on "Marsigli and the 'flowers' of coral", was drawn from her forthcoming translation of Marsigli's *Physique de mer.*

- A meeting on 'The Life and Oceanographic Times of John Young Buchanan, 1844–1925' will be held on 23 November, in the Lecture Theatre of Southampton Oceanography Centre. Chemist on the *Challenger* Expedition, Buchanan has been described as 'a consummate experimentalist'; he was involved in many aspects of the developing science of oceanography, but has remained a little known and enigmatic figure.

It is hoped to use the occasion to discuss the formation of a specialist history group within the Challenger Society, but non-members are welcome at the meeting.

For programme and registration details contact: Margaret Deacon, Department of Oceanography, University of Southampton, SOC, European Way, Southampton
SO14 3ZH, UK;Fax: 01703-593059; or Neil Wells, at the same address, or via Email: n.c.wells@soc.soton.ac.uk

Meeting Reports

Impressions of OI '96

It was a visit to Oceanology International in 1969 (the very first, I believe) that set me off on the path to a career in marine science. As a not-so-young student looking for something that would bring together my interests in physics and the oceans, 'Oceanology' seemed to me to offer the right sort of mixture of science and application that I was looking for. Oceanography then still seemed to be in a golden age of discovery – curiosity-driven and perhaps less constrained than it is today by concerns about funding; this was somehow reflected in the technology and other exhibits on display, some of which were very exciting. *GLORIA* was there I recall – a prelude to a decade of important discoveries in sea-bed mapping and bathymetry throughout the world's oceans, since added to with discoveries of black smokers and exotic life forms at mid-ocean ridges (there was little idea then what this would all lead to). Other exhibits, particularly from one or two of the Universities then engaged in ocean science, were more 'Heath Robinson'. This too was exciting – somehow capturing the thrill of experimental physics – but doing it all in a rather hostile and unforgiving environment.

As with today's OIs, there were research vessels in Shoreham Harbour. If my memory serves me correctly, the RRS *John Murray* was there. Remember those days, when the NERC fleet comprised coastal as well as ocean-going survey vessels – ships which actually went to sea? (Why is it when I visit the Southampton Oceanography Centre the ships always seem to be moored alongside?) There was also a Russian ship in Shoreham. I can't remember its name – but as I climbed to the top of the gangway on this cold and snowy Easter in 1969, I could have been in Murmansk, the fur-hatted and armed sentry a portent of the huge and secretive Soviet oceanographic data-gathering effort that I was to discover 15 years later.

This was also the beginning of the North Sea oil boom, when the streets of Brighton and the exhibition halls of the Metropole Hotel echoed to Texan accents, and high-heeled cowboy boots and stetsons were *de rigueur* if you wanted to make an impression on the offshore oil industry.

There was also a sort of innocence about the whole thing – with research scientists keen to display what they could do and willing to pass on their knowledge and skill without the need to put a price tag on them. Information was urgently required regarding extreme waves and currents to assist with the design of offshore platforms – I remember being told that every extra metre on the leg of an offshore oil or gas platform to clear the highest waves would cost about £1M. More needed to be known about the sea-bed – and about processes in the ocean. This was prior to the great discoveries of the '70s and the realisation that nearly 100 times more kinetic energy was contained in eddies than in the mean motion. At that time, no-one seemed concerned about global warming and rising sea level. Nevertheless, research was needed to provide answers, even if the costs of providing those answers were not foremost in the minds of the suppliers.

Inspired by what I had seen, I wrote immediately to the then National Institute of Oceanography (later to become the Institute of Oceanographic Sciences) enquiring about careers, and was directed to Southampton University and University College of North Wales, Bangor, where I was told I should obtain a postgraduate qualification in oceanography. Bangor was my first choice (mountains were also an interest at the time) and from there I went to IOS and the Defence Research Agency and – with many more visits to OIs – that brings me to where I am today.

Over the years I have been involved at almost every level of the 'OI process', visiting the exhibition, preparing exhibits, presenting papers, chairing sessions and working on the Conference organising committee. So how has it all changed?

Well it's bigger, much bigger, and it has acquired a truly international dimension. This year's OI featured a staggering 500-plus exhibits and there were papers from 15 countries. Over the years, oceanography has also become far more *thematic*, partly a consequence of the increasing global dimension of the subject and the rising costs of research – requiring scientists to work together to achieve common aims. Examples of this abounded at OI'96, with papers on topics such as GOOS, WOCE etc. – and with what now seem like permanent fixtures at OIs, the European stands, EC MAST, EUREKA, EUROMAR, the European Space Agency, all able to supply copius amounts of (free) documentation describing their various programmes and initiatives.

The other dominant theme of OI'96 was the extent to which the subject has become 'operational' in the sense that knowledge acquired through research can now be built into predictive models and applied in a reproducible manner to a range of problems, illustrating how knowledge has passed from scientists to users. Techniques that only a few years ago were the exclusive domain of research scientists are now in the hands of planners. Many of these models can be run on PCs or even lap-top computers (the Delft NW European Shelf pilot model demonstrated by Monique Villars was an impressive example – and was even available free on a floppy disk!) The offshore industry has of course had predictive models for some time (e.g. wave-prediction models for evaluating offshore platform design criteria). New applications, though, are being found in areas ranging from water quality to fisheries research, coastal zone management and flood prevention.

Interestingly, the availability of these models is now beginning to drive the requirement for global monitoring networks, to gather data in other coastal waters and in the deep ocean to meet real-time operational needs. This in turn is driving the requirement for new and improved instruments and better and more accurate surveying techniques. And here the enormous advances being made in satellite remote sensing of the world's oceans have to be mentioned. The increasing availablity of data is in itself becoming a problem. Better methods are required for capturing and displaying data – often in association with other information. How should the distribution of the data be managed, and how can it be made available quickly to those people who need it – perhaps in association with other data concerning environmentally sensitive areas?

All of these themes were developed in the conference sessions with papers on operational modelling, remote sensing, platforms and sensors, acoustics, data management, ocean resource management, environmental impact studies, the coastal zone, polar issues and of course GOOS – the Global Ocean Observing System.

I suppose that if I had to complain about one thing though – it would be that there wasn't much science on display, as distinct from paper presentations. OI has become more of a trade exhibition than a science fair; there were some impressive examples of what the technology can do – but where I wonder are the new ideas coming from? What will today's students think about a career in marine science? OI is an important 'shop window' for the subject and perhaps in the future we need to get the balance right between the research, the science, the things that will capture the fertile minds of young scientists, and the applications, the technology and the tools that are needed to put those bright ideas to good use.

Tony Heathershaw
Defence Research Agency
Winfrith

BRIDGE-ing the discipline gap

Did you know that fish south of Iceland just love the Jacuzzi effect of the bubbling hydrothermal plumes of Steinaholl? Or that drilling through a hydrothermal deposit is the equivalent of 'heart by-pass surgery'? Or (the big question in ocean crust studies) did the volcanic activity jump or was it pushed'? The BRIDGE Annual Science meeting was the place to find out about these and many other exciting topics related to mid-ocean ridges. One of the most impressive things about this meeting was the range of disciplines from which scientists came together in discussion, and the extent of communication between apparently disparate fields. Where else would you find a geophysicist quizzing a microbiologist about the implications of their work and (perhaps more extraordinarily) *vice versa*?

70 BRIDGE scientists gathered together in the Tilley Lecture Theatre in Cambridge in early January to present and discuss recent advances in the study of mid-ocean ridge systems. This meeting is an annual event to allow rapid dissemination of the most exciting results, often only days old. Over the last five years BRIDGE has matured to become a large community of multidisciplinary scientists collaborating on an international level. This was reflected in the novelty and exciting nature of the results from various studies presented over the two days in Cambridge – here are just some of the key issues raised in the meeting.

David Dixon (Plymouth Marine Laboratory) described the first BRIDGE biological experiment that went beyond 'peering through the Perspex port-hole' of the submersible. He spent August and September 1995 trawling the deep water of the rift valleys of the Mid-Atlantic Ridge (MAR) with fine-meshed nets. Thousands of tonnes of seawater were filtered over hundreds of kilometres of ridge, and the catch picked over to identify and understand the nature of faunal dispersal mechanisms between the ephemeral vents. The vents in the Atlantic at this latitude are dominated by the blind shrimp *Rimicaris exoculata* with lesser occurrences of two other species (*R. alvinocaris* and *R. chorocaris*). Gene flow between the TAG site at 26° N and Broken Spur at 29° N is evidenced by the similarity of the shrimp populations. However, the highway is tortuous because the topography of the MAR is rugged and each short spreading segment is offset by several tens of kilometres laterally. The remarkable discovery that David described is that juveniles identified as *R. alvinocaris* and *R. chorocaris* were found throughout the lower 1 km of the water column in both the Broken Spur segment and the so-far hydrothermally barren segment to the north. In the nets, along with the identifiable species, were numbers of a morphologically different shrimp with large lipid sacs and distinct eyes. David has spent the months following the cruise scrutinising the DNA of his catch, and to his great surprise the unidentified larval stage is none other than a juvenile *Rimicaris exoculata* with embryonic eyes that presumably disappear with maturation and colonisation of other vent sites in the Atlantic. These results are the first evidence for migration between sites in the Atlantic. Now we need to understand the mechanisms for site-colonisation.

One of the outstanding challenges in mid-ocean ridge studies is to identify the mechanisms controlling the formation of oceanic crust. This has been addressed in a variety of ways over the last few years and one of the key players in this field is the BRIDGE chief scientist Joe Cann FRS. Joe kicked off the meeting with a discussion of the 'chicken and egg' question of volcanism/magma emplacement *versus* faulting of the oceanic crust.

Detailed studies of the structure of the ocean crust can elucidate some answers but the detail is just not known yet. Model results, presented by George Tuckwell (Southampton Oceanography Centre, SOC), suggest that the local stress field can adequately explain the spatial distribution of volcanism within the median valley. George suggests that the volcanism is controlled by the fault geometry along the ridge. However the mid-ocean ridge system exhibits a wide variety of styles of spreading and we have mapped only a small portion of the globe. The non-transform discontinuities south of the Azores appear to have rather large offsets. Lindsay Parson (SOC) discussed whether these features are commonplace or oddities in the geometry of slow-spreading ridges, along with the implications for our understanding of the formation of oceanic crust.

Another way to address this problem is to choose sites where the MAR is exposed on land. Mary Gee (Royal Holloway) provided evidence from Iceland that geochemically different lavas erupt through the same fissure system over a geologically short time-scale, without any evidence for major faulting between eruptions. Other studies from Iceland (Pascal Luxey and Philippe Blondel, SOC) demonstrate previously unidentified occurrences of strike–slip lateral motion along faults, so questioning the classical Icelandic spreading-axis model.

Martin Sinha (Bullard Laboratories), Cambridge has been working further offshore on the Reykjanes Ridge, looking for melt bodies in the crust. Magma chambers or melt lenses have never been imaged along the slow-spreading MAR, yet we know that there are heat sources large enough to drive extensive hydrothermal circulation. Martin has combined seismic and electromagnetic methods in a novel way and managed to identify a melt lens at 2 km depth in the crust of the Reykjanes Ridge. This lens is not continuous along the ridge – instead there appears to be an intermittent reflector, suggesting that melt is present in 'blobs' that feed the axial volcanism.

The combination of seismic and gravity methods in areas of unusual spreading regimes allows the testing of theories of crustal accretion. Mark Muller, Nick Bruguier (Bullard Laboratories) and Neil Mitchell (Durham) have each studied areas of extremely slow-spreading ridges in the Indian Ocean to constrain the extent of mantle upwelling beneath ridge segments, to determine the extent of isostatic equilibrium and to test mantle melting models. The message from the meeting is that crustal formation is an extremely complex process that is not yet adequately explained.

The pitfalls of image- and data-processing were highlighted by both Tim Minshull (Bullard Laboratories) and Philippe Blondel (SOC). Both talks outlined the problems with some commonly held assumptions used during data-manipulation, and offered alternative methods for the discerning researcher. Tim discussed the problems of assuming a constant crustal density in gravity-data interpretation and provided estimates of the limitations of the use of mantle Bouguer anomalies so much in vogue at the moment.

The drilling of the TAG (Trans-Atlantic Geotraverse) hydrothermal Mound by the Ocean Drilling Program in late 1994 has inspired a whole host of research through the monitoring exercises that were carried out in part by the British–Russian Atlantic Vents Expedition. The TAG Mound has been studied intensively for the past ten years and the nature of subsurface processes has been inferred from the exiting fluid chemistry and surface mineralogy. Now that the interior structure and composition of the Mound is known from drilling results, the surface studies can become more quantitative and tied into models of ore formation. Rachael James (Bristol) described unique samples collected with *Medusa*, the instrument designed by Adam Schultz (Cambridge). Diffuse fluid flow through the Mound plays an integral role in continually modifying the sulphide structure and zone-refining the ore deposit. The extent of subsurface reaction can be estimated from the chemistry of the diffuse flow. Studies of sediments and pore fluids from the Mound can also give information on sub-surface processes, and these were linked to TAG drilling results by Rachel Mills (SOC). Now that we have a clearer model for hydrothermal mound formation in the modern environment, we can revisit the Cyprus-type deposits in the geological record.

Jon Copley (SOC) described results from time-lapse video images of the fauna and pre- and post-drilling submersible surveys of the TAG Mound. Drilling of 17 holes had local effects on faunal distributions and the resulting changes in fluid flow were utilised by vent shrimps to optimise their food sources. Chris German (SOC) has been involved in the on-going vent fluid time-series study since 1988 and he presented the latest chapter in the fluid story – the results of the post-drilling survey. The plumbing of the Mound changes over long time-scales due to mineralisation and tectonically induced changes in permeability, and the TAG drilling effectively introduced areas of high permeability in certain areas of the Mound. The chemical composition of the exiting fluid reflects the degree of seawater entrainment along with chemical interactions between fluid and deposit. It appears that drilling has effectively by-passed the tortuous route to the north-east of the Mound and now black smoker fluids vent from a wide area.

The value of microscale geochemical measurements in the extremely heterogeneous hydrothermal systems has recently become apparent. Hazel Prichard (Cardiff) and Chris German (SOC) both presented data that demonstrated that much of the bulk geochemistry is controlled by microscale inclusions or enrichments of specific elements within the crust and within sulphide structures. Recognition of such complexity makes interpretation of the bulk geochemistry possible. Other sulphide studies from the Broken Spur hydrothermal site emphasised the importance of an unbiassed submersible sampling strategy. Ian Butler (SOC) described a range of textures and mineralogy from the Broken Spur site linking the mineralisation processes to other hydrothermal sites world-wide. Interestingly, the Broken Spur diffuse flow ledges are dominated by pyrrhotite, unlike other bare-rock vent sites, such as TAG. Our understanding of the importance of mound formation via cementation of brecciated material is augmented by observations from TAG drilling. Deposition of mound-type structures is now recognised as a fundamental process in modifying the composition of exiting fluids and controlling the eventual ore deposit.

The importance of microbial activity in terrestrial ecosystems has been long recognised and often utilised to human advantage in mining techniques and waste-water clean-up. It seems likely that microbial reactions in hydrothermal systems, which provide such a wealth of nutrients and ecological niches for bacteria, could be similarly important. Don Cowan (University College London) has been concentrating on identifying aerobic heterotrophs in areas on the surface of the TAG Mound and has managed to culture at least one species in the laboratory. Paul Dando (Bangor) works in the Aegean in shallow water (so making the sampling simpler) and showed great video coverage of brine seeps and bacterial mats. Such studies are just the start of a range of experiments proposed to study the interactions of microbial ecosystems with hydrothermal systems.

The Chairman of the BRIDGE steering committee, Alastair Robertson, used part of the second day of the meeting to present a proposal submitted to the NERC Earth Science Technology Board and to chair an open forum discussion about the way forward for Deep Ocean Research in the UK.

Lively discussion continued during the well-presented poster session over a couple of glasses of fine wine and an excellent dinner at St Catharine's College. Although the last BRIDGE round is in review at the moment, and it is far from clear what the future holds in terms of funding for BRIDGE-type research, the atmosphere was ebullient and the general mood optimistic. BRIDGE has brought together a diverse mixture of scientists, encouraged new collaboration, and inspired world class research – whatever comes next, the legacy of BRIDGE will continue.

The meeting could not have been such a success without Keith Harrison (BRIDGE office), Harry Elderfield and Margaret Johnston (Cambridge) who organised everything so efficiently.

Rachel Mills
Southampton Oceanography Centre

The Mystery of Increasing Wave Heights

The increases in average wave heights in the north-east Atlantic and the southern North Sea in recent decades are a cause of continuing interest and concern to many people. The increases are not trivial (see Table 1), but the causes remain as elusive as ever.

It seems that although the data show an overall increase with time, the behaviour of average wave heights is erratic and there seems to be a general agreement that it would be unwise to extrapolate long-term trends for predictive purposes. In other words, nobody knows how long this increase in wave heights will continue – or even if it *will* continue. Meantime, giant waves continue to be encountered by ships in the North Atlantic – such as the 'bridge-high' monster, estimated at 95 ft (30 m), which hit the *QE2* off Newfoundland in September 1995.

As stated in the following article, there have been no measurable changes in wind speed, direction or duration that could explain these increases, but there is no shortage of attempts to account for them. Among the causes that have been proposed are:

1. If the wind fields have decreased in size while increasing in intensity, the average could stay the same but the energy transfer could increase.

2. Changes in the atmospheric pressure gradient that generates the winds over the ocean, and hence the waves. Although it is not mentioned in the article which follows, Bacon and Carter found a significant correlation between mean wave heights at Sevenstones and the mean pressure gradients between the Iceland low and the Azores high.

3. Circulation over the Atlantic as a whole could cause 'far-field' excitation of swell waves: although there is no measurable difference in wind intensity at specific points, wave energy could still increase because of swell transporting energy from more distant storms.

4. Perhaps the most novel and imaginative explanation – though not widely publicised and probably not seriously considered by anyone – is that the huge tonnage of shipping sunk during the War (in the North Atlantic) released vast amounts of oil which formed an extensive and long-lasting slick which 'calmed the troubled waters'. Gradual biodegradation of this oil has allowed the sea to resume its stormy aspect. The problem with this is that disperson of oil slicks takes years rather than decades, but the idea did have the merit of being independent of meteorological data.

Table 1 *Increases in average significant wave heights at some measuring stations*

Station	Dates	Av. sig. wave ht	% increase
OWS *India* (west of Shetlands)	1962–65 1970–75	3.37 4.15	23
Sevenstones lighthouse (Cornwall)	1962–74 1975–85	2.33 2.65	14
Texel Island (southern North Sea)	1964 1976	1.07 1.51	41
Noordbinder (W. of Rhine)	1964 1980	1.00 1.36	36

Plainly an understanding of this effect is crucially important for shipping and for the design of offshore structures. Could it be that the recent demise (temporary, we hope) of *OSPREY* might not have occurred if average wave heights had not been increasing?

The increases seem so far to have been observed only in the north-east Atlantic and the southern North Sea (presently available data suggest that the western central North Sea is less likely to be affected, as remnant Atlantic swells do not enter so far into this region). The question remains: is this trend to be expected on a global scale? Could it be observable in other areas of offshore activity such as the Gulf of Mexico and Newfoundland?

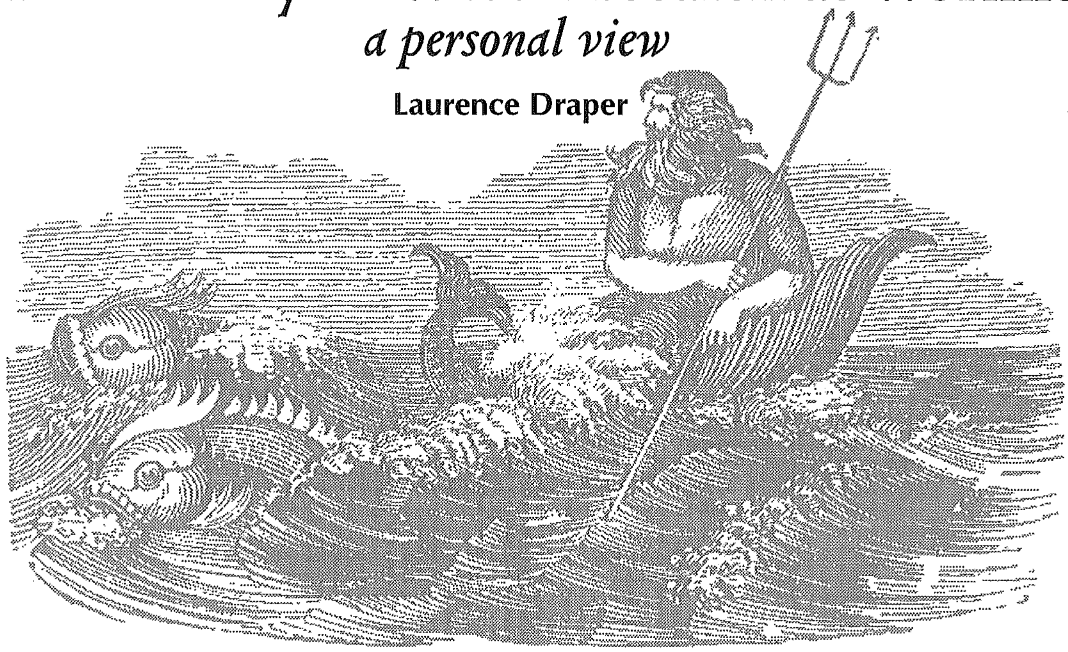
An explanation would enable attention to be focussed on areas where the effect is likely to be greatest. As noted above, there seems to be no indication that wave heights have stopped increasing in the areas where measurements have been made. It would be interesting to see how far – if at all – they still have to go in these areas, and if the effect will manifest itself in other regions. It may well be that the increases in wave height can be linked to global warming, which has been implicated in a putative increase in storminess over recent years. Indeed, there have been suggestions that increased storm frequency would reduce the time interval between storms that allow swells to decay. But that simply raises another question: how do you measure storminess?

Post Script: *In April of this year, the SUT held a meeting to discuss changing offshore meteorological conditions. There will be a report in the next issue.*

The History of Wave Research at Wormley

a personal view

Laurence Draper



During the Second World War a group named 'W' (for waves) was established within the Admiralty Research Laboratory at Teddington. Headed by a distinguished Antarctic research scientist, Dr G.E.R. Deacon FRS,* its task was to study the prediction of waves for military beach landing purposes, the main objective being conditions for the D-Day landings in Normandy. The predictions were right, but only just, and only for the earliest days of the campaign, and it was obvious that a great deal more was to be learnt, so Group W continued in being after hostilities ceased. It made remarkable progress, and included several people who were to become distinguished within the next decade. As an example of their success, the discovery that some of the wave energy arriving off the Cornish coast at Perranporth had been generated off Cape Horn was deduced by (among others) N.F. Barber, F. Ursell and J. Darbyshire, using a home-made optical wave analyzer to process analogue wave records. This analyzer was soon further developed with the help of M.J. Tucker and F.E. Pierce, and was extensively used for many tasks, not only the study of sea waves but, for example, flutter in aircraft tail structures It reigned supreme until digital analysis became an effective tool in the sixties.

My wave research career started in the Autumn of 1953, soon after NIO had moved into its permanent buildings at Wormley, Surrey. By the late forties the need for more organized British oceanographic research had been recognized by the formation of the National Institute of Oceanography (NIO). Dr Deacon was the natural choice to head it, as wave research was to be one of its principal pillars, and would continue to expand after the removal of NIO to Wormley in early 1953. Meanwhile, M.S. Longuet-Higgins was getting to grips with the theory of wave behaviour, using the early instrumental records to check his findings.

Arguably the most significant single factor in the development of wave research was M.J. Tucker's concept of the Shipborne Wave Recorder (SBWR), ably engineered by F.E. Pierce, which enabled waves to be measured in deeper water away from the influence of coasts and strong currents. Although it had some imperfections, its data-collection rate has never been equalled. Data from its more modern rival, the Waverider Buoy, can be lost at the most critical time of extreme weather, and often the instrument itself disappears; by contrast, no Shipborne Wave Recorder has ever been lost. Well over a hundred have been built and sold all over the world, including the USA and Russia, and sales continue at present. In the nineteen eighties, a detailed investigation by E.G. Pitt into the response of the SBWR, taking into account the size of the vessel on which it was mounted, further improved the ability to reduce the effects of the vessel on the data. The availability of a growing mass of data enabled D.E. Cartwright and M.S. Longuet-Higgins to extend wave theory, allowing the main wave parameters to be deduced from wave records without complex analysis.

*Later Sir George Deacon; he was Director of NIO (later IOS) from 1949 until 1971.

At this time the international reputation of NIO as a centre of excellence in wave research was considerable and growing rapidly; it was a tremendous privilege to be considered as one of the team, and the proudest statement one could then make was "I work at NIO."

The need by engineers for wave data was large and growing, and the Institute was recognised as a wonderful source of instruments and technical advice. However, the theory of wave behaviour is complex and few engineers had time to get involved with it, so the knowledge was not fully used. M.J. Tucker again came to the rescue and translated the theory into a language which was much more readily understood. Even then, many engineers found the method of analysis too time consuming, so I trimmed it slightly and presented it at the Coastal Engineering Conference in Tokyo in 1966. From then on it was universally known as the 'Tucker–Draper Method', and was the standard method of wave data-analysis world wide for almost two decades; it is still used where chart recordings are made.

In 1953, a Shipborne Wave Recorder was installed on an Ocean Weather Ship operating in the North Atlantic, and proved successful. However, as the vessel operated for only one month before returning to port, and then moved to another station, it was initially not possible to obtain a long continuum of data for any one location. In 1957 another SBWR began recording waves in the deep water of Morecambe Bay, and provided the world's first deep-water instrumentally-measured annual wave climate. The instrument was then transferred to Smith's Knoll Light Vessel off the Humber. Using data from SBWR on Ocean Weather Stations in the open Atlantic and on Light Vessels, J. Darbyshire was able to produce a wave-forecasting method based solely on instrumental data, a considerable advance on the widely used Sverdrup, Munk and Bretschneider (SMB) method which relied exclusively on visual observations. This was just what engineers needed, but its development into a practical tool for easy use held little appeal for pure scientists, and Darbyshire declined to develop his method further. It was exasperating, but I was able to persuade Darbyshire's wife, Mollie, to present the results of his method as graphs for coastal and oceanic regions in a similar form to the SMB technique, but easier to use. Mollie Darbyshire and I published the method, together with appropriate parts of the NIO theory, as a practical wave prediction scheme. This must be the most reproduced paper ever published by NIO/IOS, running into tens of thousands of copies, reprinted and republished many times world wide (including translation into, for example, Japanese), and appearing in numerous books and articles.

The prediction method was used in many ways and for many purposes, perhaps most usefully to tackle problems arising from the desire to exploit the discovery of gas, and then oil, in UK waters. As a consequence of these discoveries, there was a need to predict

Pitch and roll buoy on MV* Moray Firth *in the North Sea in 1969

Photo: Pam Draper

Positioning buoys often isn't easy: here an FM wave-recorder is about to be placed offshore from Tiumpan Head, Isle of Lewis

extreme conditions for the design of offshore structures. The estimates of extreme winds made by H.C. Shellard of the Meteorological Office, when entered into Mollie Darbyshire's graphs, allowed predictions to be made of the most probable height of the highest wave to be exceeded in a once-in-50-year storm for certain locations in the North Sea. The stock of offshore wave data was still tiny, but by great good fortune the Smith's Knoll Light Vessel was close to the first gas well, and when its wave data were extrapolated the answer was surprisingly close to the value predicted from the winds – which probably gave us false confidence in the figures. At that time the oil companies were relying on predictions from an American team which had been highly successful in the Gulf of Mexico, but their answer was 20% lower than the NIO value. Needless to say, the oil companies preferred the American figure, for all kinds of reasons, not the least of them financial. However, the first platform built was only in its second winter when someone on board was able to measure the crest and trough of a huge wave by scaling them against the position of structural members, yielding a value higher than that used in the design. The presently used values for that area are well within half a metre (3%) of that very first NIO prediction. We can only say that luck was certainly with us in a number of aspects, but without NIO's pioneering activities in wave studies there could have been major wave-induced disasters on a platform at sea in those early days.

In the early seventies the NIO (by then renamed as the Institute of Oceanographic Sciences, IOS) was able to produce, at the behest of the Department of Energy, a map of extreme wave heights in the whole of UK waters for oil- and gas-licensing purposes. This was the first time such a map had been produced for any area in the world, and was another fruit of Dr Deacon's early foresight. At the same time, fundamental research was continuing apace with studies of the measurement of wave slope and direction using innovative buoys conceived by M.S. Longuet-Higgins – including the Flying Saucer and, especially, the Cloverleaf Buoy (in the development of which N.D. Smith and F.E. Pierce played a major part); and mathematical understanding was further developed as a consequence.

Data-collection around the UK and Ireland, using Light Vessels and shore-based instruments, continued to expand. Enthusiastic engineers such as J. Cherriman and J.S. Driver were always ready and eager to install the equipment and maintain it in tip top condition. Enormous quantities (by pre-satellite standards) of data were amassed, with up to ten people being engaged in their collection, analysis and interpretation. Many aspects were still worked upon simultaneously – theory, measurement, analysis and practical uses of the data. Participation in major international exercises, such as J.A. Ewing's involvement in JONSWAP in the North Sea, continued to improve understanding of wave processes. The Institute's experience and expertise in providing a comprehensive service to engineers was recognised at an early stage, as its advice and help in setting up similar wave climate studies around the world was sought from quite a number of countries. Some people came to work at the Institute to gain such experience.

A major project begun at Wormley, and continued at Taunton after the move there of most of the wave research group, was to develop an unmanned oceanographic data-recording buoy, the first of which, 'DB1', operated in the Western Approaches and west of Shetland for many years, collecting large amounts of data in areas previously difficult to instrument. It was able to radio its data to shore, and operate for long periods without attention. Industry continues to develop and deploy such equipment.

In the late seventies and eighties, analysis and recording were transferred to computer, and a discrepancy became apparent between early datasets measured at Sevenstones Light Vessel off Land's End from 1962 and later sets collected in the eighties. (Sevenstones held, and probably still holds, the record as the world's longest-running wave recorder: it operated for 25 years – another achievement for the Institute – until funding was arbitrarily cut in 1985.) Initially the discrepancy was thought to be instrumental, but reworking of the hand-calculated early data using modern computer techniques vindicated the early results to well within one per cent, with very few significant errors. It seemed that average wave heights *had* increased substantially since the 1960s, but there was no explanation. A Meteorological Office investigation to see if the weather had changed showed that differences in wind speed, direction and duration were trivial. A similar baffling discrepancy was found with the data from Ocean Weather Ships, and then a paper by a Canadian, H. Neu, demonstrated that visually measured wave heights in the eastern North Atlantic had also increased significantly over the period – here at last was confirmation that the increase was not an artefact due to human frailty. At this juncture D.J.T. Carter was able to show that at Sevenstones the effect – an increase in wave height of 1% per annum (a staggering 25% in 25 years) – was real, with only a 2% chance of it being erroneous. This finding was published in *Nature* in April 1988 and attracted international attention, not diminished by the fact that for financial reasons the world-renowned wave research programme of the Institute was at that time being abandoned! This change in wave climate is still not understood, despite intensive efforts to seek out the reasons. Subsequently, S. Bacon and D.J.T. Carter reported a suspicion that the increase over a longer period may have been even greater.

Throughout its life, the wave research group at NIO/IOS was a focal point for coastal and offshore engineers and others who needed expert advice; its scientists were members of national and international committees charged with a wide range of tasks and setting standards which were highly respected and used world wide. Hovercraft, lighthouses, breakwaters, oil and gas platforms, shipping, and many other activities benefited from the accumulated expertise, as did swimmers and many others. By dint of its dedication to the collection, interpretation and application of quality wave data, IOS produced the world's first instrumentally-based *Wave Climate Atlas,* not surprisingly for the waters around the British Isles.

IOS is now involved with the interpretation of satellite wave data which are obtained from a radar altimeter, a remarkable instrument giving global coverage unobtainable in any other way; it is however a broad-brush exercise which cannot obtain data for localised shallow and inshore waters. It is probably fortunate that such techniques were not available before NIO was able to develop location-specific instruments, as there may never have been the incentive to obtain data of sufficient detail for the mathematicians to get to grips with the dynamics of gravity-wave behaviour.

It has been a superb privilege to have joined NIO with near perfect – nay, optimum – timing, near the beginning of wave research. My colleagues and I can rest assured that we have been valuable and respected members of society; we are all the richer, metaphorically and financially, and in all probability many people are now alive who, without Sir George Deacon's foresight, would have succumbed to less-understood forces of nature. Since the 'dead hand of bureaucracy' descended on the Institute (along with the Customer–Contractor Relationship), there has been little chance of us being able to argue successfully (as we could in the fifties) with the Department of Whatever that we should make continuing measurements of wave climate. I personally was once criticised by some outsider for wasting public money on trifling matters of wave heights when "ships have been sailing over them successfully for thousands of years – we could make better use of the money elsewhere".

Ironically, in the late sixties I was again harangued by an irate engineer – an offshore-platform designer – but this time because I was not able instantly to give him all the details of wave characteristics which he desired: "Don't just sit there on your backside, you are supposed to be paid to solve such problems!" In the eighties, however, a submission by a distinguished engineer with no direct involvement in the Institute, stated to a House of Lords' Select Committee on Marine Science that in his opinion the Institute's wave research had "saved £1 000 million and probably several hundred lives in the North Sea alone". The effects elsewhere must have been comparable. Even if he had been wildly optimistic, there must have been a tremendous saving on what I then estimated to have been an outlay of £50 million at contemporary prices.

This is an opportunity to express in print my debt of gratitude to all my colleagues (and to crave pardon from all those whom I have left unacknowledged) but in particular to thank my mentor 'Tom' Tucker without whose help I would never have become airborne – or should I say waveborne?

Laurence (Laurie) **Draper** has spent virtually all of his working life in wave research. He was seconded to be Director of the Canadian Wave Climate Study during its formative year, and has been a UN consultant on wave data collection and interpretation for engineering purposes. He has been awarded a Telford Premium Prize by the Institution of Civil Engineers and, just before his retirement, the Society for Underwater Technology awarded him their Ministry of Defence Award for Oceanography; both of these were for his work on the practical application of wave research for engineering purposes.

DIVE 3000
A Milestone of Deep Ocean Research

Pat Hickey

In today's high tech, high speed world, the number 3 000 doesn't hold much significance as a measure of great quantity. Many people travel well over 3 000 air miles a year on business and vacation. Computers store information in mega- and gigabytes. But in the realm of deep sea exploration, the number 3 000 holds great significance for the Woods Hole Oceanographic Institution operations crews of the Deep Submergence Vehicle (DSV) *Alvin* and the Research Vessel *Atlantis II*. Thirty-one years, two months and twenty-five days ago, on 26 June 1964, *Alvin* began its career as the United States', and probably the world's, premier deep-diving submersible by making its first descent into the murky waters of Woods Hole harbour, to the (then) astounding depth of 8 m. Today, 20 September 1995, *Alvin* begins yet another descent – Dive 3 000 – this time to the sea floor off the Oregon/Washington coast to study hydrothermal vents on the Endeavour segment of the Juan de Fuca Ridge. At 2 100 m, the dive site is well above *Alvin*'s 4 500 m certification depth.

History

Alvin, named after Allyn Vine, has had a long and intriguing career since that first dive in Woods Hole harbour. It was instrumental in the location and recovery of a hydrogen bomb lost in the Mediterranean Sea after a mid-air collision in 1966. After a chain parted during a launch, *Alvin* spent ten months on the sea floor before being recovered on Labour Day 1969, and undergoing a major rebuild which returned it to operating condition in 1971. In 1974, Project FAMOUS (French–American Mid-Ocean Undersea Study) brought scientists together from both sides of the Atlantic and made *Alvin* available to the world science community. In 1986, *Alvin* took historic photographs of the RMS *Titanic*, lost to an iceberg in the northern Atlantic Ocean. Celebrities like Walter Cronkite and Bill Kurtis have looked out onto deep-sea vent systems from inside *Alvin*.

Owned by the Office of Naval Research, since its construction *Alvin* has been operated by Woods Hole Oceanographic Institution (WHOI) under contract. In that time, 50 men and one woman have qualified to pilot this submarine. Until recently, *Alvin* was the only deep research submersible ever to be operated with only one pilot on board, making room for two science observers on a regular basis. Other deep-diving submersibles, both domestic and foreign, routinely carry two pilots and one observer. None has as yet come close to matching the operating schedule or number of dives undertaken each year by *Alvin*.

Dive crew

As well as being the pilot for today's dive I am the *Alvin* Expedition Leader. My name is Pat Hickey. John Delaney, the Chief Scientist for this leg, and Debbie Kelley, both from the University of Washington, will be the observers. John is a long-time user of *Alvin*, and this will be Debbie's fifth dive. The mission today will be to collect hydrothermal vent fluids and geological samples, and to map the sea floor. The Endeavour segment, and the entire Juan de Fuca area, has been the focus of intense submarine study since 1984, when the hydrothermal vent systems were first photographed and sampled by *Alvin*. John Delaney has an enormous amount of time and energy invested in this study site as well as others in the surrounding areas. I have been here so often over the last eight years that, once on station in the previously explored vent fields, I rarely need to look at *Alvin*'s in-hull navigation to get from one venting mound to another. And yet fresh discoveries are still being made. During the last trip to this location in June, and on this trip, new venting areas have been found. In addition, recent high-resolution side-scan sonar mapping has revealed numerous other likely vent locations in the new field found in June, now named 'Salty Dog'.

But before any new vent sites can be investigated, the science party, experiments and supplies, all have to be staged and loaded onto the *Atlantis II*, *Alvin*'s support vessel, and that staging took place earlier, in Astoria, Oregon.

From Astoria to Endeavour

Astoria is a medium sized town on the mouth of the Columbia River. Originally named after John Jacob Astor, it was first established as a centre for the fur trade and later as a timber-exporting port. Recently, it has become more and more a summer port of call for *Atlantis II* and *Alvin*. The summer of 1995 is no exception as nearly a third of this year's science programs are based out of Astoria, with study sites 250 to 500 miles offshore along the Juan de Fuca Ridge.

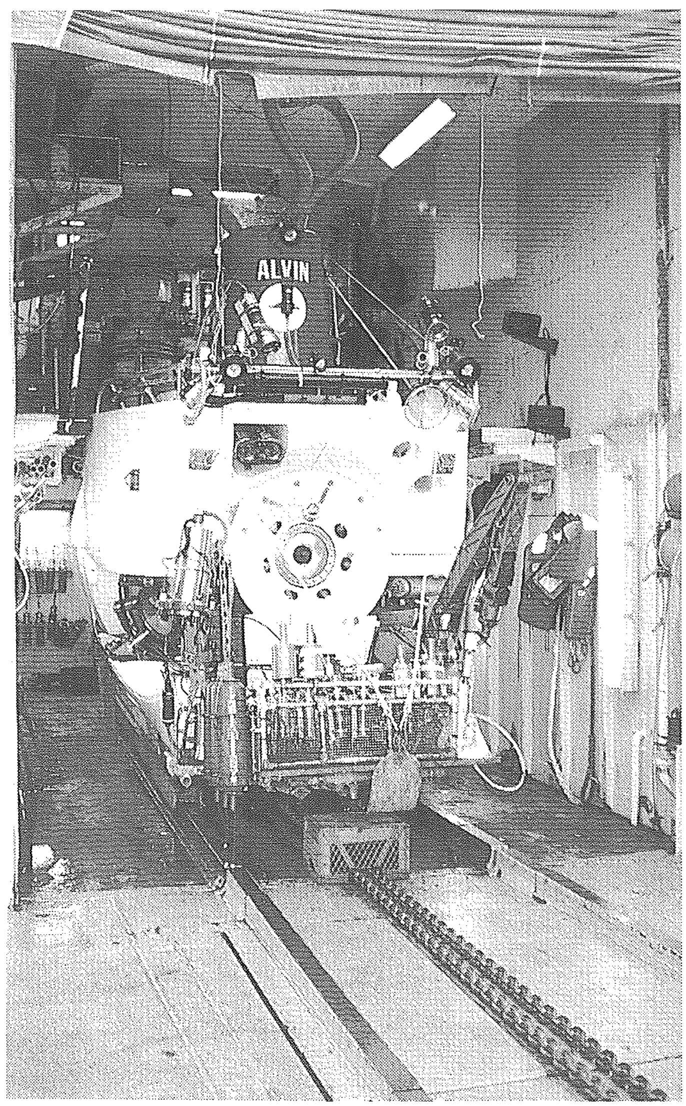
Like most deep ocean research ships, the *Atlantis II*, converted to support and tend *Alvin* operations in 1983, has spent more time on extended cruise status than in its home port of Woods Hole, Massachusetts. Bermuda, Barbados, the Azores, Panama, Mexico, Costa Rica, Ecuador, San Diego, Astoria and Seattle have all been ports of call at one time or another. And so, on 15 September 1995, the *Atlantis II* and DSV *Alvin* departed Astoria on Cruise 132, Leg 13. On board for this 13-day leg were six *Alvin* crew, 23 ship crew and 19 scientists.

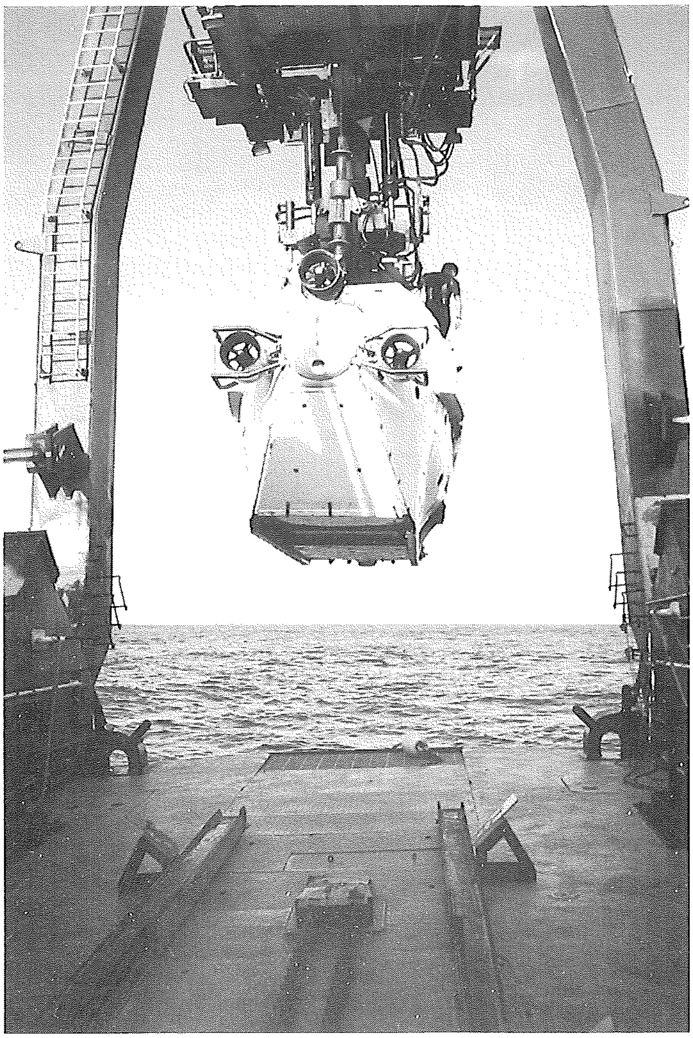
Preparations

Once we cleared the Columbia River, it took about 23 hours for the *Atlantis II* to travel to the dive site at the Endeavour Main Vent Field. During the passage out, pre-cruise dive checks of the submarine and support equipment were completed and members of the science party who would be diving received a safety briefing on the submarine and its emergency systems.

Transponders, or acoustic beacons for underwater navigation in the dive area, were being made ready. Two were already on station, left behind on our last trip here earlier in June, and would be ready for use as soon as we arrived. An additional four transponders were to be employed on this cruise to increase the accuracy and the area over which we could roam. Once the transponders had been deployed and given time to sink to the bottom, their exact locations were calculated. Each transponder listened for an interrogation signal sent from either the ship or the submersible, and each replied on a separate frequency, and was heard by sophisticated receivers on both the ship and submersible. By listening to the time it takes a signal to go out and back to the known locations of the transponders ('travel times'), positions of both the ship and sub can be computed relative to the dive site. The ship was driven in a survey pattern around the transponders, constantly sending and receiving interrogation signals. These signals are recorded on a computer along with the ship's GPS (Global Positioning System) position along the survey route. This information is then processed by a computer navigation program called GPSCAL which calculates the landing locations of the transponders. Those transponder positions are then entered into another navigation program called ACNAV, which is used to do the actual tracking of the submarine while on station. This took a few hours over two evenings after the initial dives to complete. At night, a full programme of

Waiting to go:* Alvin *in its hangar on deck





Alvin being lowered from the A-frame – you can just see one of the 'swimmers' hitching a ride

water-column sampling was carried out, and the same transponder net was used to position the instruments lowered over the side of the ship.

Four dives have been made so far since leaving Astoria on the 15th. Much of the time spent on the bottom has been devoted to the location and recovery of time-lapse cameras and various forms of temperature sensors that were deployed in June around the vent structures. Most of this equipment is picked up and carried to the surface in the submarine science basket. In the case of the cameras, however, large flotation packages are taken to the sea floor by the submarine, attached to lifting points on the camera frame, then released so that they lift the camera to the waiting ship on the surface. The crew of the *Atlantis II* then manoeuvres the ship alongside of the floats and picks up the whole lot with the ship crane.

So far during this science program we have also collected extensive water samples, and undertaken video and bottom mapping surveys and biology collections, but we are still far from being finished. While the general outline for the dive series has been laid out now for several months, modifications and changes are constantly being considered and revised as the outcome and result of each day's dive are reviewed in the nightly science meeting. These meetings and discussions lead to never-ending changes of the original dive plans. The weather – good so far since our arrival – can also greatly influence day-to-day plans.

The morning of Dive 3000

The days start early for the *Alvin* crew when at sea. Dive 3 000 is no exception. A 6 a.m. start, and the crew begins a long and intricate set of checks to ensure that *Alvin* is safe and ready to dive. Mechanical and electrical checks of every system on the submarine are completed. Navigation setups and bottom targets are entered into the submarine's computer. Life-support for the dive is checked and the submarine batteries are seen to be fully charged. A small support boat, a 16-foot semi-rigid 'Avon' inflatable which will carry the swimmers on duty during launch and recovery, is made ready. Even some of the more mundane niceties of life, like lunch and coffee, are addressed. More than 300 items are measured, inspected, filled and operated to ensure they are all in working order. This, as well as loading the sample basket with the dive's science instruments (and squeezing in breakfast), is normally accomplished before 7.30. Then it is time to move *Alvin* from its hangar and out onto the deck. Here it is attached to a large and robust A-frame, which is used to lift and swing the sub out over the stern of the ship and into the water.

On the morning of Dive 3 000, as on every dive morning, launch is scheduled for 8 a.m. Once *Alvin* is out and attached to the A-frame, the last items of the on-board pre-dive checks are completed. I remove safety pins from the dropable ascent and descent weights and science basket. Finally the pre-dive paperwork is reviewed to ensure all requirements to dive have been met. Five people – the pilot, Expedition Leader, Chief Scientist, *Atlantis II*'s Captain and the surface controller – all must be in agreement that the submarine, ship and weather conditions warrant continuing with the launch. Any one of these people can halt a launch if they feel the need. This rarely happens, and Dive 3 000 is no exception, so all is ready to go.

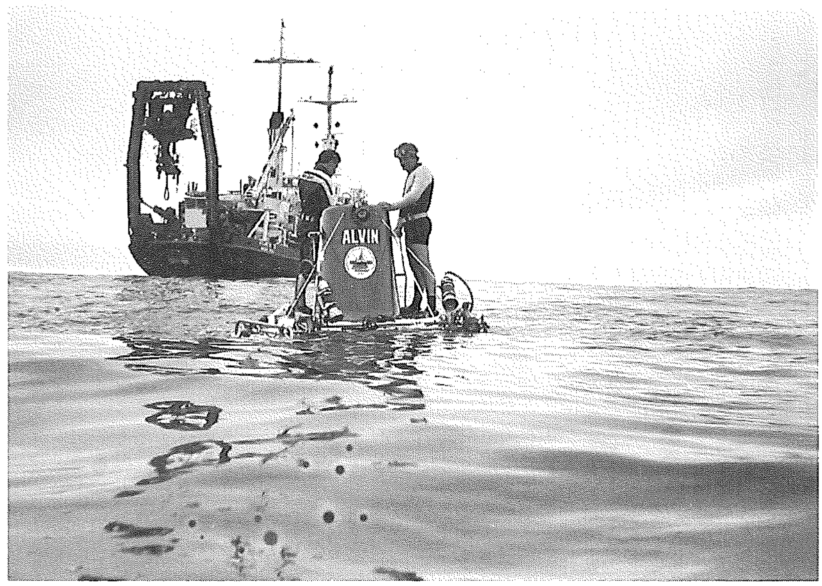
Getting ready to dive

My passengers and I climb the stairway which allows us to board and enter *Alvin*'s cramped personnel sphere. While it may seem large from the outside, the actual space occupied by the divers is a 72-inch diameter titanium ball that is crammed full of buttons, switches and electronic equipment of all sizes. The two passengers sit on the floor while the pilot has a small seat, more like a box, to sit on and look out of the forward window. The day spent on a dive might be likened to spending 8 to 10 hours in a phone booth with two of your closest friends.

Once inside, the boarding ladder is passed out and the hatch shut. During this time, the Avon is being launched by the ship's crane and will take up station astern of the *Atlantis II* to pick up the swimmers who will ride the submarine out and into the water. The launch co-ordinator, who is responsible for getting *Alvin* safely from the ship and into the water, is Bobby Lee Williams, one of *Alvin*'s three pilots on this leg. When I call "Hatch shut!" Williams informs the bridge that all is ready to go. *Atlantis II*'s Captain, Gary Chiljean, then gives us the go-ahead for the launch once he is satisfied that the ship is on the course and heading that will give the best possible stable ride as the A-frame goes out. When the word comes to go, Dave Olds, *Alvin*'s electronics technician and this morning's A-frame operator, begins the lift off the deck, booming *Alvin* out over the stern under Williams' direction. Over the stern, Olds slowly lowers us into the water. The swimmers, Paul McCaffrey, *Alvin*'s mechanical technician, and Ed Rowell, an *Atlantis II* crew member, slip the lift and tail lines and the sub floats free of the ship. Now the swimmers await word from me before proceeding any further.

Alvin's science basket, manipulators and batteries can be electrically jettisoned if the need arises. Ballast weights, which are used on every dive, are also electrically released. Inside *Alvin* I am testing these releases, checking anything which might result in a failure during the dive. Today's basket carries specialised water-sampling equipment for collecting vent fluids, whose temperatures can approach 400 °C, near 750 ° Fahrenheit. One of these sample bottles can cost as much as $4500 and there are 14 being carried on this dive, plus a sophisticated water-sampling manifold. An accidental loss of the science basket would be disastrous both monetarily and scientifically to the program. Every precaution that can be taken, is taken. When I am satisfied that the releases are operative, I have the swimmers remove the safety lines which are used on the science basket during launches and recoveries.

Next is a check of the underwater communications system, the UQC. In 'Top Lab', the station on the *Atlantis II* where all the submarine's tracking and communications is preformed, Matt Heintz, *Alvin*'s third pilot on this leg, listens for and returns my call on the UQC. He is also confirming that the sub has been launched in the right location and that the water depth conforms with what is expected at the dive site. When this is done and I am ready to go, I have the swimmers open a manual vent valve and turn on the submarine strobe locator light. They then depart and swim to the waiting Avon. Now comes the final dive check-list which Heintz, in Top Lab, signs off as I call it to him over the VHF radio. A launch altitude (water depth) and clearance to dive is radioed back. Katy Wilson, the Avon coxswain this morning, informs *Alvin* when the swimmers are in the boat. Switches that open *Alvin's* surface ballast tanks are activated, water floods in



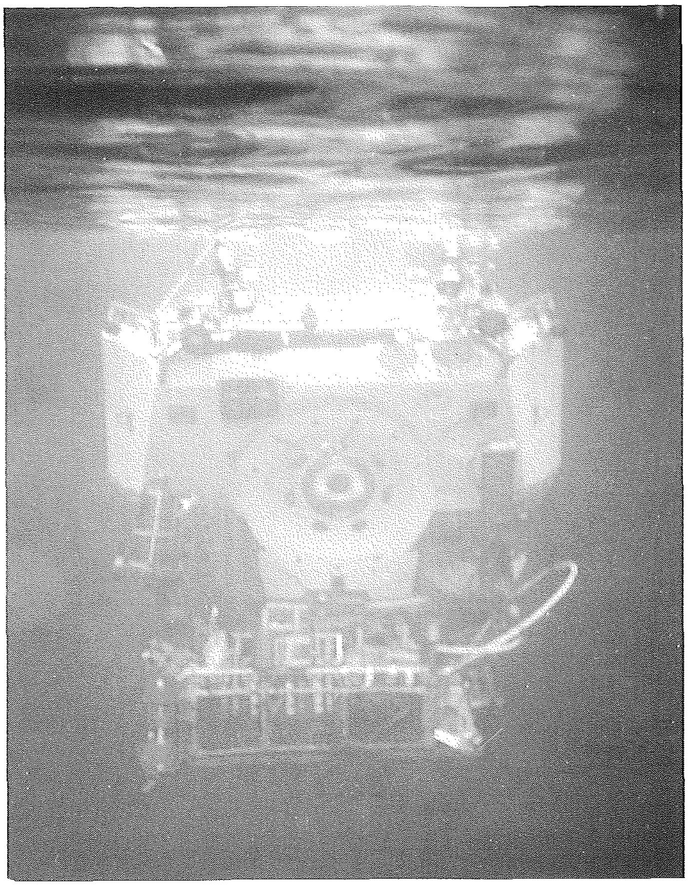
Swimmers carrying out final checks before the descent

and slowly we sink below the surface, starting the long descent to the sea floor below. Wilson radios the *Atlantis II* when the sub is submerged, and returns to the ship with the swimmers to be recovered. From the beginning of the launch to *Alvin* actually submerging has taken about ten minutes. It is 8.03 a.m.

Once the descent begins, everyone on the *Atlantis II* settles into a now familiar routine. In Top Lab, Matt follows our progress towards the bottom, contacting us at least every 30 minutes to ensure all is well. The *Alvin* and ship's crew apply themselves to the never-ending upkeep and maintenance required of the sub and ship, which contributes to the smooth operation. The science party continues to process samples collected on previous dives or catch a few hours' sleep, having worked the night shift. In the steward's department, Carl Wood, Larry Jackson and Bill Lynch clear up after preparing breakfast and begin getting ready for lunch. In all, nearly 2 000 plates of food will be required to feed the 49 people on board, not to mention snacks and beverages.

Descent

As *Alvin* begins its one-and-half hour journey to the sea floor, the colour of the water changes from the ocean blue of the surface, through varying shades, getting increasingly darker with depth, until finally all light is absorbed and blackness envelopes the submarine. This happens at around 350 m depth, and from that point, *Alvin* will have to rely on the lights mounted outside to illuminate the depths. Those lights will not be turned on, except for momentary checks, until the submarine approaches the bottom. But it is not total darkness outside. Bioluminescent creatures glow blue–green in the water as Alvin's transient presence stirs them into reaction. Jelly-like residents of the mid-water column, they use their phosphorescence both for protection and to lure potential prey close enough to capture and consume.



Leaving the sunlit surface waters ...

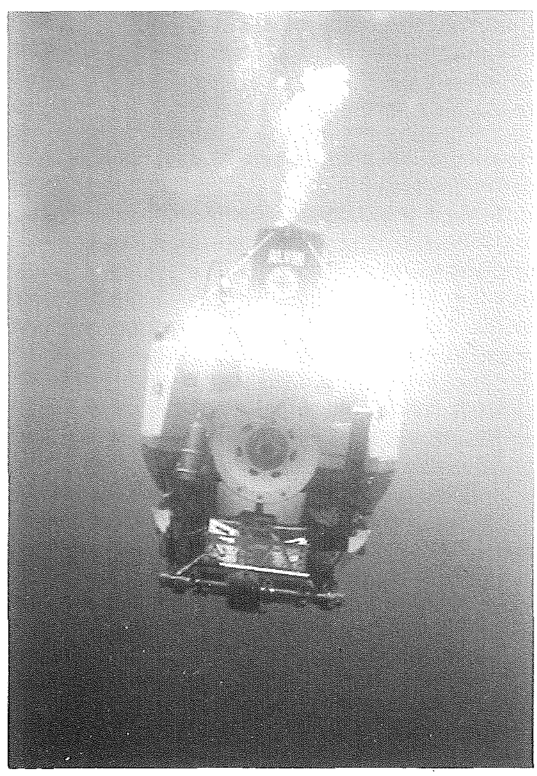
... then descent into darkness

Back in the submersible, we are descending at a rate of about 30 metres per minute. All of the sub's systems are constantly being monitored for anything that might cause any kind of failure. Because the titanium hull we ride in separates us from the outside sea pressure, we will not need to decompress like scuba divers sometimes have to do at the end of a dive. But there are other hazards to be overcome. The atmosphere inside the submarine must be maintained within certain bounds such that the carbon dioxide we are expelling is removed and the oxygen we are breathing gets replenished. This is done by constantly drawing the in-hull air through a canister of chemical absorbent that removes the carbon dioxide, and by slowly bleeding pure oxygen into the hull from high-pressure storage bottles. The deeper we go, the colder it gets outside and consequently inside as well. Below about 2 000 m the sea is a constant 1.5 °C. All the divers wear warm clothing to ward off the encroaching cold. At times, it can feel like a wintery London day. As a person breathes, he or she will expel moisture in each breath. That moisture slowly condenses on all the surfaces as the day goes on, and the dampness can make it seem colder than it really is.

Bottom approach

Since leaving the surface it has taken us about an hour to reach a depth of 2 000 m, slightly less than 150 m from the bottom. It is now time to start bringing on line systems that were turned off during the descent to conserve power. Outside light circuits are enabled and tested again. Propulsion is checked one more time. Video tapes are loaded into the recorders and time codes and dates set. The video and still cameras and strobes are turned on. Scaling lasers, which fall into the field of view of the cameras, are energized. Navigation is checked once more to ensure we land where we intended. Our fall through the water column will culminate in a location away from the new vent field so that we don't risk dropping a descent weight on a potential sample site.

One hundred metres from the bottom the altimeter on *Alvin* begins to show our height from the sea floor. At that point I release one of the descent weights and begin to slow down. A call to the surface tells Heintz my depth and altitude, and that I am now making my bottom approach and will contact him again when I arrive. At 50 m above the bottom I drop my second weight and watch it fall away on the downward-looking camera. Like an aeroplane, we must do a weight and balance for the submarine before each dive. This tells the pilot exactly what kind of payload he can carry and allows him to pre-set the submarines' trim so that it will be near neutrally buoyant when we arrive on the bottom. While *Alvin* is designed and built to operate in the harsh environment of the deep sea, its operating and handling characteristics can be likened to flying a helicopter. It can hover, move forward and reverse, go sideways, rotate 360 degrees in its own length and move up and down in the water column. But for such manoevrability it is important to be neutrally buoyant and for that we pump water into and out of special tanks that allow the mass of the submarine to be changed without changing its displacement.

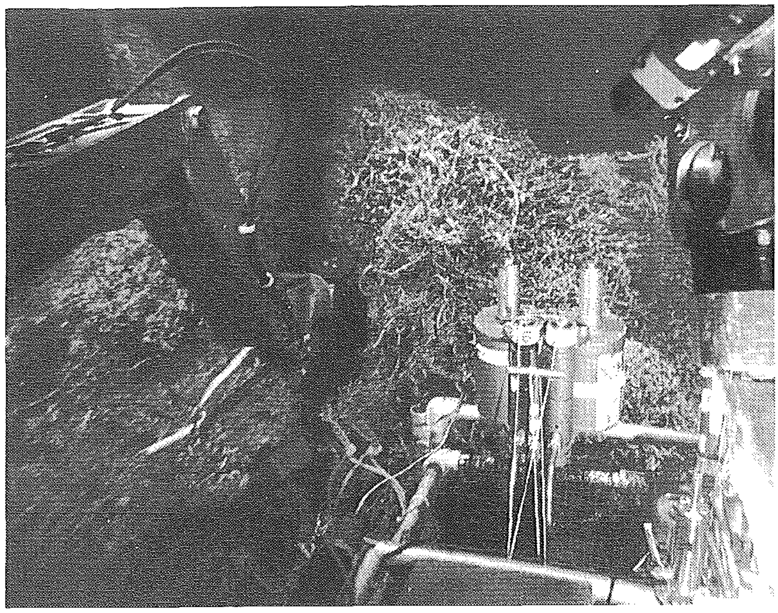


When I arrive at a neutral trim, neither sinking nor rising, I slowly begin to drive the submarine down towards the bottom. This is not the time to be in a hurry because, while we believe this to be a safe spot to land, experience tells us always to expect the unexpected, especially when working in a new area. Slowly the altimeter begins to decrease – 50 m, 40 m, 30 m, 20 m. Around 15 m from the bottom the downward-looking camera begins to show ghosty outlines of the bottom terrain, which becomes sharper and more defined the closer we get. A slow rotation in a complete circle allows me to see the entire area below me. We're now 10 m up, then 5 m. At 3 m above the bottom the submarine comes to a stop. Outside, illuminated by *Alvin*'s lights, is a scene to rival any science fiction movie.

Basaltic rocks – pillow lava and sheets – deposited by erupting sub-sea volcanoes thousands of years ago, are in view for as far as the light can penetrate the milky gloom. Erosion, so prevalent on exposed landmasses above sea level, is virtually non-existent below the water's surface. Only another eruption, sub-sea earthquake, or the slow depositing of sediment which constantly rains to the sea floor, and which can take thousands of years to build up even an inch, will ever change this seascape. But only a 100 or so metres away is part of the sub-oceanic ridge system, a fracture in the Earth's crust which encircles the globe like the seam of a baseball. Either side of this 'seam', seawater flows down cracks in the rock, where it comes into contact with the hot, near-molten rock above sub-sea floor magma chambers. Here it is superheated to phenomenal temperatures. This superheated water now becomes buoyant and works its way back up to the sea floor, dissolving minerals and leaching chemicals as it passes through. When it finally reaches the sea floor and comes into contact with the frigid water of the ocean depths, those dissolved minerals and chemicals are suddenly precipitated out in billowing black clouds – this occurs at hydrothermal vents, the objective of our dive today.

Work

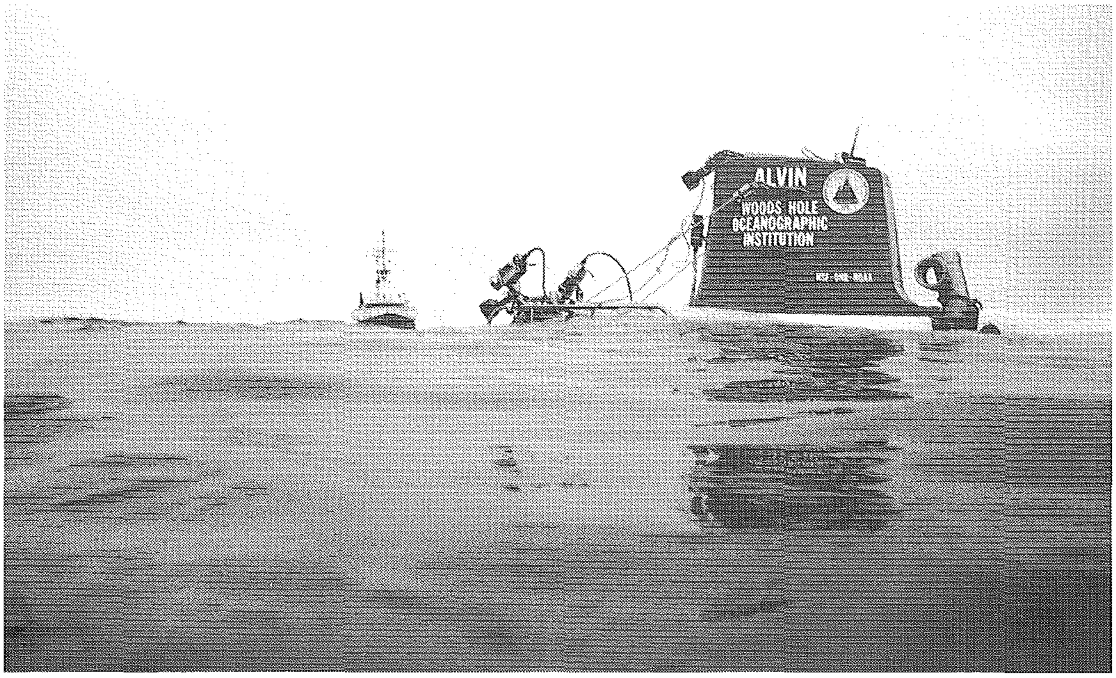
While the outside lava arena is fascinating, it is not what we have come to study so, moving slowly and cautiously over and around the fissured and craggy bottom topography, we head towards what is hoped to be the new vent field. As we approach the target site the water surrounding us becomes cloudier, signs of venting become prevalent. Marker 'AP', left in June beside a black smoker orifice, materializes out of the darkness in front of the submersible. We have arrived back at Salty Dog and the new vent field. Elsewhere along the Juan de Fuca Ridge we pass sulphide structures covered with bacterial mats, tubeworms and the creatures that feed on them, large lethargic fish, rat-tails. Named Dante, Salut, Milli-Q, Godzilla and Grotto, these are only a few of the major structures, ton upon ton of deposited material, some tens of storeys tall, which make up the Main and High Rise vent fields, just to the south of us.



Alvin's*-eye view: Ridgeia *worms crowd over chimney structures; in the foreground is the sample basket with a high-temperature water-sampler mounted along its leading edge; the robotic arm can be seen on the left

Salty Dog also appears massive, yet these smokers – chimney-like towers, belching hot water – can sometimes fall with the tiniest nudge. I have to position the submarine in such a way that, with *Alvin*'s robotic arms, I can reach out and collect a sample of the superheated water spewing forth. At more than 300 °C at the smoker orifice, this water can melt plastic in the blink of an eye – and the view ports are plastic. But only an inch or so away from the vent, the enormous heat sink of the ocean waters causes temperatures to drop to near freezing, about 1.5 °C. A close-up view of the vent's throat on *Alvin*'s colour video camera reveals the minerals in striking clarity – pyrite, chalcopyrite and anhydrite – and the near-boiling water emerging from the sea floor.

Two water samples are taken at this location as well as a video and photo survey to document this sulphide structure with its pagoda-like flanges. Then it is off to explore and map more of the area. Rarely do these massive mounds occur singly. We drop down to where the sulphide of the field meets the sea floor basalt and slowly begin to follow that contact around, using the submarine's navigation to define the size of the mound and the boundaries of this new field. Smaller mounds, covered with tubeworms basking in shimmering water, are sighted and logged on our vastly expanding maps. Another wall of sulphide looms ahead and I raise the sub up 25 m to find a second major structure, larger than Salty Dog. Spires on the flat yet craggy top make a rough, hummocky scene. It reminds Delaney of a character from the classic Old English poem, Beowulf. Grendel was Beowulf's homely mother. So Grendel is the name of this new discovery.



The sub breaks surface some distance from its mother ship, its powerful underwater lights now above the waves

There are no active smoking vents to be seen anywhere on Grendel. Overhanging flanges, with underlying reflective pools of clear hot fluids are the predominant feature of this mound. We stop our survey to sample these flange fluids, along with sulfides, and some of the local biota, and to place another marker, 'D3000'. In the distance I can see an octopus on the peak of a dead spire casually watching my progress. This animal is near the top of the food chain down here so *Alvin*'s bulking presence doesn't seem to concern it.

It is now about three hours since we reached the bottom and a call comes down that the director of the Institution, Bob Gagosian, would like to talk to us on the occasion of Dive 3000, via a phone link with Woods Hole. By connecting the UQC to the ship's INMARSAT telephone, we can talk to, or be called by, anyone in the world. A short conversation with Gagosian, and later a local Cape Cod radio station and newspaper, then it's back to work.

The final objective of this dive is to sonar map the new vent field. Rising up above the bottom to be clear of any obstacles, we have laid out a course in *Alvin*'s navigation computer which will take us over the entire venting complex in tracks spaced 25 m apart. As we move along these lines, a high resolution sonar, looking downwards and scanning from side to side, will acoustically image the entire area. The images will later be processed and merged into a contour map which will detail what we have seen. This survey takes nearly two hours to complete, during which time we maintain a constant depth.

Ascent

We've been on the bottom for over six hours now and have depleted *Alvin*'s batteries to the point where we must surface so they can be recharged for tomorrow's dive. I drive the submarine off-axis away from the vent field into a clear area where it is safe to release the two remaining weights, and call up for permission to surface. McCaffrey, surface controller for the afternoon, checks with Rick Bean, the mate on watch on the *Atlantis II*'s bridge, to ensure there are no other vessels in the immediate area, and relays back that all is clear. The weights are released and we begin another one-and-a-half hour journey back. It is finally time to relax a little, stretch out cramped legs and back, and review the dive's accomplishments so a scientific report can be relayed to the waiting science party above. I power down the non-essential systems again to conserve energy.

On the *Atlantis II* the recovery crew is swinging into action. The A-frame is powered up and prepared for lifting *Alvin* back onto the ship. The swimmers prepare their gear and the Avon operator this afternoon, Emily McClure, gets the boat ready to bring the swimmers to *Alvin* when it breaks the surface. In Top Lab and on the bridge, tracking continues so that the ship can be positioned down-wind for its recovery approach. When all is ready, the ship waits.

Below, *Alvin* has been rising to the point where tendrils of lights begin to penetrate the solid blackness which has surrounded us for the last 8 hours. At 200 m I call up our depth and the ship responds by launching the Avon and sending it to our estimated surfacing position to wait. 100 m from the surface and I begin to slow down to allow battery and compensation systems to adjust to the lower pressure now surrounding *Alvin*. 50 m and it is bright out in the water around us. Looking up through a small viewing port, I check to ensure that the surface is clear above me. And finally, 8 hours and 56 minutes after we left the light of day this morning, the submarine sail breaks the surface once again. A call to the ship on the VHF radio confirms they have us in sight and the Avon is alongside. I blow air into the surface ballast tanks for added stability and can see the swimmers, Jerry Graham and Patrick Hennessy, attaching the safety lines onto the science basket. A check with the swimmers on the sound powered phone and we are ready to be picked up by the *Atlantis II*.

Recovery

The Avon, with Hennessy aboard, returns to the *Atlantis II*, to wait off the stern of the ship for the tow line. On the *Alvin*, Graham gives me directions to steer so that I am correctly lined up as the ship passes. As the *Atlantis II* goes by the *Alvin*, word is given by Captain Chiljean on the bridge to run out the tow line. Matt Heintz, co-ordinating the afternoon recovery, sends the tow line to McClure and Graham in the Avon, who manoeuvre over to the *Alvin* and attach it to the stern towing point. Once Hennessy is back aboard *Alvin*, the towline is pulled in until the sub is below the A-frame. The main and tail lines are dropped to the swimmers and attached to lift points on *Alvin*, then the sub is lifted clear of the water as the swimmers plunge into the ocean to be picked up by the Avon. The A-frame is boomed inboard and the *Alvin* landed on its waiting transport cradle. Heintz washes the hatch down with fresh water and tells me when it is clear to open it. The boarding ladder is then passed in and finally, Delaney, Kelley and myself leave the cramped, damp, musty confines of the *Alvin* sphere and climb out into the fresh air once again.

Atlantis II's ***powerful Glasgow-built A-frame***

Celebration

A crowd of scientists and ship's crew are around to help celebrate Dive 3000, fully equipped with cameras and buckets of water for a friendly 'wetting down'. But Dive 3 000 is not over yet. The A-frame is disconnected from the submarine and *Alvin* is returned to the hangar to be secured. The day started at 6 a.m., it is 5.30 p.m. and there is still more to do. After a quick dinner, the crew returns to complete the post-dive checks. Again the various systems of *Alvin* are inspected to ensure that no damage has occurred on today's dive which might affect the dive planned for tomorrow. The submarine is unloaded and cleaned. Oxygen bottles are changed and the batteries put on charge.

The Avon returning to Atlantis II – note the tow lines

The science party has long since removed the water, biological specimens and rocks that were collected today and they will be processing those samples throughout the night, getting the samplers clean and ready for tomorrow. The night science crew is ready to start their work for the evening. And some 14 hours after the day began, *Alvin* is finally put to bed. The crew breaks for the evening – some will watch a movie, others play cards, the rest simply go to bed. Tomorrow is another day and there are still seven dives to be completed before we return to Astoria.

The future

Alvin has been a workhorse for the science community for over 31 years now and there is no end in sight. Proposals for its use continue to be submitted to the funding agencies even though government budgets are becoming tighter and tighter. In late 1996, *Alvin* will return to Woods Hole to begin a major overhaul to refurbish and upgrade its systems. The refit will take about six months, and when *Alvin* re-emerges, we will be moving onto a new support vessel. This will be Woods Hole's newest vessel, currently still under construction, and will be named *Atlantis*. The *Atlantis II* will be retired after our return in the fall of 1996. This move will facilitate an expansion not only of *Alvin's* capabilities, but of science's as well.

The *Alvin* group will merge with DSL, Woods Hole Oceanographic Institution's group who operates the remotely controlled submarine *Jason*. These can be jointly operated from the newer, larger AGOR class vessel. Woods Hole Oceanographic Institution also has another newly developing asset – ABE, for Autonomous Benthic Explorer. ABE is a free-swimming vehicle which can be pre-programmed and deployed to operate alone in selected areas, carrying various suites of sampling and data-acquisition equipment, and being recovered weeks and even months later. Working in concert with these and other instruments on a larger, more capable support ship, the United States, and worldwide science communities will have available a capability for deep sea exploration and research never seen before.

In writing this article I have tried to acknowledge as many of the scientists and crew as possible. For those that I have missed, I apologise.

J. Patrick (Pat) Hickey is Expedition Leader and Chief Pilot, Deep Submergence Research Vehicle, *Alvin*.

Celebrating Dive 3000 here are (from left to right) Pat Hickey (the author), Steve Falcoutico, Robert L. Williams, Matti Heintz, Dave Olds and Paul McCaffery.

Book Reviews

Explorations: My Quest for Adventure and Discovery Under the Sea – An Autobiography by Robert D. Ballard (1995) Weidenfeld and Nicolson, 407pp. £20 (hard cover, ISBN 0-297-81504-0).

How do we attract youngsters to go into science in general and marine science in particular? Every month or so the newspapers remind us that fewer children are studying science in school; enrolments in university science courses are dropping. Yet we live in an increasingly technological age, and logic dictates that scientists and engineers will be increasingly needed. I was attracted to marine science in the 1950s by the spectacular diving programmes produced for TV by Jacques Cousteau and Hans and Lotte Haass. But who is replacing them for today's youngsters? In this country we have our Bellamys and Attenboroughs, but they hardly merit the epithet 'marine'. The Oscar must surely go to Bob Ballard of Woods Hole Oceanographic Institution, finder of the *Titanic* and the *Bismarck* and inventor of the JASON education programme which hit Britain's shores for the first time in 1993.

The JASON programme epitomises Ballard's concept of involvement of many individuals in undersea exploration by 'telepresence' (see *Ocean Challenge*, Vol. 4, No. 3). You don't have to be there to do it. Video footage from the highly sophisticated low-light camera systems on the JASON search vehicle are relayed to the mother ship through fibre-optic cable, then via satellite link to auditoria where schoolchildren and their teachers not only see the pictures and hear the commentary but can talk back to the presenters – Ballard and his exploration team aboard their vessel – and even get to use a joystick to manouevre the vehicle from their seat. Each live exploration session, which is relayed to 500 000 school children across the USA and Canada, and now to auditoria in Liverpool, Keyworth, and Southampton, is the culmination of an education programme in which teachers use various educational materials to prepare classes for what they will see. The children are exposed to real live exploration; they participate in it at a distance. Their imaginations are stimulated, their attentions captured, their lives perhaps changed by the experience. This could be one new way to capture more hearts and minds for science.

I worked with Bob in the early 1970s when his office was across the hall from mine in the Geology and Geophysics Department of WHOI. We had the same mentor, the great K.O. Emery. Bob was still doing his PhD, but already making his mark as one of the first marine geologists to rely heavily on submersibles – in his case *Alvin* – to do his stuff. He succeeded brilliantly at promoting the use of submersibles for scientific diving. The key word is promoting. With his brash and noisy style, Bob is the Barnum of the oceanographic world, a scientific promoter, pushing the technology of undersea exploration to its limits, and getting everyone involved. Some people dislike him for it, and ridicule his efforts as not really science at all. Wiser hands know better. In the great ocean business there is room for all sorts; the backroom lads and lasses at the workbench silently toiling away, and the promoters and marketers who get out there and change the environment – usually by bringing in money in some form or another. In Bob's case, his gift was a conduit into the US Navy through which he was able to gain access to, or sponsorship for, advanced technologies, the use of which has subsquently benefitted the science of large numbers of his colleagues and, now, is benefitting hundreds of thousands of schoolchildren.

What sort of a person do you have to be to achieve what he has in his 50 or so years? To be a scientist, author, explorer, educator and TV personality? To become a legend in your own lifetime? Read this book and find out. Better still, buy it for your kids. Tell your neighbours to do the same. It is written like a thriller. I couldn't put it down, even though I knew quite a lot of the story in advance. Along with a goodly dose of adventure, whoever reads it will get some basic science about the Earth beneath the sea and the life that thrives there around hot vents, and some marine archaeology to boot, as well as a picture of how the ocean business works. If I had read this book in the 1950s it would have had the same effect on me as Cousteau's films, creating a convert to marine science. If *you* want to create a convert, buy someone a copy!

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Upwelling in the Ocean: Modern Processes and Ancient Records (Environmental Sciences Research Report ES 18) edited by. C.P. Summerhayes, K.-C. Emeis, M.V. Angel, R.L. Smith and B. Zeitzschel (1995) John Wiley and Sons, 432pp. £65 (hard cover, ISBN 0471-96041-1).

This book is a report of the Dahlem Workshop on Upwelling in the Ocean, held in Berlin in September 1994. The Workshop presented a framework within which concentrated discussion was focussed around multidisciplinary approaches to key questions about processes and consequences of coastal and open oceanic upwelling. In this volume, the editors, together with the other participants of the Workshop, both from the UK and abroad, present impressive expertise on the various disciplines.

Upwelling systems are important because they sequester nutrients that control ocean chemistry, biology and fisheries, and are very productive. Crude calculations by F.P. Chavez and J.R. Toggweiler (Chapter 15) suggest that 65% of global new production is supported directly by upwelling.

The workshop sought to establish the way in which upwelling systems operate as integrated physical, chemical and biological systems on a variety of short- and long-term timescales. Nineteen papers are presented in the volume, variously summarising present knowledge and outlining the over-riding objectives for future multidisciplinary research on the role and processes of upwelling. The book presents an interesting accumulation of facts, problems and hypotheses about coastal and open oceanic upwelling, and each chapter has been written by a group of experts within a particular upwelling-related field of study. It is well-illustrated and is likely to be of interest both to marine researchers and to post-graduate students of oceanography.

How open ocean and coastal upwelling systems operate as integrated physical, chemical and biological systems is examined, as are the effects of upwelling seen in the geological record. Upwelling zones as sources or sinks of CO_2, the effects of upwelling on the global carbon cycle, its contribution to carbon and nutrient budgets in the ocean, and its role in global carbon and climate cycles on a million-year time scale, are all addressed. Physical estimates of global new production are examined, as are particle flux and sedimentation. Questions are raised about how upwelling systems vary through time (including on millenial time-scales) and about the role of laminated sediments as records of ancient ocean variability.

Various problem areas in the investigation of upwelling, discussed during the conference, are outlined in the text. For example, the dominant role played by climate in driving physical processes and the ensuing vertical advection and resupply of nutrients to the photic zone is reasonably well-understood, but it seems that there is still some confusion about which factors determine the variability of primary production in time and space. The linkage between carbon and nitrogen cycles in upwelling systems and the nutrient reservoirs of the deep ocean through time also remains uncertain. Conditions that determine limiting nutrients need to be investigated further. More quantitative data are needed on the effect of upwelling on CO_2 levels; in particular the effect of upwelling processes on the drawdown of CO_2 is not fully understood.

The volume provides a blueprint for further multidisciplinary marine upwelling-related research. Key issues that should feature in the design of other experimental, theoretical or observational programmes are suggested, and are summarized by Summerhayes *et al.* (the editors) in Chapter 1. These include a coordinated intercomparison of modern coastal and open upwelling systems; experiments designed to establish more clearly the structure and dynamics of the physical circulations associated with upwelling, including climate forcing factors; and an investigation into the factors that determine the scales of variability in primary production (as mentioned above), including chemical, biological and physical linkages. Observations and experiments designed to investigate the sedimentary variability of upwelling on short-term and millenial time-scales are also considered to be important, as well as research into factors which affect the redistribution of sediment.

In conclusion, as a whole the volume presents an up-to-date and comprehensive summary of what is known and not known about the basic processes involved in coastal and open-ocean upwelling, along with the outstanding questions and recommendations to come out of the workshop. The text is informative, interesting and well written, and there are many useful references, not to mention the addresses of participants in the workshop. I enjoyed reading it, and thoroughly recommend it to oceanographers and post-graduate students specialising in this field.

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Dynamics and Modelling of Ocean Waves by G.J. Komen, L. Cavaleri, M. Donelan, K. Hasselmann, S. Hasselmann and P.A.E.M. Janssen (1994) Cambridge University Press, 532pp. £45 (hard cover, ISBN 0-521-43291)

This is an excellent book, indispensable reading for anyone (with some background in mathematics and fluid mechanics) interested in understanding and modelling the dynamics of ocean waves. The book is the final report of the WAM (WAve Modelling) group who came together in 1984 with the aim of developing what has become known as the third generation or WAM model. The editorial team, led by Gerbrand Komen, have successfully melded contributions from 35 different contributors to create a book with a mostly uniform and very readable style. Great care has been taken to cross-refer where necessary so that, when browsing through particular contributions, one's attention is clearly drawn to related discussions elsewhere in the book and to other work included in the extensive list of references. One gets the sense of a very lively, enthusiastic and dedicated scientific grouping that must have been great fun.

In the first chapter, after a gentle introduction to wave modelling, one is rather thrown in at the deep end with the mathematics leading up to the 'action balance equation', the basic tool of wave modelling. The mathematically shy might prefer to skip this section on first reading. The chapter finishes with a brief discussion on wave and wind measurement techniques, with the emphasis on satellite measurement (reflecting the interests of some of the authors). I was a little disappointed in the limited information given on the use of HF radar, my own area of interest.

The wave model that the WAM group had in mind in 1984 was based on a full description of all the physical processes that govern wave evolution. The second chapter presents the current state of knowledge about these processes. In all cases, one is led from the early ideas and results through to the latest theories, and to interesting areas for future research. Observational support (or otherwise) for some specific aspects of the physics is then discussed, in particular the evolution of the shape of the spectrum in fetch-limited and turning winds. The chapter includes useful discussion on importance of 'wave age' (defined as the ratio of the wave phase speed to the friction velocity) and on the debate on the use of the friction or 10 m velocity for scaling purposes. It finishes with the important comment that rarely in the field can one measure the contribution to wave development of an individual physical process. This limitation has provided the motivation for another aim of the WAM group – to develop methods for using data in an inverse modelling approach, i.e. tracing differences between model and measured data back through the model to identify the particular physical process (or combination of them) responsible for the difference and hence determine where changes to the parameterisations should be sought.

The numerical model itself is the subject of Chapter 3. Here we are required to face the constraints of computing power, at least in the context of operational modelling, and the consequent approximations that are required to the physics. The section on the computer program provides useful background for anyone thinking of obtaining the model for their own research purposes. The chapter finishes with a presentation of some simple tests of the model – the ideal experiments that, as I have already mentioned, are rarely achievable in the field.

Clearly, operational wave modelling is very dependent on operational weather forecasting to provide the wind source term. Sections 2 and 3 in Chapter 4 present a thorough account of the limitations of surface wind estimation and the consequences for predicted wave fields. Global wave modelling needs global wave measurement systems both for verification purposes and for providing initial wave fields. Satellites provide the platform for measurement on global spatial scales and Chapter 5 presents some results from both the altimeter and the synthetic aperture radar (SAR). The discussion concentrates on comparisons between the different satellite measurements and WAM; good agreement between these is not always matched by good agreement with wave buoys, but this discrepancy is not explored in detail. The apparent good agreement between SAR and WAM measurements is a little misleading since the latter are used in the interpretation of SAR images. It is interesting that this section presents the only comparisons of 2-D spectral shape to be found in the book. The shapes of WAM spectra are used elsewhere to illustrate points being made about different physical influences; but comparisons with buoy estimates would have been interesting.

Chapter 6 deals with data assimilation and inverse modelling, both of which perform, in slightly different ways, the task of using model results and observations to create an optimal estimate of sea-state. Such methods recognise that all wave measurement methods have their different weaknesses and strengths, as indeed does the WAM model. As has been implied above, the factor that most limits wave modelling accuracy is the lack of accurate wind data. Improved ocean wind field estimation is also a goal of the work described here. A number of different methods are discussed (you will need some mathematical skills to follow the details), some of which are already showing promise, others of which are still in the early stages of development. The final chapter presents a succinct summary of the areas of uncertainty in wave modelling. There are many, but the WAM group have made great progress and this book is an admirable record of their many achievements.

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Oceanography and Acoustics: Prediction and Propagation Models by Allan R. Robinson and Ding Lee (1994) 257pp. £47.50 American Institute of Physics (hard cover, ISBN 1-56396-203-9)

Published by the American Institute of Physics as part of their series on Modern Acoustics and Signal Processing, this book, not surprisingly, is a celebration of American achievements in computational ocean acoustics and numerical ocean modelling. A cynical view may be that its appearance now has got something to do with recent European initiatives, in particular the EC-sponsored series of Underwater Acoustics Conferences and Proceedings. A more favourable view is that it really has got something important to say about underwater acoustics research and – if this is something that concerns you – then you should take a closer look at its contents.

Computer modelling and simulation are now widely used in science and engineering and the realism that is afforded by such models means that it is possible to study processes and applications without the need to build prototypes or to perform time-consuming experiments. The same is true of underwater acoustics research. Until comparatively recently, advances in this area were made almost exclusively through experiments at sea and with theoretical, mainly analytical, studies. Now with the rapid growth in computer power and the development of sophisticated dynamical ocean prediction models and acoustic propagation codes, it is possible to perform acoustic propagation experiments on a global scale, without even getting your feet wet! This is not to say that experiments aren't still required. They are; there is still much that we don't understand about the oceans. The real breakthrough is that computer modelling and simulation now provide oceanographers and acousticians with powerful insights into processes, which in turn enables them to do even better experiments, and – particularly important these days – to do this in a more cost effective way.

Sophisticated computer codes are now available for predicting both the state of the ocean and the propagation of sound within it, including interactions with the sea surface and the sea-bed, and beneath this within sedimentary layers and rocks. In fact, developments have gone beyond this, leading to inverse methods and signal processing techniques (e.g. matched field processing) that are capable of inferring 3-D ocean structure from ambient noise fields and localising sound sources in range, depth and bearing. These are remarkable achievements and *Oceanography and Acoustics* really does succeed in making the point that computational ocean acoustics has come of age – both as an investigative tool and a diagnostic method.

Readers of *Ocean Challenge* wanting to find out something about basic underwater acoustics might be forgiven for feeling a little put off by the mathematical and computational prowess demonstrated in this book – preferring instead more familiar texts like Urick's *Principles of Underwater Acoustics*. My advice would be to persevere – the book really does cover new ground and illustrates how far computational ocean acoustics has come in enabling us to visualise the underwater environment.

Edited by Robinson and Lee, the book is really a collection of papers or case studies on the coupling of ocean dynamical prediction models and acoustic propagation models. A number of these articles (in whole or part) have appeared elsewhere and I have lost track of the number of times I have seen the Harvard Open Ocean Model (HOOM) described – is the Gulf Stream the only acoustically significant feature in the world's oceans?

So what has this book got to offer that hasn't already been addressed elsewhere? One answer might be 'applications'. It has got to be true that going to sea in ships to gather data is time-consuming and expensive and that much can be done to study ocean acoustic phenomena using ocean models and acoustic models in combination. But how should such models be coupled together? How sensitive are acoustic predictions to changes in ocean model parameters? What sort of horizontal resolution and how many vertical levels would you need to build into a numerical ocean model to correctly predict acoustic propagation through ocean fronts and eddies? When should you use 3-D acoustic models as opposed to cheaper and easier-to-run 2-D models? Sensitivity issues such as these are very important for the designers of ocean-acoustic prediction systems and yet it is hard to find published material on this subject. As a start then, *Oceanography and Acoustics* makes a useful contribution in plugging this gap in the literature and for this reason alone is a welcome addition to this reviewer's bookshelves.

It is also nice that there is some sort of order in the way in which the material is presented. Robinson and Lee start with their own review of ocean variability, its impact on acoustic propagation and the development of coupled ocean-acoustic models. Using the classical wave equation as a starting point, Chin-Bing, King and Boyd do a useful job in the following chapter in providing a genealogy of acoustic propagation models and a useful bibliography on the subject. This is followed with a discussion on ocean environmental change starting with sub-mesoscale effects such as internal waves and microstructure. Porter *et al.* in Chapter 3 deal with surface duct propagation and the ocean mixed layer, which should be of interest to meteorologists.

In Chapter 4, Robinson, Carman and Glenn describe what is effectively the Harvard Ocean-Acoustic Forecast system, and the development of a hierarchy of dynamical ocean models and acoustic models, together with ocean observation networks and data assimilation techniques. In an impressive and competent display of modelling techniques, they describe primitive equation, quasi-geostrophic and surface layer models which, with a 2-D implicit finite difference acoustic model, have been used to generate ocean-acoustic forecasts for the Gulf Stream, the Iceland–Faroes Gap, the eastern Mediterranean and the north-east Atlantic. Chapter 5 by Lee concerns 3-D effects, but now modelled explicitly with a 3-D acoustic model applied to the Gulf Stream region using the HOOM. This has shown that 3-D effects, in particular azimuthal coupling, should not be neglected. Lee hints at the use that may be made of coupled (3-D) ocean-acoustic models and this is dealt with in Chapter 6 by Siegmann's conclusions concerning vertical and horizontal resolution requirements in ocean models. In Chapter 7, Kuperman covers 3-D ocean acoustics from the point of view of propagation, noise and array processing. There is an exciting hint of things to come here with the possibility of passive tomographic methods for imaging 3-D environments. Chapter 8 by Chiu and Ehret follows on the 3-D theme but deals with normal mode propagation, using as an example – yes, you guessed – the Gulf Stream. Comparisons of 3-D and N x 1-D coupled model solutions emphasise the importance of horizontal refraction by mesoscale ocean features. From normal modes, we pass on to ray treatments of the wave equation and in particular 3-D Hamiltonian ray theory, extended to include current effects. Lynch *et al.* describe the use of the HARPO code with the Harvard Open Ocean Model to investigate a number of sensitivity issues, in particular the representation of sound speed fields and bathymetry (including a brief discussion on interpolating sparse, irregularly spaced and gappy data onto regular grids). Ray theory is compared with other 3-D propagation models, in particular normal mode and parabolic equation techniques, and finally we get onto some applications – other than the Gulf Stream! The most interesting of these is the Heard Island long-range transmission experiment to investigate global warming by measuring decadal variations in cross-basin acoustic travel time variability. Whether or not experiments of this type succeed in demonstrating global warming, they are a powerful example of the use of ocean and acoustic prediction models to investigate real world phenomena.

Although the book requires some familiarity with the mathematics behind the models, there is much that can be gleaned about their use without needing to dig into the detail. It deals effectively with applications and, from this reviewer's point of view, the all-important issue of sensitivity and accuracy in ocean-acoustic model coupling. If you are interested in ocean acoustics then this tome deserves a place on your bookshelf too.

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A version of this review appeared in the *Quarterly Journal of the Royal Meteorology Society* in 1995.

The Challenger Society for Marine Science

OCEAN Challenge

The Magazine of the Challenger Society for Marine Science

SOME INFORMATION ABOUT THE CHALLENGER SOCIETY

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To advance the study of Marine Science through research and education.

To disseminate knowledge of Marine Science with a view to encouraging a wider interest in the study of the seas and an awareness of the need for their proper management.

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A list of names and addresses of all members of the Society.

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The subscription for 1996 will cost £25.00 (£12.00 for students in the UK only). If you would like to join the Society or obtain further information, contact The Membership Secretary, Challenger Society for Marine Science, c/o Southampton Oceanography Centre, European Way, Southampton SO14 3ZH, UK.

ADVICE TO AUTHORS

Articles for *Ocean Challenge* can be on any aspect of oceanography. They should be written in an accessible style with a minimum of jargon and avoiding the use of references. If at all possible, they should be well illustrated (please supply clear artwork roughs or good-contrast black and white glossy prints). Manuscripts should be double-spaced and in a clear typeface.

For further information, please contact the Editor: Angela Colling, Department of Earth Sciences, The Open University, Walton Hall, Milton Keynes, Bucks MK7 6AA, UK. Tel: 01908-653647; Fax: 01908-655151; Email: A.M.Colling@open.ac.uk

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