The OMEX I Project

Introduction

The Ocean Margin Exchange (OMEX) project was a major multinational study carried out within the framework of the European Union's Marine Science and Technology programme. The first phase of the project (OMEX I) ran from the beginning of June 1993 until the end of May 1996 under the leadership of Professor Roland Wollast, assisted by Dr. Lei Chou from the Chemical Oceanography Department of the University of Brussels, Belgium (ULB).

OMEX I was largely field based, with extensive physical, chemical, biological and geological measurements made on the European continental margin off northern Norway, at the Goban Spur and off Iberia. 95% of the data collected during the field programme are presented on this CD-ROM.

This description of the OMEX I project has been subdivided into sections as follows:

OMEX I Scientific Objectives

OMEX I Sub-projects

OMEX I Fieldwork

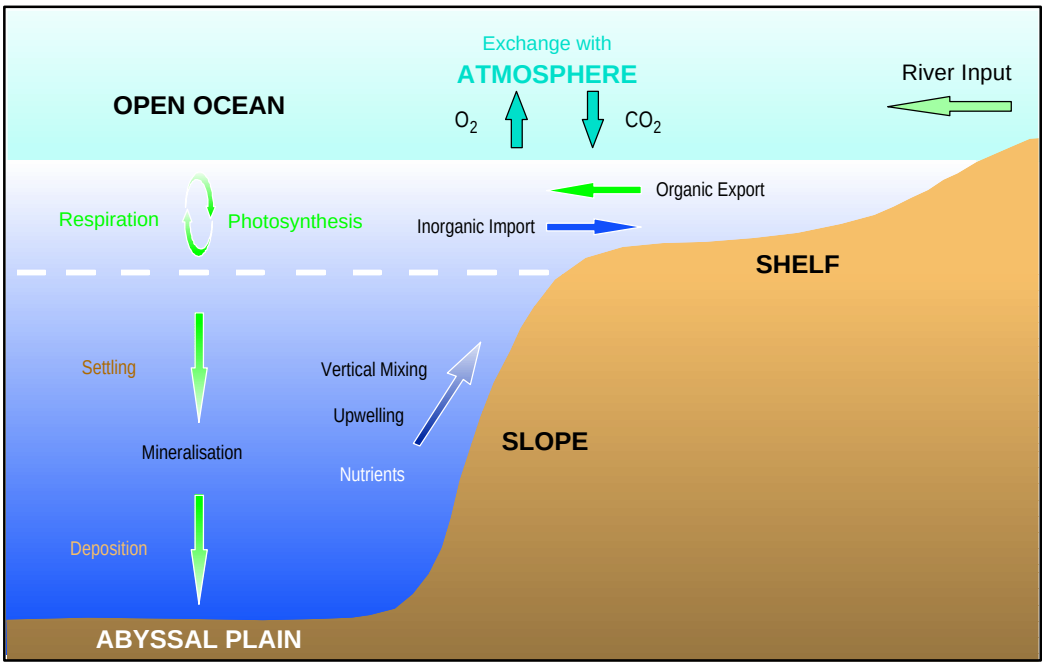
OMEX I Data Management

OMEX I Scientific Objectives

The aim of the Ocean Margin EXchange (OMEX) project was to gain a better understanding of the physical, chemical and biological processes occurring at the ocean margin of the European continental shelf in order to quantify fluxes of energy and matter across this boundary.

The objective was to provide a more accurate picture of the biogeochemical interactions between the coastal zone and the open ocean. This information is essential for the development of predictive models required to evaluate the response of the shelf and slope area to global environmental changes.

The coastal area with its enhanced productivity and strong influence from continental input is an important source of dissolved and particulate matter for the open ocean. On the other hand, deep ocean waters, rich in nutrients and high in dissolved trace elements, are transferred across the shelf edge and help to sustain the high productivity of biota in the coastal zone and shelf seas. The quantification of fluxes across the ocean margins is a fundamental requirement for the evaluation of the budgets of carbon, nutrients and trace elements between the continents, the coastal zone and the open ocean.



Processes controlling the carbon cycle at the ocean margin (*R. Wollast)*

OMEX I Sub-projects

OMEX I was subdivided into sub-projects on the basis of scientific discipline. Each sub-project was lead by a distinguished scientist in that field who, together with the OMEX chair (Professor Wollast), vice-chair (Professor Erwin Suess) and secretary (Dr. Lei Chou), formed the Scientific Steering Committee responsible for the scientific management of the project.

The sub-projects in OMEX I and their leaders were:

Physics	Dr. J.M. Huthnance, Proudman Oceanographic Laboratory, UK
Biogeochemical Cycles	Prof. R.F.C. Mantoura, Plymouth Marine Laboratory, UK.
Biological Processes	Dr. B. von Bodungen, Institut für Ostseeforschung, Germany Dr. P. Wassmann, University of Tromsø, Norway
Benthic Processes	Dr. T.C.E. van Weering, Netherlands Institute for Sea Research, the Netherlands
Carbon Cycling and Biogases	Dr. S. Larsen, Risø National Laboratory, Denmark

The leadership of the Biological Processes sub-project changed during the course of OMEX I.

Physics Sub-project

Objectives

- **To identify the various processes controlling fluxes of water and particles at the European ocean margins.**
- **To determine by *in situ* measurements and remote sensing the water mass structure, circulation and exchange characteristics along contrasting shelf edges for subsequent assimilation into physical models.**
- **To develop prognostic models involving the physically controlled advective and diffusive transport in varied shelf-edge contexts.**

Processes

An assessment was made of the physical processes active at the European continental margin. Several contributed typical currents of the order of 0.1 m/s or cross-slope transport of the order of 1 m^2/s. Some phenomena were observed to be very much stronger. For example, currents such as the Gulf Stream at the western ocean margin, meanders and eddies on strong currents, or canyons in the shelf break were identified as potential causes of large local exchange. In areas where the shelf width is wide, tidal currents can be strong. In the OMEX I physics sub-project, the scales of processes were related to factors such as shelf width, wind strength, etc.

In situ measurements

Currents were measured by mooring instruments off south-west Portugal, over the Goban Spur and off north-west Ireland. Drogued buoys and floats were released and tracked west of Portugal and northwards from the Goban Spur. The vertical distribution of temperature, salinity and other water properties was measured in all these locations by lowering instrument packages from research vessels.

West of Portugal these measurements, together with surface temperature "maps" from satellites, showed that water originally on the continental slope east of Cape St. Vincent left the slope near Lisbon as an eddy with a diameter of between 30 and 60 km that moved westwards at an average speed of 0.05 to 0.07 m/s. In this way water and its contents were transferred from slope to ocean.

Models

A three-dimensional prognostic model for currents, temperature and salinity was developed to provide detailed modelling of ocean margins. It used a special grid to resolve the upper layers and the steep slope. Aspects of the numerical calculation were also specially designed for these contexts.

Realistic winds provided by a meteorological forecast model were used to force the physical oceanographic model to produce temperature and current distribution maps. Associated routines computed fluxes and tracked particles. A sub-model of the Iberian area with a resolution of 4 km driven by locally measured winds was also developed to provide more detailed information on phenomena such as upwelling and filament formation that are associated with this region of the European continental margin.

Biogeochemical Cycles Sub-project

Objectives

- **To determine the spatial and temporal distribution of nutrients and primary production along the continental shelf.**
- **To quantify the fluxes of carbon and related elements (N, P, Si and trace elements) between dissolved and particulate phases in living and non-living reservoirs.**
- **To develop biogeochemical mass balance models describing long term flows of carbon, nutrients, trace metals and their exchange fluxes between the open ocean and the shelf seas to predict man's impact on land-ocean exchange processes.**

Nutrient Dynamics

Phytoplankton production and fertility on the shelf is critically controlled by the influx of nutrients from rivers and from the open ocean. On an annual basis, the on-shelf flux of nutrients including nitrate, phosphate and silicate are of major significance. Nutrient fingerprints and their seasonal flows were measured during OMEX I cruises for the different water masses that contribute to exchange at the shelf edge.

Productivity

Phytoplankton photosynthesis rates along shelf edge sections were measured in terms of size-fractionated components, and in terms of nitrate fuelled ‘New Production’ and ammonium fuelled 'Regenerated Production'. New production can support the fallout or export of biogenic carbon to deep waters. Bacterial degradation and microzooplankton grazing on the phytoplankton carbon recycles organic carbon back to CO_2 for exchange with the atmosphere. These competing processes were investigated simultaneously to allow the seasonal mapping of productivity to be completed and to relate these to pigment distributions determined by shipboard HPLC and remotely sensed by colour sensing satellites.

The sources and speciation of carbon and nitrogen were tracked using natural abundance of ^{13}C and ^{15}N in particulate matter. Bio-assimilation of carbon, nitrogen and phosphorus were determined by tracer additions of the isotopes ^{14}C, ^{15}N, ^{32}P and ^{33}P.

Carbon Cycle

The inventories and flows of dissolved and particulate organic carbon were tracked using novel ultra-clean shipboard analysers for dissolved organic carbon and deep *in situ* pumping systems for particulate organic carbon. Studying the ^{13}C isotope ratios made it possible to distinguish organic matter from terrestrial and marine sources. Molecular biomarkers, including pigments and biopolymers, were measured to distinguish phytogenic from trophically reprocessed forms of organic matter. Sediment traps collected the fallout of shelf and marine organic material and allowed measurements of the carbon export rate from the slopes to the deep sea to be made.

During upwelling events at the shelf edge, supersaturated CO_2 may be ventilated to the atmosphere, and so depending on the origins and hydrography, shelf edge systems can switch from being net sinks to being a net source of CO_2 to the atmosphere. During OMEX I, measurements were made of the carbonate system to investigate this.

Bioreactive elements

The inventories and fate of bioreactive elements (Ba, Ca, Al, Zn, Pb, Cd, Cu, Fe, Mn, Ni, Co) and their vertical and frontal distributions at the shelf edge were mapped to allow residence times, reactivities and shelf budgets for these geochemically and toxicologically important elements to be estimated.

Biological Processes Sub-project

Objectives

- **To identify the major biological components involved in the vertical and horizontal transport of dissolved and particulate biogenic matter in the shelf/slope region.**
- **To investigate the effect of shelf edge discontinuities on the seasonal primary production, microbial and grazing food webs and the extent of pelagic-benthic coupling along shelf slopes.**
- **To develop numerical ecological and diagenetic models for slope systems and resulting fluxes.**

Biological Transport Processes

These were investigated through the measurement of vertical fluxes of particulate matter, and the characterisation of this matter. The fluxes were measured using three moorings, instrumented with current meters and transmissometers, with sediment traps at depths of between 600 and 4000 m, deployed for periods in excess of a year. The data showed that the material flux increased with depth, demonstrating the importance of lateral transport in the vicinity of the ocean margin. In addition, process studies were undertaken to investigate the transport and fate of phytoplankton-derived carbon on the European ocean margin.

The Influence of the Shelf Edge on Biology

The relationship between the shelf break and the distribution of the zooplankton community was studied by measuring the strength of acoustic doppler current profiler signal returns. Measurements of this type taken at different times of the day showed large daily movements of several hundred mg of organic carbon into and out of the upper mixed layer that resulted from the vertical migration of the plankton.

The supply of organic carbon to deeper waters is not only controlled by the strength and duration of phytoplankton bloom, but also by the dynamics of the zooplankton that graze on them. During OMEX I the relative importance of grazing by the micro and meso-zooplankton in the shelf break area was investigated.

Modelling

Within OMEX I, ecological modelling proved an important tool for integrating the diverse data collected and testing the central questions posed by project. The contribution of modelling was not restricted to running numerical simulations for comparison with field data. Significant additional understanding resulted from the interchange of ideas necessary to develop the models. The various modelling exercises in the Biological Processes Sub-project represented an activity where the investigations from different groups of scientists and from different shelf areas found a common base.

Benthic Processes Sub-project

Objectives

- **To establish, assess and quantify transport, settling accumulation and burial fluxes of particles along the European ocean margins.**
- **To evaluate the role of benthic biota in the respiration and preservation of organic matter in the sediments.**
- **To study the diagenetic processes occurring in the recent sedimentary column and to quantify the related fluxes of elements associated with the carbon cycle.**

Transport, Accumulation and Burial

Particle transport in the shelf environment is the result of a complex interaction of a number of processes. Particles originate from both the shelf and through biological activity in the surface waters over the shelf break. They may also be resuspended into the water column under certain physical conditions into mid-water depths from sites on the slope. The concentration of particles in water column was measured by the deployment of transmissometers and nephelometers, either as part of an instrument package lowered from a research vessel or on instrument moorings.

These measurements showed the expected high particle concentrations in the surface layers and, through resuspension, near the sea bed. However, in addition a zone of enhanced particle concentration, termed an intermediate nepheloid layer, was frequently observed during OMEX I at a depth of about 1000 m. This is believed to result from sediments resuspended from the shelf break floor being advected into deeper waters. Numeric models were used within OMEX I to investigate this phenomenon.

Sediment samples from the sea floor were collected along the Goban Spur transect. From these, a picture of sediment accumulation and organic carbon burial rates across the shelf break was built up.

Benthic Biota

During OMEX I a quantitative assessment of the benthic community, from minute nematodes to large holuthurians, was made in the vicinity of the Goban Spur. The carbon remineralisation rates by this community were assessed through the determination of oxygen demand on sediment samples and through *in-situ* measurements obtained by the deployment of benthic

landers on the sea bed. Biogeochemical activity levels within the sediment were assessed through quantification of adenylates and bacterial biomass was determined through the measurement of DNA, proteins and lipids.

Diagenetic Processes

Numerical models were developed in OMEX I to help the understanding of the processes operating in early diagenesis. These models showed that the organic matter being incorporated in the sediment at 1000 m depth consists of very reactive material which is mixed at a high rate into the sediment. Sediment mixing rates based on ^{210}Pb profiles were an order of magnitude lower than the organic carbon mixing rates.

Carbon Cycling and Biogases Sub-project

Objectives

- **To describe, quantify and model air-sea exchange processes for climatically and biogeochmically important elements such as CO_2, CH_4, dimethylsulphide and their oxidation products.**
- **To study the physical parameters that underline the mechanisms controlling the gaseous fluxes in the marine atmospheric surface layer.**
- **To estimate the importance of different carbon species to the overall carbon budget at the shelf edge.**

Air-sea Exchange Processes

The exchange of biogases between the ocean and the atmosphere is of major importance for the earth climate as some of them strongly affect the world's radiation balance, i.e. they act as so called "greenhouse gases".

About 40% of the CO_2 produced by fossil fuel burning is believed to be taken up by the ocean. Sulphur gases are produced in the upper surface layer of the ocean and escape to the atmosphere, affecting cloud formation and hence the earth's albedo. The biogeochemical processes at the shelf edge control the abundance of these trace gases. Hence, estimating fluxes of biogases at the ocean margin requires high spatial and temporal resolution.

During OMEX I, concentrations of carbon dioxide, dimethylsulphide and its precursors, carbonyl sulphide and methane were measured in both the water column and the atmosphere in order to quantify this.

Gaseous Flux Mechanisms

The net flux of gases between the air and the sea depends upon the partial pressure difference and the resistance at the interface, the latter depending on physical conditions such as wind speed, sea surface temperature and whitecaps (bubbles). There are two approaches to estimate this flux. One involves direct observations of atmospheric fluctuations over the sea surface; the other is to measure the concentration gradient and parameters controlling the exchange velocity. Both techniques were employed during the OMEX I project.

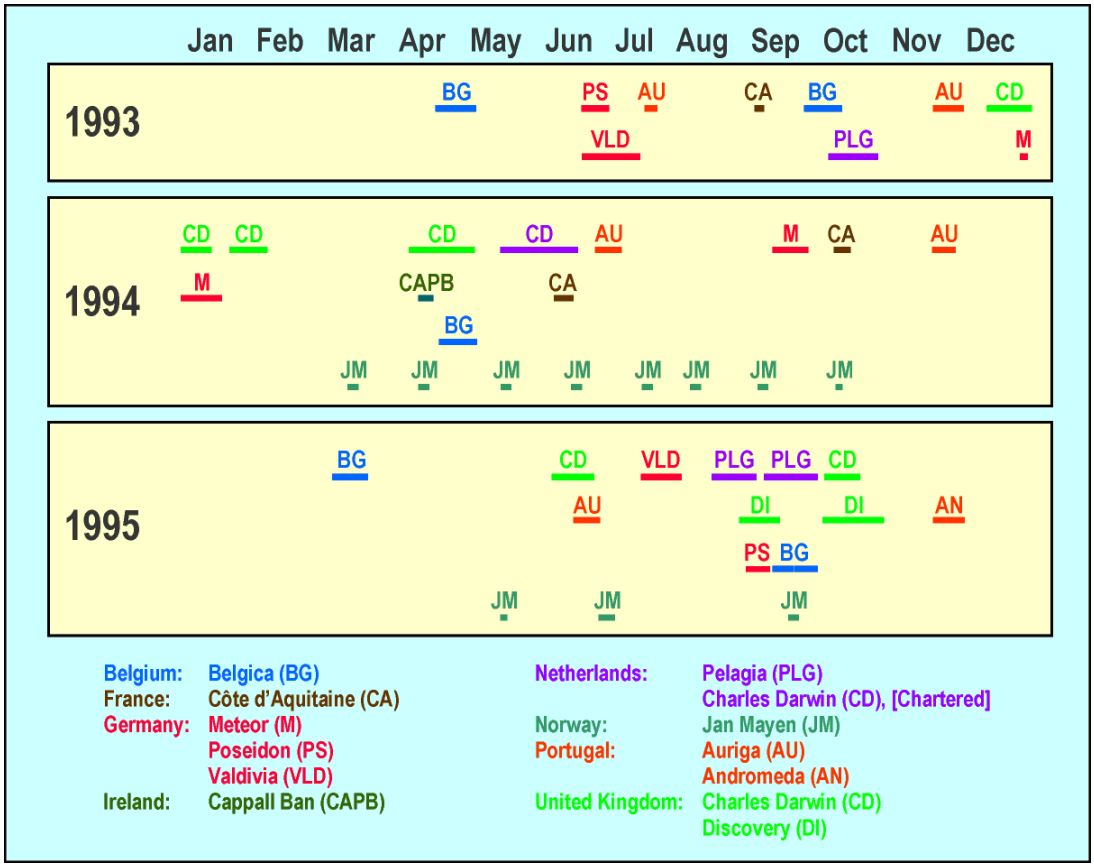
OMEX I Fieldwork

OMEX I Shipboard Activities

The shipboard activities during OMEX I may be classified into four types. The first were data collected by 'ships of opportunity'. These were merchant ships that towed the SAHFOS Continuous Plankton Recorder as they plied their normal routes between ports. The database on the CD-ROM includes data from samples collected from 295 such journeys that passed over the Goban Spur area between April 1964 and December 1995.

The second classification were cruises primarily concerned with other projects, but offered assistance to OMEX activities. Included in this are cruises deploying and recovering OMEX moorings on the Meriadzek Terrace and cruises working sections over the shelf break that offered berths to OMEX scientists. Four cruises of this type are included in the database.

The third classification are what may be termed 'day trips' where a small vessel made measurements along a shelf break section close to her home port. Included here are seven short expeditions made by FV Madorniña from Vigo, Spain in 1994 and 1995.

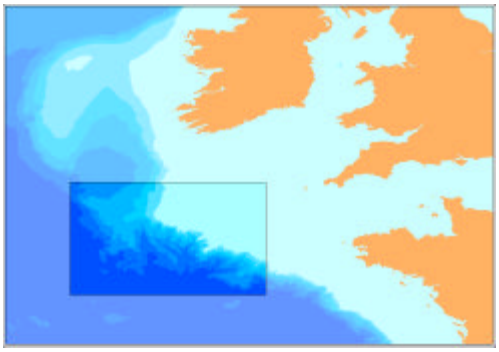


OMEX I Research Cruises

Finally, there were research cruises primarily concerned with the OMEX project. A total of 46 cruise legs involving vessels from 8 nations provided data for the CD-ROM which are summarised in the chart above.

OMEX I Field Areas

The fieldwork during OMEX I was primarily focused on three areas of the European continental margin. The first area studied was the slope off northern Norway from 69.5 to 70.6 °N and 15 to 19.4 °E. This region was visited by eleven cruises by the RV Jan Mayen collecting CTD, water bottle and drifting sediment trap data.



The main OMEX I field area was centred on the bathymetric feature known as the Goban Spur, south of the Porcupine Bight in the Celtic Sea. There were three primary stations that formed a section along the spur at which long-term sediment trap moorings were deployed. The mean positions and water depths held in the database for these stations are:

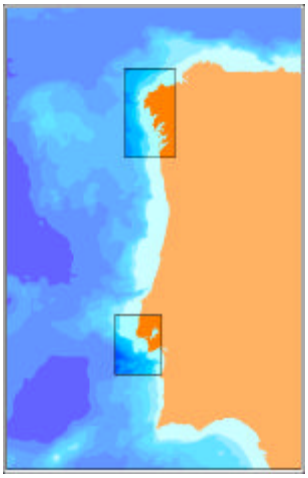
OMEX1	49.42 °N	11.52 °W	656 m water
OMEX2	49.18 °N	12.86 °W	1620 m water
OMEX3	49.08 °N	13.42 °W	3654 m water

In practice, only OMEX2 and OMEX3 returned sediment trap data because the OMEX1 mooring was trawled on its first deployment. The database includes events sampled in the vicinity of this section from 17 cruise legs showing this to be the most intensively sampled area during OMEX I.

The OMEX I 'Goban Spur' data set was not just confined to this section and data are included in the database along the shelf edge from La Chapelle Bank to the Hebridean Terrace. However, the data are noticeably concentrated to the south of 50 °N.

The scope of the data collected in the vicinity of the Goban Spur was so large that it defies description. Over 800 parameters are held in the database that were measured on air, water, particulate matter and sediment samples from this region.

The third area studied during OMEX I was the Iberian Margin. A hydrographic (CTD, oxygen and nutrients) section off Vigo, Spain, was repeatedly surveyed during the FV Madorniña campaign and the region from Vigo

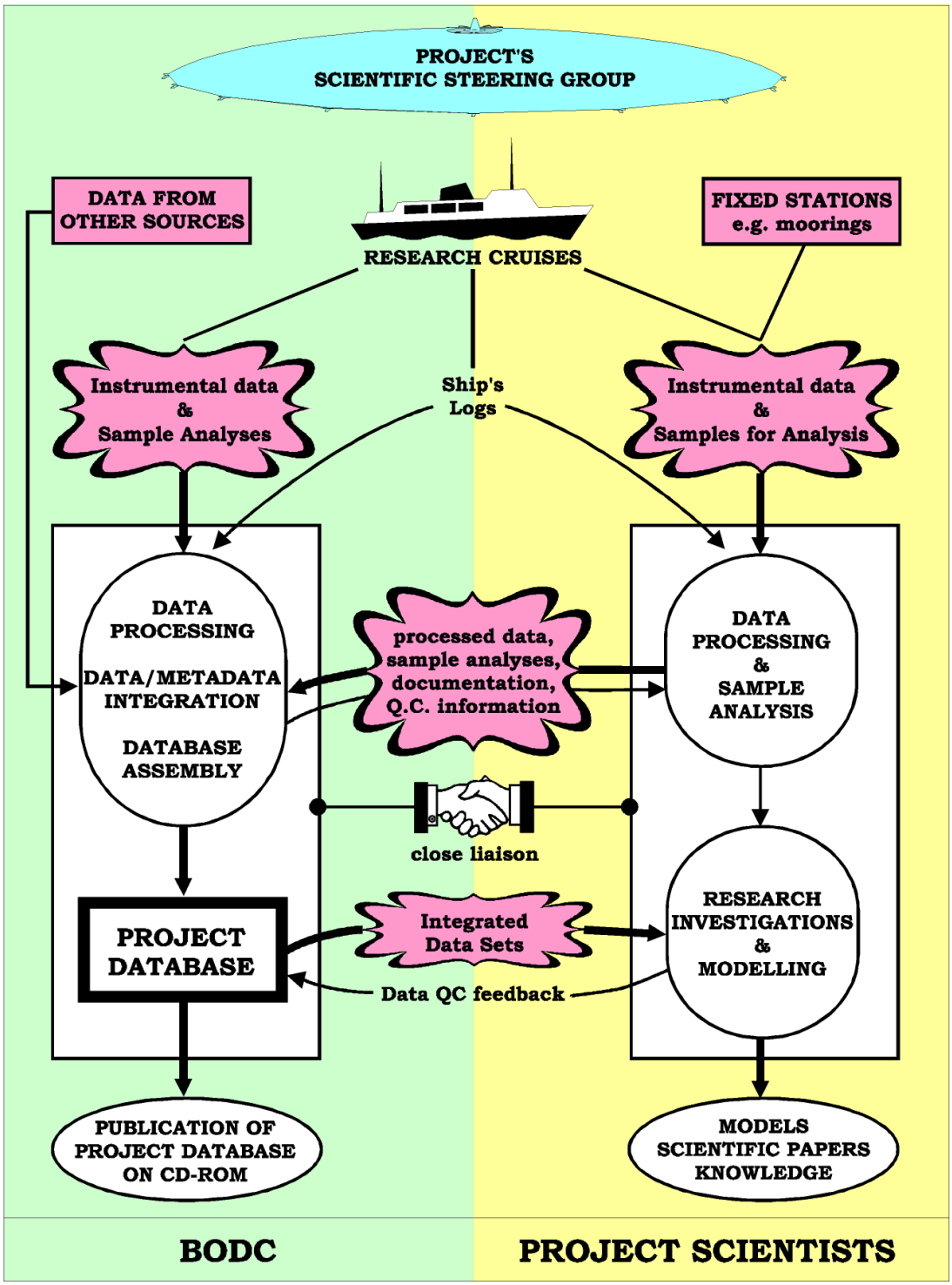


northwards was visited by one RV Belgica cruise collecting hydrographic and production data. Further to the south, in the vicinity of the River Tagus, the six PLUTUR cruises provided CTD surveys, data on particulate matter and sediment samples. Current meter moorings were also deployed off the Portuguese margin by RRS Charles Darwin.

The OMEX I data set can therefore be seen to extend over the entire length of the European continental margin and should include something of interest to anyone studying the oceanography of this important boundary.

OMEX I Data Management

Data management services to the OMEX I project were provided by the British Oceanographic Data Centre, funded by a MAST supporting initiative and the UK Natural Environment Research Council.



BODC project data management model (*M.T. Jones*)

The data management project followed the practices established by BODC for handling multidisciplinary project data management in the UK. These were founded on the building of solid working relationships with the project scientists throughout the life of the project. This was achieved by adopting the model shown in the above diagram.

The data management operation began with the collection of data at sea and culminated in the publication of the project data set as a clearly defined project deliverable.

During the life of the project, the data management team provided the following services to the project scientists:

- Calibration and quality control of automatically logged data (generally CTD and underway data) to a common standard for all cruises in close co-operation with the scientists collecting the data. This was a highly flexible service carefully tuned to the requirements and resources of the scientists concerned.

- Providing a vehicle for data exchange within the project through the provision of an on-line database and a request service.

- Adding value to the data set through the integration of large numbers of disparate data sets into a common integrated data base.

The data management operation identified a total of 602 discrete data sets collected during the OMEX I project. Of these, 95% have been assembled into the database presented on this CD-ROM. This statistic emphatically demonstrated that the data management techniques, based on close, co-operative working relationships between data managers and scientists, developed for UK national programmes could be successfully extended to a pan-European scale.