Exploring the Geology of Shelf Seas

R McQuillin D A Ardus

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Preface

We wish to acknowledge our indebtedness to the Director of the Institute of Geological Sciences for approving the preparation of this book as well as giving his permission to publish a number of IGS photographs and to draw upon open-file records for some of our illustrations. The assistance afforded us by exploration and manufacturing companies in supplying information and illustrative material is also gratefully acknowledged. The current addresses of companies referred to in the text are supplied in appendix I.

A number of colleagues have given valuable aid by reading and commenting on parts of our manuscript, in particular D K Smythe, M Bacon and A S Mould. We are particularly indebted to Linda Nisbet, for secretarial assistance, and Angela McQuillin, for preparing the illustrations.

In our attempt to provide an account of so wide a subject as the methods currently being used in the exploration of continental shelf geology, we have become very aware of its incompleteness and of our omissions, but our aim has been to concentrate on topics not adequately covered in other text books, and in particular to present a practical rather than a theoretical approach to our subject.

R McQuillin
D A Ardus
Edinburgh
August 1976.

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1 Principal Objectives of Offshore Exploration

As, with continuing exploitation, the reserves of non-renewable natural resources of the earth's land areas diminish, the need increases to win these same resources from beneath the seabed wherever they occur and can be economically exploited. Oil and gas, sand and gravel, coal, gold, iron ore, diamonds, manganese and nickel are some of the minerals and materials extracted from beneath the sea today. Most are extracted from beneath the relatively shallow seas adjacent to continental land masses. The geology of these shelf areas is of a continental (as opposed to an oceanic) type, and economic exploitation is largely within the control of the individual national governments of adjacent coastal states. In areas such as the North Sea international agreements have been reached defining the position of a median line which bounds the offshore territories of signatory nations, thus the way is prepared for commercial exploration and exploitation of sub-sea geological resources under a system of governmental control similar to that exercised in land areas. In other areas, negotiations between governments are being actively pursued.

Offshore exploration, exploitation of resources, and the engineering and construction of large seabed structures together form a major new and rapidly growing field of industrial development. A knowledge of the geology of the seabed and underlying strata is basic to this development and a knowledge of the methods used to acquire this knowledge is important to all who are either professionally involved, or training for such involvement. This book aims to explain the principles, applications and practice of methods used in offshore exploration. The nature of the problem is such that applied geophysics provides a major contribution to the exploration task and this bias is reflected in the content of the book. A number of texts already exist which adequately cover the theoretical basis of the main geophysical methods; some are suggested as further reading or for additional reference. Little, however, has been published giving an overall view of the nature of the practical problems to be encountered studying offshore geology. The marine environment is very different to that of the land; in some ways it makes exploration more difficult, in others more easy. The methods used are in many respects different.

In the chapters ahead, each method is treated individually and the applications to which it may be put are discussed. In practice, integration of a number of methods is usually necessary to solve a particular problem. For a complete geological interpretation, a combination of the results of all methods to be described must be amalgamated into an easily-understood geological synthesis. Written reports play an important role, but the main output from geological exploration is a series of maps. This series will include maps of bathymetry, of seabed sediment distribution, of thickness of superficial deposits, of bedrock geology, of geological structure, of isopachs to important horizons, of net thicknesses of important geological units etc. A general system for geological exploration is shown in figure 1/1. Many problems, particularly if linked to a single commercial objective, can be solved using only a limited part of this system. Everything depends on the aim of the work, the nature of the problem, and the finance available.

The oil industry has been, over the past decade, the major force behind development of exploration technology as well as providing most of the funds for the acquisition of data. Over this same period, research institutes and university departments have, with more meagre resources, played an important role, and it is on the results of research and exploration by such bodies that much published knowledge of offshore regional geology depends. Today, one of the more actively growing areas of the offshore survey scene is concerned with problems of site investigations for large-scale constructional and engineering work. Special problems of accuracy of location and precision of geological data arise in such work and methods are being developed to meet these needs.

Offshore exploration is costly. Operations at sea, even of a simple nature, involve use of large capital resources. Some examples can be quoted.

(i) Inshore survey for pipeline route or coastal geological study: £300–£1000 per day.

(ii) Regional geophysical survey; bathymetry, gravity, magnetics, shallow seismics and sonar: £3000–£5000 per day.

(iii) Deep reflection seismic survey; usually quoted per line kilometre; £100–£200 including cost of processing. Daily rate about £5000–£10,000, ship and acquisition only.

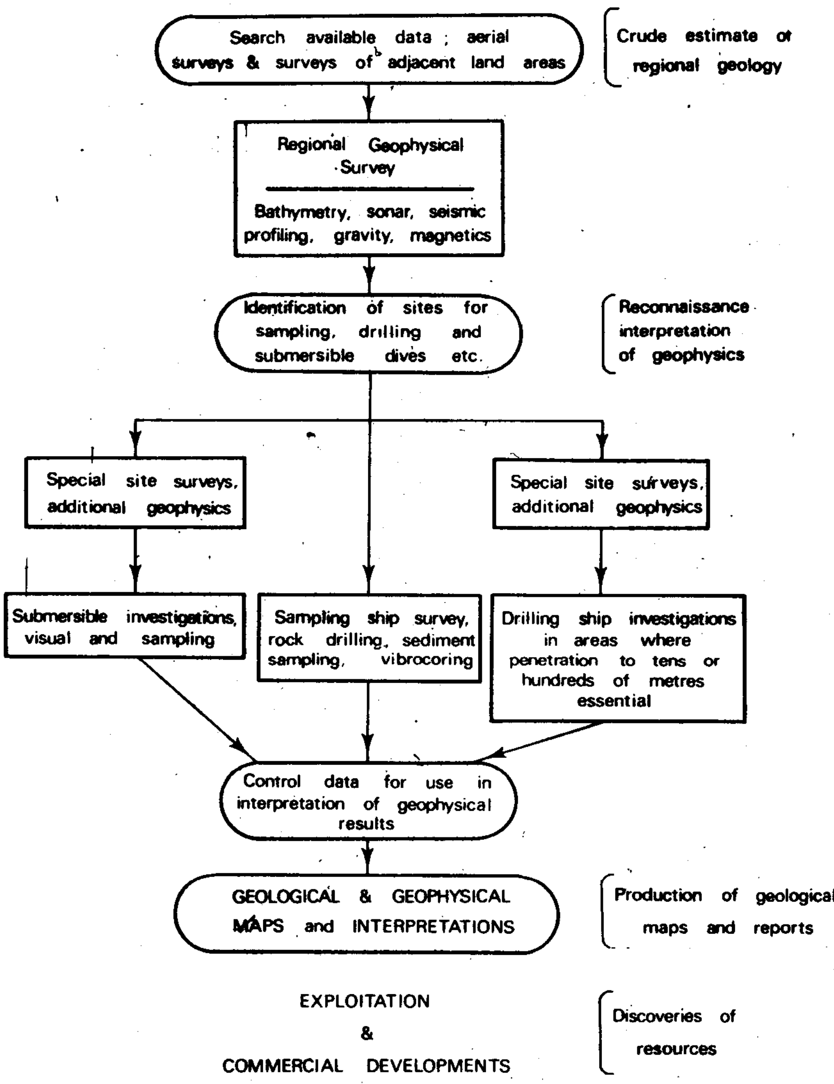

Figure 1/1 General scheme of offshore exploration operations.

(iv) Ship fitted for seabed sampling: £2000—£5000 per day.
(v) Ship fitted with dynamic positioning and drilling capacity to, say, 200—500m beneath sea bed: £10,000—£15,000 per day.
(vi) Semi-submersible drilling platform: £20,000—£30,000 per day.

The above figures are *very* general and can be considerably affected by a wide range of factors such as time of year and expected local weather conditions, depths of seas to be worked in, proximity to land and good service ports, factors concerned with conditions of contract, length of contract involved, required accuracies in position-fixing and other measurements to be made, and many others. Nevertheless it can be seen that when one considers daily costs, the offshore operation commences at a few hundred pounds per day and this can rise up to 100 times that cost. It is because of the high costs involved that planning is so important and that once a problem has been defined, the correct methods are chosen and properly applied.

Twenty years ago, in a book such as this, there would have been little to write about and few to write for. Now, the most difficult task facing the authors has been that of dealing adequately with their selected theme without indulging in too specialised a treatment of specific topics.

As a starting point, a chapter on position-fixing is included because a knowledge of positioning methods and their limitations is essential to an understanding of how the offshore survey is conducted.

Acoustic methods are of paramount importance; these are used to a limited extent in position-fixing and they are fundamental to studies of seabed topography using echo sounders and scanned sonar, in seismic reflection profiling of shallow sub-bottom layers, and in investigations of deep structure using digital seismic reflection as well as seismic refraction techniques.

The potential field methods—gravity and magnetics—play an important but less essential role. These methods are often used in reconnaissance surveys being less expensive than seismic work. More important is their role as an adjunct to seismic exploration. In this connection, gravity interpretation can solve problems of deep structure such as the tracing of major fault patterns and how basement structure controls the formation of structural elements at higher levels. Magnetic data can be used in detailed mapping of igneous and other magnetised formations, but again a more important role lies, perhaps, in the provision of regional information on the relationship between deep crustal structure and the genesis, history and structural form of sedimentary basins, the uppermost parts of which can be mapped in detail by the seismic methods. Over the past few years, the value of gravity and magnetic data has begun to assume an increasing importance in the regional interpretation of hydrocarbon provinces. Whereas, in early reconnaissance exploration of the North Sea, gravity surveys were not made by exploration companies whilst conducting seismic surveys, now, many speculative surveys being made around Britain are conducted to provide a package of data which includes seismic, gravity and magnetic results.

Geophysics, through various processes of interpretation, provides the geologist with a three-dimensional structural picture of the distribution of rocks and sediments at and beneath the seabed. To complete this picture he needs only to sample these rocks and sediments, study their composition, the fossils they contain, determine their age and chemistry, and ultimately make a stratigraphic identification (or estimate) and classify the samples as a particular type of rock or sediment. The geophysicist's structural interpretation is both incomplete and ambiguous until such geological control data can be incorporated into it. Unfortunately Man is not well equipped for field work on the seabed and the business of obtaining the desired samples is not simple. The scuba-diving field geologist is able to provide only a very limited contribution to the offshore exploration task. His endurance at the seabed is too short, his work is limited to shallow depths, and his mobility between sites is severely restricted. In many situations which are conducive to direct study, the diver still needs the fairly expensive backup of ship, support divers, and position-fixing equipment. His more mobile colleague, the geologist in the manned submersible, has at his disposal a technology which allows him to make a much more effective contribution to geological exploration, and much valuable work, including the collection of important rock samples, has been accomplished by geologists using small submarines. However, such an approach is costly, and routine sampling surveys over large areas of the seabed using such a method would be inordinately expensive. For this reason a wide range of tools has been developed which can be operated from an anchored or dynamically-positioned ship. The requirement is not simple and includes such tasks as that of removing a patch of seabed sediments a few centimetres thick from place of extraction to a sedimentology laboratory on land without excessive disturbance of the structure of this thin layer of unconsolidated material. Other tasks include that of obtaining sediment cores of a few metres length, of coring into bedrock, and in some circumstances that of coring through tens, or even hundreds, of metres of sediments and rocks. It is important that many of the sampling procedures should be linked to visual observations and a number of techniques have been developed for this purpose. Just as important is the need for close integration of all sampling and drilling work with previous geophysical surveys, through the selection of sampling and drilling sites on the basis of a preliminary geophysical interpretation, and the maintenance of adequate positioning accuracy during all phases of the exploration programme.

Advances in offshore exploration technology have been so rapid in recent years that this book can do no more than describe the state-of-the-art at the time of writing. In our final chapter, however, we look at some presently discernible trends towards development of new techniques viewed against our opinion of future demands for offshore geological data. In addition, some methods not described in the main text are briefly referred to such as the applications of radioactivity and geochemical exploration techniques; techniques which have so far had only limited application at sea when compared with their very wide application on shore.

Some topics have been omitted because in our view they are not sufficiently relevant to our principal theme of geological exploration; such topics include the techniques which have been developed for geophysical logging tests in boreholes, and the major technology of deep exploration and production drilling from large rigs and platforms. These subjects are briefly described in a companion volume: *Geology of the North-West European Continental Shelf, Volume 2*, by Pegrum, Rees and Naylor, within the more relevant context of exploration drilling for oil in previously identified prospective traps, and the use of geophysical logs to determine reservoir characteristics.