PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

The History and Future of North Sea Oil and Gas: An Environmental Perspective [and Discussion]

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The history and future of North Sea oil and gas: an environmental perspective

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The history of the development of the hydrocarbon resources of the North Sea is reviewed in an environmental context. The development of impact assessment techniques and practices and the evolution of monitoring of the physical, chemical and biological environment offshore and onshore, with reference to platforms, subsea pipelines, pipeline landfalls and terminal construction and operation is discussed. A brief account of the development of environmental protection management practices and their application to the design, construction, operation and management of major production projects follows. The paper concludes with a look at the environmental conditions likely to be established as the industry moves into the northern North Sea and areas such as the West Shetland Basin, and their significance for the petroleum industry.

Introduction

The organizers of this discussion meeting asked me for a background on oil and gas in the North Sea Basin, with particular emphasis on the environmental aspects of the development of this new hydrocarbon province. Because the first offshore gas discovery was made more than 20 years ago in 1965, followed by the first commercial oil discovery in 1969, it occurred to me that many younger scientists might well be unaware of the historical background to the oil industry as we know it today. I decided to present a highly selective annotated chronology of the main scientific, legal and technological events of this development. The first part of the paper constitutes this historical summary. The second and third sections discuss the potential impact and future developments of North Sea oil and gas development respectively.

Historical summary

1815 William Smith published the fifteen sheets of his 'Geological Map of England and Wales with part of Scotland'; the map series was based on observations made while working as a surveyor (and later as an engineer) on the construction of the English canals. As a consequence of this pioneering work, Smith is generally regarded as the father of English geology.

At about the same time, two French zoologists, Cuvier and Brongniart, published the first French geological map of the distribution and structural relations of the major rock units of the Paris Basin and north central France.

Up to the late 1920s knowledge of the geology of Europe was based mainly upon surface mapping supplemented by sub-surface information from mining, tunnelling and water-well drilling.

From the 1930s this was supplemented by data from exploratory drilling for oil.

In the early 1930s serious oil exploration in northern Europe started in Austria, Germany, The Netherlands and the United Kingdom, and by 1939 small oilfields had been discovered in all of these countries.

1939 D'Arcy Exploration Company (as the exploration arm of British Petroleum was then known) discovered oil at Eakring in England and this was followed by the discovery and commercial development of a whole series of small fields mainly in the east Midlands in England, but also including one at Kimmeridge in Dorset, England.

1959 The discovery of a huge onshore gasfield at Groningen in The Netherlands by Shell was a major breakthrough. Gas at Groningen was in a Lower Permian sandstone capped by evaporites (including salt). From drilling in the east Midlands, eastern and northeast England the stratigraphic succession was known to be similar and the rocks at these horizons were probably laid down in the same depositional basin, part of which now lay under the southern North Sea between the two countries.

It followed that if there were structures large enough to warrant offshore development there was a good chance that reservoir sands and caprock conditions similar to those of The Netherlands would also exist beneath the seabed in the southern North Sea.

1962 On the basis of this hypothesis, a group of companies performed a reconnaissance seismic reflection survey.

1963 Following the above survey, these companies implemented an aeromagnetic survey of most of the area south of 58°N, together with some additional seismic reconnaissance. The results were encouraging and the technology was available to explore for, produce and develop oil or gas fields in the prevailing conditions (water depths, wind, waves etc.) in the southern North Sea.

Hiatus: drilling was not possible because bordering states had not yet agreed the ownership of the continental shelf outside their territorial waters and states could not grant title to offshore tracts. The Geneva Convention on the Law of the Sea resulted from the first UN Law of the Sea Conference in 1958, and it established the sovereign rights of states bordering the continental shelf as: 'the... seabed and the subsoil of the marine area adjacent to the coast to a depth of 200 metres or beyond that limit to where the depth of the superjacent waters admits the exploitation of the natural resources.'

1964 Her Majesty's Government passed the Continental Shelf Act in April 1964 and ratified the Geneva Convention in the following month. The sub-division of the North Sea sector of the European Continental shelf was then settled between the riparian states either on the basis of median lines or by mutual agreement.

1965 Drilling started and that year British Petroleum discovered the first commercial hydrocarbons in its 48/6 well, the discovery well of the West Sole gasfield. In the next three or four years the southern North Sea was extensively explored and some dozen gas fields discovered. Success came early in the exploration of this basin, but it is important to note that the industry drilled over one hundred dry holes (absence of reservoir sands was the main reason for failure). Results suggested that the southern basin was predominantly a gas province and in the search for oil the focus shifted northwards to a thicker accumulation of sediments in a deep basin lying in much deeper water between Scotland and Norway. Drilling in this basin started in Norwegian waters.

1969 In November of this year Phillips made the first commercial oil discovery, the Ekofisk field, in the Norwegian sector.

1970 British Petroleum made the first commercial oil discovery in the British sector with its 21/10-1 well, the Forties Field discovery well. (This was not the first oil discovery; that honour belongs to Amoco's Montrose discovery.)

1971 In July, Shell discovered the Brent oil field in the East Shetland Basin.

1977 In July, British Petroleum made a significant discovery at Clair in very deep water in the West Shetland Basin.

The southern North Sea gasfields were in relatively shallow water and as previously noted the technology for their development was already available. When the industry moved northwards in the North Sea, conditions were vastly different and the main challenge lay in the combination of environmental factors which included such things as: deep water; extreme wind and wave conditions; air and water temperature; bottom sediment character; long distance from shore. Oil development had not previously been attempted in this combination of extreme marine environmental conditions. After the fact, some idea of the magnitude of the engineering design problems faced can be shown from a comparison of just two major features of the West Sole and Forties platforms:

	West Sole	Forties Charlie
deck load	2 kt	12 kt
support jacket	*ca.* 0.6 kt	*ca.* 16 kt

Another critical factor was the design of foundations because soil mechanics data were sparse. But solutions were found and there are now steel jackets, concrete gravity platforms, tethered semi-submersibles (Buchan), tension leg platforms (Hutton), Shell's underwater manifold systems (North Cormorant), sub-sea pipelines; in short the whole panoply of oil and gas production systems in place and producing.

Therefore in 20 years the United Kingdom offshore oil and gas industry has developed from nothing in 1964 to an annual average North Sea oil production rate of *ca.* 2.5 million barrels† of oil per day and over 10^8 m^3 of gas per day. (There were major developments in the Norwegian, Dutch and Danish sectors during this period and these effectively parallel events in the United Kingdom sector, but time and space preclude a detailed account here.)

How much of this oil produced has gone astray?

The following figures are taken from the United Kingdom Department of Energy 'Brown Book' (1985). From 1979 to 1984 inclusive, the total stabilized crude oil production was 574.3 Mt. There were 335 spills, resulting in 1.782 kt of spilled oil. These figures include one spill of 980t and five spills averaging 55 t each, and if these isolated (and relatively minor) events are excluded the average size of oil spill over the most recent six year period for which figures are available is in the range of 1–3 t. This input is not significant. However, in addition there were long-term, low-level (chronic) hydrocarbon inputs from, for example, the discharge of drill cuttings and oil-based drilling muds. The impact and significance of these are discussed by other speakers in this meeting.

† 1 barrel ≈ 0.159 m^3.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Potential impacts

The potential impacts are many and varied and the discovery of oil and gas in the North Sea basin exposed the paucity of our knowledge of the physical and biological characteristics of the seabed and the superincumbent waters. Added to this, oil is where one finds it which severely limits the options for locating production, transport, storage and export facilities. The design of the best possible system must seek to ensure the safety and integrity of all components, minimize the environmental impact, and resolve potential conflicts with other users and to this end, the requirements of good engineering practice and protection of the environment are to a large extent synonymous.

Sea and sea-bed

Existing uses include fisheries, shipping, gravel extraction and recreation. Possible conflicts include:

(a) location of platforms and other production installations;

(b) location of sub-sea pipelines;

(c) interruption to seabird migration by flares on platforms and major pollution incidents such as a well blow-out during the annual auk (Alcidae) migration across the North Sea;

(d) pollution as a result of an accident to a platform, pipeline or other production installation.

Coastline

Existing applications include residential use, recreation (e.g. beaches, marinas and golf-courses) commerce, nature reserves and sites of special scientific interest, defence and agriculture. Possible conflicts include:

(a) sensitive shorelines such as important coastal habitats, pipeline landfalls, impact of helicopter overflights on seabird colonies;

(b) amenities, for example Forties pipeline landfall at south end of Cruden Bay golf course;

(c) disruption of traditional activities in harbours and pre-empting berthing space;

(d) pollution from pipeline failure, offshore blow-out, or terminals which can be accidental or chronic (including both liquid effluent and emissions to the atmosphere).

Environmental management

It was apparent from the outset that the extreme conditions existing in the northern North Sea would necessitate particular attention to the environmental aspects of the development at all stages of the operation. Nobody had developed oilfields or laid large diameter pipelines in such water depths and at such distances from shore, and reliable baseline data on the physical and biological environment was in short supply. In consequence a lot of work had to be done to get information on such factors as wind speed, wave heights (for example the '100 year' wave), amplitudes, velocities and frequency, bottom-sediment conditions (for platform foundations and pipe-laying), bottom currents, rates of biological colonization of structures (for platform design and maintenance to obviate potential fouling problems), the impact of platform emplacement and operation on the benthic fauna, and the wind and current systems which would determine the movement of oil (essential for oil-spill trajectory modelling), to name but a few.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

In my Company, the techniques of environmental impact analysis (EIA) were formulated and applied to the development of the Forties field, starting at the design stage of the project, and the importance of environmental baselines, not only for the offshore part of the development (platforms and submarine pipelines), but also for the onshore elements (e.g. pipeline landfall, overland pipelines and storage and export terminals), was recognized from the outset.

The EIA was supported by a comprehensive physical, chemical and biological monitoring programme during construction, commissioning and operation, aimed at determining the nature and extent of change consequent upon the development. From an initial 'in house' requirement this philosophy was extended to major multi-participant projects in which British Petroleum was involved (e.g. Sullom Voe terminal in Shetland).

Over time, monitoring techniques have evolved, and this is particularly so in the case of biological monitoring, where there have been major scientific advances related to the development of 'effects monitoring'. This involves the detection of changes in an organisms's response to petroleum hydrocarbons at the molecular or cellular level, and the results are of great scientific interest as they are providing an insight into the defensive physiology of marine invertebrates in response to environmental perturbations (both natural and man-made). This is a reversal of the usual relation between basic and applied science, and in this case research originally commissioned for applied industrial purposes has opened up a wider field of basic interest to science.

Having done the impact assessment and the monitoring programme, there is an essential third element in the process, namely to assess performance against prediction as objectively as possible. This can be achieved by an audit–review of the project when it has been in operation for some time, and the procedures of impact assessment, monitoring and audit–review are the essential components of environmental protection management. These procedures, well conducted, will ensure that the environmental impact of industrial activities is comprehensively assessed and appropriate technical and operational procedures adopted to minimize the adverse impact. This approach places the emphasis on good management techniques, together with sound science, and is an integral part of the management of many of British Petroleum's industrial activities world-wide. I speak only for my own company regarding such an approach to integrating environmental conservation and management, and other companies or consortia will have their own approaches. The orderly development of the North Sea oil and gas province to date, with minimal adverse consequences for the marine environment, could not have been achieved unless these or similar practices were the norm throughout the offshore oil and gas industry.

What next?

Forecasting, a risky process at the best of times, is even more fraught with difficulty given the present state of the crude-oil market.

If exploration picks up again the following considerations will be relevant:

as of 1985 the total proven and probable reserves in the United Kingdom sector of the North Sea were 15×10^9 barrels (2×10^9 t);

by the end of 1984 a total of 5.2×10^9 barrels had been produced;

in the development of the North Sea offshore oil province the big discoveries came early in the search, followed by a progressive reduction in average size with time;

it has recently been estimated by the United Kingdom Offshore Operators Association

(UKOOA) that about 80 new fields could be developed by the year 2000 and in British Petroleum's opinion, apart from finds in the as yet largely unexplored, recently licensed areas, the next generation of fields is likely to average 100 million barrels or less;

the 'frontier areas' west of Shetland and Scotland extending into the Atlantic towards Rockall, recently licensed, are aptly named (further offshore, in very deep and stormy waters) and largely unexplored;

reservoirs within the North Sea basin proper will be smaller and more complex, including gas condensates where a high proportion of hydrocarbon liquids must be separated from the gas before each is piped ashore;

exploration will extend further north, and this trend is already evident in the Norwegian sector;

solutions to the problems may include putting more of the production facilities on the seabed, more remote control and less manual intervention (e.g. remote controlled, unmanned platforms being developed for British Petroleum's new southern North Sea gasfields).

Should the UKOOA estimates prove correct, development of the 80 new fields referred to above would require a capital investment programme well in excess of the total sum expended on all the development to date. At the time of writing (February 1986), given the economic circumstances attendant upon the fall in oil prices, it is a moot point when this development will take place.

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Discussion

R. B. Clark (*Department of Zoology, University of Newcastle upon Tyne, U.K.*). What will be done with redundant platforms after exhaustion of an oilfield?

F. G. Larminie. The short answer is nobody knows. SERC funded a study by the Institute of Offshore Engineering at Heriot Watt University, U.K. on alternative uses of offshore installations, and the question is currently the subject of active debate between the oil industry, the fishing industry and the U.K. Department of Energy. In the southern North Sea the smaller, lighter, gas production platforms in relatively shallow water can be removed and British Petroleum has already removed a redundant platform from its West Sole gasfield.

J. K. Rudd (*Amoco Europe and West Africa, Inc., Tottenham Court Road, London, U.K.*). With his extensive experience of monitoring around platforms, and with the benefit of hindsight, what would the speaker do now?

F. G. Larminie. Much as before, but in the established production areas there is now a body of knowledge which would reduce the need for baselines, and it is my opinion that a combination of bottom sediment studies, biological effects monitoring of selected benthic

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

organisms and chemical analysis of the superincumbent waters would provide an effective framework for a monitoring programme. Outside the established areas, for example west of Scotland and north of 62° N, more baseline work will be required and here too the monitoring programme will be tailored to address the specific site-related impact of the installation.

M. L. Tasker (*Nature Conservancy Council*, 17 *Rubislaw Terrace*, *Aberdeen*, *U.K.*). With the move of the oil and gas industry into deeper water, new techniques of oil production will be used. Some of these involve remote controlled systems based on the seabed. Is it possible to foresee any new dangers to the environment arising from such systems?

F. G. Larminie. The most obvious possibility is 'out of sight, out of mind', but I tend to think that the performance and integrity of remote-controlled systems is likely to be even better than that of manned installations. They will be scrutinized by remote imaging systems and will probably be far more regularly and closely monitored than is the case with the sub-sea part of existing installations. The effect of an oil spillage would be much the same as that from a seabed blow-out at a conventional drilling–production system, and existing proven practices would be used to kill a wild well.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES