THE DEVELOPMENT OF NORTH SEA OIL AND GAS

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Abstract. The development of North Sea oil and gas was initially stimulated by the growing dependence of Western Europe on increasingly-expensive oil imports. Following a major gas discovery in 1959, several more gas fields were located in the southern North Sea, but as exploration has moved north, oil has become the more important element in new discoveries. While the UK has been anxious to develop its offshore resources as quickly as possible, Norway has favoured a slower rate of development. The onshore impact of offshore development varies as one moves from the exploration to the development and extraction stages. While traditional industrial centres have benefitted from offshore development, so also have many peripheral coastal areas, although not without experiencing many social and physical planning problems. In the longrun, the main effects of offshore development are derived from the additional wealth made available by oil/gas exports, reduced oil/gas imports, and the use of oil/gas as an industrial raw material.

INTRODUCTION

The rapid development of the oil and gas resources of the North Sea in recent years can be fully appreciated only when viewed in the light of some fundamental changes which have been taking place in the economic structure of Western Europe in the postwar period – changes which have had growing political connotations. The most important change in question has been the rapid replacement of solid fuels, especially coal, by oil as the prime motive force in the energy-intensive economies of Western Europe. Whereas before World War II, 90% of West Europe's energy was derived from coal, by 1972 this proportion had dropped to 26%. The main reason for this changeover was, of course, the relative cheapness of oil compared to coal.

A crucial geographical aspect of this changeover was that Western Europe became increasingly dependent on imports from abroad to supply its energy requirements, since indigenous known reserves of oil were negligible. By far the leading source of oil imports into Western Europe was the Middle East, and the first indications of the strategic vulnerability inherent in such a degree of dependence on a single energy source became apparent with the Suez crisis in 1956. This was rendered even more apparent by the Arab-Israeli conflict of 1967, and was driven home with jarring effect by the 1973 oil embargo.

The need for Western Europe to develop its own indigenous oil resources therefore achieved increasing urgency through the 1950s and 1960s, and this provided a powerful political stimulus to the development of the North Sea's hydrocarbon resources. However, it is unlikely that the American-dominated oil industry would have been unduly moved by these political motivations were it not for the addition of further stimuli of an economic nature. Among these were: the easy terms under which the earliest North Sea exploration licences were issued; the formation in 1960 of the Organisation of Petroleum Exporting Countries (OPEC), which provided an incentive to find oil in non-OPEC areas; the quadrupling of oil prices in 1973, which was a direct consequence of OPEC's formation, made the task of tackling the North Sea's difficult environment more worthwhile than ever; and above all the growing realisation that the North Sea did possess vast oil and gas resources.

The following account of the development of the North Sea's oil and gas resources is divided into two parts. In the first part the pattern of offshore development is reviewed and in the second part the onshore impact of this offshore development is discussed.

THE PATTERN OF OFFSHORE DEVELOPMENT

The geological setting

Before outlining the chronology of North Sea exploration and development, it is necessary to look briefly at the geological setting in which this activity has taken place. The North Sea is the submerged portion of a major sedimentary basin extending from Poland through north Germany, Denmark and the Netherlands into eastern England. It is bounded to the north-west by the Caledonian folding, extending from north-west Ireland through Scotland and into Norway; on the north-east by the ancient Baltic Shield; to the east by the Russian Platform; and to the south and south-west by the Variscan foldings of Hercynian age. Into this basin sediment was carried by rivers emanating from the surrounding uplands, and depending upon environmental conditions, this sediment has been compacted into distinctive rock strata over the years. While the stratigraphic succession is not uniform throughout the basin, nevertheless it is possible to suggest a generalised picture (Fig. 1).

With the gradual uplift of the southern portion of the basin, the deposition of sediment became increasingly confined to the northern section, so that the thickest sediment accumulations occur under what is now the North Sea. The accumulation of sediments within the present North Sea has been further localised by a varied submarine physiography brought on by ongoing warping, faulting and folding. Thus within the North Sea, a number of local accumulations of sediments may be identified (Fig. 2). Since normally the prospects of finding hydrocarbon reservoirs is directly related to sedimentary thickness, it follows that the spatial pattern of exploration in the North Sea has been greatly influenced by this pattern of localisation.

The chronology of development

The failure to investigate such a likely geological environment until relatively recently was due mainly to the common estimation that the prospects were not worth the extra costs involved in offshore drilling. Up to the 1960s, it should be remembered, offshore oil technology was primitive compared

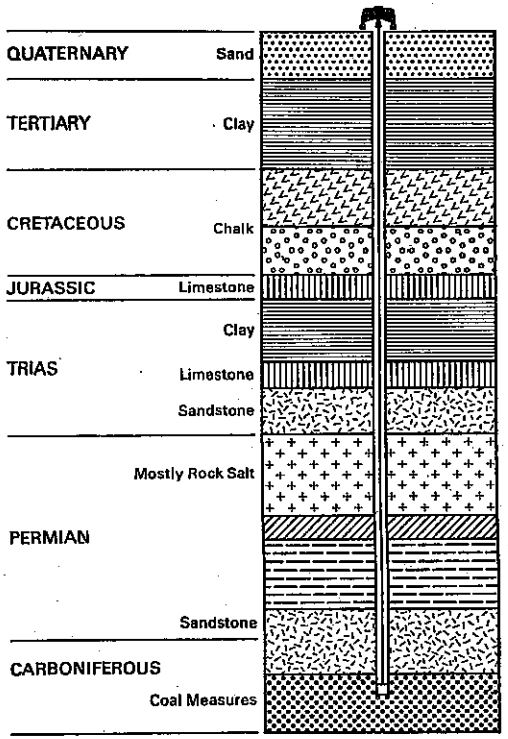

Figure 1. The North Sea: typical stratigraphic sequence (Source: R. Bunyan (1973), *Ireland and natural gas,* United Dominions Trust, Dublin, Fig. 1)

with the levels which have already been achieved today. The shallowest part of the North Sea – the southern part – is surrounded by land displaying similar stratigraphic sequences, so it could be assumed that the intervening seabed was of the same nature. The absence of worthwhile oil and gas fields on the adjacent land acted as a strong disincentive against exploration in the more difficult marine areas.

This attitude was revolutionised by the discovery in 1959, at Slochteren, near Groningen in the Netherlands (Fig. 2), of a gas deposit which subsequently proved to be one of the largest in the world. This deposit was found at 1,000 m, well below the depths of the previous small onshore discoveries, and in a geological environment which had not been seriously investigated before. This gas is different from most hydrocarbons, in that it is of vegetable origin, derived from vegetation laid down in freshwater swamps of carboniferous age (350 M years ago). The gas subsequently migrated upwards into overlying sandstones of Permian age (250 M years ago). Further migration

was then halted by an overlying layer of impermeable rock salt (Fig. 1). This salt represents intense evaporation of shallow seawater in very warm conditions.

The Slochteren discovery led to a surge of interest in the hydrocarbon prospects of the southern part of the North Sea. However, a large-scale exploration effort required the preparation of appropriate administrative legislation by the various governments whose territories are adjacent to the North Sea. Such legislation had to incorporate three main components:

(1) Jurisdiction over the resources of the North Sea had to be divided between the littoral states. Fortunately, a framework for doing this already existed in the form of the UN Convention on the Continental Shelf, dating from 1958, and based on the Equidistance Principle. Between March 1965 and March 1966, agreement was reached between the UK, Norway, Netherlands and Denmark, but it was not until 1972 that agreement was finally reached between Germany, the Netherlands and Denmark (Fig. 2). This agreement gave Germany 50% more than it would have got under the Equidistance Principle.

(2) A spatial framework for issuing of exploration licences was required. No two of the littoral states have the same system (Fig. 2). Denmark licensed its entire offshore area to a conglomerate. Germany has licensed areas of various shapes and sizes. The Norwegian, British and Dutch systems have divided one-degree quadrangles into regular blocks, but the size and number of blocks varies in each instance: in the UK, each quadrangle is divided into thirty blocks of approximately 250 km^2 each; the Dutch quadrangles comprise eighteen blocks of 400 km^2 each; and Norway's quadrangles contain twelve blocks of 550 km^2 each.

(3) The terms under which exploration licences would be issued had to be drawn up. These cover such things as the cost of licences, the amount of work to be done and the government's cut from any commercial finds made. Generally speaking, it can be said that the initial licensing terms in all instances were very generous to the exploration companies, although things have been tightened up considerably since, especially in the British and Norwegian sectors, where the degree of success has been beyond all expectations.

The British were the quickest off the mark in exploring the southern part of the North Sea, and five large fields were discovered between 1964 and 1966 (Fig. 2). By 1972, 90% of British gas consumption was being supplied by indigenous natural gas. In the Netherlands, exploration was held up until 1968 by a protracted debate over licensing laws, but the success rate since then has been moderate. In Germany, exploration was also held up by the boundary dispute with Denmark and the Netherlands and an internal dispute over jurisdiction between federal and state governments, and no offshore breakthrough has been made yet. In Denmark, the exploration effort has been inhibited by internal stresses within the monopoly licensee and by the very fact that there is a monopoly, in that the competitive element which has accelerated exploration elsewhere has been absent. Discoveries so far have been very small.

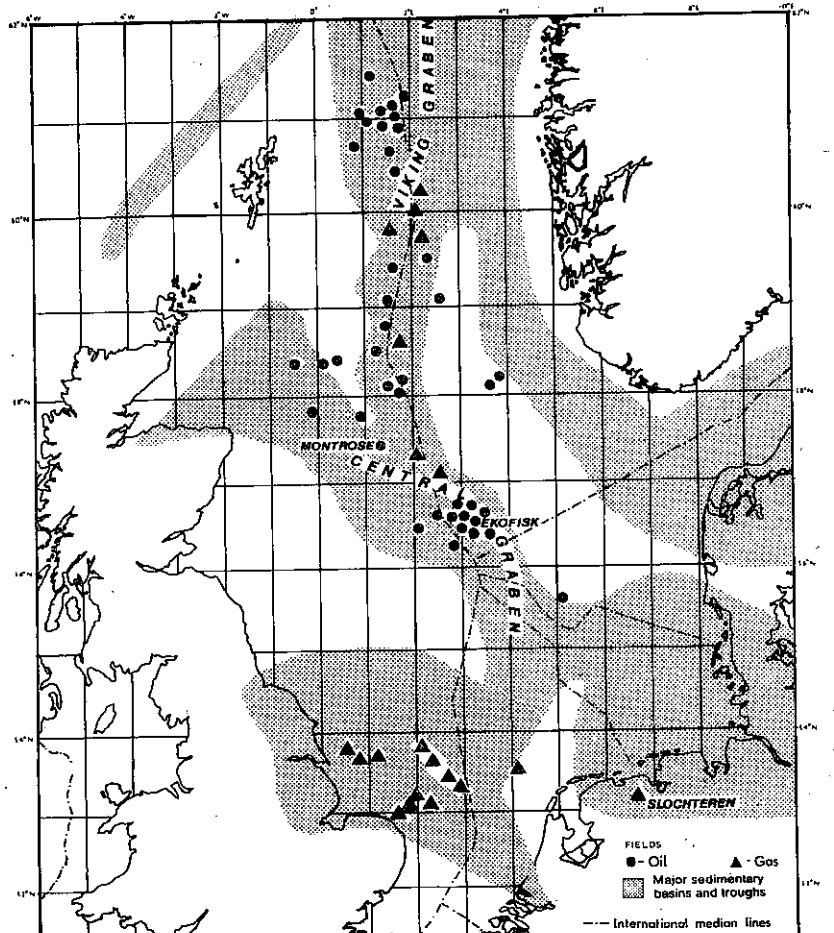

Figure 2. The North Sea: the offshore pattern.

The focus of attention in the North Sea was transferred northwards by two significant oil finds, one each in the British and Norwegian sectors, in 1969 (Montrose and Ekofisk, Fig. 2). The fact that these were discoveries of oil, and were found in completely different geological environments from the previous gas finds, introduced an entirely new dimension to North Sea exploration. In fact, although there are notable exceptions, most of the oil finds in the North Sea have been found in Jurassic and Cretaceous rocks, and are associated with the inundation of the North Sea by the Atlantic from the northern end some 150 M years ago, creating a marine environment suitable for oil formation. This, plus the particular thickness of the sediments in the central part of the North Sea, has produced the conditions leading to massive oil and gas discoveries.

The pattern of exploration and development in the northern part of the North Sea after 1969 has been shaped by the contrasting economic circumstances prevailing in Norway and the UK. The UK is a major energy user, requiring something of the order of 100 M tonnes of oil per year. The UK has also been in economic decline for quite some time, and the heavy oil bill, much aggravated after 1973, was a major element in its chronic balance of payments problems. Thus, the British Government could not get oil ashore fast enough from its offshore area. In addition, the strict price control applicable to natural gas encouraged the oil companies to switch over to exploration for oil in the northern part of the North Sea, as the same controls did not apply to oil.

As a result of all this, the exploration effort in the British sector has been intense, and amazingly successful. As exploration moved gradually northwards from the Central Graben to the Viking Graben (Fig. 2), so has the scale of finds increased. By the beginning of 1977, seven fields were in production with several more undergoing development, so that it is anticipated that by 1980, the UK will be self-sufficient in oil and among the world's top ten producers.

This massive effort has involved correspondingly massive costs: by the end of 1976, £5000 M had been invested in North Sea oil, and another £5000 M will have been added by 1980. In 1976, oil-related investments alone represented 25% of all industrial investment in the UK.

The Norwegian economy, on the other hand, is relatively small, while its tremendous hydroelectric potential reduces still further its oil requirements, which are less than 10 M tonnes per annum. The Ekofisk field alone produces well in excess of this. Therefore, there has been no pressure on Norway to hurry up the exploration programme, especially since already it has one of the highest standards of living and one of the lowest rates of unemployment in the world. However, it has been forced by simple geography to move faster than it would otherwise have liked. The problem is that the median line between the British and Norwegian sectors bisects almost perfectly the highly productive Viking Graben (Fig. 2), and with finds being made very close to the median in the British sector, the Norwegians have had to explore their own side in case any finds made in the British sector might extend across the median line. As a direct result, the Statfjord field – the largest found so far

in the North Sea, and which in fact straddles the boundary – was discovered in 1974. The large Frigg gas field was found in similar circumstances. Thus, although the Norwegian government had set an eventual limit of 90 M tonnes per annum of oil and oil equivalents on production from its sector, this limit will necessarily be exceeded when Statfjord reaches full production in 1984. By this time Norway will be exporting 90% of its North Sea production.

It still remains to be seen just how great the North Sea's oil and gas resources will prove to be, and this is a highly controversial question. Oil companies traditionally tend to be very conservative in estimating the size of existing discoveries, not to mention possible future discoveries. Nevertheless, there has been a constant escalation of estimates of both known and ultimate reserves ever since hydrocarbons were first discovered in the North Sea, as finds have consistently outstripped expectations. Already, known reserves are of the order of 6,000 M tonnes, which is one thousand times Ireland's annual requirements, with well under one-third of the exploration work yet completed.

A constant and prominent critic of both company and government estimates has been Professor Peter Odell, a geographer at Erasmus University in Rotterdam. He has developed a celebrated model of future North Sea oil developments which predicts total ultimate reserves of 11-19,000 M tonnes of oil, between two and four times existing known reserves. Assuming that both Britain and Norway explore and develop with maximum alacrity, he forecasts that North Sea production will peak at around 750 M tonnes per annum around 1990 (Fig. 3). Such a level of production would equal 7½ times Britain's current needs, and would be much greater than Western Europe's requirements at the time. (As North Sea oil is mostly light oil, imports of heavy oil into Western Europe will continue to be necessary. Hence, North Sea oil will be able to satisfy only 75% of Western European requirements, which is the target figure used in Fig. 3). Odell therefore recommends a less rapid rate of development than represented by the model, so that Western Europe could remain self-sufficient in oil until well into the next century, by which time he anticipates that oil will be substitutable by competitive alternative sources of energy. Odell's constant preoccupation is Western Europe's vulnerable dependence on outside sources of energy supply, and he has consistently called for supervision of North Sea development at the Western European level, rather than at the national level. However, EEC experience suggests that genuine political commitment at the supranational level in Western Europe is still quite some distance away.

THE ONSHORE IMPACT

Introduction

The onshore impact of the offshore oil and gas industry may be seen as beginning in modest fashion with the initial wildcat exploration phase, fol-

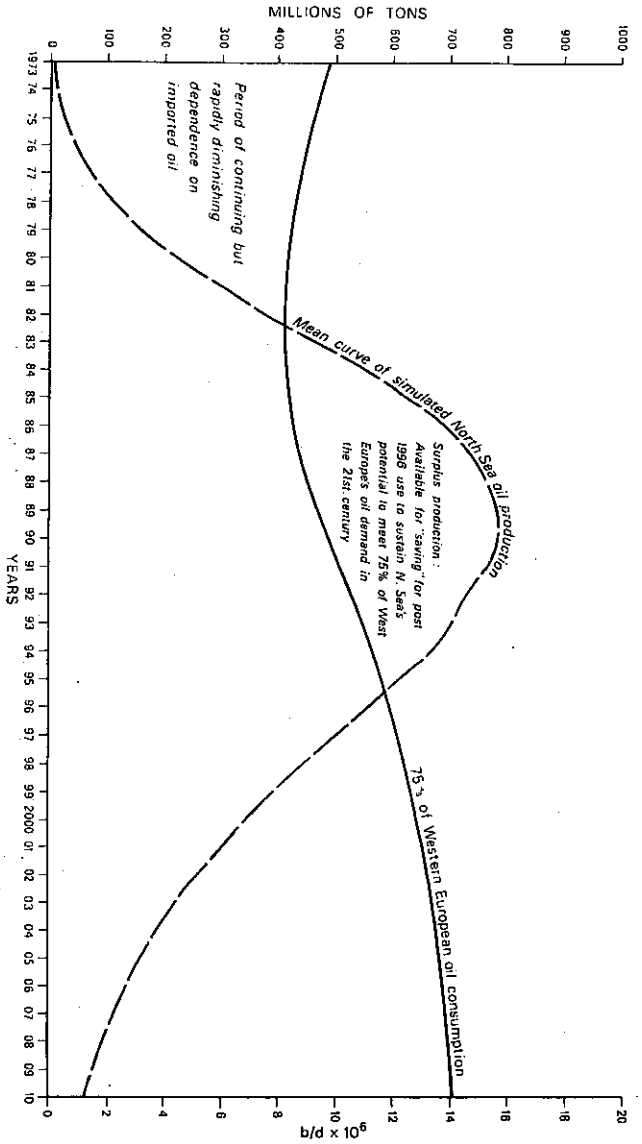

Figure 3. Odell's model of North Sea oil production (Source: P. R. Odell and K. E. Rosing (1974), *A simulation model of the development of the North Sea oil province 1969-2030,* Economisch-Geografisch Instituut, Erasmus Universiteit Rotterdam, mimeo)

lowed by a major spurt after the first discoveries, as renewed optimism leads to a more intensive exploration effort and better geological information produces greater accuracy. Thus, in the North Sea, the initial breakthrough in both the northern and southern sectors was followed by a spate of further finds. The development of these finds raises the level of expenditure, with consequent onshore spinoffs, to unprecedented dimensions. Even though the rate of new discoveries quickly begins to tail off, the extraction of oil and gas from existing fields maintains the level of onshore impact at a fairly steady level for 10-15 years, until the smallest and earliest fields become exhausted, and there is a gradual phasing-out of offshore activity over, perhaps, a further twenty years.

The three main phases of offshore activity – exploration, development and extraction – each has its own peculiar onshore impacts, and each will be considered in turn. It should be borne in mind, however, that over the North Sea in its entirety, all three phases overlap, so that extraction from some fields, development of other fields and exploration for new fields, are all taking place simultaneously.

Exploration

The two main onshore activities required in the exploration phase are the construction and servicing of drilling ships and rigs. Britain's participation in drill-rig construction has been virtually zero compared with the other North Sea countries (Fig. 4). Norway, in particular, has exploited its traditional expertise in shipbuilding and marine engineering in order to develop an international reputation in this sector of offshore activity, and now exports drilling rigs throughout the world.

Offshore servicing (that is, the supply of food, materials, specialist services etc. to drilling, and subsequently development and extraction operations) requires onshore bases which, at minimum, can provide all-weather access at all tide levels, and sufficient portside storage for materials and equipment. In the North Sea, the pattern has been for each principal area of activity (the UK gas sector in the south, and the UK and Norwegian oil sectors in the north) to develop a major service base which becomes the centre of operations for that area. Great Yarmouth, Aberdeen and Stavanger have emerged as the major bases for each of the three main areas (Fig. 4). These have become the regional headquarters for the exploration companies, have developed various industries manufacturing offshore supplies, and have become regional bases for specialist service companies (welding, diving, recreational facilities, etc.).

In addition a number of secondary or advance service bases has emerged (Fig. 4), whose location is primarily determined by proximity to current exploration activities. These bases act as stores for materials and equipment manufactured elsewhere, and their operations are generally co-ordinated from the major bases.

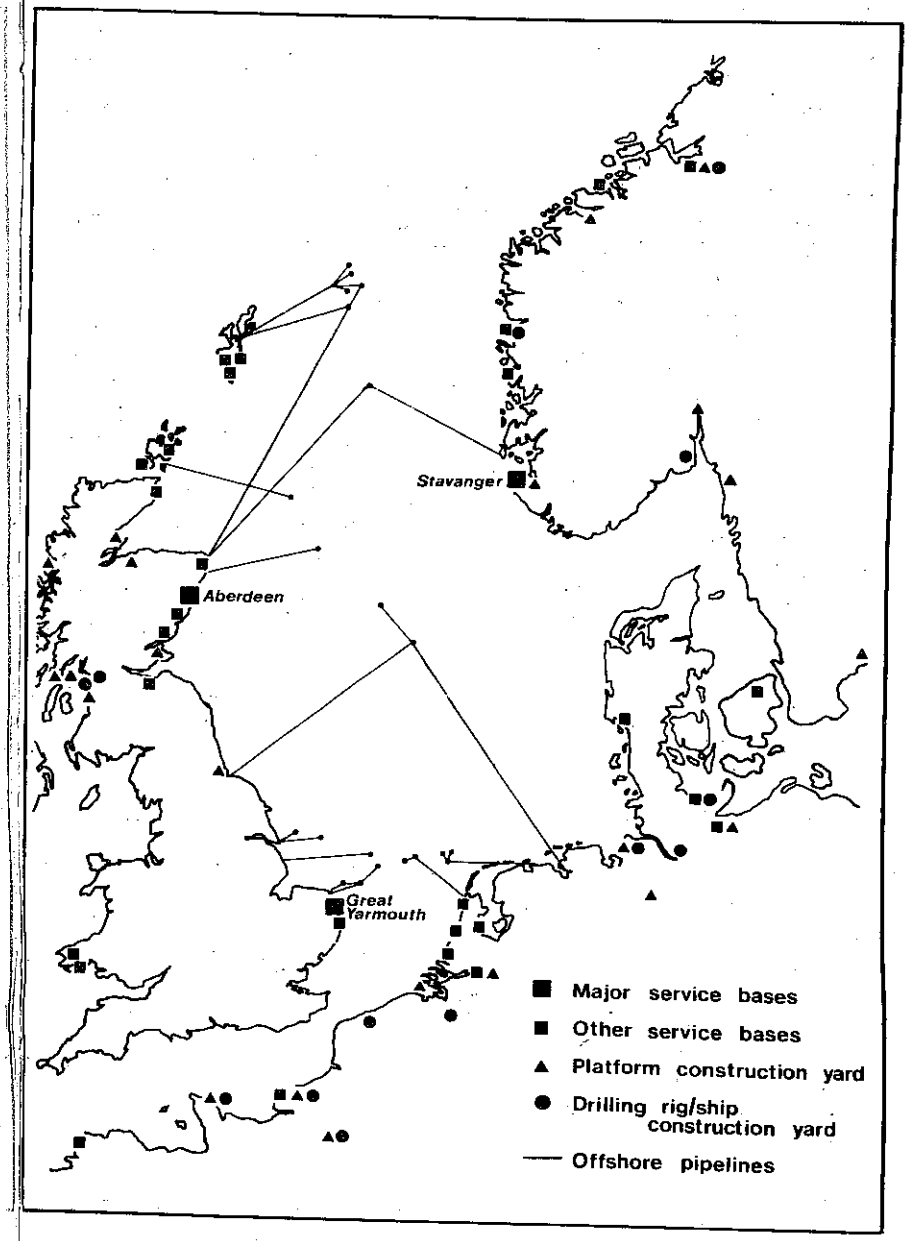

Figure 4. The North Sea: pipelines and onshore operations

Development

The decision to develop an oil or gas field implies expenditure of a totally different order of magnitude compared with exploration. While a typical exploration well in the North Sea costs about £2 M in 1978 prices, field development costs run into hundreds, and in some cases thousands, of millions of pounds. The major items of development expenditure are the production platforms, which can account for up to one-half of total costs. These massive structures, which normally have to stand firm in hundreds of metres of water, have very stringent requirements in terms of construction sites. Steel platforms require an extensive flat site adjacent to water in order to facilitate fabrication; concrete platforms do not require such an extensive waterside site, as they are more or less built in the water, but this very fact requires a combination of shelter and deep water immediately adjacent to land. Thus, whereas the coast of eastern Scotland has numerous sites suited to steel platform construction, appropriate sites for concrete platforms occur only in the fjords on the west coast, somewhat removed from the main centre of development activity in the North Sea (Fig. 4). The Norwegian coast combines numerous suitable sites with proximity to the offshore fields, and hence Norway was the pioneer of this type of platform construction (Fig. 4).

Once the platforms have been set in place on the seafloor above the oil/gas fields, they are equipped with various modules, each designed for a specific purpose (for example accommodation, storage, recreation and generators). These modules are normally manufactured in existing shipyards, and have been a valuable source of business during a recession period in the shipbuilding industry. Indeed, many of the depressed regions of the UK in particular, dependent on heavy engineering industries, have received a welcome boost from the development of North Sea oil and gas, involving not only platform and module construction but also the manufacture of pipes, barges, storage tanks, processing equipment and other requisites.

After platforms, pipelaying is the next major cost item in field development. Due to the very high cost of laying pipes on the seafloor, the normal strategy is to direct the pipeline to the nearest available landfall (Fig. 4), from where it can be continued by land to the consumption centres. However, in Norway, the presence of a deep seabed trough immediately adjacent to the coast meant that the oil from the earliest fields was piped to the UK. Technology is now being developed to overcome this problem in order to ensure that oil and gas from new fields will be landed in Norway.

Extraction

The development of oil and gas fields tends to be a spectacular exercise because of the heavy expenditures involved and the physical effects experienced by many isolated coastal localities. Nevertheless, even these effects are ultimately dwarfed by the economic impacts resulting from the extraction of oil and gas from the North Sea. Since estimates of total North Sea reserves vary greatly, it is accordingly difficult to quantify the value of these reserves, but

figures of about £200,000–300,000 M are currently in vogue. By comparison, Ireland's total GNP in 1977 was of the order of £5,000 M. These figures refer only to the value of the crude oil and gas coming ashore, and could be greatly enhanced, depending on the extent to which the oil and gas are further processed before consumption. In addition, the multiplier effects of the extra money circulating in the various national economies will add further to the economic benefits which the North Sea resources will generate.

The geographic consequences of this massive injection into the economies of the North Sea states is difficult to predict, apart from the direct effects associated with offshore development previously outlined. A large proportion of the extra wealth will accrue to the economy in general, and will simply reinforce existing spatial trends. A further large proportion will accrue directly to governments in the form of taxes, royalties and dividends, and will undoubtedly be utilised, at least in part, to implement regional planning policies.

In the UK, the most immediate effect of North Sea development has been to relieve balance of payments pressures arising in large part from oil imports which, in the absence of North Sea oil, would have amounted in 1978 to about £5,000 M. This, then, is the extent of the savings which will be achieved by the UK economy in 1980 when North Sea production will equal national requirements. The great bulk of this production will be used as a fuel, and hence there will be relatively little spin-off in the form of petrochemical industries. And since the UK has traditionally refined most of its oil imports, no great increase in oil-refining capacity is anticipated, although there have been some proposals to build refineries and petrochemical plants in the vicinity of pipeline landfalls.

In Norway, offshore developments have had the welcome effect of shifting the focus of new industrial investment away from the Oslo region to the west coast. In this case, major emphasis has been placed on the development of petrochemical industries, as Norway's oil requirements are small, and it is government policy to control the location of these industries in the interest of regional planning and settlement policy.

At the same time, Norway's offshore riches have brought many problems in their wake. The government has been forced to develop its oil at a much quicker pace than desired because many of the fields straddle the dividing line between Norway and the UK. This has generated great pressures within an economy which was already operating at full capacity, with virtually no unemployment. One result has been a movement of workers out of less well-paid sectors and less well-off regions into the oil sector. Thus, housewives and schoolgoers are being sucked into employment with attendant social side-effects. Pressure on employment has driven up wages and hence prices, so that many of the potential oil-generated benefits are being eroded by inflation. The government has decided to open up the region north of 62°N, hitherto the northern exploration limit, in an attempt to prevent further depopulation in the country's northern regions through migration to the oil

industry centres further south. Despite an original government intention to fully process all oil and gas resources in Norway, crude exports are now being allowed simply because the workers are not available to man the necessary processing facilities. Throughout all this, the government has steadfastly refused to allow immigration to provide the necessary work force, in view of the problems associated with immigrant labour in other European countries.

Regional and local planning aspects of North Sea oil and gas development

Some indications have already been given concerning the regional planning implications of the development of North Sea oil and gas resources. The main point here is that peripheral areas which previously had found it extremely difficult to attract any kind of industry have suddenly become the focus of massive industrial developments. For example, of the 16,000 jobs directly created in Scotland by offshore activities by 1974, over three-quarters were located outside central Scotland. However, these figures greatly underestimate the ultimate employment effect of the oil industry, as they do not take into account extra employment generated in existing industry by the new demands created. It is estimated that about 100,000 new jobs in all have been generated in the UK as a result of the North Sea discoveries, one-half located in Scotland. Estimates of similar magnitude have been produced by the Norwegian government.

However, most of this employment has been associated with the development phase of offshore fields, and as such is essentially of a short-term nature. The emphasis is now turning to the location of whatever additional processing facilities will be generated by North Sea resources. There has been a great demand from Scottish sources that these should be located there, while within Scotland, a further argument has developed as to whether they should be located in the underdeveloped Highlands region, or in the Clydeside region where unemployment among industrial workers is a major problem.

Finally mention should be made of the many local planning problems which have been associated with oil-related developments in peripheral areas. Many coastal districts of high scenic amenity have been threatened by oil-related developments. In those districts where such developments have taken place, severe inflationary pressures have invariably resulted, to the detriment of the indigenous population. For example, house prices have soared, while local businesses have found themselves losing workers to the high-wage oil industry activities. Local public services and infrastructure (roads, health services, telephones, etc.) have been subjected to intense pressure by the sudden upsurge in utilisation, and local authorities have been faced with the problem of providing additional capacity which may not be needed after a couple of years. Social problems have been created by the injection into remote areas of hundreds, and perhaps thousands, of mostly young male workers. In addition, local authorities have found it difficult to appraise development proposals for oil-related activities in the absence of any national plans or even guidelines for the control of such activities, although some such guidelines have eventually materialised. Most authorities have found themselves both understaffed and operating under laborious planning regulations which are frequently unsuited to the rapid-action nature of oil development.

Nevertheless, it will generally be agreed that the long-term overall economic benefits of offshore oil and gas greatly outweigh the temporary difficulties experienced by particular localities in making these benefits available. At the same time, there is much to be learned from the North Sea experience by other regions, such as Ireland, where offshore exploration is only now beginning in earnest. It is to be hoped that the Irish authorities will have cause to put into effect whatever lessons have been learned from their neighbours.

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