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Natural gas in the Netherlands: exploration and development in historic and future perspective

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Key words: exploration history, gas reserves

Abstract

The discovery in 1959 of the giant Groningen gas field with reserves of 2750 billion (10^9) cubic metres (bcm) triggered a strong revival of the hydrocarbon exploration in the Netherlands. Over the last decades, the country has proven to be a very prolific hydrocarbon province, particularly for natural gas. Supported by the favourable exploration climate, exploration efforts have been generally at a high and sustained level. Well over 250 gas accumulations have been discovered throughout the stratigraphic column in various plays. Field sizes range from medium (of the order of 50 bcm) down to very small (2 bcm or less). The total initial reserves in these fields are around 1150 bcm. A mature stage of exploration has now been reached in many areas. Within a few years virtually all production acreage and large parts of the exploration acreage in the Netherlands will have been covered with 3D seismic. The introduction of 3D seismic has led to an improvement of exploration drilling efficiency and to increased technical success rates. Moreover, the application of 3D seismic has indicated additional prospectivity undetected before. It provides a major opportunity, and challenge, for finding incremental reserves. On the development side, nearly all large and medium-size gas fields have, or shortly will, come on stream. However, the majority of the relatively large number of small and marginal fields is still undeveloped. The challenge here is to reduce economic limits by further expansion of the infrastructure and application of modern marginal-field development technology.

Introduction

The following overview of natural gas exploration and development in the Netherlands is presented from a historic and future perspective. The objective is to show important aspects and trends in exploration and production activities. The history of these activities in the Netherlands will be reviewed in order to illustrate how and under which conditions the present situation has emerged, and to look how it is likely to develop in the future.

The paper will not focus on individual fields but on groups of fields in terms of exploration efforts, the specific plays they are found in, and on their reserves, field sizes and stages of development.

Note that in this paper, all volumes of natural gas, i.e. hydrocarbons and associated non-combustible gases, are specified under standard conditions of 1.01325 bar and 15 °C (ISO 5024–1976(E)).

A detailed account of the exploration and production history up to 1987 for oil and gas in the Netherlands was presented by Knaap & Coenen (1987).

Exploration

Trigger

The first commercial gas discovery in the Netherlands was that of Coevorden in 1948 (Knaap & Coenen 1987). The most important event and trigger for natural gas exploration and development in the country, and even abroad in the United Kingdom and Germany, undoubtedly has been the discovery of the giant Groningen field. The discovery well Slochteren-1, drilled in 1959, demonstrated Permian Rotliegend sandstones to be gas-bearing. After a few other successful exploration wells, it became clear that a huge

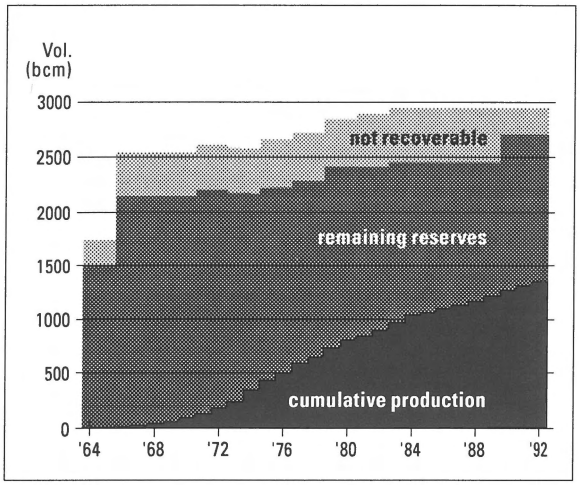

Fig. 1. The Groningen gas field, reserves and production.

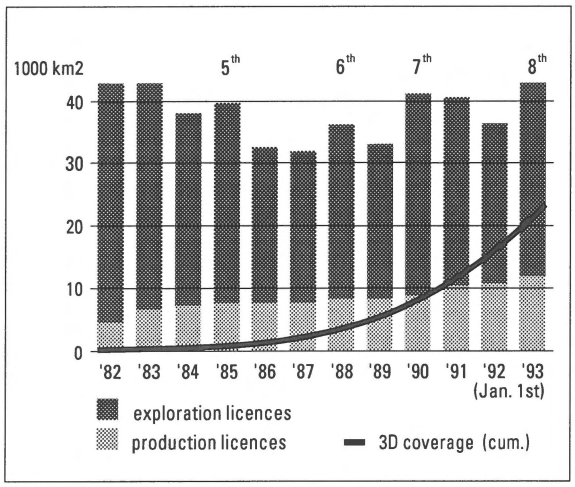

Fig. 2. Licence acreage and 3D seismic coverage offshore (January 1993). Note: 5th through 8th round awards indicated.

gas accumulation had been found in what was then named the Slochteren Formation. The accumulation has been charged from Carboniferous coal measures and is sealed by Zechstein evaporites (Van Wijhe et al. 1980).

The extent of the Groningen field was only recognized a few years after the discovery well. The appreciation of the volume of Gas Initially In Place (GIIP) and of the reserves has been growing over the years (Fig. 1). At present the GIIP estimate of the Groningen field stands at around 2870 billion (10^9) cubic metres (bcm), of which more than 90% is expected to be ultimately recoverable. The Groningen field therewith is the largest gas field in western Europe and ranks amongst the largest fields in the world.

Climate

The large Groningen field has proven to be a very good and flexible producer. These favourable properties have been the basis for the Dutch government's 'small fields policy' developed in the 1970s (Dessens, this volume). The goal of this policy was, and still is, to stimulate the exploration, development and production of small fields and to use the Groningen field as a balancing producer to match demand. The policy has been very successful over the last decades in that many smaller fields have been discovered and developed. Therefore, the production from the Groningen field has been lower than originally anticipated.

Other factors that have favourably contributed to the exploration climate in the Netherlands are stable, well-defined licensing conditions, guaranteed sales of gas to N.V. Nederlandse Gasunie (Dessens, this volume) and shallow water conditions in the offshore.

Efforts

Acreage

Many oil and gas operating companies have shown continuous interest in being active in the Netherlands. Large parts of the available acreage have been licensed over the last 25 years and the present licence map shows that interest has not ceased as yet (PGK 1993: fig. 6; this volume).

As an example we take the offshore, opened up for exploration in 1968 after the Continental Shelf Mining Law was established in 1965. Exploration acreage has been granted in eight rounds up till now. As from 1982, the licensed acreage has been maintained at a high level between 56 and 75% of the total acreage, with a steady growth in production acreage (Fig. 2).

Drilling rate

Exploration drilling has generally been at a high and sustained level as is shown in Figs 3 and 4. Oil price fluctuations appear to have had little effect.

Results

Success rates

Overall, technical success rates have been at a level of around 1 in 3, both onshore and offshore (Figs 3 and

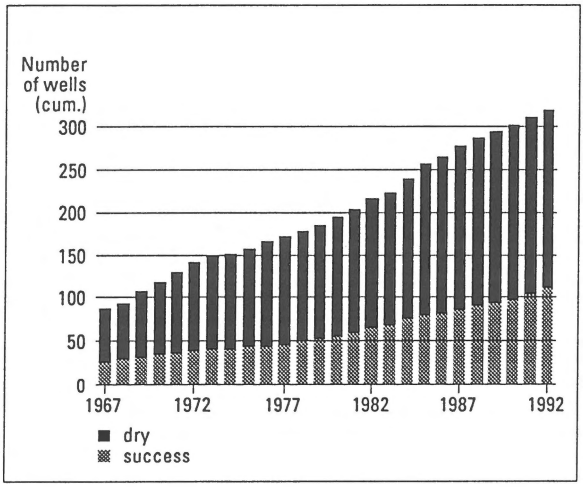

Fig. 3. Exploration drilling rate and success rate onshore.

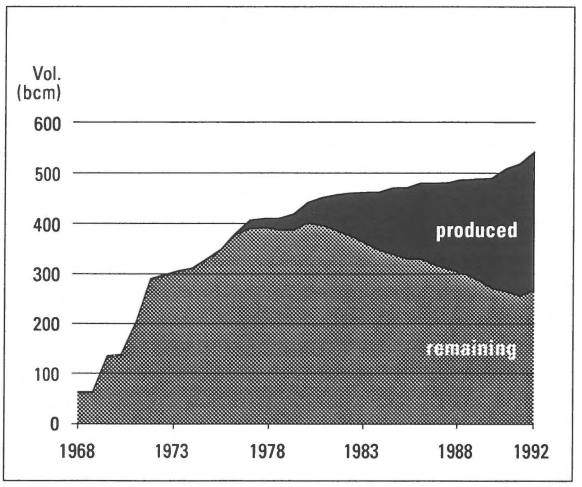

Fig. 5. Gas reserves and production onshore, excluding Groningen field.

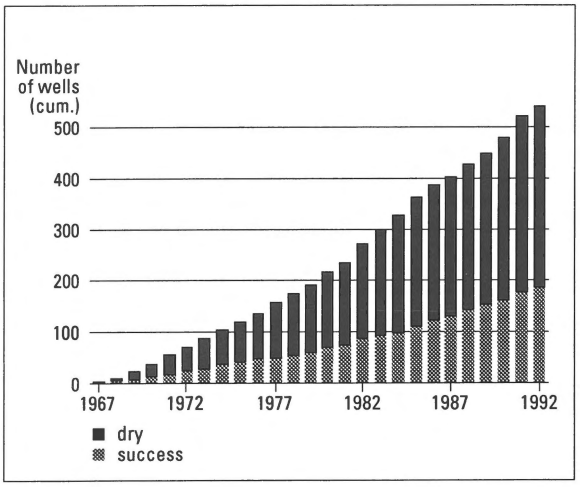

Fig. 4. Exploration drilling rate and success rate offshore.

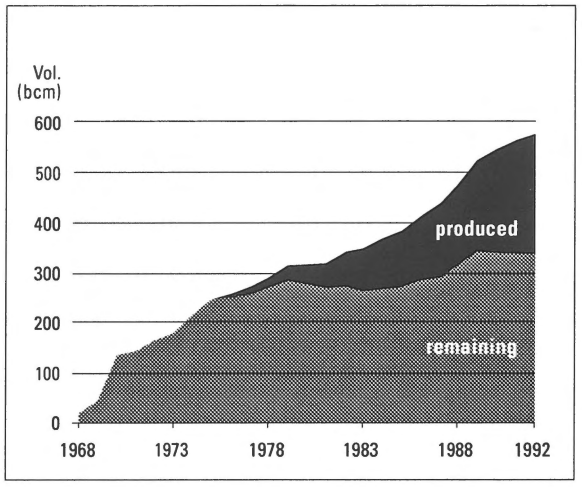

Fig. 6. Gas reserves and production offshore.

4), which is high in comparison with many other areas in the world.

Reserves and production

Up till present, total gas reserves of 1138 bcm, equivalent to some 40% of the initial reserves of the Groningen field, have been discovered in 277 fields outside that field. The cumulative growth of initial gas reserves is shown in Figs 5 and 6 (onshore: 552 bcm in 126 fields; offshore: 586 bcm in 151 fields). Both onshore and offshore, a number of relatively large discoveries with reserves in the order of tens of bcm, were made in the early years of exploration after the discovery of the Groningen field. Up till around 1985, the discovery curve shows a more pronounced creaming-off onshore than offshore. At first glance, the onshore has reached a more mature stage of exploration than the offshore. A review of recent exploration given below will put this observation in a different perspective.

Field sizes

Exploration has resulted in a series of natural gas discoveries, that have tended to become smaller in volume with time. This is clearly illustrated in Fig. 7 by a comparison of the present-day field size distribution with that of 1980, halfway the main exploration phase. It

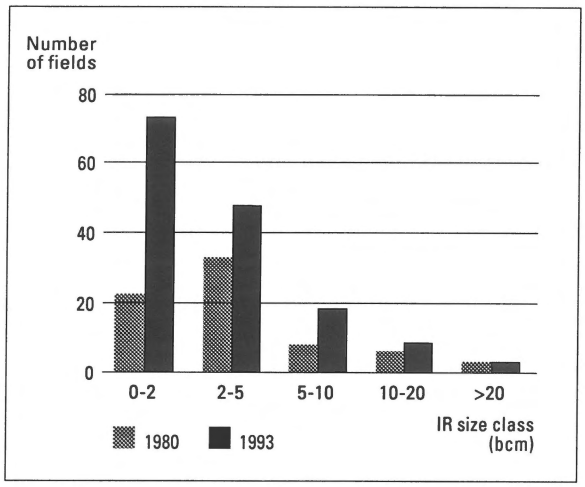

Fig. 7. Gas field size distribution offshore. IR = initial reserves.

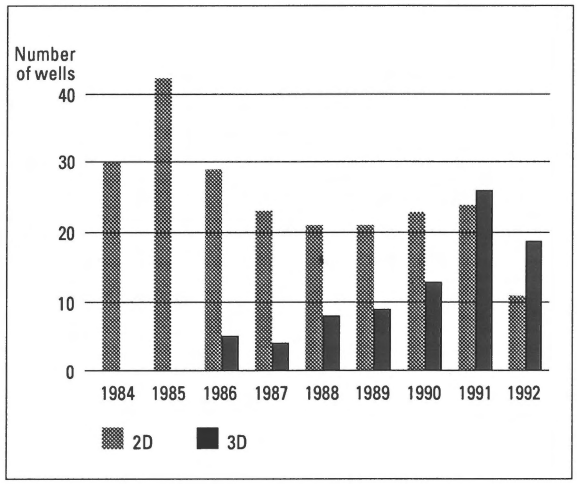

Fig. 9. Exploration drilling rate, 2D versus 3D seismic based.

shows a relatively strong increase in the range of very small fields with reserves below 2 bcm. Considering the steady drilling effort and success rate, this again indicates the maturing of exploration.

Recent exploration

Before trying to see what future exploration may bring, it is useful to have a closer look at recent exploration. Specifically, the introduction of 3D seismic in exploration during the mid 1980s, and the further diversification of exploration over various geological plays, will be shown to be important for the future.

3D Seismic

Coverage

In the Netherlands, the acquisition of 3D seismic surveys started in the early 1980s, both onshore and offshore. At present virtually all fields, certainly the producing ones, have been 3D-covered (Fig. 8). This has provided a wealth of information used for optimizing field appraisal and development. In addition, 3D seismic became important in the exploration stage as will be discussed below, taking the offshore as an example.

The first offshore 3D surveys covered only modest areas ranging from a few to some tens of square kilometres (Fig. 2). They were planned for optimizing development of individual discoveries. Around 1987, however, the capacity of offshore 3D seismic acquisition had been increased to a level at which an area equivalent to that of one offshore block (i.e. 400 km^2) could be covered in a single survey. Since then, the annual 3D acquisition has strongly progressed, peaking at a total of around 5000 km^2, equivalent to 12 offshore blocks, in 1991. The present offshore 3D coverage of well over 20000 km^2 greatly exceeds the production licence area, implying that a significant part of the exploration acreage has been covered (Fig. 2). Over the last six years therefore, 3D seismic has become an important exploration tool, replacing 2D seismic at great pace.

Drilling and success rates (2D versus 3D)

Exploration drilling in the Netherlands has changed from exclusively 2D-based up to 1986 towards mainly 3D-based now within a period of only six years (Fig. 9). Last year (1992), 2D-based drilling indeed strongly declined in comparison with previous years.

In the Netherlands, technical success rates have been significantly higher for 3D than for 2D-based exploration drilling: the rate for 3D averages around 65%, which is almost twice as high as the average for 2D over the same period and before (Fig. 10). It should be noted, that much of the 3D-based exploration drilling has been carried out within acreage that already had been intensively drilled on the basis of 2D seismic. The 3D seismic located additional prospects in 'mature' areas and also led to a high exploration drilling efficiency.

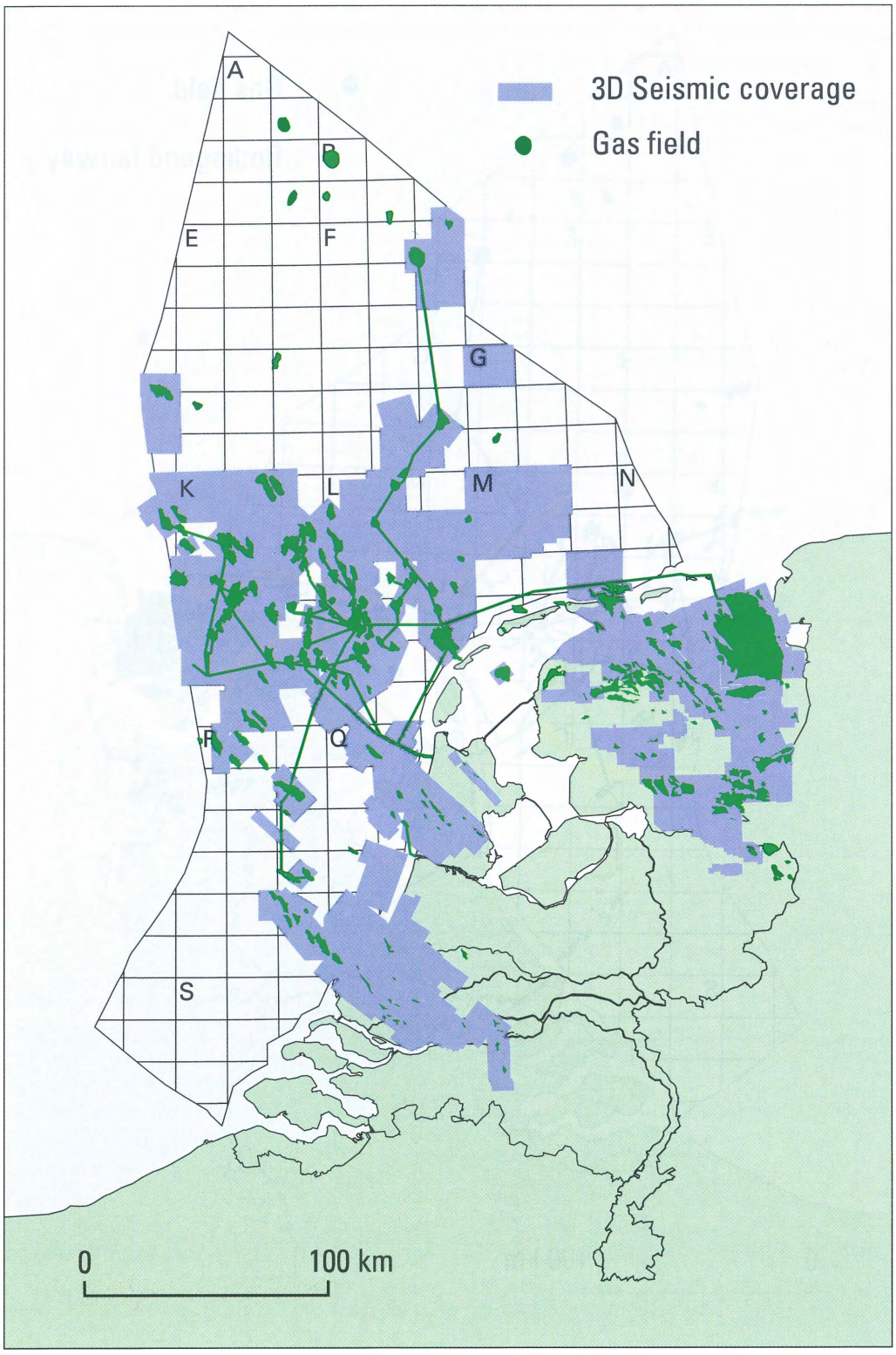

Fig. 8. 3D seismic coverage of gas fields (January 1993).

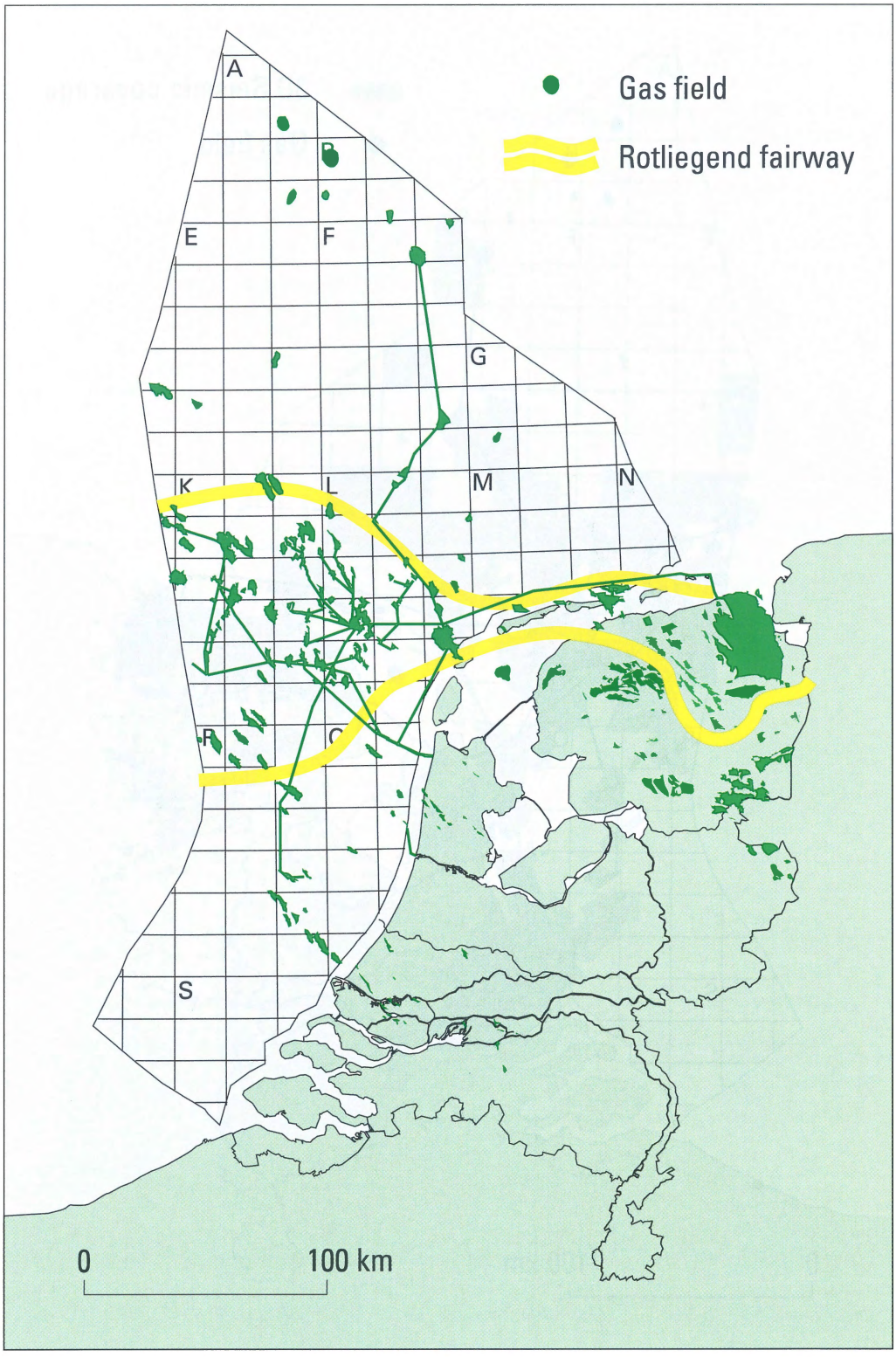

Fig. 11. Rotliegend gas fairway.

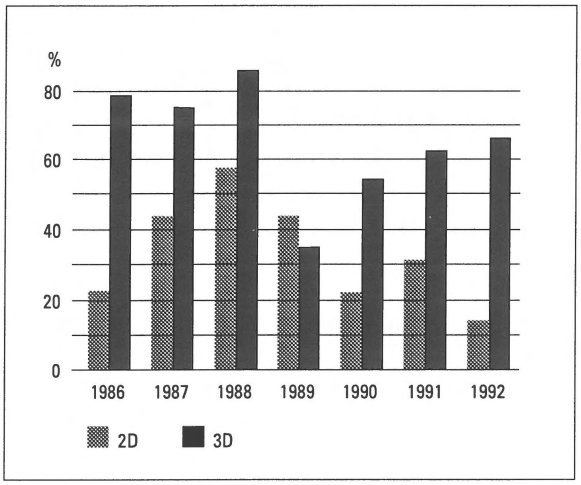

Fig. 10. Exploration success rate, 2D versus 3D seismic based.

Table 1. Initial gas reserves by play (bcm).

	Onshore	Offshore	Total
Post-Triassic	63	32	95
Triassic	60	83	143
Permian*	390	454	844
Pre-Permian	39	17	56
Total	552	586	1138

* Groningen field (2750 bcm) excluded.

Play-wise growth of reserves

Based on the play concept proven in the Groningen field, many other gas discoveries have been made in the Permian Rotliegend fairway in the northern onshore and central offshore (Fig. 11). Less important in number and volume, gas discoveries have also been made in other plays, notably in pre-Permian Carboniferous and in Triassic and post-Triassic reservoirs (Zijp 1987). Generally these discoveries are restricted to smaller basins or areas.

Onshore

The onshore discovery profile (Fig. 12) shows that non-Permian discoveries, some of which predate the Groningen discovery, have contributed significant gas volumes (Table 1). Nevertheless, this profile has been rather flat between 1975 and 1985. Recently, however, a clear upturn is observed due to successful exploration

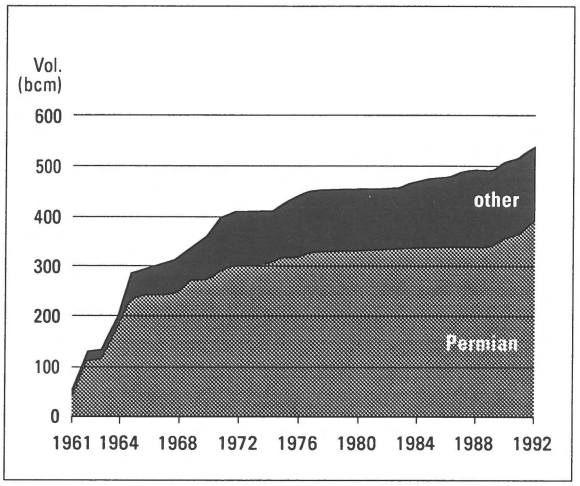

Fig. 12. Growth of initial gas reserves discovered in Permian Rotliegend and non-Permian reservoirs onshore, excluding Groningen field.

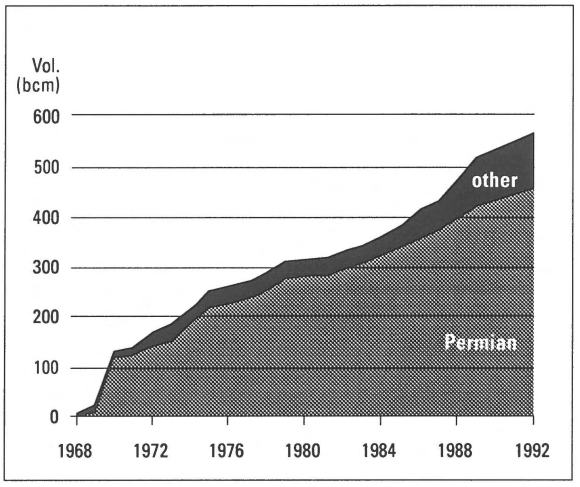

Fig. 13. Growth of initial gas reserves discovered in Permian Rotliegend and non-Permian reservoirs offshore.

in the Triassic gas play in the southwestern onshore. Moreover, in 1990 the first 3D-based exploration well, targeted to the Rotliegend play in the north (Grijpskerk-1), turned out to be surprisingly successful. This well opened up significant new potential as has already been proven by subsequent drilling in a play that had previously been deemed 'mature'.

Offshore

The growth of initial reserves offshore has been largely determined by discoveries in the Rotliegend (Fig.

13, Table 1). Apart from a few early, relatively large discoveries, the Rotliegend discovery rate from 1970 onwards has been fairly steady at around 15 bcm per year.

Other plays, both in pre- and post-Permian reservoirs, have shown modest early discoveries and subsequently a minor contribution until 1985. From that year onwards the non-Permian plays, in particular the Triassic play, have started to contribute significantly, giving rise to an upturn in the total discovery profile. Note that most of the non-Permian discoveries have been made on the basis of 2D seismic. These discoveries are nowadays followed up by 3D-based exploration drilling.

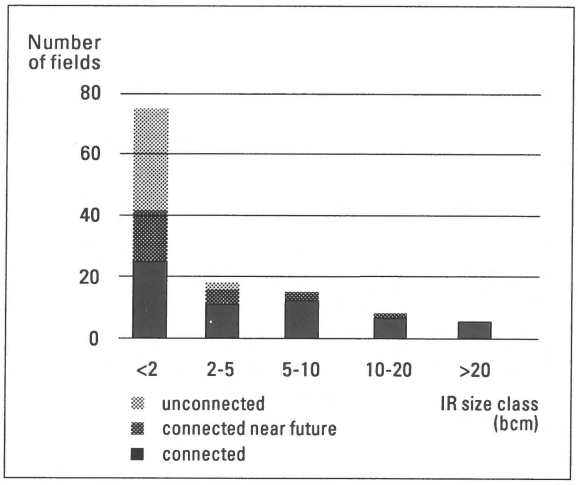

Fig. 15. Field size distribution and degree of development onshore. IR = initial reserves.

Future exploration

Effort

The drilling activity in the Netherlands has strongly declined since 1992, in line with what has been observed elsewhere. Still, it is expected that this activity can be maintained at about the 1992 level. The 3D seismic acquisition still continues over exploration acreage offshore, thus securing new and valuable information on prospectivity.

Future reserves

The Geological Survey of the Netherlands routinely assesses the exploration potential of the country. According to the 1993 estimate (Ministerie van Economische Zaken 1993), the reserves from future discoveries are expected to range between 190 and 410 bcm. To put these numbers in perspective: the most likely value represents about one quarter, and the maximum over one third, of the already discovered non-Groningen gas reserves. Only identified prospects in 'proven' plays have been taken into account in the assessment. This leaves room for speculating about yet unidentified prospects, to be generated from 3D seismic data, or even about yet unproven play concepts.

Development

Introduction

Each individual discovery has its own story with regard to development opportunities: a complex of geological, technical and economic factors eventually will determine which fields will come on stream and when. Here, the relationship will be discussed between field size distributions as derived from exploration results and size distributions of fields that have been or are likely to become connected to the production infrastructure. This will indicate where apparent thresholds for development exist and which part of the discovered initial reserves is likely to be brought on stream under the present conditions.

Evidently, there are significant differences between onshore and offshore regarding the techno-economic conditions for development. It is therefore appropriate to treat these areas separately.

Onshore

The proven onshore gas fields are shown in Fig. 14: connected or producing fields as well as unconnected or non-producing fields. By virtue of the extensive pipeline network, 83% of the discovered onshore reserves at present is in connected fields. Taking into account the likely near-future developments within say the next five years, an additional 77 bcm will become connected (Table 2). From a development point of view, the present discovery population will by then have been strongly creamed off, leaving only very small discoveries undeveloped: of the remaining 37 discoveries with reserves less than 2 bcm, 26 are smaller than 0.5 bcm (Fig. 15). Connection of these very small accumulations into the Gasunie transport net-

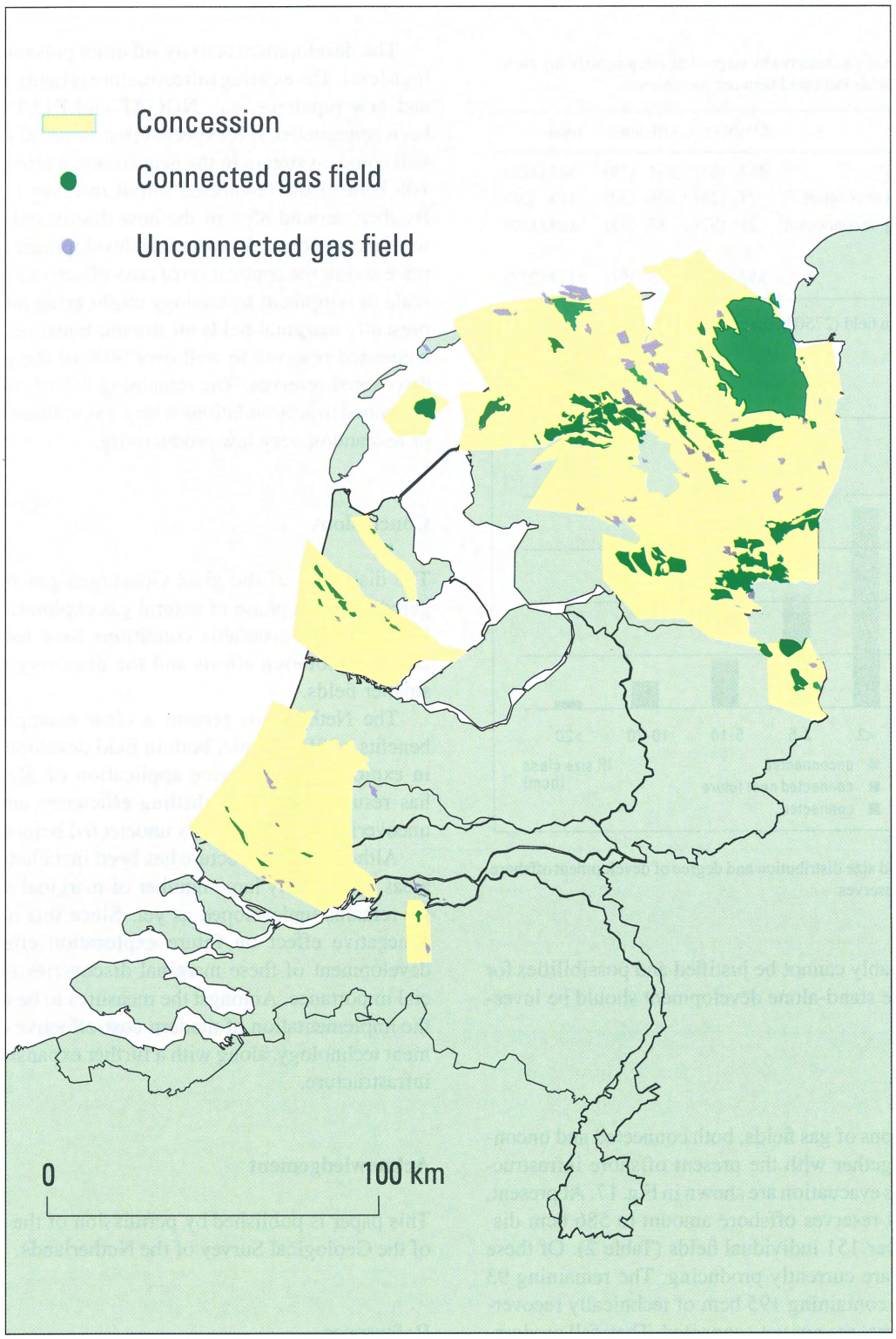

Fig. 14. Connected and unconnected gas fields onshore (January 1993).

Table 2. Initial gas reserves by stage of development (bcm). Note: number of fields indicated between parentheses.

	Onshore	Offshore	Total
Connected*	454 (64)	391 (58)	845 (122)
Connected near future	77 (25)	108 (30)	185 (55)
Remaining unconnected	21 (37)	87 (63)	108 (100)
Total	552 (126)	586 (151)	1138 (277)

* Groningen field (2750 bcm) excluded.

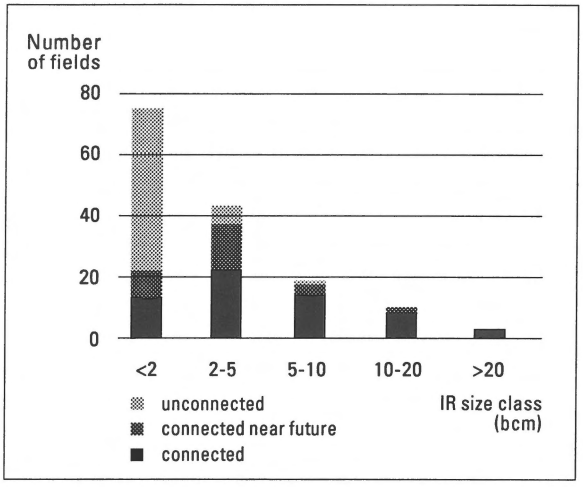

Fig. 16. Field size distribution and degree of development offshore. IR = initial reserves.

work probably cannot be justified and possibilities for small-scale stand-alone development should be investigated.

Offshore

The locations of gas fields, both connected and unconnected, together with the present offshore infrastructure for gas evacuation are shown in Fig. 17. At present, discovered reserves offshore amount to 586 bcm distributed over 151 individual fields (Table 2). Of these fields, 58 are currently producing. The remaining 93 gas fields, containing 195 bcm of technically recoverable reserves, are not yet connected. They fall predominantly in the minor field size categories (Fig. 16). This results from the fact that recent discoveries on average have been smaller and that the larger discoveries have been developed first.

The development activity offshore presently is at a high level. The existing infrastructure is being extended and new pipelines, e.g. NOGAT and P15/P18, have been constructed. It is expected that some 30 gas fields will come on stream in the near future, adding another 108 bcm to the connected initial reserves (Table 2). By then, around 85% of the now discovered reserves will be connected. A favourable development of the oil price and/or the application of cost-effective and small-scale development technology might bring another 24 presently marginal fields on stream, boosting the total connected reserves to well over 90% of the presently discovered reserves. The remaining 6% of reserves is contained in accumulations with a gas volume of 1 bcm or less and/or very low productivity.

Conclusions

The discovery of the giant Groningen gas field triggered the main phase of natural gas exploration in the Netherlands. Favourable conditions have led to sustained exploration efforts and the discovery of many smaller fields.

The Netherlands present a clear example of the benefits of 3D seismic, both in field development and in exploration. The wide application of 3D seismic has resulted in a high drilling efficiency and in the uncovering of prospectivity undetected before.

Although infrastructure has been installed in many areas, a relatively large number of marginal discoveries remains undeveloped as yet. Since this may have a negative effect on future exploration efforts, the development of these marginal discoveries is of crucial importance. Amongst the measures to be taken are the implementation of modern cost-effective development technology, along with a further expansion of the infrastructure.

Acknowledgement

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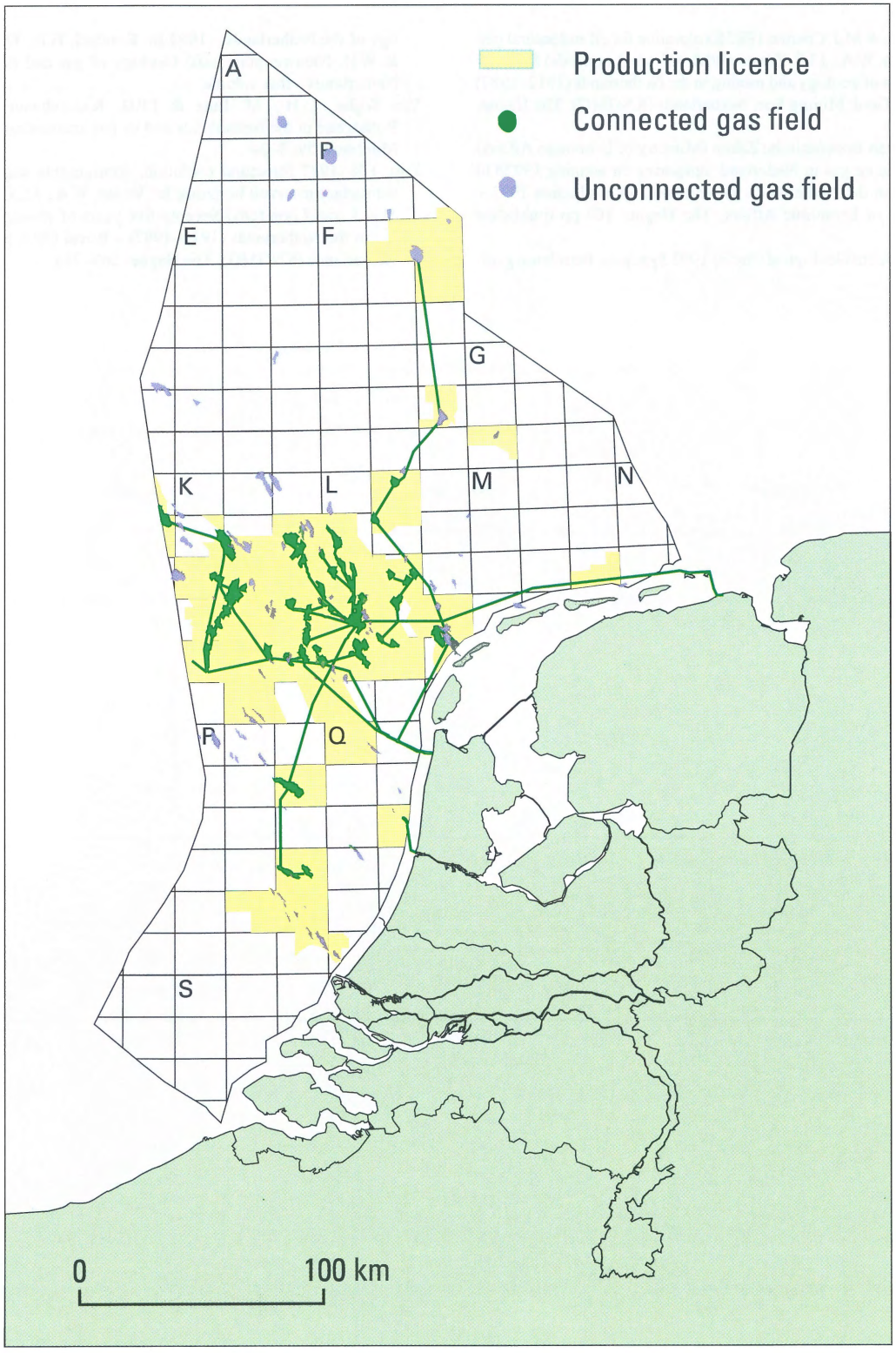

Fig. 17. Connected and unconnected gas fields offshore (January 1993).

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