

Resources of the Sea

OIL FROM THE SEA FLOOR

by B.M. Hopkins

Oil and Gas Division, B.H.P., Melbourne

(with four text-figures, four plates and two tables)

ABSTRACT

Commercial exploitation of petroleum commenced in Pennsylvania in 1859 and the first exploitation offshore occurred in 1926. Massive offshore search began in 1947 and is now the most significant component of oil search. Search involves geological work onshore then usually magnetic and seismic surveys offshore. Subsequently drilling from off-shore platforms or drilling ships may occur and lead to oil production usually obtained by drilling from a central fixed platform from which subsequent production is controlled. Seventeen holes have been drilled in the Bass Basin but have not resulted in production in contrast to the situation in the Gippsland Basin where similar rocks occur.

Drilling and production platforms do not appear to have had a deleterious effect upon marine life, rather the converse. Spillage from damaged drilling rigs has occurred but in the thirty year period 1942 - 1972 only four major spillages occurred, an accident rate of 0.022%.

INTRODUCTION

The petroleum era commenced when oil was recovered from a well drilled in Pennsylvania, United States of America, in 1859. The development of the geological sciences in relation to the occurrence of petroleum in sedimentary basins has gone hand in hand with the developing technology in exploration and production of petroleum. Transportation equipment has also developed to conquer any new environment, e.g. desert, coastal swamps, jungle and Arctic lands where petroleum is thought to occur.

It was only 67 years after the first discovery of oil that man went to sea to continue the search for oil. This was in Lake Maracaibo, Venezuela in 1926. However, oil had been produced from offshore southern California in 1896 by building wooden piers out from land.

Other significant dates in the search offshore were:-

- 1932 Oil discovered on Bahrain Island brought realisation of the large deposits which may be beneath the Persian Gulf.
- 1938 Oil discovered 1.6 km from shore off Louisiana in 8 m of water. Well drilled from rigid platform.
- 1947 First well completed from a mobile platform in the Gulf of Mexico. Therefore, 1947 is the year which may be documented as the year of commencement of a massive offshore search which in 1972 extended to 80 countries (see map) and included 134 companies involved in the search.

The petroleum industry moved to the offshore in response to increasing consumption of the world's industrialised nations. Active exploration in many of the world's sedimentary basins had discovered the greater part of the oil which may be expected to occur, and new potential areas had to be tested. Land areas will continue to be studied, but emphasis has now shifted to the marine areas. Figure 22 shows the areas of exploration activity in the world and figure 23 relates to Australia.

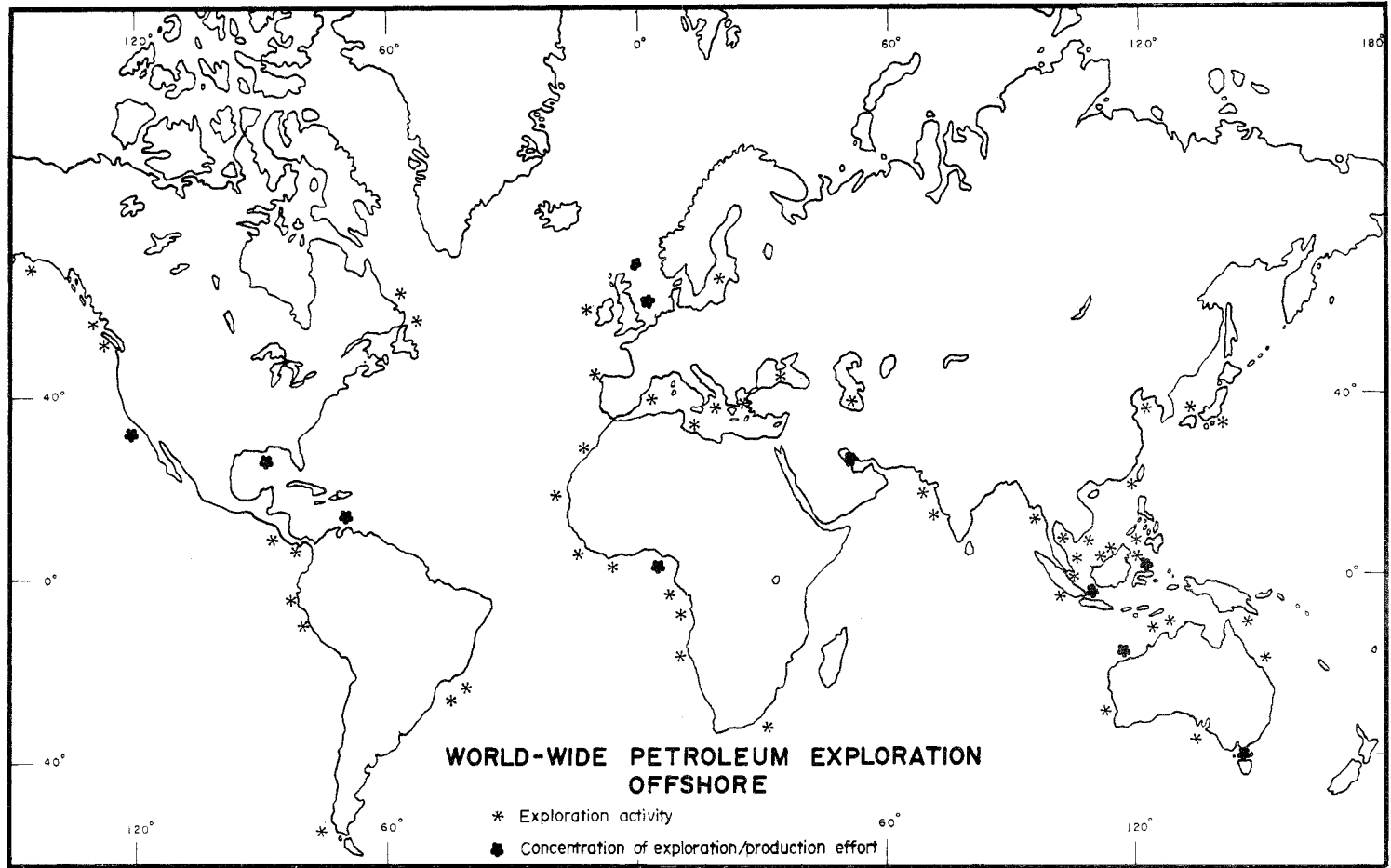
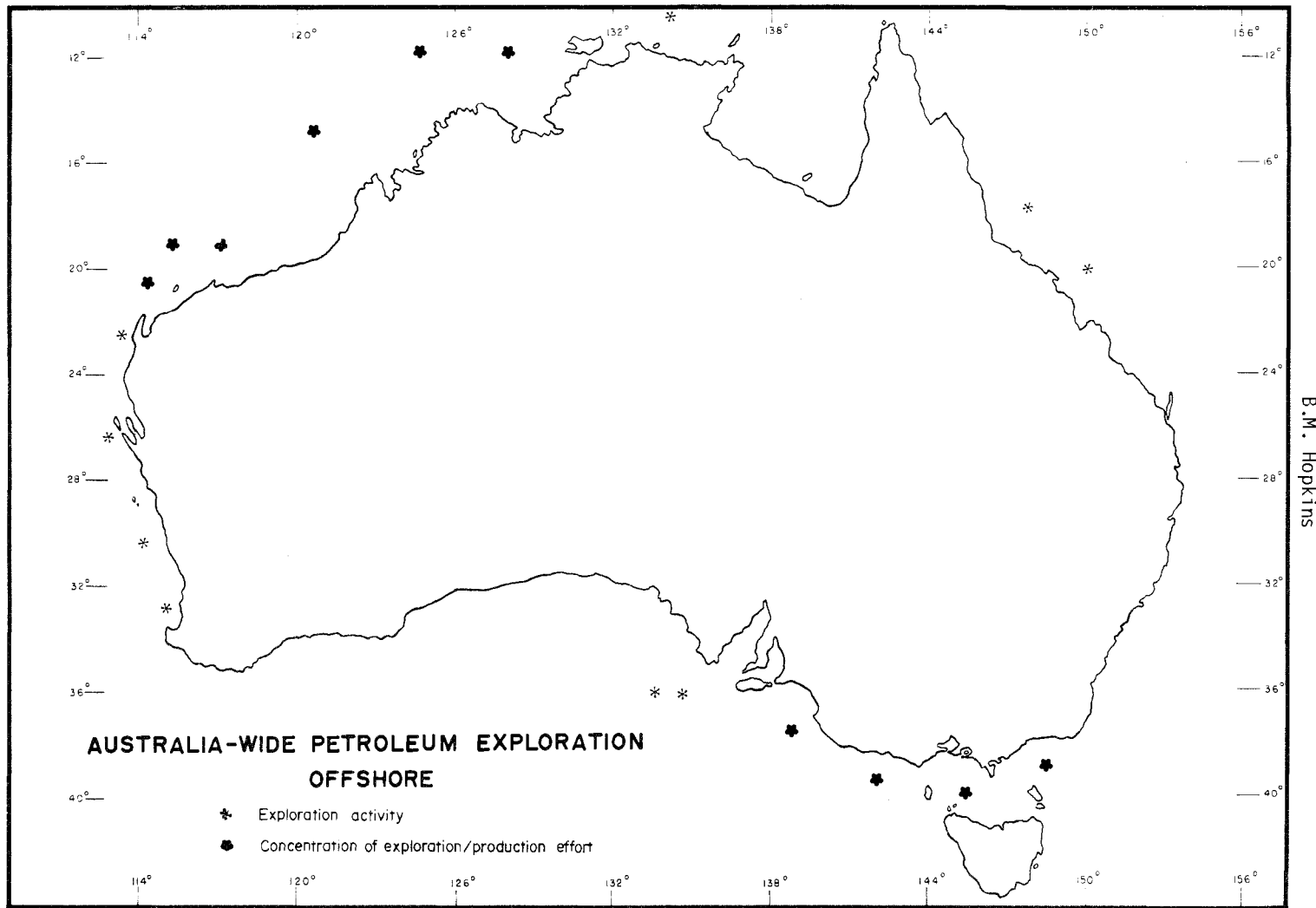


FIG. 22. - Exploration activity - worldwide.



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FIG. 23. - Exploration activity - Australia.

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GEOLOGICAL THOUGHTS

The occurrence of oil in coastal sedimentary basins is governed by various geological factors which are part of the history of the basin. The present day coastline is an arbitrary boundary which is not necessarily related to any geological feature. There are exceptions, such as fault escarpments e.g. Otway Coast, Victoria and very young anticlinal features e.g. Barrow Island, W.A. However in older sedimentary basins where the history of deposition has indicated one or more unconformities, or episodes in the formation of the basin the coast is a modern morphological feature.

Following detailed exploration in a coastal basin, it was only a matter of time before it was realised that the fields may extend under the continental shelf. All the early exploration activity in the offshore followed this pattern. In this respect, the search in Bass Strait was unique as there was no record of production in the onshore part of the basin (except the seepage oil produced during World War II at Lakes Entrance) to provide the impetus for the more expensive search offshore.

OPERATIONAL SEQUENCE - OFFSHORE

Exploration

Exploration for petroleum is largely dependent on geophysical techniques establishing the presence and thickness of sedimentary basins and the attitude of the sediments therein.

In an onshore basin, initial geological mapping indicates the presence of a sedimentary basin. Most early exploration efforts in the offshore followed the establishment of nearby production from a sedimentary basin whose bounding margins are not confined to the land area.

In Bass Strait the only evidence of the thick sedimentary Bass Basin was the occurrence of thin outcrops of Tertiary limestone in the north-western part of Tasmania and on King Island. Late Mesozoic sediments do not outcrop in Tasmania.

Two geophysical methods are available to determine the presence and shape of a sedimentary basement. These utilize magnetic properties of rocks, or their density (measured by variation in the earth's gravity at any point). Each method depends upon a contrast of these properties between sedimentary rocks and igneous or metamorphic basement and their application depends upon the geological circumstances being investigated. In marine areas the magnetic method can be utilized from an aircraft and the speed of operation provides a cheap and effective determination of the sedimentary basin for the later more expensive methods of seismic survey to determine drilling locations.

Magnetic Surveys. The magnetometer records variation in the total magnetic intensity of the earth immediately below the aircraft. This measurement depends on the geographic position on the earth's surface (this component can be calculated) and the magnetic intensity of the surface rocks beneath the cover of the sea (this component is variable and dependent upon local geological structure).

The magnetometer may be housed in the aircraft or suspended on a trailing cable. The aircraft flies a grid pattern preferably at right angles to any known geological trends to provide better data definition. The aircraft's position at all times is controlled by radio navigation network.

Data is computerised and presented as a map of "total magnetic intensity" or as an interpretation of "depth to magnetic basement" thus outlining the sedimentary basin parameters, i.e. areal extent and thickness of sedimentary rocks.

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Seismic Exploration. The method of reflection seismic exploration was first used successfully for oil exploration in Oklahoma in 1921. An explosive charge is placed at the bottom of a drill hole and detonated electrically. The resulting seismic energy is transformed into electrical energy on reaching the vibration detectors or seismometers at the surface and is thus recorded graphically on a magnetic tape.

Land operations consist of an instrument survey to locate shot points, the drilling of the shot-hole and layout of the seismometer spread in the desired manner and the actual detonation and recording of the shot.

The adaption of the seismic method for use on water covered areas has presented few problems. In its present form marine operations have decided advantages in economics and output over the land surveys. This is brought about by the elimination of the drilling of shot-holes and the slow surveying methods available to the land crew. The cost per line-kilometre for marine work is approximately one-fifth that of land seismic survey.

Modern Developments of Seismic Techniques. Early Bass Strait programmes recorded the seismic energy on magnetic tapes and used an explosive energy source. Major developments in seismic technology over the past 10 years have been:

1. The two boat operation as used in our initial surveys was replaced by a single large vessel to perform both the shooting and recording operations.
2. Elimination of explosive charges (except for refraction type surveys) by the introduction of implosion sources, e.g. aquapulse, gas-gun and air-gun. These had the benefit of eliminating the accidental fish kill which could have resulted from the many explosive detonations.
3. Recording of the seismic energy on magnetic tape was superseded by a digital conformity.
4. Improvement in the tone of the recording cable which resulted in removal of extraneous noise due to weather conditions and the state of the sea. This is a continuing problem in Bass Strait where weather noise masks real seismic events.
5. The multiple recording techniques developed so that the energy return from any one point in the subject surface is recorded at several points on the surface and stacking to increase the signal to noise ratio of a valid seismic event.
6. The use of computers in handling the digital format records has revolutionised the processing of seismic data. It allows accurate determination of the interval velocities of the various sediments in the basin and this may be utilized in the indication of the presence of oil and gas in a structure before it is drilled.

The old method of recording data on magnetic tape has not been utilized in Bass Strait since 1966. However, the list of improved techniques above resulted in changes so dramatic that some of the later surveys (post 1970) have had to re-record data obtained from the earlier reconnaissance group. A comparison of the seismic data recorded early in Bass Strait and in later years is shown as table 10.

TABLE 10

SEISMIC SURVEYS - BASS BASIN

<u>Period</u>	<u>Programme</u>	<u>Source of Energy</u>	<u>Shooting Coverage</u>
1963 - 1967	6200 km	Dynamite	Single - 6 fold
1967 - 1969	2700 km	Aquapulse	6 - 12 fold
1969 - 1973	7000 km	Air Gun	24 - 72 fold
	<u>15,900</u> km		

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Drilling Techniques

As stated earlier, the first offshore drilling was from piers built out from the shore along the coast of Southern California. The Russians also use this technique in the Caspian Sea.

In Lake Maracaibo and offshore Louisiana fixed platforms were built away from the land and serviced by ships. A conventional land rig was used to drill the wells using rotary drilling techniques developed in the preceding years.

The discovery of oil in the Gulf of Mexico on 4th October, 1947 was made by Kerr McGee Company, who converted navy equipment to form a mobile drilling platform. The success of this well meant that exploration drilling was no longer restricted to shallow water depths requiring permanent offshore facilities.

The development of drilling vessels followed a similar pattern. Experimentation by converting a ship to hold a conventional drilling rig proved successful but there were limitations imposed by weather conditions, e.g. wind velocity, wave height and sea swell. Alterations were made in the technique of stabilising the vessel against these movements and in the method of anchoring the ship at the drill site. A ship with bow and stern anchors has only a small amount of movement to allow it to take the best position to minimise the effect of the sea state. Later vessels have anchor chains radiating from the "moon pool" or drilling well in the centre of the ship and a vessel of this type may be rotated to any position. Figure 24 is a schematic diagram of the drill-ship and its drilling assembly including "blow-out preventers" on the sea floor.

The latest vessels designed to operate in very deep water greater than 450 m use bow and stern thrusters to position the vessel over the drill hole and to maintain the drilling position in all types of weather. The use of the thrusters is controlled by computers which use, as their point of reference, sonar beams placed around the drilling location on the ocean floor.

In the drilling operation the drilling rods are stacked inside the derrick for ease of handling and the increased weight above the ship creates an instability which is particularly vulnerable to the weather. Mechanical pipe racking devices have been designed to allow these drill rods to be laid down horizontally in the forward part of the ship adjacent to the derrick and thus the vessel is able to operate for greater periods of time in any drilling location.

The second type of offshore drilling unit is the semi-submersible platform, which is in effect a drilling platform supported by buoyancy chambers or legs at a height above sea level which negates the wave and storm action. The buoyancy chambers may be progressively flooded to obtain the correct position for operations or when the vessel is under tow. The drilling floor may be as high as 30 m above sea level. The construction of these units is such that if the water depth is shallow they may rest on the sea floor and act like any other drilling platform. There is no specific design as to the drilling platform, it may be triangular or rectangular depending upon the drilling contractor's preference.

However, while these units can operate in extremely rough weather, they have a limitation in the storage of materials for the drilling operation and must be supplied by smaller work boats which are in turn vulnerable to the weather conditions. Similarly they are not self-propelled and must be towed to any location. This also requires favourable weather conditions. This limitation is being removed in the modern units by allowing them to be self-propelled. Plate 4 shows "Ocean Digger" a vessel of this type which was built in Australia and has been used in Bass Strait.

The third type of drilling unit is the jackup platform which sits on the sea

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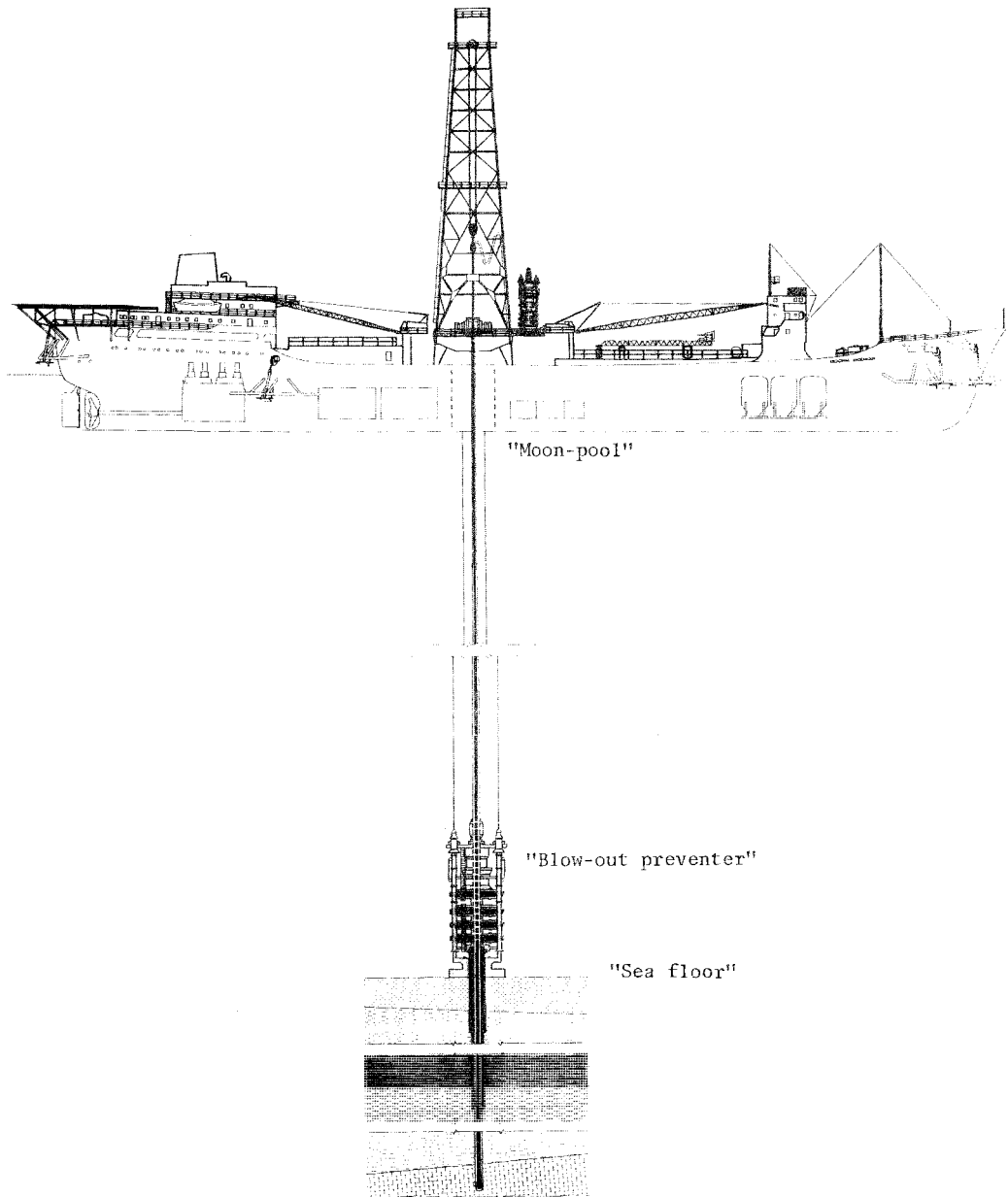


FIG. 24. - Schematic diagram of drill ship and drilling assembly.

floor. The hull is towed into position and the legs lowered until they are firmly embedded in the sea floor. The hull is then jacked up until it is out of the reach of the sea conditions and forms a temporary drilling platform. These units are not self-propelling and are also subject to the supply boat problem. They have a further limitation in the length of the legs and to date the maximum depth at which they can work is in the order of 100 m. To ensure stability while on location the "feet of the legs" are caissons or platforms to provide greater control and maintenance of

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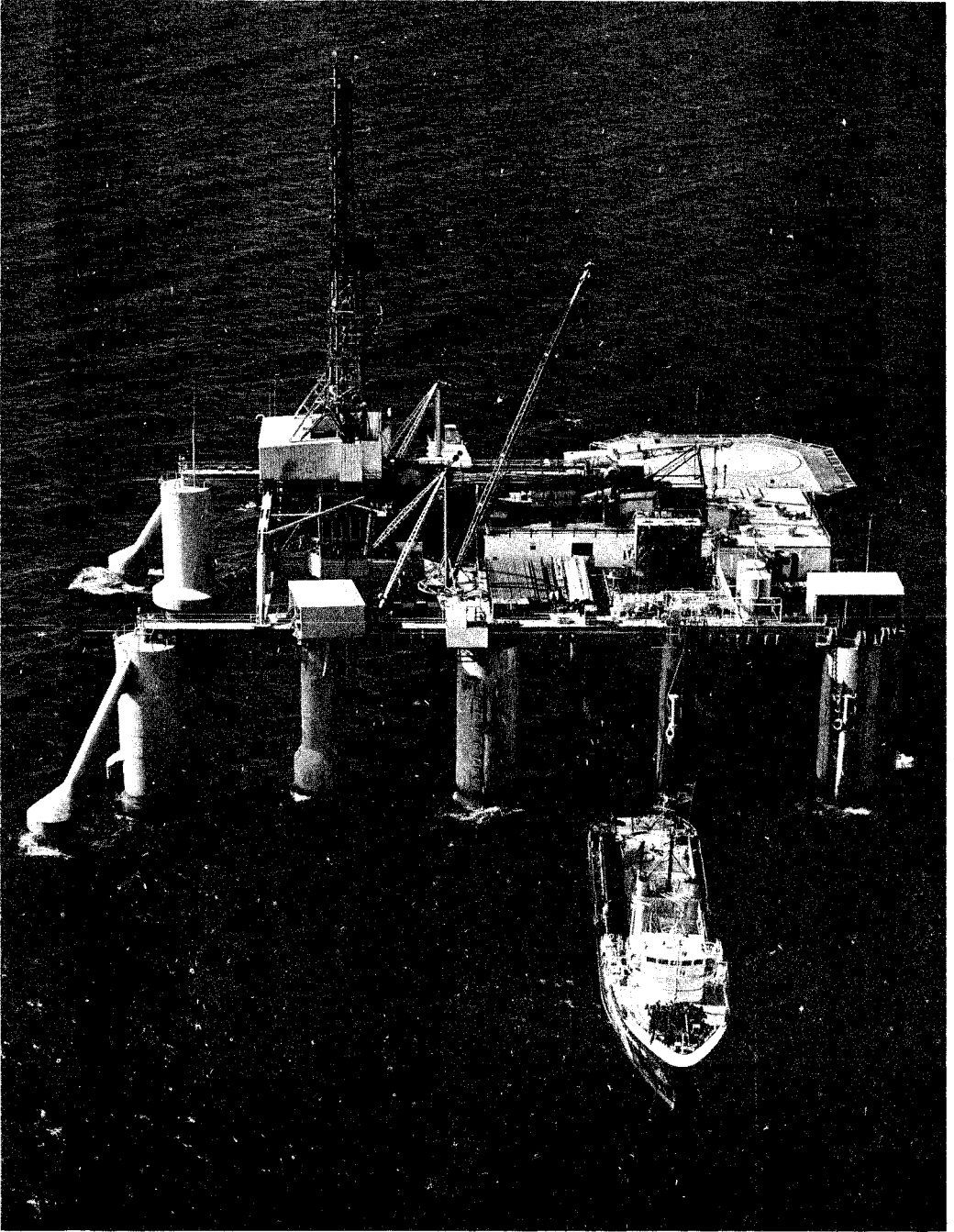


PLATE 4. - "Ocean Digger" drilling rig.

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drilling position.

Development of a Field for Production

Following the exploration wildcat success and the determination of the size of the field by the seismic method and delineation drilling, a site is selected for the installation of production platforms.

The development of an onshore field is relatively simple as the drilling rig is moved to the individual locations and the production from the wells drilled is gathered by a system of pipe lines. This method, although it can be used in the off-shore, is relatively expensive and the most favoured development system is to install a central platform which can accommodate up to 48 wells. The combined flow from these wells is gathered on the platforms and transferred to shore facilities by a single pipe line.

To provide an effective spread of drainage points within the oil or gas reservoir the drill holes are deviated with great accuracy to a programmed point in the reservoir. They are drilled vertically to a depth of 1000 m and then deviated by various mechanical or pressure methods at angles up to 60° to the vertical to intersect the reservoir horizon at a known location. The solving of the reservoir drainage problems is based on all available exploration knowledge co-ordinated by the reservoir engineers. Plate 5 shows the manner in which deviated wells act as drainage points in the reservoir.

The central platform (plate 6) consists of three components, the jacket, a deck which hold all facilities and a system of piling which anchors the platform into the sea floor. The jacket is fabricated from steel tubulars onshore and the necessary precautions from rust are taken in the form of a protective coating in the splash zone, i.e. the area which is exposed to salt water and to the atmosphere. The jacket with the necessary conductor piles for the drilling operations is placed on a flat top barge and taken to the offshore site. The barge is flooded at one end and the jacket slides off into the sea. At this stage it is buoyant and the lower parts are subsequently flooded to bring it into the vertical position. Steel piling is driven through the legs of the jacket into the sea bed to depth in excess of 75 m. The jacket is merely a method of holding the steel piling together on the site. Subsequently, the decking is placed on top of the piles so that the load of the deck, drilling rig and/or product-

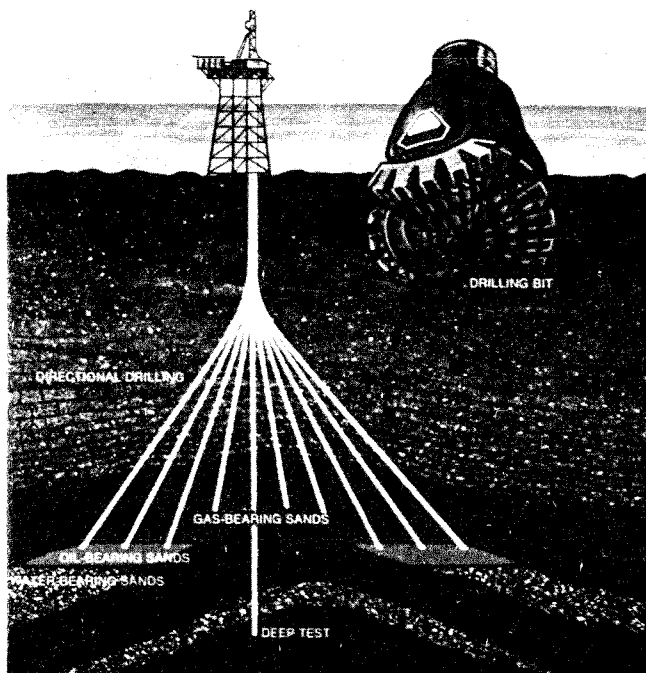
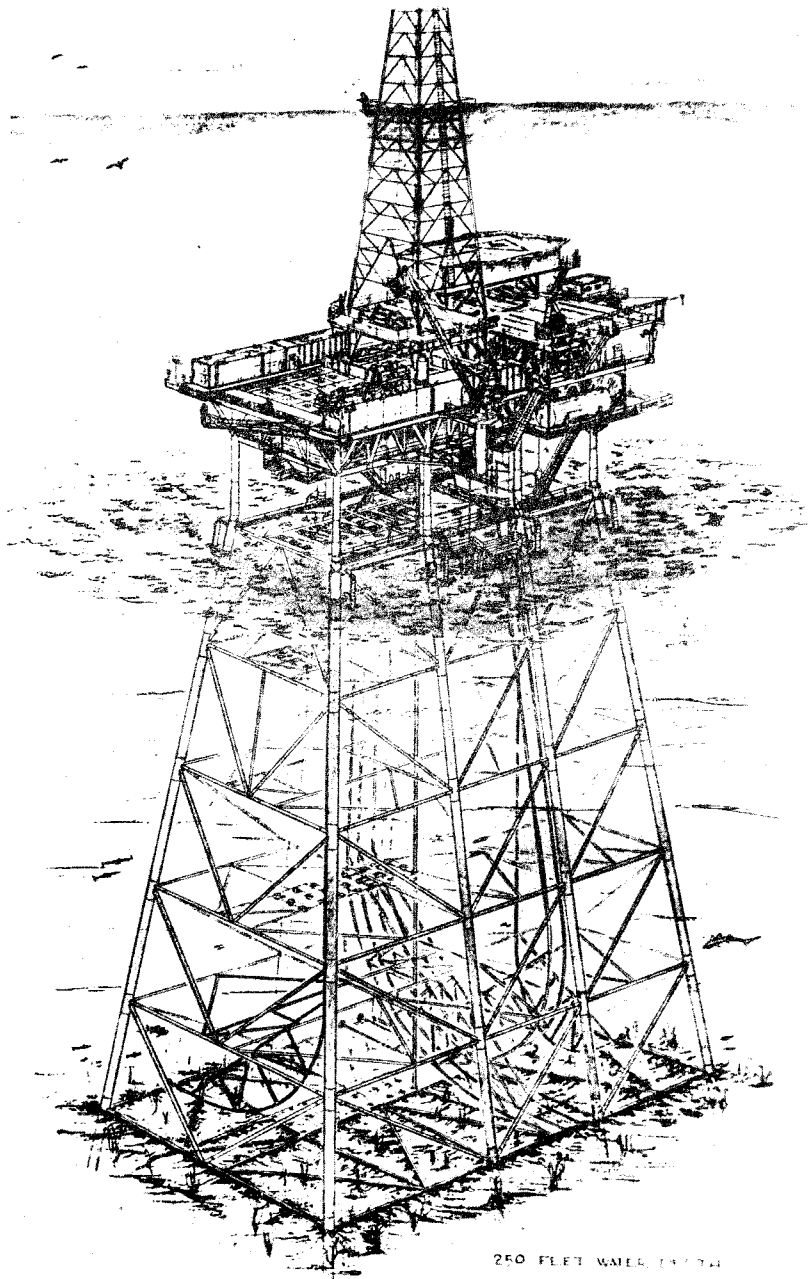


PLATE 5. - Sketch of deviated drilling into reservoir

placed on top of the piles so that the load of the deck, drilling rig and/or product-

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250 FEET WALL DIA.

PLATE 6. - Diagrammatic sketch - production platform.

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ion facilities is borne by the piling which in turn is anchored to the rock strata beneath the sea floor. A drilling rig is placed in position and used to continuously drill the necessary wells for production after which it is removed and the wells are tied into the production facilities on the platform. Therefore production cannot commence until the field has been completely drilled as it is an extremely expensive operation to bring the rig back for any subsequent drilling. Pipe laying in offshore waters is carried out from a barge on which the individual lengths of pipe are welded together in a similar manner to any onshore operation. As the barge is moved along the line of the pipeline it is progressively laid on the sea floor.

The deepest water in which platforms are in use or contemplated is around 150 m in the North Sea. In Bass Strait the Halibut and Kingfish platforms are in water depths of around 250' (80 m). However, it is noted that water depth is not the only limiting factor as the weather conditions in the area of installation are critical in the handling of these large structural units.

As the exploration sphere changes and man's ability to drill progresses into water depths up to 600 m consideration is being given to sub-sea structures with automatic equipment and mechanisation being geared to allow safe operations at that depth. This is the limit of technology at the present time and because of the huge expense involved, only the largest companies in the world are able to carry out the research and development of the prototype systems necessary. In terms of the continental shelf, i.e. out to the 200 metre line, the major proportion of production will continue to be from platforms fixed to the sea floor.

Our experience in Bass Strait has shown that a drilling platform becomes the focus for large increases in marine life in the surrounding area. Possibly this is due to an increased food supply (from man's existence on the platform) or from the shelter it provides for certain marine organisms. It was originally thought, especially in the Louisiana Gulf Coast area of the United States, that the petroleum industry's intrusion into this offshore environment would be detrimental to the fishing industry and marine life in general. However, history has not proved this to be the case.

THE BASS BASIN

Exploration Programme

Early exploration for oil along the southern coast of Australia concentrated on the Lakes Entrance area and around Torquay, south-west of Melbourne. The oil discovered at Lakes Entrance within the Gippsland Basin in 1924 was approximately 15° API and was possibly a fossil remnant of oil accumulation. This discovery led to approximately 100 wells being drilled near Lakes Entrance. The Victorian Government drilled several wells early in World War II to approximately 1200 m in the deepest part of the basin onshore. These were unsuccessful, but did provide a great deal of stratigraphic information in assessing the Tertiary section overlying a tight Lower Cretaceous sequence, the Strzelecki Group. The latter was regarded as economic basement and present day exploration has not changed this concept.

B.H.P. acted on the advice of Lewis Weeks, a petroleum geological consultant from Connecticut, U.S.A., who applied the concept of extending the areas of favourable young sediments known on land, to exploration on the continental shelf. In addition, it was reasoned that the large central area of Bass Strait could hold a sedimentary basin having similar depositional history to those already known on land.

One of the most important sedimentary basins on the southern continental shelf is the Bass Basin and an active exploration programme has been carried out by B.H.P. and Esso.

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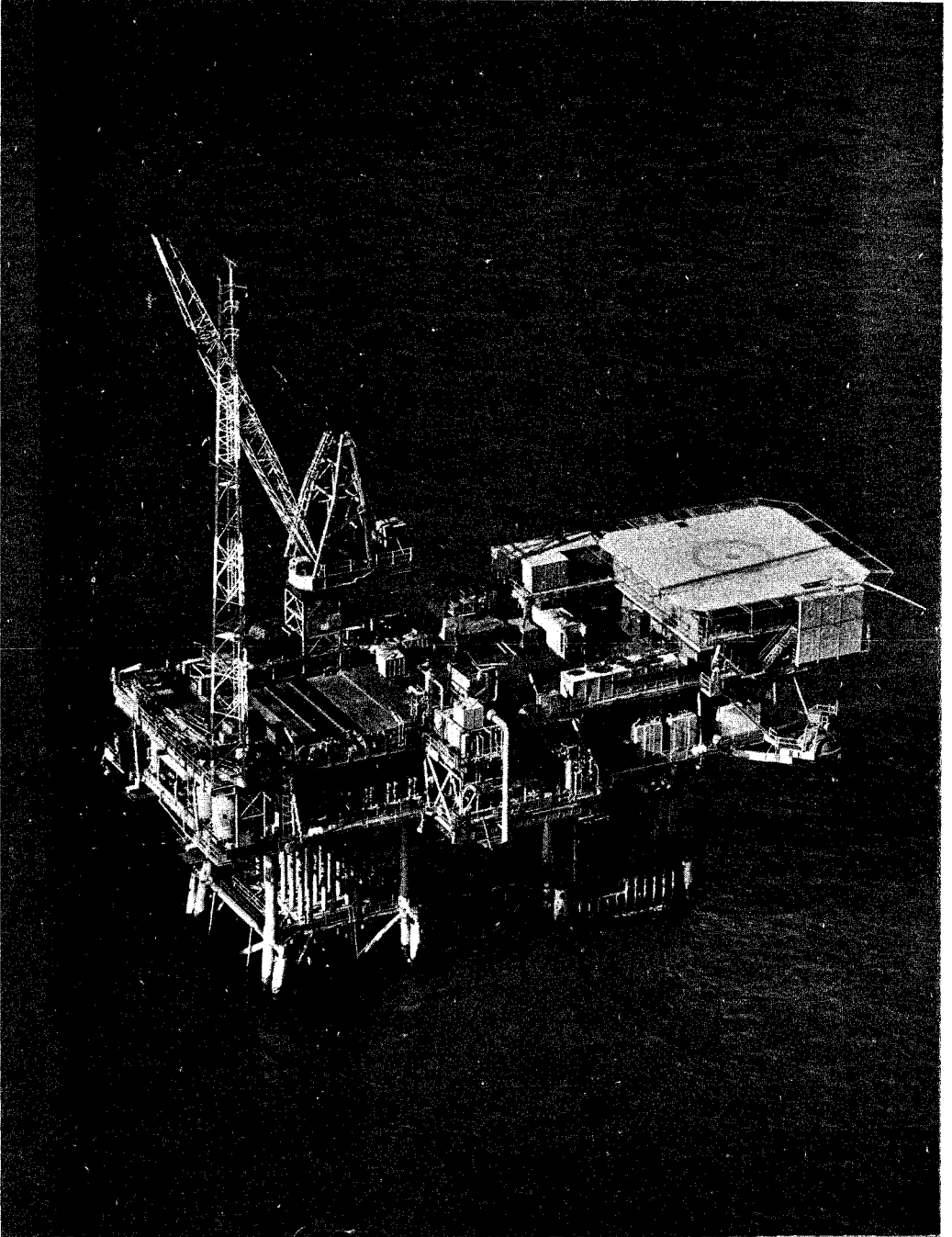


PLATE 7. - "Kingfish A" platform in 77 m (253 ft) of water, 76 km (47 mls) offshore in Bass Strait.

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Petroleum exploration permits have at some stage been taken out over the whole of the continental shelf of Tasmania. The active companies were B.H.P., Esso, Magellan Petroleum, Planet Oil and Gas and Amoco. Most of these areas have been relinquished as a result of disappointing results of geophysical surveys.

Geology. The offshore Bass Basin covers an area of approximately 52,000 square km and lies wholly on the continental shelf beneath the waters of Bass Strait. It is enclosed by the mainland to the north, Tasmania to the south and King and Flinders Islands to the west and east respectively. The Basin contains sediments of Early Cretaceous to Late Tertiary age as follows:

1. Torquay Group: limestones, marls and glauconitic clays - Oligocene to Miocene.
2. Tertiary: Demons Bluff formation - brown to black arkosic siltstone and greywacke - Eocene.
3. Mesozoic/Tertiary: Eastern View Coal Measure - sandstones, siltstones, shales and coals - Upper Cretaceous to Eocene.
4. Mesozoic: Otway Group of weathered lithic sandstone of Lower Cretaceous age.
5. Basement Palaeozoic rocks: were recorded in two wells and these can correlate with outcropping basement in Tasmania.

The structure of the basin is relatively simple. The major axial alignment is northwest to southeast and represents a basin of deposition with few structural irregularities in the Tertiary sediments. The only disturbance in this period is the widespread igneous (volcanic) activity.

However, the major feature in the Mesozoic and earliest Tertiary section is the occurrence of structural noses developed from the basin flanks extending into the deep basinal area. These features appear to be fault controlled and are related to deep-seated movements associated with tilted fault blocks in the early development of the basin down-warp.

Petroleum Potential. Bass Basin is one of the few young sedimentary basins developed on the margin of the Australian continent. It has a thick sedimentary sequence similar to the Gippsland Basin, but does not appear to have undergone the structural movements (folding and faulting) which characterise the Gippsland Basin. The prospective section is the stratigraphic equivalent of the Latrobe Valley Coal Measures which is the reservoir for all of the discoveries in the Gippsland Basin. Hydrocarbons have been discovered in the Bass Basin from this interval in four wells namely:

Bass-3	Gas condensate	2055 metres
Cormorant-1	Oil	1500 metres
Pelican-1	Gas condensate	Below 2468 metres
Pelican-2	Gas condensate	Below 2773 metres.

Exploration Statistics. Tables 10 and 11 provide the principle statistics in the exploration to date in the Bass Basin. In addition, the data on seismic surveys reflect the changing technology in the use of non-explosive energy sources and the degree of complex shooting techniques now being developed. Well locations are shown on figure 25.

GENERAL COMMENTS - OFFSHORE OPERATIONS

There is no doubt that marine operations in the search and production of petroleum introduce a hazard in that man is not working in a familiar environment. Weather conditions play an important part in these operations. Cost of drilling a well varies with the geographical location and may even influence the choice of a drilling rig for any project. The semi-submersible rig, while immune from the surface sea state is dependent on the use of smaller supply vessels as it cannot store the necessary materials for a long period of work. On the other hand, a ship-shaped

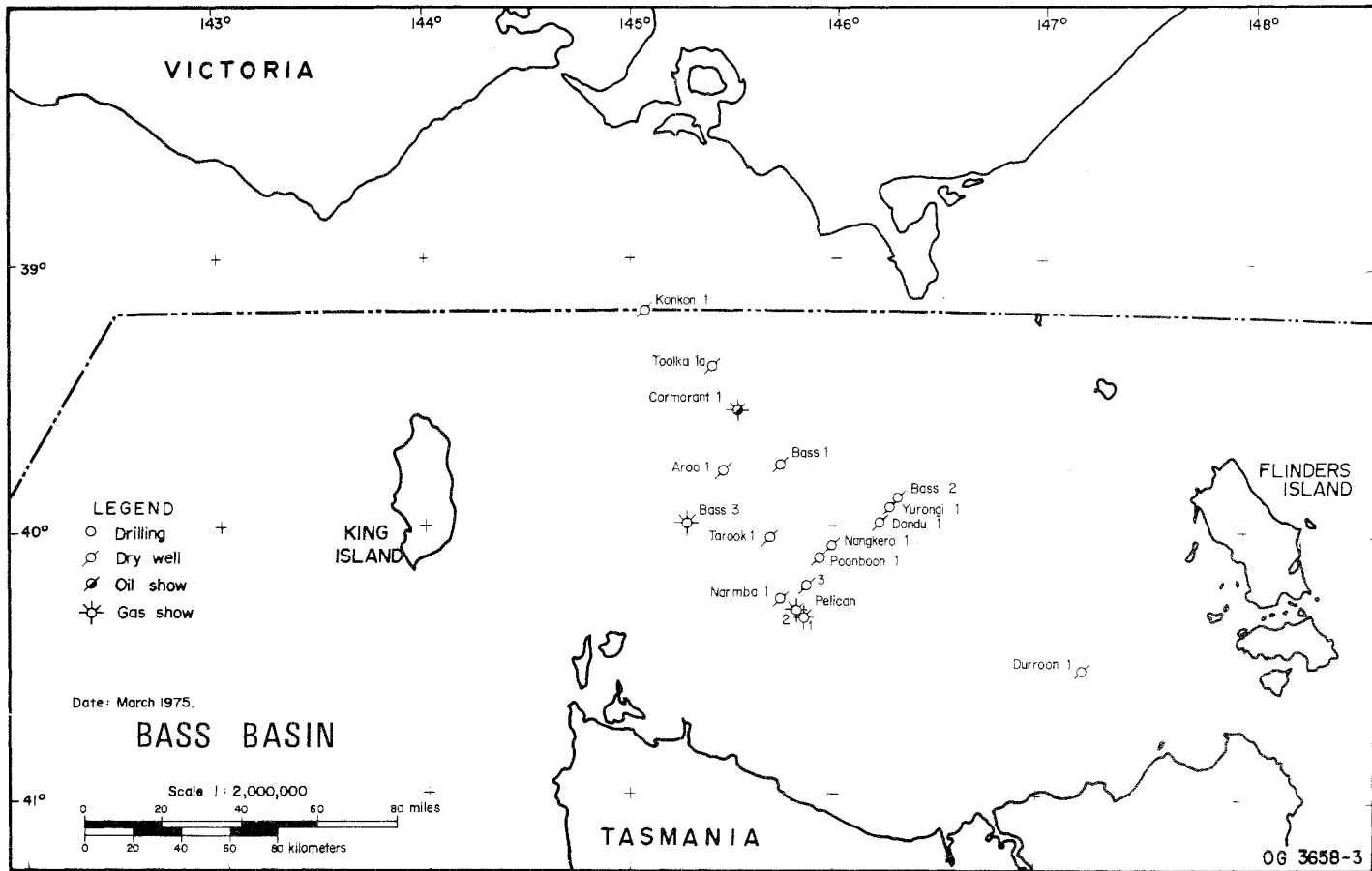


FIG. 25. - Well Locations - Bass Basin.

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vessel with the normal hull configuration has adequate storage for all drilling materials and can operate for longer periods remote from onshore support.

TABLE 11

DRILLING - BASS BASIN

for Location of Wells see fig. 25

<u>Type of Rig</u>	<u>Period</u>	<u>No. of Wells</u>	<u>Cumulative Metreage</u>
Floating Rig "Glomar II"	1965 - 1967	3	6585 m
Semi-submersible "Ocean Digger"	1970 - 1972	3	9247 m
Floating Rig "Glomar Conception"	1972 - 1974	11	31511 m
			<hr/> 47343 m

Severe offshore storms are the major cause of rig mishaps. Since 1955 (the year in which mobile rig activities were broadened on a world wide scale) approximately 45% of the rig mishaps in this 19 year period were due to storms. It is noted that much of the petroleum exploration is in tropical waters which are calm for the greater part of the year, but are also subject to the most violent storms. In recent years, drilling activity has spread to the higher altitudes, e.g. the North Sea, offshore Canada, the Straits of Magellan and the Bass Strait area and while a greater percentage of lost time occurs due to the higher frequency of rough weather, these areas lack the more destructive storms.

Statistics show that 36 rigs were totally lost in the period and this figure may be subdivided into 5 semi-submersible types, 20 jack-up rigs and 11 floating rigs. The statistics of rig mishaps are important as they illustrate the chance of an oil spillage as a result of some type of accident. Not all of the wells drilled in the sea floor find traces of hydrocarbons and indeed the success ratio for a commercial discovery, i.e. one capable of discharging oil on to the sea is in the order of 1:40. The industry is still in its infancy and the only place where detailed records are available is from the United States. During the period 1942-72 only four major occurrences of oil spillage have been recorded. These were attributed to a blow-out off Santa Barbara, fires at two locations and storm damage offshore Louisiana. During this period approximately 18,000 wells have been drilled therefore the accident rate of 0.022%. An added factor to be assessed in the case of a spill is the probability of the discharge of material reaching the shore.

In this latter case wind conditions and sea currents will contribute to the movements of the oil on the surface and while a fairly significant spillage may occur from a rig 80 km off the coast, there is no certainty that the spillage will cause damage to the sea shore in that vicinity.

Unfortunately, adverse publicity resulted from the oil spillage in Santa Barbara and a chain of fortuitous circumstances may have contributed to the severity of the damage done. However, industry should have been able to provide a better yard stick or base case on which to assess the true damage due to the oil lost.

In Australia we have been fortunate in that the three blow-outs that have occurred which had sufficient magnitude to be a possible source of danger to the environment,

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discharged only gas. Two cases are known from the Marlin Field in the Gippsland Basin, one of which was brought under control after 30 days, although the majority of that time was due to weather conditions hampering the remedial action to be taken. In the northwest of Western Australia the Petrel well was damaged while the semi-submersible rig was drilling a wildcat exploration well. This subsequently caught fire, fortunately with no loss of life and continued to burn at the surface of the sea for over 12 months.

All reasonable precautions are taken to minimise the likelihood of a spillage occurring, but the industry acknowledges that the possibility is present as long as the vital search is maintained.