

An overview of the exploration history and hydrocarbon potential of Cambodia and Laos

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Abstract: The petroleum geology and hydrocarbon potential of both Cambodia and Laos is virtually unknown with Laos being totally frontier, whilst Cambodia has had only three wells drilled.

It is considered that the hydrocarbon potential of the Mesozoic and Cainozoic basins of both Laos and Cambodia, although frontier and high risk, is worthy of further investigation by the industry.

INTRODUCTION

This paper sets out to review the history of exploration as well as the petroleum geology and hydrocarbon potential of both Laos and Cambodia in the light of the paucity of both published information and the lack of exploration data available. It is hoped that this paper will disseminate to the international oil industry the frontier nature of exploration in these countries and provide a basis for further study.

CAMBODIA

Exploration History

Cambodia, both on and offshore, remains essentially unexplored. Cambodia was one of the first countries to claim continental shelf jurisdiction both internally and at international level, when it passed domestic legislation in 1957, and ratified the Continental Shelf Agreement in 1960 (CCOP, 1976).

During the summer of 1958, it was reported that a team of Communist Chinese geologists undertook geological mapping in Central Cambodia. These geological surveys were completed in January 1960. Shortly thereafter, the Royal Cambodian Government began negotiating with the Communist Block for the purchase of drilling equipment (Kaufmann, 1959, 1960). It is believed that Shell International also undertook reconnaissance field mapping.

During the period 1960–62, East European geologists, reportedly from Poland and the Soviet Union, undertook geological field mapping in western Cambodia.

In 1965 the Royal Cambodian Government called for international bids for oil exploration, but none were received. In 1966 petroleum exploration was taken up again, within the framework of bilateral French–Cambodian co-operation, to undertake the compilation of geological maps of areas with petroleum potential. This was done under the direction of the French Bureau de Recherches Géologiques

et Minières and three areas were mapped by geologists of that organisation together with petroleum geologists from the Elf-Erap Société, and Cambodian technicians.

The first exploration phase began in 1970 when the Government granted rights (under the Mining Law of 1968) to 80,000 km² of shelf area to Elf du Cambodge. The terms of the concession called for a 50% relinquishment after 18 months with an initial exploration period of 5 years, with one extension phase of a further two years (Humphrey, 1971). Drilling was to commence within two years, with a minimum of US\$5.5 million financial commitment to be expended during the initial 5-year exploration period. Under the terms of this agreement, the Cambodian Government had a 20% option in the event of a commercial discovery being made. Profits were to be taxed at 50% and Royalties fully credited against taxes. Taxation and Royalties were based upon fully realised prices (Humphrey, 1970).

A refinery at Sihanoukville and a State marketing company (Telakhmer) ensured a market for any discoveries. The French built refinery had an ultimate annual capacity of 600,000 tonnes (4.5 million barrels) and had been operating since 1968 supplying the domestic market.

During 1970 Elf acquired 2,880 line km of seismic using CGG (Tanner and Kennett 1972).

In 1970 the University of London undertook a seismic refraction survey in the vicinity of Poulo Panjang. This survey demonstrated the extension of the onshore Mesozoic basins to the offshore (Dash *et al.*, 1970).

During 1971 Elf drilled one wildcat well, the H-1X well, which reached a total depth of 2,437 m (7,997 ft). The well was rumoured to have encountered oil and gas in its upper section (Fig. 1).

In October 1972, Elf relinquished approximately 50% of its acreage (40,000 km²) and Esso acquired a 35% interest in the retained acreage (39,100 km²). The Government offered the relinquished acreage together with several blocks in a licensing round to the industry at large, but there were few applications by the closing date of December 1972 (Kennett, 1973).

Marine Associates (Hong Kong) Ltd. acquired a 17,000 km² concession on the continental shelf in June 1973 on a block, part of which was originally held by Elf. The block outline is elongate, and forms a frame along the eastern, northern and northwestern boundaries of the Elf/Esso block. Marine Associates acquired 1,992 km of seismic. Some 11,400 km² (63%) of the Marine Associates concession lay in disputed areas (Fig. 1).

In November 1973 Marine Associates farmed out 75% to Canadian Reserve Oil and Gas Ltd. of Calgary, and subsequently additional farmouts were made with the concession equities becoming:

- Canadian Reserve 51.5%
- Marine Associates 25.0%
- Sunlight Oil 23.5%

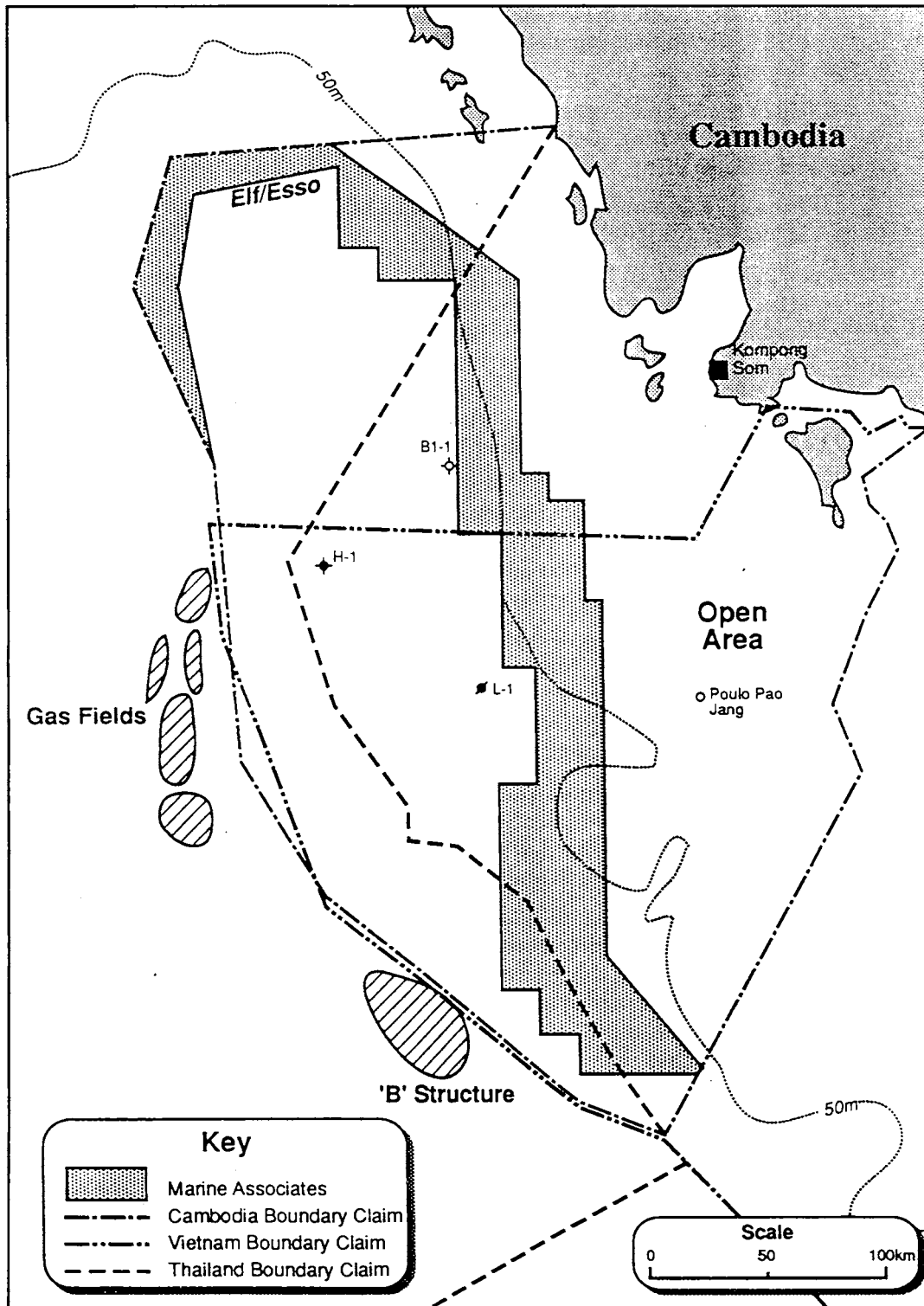


Figure 1: Cambodia – Cambodian Shelf Concessions 1975.

Exploration activity in Cambodia was limited to one offshore seismic survey during 1973 when Elf/Eso completed a 2,159 km marine seismic survey (Bowman, 1974).

In 1974 the Elf/Eso consortium drilled the L-1 well (TD 1,714 m) and the B-1-1 well (TD 1,983 m). Both wells were completed as tight holes, but were rumoured to be dry.

During 1974 Canadian Reserve completed a 1,994 km seismic survey shot by Delta Exploration (Caldwell, 1975).

As of 2 October 1972, the Committee for Co-ordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas (CCOP) had conducted three surveys in the Republic, two of which related to petroleum viz CCOP.1/KHR.2 (seismic and sonic) and CCOP.1/KHR.3 (aeromagnetic). In addition, other surveys by Thailand and the Republic of Vietnam, CCOP and private companies related to the general framework of the Khmer Republic's portion of the Gulf of Thailand. Thus project CCOP.1/IZ.4 (1969) included approximately 200 line km of seismic and magnetic studies in Khmer waters in the Gulf of Thailand (CCOP, 1974).

Following the fall of Phnom Penh to the Khmer Rouge in 1975, the agreement between the Elf-Erap Group and the Cambodian Government lapsed. Thus there has been no reported hydrocarbon activity owing to the unsettled political situation arising from the change in government.

Shortly after the Vietnamese invasion and the deposing of the Khmer Rouge régime, geological research resumed under the auspices of Vietnamese and Soviet geologists with a regional grid of seismic lines being acquired by the Vietnamese with Soviet help. Gas seepages were reported from the Permian limestones in the vicinity of Battambang and along the Mekong river southwest of Kratie.

At the present time, no oil and gas concessions have been awarded in Cambodia. The civil war has essentially precluded the onshore area from award, whilst the offshore area in the Gulf of Thailand (Pattani Trough) is located in a disputed zone between Vietnam and Thailand.

Despite the difficulties, the Cambodian Government hopes to commence offshore exploration for hydrocarbons by involving international oil companies during 1991. It is expected that this exploration will be focussed in the Cambodian sector of the Gulf of Thailand in the acreage previously held by the Elf/Eso Group and Marine Associates. In July 1989, the Cambodian Government passed a Foreign Investment Law aimed at encouraging overseas investment in Cambodia.

Currently Cambodia requires 300,000 tonnes of oil annually, with the Soviet Union providing 220,000 tonnes per year.

It is interesting to note that Petrofina was awarded a seismic option contract covering 27,000 km² in the northern half of the Malay basin in the disputed area claimed by Cambodia and Vietnam. The contract was signed on 9 August between Petrovietnam and Petrofina and is effective for 18 months (to March 1992) after

which a Production Sharing Contract must be signed for an area no larger than 11,000 km².

Hydrocarbon Potential

Mesozoic and Cainozoic basins have been identified both on and offshore (Fig. 2 and 3).

Offshore

The Khmer Shelf is located between the Malay Basin and the coast of Indochina, extending southwards as the Khorat–Natuna Swell. It comprises Palaeozoic igneous, metamorphic and sedimentary rocks unconformably overlain by Mesozoic continental sediments analogous to those of the Khorat Basin, with only a thin discontinuous Tertiary cover. This Mesozoic basin extends onshore (Sawamura and Laming, 1974) as the Cardamome/Elephant Mountains. Three offshore basins can be recognised. These are, from west to east:

- i) the Pattani Trough of Thailand
- ii) the Tertiary Khmer Shelf
- iii) the Panjang basin

The Panjang Mesozoic basin is located to the east of the Tertiary basin where Elf drilled their three exploration wells. These wells were located on the eastern flank of the productive gas and gas condensate producing Pattani Trough which is an extensional basin of Oligocene to Recent age. The Tertiary sediments thin towards the eastern flank of the Pattani Trough.

PATTANI TROUGH

The Pattani Trough is a rift basin and is elongate in a north-south direction. The basin thins to the east towards the Khmer Shelf. It contains up to 8 km of almost entirely non-marine fluvio-deltaic Tertiary to Quaternary sediments and has been established as a prolific gas and gas condensate producing basin (Lian and Bradley, 1986).

Hydrocarbons are entrapped in both structural and stratigraphic plays, with reservoirs being thin, randomly distributed and occurring between 1,200–3,000 m below sea level. At depths greater than these, very high temperatures cause degradation of reservoir properties. The structures are complex, being densely faulted and are often compartmentalised into several gas accumulations. Geothermal gradients from the producing zones of the major Pattani Trough gas fields are very high ranging 4–5.8°C/100 m. Gradients decrease along the flanks of the basin and to the north and may explain the presence of oil rims at shallower depths. The oil and gas window occurs at depths of approximately 1,400–2,100 m and 1,900–2,900 m respectively (Trevena and Clark, 1986; Prakal *et al.*, 1986).

The main north-south gas and gas condensate fairway of the Pattani Trough is not developed in Cambodian waters as its eastern flank thins dramatically to the east against the Khmer Shelf.

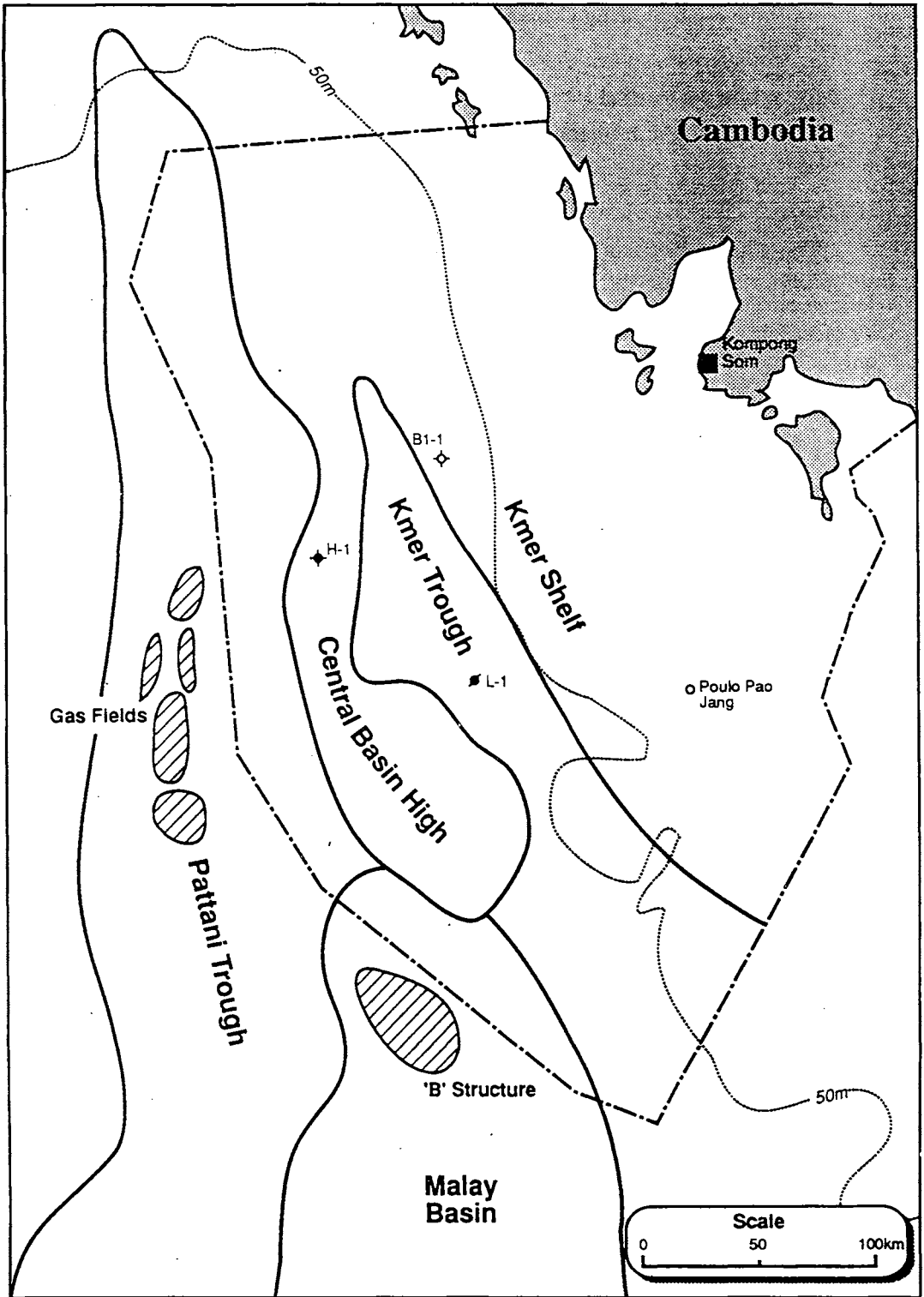


Figure 2: Cambodia – Structural Elements of the Cambodian Offshore (after Stokes, 1990).

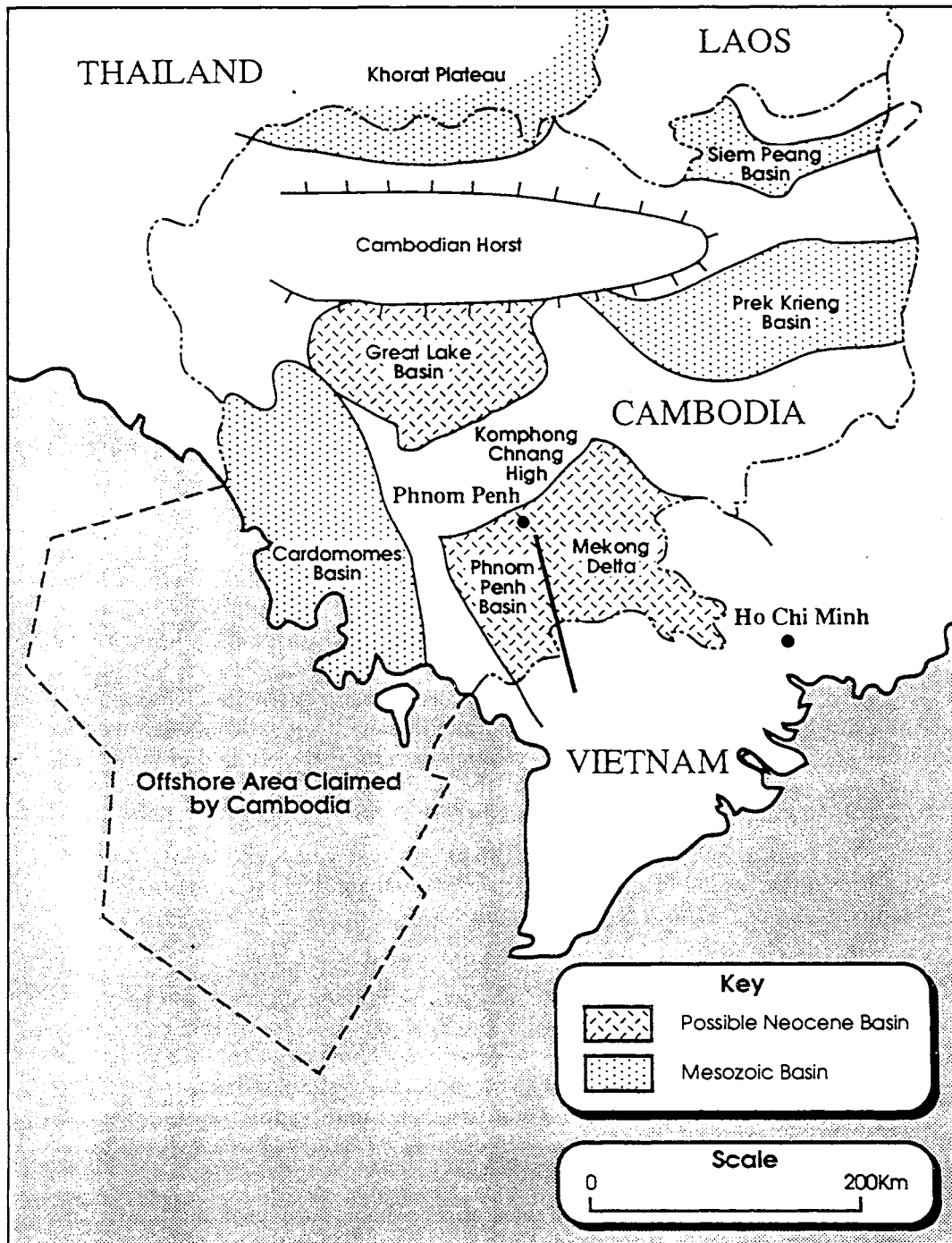


Figure 3: Cambodia – Mesozoic and Possible Neogene Basins (after Stokes, 1990).

TERTIARY KHMER SHELF

This basin is located to the east of the Pattani Trough and is separated from it by the Khmer Ridge. This Tertiary basin trends north-south and was the focus of exploration drilling by the Elf/Eso group. Reservoirs are probably analogous to those in the Pattani Trough and the basin is probably gas-prone.

PANJANG BASIN

The island of Poulo Panjang, located south of Kamphong Son Bay, Kampuchea, comprises sediments of the 'Upper Sandstone' which are regarded as of Jurassic age (Workman, 1977). Nearby islands exhibit outcrops of Palaeozoic sandstone and Permian limestones (Du Bois, 1985).

Seismic refraction profiles in the vicinity of Poulo Panjang suggest the presence of Mesozoic sediments in excess of 3 km thickness underlain by rocks of probable Palaeozoic age which range in thickness from 3 to 4.5 km (Dash *et al.*, 1970, Paul and Liam, 1975). The basin has a geothermal gradient range of 3.4–6°C/100 m. It is probable that the rocks exposed in the islands and disclosed by the seismic surveys are closely related to those which outcrop in the Cardamome Mountains of western Kampuchea.

The rocks of the Cardamome Mountains bear close resemblance to those of the Khorat Basin. The Early or Late Permian is represented by fossiliferous limestones and shales. The limestones bear abundant fusulinids and crinoids. The overlying Liassic/Triassic strata consist of polymict conglomerates, sandstones, mudstones and rhyolitic tuffs. These sediments are in turn overlain by the Phu Kradung and the Phra Wihan Formations of the Khorat Plateau. These include as much as 1,000 m of sandstones with interbeds of conglomerate, shale, sandy shale and marl, and occasional beds of lignite (Du Bois, 1985). Palynological dating has indicated a Lower Cretaceous age for the sediments of the upper part of the section.

The basin is believed to be limited on its east and west flanks by major north-south trending faults. These faults are orientated similarly to those of the Thai basin and, no doubt, have common origin.

To date no hydrocarbons have been discovered in the basin.

The continental nature of the Cretaceous sediments suggests that they may constitute a gas-bearing target below the Tertiary deposits of the Thai/Malay basins. It is also possible that the Permian carbonates constitute an additional target at considerably greater depth (or at moderate to shallow depths where they have been tectonically uplifted). An additional play may be present in those areas where tectonic uplift has been followed by draping of Tertiary source sediments over Mesozoic and Palaeozoic reservoirs.

The main exploration risks of these offshore basins are reservoir quality and productivity in the thin, ratty sands (cf Pattani Trough) and the volume of suitable source rock, which is assessed to be gas prone, particularly in the Tertiary and Panjang basin.

Onshore

The onshore basins of Cambodia (Fig. 3) have been poorly documented and, consequently, very little is known of their petroleum geology. The basins are:

- i. Cardomomes/Elephant Mountains
- ii. Central basins (Phnom Penh and Tonle Sap /Great Lakes)
- iii. Mekong basin
- iv. Eastern basins (Prek Krieng and Siem Peang)

The basins in east Cambodia probably have an affinity with those in Vietnam (such as Dalat, Mekong and Nambo) (ESCAP, 1986) (Fig. 3).

The onshore sector of the Mekong Delta basin has a Quaternary cover, but some basement outcrops occur. The presence of a sedimentary basin beneath the Quaternary has not been established. Fontaine and Workman (1978) predicted the existence of a buried northwest trending fault between Ho Chi Minh City and Phnom Penh and Tonle Sap Lake, and hence the development of a graben of aulocogenic origin may be postulated. Such structures are known to contain prolific oil and gas accumulations in the Gulf of Suez, Sirte Basin (Libya) and Cambay Basin (India). LANDSAT imagery of the area (Hayashi, 1988) illustrates the presence of many circular anomalies representing tonal anomalies: there is a high correlation between tonal anomalies and hydrocarbon occurrence (Halbouty, 1976, 1980). It is probable that small Tertiary intermontane basins, analogous to those in central Thailand, may be developed in the Tonle Sap basin.

The Mesozoic basins of eastern Cambodia (Dalat) have a basin fill of terrigenous and volcanogenic rocks ranging in age from Palaeozoic to Cretaceous. The Mesozoic cover reaches a thickness of 3 km. Potential reservoirs would be basal conglomerates and calcareous sandstones of Lower Jurassic age with marls and claystones as potential source rocks and seal.

The basins of southwest Cambodia (Nambo?) are essentially extensional rift basins with a sedimentary fill of approximately 3 km (Upper Carboniferous to Cainozoic in age). The lithology of the basin fill comprises limestones, calcarenites, tuffaceous sandstones with interbedded shales and tuffs, which provide source and seal respectively (ESCAP, 1986).

The main exploration risk in these Tertiary and Mesozoic basins is the development and volume of potential source and reservoir rocks and reservoir productivity.

LAOS

Exploration History

The first oil show reported from Laos was recorded by Bourret and Hoffet in 1935 from the Mesozoic Savannakhet basin. The French Société Financière pour la France et les Pays d'Outre Mer (SOFFO), was considering exploration for hydrocarbons in the Savannakhet and Vientiane basins during 1958, with initial exploration activity scheduled to commence during 1959 (Kaufmann, 1958, 1959).

However, the acreage was subsequently relinquished without any exploration activity having taken place as a result of Communist anti-Government activity.

In 1959 two permits, one near Vientiane and the other in the Savannakhet basin of southern Laos, were granted to Société des Études et d' Exploitation Minières de l'Indochine (SEEMI). Both of these areas are adjacent to the Thai–Laos border (Kaufmann, 1959). Work was limited to the Savannakhet basin permit, where occurrences of oil had been encountered in a sandstone quarry, 140 km from Savannakhet towards Tchepone. A sand with an asphalt matrix gave 4 cm³ oil per kilogramme of rock (40 l/tonne) on distillation. SEEMI drilled 5 coreholes, the deepest at 147 m (482 ft). Several thin beds of oil impregnated sandstone were encountered. Exploration was later suspended and, in 1960, SEEMI relinquished the permits.

A French consortium 90% capitalised by SEEMI, LAOREP, was formed in 1974 to reinitiate exploration but, with the rise of Communist activity, lapsed in 1975.

Thus since 1960 there has been no reported hydrocarbon exploration activity within Laos. However, in 1971 the Meridian Oil Company acquired a 4,740 km² concession on the south-eastern quadrant of the Khorat Plateau in Thailand, adjacent to the Laotian border. No exploration activity was undertaken and Meridian relinquished in 1981 (Fletcher, 1981).

Over the period 1967–73 a photogeological reconnaissance map of northern Laos was produced at a scale of 1:250,000 by the overseas division of the Institute of Geological Sciences of Great Britain in collaboration with the Laotian Bureau of Mines. The Lao People's Democratic Republic founded the Department of Geology and Mines which, from its inception in 1985, has undertaken detailed mapping at various scales using aerial photographs, satellite imagery and geological field survey. No geophysical maps (gravity/magnetics) are thought to have been compiled.

During 1984 a 465 km crude oil pipeline linking Vientiane to the Vietnamese port of Da Nang was completed through the joint efforts of Laos, Vietnam and the USSR. An oil storage facility was also constructed by the USSR in Vientiane.

To facilitate the involvement of international oil companies in the search for hydrocarbons in Laos, the Laotian Government passed the Foreign Investment Law in July 1988.

In 1989, the Laotian Government actively began discussing acreage awards with four international oil companies. Dr. Soulivong Daravong, Minister for Industry and Handicraft, headed these negotiations despite Laos having no oil and gas legislation. Any awards were to be based upon the Laotian Foreign Investment Law which took effect on 25 July 1988.

Following these negotiations, Enterprise Oil plc announced that it had signed a PSC with the Government of the People's Democratic Republic of Laos on 13 September 1989 (Fig. 4). The PSC gives Enterprise Oil plc (70%), and its partner Compagnie Européenne des Pétroles (30%), exclusive exploration rights over a

frontier area of 20,200 sq km in the Savannakhet basin of Central Laos. The exploration period of the licence is 8 years (with the operator having the right to relinquish the acreage after each successive exploration phase without committing to a well) and, during 1989/90, geological field surveys, an aeromagnetic survey (11,100 km) and gravity surveys (950 km) were undertaken. The results are currently being evaluated. Initial conclusions are that the Savannakhet basin geology compares favourably with that of the adjacent Khorat Plateau area of Thailand, where significant hydrocarbon discoveries have been made. Preliminary work indicates the Savannakhet basin has thick potentially prospective Palaeozoic and Mesozoic sediments, and structural geology studies justify early conclusions that possibilities for trapping commercial quantities of hydrocarbons are good.

On 23 February 1990, after two years of negotiations, Laos Hunt Oil Company signed a PSC agreement on a 26,000 km² concession in the Saravane–Pakse basin of Southern Laos immediately to the south of the Enterprise acreage (Fig. 4). This agreement allows for an initial 2-year exploration term with options for four additional 2-year terms. Laos Hunt Oil Company will conduct geological and geophysical surveys in the first two years of operations and acquire at least 500 km of seismic during the second two year period. Initial geological fieldwork was completed in May 1990 and surface samples are currently being analysed. Exploration wells will be drilled to maintain the contract beyond the fourth year (1992–94).

The PSC agreement is being administered by the Lao Ministry of Industry and Handicraft on behalf of the Government.

The Laotian Government is expected to offer additional acreage for licence award in the Vientiane basin in the northwest part of the country in the near future. It is understood from the Laotians that Petrocorp of New Zealand is nearing the finalisation of negotiations for acreage in the vicinity of Vientiane. The Vientiane basin is the southeast-plunging extension of the Sakhon–Nakhon basin of northeast Thailand. The Vientiane basin has, reportedly, gas seepages which were discussed at the 1986 Indo-China Symposium in Hanoi (Bosaykhan, 1986).

Hydrocarbon Potential

Two phases of basin development can be recognised in Laos (Fig. 5):

- Continental Mesozoic basins
- Neogene basins

Continental Mesozoic basins

The five major Mesozoic continental basins are:

- i. Vientiane basin of northwest Laos
- ii. Sakhon–Nakhon basin of central Laos
- iii. Nam Theun basin of central Laos
- iv. Savannakhet basin of central Laos
- v. Saravane–Attopeu basin in southern Laos

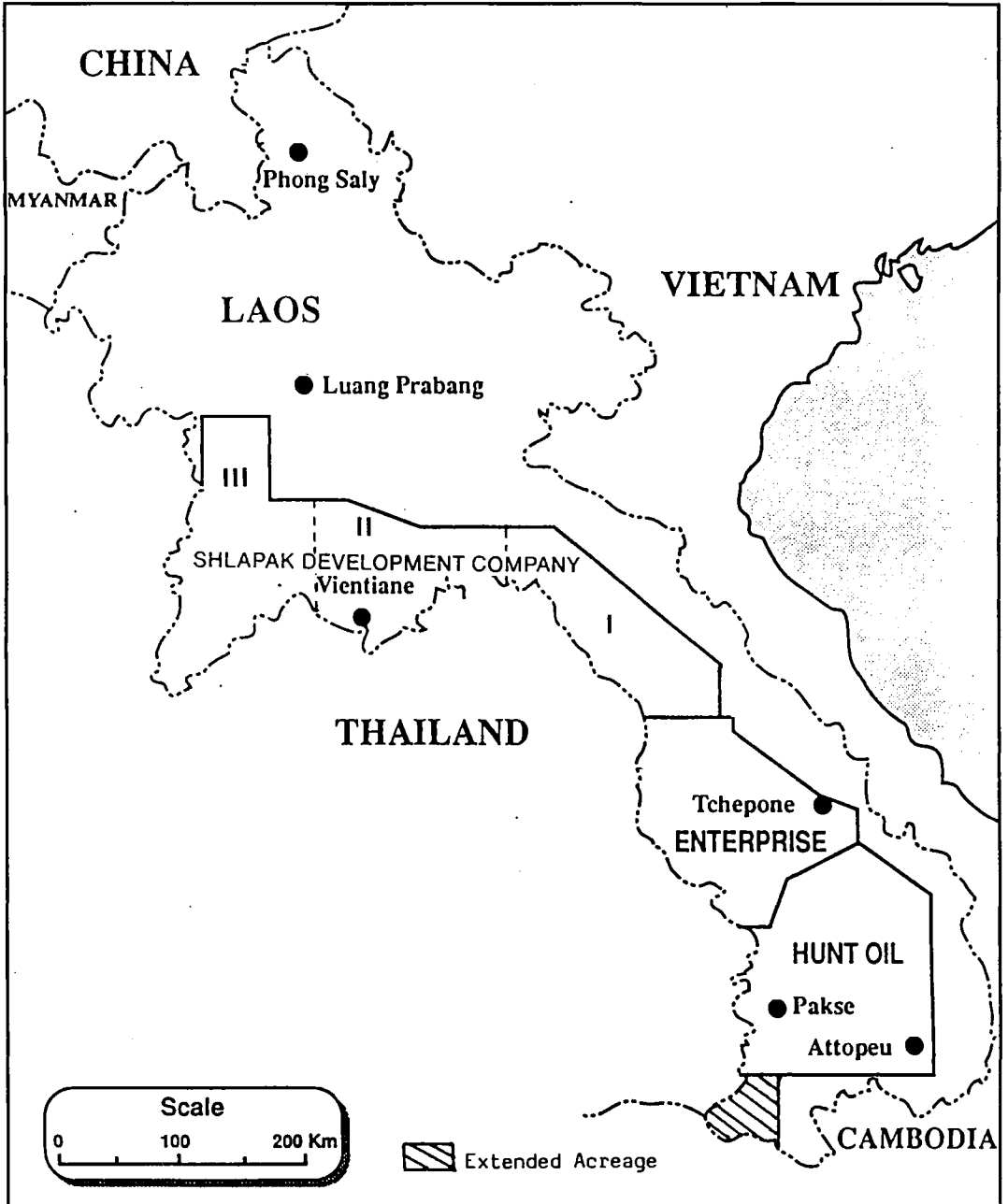


Figure 4: Laos – Basin Concessions

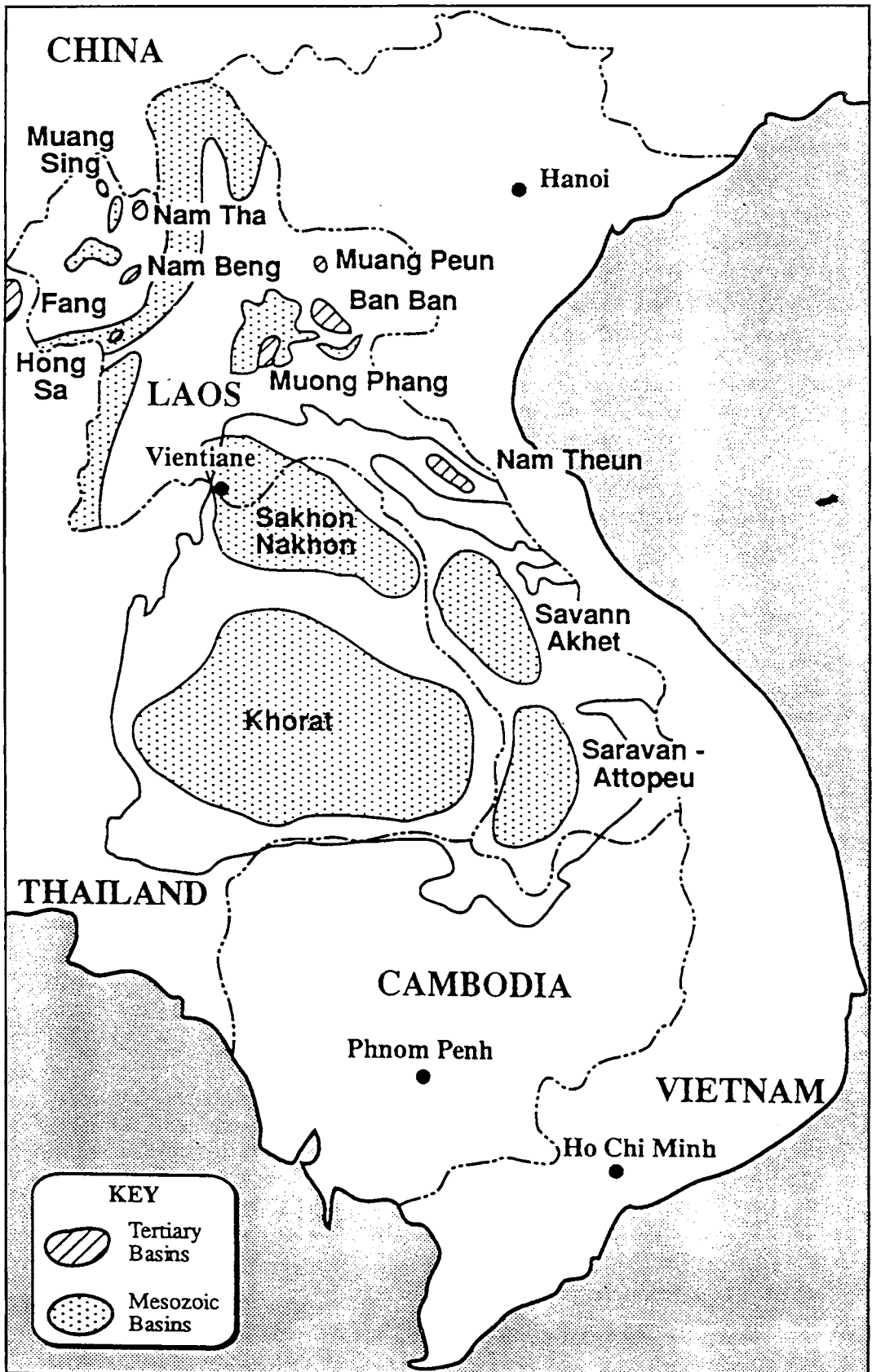


Figure 5: Laos – Sedimentary Basins

Very little is known about the stratigraphy or petroleum geology of these basins. These basins are regarded as analogous to the Khorat Basins of Thailand, where gaseous hydrocarbons have been discovered by Esso (Nam Phong).

The Triassic basins in northeast Thailand and, by analogy, the Laos basins, developed as a series of major half grabens, probably controlled in orientation by the pre-existing Indosinian structural grain and by the facies distribution of the underlying Permian sediments.

The northwest-southeast structural trends of large folds in the central Khorat Plateau conform with structural trends in eastern Laos and Vietnam which parallel the Red River Trough and the margin of the South China Sea. Northeasterly orientated structural trends of the western Khorat Plateau relate to the margins of the Indochina and Eurasian plates. In both areas, tectonism was probably initiated in early Triassic time and accentuated during the Late Cretaceous. Evidently, during the period Late Triassic to Late Cretaceous, the Khorat Plateau was a low lying, stable area that was gradually subsiding and receiving fluvial deposits (Japakasetr and Workman, 1981).

The upper part of the Khorat Group contains thick evaporites (Ramingwong, 1978). This evaporite-bearing Cretaceous formation occurs in two structural basins in Thailand. The Khorat and Sakhon-Nakhon Basins are separated by a belt of pronounced anticlinal folding on WNW-ESE axes, bringing the underlying Triassic-Jurassic sandstones of the Lower and Middle Khorat to the surface (the Phu Phan anticlinorium). Along the western, southern and eastern periphery of the Khorat Basin, the red beds of the Khok Kruat formation and the underlying quartzites of the Middle Khorat dip gently inward toward the basin. The same applies around the Sakhon-Nakhon Basin except that the northeast margin of this basin is probably fault bounded.

In places along the southern and northern margins of the Sakhon-Nakhon Basin, and to a lesser extent along the northwestern margin of the Khorat Basin, plunging anticlinal folds in the underlying Middle Khorat quartzites can be traced toward basins, but there is no evidence that any of these folds affects the Maha Sarakham Formation.

However, generalised comment can be made on the hydrocarbon potential of the Laos Mesozoic basins. The stratigraphy of these basins in general terms comprises sandstones, shales and evaporites of Mid to Late Cretaceous to Palaeocene age.

Triassic lacustrine shales and coals are considered potential source rocks. These lacustrine sediments may be overlain by a sequence of continental Mesozoic clastics (sandstones and conglomerates) and carbonates which would constitute potential reservoir rocks, with seal provided by intraformational shales and evaporites. Potential trapping mechanisms would be both structural (as the result of post-Indosinian folding of Permo-Jurassic age) and stratigraphic.

Hydrocarbon generation is manifest by the live, non-biodegraded oil seeps that have been reported in the Savannakhet area.

The distribution of marine Liassic shales and associated evaporites is limited to southern Laos. Their development and areal distribution is considered critical as they will provide the potential source rock and regional seal respectively.

Fontaine *et al.* (1983) discussed the distribution of marine Jurassic in Laos where they recognised a large basin with hydrocarbon potential in southern Laos which straddles the border with Cambodia and Vietnam. This would appear to be the Saravane–Attopeu basin which has a fill of clastic sediments, mainly shales, sandstones and a few thin carbonate intercalations. Subsidence was slow and the environment of deposition was shallow marine. Consequently, large areas became emergent or flooded by small changes in sea level resulting in marine/continental intercalations. The basin extended along faults trending in a north-south direction and attained great sediment thicknesses.

Neogene basins

The Neogene basins of northwestern Laos are underexplored (Fig. 5).

The Upper Tertiary intermontane basins of Northern Laos are analogous to the Tertiary intermontane basins of Northern Thailand, that is; Mae Sai, Chiang Saen and the Yao, which extend across the border into northern Laos. In northern Thailand the Fang basin is productive, although accumulations are small. The characteristic lacustrine-derived crude oil from the Thai basins ranges from paraffinic to asphaltic base. This difference is due to biochemical and physiochemical degradation during secondary migration.

Permo-Carboniferous shales are also considered potential source rocks, as are Tertiary coals (cf Mae Sot basin of northwest Thailand) (Fontaine *et al.*, 1986).

The Fang Basin has a geothermal gradient of 7.2–9.3°C/100 m. The main source rock generating kitchen area would appear to be the central sub-basin, which has probably acted as the source area for the three known fields. The oil window in the Fang Basin would appear to be between 1,100–1,400 m, hydrocarbons being generated from Late Miocene onwards.

Hydrocarbon accumulations are present in stacked sequences of synrift sediments with deposition and preservation controlled by multi-directional intersecting fault systems. Both intracrustal and supracrustal fault development have important consequences in that they may control the maturation, migration and entrapment of hydrocarbons and probably also the reserve distribution.

The Thai basins which straddle the boundary with Laos are reviewed below:

The Chiang Rai and Phayao Basins are intermontane basins located in northernmost Northern Thailand. Geological mapping indicates the area to comprise Mesozoic continental sediments which have undergone moderate deformation. These are underlain by highly deformed Permo-Triassic sediments which are flanked by Palaeozoic sediments and granites with igneous intrusions. The Mesozoic is covered by Quaternary sands and gravels. The basins are separated by saddles, the remnants of eroded anticlines.

Other sub-basins in the area are Chiang Saen and the Yao, which straddle the Thai/Laotian border, the latter being a thin sinuous basin with a northeast-southwest trend. These basins are unexplored and therefore frontier in terms of exploration activity.

Prospectivity of Laotian basins

The basins and sub-basins mentioned above represent rank frontier acreage. The only well having unsuccessfully tested the Mae Sai Basin in Thailand, no geophysical exploration has been undertaken in the majority of the basins. However, present information would indicate that the basins have a thin, or non-existent, Tertiary cover and that any prospectivity lies within the Mesozoic and deeper Palaeozoic sequence.

The Mesozoic in Northern Thailand is continental in terms of depositional facies. The major exploration risk are adequate source rocks and the sufficient maturation and migration of hydrocarbons.

Thus the prospectivity of the Laotian basins (particularly the Savannakhet, Sakhon-Nakhon and Vientiane) as postulated analogues to the Khorat Plateau basins of Thailand, lies in the Mesozoic and Palaeozoic. The main objectives are carbonate reservoirs and Triassic clastics. Both objectives necessitate deep drilling below 10,000 ft. The presence of lignite associated with continental and/or near shore sequences of clastics makes gas the most likely hydrocarbon to be encountered, as exemplified by the Namphong Field. The marine limestones of the Rat Buri Group, or their equivalents, constitute additional prospects at depth which may be oil bearing (although producibility from limestones is dependent upon fracture geometry and/or the development and enhancement of poroperm from diagenetic processes).

The Triassic pre-Khorat sediments (i.e. the lacustrine shales and limestones) demonstrate good potential as source rocks. Good reservoir potential is evident in fluvio-lacustrine sheet and shoe-string sands. The basal conglomerates also demonstrate reservoir potential, particularly when associated with fractures. The sandstones of the Lower Khorat sequence, or their equivalents in Laos, may also provide additional reservoirs where better poroperms are developed (i.e. 10-30% porosity).

These reservoirs may be sealed in roll-over anticlines and fault-bounded or stratigraphic pinchout traps. Permian carbonates may also provide potential traps (i.e. buried hill-type plays).

CONCLUSIONS

On the Cambodian Shelf, the Mesozoic section of the Panjang Basin, in both its off and onshore (Cardamome) development, has, to date, not been tested and remains high risk.

The petroleum geology of Cambodia is unknown with only three wells having been drilled in the offshore Panjang Basin in the Gulf of Thailand. These appear

to have been Tertiary tests located on the flanks of the Pattani Trough and the Mesozoic section is, therefore, untested. Hydrocarbons could conceivably have migrated from the deeper Tertiary basins located to the west of the Cambodian Shelf.

As far as is known, no onshore exploration has been undertaken in the onshore basins of eastern and central Laos which thus remain rank frontier areas.

The Laotian basins represent rank frontier acreage, with little or no published information available. Any indications regarding their hydrocarbon potential must be drawn by analogy with the Khorat Basins. Esso's exploration campaign in the Thai sector of the Nakhon-Sakhon Basin has not been commercially successful to date.

Both Laos and Cambodia offer the international oil industry a rare opportunity to acquire acreage in which rank frontier exploration may be undertaken (Figs 6 & 7). Both countries are surrounded by proven hydrocarbon provinces, with Thailand to the west, Vietnam to the east and the prolific Malay and Natuna basins to the south and southeast respectively.

It is considered that the hydrocarbon potential of the Mesozoic and Cainozoic basins of both Laos and Cambodia, although frontier and high risk, is why worthy of further investigation by the industry.

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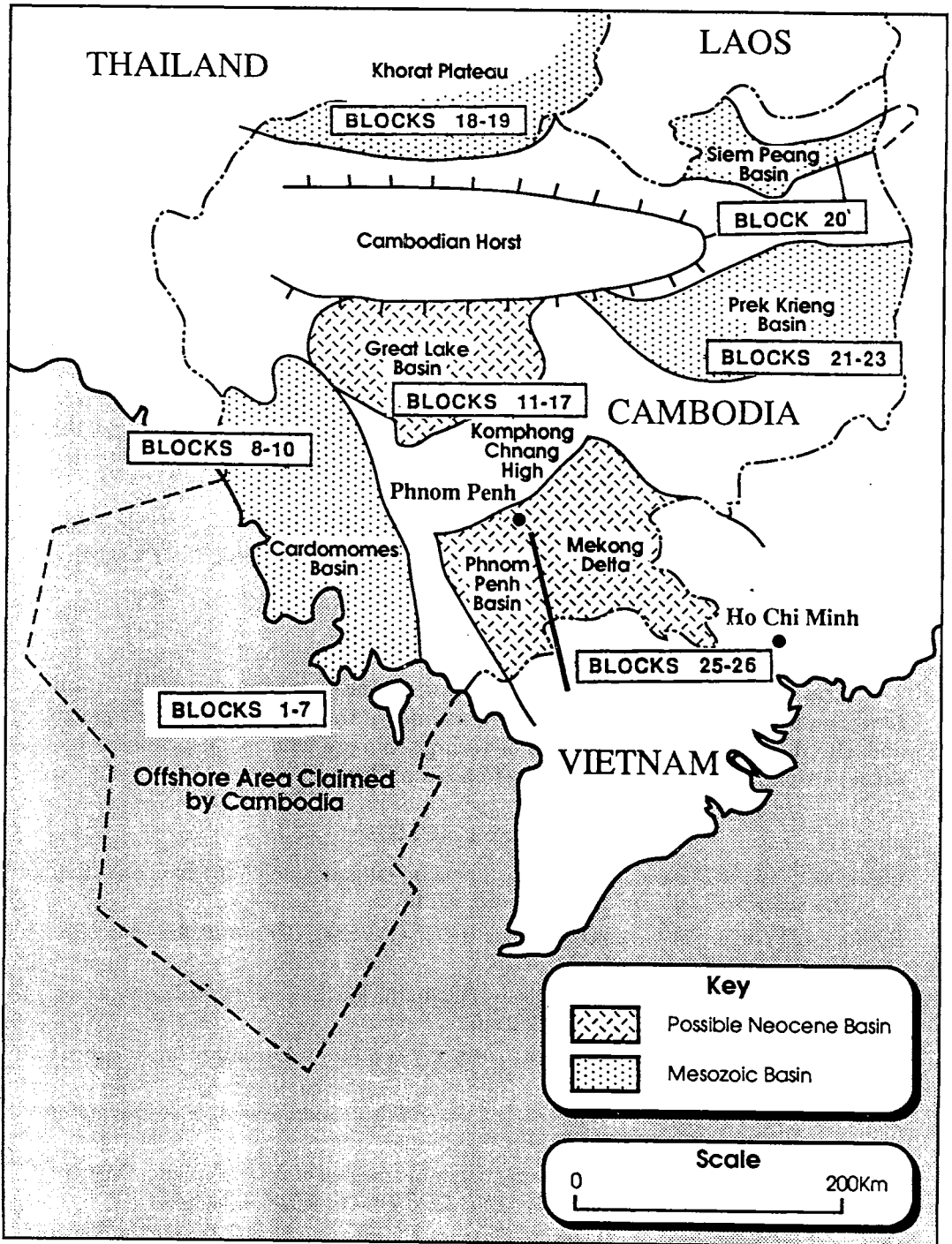


Figure 6: Cambodia – Onshore and Offshore Basins Showing Blocks for Competitive Bidding in First and Second Licensing Rounds.

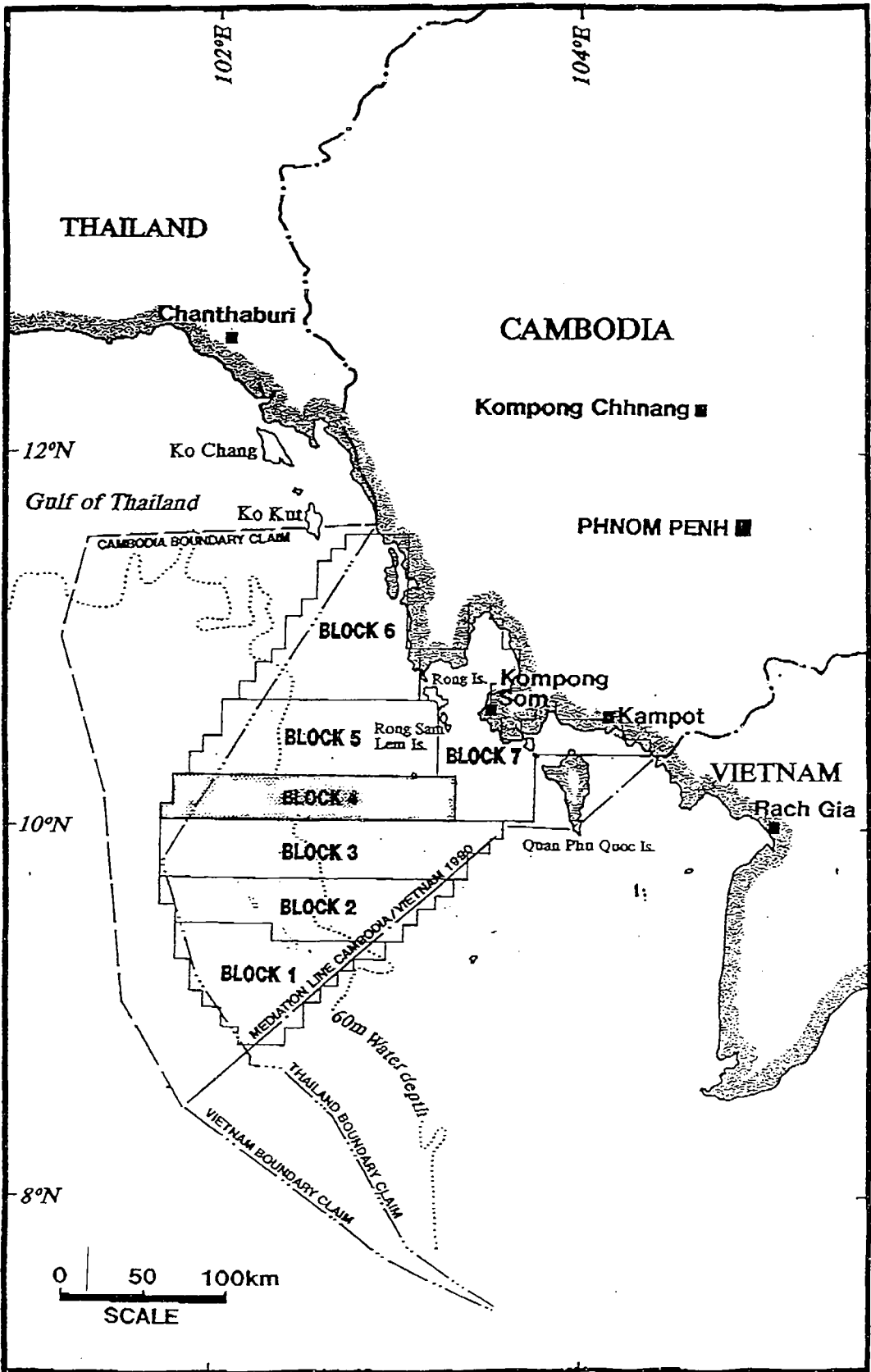


Figure 7: Cambodia – Cambodian Shelf Showing Blocks for Competitive Bidding in First and Second Licensing Rounds.

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