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PETROLEUM POTENTIAL OF THE CAUVERY BASIN, SRI LANKA: A REVIEW

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ABSTRACT

The Cauvery Basin is located between the southeastern region of India and the north and the northwestern region of Sri Lanka. It is a pericretonic rift basin evolved due to the crustal extension between the Indo-Lanka landmasses. The rifting has given rise to northeast-southwest trending horst/ basement ridges subdividing the basin into four distinct sub basins/depressions. The Pesalai-Palk Bay depression and a part of the Ramnad-Palk Bay-Nagapattinam depression, separated by the Mandapam-Delft ridge, constitute the Sri Lankan sector of the Cauvery Basin. The Indian sector of the basin is producing both oil and natural gas. Six exploration wells drilled in the Sri Lankan sector of the Cauvery Basin during 1972-1981 was dry. Little further exploration has taken place in the Sri Lankan sector of the Cauvery Basin since 1981. In 2011, three exploration wells were drilled in the Mannar Basin, which is located immediately south of the Cauvery Basin, and discovered natural gas in two wells. These maiden hydrocarbon discoveries in Sri Lanka confirmed the occurrence of an active petroleum system in the Mannar Basin. The resumption of hydrocarbon exploration in the Sri Lankan sector of the Cauvery Basin has been taken into consideration since the maiden hydrocarbon discovery. However, the petroleum potential of the Sri Lankan sector of the Cauvery Basin is little known. The objective of this study was to evaluate the petroleum potential of the Cauvery Basin under the Sri Lankan jurisdiction based on a limited dataset, which include seismic, lithostraigraphy and biostratigraphy data and Rock Eval Pyrolysis, maceral composition analysis, total organic carbon and vitrinite reflectance data.

The results of the study show that the stratigraphic thickness in the Sri Lankan sector of the Cauvery Basin is smaller compared that in the Mannar Basin. In the Sri Lankan sector, the potential hydrocarbon source could be Albian and older claystones, the Late Cretaceous sandstone, and Paleogene carbonate rocks could be the potential hydrocarbon plays, and Faults, anticlines, channel fills, and stratigraphic pinch outs could act as hydrocarbon traps. There is a possibility that an active petroleum system exists in the Sri Lankan sector of the Cauvery Basin. One of the reasons for not finding hydrocarbon deposits during 1972-1981 exploratory drilling could be due to the location of most wells on structural highs. The lack of understanding of the stratigraphic thickness, thermal and burial history, and hydrocarbon entrapment amidst tectonic activities that lead to larger hiatuses have to be clearly understood to reduce the exploration risk in the Sri Lankan sector of the Cauvery Basin.

Key words: *Sri Lanka, India, Cauvery Basin, Pesalai, Palk Bay, Petroleum system*

INTRODUCTION

The Cauvery Basin, located between the southeastern region of India and the northwestern area of Sri Lanka (Fig. 1), is a pericretonic rift basin (Sastri *et al*., 1973; 1981). Studies on the Indian sector of the Cauvery Basin (eg. Sastri, 1973; 1981; Chandra *et al*., 1991; Ram Babu and Lakshmi, 2004) show that NE-SW trending basement ridges divide the basin into several distinct sub basins/depressions. They are named, Ariyalur-Pondicherry, Thanjavur-Tranquebar, Ramnad-Palk-Bay-Nagapattinam depressions (Fig. 1). The seismic data acquired in the northwestern offshore area of Sri Lanka show the structural feature to continue into the Sri Lankan sector. Most of the northwestern offshore area of Sri Lanka comes under the Pesalai-Palk-Bay depression, which is bounded to the North and NW by the Mandapam-Delft ridge, to the South by the Mannar Island and *Rama Setu* and to the

East by the northwestern coastal belt of Sri Lanka (Fig. 1). The North and northwestern offshore area of Sri Lanka lies in 10-200 m. water depths. The Sri Lankan sector of the Cauvery Basin consists of the Pesalai-Palk Bay depression, Mandapam-Delft ridge and a smaller part of the Ramnad-Palk Bay-Nagapattinam depression. The Indian sector of the Cauvery Basin, occupy an area of about 25,000 km^2 in the southeastern onshore part of the Indian peninsula and another 35,000 km^2 in the southeastern offshore area under the Indian jurisdiction (Kumar, 1983). The Sri Lankan sector of the Cauvery Basin extends over 15,000 km^2 in the northeastern onshore and offshore areas of Sri Lankan. Many studies on the Indian sector of Cauvery Basin (eg. Murthy *et al*., 2008; Rana *et al*., 2008; Rao, *et al*., 2010) have considered the Gulf of Mannar as a sub basin of the Cauvery Basin due some similarities in their formation, evolution and the tectonic history. However, the two basins have some differences such as the occurrence of basement ridges in the Cauvery Basin and their absence in the Mannar Basin; the occurrence of thick igneous rocks interbedded with the Late Cretaceous sediments all over the Mannar Basin and their absence in the Cauvery Basin. Therefore, many studies carried out of the Sri Lankan sector of the Gulf of Mannar (eg. Baillie *et al*., 2003; 2004; De Silva, 2006; Premarathne *et al*., 2013; 2014; 2015) have referred it to as a discreet basin called the Mannar Basin. Therefore, this study considers the Sri Lankan sector of the Cauvery Basin separately from the Mannar Basin.

Six hydrocarbon exploration wells were drilled in the Sri Lankan sector of the Cauvery Basin during 1974-1981. First three wells located in the Pesalai area on the Mannar Island, are named as Pesalai 1, 2 and 3 (Fig. 1). Other wells located in the NW offshore areas are Palk Bay-1 and Delft-1 drilled in 1976, and Pedro-1 drilled in 1981. The Delft-1, Palk Bay-1, and Perdro-1 wells are located on basement ridges/ structural highs (Fig. 1). None of these wells penetrated any economically viable hydrocarbon deposit. Little further hydrocarbon exploration took place in Sri Lanka during 1984-2001.

Thomlinson Geophysical Services Limited (TGS) resumed the hydrocarbon exploration in the Mannar Basin by undertaking a two-dimensional (2D) marine seismic survey in 2001. In 2011, Cairn Lanka Private Limited, drilled three exploration wells in an exploration

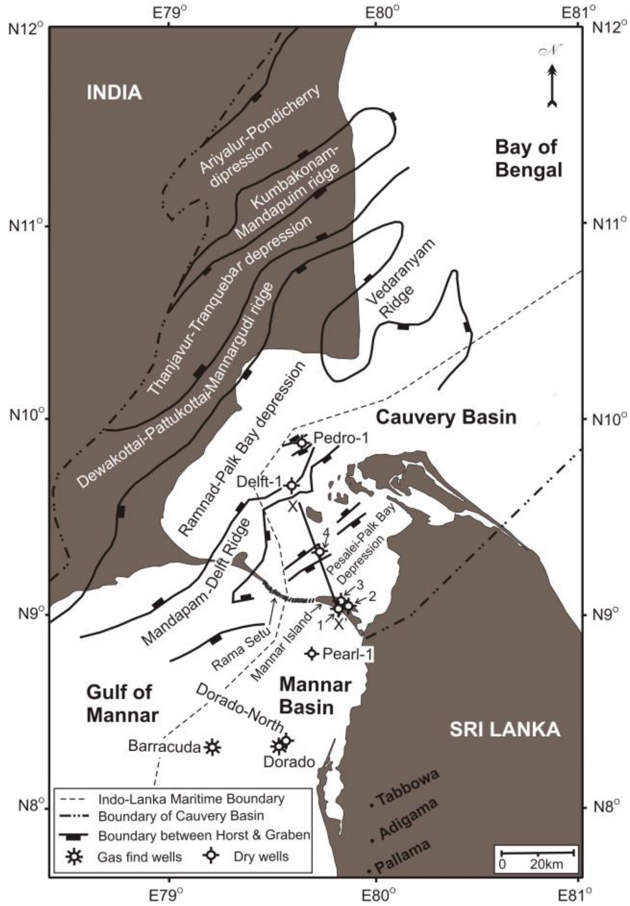

Fig. 1 Extent of the Cauvery Basin and its structural elements. The structural elements in the Indian sector of the Cauvery basin are based on Chandra et al. (1991), while those in the Sri Lankan sector are based on an unpublished basement isopach map held at the Petroleum Resources Development Secretariat (PRDS) in Sri Lanka. The exploration wells drilled in the Sri Lankan sector of the Cauvery and Mannar Basins are also shown. The locations of wells in the Mannar Basin are based on Premarathne et al. (2013). Numbers 1, 2, 3 and 4 in the figure refer to the Pesalai-1, 2, 3, and Palk Bay-1 wells, respectively.

block located in the northern part of the Mannar Basin and discovered natural gas in two wells named Dorado and Barracuda (Premarathne *et al*., 2013; 2014; 2015; Fig. 1). This is the maiden hydrocarbon discovery in Sri Lanka and in the Gulf of Mannar. The discoveries proved the existence of an active petroleum system in the Gulf of Mannar (Mahapatra *et al*., 2012; Premarathne *et al*., 2013). The resumption of hydrocarbon exploration in the Sri Lankan sector of the Cauvery Basin has been taken into consideration since the maiden hydrocarbon discovery in Sri Lanka. The Indian sector of the

Cauvery Basin, in which hydrocarbon exploration began in 1958, is now producing both oil and natural gas (Singh, 2002). The PH-9-1 well, drilled in the Ramnad-Palk-Bay-Nagapattinam depression about 21 km west of the Indo-Lanka maritime boundary (Ramana *et al.*, 1995), is the hydrocarbon discovery in India closest to Sri Lanka. About 26 small and medium sized oil and gas fields have been discovered in the Indian sector of the Cauvery Basin (Ram Babu and Lakshmi, 2004). The northern part of the Ramnad-Palk Bay-Nagapattinam depression is considered the main fair way of oil and gas finds in the Cauvery Basin (Anandan *et al.*, 2004). The petroleum system of the Indian sector of the Cauvery Basin is well known (e.g. Vasudevan *et al.*, 2008; Chaudhuri *et al.*, 2010; Phaye *et al.*, 2011). On the contrary, the Sri Lankan sector of the Cauvery Basin remains relatively poorly understood with only a handful of studies (eg. Cantwell *et al.*, 1978; Premarathne, 2008). The objective of this study is to review the petroleum prospectivity of the Sri Lankan sector of the Cauvery Basin based on a limited data set from previously drilled exploration wells.

TECTONIC HISTORY

Fragmentation of East Gondwana (Fig. 2) has given rise to the Cauvery Basin and other Mesozoic rift basins such as the Krishna-Godavari, Mahanadi, and Bengal basins in the east coast of India (Katz, 1978; Sastri *et al.*, 1981; Lal *et al.*, 2009). The separation of Gondwana into east and west sections (Fig. 2) initiated in the Middle Jurassic around 167 Ma (Reeves *et al.*, 2002). Further separation of the East section Gondwana commenced with the onset of southward moment of Antarctica in the early Cretaceous around 130 Ma (Katz, 1978; Subrahmanyam and Chad, 2006; Lal *et al.*, 2009). This event was followed by the northward movement of India, Madagascar, Sri Lanka, and Seashells as a single landmass (Torsvik *et al.*, 2002). Some palaeomagnetic measurements on core samples from the Pesalai wells, which are currently located at 8^o North latitude, indicate their location at 16^o South latitude in the early Cretaceous (Cantwell *et al.*, 1978). The onset of rifting of Sri Lanka from India and the formation of the NE-SW trending basement ridges in the Cauvery Basin are synchronous with the separation of Antarctica from India (Lal *et al.*, 2009). Chari *et al.* (1995) suggests that the separation of the Indo-Lanka

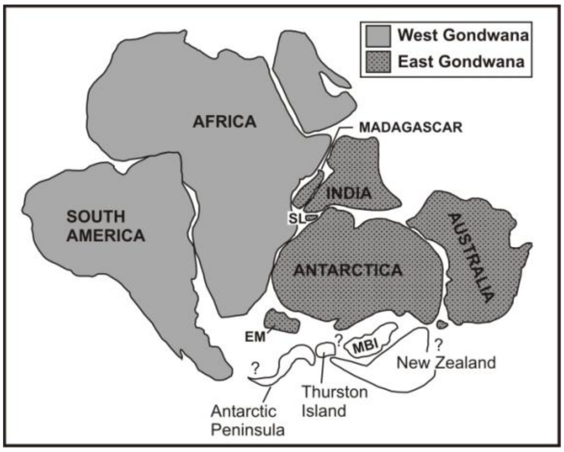

Fig. 2 Gondwana assembly reconstruction (modified after Grunow et al., 1996). Western and eastern Gondwana division is based on Porada, (1989). EM =Ellsworth-Whitmore Mountains; MBI= Marie Byrd Island; SL = Sri Lanka

landmasses initiated along a pre-existing older Precambrian lineament (Proto Boundary Fault). Thomson (1976) suggests that Sri Lanka's separation from India might be similar in fashion to Madagascar's separation from Africa. Paleogeographic reconstructions of Sri Lanka and India in Gondwana (eg. Katz, 1978; Yoshida, *et al.*, 1992; Dissanayake and Chandrajith, 2011; Fig. 3) suggest that the separation of the Indo-Lanka landmasses should have occurred as part of Sri Lanka's counter clockwise rotation with respect to India. Sri Lanka's counter clockwise rotation, probably acting the northern part of the island as a pivot, could be thought to have created a smaller crustal extension in the northwestern offshore area of Sri Lanka than that towards the southern part of the Gulf of Mannar. This hypothesis is supported by the higher stratigraphic thickness in the Gulf of Mannar (eg. Rao *et al.*, 2010; Rana *et al.*, 2008; Premarathne *et al.*, 2013; 2015) than that in the Pesalai-Palk Bay depression (e.g. Cantwell *et al.*, 1978; Sastri *et al.*, 1981) and in the Ramnad-Palk Bay-Nagapattinam depression (e.g. Ramana *et al.*, 1995). In addition, the counter clockwise rotation of Sri Lanka has brought about the Cretaceous marine entry into the Gulf of Mannar earlier than similar events in the Palk-Bay area (Cantwell *et al.*, 1978). The anticlockwise rotation of India and Sri Lanka continued until about 96 Ma (Chari *et al.*, 1995).

Rifting in the Ramnad-Palk Bay-Nagapattinam sub basin has stopped around 70 Ma and in the Ariyalur-Pondicherry and Thanjavur-Tranquebar sub basins around 84 Ma (Chari *et*

Fig. 3 Juxtaposition of Sri Lanka, Madagascar, and India in Gondwana as suggested by Dissanayake and Chandrajith, (1999)

al., 1995). Rifting in the northern part of the Mannar basin has stopped around 66 Ma (Chari *et al*., 1995; Baillie *et al*., 2003; Premarathne *et al*., 2015). Baillie *et al*. (2003) reported that the Mannar Basin has undergone at least two phases of rifting first with the separation of Antarctica from India and the second phase with the detachment of Madagascar from India, which Lawver *et al*., (1992) thought to have occurred around 90 and Storey, (1995); Storey *et al*., (1995) around 88 Ma. Since the tectonic history of the Mannar and Cauvery Basins are closely, related, above-mentioned inferences on the Mannar Basin may be valid for the Cauvery Basin as well. The northwestern offshore area of Sri Lanka could be thought to have undergone thermal subsidence from the early Palaeocene. The Cauvery Basin is underlain by the continental crust (Chari *et al*., 1995).

The Indian plate collided with Eurasia in the early Eocene and gave rise to the Himalayan orogeny (Torsvik *et al*., 2002; Baillie *et al*., 2003). Baillie *et al*. (2003) inferred that the periodic intra-plate deformation, which followed the collision of India with the Eurasian plate, resulted in upliftment and punctuated the overall subsidence history of the northwestern area of Sri Lanka with discrete episodes of erosion and rapid deposition. This is pronounced in the well stratigraphy as several unconformities after the Eocene (Fig. 4B). The rapid upliftment and erosion of the Himalayas gave rise to an influx of terrigenous sediments into dipocentres of the Cauvery and the Gulf of Mannar Basins and into the Bay of Bengal. The tectonic evolution of the Cauvery Basin has been addressed in detail by Katz (1978); Sastri *et al*. (1981); Chari *et al*. (1995); Subrahmanyam and Chand (2006).

STRATIGRAPHY

The thickness of the recent to Permian aged stratigraphic section of the Indian sector of the Cauvery Basin reaches around 6,000 m (Ram Babu and Lakshmi, 2004; Phaye *et al*., 2011). Sastri *el al*. (1978) reported that a well drilled in the Indian sector of the Cauvery Basin penetrated Jurassic sediments.

Pesalai-1, 2 & 3, Palk Bay-1, Delft-1, Pedro-1 wells located in the Sri Lankan sector of the Cauvery Basin (Fig. 1) were drilled up to a total depths of 2554, 2628, 2874, 2012, 1734, 1417 m, respectively (Cantwell *et al*., 1978). All these wells encountered crystalline basement. The deepest well among these are Pesalai-3, which reached a total depth of 2874 m. The oldest sediment penetrated by these wells is the Albian stratigraphic section penetrated by the Pedro-1, Delft-1, and Pesalai -1, 2, & 3 wells. Though no well drilled in the Sri Lankan sector of the Cauvery Basin penetrated Jurassic sediments, they are cropping out in the Tabbowa, Aadigama, and Pallama grabens located close to the western coastline of Sri Lanka (Wayland, 1920; Daraniyagala, 1939; Sitholey, 1942; 1944; Money and Cooray, 1966; Fig. 1). The stratigraphic thickness in these grabens vary 0.9-1.5 km (Tantrigoda and Geekiyanage, 1991).

The Early Cretaceous sediments penetrated by the Pedro-1, Delft-1, and Pesalai-1, wells include sandstone, claystone, and conglomerates (Fig. 4). The Early Cretaceous sediments penetrated by the Pedro-1 well are overlain by the Eocene sediments, while those penetrated by the Delft-1 well is overlain by the Oligocene sediments (Fig. 4C & D). In other words, the late Cretaceous, and Palaeocene sections in the Pedro-1 well, and the late Cretaceous, Palaeocene, and Eocene sections in the Delft-1 well are missing. The late Cretaceous section in the Pesalai wells and Palk Bay-1 well are mainly composed of sandstone and claystone layers (Fig 4A & B). The presence of conglomerates indicates the deposition of Albian sediments in relatively high-energy environment and they

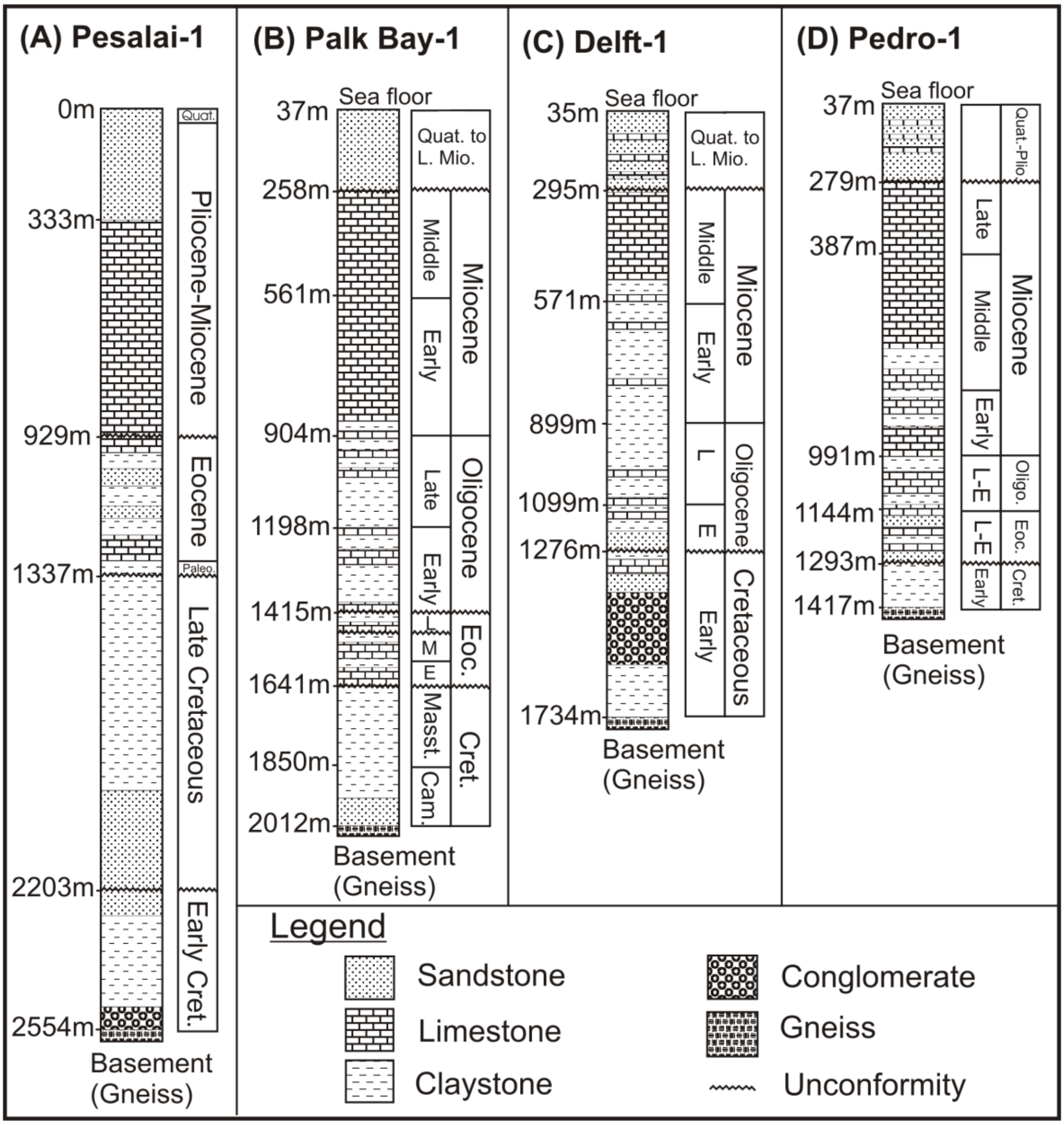

Fig. 4 Generalized stratigraphic sections of wells drilled in the Sri Lanka side of the Cauvery Basin (modified after Cantwell et al. (1978); Sastri et al. (1981). Quat. = Quaternary; Plio = Pliocene; Mio. = Miocene; Eoc. = Eocene; Palio. = Pliocene; Cret. = Cretaceous; Masst. = Maastrichtian; Camp. = Campanian; E= Early; M = Middle; L = Late

resembles paleo stream channels. The relatively larger hiatuses in the Pedro-1, and Delft-1 wells, which are located on structural highs, suggests erosion or non-deposition of sediments from the Albian to the end of the Eocene. Based on this observation, it could be thought that the formation of the Mandapam-Delft ridge might have taken place from the Albian to the end of the Eocene. The Eocene and Oligocene sections in the Pesalai-1, Pedro-1, and Palk Bay-1 wells are composed of interbedded claystones, sandstones, and limestones. In the Palk Bay-1 well, a few smaller hiatuses occur between the middle and late Eocene and between the Eocene and Oligocene. In the Pesalai wells, the Oligocene section seems to be missing.

A few smaller hiatuses in the Eocene and younger sections may be related to the intra-plate deformation, which Baillie *et al*. (2003) suggested to have followed the collision of India with Eurasian.

The Miocene section in the wells drilled in the Sri Lankan Cauvery Basin is mainly composed of limestones. Erosional unconformities are encountered between the middle and late Miocene sections in the Palk Bay-1 and in the Delft-1 wells, while in the Pedro-1 well between the late Miocene and Pliocene. Miocene

Table 1 Some geochemical data that Cantwell et al. (1978) reported for the Pesalai-1 well. Al= Algal; Am= Amorphous sapropel; H= Herbaceous-Spore/Cuticle; W= Woody; C= Coaly. The proportion of maceral; predominant = 60-100%: secondary = 20-40% and trace = 1-20%, respectively

Name of well	Depth (m)	TOC (wt.%)	Kerogen Type	Total HC Extract (ppm)	Straigraphic section
Pesalai-1	1973	1.14	W-C: H: Am(Al)	52	Late Cretaceous
	1974	1.16	W-C: H: Am(Al)	26	" "
	1977	1.61	W-C: H: Am(Al)	103	" "
	2021	1.97	Am: H: W-C	135	" "
	2040	2.95	H: Am(Al): W-C	87	" "
	2097	3.43	W-C: H: Am	46	" "
	2101	0.88	Am (Al)-H; W-C	44	" "
	2175	0.79	Am (Al)-H; W-C	36	" "
	2422	2.87	W-C: H: Am(Al)	209	Early Cretaceous
	2547	6.92	W-C: H: Am	2113	" "

Table 2 Rock Eval Pyrolysis data for the Perdo-1 well from unpublished reports at PRDS. nd = not detected

Depth (m)	TOC (wt.%)	T_{max} (^oC)	mg HC/g rock		PI	HI (mg HC/ g TOC)	Stratigraphic section
			S_1	S_2			
817	0.59	433	0.12	0.77	0.13	130.5	Late Miocene
871	0.65	430	0.09	1.2	0.07	184.6	"
904	0.75	434	0.1	0.72	0.12	96.0	"
960	0.71	420	0.12	0.32	0.27	45.1	"
1,153	0.48	430	0.01	0.13	0.07	27.1	U-M Miocene
1,155	0.81	430	0.01	0.29	0.03	35.8	"
1,258	0.18	n.d	n.d	n.d	n.d	n.d	"
1,294	0.04	n.d	n.d	n.d	n.d	n.d	Early Cretaceous
1,351	0.16	n.d	n.d	n.d	n.d	n.d	"
1,412	0.85	430	0.05	0.833	0.06	98.0	"

limestones are cropping out in the north, northwestern and northeastern coastal belt of Sri Lanka (cf. Cooray, 1984). These Miocene limestones contain silicified fossils of gastropods and pelisipods. Well-rounded Quaternary sand coated with ferric oxide, which earned them the name "Red Earth", overlie the Miocene limestone in the North and NW onshore areas of Sri Lanka.

The presence of limestone in the north and northwest onshore areas of Sri Lanka indicates relatively high sea levels and marine transgression during the Miocene. This observation is in general agreement with the high eustatic sea levels during the Miocene proposed by Vail *et al*. (1978). There have been upliftment and marine regression after the middle Miocene. This regressive phase seems to have created an oxic depositional environment, during which the Quaternary Red Earth was deposited.

PETROLEUM SYSTEM

SOURCE ROCKS AND THEIR THERMAL MATURITY

The source character of sediments penetrated by the Pesalai-1 well, has been reported by Cantwell *et al.* (1978; Table 1). The Rock Eval Pyrolysis data for the sediments from the Pedro-1 are listed in Table -2, and the Delft-1 and Palk Bay-1 in Table 3. The data show that total organic carbon (TOC) of the Early Cretaceous claystone from the Pesalai-1 well ranges 2.87-6.92 %, the Pedro-1 well 0.04-0.85%, and the Delft-1 well 0.37-2.26%. TOC of the Late

Table 3 Rock Eval Pyrolysis data for the Delf-1 well from unpublished reports at PRDS

Well Name	Depth (m)	TOC (%)	S_1 (mg HC/g rock)	HI (mg HC/ g TOC)	Stratigraphic section
Delft-1	862	0.88	0.643	73.1	Miocene
	886	0.79	0.306	38.7	"
	904	0.71	0.296	41.7	Oligocene
	964	0.51	0.077	15.1	"
	1018	0.46	0.21	45.7	"
	1057	0.74	0.308	41.6	"
	1132	0.49	0.18	36.7	"
	1300	0.37	0.525	141.9	Early Cretaceous
	1321	0.6	0.373	62.2	"
	1613	2.26	0.319	14.1	"
	1658	0.63	0.264	41.9	"
	1685	1.67	0.631	37.8	"
	1715	2.1	0.682	32.5	"
Palk Bay-1	1075	1.25	1.08	86.5	Oligocene
	1126	1.15	0.97	84.3	"
	1174	1.01	1.11	110.3	"
	1249	0.90	0.71	78.8	"
	1420	0.61	0.57	92.8	Maastrichtian
	1646	0.28	0.43	151.8	"
	1682	0.45	0.46	102.2	"
	1742	0.47	0.42	88.5	"
	1790	0.57	0.83	144.7	"
	1835	0.49	0.69	140.8	"
	1898	0.53	0.45	85.1	Campanian
	1925	0.52	0.34	65.6	"

Cretaceous sediments from the Pesalai-1 well ranges 0.79-3.43% and the Palk Bay-1 well from 0.28-0.61%. The Miocene sediments penetrated by the Pedro-1 well and the Oligocene and Miocene sediments penetrated by the Delft-1 well have a less than 1% TOC. TOC of the Oligocene sediments from the Palk Bay-1 well ranges 1.1 to 1.25%.

The TOC data indicate that the Cretaceous claystones penetrated by the Pesalai-1 well have a very good to excellent hydrocarbon source potential (cf. Peters and Cassa, 1994). Based on the TOC, the Early Cretaceous sediments penetrated by the Delft-1 well also have fair to good hydrocarbon source potential. The maceral composition of the Early Cretaceous sediments penetrated by the Pesalai-1 (Table 1) and Delft-1 (Table 3) wells has a significant quantity (~20%) of Type II kerogen. The hydrogen index (HI) of the Early Cretaceous sediments from the Delft-1 well ranges 32 -142 mg HC/ g TOC (Table 3). The HI of the Late Cretaceous (Maastrichtian to Campanian) sediments from the Palk Bay-1 well ranges 65-152 mg HC/ g TOC (Table 3). The sediments from the Pedro-1 well are rich in Type III and IV kerogen (Fig. 5).

Overall, the source character data indicate that the Early and Late Cretaceous sediments from the Pesalai-1 well and the Early Cretaceous sediments from the Delft-1 well have good hydrocarbon source potential. The sediments penetrated by the Pedro-1 well and the Late Cretaceous sediments from the Palk Bay-1 well have a fair hydrocarbon source potential.

The vitrinite reflectance (VR) data reported by Cantwell *et al*. (1978; Fig. 6) show that the sediments below 2500 m depth in the Pesalai wells have entered the oil window (VR = 0.6-1.35%R_o; Peters and Cassa, 1994). The sediments penetrated by the Palk Bay-1 and Delft-1 wells have vitrinite reflectance values

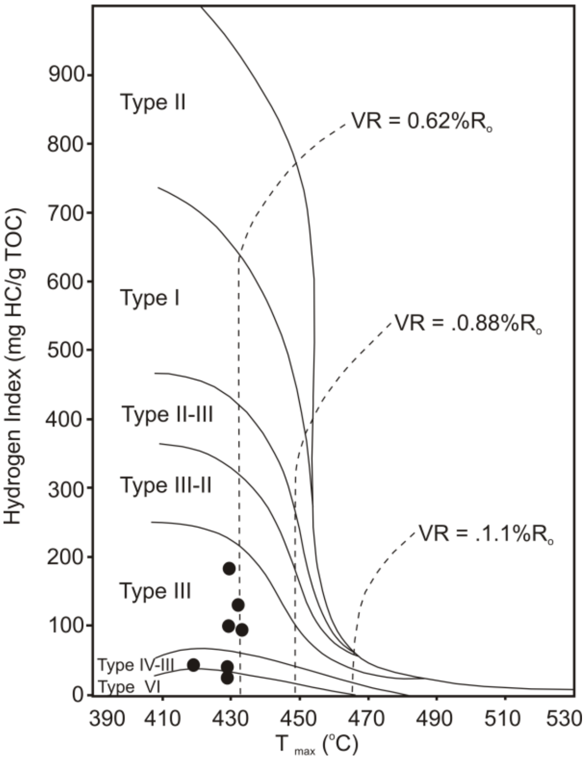

Fig. 5 The plot of T_{max} (°C) versus hydrogen index (HI) of the analysed samples from the Pedro-1 well, showing the sediment to contain Type III/IV kerogen and plot within the immature to marginally mature oil window as indicated by vitrinite reflectance (VR) (cf. Peters and Cassa, 1994; van Koeverden et al., 2011).

less than 0.6%R_o (Fig. 6). Though, VR data is not available for the Pedro-1 well, the Rock Eval T_{max} data, which could be used as an alternative maturity indicator (e.g. Peters and Cassa, 1994), yield < 435 °C (Table 3).

The maturity data suggest that the Pesalai-1 well just penetrated the marginally matured Early Cretaceous claystones, while the Pesalai-2 & 3 wells penetrated the matured Cretaceous sediments. The Palk Bay-1, Delft-1 and Pedro-1 wells have not penetrated thermally matured sediments. This could be due to their location on structural highs. An unpublished basement isopach map held at the PRDS show areas with more than 2500 m stratigraphic thickness in the Sri Lankan sector of the Cauvery Basin. The Early Cretaceous claystones at such depths could be expected to mature and have generated oil.Chandra *et al*. (1991) reported that the TOC content of the Albian and earlier claystones in the Indian sector of the Cauvery Basin varies 0.34-2.49% and these sediments have around 20% contribution from Type II kerogen. These claystones deposited under an anoxic condition associated with the Pre-Albian to Cenomanian

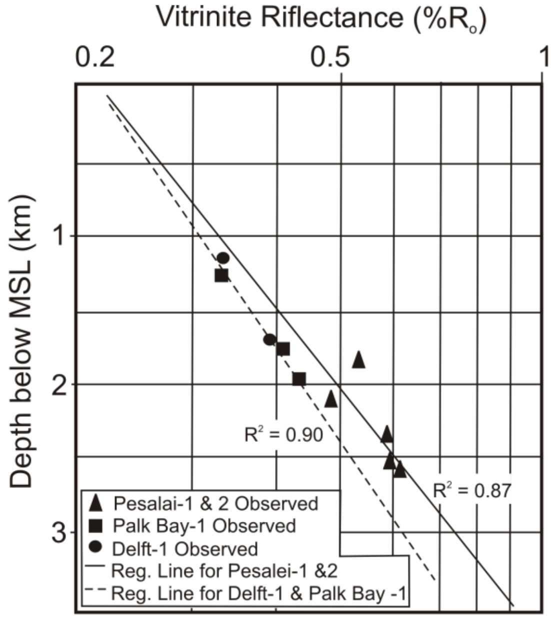

Fig. 6 Kerogen maturation profiles for Pesalai-1 & 2 and Palk Bay-1 wells (After Cantwell et al., 1978). %R_o = percent reflectance of white light in oil. Reg. = regression

major marine transgression (e.g., Schlanger and Jenkyns, 1976; Arthur et al., 1987) could be the most potential hydrocarbon source in the Indian sector of the Cauvery Basin (Chandra et al., 1991).

RESERVOIR ROCKS

Fig. 7 shows the generalized stratigraphic cross-section across the Pesalai-Palk Bay depression (X-X' in Fig. 1). The Cretaceous and Paleogene stratigraphic intervals in the Pesalai-Palk Bay depression have clastic and carbonate rocks overlain by claystones (Fig. 4). The Pesalai-well has penetrated more than 200 m thick cretaceous sandstone overlain by a thick claystone layer (Fig. 4A).

The oil and gas accumulations have been found in fractured basement and in the Cretaceous to Oligocene sandstones in the Indian sector of the Cauvery Basin (Ram Babu and Lakshmi, 2004). Late Cretaceous regression and the Horst-Graben morphology in the Cauvery Basin have, resulted in a number of deeply incised submarine canyons, giving rise to excellent reservoir rocks (Anandan *et al.*, 2004). Well stratigraphy data show Albian and Late Cretaceous sandstones and Paleogene and Neogene clastic and carbonate rocks could be the potential hydrocarbon plays in the Sri Lankan sector of the Cauvery Basin.

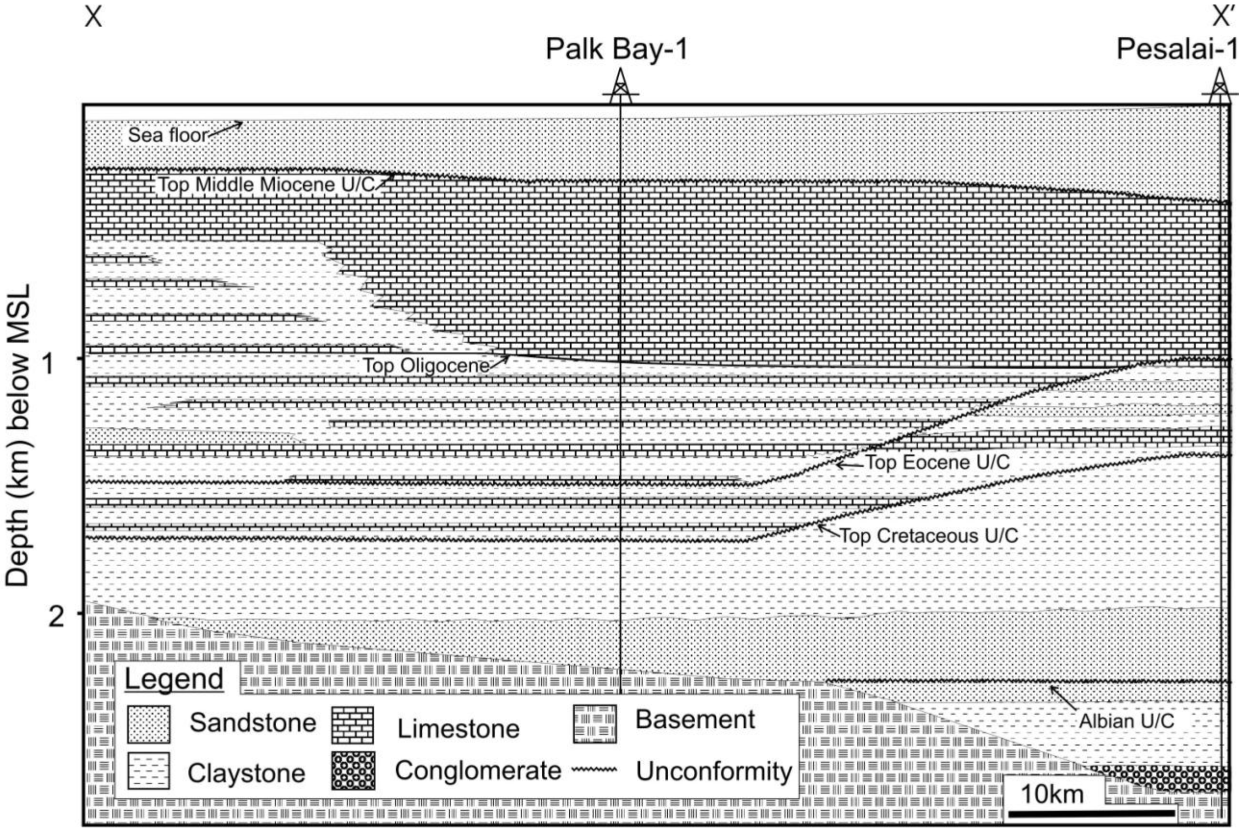

Fig. 7 The generalized stratigraphic section across X-X' points in Fig. 1. The compilation is based on the correlation of the stratigraphic sections of the Palk Bay-1, Pesalai-1, and Pedro-1 wells. The stratigraphic sections of these wells area shown in Fig. 4 . U/C = unconformity

SEALS AND TRAPS

The stratigraphic column of the Pesalai-1 well indicates that a Cretaceous sandstone layer is overlain by a more than 500 m thick Late Cretaceous claystone layer (4A). Similarly, the stratigraphic column of other wells clearly demonstrate claystone layers, which can act as potential seal/cap rocks, underlain by clastic and carbonate potential reservoir rocks in the Cretaceous, Paleogene, and Neogene stratigraphic intervals (Fig. 4B, C, and D).

Seismic and well data (e.g. Cantwell *et al*., 1978) show that both structural and stratigraphic traps seem to occur in the Sri Lankan sector of the Cauvery Basin. Structural traps include faults and anticlines, while stratigraphic traps include channel fills and stratigraphic pinch outs.

The Indian sector of the Cauvery Basin produces both oil and gas from Early Cretaceous to Palaeocene sandstone reservoirs mainly in stratigraphic traps (Dubey and Mahapatra, 2013).

HYDROCARBON GENERATION, MIGRATION AND ACCUMULATION

Vasudevan *et al*., (2008) modelled the peak oil generation in the Ramnad-Palk Bay-Nagapattinam sub basin to be around 70 Ma. Phaye *et al*., (2011) modelled the critical moment of the Ariyalur-Pondicherry sub basin to be around 65.5 Ma with the oil window below the depths of around 3000 m.

Chaudhuri *et al*. (2010) have worked out for the Indian sector of the Cauvery Basin a heat flow of 80 mW/m^2 during the syn-rift stage and 45 mW/m^2 during the post rift period based on the calibration with VR and bottom hole temperature (BHT) data. The surface heat flow in most part of the Indian sector of the Cauvery Basin ranges 40-70 mW/m^2 and in some places, it ranges 70-100 mW/m^2 (Shanker, 1988; Shanker *et al*., 2012). Premarathne *et al*. (2015) modelled a heat flow of 65-71 mW/m^2 at the end of rifting and a present day heat flow of 33-40 mW/m^2 in the northern part of the Mannar Basin by calibrating with VR and BHT data, respectively.

The thermal history of the Sri Lankan Cauvery Basin is poorly understood. However, above mentioned heat flow data suggest that, in the northwestern areas of Sri Lanka, the heat flow at the end of rifting around 66 Ma would have ranged 70-80 mW/m^2. The present day heat flows in this area may be 40±10 mW/m^2. If this heat flow history is true and if the Sri Lankan sector of the Cauvery basin, specially the Pesalai-Palk Bay depression, have areas with more than 3000 m sediment thickness, the peak oil generation could be thought to have taken place during the Maastrichtian. In this case, the Cretaceous and younger clastic and carbonate potential reservoirs might have been charged with hydrocarbons through vertical and lateral drainage. The basement ridges could be thought to have inhibited or hindered the lateral hydrocarbon migration between the sub basins. The lack of understanding on the stratigraphic thickness, thermal and burial history, and hydrocarbon entrapment amidst the tectonic activities that lead to larger hiatuses have to be clearly understood to reduce the exploration risk in the Sri Lankan sector of the Cauvery Basin.

CONCLUSIONS

Pesalai-Palk depression and a part of the Ramnad-Palk-Bay-Nagapattinam depression and the Mandapam-Delft ridge constitute the Sri Lanka sector of the Cauvery Basin. The stratigraphic thickness of the Sri Lankan Cauvery Basin is smaller compared that in the Indian sector and Mannar Basin. Most of the previously drilled exploration wells are located on structural highs. The Paleogene, Neogene, and Late Cretaceous sediments penetrated by the wells are thermally immature. Albian and older claystones could be the potential hydrocarbon source in the Sri Lankan Cauvery Basin. The Late Cretaceous sandstone and Paleogene and Neogene clastic and carbonate rocks could be the potential reservoirs. Faults, anticlines, channel fills, and stratigraphic pinch outs could act as hydrocarbon traps. There is a possibility that an active petroleum system occurs in the Sri Lankan sector of the Cauvery Basin.

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