CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Gippsland basin is located between Australia mainland and Tasmania, underlying ±46,000 km^2 in which 75% of the basin is located offshore and the rest are onshore in the region of the state of Victoria.

The basin bounded to the north by Tasman Fold Belt and the Selwyn fault separated the northwestern part of basin with Otway Basin. The southwestern part of the Gippsland basin is separated from the Bass basin by the Bassian rise which is a southeast trending basement ridge and the basin is open to the east where the basin sediment extends beyond the shelf break.

2.2 BASIN EVOLUTION AND TECTONICS DEVELOPMENT

The origin and tectonic evolution of the Gippsland basin are related to the breakup and fragmentation of Gondwanaland. Rahmanian et al. (1990) divided the Gippsland basin tectonic evolution into five stages:

- Early Cretaceous Rifting (130-95 Ma)

Gippsland basin sedimentation started in the Earliest Cretaceous (approximately 130 Ma) when a pre-break up depression formed along the southern margins of Australia. The depression later developed into complex rift system (figure

2.1), covering area up to several hundred kilometers wide occupied by the present Gippsland, Bass and

Otway basins. In the Gippsland basin area the rift had an east-west trend and filled with thick volcano-clastic sediments of the Strzelecki Group.

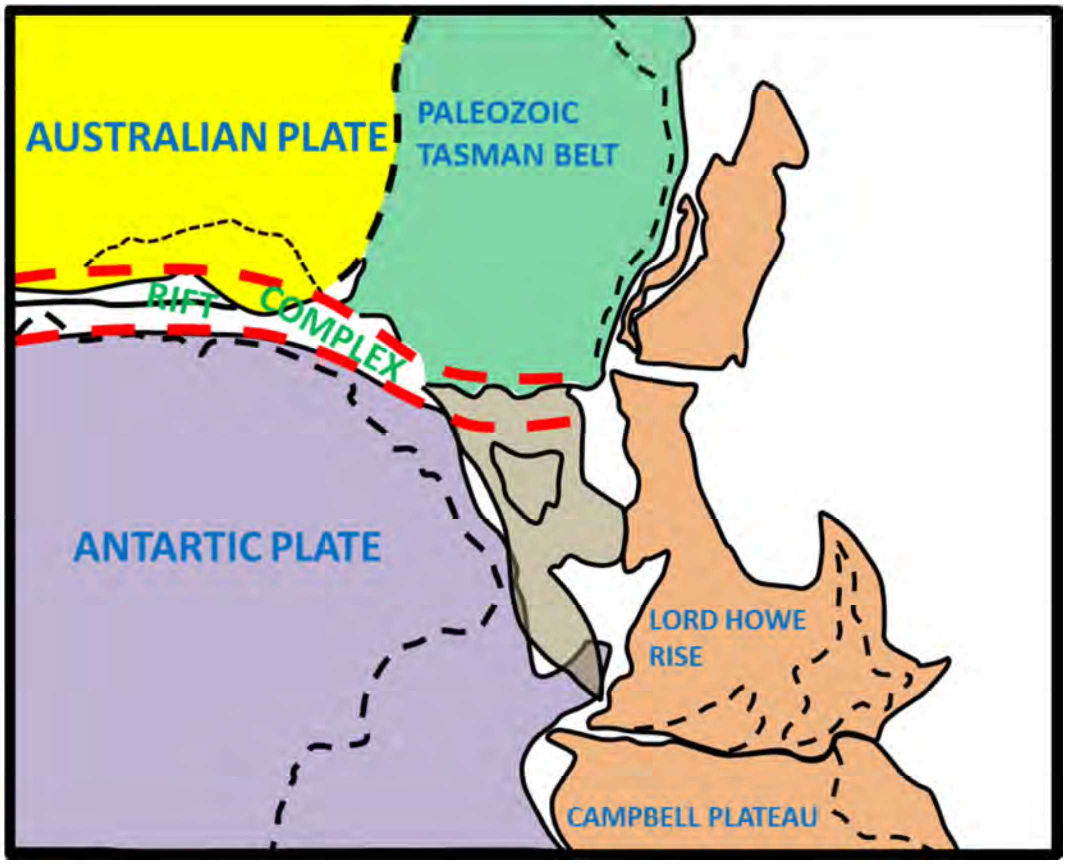

Figure 2.1 Early Cretaceous rifting in Australia
Source: Modified from Rahmanian et al. 1990

- Early Cretaceous tectonism (approximately 95 Ma)

Australia separated from Antarctica at approximately 95 Ma, even though the break up did not extend in to the Gippsland basin area a tectonic readjustment took place in the basin caused two significant consequences in the basin. The first adjustment was the major provenance change from lithic and volcano-clastic deposits of the Strzelecki Group to the quartoze deposits of the Latrobe Group (Golden Beach Sub groups); the second adjustment was the area of the deposition became more confined in the "Central deep" graben. The major ridges which separate the Otway, Bass and Gippsland basins also emerged at this time and became prominent structural features and barriers to deposition.

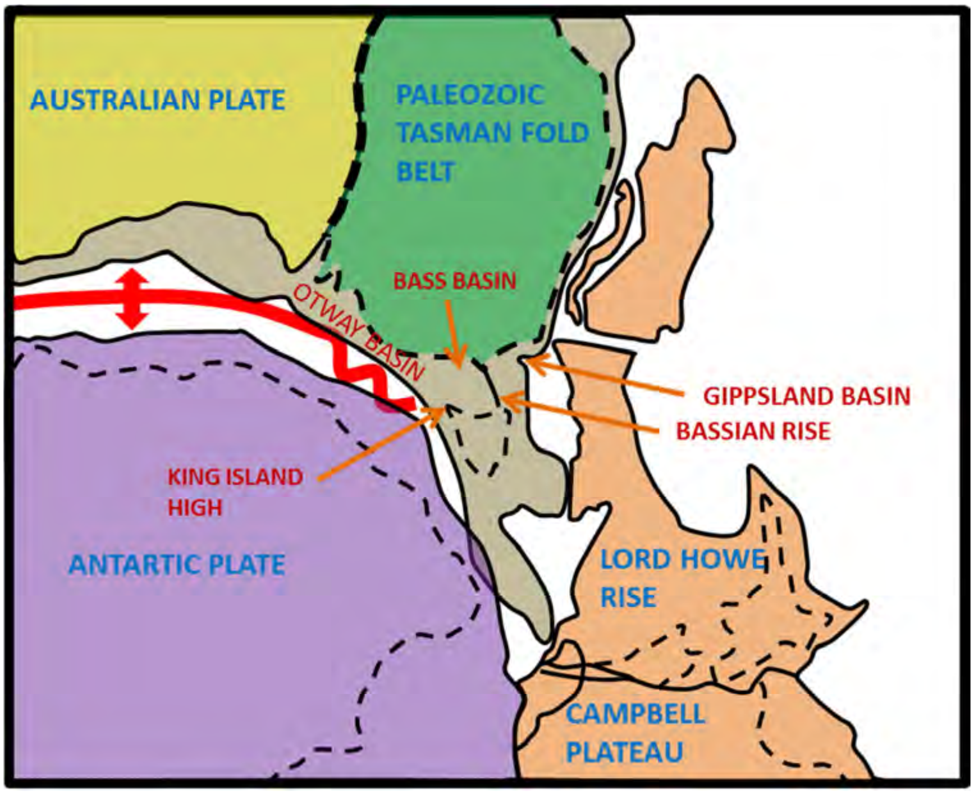

Figure 2.2 Mid Late Cretaceous rifting

Source: modified from Rahmanian et al. 1990

- Late Cretaceous Rifting (95-80 Ma)

Latrobe group sedimentation continued during this stage in the well-developed 40-80 km rift valley which has east-west trend. The rifting continues with the direction of extension were NE-SW which result fault controlled subsidence with NW-SE oriented normal faults shown in Figure 3. This rifting phase lasted about 15 million years, creating a rift that had asymmetric shape with maximum down faulting occurred at the northern margin.

Rifting along eastern margin of Australia is interpreted to happen almost at the same time as the Late Cretaceous rifting in the Gippsland basin, where triple junction connecting the two rifts. This break up along the eastern edge of Australia caused a minor unconformity and peak of volcanism in the Gippsland basin.

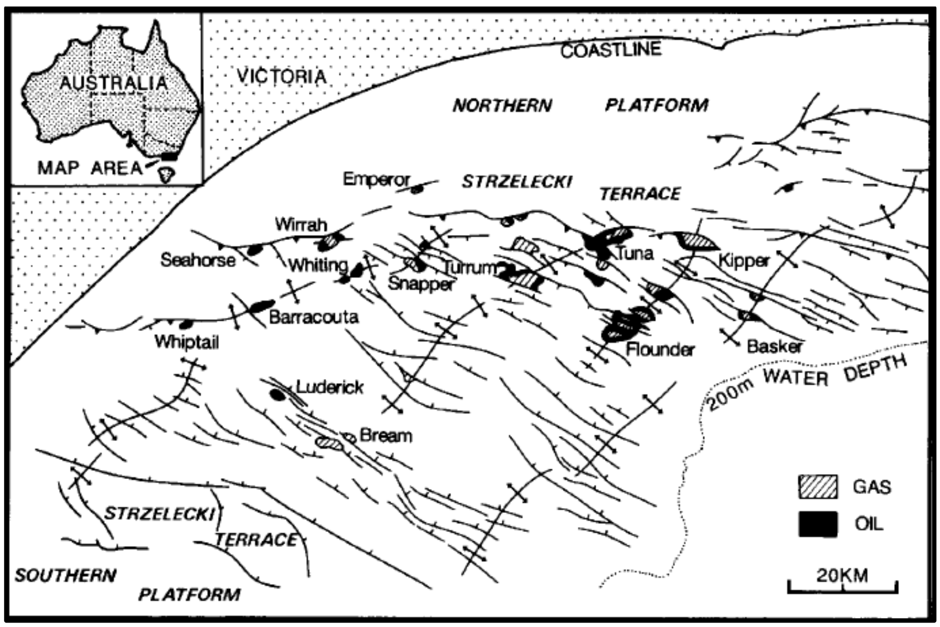

Figure 2.3 Major fault patterns in the Latrobe Groups

Source: modified from Rahmanian et al. (1990)

- Late Cretaceous –Eocene: transition from fault controlled subsidence to marginal sag (80-39 Ma)

Gippsland basin became a failed rift basin once the break up along the eastern Australia happened. The basin evolved from a fault controlled depression to marginal sag causing a decrease in the subsidence and sedimentation rates in the basin. Encroachment of the Tasman Sea from the southeastern side of the basin gave more marine influence on the deposition of the Upper Latrobe Group compare to the lower Latrobe group. During this stage, submarine erosion, canyon formation and infill occurred at the eastern part of the basin.

- Late Eocene – Recent: Structures and late sag-phase deposition

Compression tectonics happened during this Late Eocene-mid Miocene period affecting the Gippsland basin creates folding and inversion of old faults formed NE-SW trend anticlinal features. The compressional tectonics also caused uplift to the basin that were resulting the regional erosion across the basin that formed the unconformity at the top of Latrobe group.

During the compressional phase, the basin continued to subside, allowing the deposition of fine-grained shales and marls of Lake Entrance Formation in shelf, slope and basinal environments on top of the underlying unconformity (Top of Latrobe Group). This Lake Entrance formation provides the regional seal for the basin. Marine channeling follows the deposition of the Lake Entrance which also accompanied by the deposition of Gippsland limestone.

2.3 DEPOSITION

2.3.1 Introduction

According to petroleum geology summary of the Gippsland basin issued by the Australia's Departement of Resources, Energy and Tourism (DRET) on the Australia at 2011 offshore petroleum exploration acreage release, the Stratigraphic succession in the Gippsland basin (figure 2.4) can be divided into three major groups based on lithological variations.

2.3.2 Strzelecki Group (Lower Cretaceous)

The Strzelecki group was started to be deposited in the basin unconformably on the underlying Paleozoic igneous and folded sedimentary rock of the pre-break up depression in Gondwanaland which then separated Australia Plate with Antarctica plate. The group consists of greywackes, mudstones, sandstones conglomerates, coals and volcaniclastics with depositional environment ranging from lakes, swamps to floodplains.

Thickness of the Strzelecki Group is not well known it's expected to ranges from a few hundred meters to more than 2600 meters (Douglas & Ferguson 1976, McPhee 1975 as quoted by Bishop 2000) and 6000 meters (McPhee 1975 as quoted by Bishop 2000) in some parts of the basin. The Strzelecki group had been regarded as "economic basement" but recently it is considered to have hydrocarbon generation and accumulation potential. The Strzelecki group was deformed and eroded by an event on 96 Ma (Duff et al. 1991 as quoted by Bishop 2000)

2.3.3 Latrobe Group

Latrobe Group was deposited during the active synrift to early post rift tectonics phase of the basin. The Latrobe Groups is divided into four subgroups (DRET, 2011), namely the Emperor subgroup, Golden Beach subgroup, Halibut subgroup and Cobia subgroup (Figure 2.5).

Emperor subgroup, Turonian age, consists of medium to coarse-grained alluvial fan and lacustrine facies deposit which indicates the characteristics of rift valley deposition prior to continental break up. Uplift along the basin margin during Early Cretaceous cause The Emperor subgroup deposited unconformably on top of the Strzelecki Group, which also change in the provenance from volcaniclastic in Strzelecki Group to quartoze in the Latrobe Group

The deep lakes form a large lacustrine within the rift valley assumed to occupied most of the Turonian rift valley and received sediments from the basin margins, and this form the Kipper Shale. Coarse grained feldspathic sandstone, Kersop Arkose, is the evidence of the first erosion on the uplifted granites basements at the southern margin of the basin. The Admiral formation consists of quartz dominated lithic arenites where the predicted source is the Paleozoic sedimentary and metamorphic basement and the uplifted Early Cretaceous sediment (Strzelecki Group). The Curlip formation characterized by sandstones and conglomerates that interbedded with shales and coals. Longtom unconformity is the top of the Curlip Formation and this unconformity caused the termination of the Emperor Subgroup deposition (Partridge, 1999 as quoted by DRET, 2011]).

There are two formations that can be distinguished from the Golden Beach Subgroup, the Anemone Formation which was marine origin and Chimaera Formation which was fluvial origin. The Anemone Formation, which was deposited in the eastern part of the basin, consists of mudstones, shales and other fine grained siliciclastics that characterized shallow to open marine depositional environment, this formation indicates the opening of the Tasman Sea adjacent to the basin.

The Chimaera Formation is a non-marine deposit that consists of coarse grained alluvial/fluvial sediment and including fine-grained floodplain and coals. The Golden Beach Subgroup also has several volcanic intervals that are likely to be Campanian in age, and this causes the termination of the Golden Beach Subgroup deposition and gave another unconformity event known as Seahorse Unconformity.

There are five formations in the Halibut Subgroup that were distinguished by their dominant depositional facies changes from non- marine to marine. Barracouta Formation represents the upper coastal plain deposits which characterized by fluvial sediments and contain minor coal deposits. The lower coastal plain with coal rich deposits were grouped into Volador and Kingfih formation where the two formation separated by the Kate Shale, a Cretaceous/Paleogene marine deposit which regionally recognized across the basin. The Mackerel Formation characterized by near-shore marine sandstones with excellent reservoir quality, intercalated with marine shales.

Basin inversion caused a sea level fall in the early Eocene; this initiated the major canyon cutting that erodes the lower coastal plain and the shelf. The later transgression filled the channels that were formed because of the previous erosion with marine sediments, and this is the Flounder Formation. The major erosional event associated with channel incision, The Marlin Unconformity, terminated the deposition of the Halibut Subgroup (Johnstone et al, 2001 as quoted by DRET 2011)

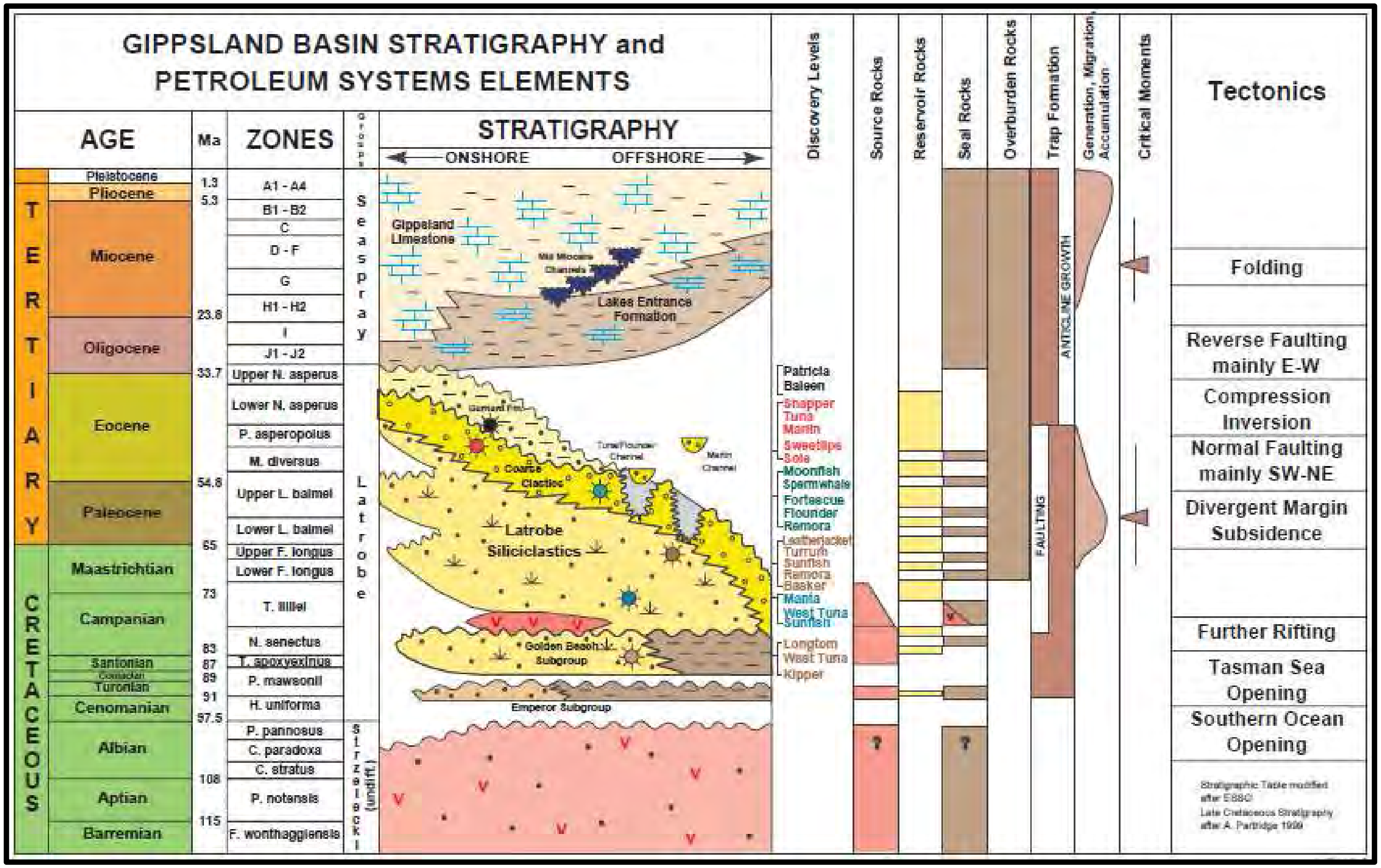

Figure 2.4 General Stratigraphic Column of Gippsland Basin

Source: Modified from Geoscience Australia

Cobia Subgroup, middle Eocene to Lower Oligocene age, consists of Burong Formation, coal bearing formation with lower coastal plain facies and Gurnard Formation, shallow to open marine facies composed of fine to medium grained glauconitic silisiclastics. Gurnard Formation became the reservoir for several gas fields.

Turrum Formation also included in the Cobia Subgroup, consist of middle Eocene marine channel fill. The Cobia Subgroup deposition ceased on Early Oligocene because the decreased of sediment supply. Condensed section developed across the basin and this marked the Latrobe Unconformity

2.3.4 Seaspray Group

The Seaspray Group unconformably deposited on top of the Latrobe Group, it consist of calcareous sediments that resulted from changes in the ocean circulation along the Australian Southern margin.

The Seaspray group that consists of Lake Entrance Formation and Gippsland Limestone provides the load that matures the source rock for the hydrocarbons, and The Lake Entrance Formation in Seaspray Group is the regional seal to hydrocarbon accumulation in the Latrobe Group. The work of O'brien et al. (2008) as quoted by DRET (2011) gave information that the Lake Entrance Formation is smectit marl with the ability to contain significant hydrocarbon column.

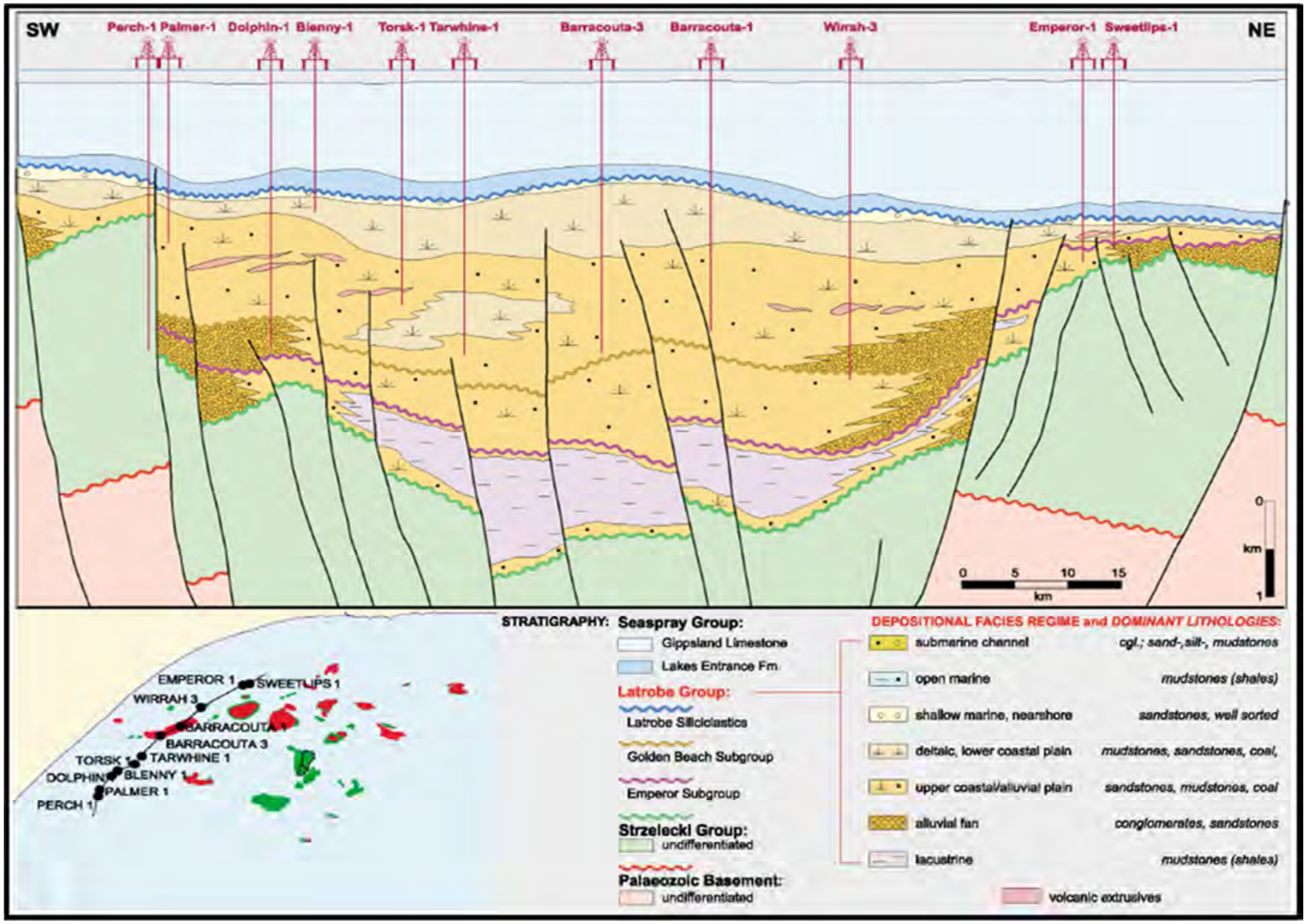

Figure 2.5 Latrobe Group facies association

Source: modified Petroleum Atlas of Victoria Australia, 2001

2.4 PETROLEUM SYSTEM

Source Rocks

Geochemichal analysis of the oil sample and the potential source rock sample show there's a good correlation with the produced oil from the Gippsland basin with the terrestrial source rock (Moore et al. 1992, Philp, 1994 as quoted by Bishop 2000). The main source rocks for the Gippsland basin petroleum system are the carbonaceous shales and coals of the Latrobe Groups (Cobia and Halibut Subgroup).

Reservoir

The hydrocarbon in Gippsland basin are mostly contain the sandstone reservoir of Latrobe Group, with the depositional environment ranging from fluvial to marginal marine such as alluvial fan, braided stream, coastal plain, estuarine and marginal marine. The porosity of Latrobe group reservoir is ranging from 15-25% and decreasing with depth.

Seals

The Lake Entrance Formation in Seaspray Group provides the regional seal for the basin. Thickness of this regional seal is varying from 100-300 meters (O'brien et al. 2008 as quoted by DRET 2011). There are also intraformational seals within the Latrobe group, which include the floodplain sediments and lagoonal to offshore marine shales. Fault seal are also available, juxtaposing the shales with the reservoir.

Trap

The dominant hydrocarbon trap in the Gippsland basin is Structure related trap such as anticlines, faulted anticlines, fault inversion compressional rolls, and fault dependent trap that was resulted from the tectonic compression event started in the Eocene till recent.