Chapter 1

Introduction to the Petroleum Geology of Myanmar

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Before the birth of the modern, mechanized, petroleum industry, Myanmar (formerly Burma) was an exporter of oil products from its hand-dug wells in the centre of the country. It is now an important exporter again, but of gas from its offshore fields, and the international petroleum companies are keen to obtain acreage both onshore and offshore; in the lead-up to the 2013 offshore round no fewer than 60 companies pre-qualified with the Ministry of Energy of the Myanmar government.

Past petroleum studies

It was not until the incorporation of Burma into British India in 1885 that extensive geological research was initiated in the country, with many of these articles (up to independence in 1948) being published in reports of the Geological Survey of India. Historically important publications by their geologists included a study of the all-important Tertiary rocks by Noetling (1895) followed by his account of the country’s petroleum occurrences (Noetling 1897). A more detailed study followed, covering the core petroleum-bearing area (what we now call the Salin Basin in the Central Burma Depression, Fig. 1.1) by Grimes (1898). As a modern petroleum industry became established following the formation of the Burmah Oil Company in 1886, the Geological Survey of India (Pascoe 1912) published a major update of what the author described had become ‘...one of the most important industries of the Indian Empire.’ Accounts of the oil fields by industry geologists included those by Stamp (1927), Evans (1941) and Taingsh (1950); meanwhile, a major study of the wider geology of Burma was published by Chhibber (1934a) and of its mineral resources by the same author (Chhibber 1934b). In many respects those works by Chhibber remain standard references on Burmese geology, as does the later study by Pascoe (1950–1964).

Most geological fieldwork since independence has focused on mineral exploration, with systematic mapping of selected areas only starting in the late 1960s. Some of that information is in reports which have limited availability, such as the study of the Shan scarps region by the United Nations Development Programme (1978); that which is more widely published tends to be on metallogensis, tectonics and local gravity surveys. A series of papers was published between 1968 and 1971 on petroleum geology in the Union of Burma Journal of Science and Technology. Further publications have come from bilateral development projects with Australian, British, French and German government bodies. The latter gave rise to what is still the current authority on the geology of Burma as a whole (Bender 1983), which contains an exhaustive bibliography.

Mention should also be made of Mitchell who, although not a petroleum geologist, has done more than most to stimulate discussion of the tectonic history of Myanmar. Mitchell (1986) coined the term Victoria Land for the Gondwana-derived platelet which forms the eastern belt of the Indo-Burman Ranges, and other notable contributions include Mitchell (1981, 1992) and Mitchell et al. (2007, 2012).

Pascoe (1950–1964) and Bender (1983) include brief sections on petroleum geology in their wide-ranging geological accounts of the country, but understandably they were unable to include the offshore geology. Since then papers have been published on particular aspects of onshore and offshore petroleum geology, but to our knowledge, none on Myanmar’s overall petroleum geology. The present account therefore seeks to provide such an overview, using as data sources published papers, information gathered from companies’ websites and Powerpoint presentations, in particular those by Myanmar Oil and Gas Enterprise (MOGE), the instrument of the Myanmar government for petroleum exploration, development and production.

Current oil and gas production

Oil and gas are produced in Myanmar from Cenozoic sedimentary rocks that occur in the 1200 km-long Central Burma Depression as well as in the three areas into which the Ministry of Energy has divided its offshore territory (Fig. 1.2). The onshore Rakhine coastal strip (R in Fig. 1.2) saw minor oil production from hand-dug wells in the past and is included in this study for completeness. However, MOGE’s presentation material states that basins on the Shan Plateau (Namyau, Hsipaw-Lashio and Kalaw basins) and at the northern end of the Tanintharyi peninsula (Mawlamyine and Mepale basins) (Fig. 1.2) also have petroleum potential, but they have seen little or no exploration and available geological data are limited. These frontier basins are discussed in Chapter 5.

While oil continues to be produced onshore from a number of small- to medium-sized fields, it is the discovery and production of offshore gas and associated gas-liquids which have transformed the country’s petroleum prospects and economy, as shown in Figure 1.3. In June 2013 the Ministry of Energy announced that onshore oil production was averaging 7500 b/d and gas 65 MMcf/d (the Ministry’s daily gas production figure in 2013 compares with MOGE’s figure of 56–490 MMcf/d in 2014; Kyaw Kyaw Aung 2014); offshore production was around 10 000 b/d of gas-liquids and oil and 1.4 Bcf/d of gas. MOGE’s estimate of proven (?remaining) reserves in 2006 was 115,116 MMbbls oil and 0.309 Tcf gas (onshore) and 100,892 MMbbls condensate and 15.845 Tcf gas (offshore).

Independent estimates of the country’s proven gas reserves by BP have varied year by year as more data have become available. For example, at end-2009 BP’s estimate of proven reserves was 20.1 Tcf; by end-2010 reserves had dropped to 11.8 Tcf; and by end-2011 it had fallen again to 7.8 Tcf. This figure was adopted again for end-2012, before rising to 10 Tcf at end-2013 (BP Statistical Review of World Energy 2009, 2010, 2011, 2012, 2013, 2014). For comparison, the United Kingdom’s proven gas reserves at end-2013 are stated by BP to be 8.6 Tcf. BP does

not provide an estimate of Myanmar’s oil reserves, but we estimate the proven reserves, including condensate, to be in the hundreds-of-millions of barrels range rather than billions. For the

Fig. 1.1. Myanmar, the largest country in mainland SE Asia, with main rivers and administrative states shown in various tones. The longest river is the Thanlwin (formerly the Salween), one of the great rivers which rises on the Tibetan Plateau, reaching the sea in the Gulf of Moattama. Note that some of the states of the Central Burma Depression are small in area and have been omitted.

Fig. 1.2. The petroliferous areas of Myanmar. The onshore Central Burma Depression is gas and oil bearing whereas the offshore area is mostly gas bearing, with some condensate. The boundaries of the offshore area with neighbouring Thailand, India and Bangladesh are approximate. Bathymetric contours greater than 1000 m have been omitted. R is the onshore Rakhine coast where minor oil occurrences have been produced in the past from hand-dug wells. Questionable onshore basins considered by MOGE (e.g. Tin Maung Yee 2012) also to be prospective are N (Namyau), H-L (Hsipaw-Lashio), K (Kalaw), Mp (Mepale), S (Sittaung Valley) and M (Mawlamyine). Basins within the Central Burma Depression are shown in red, the boundaries between them being arbitrary or marked by subtle structural highs.

Physiography and drainage

Myanmar is the largest country in mainland SE Asia, with a land area of some 676 577 km² and a continental shelf area of 229 754 km² down to the 200 m isobath (510 335 km² to the 200 km territorial limit from the shoreline). The shoreline has a total length of 2052 km (Figs 1.1 & 1.4).

The country comprises five main topographic regions: (1) the Kachin Ranges (part of the greater Sino-Burman Ranges) in the north; (2) the Indo-Burman Ranges in the west, the coastal Myanmar portion of which is referred to as the Rakhine Yoma (formerly Arakan Yoma); (3) the Shan Plateau in the east; (4) the Central Burma Depression in the middle which is the habitat of most of the onshore petroleum; and (5) to the WSW the Rakhine Coastal Lowlands where oil and gas are present and have been produced on a small scale hitherto.

The Indo-Burman Ranges extend some 1300 km to the southern tip of the Rakhine (Arakan) Peninsula, and their geological analogue reappears 1700 km further south as the Andaman Islands. The ranges form the border between India and Myanmar in the north while in the south they separate the Rakhine Coastal Lowlands from the Central Burma Depression. The southern, peninsular, portion of Myanmar adjoining Thailand is Tanintharyi Province (previously Tenasserim), comprising mountains and narrow coastal plains.

The Central Burman Depression comprises a complex of basins straddling a partly concealed volcanic arc which appears most prominently at Mt Popa (1518 m) and Taungthonlon (1708 m, 340 km north of Mandalay) (Fig. 1.5). The southern part of the depression is divided unequally into the Ayeyarwady (formerly Irrawaddy) valley in the west and the smaller Sittaung Valley in the east adjacent to the Shan Plateau, and are themselves separated by the Bago Yoma range of hills (formerly the Pegu Yoma). The deltaic lower
portions of the Ayeyarwady and Sittaung valleys cover a level and low-lying delta-plain of some 31,000 km² which is prone to flooding; wide areas were devastated by the tsunami resulting from the 26 December 2004 Great Sumatra earthquake.

Two large tropical Neogene deltas drain into offshore Myanmar. The Ganges/Brahmaputra at the head of the Bay of Bengal is responsible for the Bengal Fan which has an offshore area in Myanmar of 171,361 km² and a Miocene–Pleistocene sediment thickness of up to 20 km. The Ayeyarwady Delta is prominent onshore, but offshore its sediments were deflected eastwards into the Martaban Basin where they cannot easily be distinguished from input from the Sittaung and Thanlwin rivers.

The principal drainage system onshore Myanmar comprises the north–south-flowing Ayeyarwady River and its associated tributaries, which drain around 66% of onshore Myanmar with the main part of the Ayeyarwady system emptying into the Andaman Sea. The Chindwin River drains the northwestern part of the country before joining the Ayeyarwady downstream of Mandalay. The much smaller Pathein River drains the southeastern Rakhine Yoma and the Rangoon River drains the southern Bago Yoma, both joining the network of waterways which is the Ayeyarwady Delta. The Shan Plateau in the east is drained by the Thanlwin (Salween) River which enters the Gulf of Martaban south of the Sittaung River and is one of the great rivers which rise on the Tibetan Plateau. These rivers contributed most of the clastic sediment-fill observed offshore in the Gulf of Moattama Basin, much of which is of Pliocene age. Along the Rakhine Coastal Lowlands short rivers flowing westwards into the Bay of Bengal provided a significant portion of the Plio-Pleistocene sediment-fill in the offshore Rakhine Basin, while the Brahmaputra river system (as part of the Bengal Fan) provided sediment input into the Rakhine Basin from the north throughout the Neogene. The hill country of peninsular Myanmar (Tanintharyi) is drained by short rivers flowing westwards into the Gulf of Moattama and the Tanintharyi Shelf area.

A notable feature of Myanmar’s rivers is the extent to which they follow the structural grain of the underlying rocks. In places this involves a large change in the direction of flow, for instance the Moei River that partly forms the border with Thailand doubles back from NW-flowing to SSE-flowing where it joins the Thanlwin River at about latitude 17°N. River capture may have played a part in the development of the country’s drainage pattern through the Cenozoic, as suggested by Robinson et al. (2014).

**Fig. 1.4.** (a) Digital elevation model (DEM) of Myanmar and surrounding region (courtesy of NASA and the US Geological Survey). (b) Simplified key to principal geographical features of the DEM; approximate outlines of upland areas are shown in pale brown.
Fig. 1.5. Digital elevation model (DEM) of part of the Central Burma Depression; the E–W width of the area covered is c. 125 km. The Indo-Burman Ranges are in the SW corner and the Shan Plateau in the east. Mt Popa is the conspicuous cone in the top-centre. The western part of the depression comprises the Cenozoic petroleum-bearing Salin Basin, the steeply dipping western flank of which is the belt of ridges termed the Western Outcrops. The hilly ground forming a NNW–SSE belt east of Mt Popa is the Bago Yoma, an anticlinorium of Cenozoic sediments, bounded on the east by the nearly N–S dextral Sagaing Fault. A distinct WNW–ESE lineament crosses almost the entire width of the Central Burma Depression just below the centre of the image, and is inferred to be a fault.

Fig. 1.6. Simplified neotectonic map of Myanmar and surrounding areas, showing active faults (including inferred faults) and anticlines and also the epicentres of the twentieth and twenty-first century earthquakes of $M > 6.5$. Modified from Wang et al. (2014).
An excellent and easily obtained topographic map of Myanmar at 1:1 200 000 scale is published by Freytag and Berndt of Vienna (ISBN 3-7079-0652-3; www.freytagberndt.com).

Seismicity

Myanmar is one of the most seismically active countries in the world. The country’s seismicity reflects the continued northwards collision of the Indian Plate with Eurasia, the Burma Platelet being the buffer zone between the two (see Chapter 2). The crustal reaction to that oblique convergence has been widespread earthquakes which are related to: (1) the subduction of the India Plate beneath the Burma Platelet (although Rangin et al. (2013) argue that the western boundary of the Burma Platelet north of the Andaman Islands has not been subducted since the Mesozoic, the seismicity in that northern zone therefore resulting from ongoing detachment and sinking of an old slab); (2) right-lateral movement on mostly N–S or NW–SE wrench faults with accompanying thrusting; and (3) left-lateral movement on wrench faults with WSW–ENE trends, caused by the clockwise flow of the lithosphere as it is displaced under gravity from beneath the eastern Himalaya syntaxis. A study of the neotectonics of Myanmar has been carried out by Wang et al. (2014) from satellite imagery and fieldwork, and their simplified map is provided in Figure 1.6.

It is not clear the extent to which recent movements, for example on faults, have affected the petroleum trap potential of structures. There is a risk that pre-existing traps might have been breached and allowed oil or gas to escape, and any prospect which is dependent on sealing by a still-active fault might have an extra degree of risk because of it. However, Curiale et al. (1994) argue that (onshore at least) generation and migration are still continuing, tending to keep traps topped up as they may become modified by young structural deformation. Another consequence of the seismicity of Myanmar and surrounding regions is the risk that it poses to operations, including the risk of structural damage to buildings, roads, railways, dams and pipelines. An equally serious risk is that of flooding of lowland coastal areas by tsunamis generated offshore; as mentioned above, much of coastal Myanmar was devastated by the tsunami caused by the Boxing Day 2004 Sumatran earthquake. Landslides can also be triggered by earthquakes, both onshore and offshore, and it is thought that major submarine slides which fan out into deep water off the Rakhine coast were triggered by such seismic shocks.

References

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