Geological and tectonic evolution of the Indo-Myanmar Ranges (IMR) in the Myanmar region

KYI KHIN[1]*, KHIN ZAW[2] & LIN THU AUNG[3]

[1]*SK Engineering and Construction, Singapore Branch, 415979, Singapore*

[2]*CODES ARC Centre of Excellence in Ore Deposits, University of Tasmania, Private Bag 126, Hobart, Tasmania 7001, Australia*

[3]*Earth Observatory of Singapore, Nanyang Technological University, 50 Nanyang Avenue, N2-01a-14, 639798, Singapore*

**Correspondence: kyikyaw2@gmail.com*

The Indo-Myanmar Ranges (IMR) of Myanmar, also known as the Indo-Burman Ranges (IBR) or the Western Ranges, extend from the East Himalayan Syntaxis (EHS) southwards along the eastern side of the Bay of Bengal to the Andaman Sea, comprising the Naga Hills Tract in the north, the Chin Hills in the middle and the Rakhine (Arakan) Yoma in the south. The IMR is economically important; major discoveries of oil and gas have been made in the Bay of Bengal to the west of the Rakhine Yoma, and there are several occurrences of chromite and nickel deposits (e.g. Webula, Mwetaung in Chin State) and submarine volcanic-hosted massive sulphide deposits (e.g. Laymyetna in Ayerwaddy Region). The IMR occupies a complex tectonic zone as the southeastwards continuation of the Indian–Asian collision belt in Tibet and Assam, and lies north of the active subduction zone of the Sunda–Andaman arc (Figs 4.1 & 4.2). The IMR occurs along the western margin of the Myanmar Microplate, also known as the Burmese Platelet or the West Myanmar Terrane or Block, situated between the Eurasian Plate to the east and the Indian Plate to the west (e.g. Fitch 1972; Curray *et al.* 1979; Mukhopadhyay & Dasgupta 1988; Pivnik *et al.* 1998; Bertrand & Rangin 2003; Shi *et al.* 2009; Baxter *et al.* 2011; Garzanti *et al.* 2013; Soibam *et al.* 2015). The West Myanmar Block has been also described as a forearc sliver, bounded on the west by a subduction zone and a strike-slip margin, on the east by a strike-slip fault (Sagaing Fault), on the south by a spreading centre and on the north by a compressional plate boundary (Curray *et al.* 1979; Pivnik *et al.* 1998; Nielsen *et al.* 2004).

The IMR is considered to have formed as an accretionary wedge, linked to the eastwards subduction of thinned continental crust beneath the Bengal Basin under the West Myanmar Block (e.g. Mitchell 1989, 1993; Sengupta *et al.* 1990; Kaila *et al.* 1992; Searle *et al.* 2007; Garzanti *et al.* 2013). Major tectonic processes such as subduction, obduction, accretion and collision events have been identified in the IMR from the Early Cretaceous to the Middle Miocene and Quaternary (Mitchell 1989, 1993; Allen *et al.* 2008; Morley 2014; Zhang *et al.* 2015; Liu *et al.* 2016) and the highly oblique subduction of the Indian Plate in this region is still active (e.g. Steckler *et al.* 2016).

Many workers (e.g. Curray *et al.* 1979; Bender 1983; Mitchell 1986; Khin Zaw 1990) have made plate tectonic interpretations of geological events within the Myanmar region. Most authors agree that the Myanmar region separated from Gondwana during the Phanerozoic. These interpretations have not been able to satisfactorily explain the detailed geological framework and evolution of the IMR, but they serve as an initial step towards integrating the highly diverse data from a large region into a coherent pattern. There have been an increasing number of studies in the IMR of Myanmar aiming to understand the nature and origin of the continental crust beneath Myanmar, significant for Mesozoic and Cenozoic plate tectonic reconstructions of Southeast Asia. In this chapter we present a review of previous studies. We also provide the setting and a revised tectonic model of the IMR, focusing on basin development and mineral and energy potential, together with comments on further work required to understand this important resource-rich tectonic unit in Southeast Asia.

Previous studies

Theobald (1871, 1872) and Oldham (1883) made the first geological investigations in the IMR, based mainly on palaeontological and stratigraphical studies. Theobald (1871) introduced the term ‘Axial Group’ for the Triassic sedimentary and metamorphic rocks exposed in the Rakhine Yoma in the southern part of the IMR; these sequences are flanked by rocks of Cretaceous and younger ages. Geological mapping was carried out in central Myanmar and east of the Mindat-Saw area by staff members of the Geological Survey of India (GSI) and the Burmah Oil Company (BOC); their results were summarized by Cotter & Clegg (1938). Geological traverses and studies between Padaung and Taungup across the IMR were made by Pascoe (1912), Stuart (1923), Chhibber (1927), Clegg (1938, 1941, 1954) and Ngaw Cin Pau (1962). Stuart (1923) made a geological traverse across the Patkoi Ranges in the northernmost part of the IMR near the Indian border, and provided the first geological information concerning the occurrences of molasse, flysch and serpentinite.

From 1959 to 1963, R.O. Brunnschweiler investigated the IMR for the Government of the Union of Myanmar under the auspices of the Colombo Plan, a collaborative programme between geologists from Myanmar Petroleum and Mineral Development Corporation and Australian Bureau of Mineral Resources (BMR). They made traverses across the IMR through the Naga Hills, Chin Hills and Rakhine Yoma and published landmark contributions on the IMR (Brunnschweiler 1966, 1974; ECAMS 1982, 1986; Bannert *et al.* 2011). These studies recorded thin, laminar, feeder meta-basaltic and peridotitic dykes and submarine pillow lavas, occurring as layers within garnet-amphibolite mica schists in the basement complex, and submarine extrusions in the Triassic flysch sequence, occurring north and south of Kale Township (eastern part of northern Chin Hills) and NW of Mindon Township (eastern part of central Rakhine Yoma). Sills in the metamorphic rocks represent contemporaneous feeder channels for

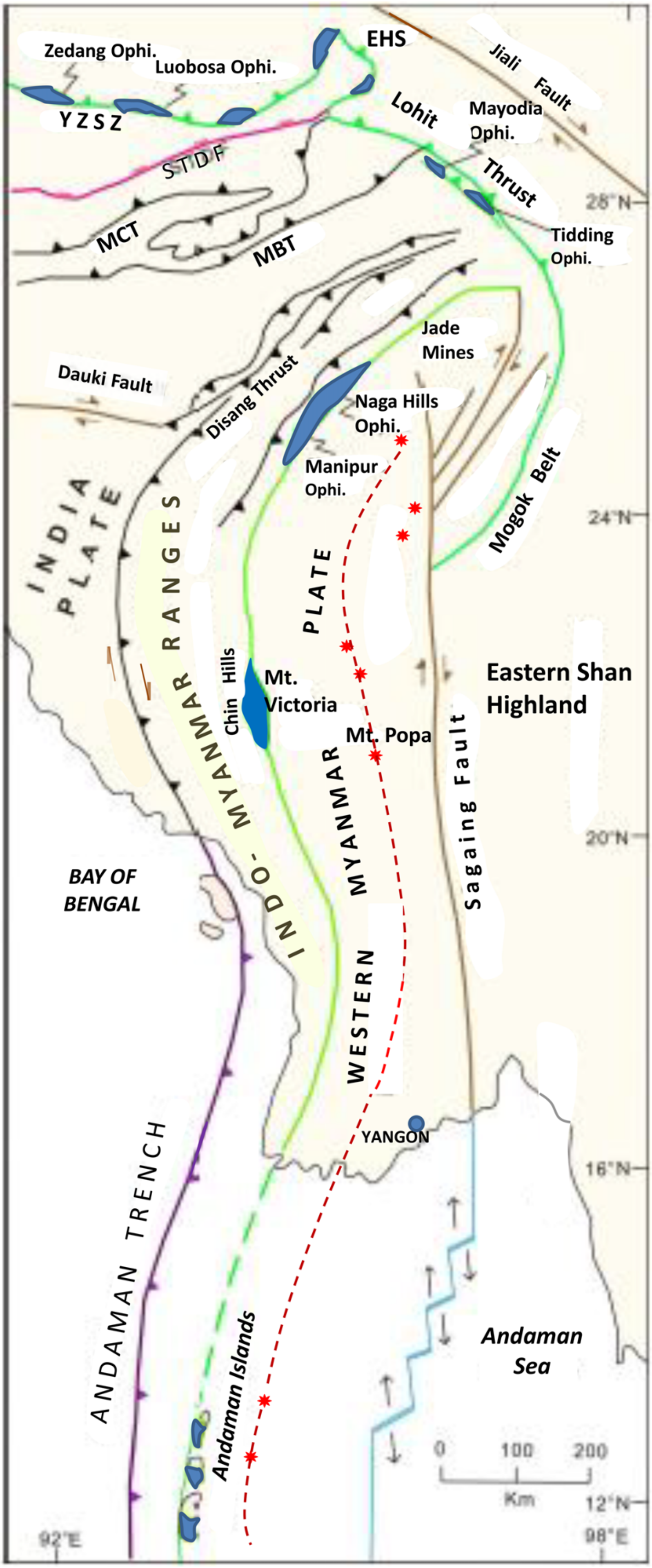


Fig. 4.1. Tectonic map of Myanmar region showing Indo-Myanmar Ranges and the plate boundary interactions between India, Myanmar and Sunda (modified after Fareeduddin & Dilek 2015). EHS, Eastern Himalaya Syntaxis; YZSZ, Yarlung–Zangbo Suture Zone; STDF, South Tibetan Detachment Fault; MCT, Main Central Thrust; MBT, Main Boundary Thrust. Also shown are the seafloor-spreading system (light blue) in the Andaman back-arc basin, the Chin–Nagaland–Manipur Hills ophiolite outcrops (dark blue) and inner volcanic arc (red dotted line) with Cenozoic volcanoes (red stars).

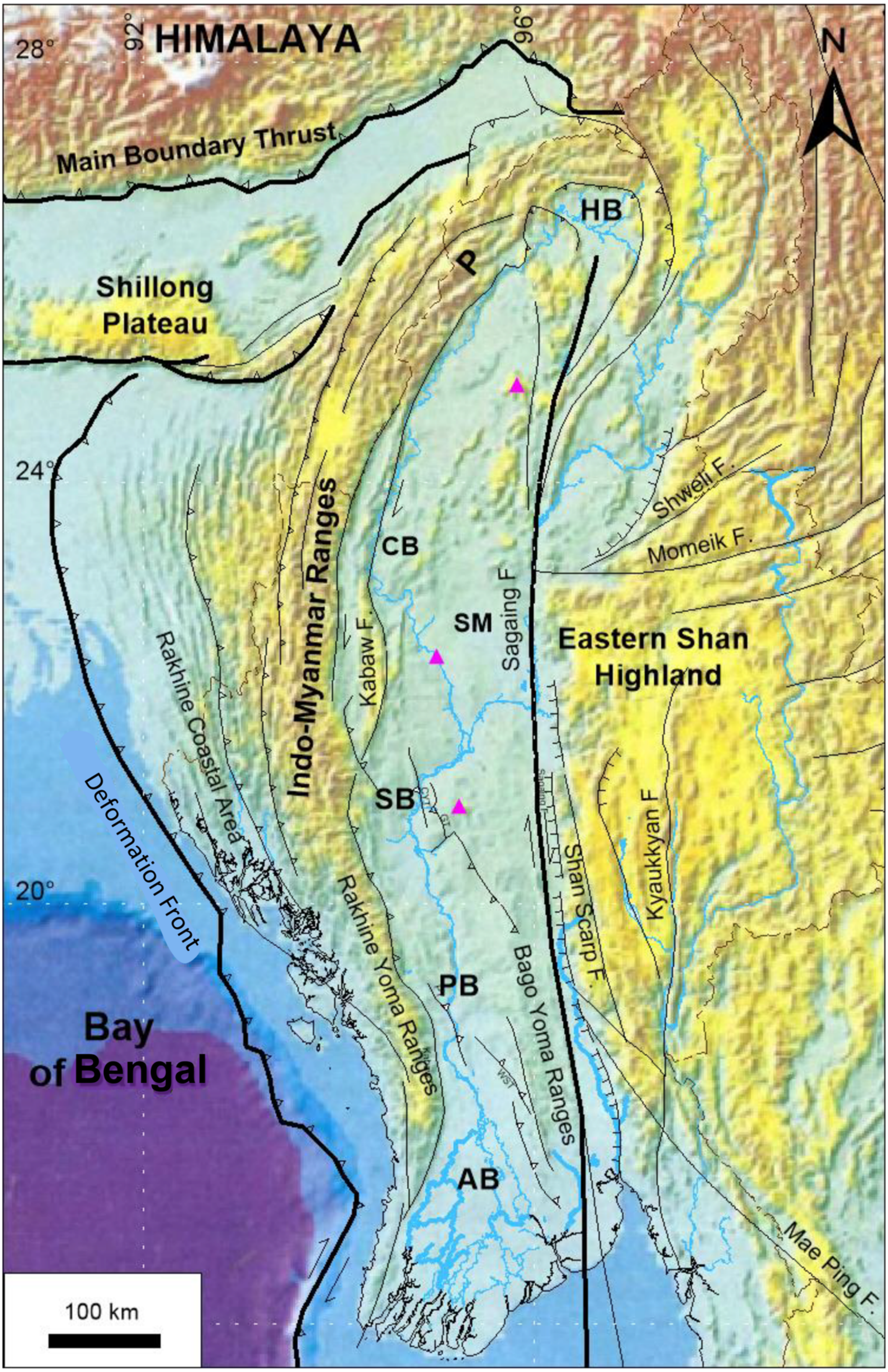


Fig. 4.2. Map showing location of Indo-Myanmar Ranges, Kabaw Fault, Sagaing Fault and Eastern Shan Highland (Sinbumasu). P, Patkoi Ranges; HB, Hukaung Basin; CB, Chindwin Basin; SM, Shwebo–Monywa Basin; SB, Salin (Central) Basin; PB, Pyay (Prome) Basin; AB, Ayeyarwady Embayment Basin. Pink triangles are Quaternary volcanoes (after Lin Thu Aung *et al.* 2015).

extrusions in the flysch; subsequent thrust movements used these ultramafic sills as glide planes. The thrust plane between flysch (below) and metamorphics (above) was lubricated by a serpentinite layer, occurring along the tectonic contact. Garnet-amphibolite schists are known from other ophiolitic belts, where they are regarded as the metamorphosed original volcanic-sedimentary cover of the ocean floor.

Myint Lwin Thein (1970) and Gramann (1974) recorded Upper Triassic fossils in sediments in the Chin Hills. Tin Aung Han *et al.* (1972) made a geological map of the Hainggyi Island, the southernmost part of the IMR, and reported Upper Triassic fossils in the sediments of the Island. Many geologists (e.g. Ngaw Cin Pau 1962; Than Tun 1973; Than Htut 2017) from DGSE and MOGE carried out geological surveys in the Chin-Naga Hills and southern Rakhine Yoma. Win Swe (1972) published a proposed plate tectonic model for the IMR for Middle Triassic–Recent time.

From 1972 to 1989, the Federal Institute for Geosciences and Natural Resources (BGR) from Hannover, Germany published new observations on the geology and mineral occurrences in Myanmar in collaboration with the Myanmar Oil Corporation (MOC), the Department of Geological Survey and Mineral Exploration (DGSE) and the Technical Services Corporation (TSC). During 1980–84, UNDP–Burmese co-operative projects continued in selected areas with systematic geological mapping. UNDP (United Nations 1978*a*) reported the results of reconnaissance geology and geochemical stream sediment sampling, and prepared geological maps of parts of the eastern Chin Hills and the Rakhine Yoma. The German-Myanmar cooperation project, Eastern Chin and Arakan Mineral Survey (ECAMS 1982, 1986) 1980–86 made two traverses in the Naga Hills, and made further geological observations from the western outcrops of the Innerburman Tertiary Basin into the Rakhine Yoma and Chin Hills. Ghose & Singh (1980) and Singh & Ghose (1982) also published acounts of the geology of the Indian border region, west of the Naga Hills, and discussed the tectonic setting of the IMR.

Le Dain *et al.* (1984) studied active faulting and tectonic features in and around the Indo-Myanmar region by integrating information derived from Landsat imagery and information already available on the Cenozoic and Quaternary tectonics of the region. They reveal roughly parallel north–south-trending folds, often verging towards the west. They considered that deformation in the IMR was decoupled from that in the underlying Indian Plate, while northwards movement of the ranges was accommodated along the Sagaing Fault and parallel faults further east. Acharyya & Lahiri (1991) reported ophiolite occurrences in the IMR and the Andaman–Nicobar Island Arc. Mitchell (1993) published an account of Cretaceous–Cenozoic tectonic events in western Myanmar and the Assam region. Nandy (1986, 2001) summarized earlier geological descriptions of the IMR. Ni *et al.* (1989) and Guzman-Speziale & Ni (2000) studied the nature of the accretionary tectonics and geometry of Wadati-Benioff Zone to the east of IMR, using seismic profiling to determine the geometry of the subducted Indian Plate.

Socquet *et al.* (2002) interpreted the Kanpetlet Schists in the IMR as forming part of the continental basement, uplifted by movements along a right-lateral shear zone. Earlier workers such as Fitch (1970, 1972) studied the effects of unique and the complex tectonics resulting from oblique subduction in Southeast Asia, and Satyabala (1998, 2000, 2003) added understanding of subduction during oblique plate convergence in the Indo-Myanmar region. Bannert *et al.* (2011) published a comprehensive account of the geology of the IMR in Myanmar. Tin Tin Naing *et al.* (2013) determined the provenance and source of Eocene–Miocene sandstones of the Rakhine Coastal area, identifying the source as a Late Cretaceous–Palaeogene magmatic arc in Central Myanmar. Sevastjanova *et al.* (2016) studied detrital zircons from Upper Triassic sandstones in the Chin Hills (Mt Victoria) area, and suggested that the West Myanmar Block and IMR was part of Southeast Asia before the Mesozoic. Kyi Khin *et al.* (2014, 2017) established that the Neogene clastic sequences preserved in the western on-land part of the IMR provided detrital information documenting the erosional unroofing history of the Eastern Himalayas, the Burmese Arc and India–Asia Collision Zone. All of the sedimentological and provenance data are linked to syntectonic sedimentation and sequential evolution of the Bengal Basin, a remnant ocean basin south of the Eastern Himalaya. Zhang *et al.* (2015) interpreted the multi-phase uplift of IMR and western thrust belt of Minbu sub-basin based on apatite fission track (AFT) ages in four major Cenozoic cooling episodes: Late Oligocene, Early–Middle Miocene, Late Miocene, and Pliocene–Pliestocene. Liu *et al.* (2016) studied zircon secondary ion mass spectrometry U–Pb ages and Hf–O isotopes of two Myanmar ophiolites – Kalaymyo ophiolite from the Western Belt and the Myitkyina ophiolite from the Eastern Belt – and their results showed that the Kalaymyo ophiolite of northen IMR has an Early Cretaceous age (*c.* 127 Ma).

Regional geological framework

The general geological setting and lithological units in the IMR are shown in Figure 4.3. The IMR trends roughly north–south or NNE–SSW and the rock sequences consist of Triassic, Cretaceous and Eocene pelagic metasediments and ophiolitic (ultramafic) rocks in the east and a thick section of Eocene–Oligocene flysch overlain by Miocene to Pliocene molasse in the west, propogating into the Bay of Bengal. The easternmost metasedimentary units form a metamorphic complex, described by Brunnschweiler (1966) as the Naga metamorphics and assigned a pre-Mesozoic age; Acharyya (1986) assigned them to the Proterozoic. Adjacent ophiolitic units of Early Eocene–Late Cretaceous age (Ghose & Singh 1980) are overthrust by the metamorphics.

In the north, the IMR forms the border between India and Myanmar, and in the south separates the Rakhine Coastal lowlands from the Chindwin Basin (part of Myanmar Central Basin). The IMR consist of a north–south-oriented, broad, west-verging fold and thrust belt, forming a tectonic block between the Assam Shelf and Bay of Bengal in the west and the Central Myanmar Basin (CMB) in the east. The eastern margin of the IMR is fault-bounded. The fault originated during the pre-Tertiary, but was reactivated during the Tertiary. The fault separates flysch-like sediments of the IMR in the west from the Tertiary sedimentary infill of the CMB in the east. The eastern margin of the IMR is bounded by the Kabaw Fault, and the western margin is represented by the Kaladan Fault (Myauk U Fault). The Kabaw Fault is considered to have accommodated a considerable amount of right-lateral strike-slip displacement (Hla Maung 1987; Khin Zaw 1989). The margin of the eastern foothills is considered in this account to coincide with the western boundary of the West Myanmar Block, which overrode the Indian Plate. Throughout the history of collision, the convergent margin has been complicated by right-lateral strike-slip motion along the Kaladan Fault in the west and Sagaing Fault in the east (Ni *et al.* 1989; Johnson & Alam 1991; Uddin & Lundberg 2004).

Distribution of sediments

Sedimentary rock units in the central part of the IMR comprise a folded Early Mesozoic–Palaeogene flyschoid sequence. The western part of the IMR is composed of Neogene fluvio-deltaic sediments and turbidites, sourced primarily from the Ganges–Brahmaputra river system, and folded during Late Miocene–

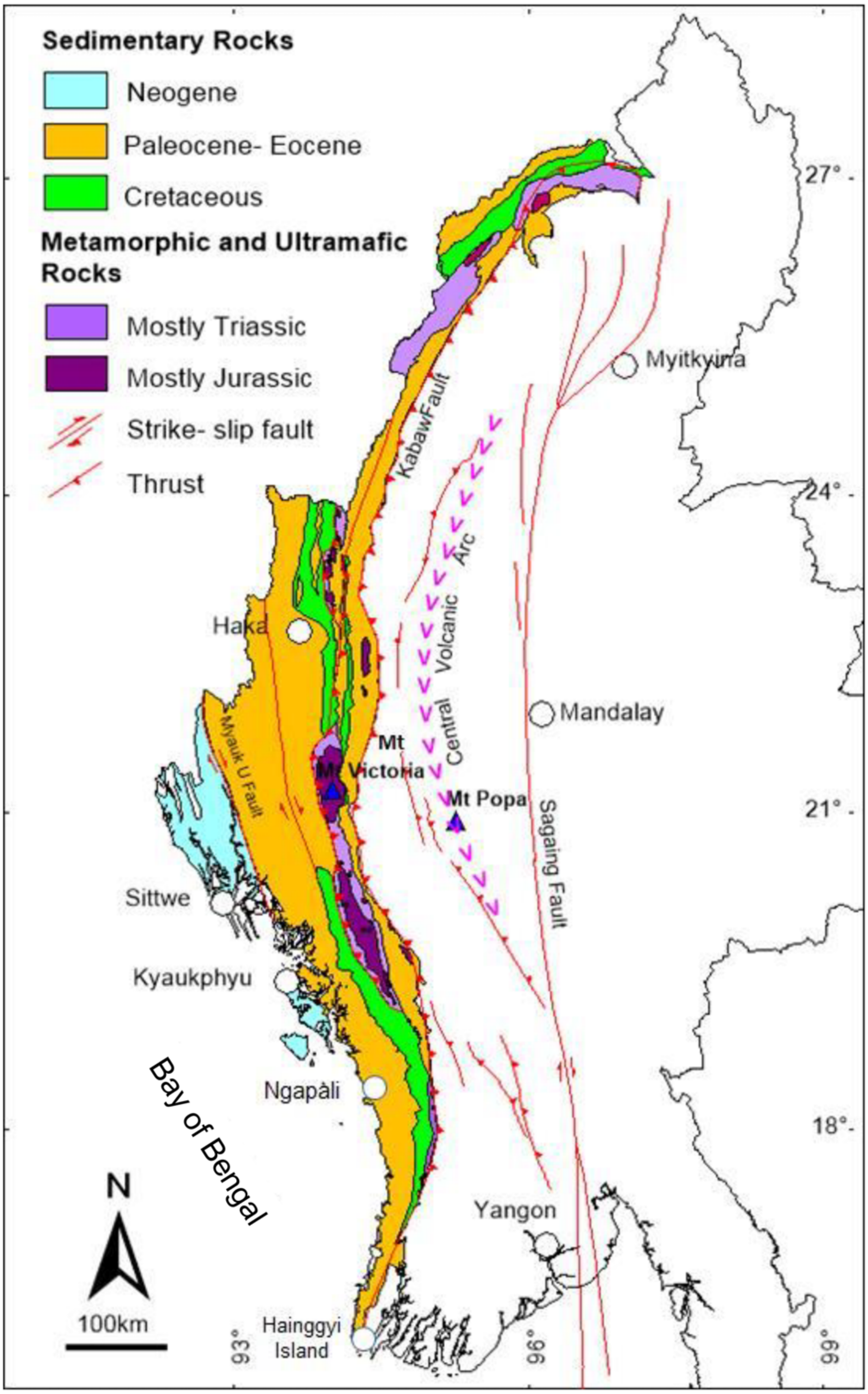
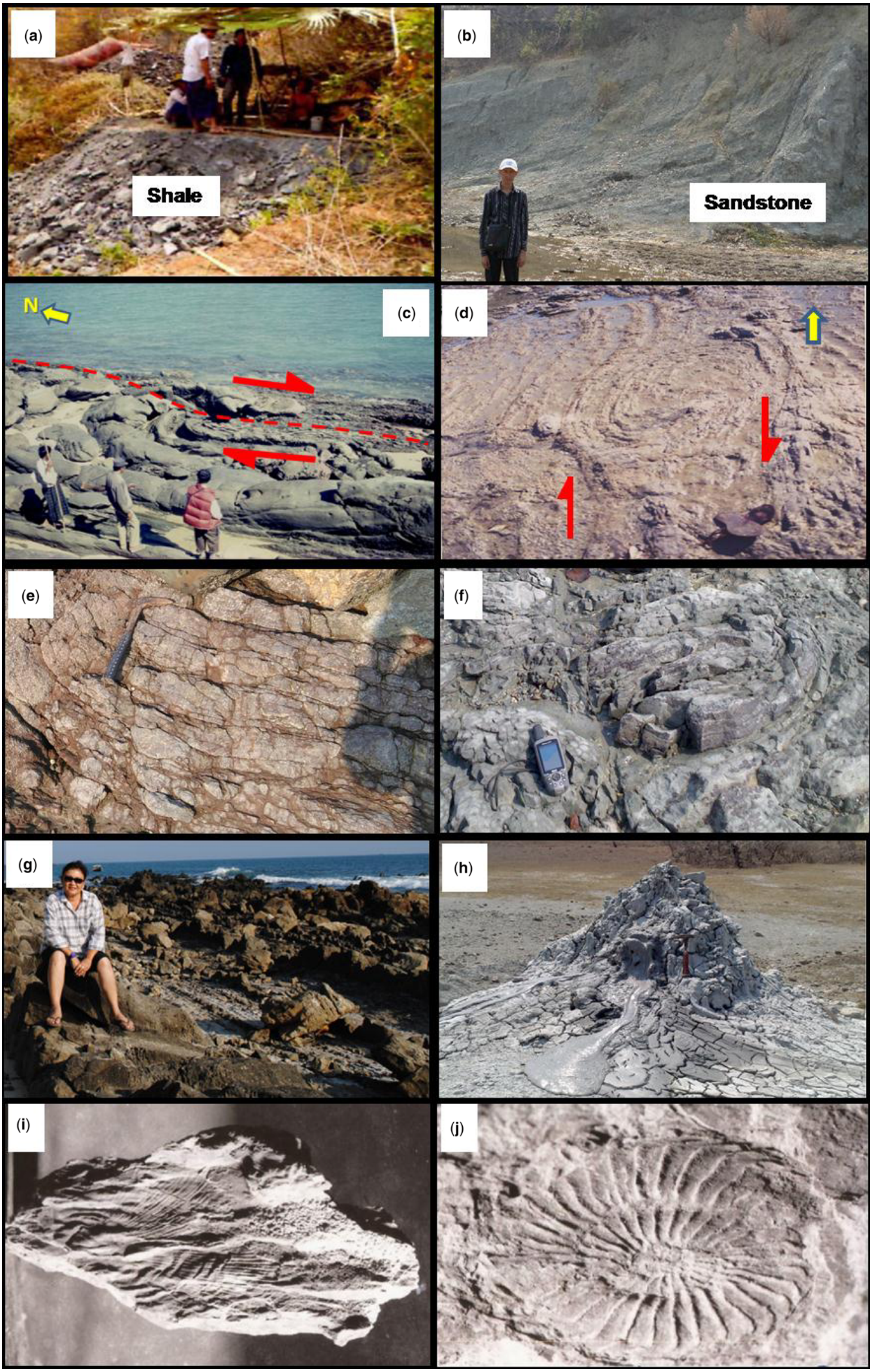


Fig. 4.3. Regional geological setting and age of different lithological units in Indo-Myanmar Ranges (adapted after Myanmar Geological Map 2014 – see foldout at back of this volume).

Recent time (Sikder & Alam 2003; Kyi Khin *et al.* 2014, 2017). Close to the eastern margin of the IMR, metamorphic rocks, dismembered ophiolites and ophiolite-derived cover sediments are exposed. The eastern margin is also composed of Upper Triassic quartz-rich turbiditic (flysch-like) sandstones and marbles, in tectonic contact with a belt of metamorphic schists (Mt Victoria Land of Mitchell 1986, 1989) (Fig. 4.3). In this area, the IMR consists primarily of Upper Cretaceous–Palaeogene deep-water sediments and ophiolitic mélange, containing blocks of gabbro, pillow basalt, serpentinite, chert, limestone and schist (Brunnschweiler 1974; Mitchell 1993). The rock sequences of IMR are progressively younger from east to west. The lithological characteristics of rock sequences in the IMR are shown in Figures 4.4 and 4.5.

In the Naga Hills in the north, the Naga Flysch overlies mafic volcanics of an ophiolite suite. Flysch-type sandstones occur towards the Myanmar–Indian border. A Cretaceous age has been reported from India (Ghose & Singh 1980; Singh & Ghose 1982) and Myanmar (Brunnschweiler 1966; United Nations 1978*b*). In the Naga–Manipur Hills region, rare arenaceous and benthic foraminifera, plant fragments and *Ophiomorpha*-type burrow structures indicate that these rocks were deposited in a shallow-marine to deltaic environment (Acharyya *et al.* 1989; Acharyya 1990).

Ophiolitic rocks occur along large fault zones within the flysch, dissecting the IMR (Hla Htay *et al.* 2017). They are restricted to the eastern parts of the mountains and are very commonly associated with occurrences of metamorphic rock.



(a)
Shale
(b)
Sandstone
(c)
N
(d)
(e)
(f)
(g)
(h)
(i)
(j)

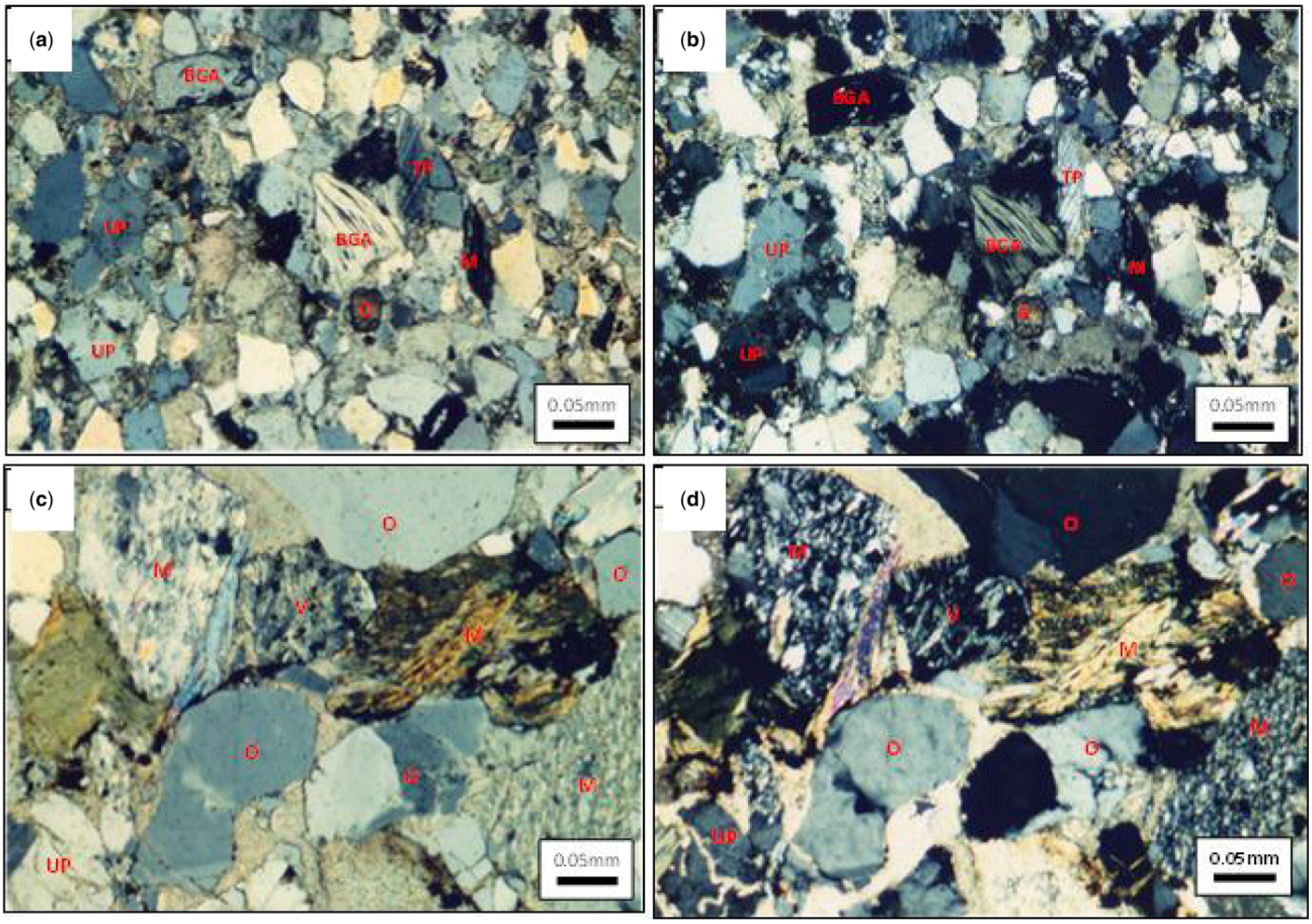


Fig. 4.5. Petrology of Lower Miocene sandstone (Laung Formation) from the Rakhine coastal area. (**a**, **b**) Photomicrograph of quartzose sandstone. Densely packed, angular quartz and blue-green amphibole (BGA), un-twinned plagioclase (UP), twinned plagioclase (TP), garnet grain (G) and metamorphic lithic-fragment (M) set in sparse clayey matrix under (a) plane-polarized and (b) cross-polarized light. (**c**, **d**) Photomicrographs of various sizes of lithic fragments in the Middle Miocene sandstone (Yezaw Formation). Mafic volcanic lithic fragment (V), meta-sedimentary lithic fragment (M), un-twinned plagioclase feldspar (UP) and abundant orthoclase feldspars (O) in the poorly sorted sub-arkosic sandstone under (c) plane-polarized and (d) cross-polarized light.

Bannert *et al.* (2011) described three varieties of ophiolitic rocks: (1) small, elongated tectonized serpentinite bodies within the low-grade metamorphic rocks; (2) serpentinite and pillow basalts with cherts and limestones, associated with the Triassic Pane Chaung Formation, regarded as pre-Upper Triassic ocean floor; and (3) slightly tectonized or untectonized serpentinite and associated rocks.

The Naga Metamorphic Complex has been thrust westwards over the Upper Cretaceous flysch-like sequences and older rocks, which include limestones and low-grade metamorphic rocks locally. Bannert *et al.* (2011) described blueschists in the Naga Hills for the first time. The eastern part of the Naga Hills is covered partly by molasse of the Chindwin Basin, which consists largely of massive sandstones of Miocene/Pliocene age.

In the Chin Hills, lithologies exposed range in age from Triassic to Cretaceous to Eocene, and are represented by greenstone, schist, peridotite, limestone and turbiditic sandstone. The Triassic sedimentary rocks are bedded sandstones with well-developed sole marks, shales and locally limestones. The age of the sandstones is based on the occurrence of the thin-shelled Triassic lamellibranch, *Halobia* (Bannert *et al.* 2011). In the northern Chin Hills low-grade metamorphic mica and chlorite schists comprise the Kanpetlet Schists and the Yazegyo Metamorphics. Higher-grade amphibolitechlorite–epidote–garnet schists have also been recognized among the Yazegyo Metamorphics (United Nations 1978*b*). There is uncertainty concerning the age of metamorphic rocks in the Chin Hills. Earlier workers correlated the schists with the Chaung Magyi Group of the Eastern Shan Highlands and suggested that all these metamorphic rocks are of Late Precambrian–Cambrian age. Bender (1983) and Mitchell (1993) described a stratigraphic connection with the overlying Triassic flyschoid sediments, suggesting a Triassic age for the Kanpetlet Schists. Most recent workers (e.g. Mitchell *et al.* 2004, 2010; Maurin

Fig. 4.4. Lithological characteristics and field photographs of sedimentary units in Indo-Myanmar Ranges in Chin Hills and Rakhine coastal areas. (**a**) Cretaceous shale at Mindat area, Chin Hills (courtesy of Tay Thye Sun). (**b**) Cretaceous sandstone at Mindat area, Chin Hills (courtesy of Tay Thye Sun). (**c**) Strike-slip fault running NNW–SSE in direction between coarsening-upwards sandstone and shale alternation unit and thick mudstone of Yezaw Formation (Middle Miocene) at eastern part of Middle Baronga Island. (**d**) Slump-fold structure in thick mudstone and thinly bedded silt–mud alternation unit of upper part of Laung Formation (Lower Miocene), western part of Middle Baronga Island. Arrows indicate rotation and strike-slip direction. (**e**) Red bedded chert from Late Cretaceous Kyauknimaw Formation exposed near Kyauknimaw village. (**f**) Slump and folded Palaeogene sandstone/shale interbedded unit of mélange deposits exposed about 2 km NW of Zin Chaung village, south of Kyaukphyu. (**g**) Eocene turbiditic sandstones at Ngapali Beach, Rakhine Yoma. (**h**) Active mud volcanic cone, near Shauk Chaung village, about 5 km SE Kyaukphyu (photo taken by Lin Thu Aung). (**i**) Upper Triassic fossil (*Halobia* sp.) from Hainggyi Island (5 cm in width of view). (**j**) Triassic ammonite fossil from Hainggyi Island (5 cm in width of view).

& Rangin 2009) also support a Triassic age for the Kanpetlet Schists. Socquet *et al.* (2002) identified the age of metamorphism of the Kanpetlet Schists as Late Cretaceous–Paleocene in the eastern part of the southern Chin Hills near Mt Victoria, and concluded that there was crustal thickening of 25–30 km in a wedge in front of the obduction front, formed during Late Cretaceous–Eocene time.

There are two possible explanations for the formation of the Kanpetlet Schists: (1) a heterogeneous protolith of a single rock unit; or (2) what is mapped as the Kanpetlet Schists at present includes several discrete lithological units, possibly of different ages. There are no isotopic age data available for the Kanpetlet Schists, and further studies are required for a more detailed interpretation.

Ultramafic rocks are particularly abundant in the northern Chin Hills, and have been observed to occur associated with higher-grade amphibolite facies metamorphic rocks (United Nations 1978*a*; Mitchell *et al.* 2010). Maurin & Rangin (2009) interpreted the Kanpetlet Schists as the uplifted deepest part of a right-lateral shear zone which affected the eastern part of IMR and was exhumed by continuous deformation. Analyses of the pressure–temperature path demonstrate a 25–30 km slow exhumation that can be related to movements on a shear zone, putting Triassic flyschoid sediments of the roof into contact with mica schists of the core (Socquet *et al.* 2002). Mitchell (1981) regarded the whole sequence in the Chin Hills as the western part of the Western Burma Plate, which docked with the former southern Eurasian suture zone in Santonian (Late Cretaceous) times (Heine *et al.* 2004). Liu *et al.* (2016) argued that the Early Cretaceous age (*c.* 127 Ma) of the Kalaymyo ophiolite in the IMR is coeval with Neotethyan ophiolites along the Yarlung–Tsangpo suture. The two Myanmar ophiolite belts belong to two different sutures of the Mesotethys and Neotethys, and the boundary between the Sibumasu and west Myanmar blocks is a Jurassic suture rather than a transcurrent shear zone. However, the Early Cretaceous age data lack a local geological context. In contrast, Mitchell (1981) reported a K–Ar age of 158 ± 20 Ma (Jurassic) for a hornblende pegmatite intruding serpentinites in the Chin Hill ophiolite in the IMR. Stratigraphic relationships suggest a Late Triassic age for this ophiolite (Mitchell 1986, 1989). Further geochronological work is required to confirm the age of sediments and the age of formation of the IMR ophiolites.

In the north, Oligocene molasse sediments indicate a tidal-flat depositional environment. A pebbly conglomerate with occasional cobbles occurs at the disconformable contact with underlying gently eastwards-dipping rocks of the Naga Metamorphic Complex. The pebbles are derived from the underlying Naga Metamorphic Complex and the ophiolitic suite at the base of the Indo-Burman flysch. Along the eastern margin of the Chin Hills, Triassic turbiditic sandstones and pillow lavas are overlain unconformably by Upper Cretaceous *Globotruncana* limestone. However, this geological contact and the nature of limestone within the flysch are not compatible with an autochthonous setting, as reported by Brunnschweiler (1966). There is no transition between flysch shales and limestone blocks; the latter could be interpreted as an olistostromic mélange, composed of allochthonous limestone floaters within the younger Early–Middle Eocene flysch (Ghose & Singh 1980).

The Kabaw Formation of Maastrichtian–Paleocene age (Clegg 1938; Gramann 1974) overlies the limestone between Saw Township in the south and Kalay Township in the north. Late Cretaceous shales, with occasional turbiditic sandstone of Kabaw Formation, host amber deposits at Hti Lin, Mindat-Saw area in the Chin Hills (Tay Thye Sun *et al.* 2015) (Fig. 4.4a, b).

To the east of the Chin Hills, Eocene sandstones contain chert pebbles with lower Upper Jurassic radiolaria (Suzuki *et al.* 2004; Mitchell *et al.* 2010). These are overlain by Paleocene–Middle Eocene, Oligocene and Miocene siliciclastic and calcareous rocks. Singh & Ghose (1982) determined a Late Cretaceous age for the low-grade metamorphic rocks of the Leikhimaro Formation in the Naga Hills, the northern continuation of Chin Hills. Radiolarians, extracted from cherts collected from an ophiolitic mélange near Salumi, Nagaland, NE India, have been assigned to the Upper Jurassic (Kimmeridgian–lower Tithonian) for the first time (Baxter *et al.* 2011). They are significantly older than fossils previously reported from this mélange, and their ages are similar to those determined radiometrically from associated igneous units.

In the Rakhine Yoma, the best exposures of sedimentary units can be found along the tidal areas of the Rakhine Coast and the nearby islands as well as along the major rivers draining the IMR. Along the Rakhine Coast most of the sediments are deep-water siliciclastics, deposited as turbidites, ranging in age from Early to Middle Miocene (Kyi Khin *et al.* 2014, 2017). Characteristic features such as graded bedding, parallel lamination, climbing ripple lamination, convolute bedding, load casts, flute casts, etc. can be observed throughout the flysch sequence. Slumping and faulting within the flysch sequence are observed frequently in coastal and island areas (Fig. 4.4c–g). Thick turbidite sandstones are commonly interbedded with grey shales and mudstones. Mud volcano eruptions occur on the Rakhine Coast and in the nearby islands (Fig. 4.4h).

Although Brunnschweiler (1966) reported that the flysch sediments are of Cretaceous age, Palaeogene flysch sediments have also been found and are widespread. The flysch includes numerous Cretaceous limestone 'floaters' and blocks of Eocene *Nummulitic* limestone and sandstone, as reported by Tin Myint *et al.* (2003). At Mazin Point near the Thandwe Airport, a limestone floater yielded *Globigerinidae* and *Globorotalia aequa* of Late Paleocene–Early Eocene age, associated with blocks of volcanic pillow lava derived from a nearby submarine volcano within the flysch (Bannert *et al.* 2011). On this basis, the flysch sedimentation in most of the IMR appears to be of probable Early Eocene to Early Miocene age.

In the central Rakhine Yoma, Brunnschweiler (1966) observed floaters of tectonized Upper Cretaceous limestone containing Maastrichtian *Globotruncana* within Lower–Middle Eocene flysch along the road from Prome to Taungup near Taungup Pass. Gramann (1974) also recorded the large foram *Lenticulina* sp. from limestone blocks in a thick turbidite sequence exposed along the Padaung to Taungup road, confirming an Eocene age (Bender 1983). To the north of the Taungup Pass, the sequence is composed of unfolded, shallowly eastwards-dipping homogeneous sandstone of molasse facies. In the southern part of the Rakhine Yoma, the Eocene is represented by massive sandstones with occasional conglomerates, almost entirely devoid of shale.

Metamorphic rocks have been found in a more or less continuous belt extending southwards into the area north of Ngathainggyaung. Beds containing the Triassic fossil *Halobia* sp. and ammonites are well exposed in the Ngayant San stream and at the top of the hill on Hainggyi Island (Tin Aung Han *et al.* 1972; Than Htut *et al.* 2012) (Figs 4.3 & 4.4i, j). The Negrais Group of the southern Rakhine Yoma consists of indurated, contorted sandstones and shales, with rare conglomerates. Boulders and blocks of limestone contain larger foraminifera such as *Nummulities*, *Operculina*, *Assalina*, *Discocyclina*, *Lenticulina* and some *Ranikothalia* sp., indicating an Early Eocene age, occurring as olistoliths in the siliciclastic sequence, derived from a neighbouring carbonate platform. The flyschoid Negrais Group is identical to undifferentiated Eocene and older Paleocene sediments.

In the southern part of the Rakhine Yoma, Moore *et al.* (2015) recently reported mud volcanoes 50–300 m in diameter (Fig. 4.4h) that cut across the older, deformed deep-water Eocene–Oligocene siliciclastic turbidites, overlain by Miocene and younger trench-slope deposits in Ramree and Cheduba islands. They also noted strongly folded and sheared ultramafic rocks in fault contact with the turbidites and silicified limestones and cherts, containing Upper Cretaceous fossils. They interpreted these assemblages as fragments of oceanic crust scraped off the subducting Indian Plate and accreted to the IMR. These blocks, and blocks of the underlying turbidites/slope sediments, have been carried to the surface by rising mud to form a diapiric mélange due to overpressuring caused by thrusting, with the mobilization of fine-grained sediments. GPS measurements of plate motions in Bangladesh, combined with measurements from Myanmar and NE India, reveal 13–17 mm a^{-1} of active plate convergence along a shallowly dipping and locked megathrust fault (Steckler *et al.* 2016).

Source region of sediments

The sediments in the IMR are interpreted either as accreted sediments of the early Bengal Fan, derived from the India–Asia collision (Mitchell 1974; Curray *et al.* 1979; Bender 1983; Hutchison 1989; Curray 2005), or as sediments shed either from the Indian margin (Sengupta *et al.* 1990) or from the Burmese active volcanic arc (Allen *et al.* 2008). Tin Tin Naing *et al.* (2013) concluded that the dominant source for the Palaeogene sandstones exposed in the Rakhine Yoma and the coastal area, and Neogene sandstones in the middle part of the Rakhine coastal region, was a Late Cretaceous–Palaeogene magmatic arc. These deposits do not yet show the strong influx of detritus from the Himalayan region, but some river confluence and consequent mixing of provenances may have occurred. In contrast, Allen *et al.* (2008) and Kyi Khin *et al.* (2014, 2017) concluded that Neogene flysch in the Rakhine coastal area received clastic material from the rising Himalaya to the north (Fig. 4.5a–d). Precise discrimination of the effects of each of these sources remains difficult to assertain because of their intrinsic complexity; further studies are required.

The abundance of Permian and Triassic zircons, occurrences of Cr spinel and the turbiditic character of the Upper Triassic sandstones in the Chin Hills (Mt Victoria) suggest that the West Myanmar Block was part of Southeast Asia before the Mesozoic. Detrital zircon U–Pb ages suggest that during the Proterozoic West Myanmar was situated in the Gondwana supercontinent, close to Sibumasu, Western Australia and the Carnarvon Basin but far away from Indochina (Sevastjanova *et al.* 2016).

In comparison, metamorphic events occurring during the Cenozoic adjacent to the developing, largely undeformed Central Myanmar Basin (CMB) suggest that the basin is likely to be a crustal-scale piggy-back basin between the compressed regions of the Mogok Metamorphic Belt (MMB) and the IMR. Based on provenance and sedimentary structures, the source for the Eocene sediments in the CMB is interpreted to have been a volcanic-arc terrane lying to the east and NE (i.e. in the Shan Plateau area; Kyaw Linn Oo *et al.* 2015) and from Tibet to the north (Licht *et al.* 2013). The IMR and the CMB were then affected by transtensive and transpressive north–south dextral shear during the continuous northwards movement of the Indian Plate, with tectonic overprinting of the India–Bengal Basin along the western continental margin of the Sunda Plate (e.g. Maurin & Rangin 2009).

Ultramafic (ophiolitic) bodies

There are three ophiolitic belts in Myanmar (from west to east): the Western Ophiolite Belt (WOB); the Central Ophiolite Belt (COB); and the Eastern Ophiolite Belt (EOB) (Hutchison 1975; Hla Htay *et al.* 2017). The belts are parallel to each other and trend in a nearly north–south direction. Among these belts, the ophiolites in the IMR correspond to the WOB, the longest belt extending from northern to southern Myanmar, with ophiolites exposed in the eastern Naga Hills, the Chin Hills and the Rakhine Yoma. The ophiolitic rocks are mostly dismembered but best preserved along the eastern margin of the IMR, defined by a discontinuous line of ophiolite and ophiolite-derived blocks. The ophiolitic sequence is overlain by the Palaeogene/Neogene Indo-Burman flysch (Bannert *et al.* 2011). Metamorphic rocks are commonly associated with ophiolitic rocks occurring along large fault zones, dissecting the IMR. In the IMR ophiolitic rocks occur as small and elongated tectonized serpentinite bodies within the low-grade metamorphic rocks. These IMR ophiolitic sequences occurs as subhorizontal rootless bodies as evidenced by the lack of dense underlying material, shown by gravity data, and are overlain by Eocene–Oligocene flyschoid sediments (Kumar 1990; Acharyya 2007).

Mitchell (1986) reported a Late Jurassic K–Ar age of 158 ± 20 Ma for the ultramafic rocks of the ophiolitic suite in the IMR from a hornblende-bearing pegmatite intruding serpentinites in the Mt Victoria area. The core of the IMR is made of high-grade metamorphic rocks, tectonically imbricated with Mesozoic ophiolites and sedimentary sequences of Late Triassic–Late Cretaceous age (Bender 1983). To the east, the root zone of the IMR ophiolitic rocks may be marked by sporadically exposed ophiolites close to the volcanic line in Central Myanmar and Sumatra (Sengupta *et al.* 1990). In comparison, Pedersen *et al.* (2010) reported a Late Cretaceous U–Pb zircon age of 95 ± 2 Ma for trondhjemites in the Andaman ophiolites to the south of IMR, and suggested that the U–Pb zircon age records the beginning of subduction beneath the Andaman–Sumatra arc. However, the trondhjemite is a plagiogranite differentiated from basaltic magma at a spreading ridge, indicating the age of formation of the the oceanic crust, which was later followed by the emplacement and obduction of ophiolites during the late Early Eocene (Acharyya 2007). However, zircon U–Pb ages of rodingites represent the crystallization ages of protoliths intruding the mantle peridotites and suggest that the Kalaymyo ophiolite (WOB) was formed during the Early Cretaceous, that is, *c.* 125 ± 2 Ma (Liu *et al.* 2016).

In the Naga Hills, the ophiolite belt is locally about 200 km wide (Acharyya 2007), and follows the general north–south strike. Ophiolitic volcanics, including pillow basalts, are closely associated with radiolaria-bearing cherts, oceanic pelagic sediments and radiolaria and foram-bearing limestones, indicating ages of Late Jurassic–Early Eocene (Acharyya *et al.* 1989). Two types of sedimentary rock are closely associated with the ophiolites. One type includes shallow-marine to paralic ophiolite-derived and plagioclase-bearing clastics (Middle Eocene). The other type is a mélange unit, consisting of variable-sized blocks of mixed Upper Cretaceous, Paleocene and Lower–Middle Eocene fossiliferous limestones, ophiolitic and locally continental metamorphic rocks in a shaly matrix. This unit underlies the dismembered ophiolitic rocks tectonically. The ophiolites are in turn overthrust by continental metamorphic rocks, for example the Naga Metamorphics.

In the Chin Hills, ophiolitic suites appear between Tertiary molasse sediments of the Inner-Burman Tertiary Basin and the Indo-Burman Flysch. However, in the Saw-Kanpetlet area ophiolitic units are associated with the Upper Triassic Pane Chaung Formation and are regarded as pre-Upper Triassic ocean floor, composed of serpentinite, pillow basalt and associated chert and limestone (Bannert *et al.* 2011). Gramann (1974) observed spilitic basalts and dyke-like serpentinized volcanic rocks at the contact between the Kanpetlet Schists in the west and fossiliferous Triassic sediments to the east. In the area west of Mt Victoria, thrust slices of ophiolitic, metamorphic and sedimentary rocks abut against a sequence of shale and siltstone of Late Cretaceous and Early–Middle Eocene age. This sequence is gradationally overlain by thick cross-bedded sandstones of Eocene or younger age, occupying a synclinal core (Mitchell 1993). In the northern Chin Hills ultramafic rocks are particularly abundant (United Nations 1978*a*; Mitchell *et al.* 2010), but unmetamorphosed volcanic rocks of the ophiolite suite have not been found in this area.

Bender (1983) reported that mafic volcanic rocks occur sporadically in the central part of the Rakhine Yoma, but gave no details. Along the Rakhine Coast, near Thandwe, outcrops of serpentinite are common and ophiolitic bodies are found as dykes and sills in places, associated with tuffaceous breccias. The ophiolite bodies are conformable with the Upper Cretaceous flysch sequence, and are interpreted as sills and/or submarine extrusions. Fragments in the breccias are small, and are derived from the immediately underlying Upper Cretaceous rocks.

Tectonic setting

In this chapter, we specifically consider only the tectonic setting and evolution of the IMR in the Myanmar region. The tectonic evolution of IMR in the Myanmar region is diagramatically shown in Figure 4.6. The following tectonic features are taken into account in interpreting the development of the tectonic history of the IMR.

(1) The IMR is a fold-and-thrust belt, composed of ultramafic rocks, schists, pillow lavas and Triassic–Eocene sedimentary rocks. The IMR changes its strike to NE–SW in the Naga Hills, north–south in the Chin Hills and NNE, and later swings into a SSW direction in the Rakhine Yoma. Generally, the intensity of tectonic deformation decreases towards the west, where the northern extension of the Sunda Arc subduction zone passes into a strike-slip fault parallel to the Rakhine Coast. Seismic profiling and swathe mapping shows that the Rakhine margin is at present a strike-slip margin (Nielsen *et al.* 2004), with no active subduction along this margin (Sahu *et al.* 2006). A palaeoseismological field survey with carbon dating, to investigate the past geological and geomorphological evidence of earthquakes and tsunamis along the west coast of Myanmar near Sittwe and in the Thandwe area, showed that only minor uplifting events have occurred during the past 3000 years (Than Tin Aung *et al.* 2006, 2008). Deformation weakens westwards and gradually merges with sediments of the Bay of Bengal fan. The Triassic turbidites are recumbently folded and appear to pass transitionally, and locally stratigraphically, into biotite schists and minor greenstones, which are interpreted as meta-greywackes and meta-basalts, respectively. The overall structure suggests a major east-facing recumbent fold. The structural style of the eastern IMR is similar to that in the western and central parts of the ranges (United Nations 1978*b*, *c*). The western and central parts of the IMR essentially consist of Early Tertiary flysch-like sediments. These sediments are present in the upper levels of the ophiolite nappes. The wide extension of mélange and the association with the ophiolite suggest that it may be related to the Middle Eocene ophiolite obduction interpreted by Acharyya (2006). Parts of the IMR locally display the characteristics of a mélange zone with intercalated allochthonous Cretaceous rock masses, overthrusts, imbricate structures with epimetamorphic sediments and ophiolites. The flysch-like sediments were deposited as turbidite fans during the Triassic, as evidenced by the presence of Triassic *Halobia* sp. fossils (Fig. 4.6a). They were later deformed during the Eocene–Oligocene during ophiolite obduction.

(2) The eastern IMR consists of schists and Middle–Late Triassic turbidites overthrust by serpentinized harzburgites, and locally by pillow lavas and hornblende gabbros. In the Chin Hills in the Mt Victoria area, the Kanpetlet Schists form a folded dome tectonically underlying overfolded Triassic flysch and ophiolitic units, emplaced during the Early Cretaceous. This setting appears to have been caused by the collision between Sino-Myanmar (Sibumasu) and a Central Myamar microcontinent of small size, due to the closure of an ocean basin which lay between them (Acharyya 2007). The Kabaw Fault is the easternmost major fault of the IMR. It forms an E-verging reverse-dextral fault zone between the ophiolites and metamorphics to the west, and clastic Late Cretaceous Kabaw Formation to the east (Maurin & Rangin 2009). A Jurassic age for the generation of the ultramafic (ophiolitic) rocks is indicated by a K–Ar age of 158 ± 20 Ma on a hornblende pegmatite-intruding serpentinite in the IMR (Mitchell 1986), although K–Ar ages can be reset and further geochronological work is required. The Jurassic age of the ultramafic (ophiolitic) rocks suggests that the ocean floor was later obducted and deformed during Cretaceous–Eocene time.

(3) Late Cretaceous–Eocene eastwards subduction of the ocean floor beneath the IMR (Fig. 4.6b) is indicated by the presence of a magmatic arc of granodioritic plutons which intrude basaltic andesites and yield Middle Cretaceous K–Ar and U–Pb zircon ages (Mitchell 1993; Barley *et al.* 2003) in the Central Volcanic Belt, and also possibly by Middle Jurassic and younger granites in the Mogok Belt further to the east. The serpentinites and pillow basalts of the IMR can best be interpreted as ophiolitic rocks created at a Jurassic–Early Cretaceous or older oceanic spreading centre.

(4) Rock units in the Indo-Myanmar Ranges are characterized by frequent chaotic mélange units containing blocks of a variety of lithologies. The wide extent of these mélanges and their association with ophiolites are typically developed in the Manipur, Chin Hills, Rakhine Yoma and on the Rakhine Coast (Brunnschweiler 1966; Acharyya *et al.* 1989).

These mélange units are of three types: (a) ophiolitic mélange, with blocks of peridotite, usually sepentinized, together with blocks of hornblende gneiss and schist and metasedimentary rocks, including high-pressure blueschists, in a fine-grained serpentinous, often schistose, matrix (Fareeduddin & Dilek 2015); (b) olistostrome mélange, composed of individual carbonate blocks of Cretaceous or Palaeogene age, sometimes up to tens of metres in size, which may occur as layers within particular horizons in turbiditic sandstones (Bannert *et al.* 2011); and (c) diapiric mélange, composed of blocks of a variety of lithlogies in a scaly clay matrix, described from Ramree Island (Maurin & Rangin 2009; Moore *et al.* 2015).

Ophiolitic mélange is interpreted as having formed during subduction of the ocean floor due to mobilization of serpentinite by fluids released from metamorphosed basic rocks and sediments. Mobilized serpentinite rises diapirically up the subduction channel, incorporating peridotite, serpentinite, metabasic and metatasedimentary blocks, prised from the walls as it rises.

Olistostromes of carbonate blocks in the IMR are interpreted as derived from Cretaceous–Palaeogene carbonate shelves, cut by turbidite channels. Blocks collapsed from unstable channel walls were carried by the turbidite flows and deposited, together with the coarser sediments, when the flows came to rest, forming a turbidite fan.

Diapiric mélanges are formed when sediments become overpressured due to rapid sedimentation, or an increase of overburden by the addition of thrust slices in an accretionary complex. Overpessured fluids mobilize shale units within a sedimentary sequence which rise as diapiric

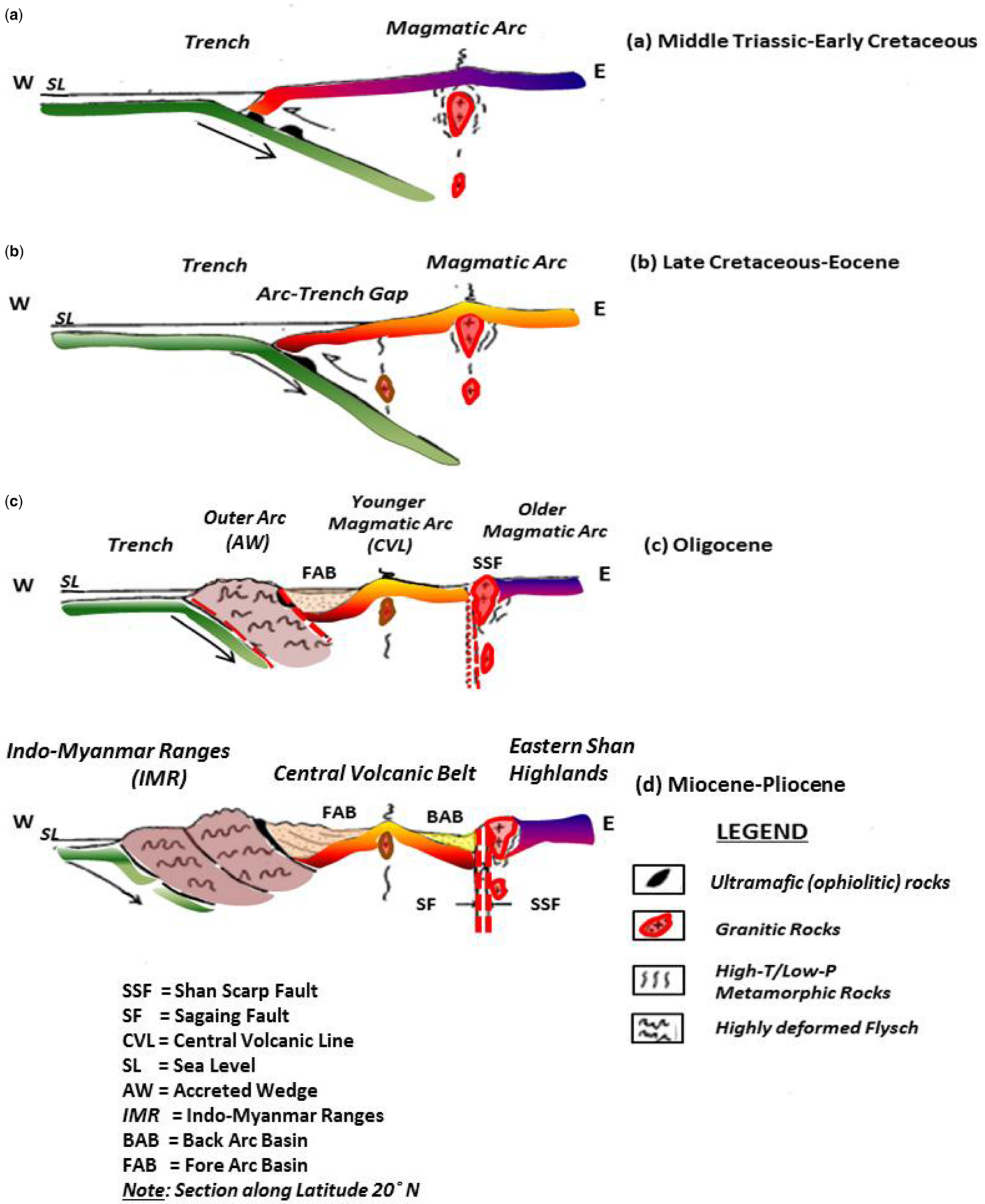


Fig. 4.6. Tectonic model of IMR during Triassic–Recent time (adapted after Win Swe 1972; Acharyya 2007).

intrusions, incorporating blocks of all the overlying units and may erupt at the surface as mud volcanoes. Blocks in diapiric mélanges are frequently enclosed in a scaly clay matrix, with a fabric due to the parallel alignment of clay minerals induced by flow (Barber *et al.* 1986; Festa *et al.* 2010; Barber 2013).

(5) In the northernmost part of the IMR, Palaeogene sediments were deposited in a shallow marine to deltaic setting based on the occurrence of benthic foraminifera, plant remains and *Ophiomorpha*-type burrows (Acharyya *et al.* 1989, Acharyya 1990, 1998; Sengupta *et al.* 1990). Thick unfossiliferous Palaeogene turbidite sequences

exposed further south in the IMR may have been deposited in deeper water.

(6) The Western Ophiolitic Belt follows the eastern margin of the IMR and the Andaman outer-island arc. These ophiolites were accreted during Early Cretaceous and Middle Eocene (Acharyya 2007) time and formed the proto-outer arc of the IMR at the end of the Oligocene (Fig. 4.6c). Soibam *et al.* (2015) also concluded that the IMR accretionary prism and its imbricate thrust system had deveoped by the Late Oligocene. Liu *et al.* (2016) suggested that the West Burma Block separated from Gondwana due to the opening of the Neotethys Ocean in the Late Triassic, and eventually accreted to the western margin of Sibumasu in the Cretaceous (Metcalfe 1996).

(7) In the Rakhine Yoma, the oldest rocks of the western belt are recumbently folded turbidites. These rocks probably continue northwards beneath the Late Tertiary sediments to the west of the Late Cretaceous–Eocene succession of the Chin Hills. In the Rakhine area, equivalents of the Chin Hills rocks have probably been thrust eastwards beneath Triassic rocks of the eastern belt. The Triassic beds were exhumed by the Seindaung Fault Zone (local name) in the Rakhine Yoma, which may be an extension of the west-dipping Kabaw reverse fault zone (Socquet *et al.* 2002; Maurin & Rangin 2009). Tectonic emplacement of Upper Cretaceous magmatic rocks of the Central Myanmar Basin (CMB) over coeval flysch of the IMR was followed by a Late Eocene–Oligocene magmatic event (Barley *et al.* 2003). During the Middle–Late Miocene, molassic sediments were deposited in the Rakhine Coastal Strip and the opening of the Andaman Sea occurred (Curray *et al.* 1979; Curray 2005). The Indian Plate converged towards Asia in a NE direction, and the present-day dextral Sagaing Fault was initiated. The whole forearc basin area was uplifted in the Late Miocene, either gradually or rapidly, to form an island chain. Following the uplift of the IMR, the Rakhine Basin regressed southwesterly, where molasse sediments were deposited. During the Pliocene the collision between Indian Plate and the Burma Plate resulted in the formation of the outer island arc of the IMR (Fig. 4.6d), the hilly Pegu ranges and the uplift of the Andaman Islands to their present level.

(8) Cretaceous–Palaeogene deformation involved ophiolite obduction, uplift and erosion (Bhattacharjee 1991; Acharyya 2007) until the collision of India with Eurasia; coupling with NW Myanmar terminated the early accretionary history (Morley 2012). After collision, India has undergone highly oblique convergence with Southeast Asia, and is presently moving northwards relative to Sundaland. This motion is accommodated by distributed deformation on numerous strike-slip faults across the West Myanmar microplate, of which the largest is the dextral Sagaing Fault.

(9) The IMR is an inactive accretionary wedge, developed initially as a result of north to NE subduction of the Neotethys Ocean (Ni *et al.* 1989; Nielsen *et al.* 2004). The innermost wedge is affected mainly by righ-lateral north–south shear, and the deformation that has taken place in the outer wedge, not older than 2 Ma, was due to the rapid westwards propagation of the IMR (Maurin & Rangin 2009). The metamorphic core of the IMR experienced multi-phase rapid uplifting and fast westwards growth of accretionay wedge (Zhang *et al.* 2015). Active deformation in the strike-slip fault and thrust belt in the western part of IMR continues to affect NE India, the Myanmar border and the Rakhine Coast (Win Swe & Soe Thura Tun 2008; Kumar *et al.* 2011; Steckler *et al.* 2016).

Concluding remarks

The IMR extends from Assam and Manipur to western Myanmar and consists of slope and shelf sediments of Late Triassic age, deposited disconformably on schists and gneisses of pre-Mesozoic age. Late Cretaceous–Palaeogene marine sedimentary rocks overlie unconformably Upper Triassic flysch-type sediments, associated with ophiolitic rocks. These sequences are thought to be the southern continuation of the Indus-Yarlung Tsangpo Suture Zone in Tibet (Mitchell 1993). There are at least three distinct, parallel belts of Upper Mesozoic–Lower Eocene ultramafic rocks in Myanmar, usually considered to be ophiolitic (Hutchison 1975; Hla Htay *et al.* 2017).

Ultramafic bodies in the Western Ophiolitic Belt, along the Naga and Chin Hills and the Rakhine Yoma appear to be due to the westwards propagation or obduction of ophiolite nappes across the IMR, from an easterly located suture during Late Oligocene collision (Acharyya 2007). These bodies are dismembered, rootless, discontinuous traces of oceanic crust, possibly indicating the position of a Tertiary subduction zone. They could be remnants of the old Tethyan seafloor, indicating the subduction of the Tethyan seafloor under the Eurasian Plate. The ophiolitic rocks are in tectonic contact with a belt of mica schists (Mt Victoria–Kawlun belt) to the west. The Naga Metamorphic Complex and the Kanpetlet Schists, which are of similar lithology, are faulted against the Tertiary Indo-Burman Flysch. The ophiolites underwent high-pressure metamorphism, indicated by the presence of blueschist in ophiolitic mélange. The occurrence of low-temperature/high-pressure regional metamorphic rocks supports the existence of a subduction zone on the site of the IMR during the Mesozoic–Early Tertiary. Granitic plutons of Mesozoic–Early Tertiary age, and associated high-grade regionally metamorphosed rocks in the Mogok Metamorphic Belt (MMB), are also overprinted by Cenozoic high-temperature/low pressure metamorphism related to this same phase of subduction (Searle *et al.* 2007, 2017).

The Triassic–Tertiary flysch sediments of the Rakhine Yoma and the Chin and Naga Hills were deposited in a subduction trench developed within the Tethys Ocean. They were deposited south of India on newly generated Indian Oceanic crust. Combined petrographic and isotopic results from the Palaeogene deposits of the IMR show that they have a significant east-derived arc component, whereas Neogene deposits were predominantly derived from the Himalayas (Allen *et al.* 2008; Kyi Khin *et al.* 2014). Maurin & Rangin (2009) proposed that the western IMR was mainly built up during the Late Neogene by fast accretion of Bengal basin sediments while the internal part of the IMR was controlled by dextral strike-slip faulting, absorbing a large part of the partitioned India/Sunda oblique motion.

West Myanmar, encompassing the IMR, is most commonly interpreted as a block that separated from Gondwana/Australia during a Jurassic rifting episode, and was added to Southeast Asia in the Cretaceous (e.g. Longley *et al.* 2002; Heine *et al.* 2004). However, other authors have suggested that West Myanmar was part of Southeast Asia before the Mesozoic, implying that it was part of Gondwana Sibumasu or the Cathaysian West Sumatra Block (e.g. Mitchell 1992; Barber & Crow 2005, 2009; Hall 2012; Metcalfe 2013; Liu *et al.* 2016). The IMR is tectonically important for the understanding of the opening and closure of Neotethys in Southeast Asia during oblique subduction. It is not only the site of subduction, but also the location of obducted ophiolitic slabs and sediments, especially in the eastern part of the IMR. Further work is necessary to establish more precisely the timing of rifting, subduction, obduction, accretion and the terminal collision in this resource-rich region. Most of the IMR in Myanmar region is dominated by oceanic materials, whereas continental accretion and collision processes affected the Indian regions of Nagaland, Manipur and Mizoram. Detailed tectonic, geochemical and geochronological studies across the borders of both countries are neccessary to better understand the development of the whole IMR.

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