Geologic evolution of the Philippines

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Abstract

Ophiolite emplacement, volcanic activity and sedimentary deposition have been used to reconstruct the geologic evolution of the Philippine Archipelago. Converging plates created the modern Philippines through subduction related volcanism, strike slip faulting, continent-arc collision, and ophiolite accretion. The Philippines first emerged as an island arc during the Cretaceous. Rifting, following Andean-like subduction split off the marginal sliver of the Eurasian Plate. Fragments of Eurasia drifted southward and eventually collided with the still developing Philippine arc beginning in the Middle Miocene. The development of a large fault system through the Central Philippines accommodates the stress from converging westward and eastward moving oceanic plates on either side of the Philippines.

Introduction

The Philippines is one of several island chains strung along the Western Pacific. Prone to volcanoes and earthquakes, the Philippines is a continually evolving archipelago. This tectonically active region is bounded on nearly all sides by deep trenches, while the center of the archipelago is subject to the large strike-slip Philippine Fault Zone (PFZ). Further complicating the story are continental blocks of Eurasian affinity (see Palawan-Mindoro Microcontinent) that have collided with the island arc. The emergence of the Philippines is among the most intricate
episodes in the Western Pacific and can be used as an analog to better understand inactive and accreted island arcs.

Setting

The Philippines is an archipelago of 7,107 islands (Wikipedia, 2014) separating the South China, Sulu, Celebes and Philippine Seas (Figure 1). The two largest islands, Luzon and Mindanao, are at the northern and southern extremes of the archipelago. Smaller linear, northeast-southwest and northwest-southeast trending islands between Luzon and Mindanao comprise the Central Philippines. Luzon, Mindanao and the Central Philippines make up the Philippine Mobile Belt (PMB). In addition Palawan intersects the Central Philippines from the

Figure 1: The Philippines lies at convergence of multiple oceanic plates. It is bounded on all sides by oppositely dipping subduction zones, and its center is composed of the seismically active Philippine Fault Zone. In addition it is intersected by the Palawan-Mindoro Microcontinental Block. Legend: NWL- Northwest Luzon oceanic bathymetric high, BR-Benham Rise, SS- Scarborough Seamount, CSR-Cagayan de Sulu Ridge, MT-Manila Trench, ELT- East Luzon Trough, PT-Philippine Trench, PaT-Palawan Trough, NT-Negros Trench, CT-Cotabato Trench, Mi-Mindoro, Ta-Tablas, Ro-Romblon, Si-Sibuyan, CIG-Calamian Island Group, Pa-Palawan, Pan-Panay, Ne-Negros, Ma, Masbate, Sa=Samar, Le-Leyte, Ce-Cebu, Bp=Bohol, Za-Zamboanga, Su-Sulu, MC-Macolod Corridor. (From, Yumul et al., 2004)
southwest. (Figure 1) Geologically the Philippines lies at the convergence of the Eurasian, Philippine Sea, and the Indo-Australian Plates (Rangin, 1991).

**Boundaries**

The Philippines is bound on the west by the east dipping Manila and Negros Trenches and the southeast dipping Sulu and Cotobato Trenches. The South China Sea Plate subducts along the Manila Trench, and the intersection of Palawan-Mindoro Microcontinent with the PMB marks the southern boundary of the Manila Trench. The Sulu Sea Plate subducts along the Negros and Sulu Trenches. The southernmost Celebes Sea Plate subducts along the Cotabato Trench. (Figure 1) The South China Sea Plate began opening during the Early Oligocene and continued into the Early Miocene based on examination of seafloor magnetic lineations (Sorkhabi, 2013). Examination of magnetic lineations also shows two phases of sea floor spreading. During phase one, beginning in the Early Oligocene and continuing to the Early Miocene the spreading ridge was in an east-west orientation, following this phase, the spreading ridge translated to a northeast-southwest trend for approximately three million years before spreading ceased. The Sulu Sea Plate is dated to the Early to Middle Miocene while the Celebes Sea Plate is dated to the Middle to Late Eocene based on magnetic anomaly identification is cores taken from the basement (Lewis, 1991).

To the east, the Philippines is bound by the west dipping East Luzon and Philippine Trenches. The Philippine Sea Plate subducts along both trenches (Figure 1). Dating and movement of the West Philippine Sea Basin is based on identification of magnetic anomalies (Fang et al., 2011). The West Philippine Sea Basin began opening during the Early Paleocene with a northeast-southwest orientation which continued until the Early Eocene, spreading continued un-
til the Late Eocene in a north-south orientation. In addition the Philippine Sea Plate has undergone constant movement and rotation after its formation near the equator. Early rotation of $50^\circ$ occurred during the Early Eocene followed by a period of no rotation. Present, continuous rotation began in the Late Oligocene and continues to modern times.

**Philippine Mobile Belt**

The PMB is subject to continent-arc collision (Figure 2c), east and west dipping subduction (Figure 2d), and accretionary complexes (Figure 2b). The PMB is an amalgamation of volcanic rocks with associated sediments and pyroclastics, plutonic rocks, uplifted shallow and deep water marine sediments, and terrestrial sediments (Figure 3 and Figure 4) bisected by the north-south trending strike-slip PFZ (Rangin, 1991). The westward movement of the Philippine Sea Plate and the collision of the Palawan-Mindoro Microcontinent with the PMB resulted in the development of the PFZ to accom-
**Legend**

<table>
<thead>
<tr>
<th>Color</th>
<th>Description</th>
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<tbody>
<tr>
<td>Blue</td>
<td>Open Water</td>
</tr>
<tr>
<td>Red</td>
<td>Recent alluvial, lacustrine or beach deposits.</td>
</tr>
<tr>
<td>Grey</td>
<td>Quarternary. Active volcanoes with activity since 1616.</td>
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<tr>
<td>Orange</td>
<td>Pliocene-Quarternary. Non-active cone (general pyroxene andesite) with dacitic or andesitic plugs.</td>
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<tr>
<td>beige</td>
<td>Pliocene-Quarternary. Volcanic plain or piedmont pyroclastic deposits.</td>
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<tr>
<td>Yellow</td>
<td>Pliocene - Pleistocene. Marine and terrestrial sediments.</td>
</tr>
<tr>
<td>Dark yellow</td>
<td>Pliocene - Pleistocene. Marine and terrestrial sediments.</td>
</tr>
<tr>
<td>Green</td>
<td>Upper Miocene - Pliocene. Thick, extensive, transgressive mixed shelf marine deposits, largely wackes, shales and reef limestone overlain by conglomerate and/or paralic coal.</td>
</tr>
<tr>
<td>Light blue</td>
<td>Upper Miocene - Pliocene. Largely marine clastics overlain by extensive locally transgressive pyroclastics and tuffaceous sedimentary rocks.</td>
</tr>
<tr>
<td>Brown</td>
<td>Miocene-Pliocene. Principally dacite and/or andesite flow with pyroclastics.</td>
</tr>
<tr>
<td>Purple</td>
<td>Miocene-Pliocene. Marine clastics overlain by extensive, locally transgressive pyroclastic and tuffaceous sedimentary rocks.</td>
</tr>
<tr>
<td>Pink</td>
<td>Neogene. Largely intra-Miocene quartz diorite. Mostly batholiths and stocks, some laccoliths with associated sills and dikes. Includes granodiorite and diorite porphyry facies and Late Miocene dacite.</td>
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<tr>
<td>Dark red</td>
<td>Oligocene-Miocene. Mostly submarine andesite and/or basalt. Intercalated with pyroclastic and clastic sedimentary rocks and/or limestone lenses.</td>
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<tr>
<td>Beige</td>
<td>Oligocene-Miocene: Thick transgressive mixed shelf marine deposits: wackes, shales and reef limestone. Underlain by conglomerate and/or paralic coal.</td>
</tr>
<tr>
<td>Green</td>
<td>Oligocene. Minor limestone, wackes and shales. Generally associated with deratophyres and andesite flows.</td>
</tr>
<tr>
<td>Yellow</td>
<td>Oligocene. Essentially keratophyre and andesite flows. Often with pyroclastics and cherts. Undifferentiated from early Miocene sediments in some areas.</td>
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<tr>
<td>Light green</td>
<td>Paleogene. Quartz diorite.</td>
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<tr>
<td>Dark green</td>
<td>Paleocene-Eocene. Extensive mixed shelf and deep water marine deposits. Large wackes and shale with minor pyroclastic and conglomeratic deposits.</td>
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<tr>
<td>Green</td>
<td>Paleocene (?) - Eocene. Limited dacite and andesite flows and dikes, generally intercalated with Eocene clastics.</td>
</tr>
<tr>
<td>Light blue</td>
<td>Cretaceous-Paleogene. Undifferentiated ultramafic and mafic plutonic rocks. Predominately peridotite associated with late gabbro and diabase dikes.</td>
</tr>
<tr>
<td>Yellow</td>
<td>Cretaceous. Extensive, transgressive graywacke-shale sequence with intercalated siltites.</td>
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<tr>
<td>Beige</td>
<td>Jurassic. Arkose, subgraywacke, mudstone</td>
</tr>
<tr>
<td>Brown</td>
<td>Pre-Jurassic. Granite in western Zamboanga, mafic dikes (?) in Batangas</td>
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<tr>
<td>Light green</td>
<td>Undifferentiated. Largely graywacke and metamorphosed slae interbedded/intercalated with phyllitic, basic and intermediate flow and/or pyroclastics.</td>
</tr>
<tr>
<td>Green</td>
<td>Undifferentiated metamorphosed submarine flows. Largely siltites and basalts.</td>
</tr>
<tr>
<td>Yellow</td>
<td>Undifferentiated amphibolite basement complex, quartzofeldspathic and mica schist, and phyllites-slates frequently associated with marble and quartzite.</td>
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Figure 3: Legend for figures 4, 5 and 7. (Modified from Mines and Geoscience Bureau of the Philippines, 2014)
Figure 4: Geologic map of the Philippines. Detailed areas are discussed in Figures 5, 7 and 9 (Modified from Mines and Geoscience Bureau of the Philippines, 2014)
modate collisional stresses not relieved by subduction (Rangin, 1991). Aurelio et al. (2013) outlines the basic stratigraphy of the PMB based on the 1:1 000 000 scale map shown in figure 4. The basement of the PMB is composed of Cretaceous ophiolites, green schists basalts, andesites, diorites and associated pyroclastics and sedimentary sequences. The Paleocene is only recorded in off shore drill cores collected west of Palawan that include beds of arkosic sandstone, conglomerate, mudstone and limestone and a small unit of foraminiferal limestone in central Luzon. Generally conformable, Eocene and Oligocene units consist of diorite, syenite and alkali intrusions, volcanic complexes, clastic rocks and limestone. Miocene units are dominantly clastic rocks and limestones with subordinate basalt. Andesite, diorite and pyroclastics increase in abundance beginning in the Middle Miocene and continue to the Pliocene. Deposition of clastic rocks, limestones, plutonic and volcanic rocks and associated pyroclastic material continues into contemporary times.

The Palawan-Mindoro Microcontinent trends northeast-southwest into the PMB approximately halfway between Luzon and Mindanao (Figures 1 and 2). Islands north of Palawan-Mindoro appear to show a counter-clockwise rotation while islands south of the intersection appear to show a clockwise rotation (Figure 2a). Analysis of paleomagnetic data by McCabe et al. (1987) supports this observation. Samples of Pliocene and Pleistocene age show no resolvable rotation, suggesting the PMB has behaved as a single block in recent geologic time. Late Miocene sites from western Luzon show a clockwise rotation of 20°. Another group of Late Miocene rocks from Mindanao and the southern Central Philippines show no rotation. This suggests and unidentified collision involving the northern PMB that did not effect the Central and Southern PMB. Early Neogene samples show a large counterclockwise rotation in the Central Philippines and a clockwise rotation in the southern Central Philippines and Mindanao.
The northernmost exposure of the PMB is Luzon. Luzon is transversed by the Central Cordillera and Northern Sierra Madre mountain ranges (Figure 2). Figure 5 shows a 1:1 000 000 scale geologic map of Luzon. Mountain ranges are composed of uplifted basalts and spilites (dark green) and Jurassic and Miocene marine sediments (grey and reddish-purple). In addition, Tertiary volcanics (light purple) and metamorphosed basement units (purple) are also present. Sedimentary basins between uplifts (yellow) make up the remainder of Luzon.

A close analysis of the Baguio District (Figure 6) by Yumul et al. (2003) documents arc flipping and subduction initiation, a dominant tectonic process on Luzon. The oldest unit in the Baguio District is the undifferentiated Dalupirip Schist and the Cretaceous to Eocene Pugo Metavolcanics. Unconformable with the Pugo Metavolcanics is the overlying Oligocene Zigzag Formation which consists of deep marine sediments. The Zigzag formation, Miocene Kennon Limestone and Klondyke Formation are intruded by calc-alkaline batholiths of the Central Cordillera Complexes (Figure 6b, 6c and 6d). Conformable Late Miocene to Pleistocene units, the Pico Formation and Mirador Limestone, are shallow water clastic and carbonate rocks.
Figure 6: Geologic map of western Luzon near Baguio City (insert a). Geologic cross sections shows the presence of Zigzag Formation xenoliths in Atake Creek Basalt (insert b), the change from Zigzag Formation to Kennon Limestone to Klondyke Formation (insert c) is related to the transition from a marginal basin to an island arc, basement Dalupirip Schist and Pugo Metavolcanics are intruded by gabbros and diorites generated from subduction along the Manila Trench. A stratigraphic column for the area is shown in insert e. (From Yumul et al., 2003)
Geochemical analysis of the Pugo Metavolcanics suggests these rocks derived from a subduction related marginal basin other than the western adjacent South China Sea basin. It is most likely the basin was the back-arc basin of the west dipping proto-East Luzon Trench. The Zigzag Formation is of deep marine origin and contains a monomictic conglomerate derived from the Pugo Metavolcanics. This suggests a major uplift between the Eocene and Oligocene which eroded a portion of the Pugo Metavolcanics and redposited the eroded clasts in the Klondyke Formation, most likely as a transgressive lag. Following this uplift, the Kennon Limestone was deposited in a reef setting. The intrusion of calc-alkaline batholiths during the Middle to Late Miocene marks the initiation of subduction along the east dipping Manila Trench. A polymictic conglomerate within the Klondyke Formation is dioritic in composition suggesting this unit was eroded from the emerging island arc. The change in clast composition from marginal basin clasts in the Zigzag to island arc derived clasts in the Klondyke Formations show the transition from a subduction related marginal basin to an active island arc. Younger units were uplifted due to the continuing tectonic activity along the Manila, East Luzon Trenches and PFZ.

**Mindanao**

Mindanao is the southernmost portion of the Philippines. Figure 7 shows a 1: 1 000 000 scale geologic map of Mindanao. Geologic units include uplifted Jurassic and Miocene marine sediments (grey and red), Tertiary volcanics (light purple) and metamorphosed basement units (purple). Sedimentary basins between uplifts (yellow) make up the remainder of Mindanao.

The Pujada Ophiolite, southeast Mindanao (Figure 8) is described in detail by Yumul et al. (2003) and helps to better understand ophiolite obduction. The Pujada Ophiolite is a complete ophiolite sequence composed of pillow lavas, dyke complex, isotropic to layered gabbros, troctolites, norites, clinopyroxenites, dunites and harzburgites. In the Pujada Opjiopite, gabbros
show a crystallization order of olivine-plagioclase-clinopyroxene and norites show a crystallization order of olivine-orthopuroxene-clinopyroxene-plagioclase. Dunites and harzburgites show varying degrees of serpentini- zation and hob-nail texture is apparent in serpentinized harzburgites. Troctolites developed from anorthosite dykes interacting with dunite. Overly- ing the Pujada Ophiolite, the Iba Formation is composed of cherts, limestones and red pelagic mudstones. A deep marine fossil assemblage dates this unit to the Late Cretaceous. The Sang- hay Formation contains clasts of chert, limestone, lithics, basalts and gabbros. The Sigaboy For- mation primarily contains ultramafic clasts.

The Pujada Ophiolite is dated to the Early Cretaceous based on fossil assemblages of the deep marine sediments in overlying and conformable the Iba Formation. Pyroxene crystalliza- tion ahead of plagioclase in norite suggests an arc environment. In addition, basalts show a back arc basin affinity. Petrography and whole rock geochemistry suggest the Pujada Ophiolite is an autochthonous suprasubduction zone ophiolite. The two overlying units show clast composition similar to that of the Iba Formation and Pujada Ophiolite suggesting that overlying units repre-
sent the continuous uplift and unroofing of the Pujada Ophiolite Complex and deposition of eroded material.

**Palawan-Mindoro Microcontinent**

The core of the Palawan-Mindoro Microcontinent is exposed on Palawan, while the suture zone between Palawan-Mindoro Microcontinent and the PMB bisects Mindoro, Panay Island, the Zambanga Peninsula (western Mindanao) as well as several small islands in the Central Philippines. Figure 9 shows a 1:1 000 000 scale geologic map of the Palawan-Mindoro Microcontinent. Geologic units include uplifted Jurassic and Miocene marine sediments (grey and
Yumul, et al (2009) have completed an extensive study of the Palawan-Mindoro Microcontinent. Palawan is an elongated northeast-southwest trending island composed of two geologic blocks (Figure 10).

Sedimentary rock in northern Palawan consist of quartz-rich sandstones, pebble mudstones and mudstones. Metamorphic rocks consist of schists, phyllites, quartzites and slates with sedimentary protoliths. Paleontological dating of sedimentary sequences on northern Palawan suggests Late Cretaceous to Eocene age. Metamorphism occurred during the Late Eocene based on $^{39}$Ar-$^{40}$Ar dating of hornblende in amphibolite and mus-
covite in schist. Additionally, identification of olistostromes in far northern Palawan are interpreted as remnants of an accretionary prism. Dating of chert, clastic, and limestone sequences of these olistostromes show a Middle Jurassic to Early Cretaceous age.

Provenance of north Palawan rocks was determined based on point count analysis of medium to coarse grain sandstones and show 46-50% modal quartz, 6.5-11% modal feldspar and abundant acidic volcanic fragments. When plotted on a QFL diagram showing provenance fields the samples plot within the recycled orogen field (Figure 11). This suggests a continental origin. The nearest continent is the southeast margin of Eurasia; therefore, the Palawan-Mindoro Microcontinent block likely represents a rifted portion of the southeast margin of the Eurasian plate that has since collided with the PMB.

Southern Palawan is comprised of the Palawan Ophiolite Complex. Volcanic rocks in the ophiolite are comprised primarily of boninites and harzburgites with overlying chert, clastics and carbonates. Formation is dated to Late Cretaceous to Eocene based on radiolarians extracted from chert. The ophiolite is interpreted as a supra-subduction zone ophiolite that has undergone a high degree of partial melting.

Mindoro is a small northwest-southeast trending island northeast of Palawan (Figure 9). Two geologic blocks (a northeast and southwest block) are separated by a central mountain range
When sandstone samples are plotted on a QFL diagram, the northeast block plots as a transitional arc while the southwest plots within the recycled orogeny, dissected arc and transitional arc (Figure 11). With transitional arc affinity, the northeast block is composed of rocks derived from the Philippine archipelago. The southwest block is interpreted to be largely composed of the Palawan-Mindoro Microcontinent.

The juxtaposition of island-arc and continental rocks indicates that Mindoro represents a suture between the PMB and the Palawan-Mindoro Microcontinent. This is further supported by a foreland thrust belt (Figure 12) that arose due to the collision of Palawan-Mindoro with the PMB. The angle of faults suggest that the PMB has thrust on top of the Palawan-Mindoro Microcontinent.

Three ophiolite complexes have been mapped across Mindoro: Mangyan Ophiolitic Complex, Puerto Galera Ophiolitic Complex and Amnay Ophiolitic Complex (Figure 12). The Mangyan Ophiolite Complex is believed to have been emplaced during the Late Oligocene based on regional correlation with nearby ophiolites. An amphibolite sole beneath ultramafic rock in the Mangyan Ophiolitic Complex suggest that is was emplaced shortly after generation. The
Puerto Galera Ophiolite Complex is believed to have been emplaced during the Oligocene based on regional correlation with the Zambales Ophiolite in western Luzon. Both the Mangyan and Puerto Ophiolites show melanges, suggested both complexes either emplaced due to, or heavily affected by strike-slip faulting. The Amnay Ophiolite is believed to have been emplaced during the Early to Middle Miocene based on paleontological dating of sediments. Volcanic rocks show calc-alkaline to minor tholeiitic characteristics suggesting a back-arc basin. In addition, gabbros show a plagioclase-clinopyroxene crystallization trend which is consistent with mid-ocean ridges.

The Palawan-Mindoro Microcontinent is present on Mindanao in the western Zambanga Peninsula which is composed of gneisses, schists and meta-ophiolites. Lithologies are similar to those present in northern Palawan leading to the understanding that the Zamabanga Peninsula is of Eurasian affinity. Volcanic rocks deposited ontop of the metamorphic basement are Middle Miocene.

**Tectonic Evolution**

Figure 13 outlines the time period of major sea-floor spreading, tectonic and magmatic events that have shaped the Philippines since the Mesozoic. Many of these events exemplify major tectonic events that have occurred due to the subduction and fragmentation of the
Pacific Plate. In addition, ophiolite obduction and sedimentary sequences have played a major role in recognizing the complexities involved in the evolution of the Philippine archipelago.

**Late Mesozoic**

Oliostromes in northern Palawan are dated to the Jurassic to Early Cretaceous and interpreted as remnants of an accretionary complex. Similar features have been identified from Russia to southern China. This large string of accretionary complexes lead to the identification of a large Andean style subduction along the eastern margin of Eurasia during the Mesozoic. (Aurelio et al., 2013) Similar features on Palawan to those identified on eastern Eurasia lead to the understanding that the Palawan-Mindoro Microcontinent first developed as part of the same major Andean style subduction. The Palawan Ophiolite Complex was also emplaced during this Late Mesozoic subduction event.

Volcanism began on the PMB in the Late Cretaceous but did not peak until later. Jurassic and Cretaceous aged rocks are concentrated in the eastern Philippines which suggests that this early volcanism marks the formation of an incipient volcanic arc from west dipping subduction.

**Paleocene**

Few Paleocene age rocks are present on either the Palawan-Mindoro Microcontinent or PMB. The lack of Paleocene dated units represents a cessation of magmatic activity and a relatively tectonically stable period in the Philippine’s evolution.

**Eocene - Oligocene**

Eocene and Oligocene units are generally conformable on the Palawan-Mindoro Microcontinent and PMB; therefore, events in both epochs are interpreted to represent a continuous
tectonic regime. The Philippine Sea and Celebes Sea began opening during the Early Eocene and Middle Eocene respectively due to extensional stress from roll back of the Australian Plate and slab pull along the proto-South China Sea (Figure 14). Extension in what would become the South China Sea began in the Cretaceous, however, it was not until the Late Eocene to Early Oligocene that regional extension gave way to sea floor spreading. This spreading gave rise to the Palawan-Mindoro Microcontinent being rifted off of Eurasia.

In the PMB Eocene to Oligocene units are igneous, pyroclastic and sedimentary units. Igneous activity likely stems from the subduction of the proto-South China Sea (Figure 14). This is further supported by suprasubduction zone ophiolite obduction on Mindanao and Mindoro during this time. This activity continued until the early Miocene when a compressional regime cause igneous activity to cease for a short period of time.
Miocene

The Miocene is characterized by the collision of the Palawan-Mindoro Microcontinent with the PMB (figure 15). This collision led to the PMB being thrust on top of the Palawan-Mindoro Microcontinent. This is supported by the emplacement of several ophiolite sequences on Mindoro with age of formation ranging from the Cretaceous to the Miocene, rotation of islands in the PMB and the metamorphism of rocks along the suture zone. This collision likely affected the opening of the Sulu Sea during the same period (Figure 15). Increasing igneous activity during the Late Miocene stem from subduction beginning in the Manila and Negros Trenches.
Pliocene and Quaternary

After collisional stresses from the Palawan-Mindoro Microcontinent-PMB collision waned subduction began in earnest on all boundaries of the Philippines. Stresses, not accommodated by subduction led to the development of the PFZ in the Pliocene. Tectonic activity continues into the modern day. The Global Volcanism Program (2013) cites 50 active volcanoes and earthquakes along the PFZ (Ramos, 2010) are the continuing effects of subduction and collision related processes.

Conclusion

The Philippine system displays many of the complexities found in subduction zones. Subduction, ophiolite emplacement, oceanic spreading, continental rifting, continent-arc collision and strike-slip faulting have built the modern Philippines from the Cretaceous into the present. The story of the Philippines begins in the Cretaceous with a continental arc forming along the margin of Eurasia and an oceanic arc forming along the incipient Philippine arc. Rifting occurred along the Eurasian continent and a sliver of continental material began drifting toward the rising Philippines. This sliver collided with the Philippines in the Miocene which gave rise to a foreland thrust belt and ophiolite obduction. After this collision subduction of all surrounding oceanic plates began and the PFZ developed to accommodate the additional stresses. Overall, the Philippines provide an active setting in which to study active, dynamic geologic processes in subduction related environments.
Reference List


