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Middle to Late Cenozoic tectonic events in south and central Palawan (Philippines) and their implications to the evolution of the south-eastern margin of South China Sea: Evidence from onshore structural and offshore seismic data

Mario A. Aurelio [a,*], Monina T. Forbes [b], Kristine Joy L. Taguibao [a], Raymundo B. Savella [b], Jaime A. Bacud [b], Dieter Franke [c], Manuel Pubellier [d,e], Dimitri Savva [e], Florian Meresse [e], Stephan Steuer [c], Coleen D. Carranza [a]

[a] Structural Geology and Tectonics Laboratory, National Institute of Geological Sciences, University of the Philippines, Velasquez St., UP Campus, Diliman, Quezon City 1101, Philippines
[b] Philippine National Oil Company – Exploration Corporation, PNPC Complex, Merritt Road, Fort Bonifacio, Taguig City, Philippines
[c] Federal Institute for Geoscience and Natural Resource (BGR), Hannover, Germany
[d] Universiti Teknologi Petronas, 31750 Tronoh, Malaysia
[e] Ecole Normale Supérieure de Paris, 24 Rue Lhomond, Paris, France

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ABSTRACT

Using recently gathered onland structural and 2D/3D offshore seismic data in south and central Palawan (Philippines), this paper presents a new perspective in unraveling the Cenozoic tectonic history of the southeastern margin of the South China Sea. South and central Palawan are dominated by Mesozoic ophiolites (Palawan Ophiolite), distinct from the primarily continental composition of the north. These ophiolites are emplaced over syn-rift Eocene turbidites (Panas Formation) along thrust structures best preserved in the ophiolite–turbidite contact as well as within the ophiolites. Thrusting is sealed by Early Miocene (~20 Ma) sediments of the Pagasa Formation (Isugod Formation onland), constraining the younger limit of ophiolite emplacement at end Late Oligocene (~23 Ma). The onset of ophiolite emplacement at end Eocene is constrained by thrust-related metamorphism of the Eocene turbidites, and post-emplacement underthrusting of Late Oligocene – Early Miocene Nido Limestone. This carbonate underthrusting at end Early Miocene (~16 Ma) is marked by the deformation of a seismic unit corresponding to the earliest members of the Early – Middle Miocene Pagasa Formation. Within this formation, a tectonic wedge was built within Middle Miocene (from ~16 Ma to ~12 Ma), forming a thrust-fold belt called the Pagasa Wedge. Wedge deformation is truncated by the regionally-observed Middle Miocene Unconformity (MMU ~12 Ma). A localized, post-kinematic extension affects thrust-fold structures, the MMU, and Late Miocene to Early Pliocene carbonates (*e.g.* Tabon Limestone). This structural set-up suggests a continuous convergent regime affecting the southeastern margin of the South China Sea between end Eocene to end Middle Miocene. The ensuing structures including juxtaposed carbonates, turbidites and shallow marine clastics within thrust-fold belts have become ideal environments for hydrocarbon generation and accumulation. Best developed in the Northwest Borneo Trough area, the intensity of thrust-fold deformation decreases towards the northeast into offshore southwest Palawan.

1. Introduction

Located on the south-eastern margin of the South China Sea (Fig. 1), Palawan Island is often mentioned as being composed of 2 contrasting tectonic terranes. The northern half is underlain by a continental microblock that drifted away from mainland Asia and collided with the Philippine arc in Miocene times (Holloway, 1981;

* Corresponding author. Tel.: +63 29260246, +63 917 8242404 (mobile); fax: +63 29260246.
E-mail address: maurelio.nigs@gmail.com (M.A. Aurelio).

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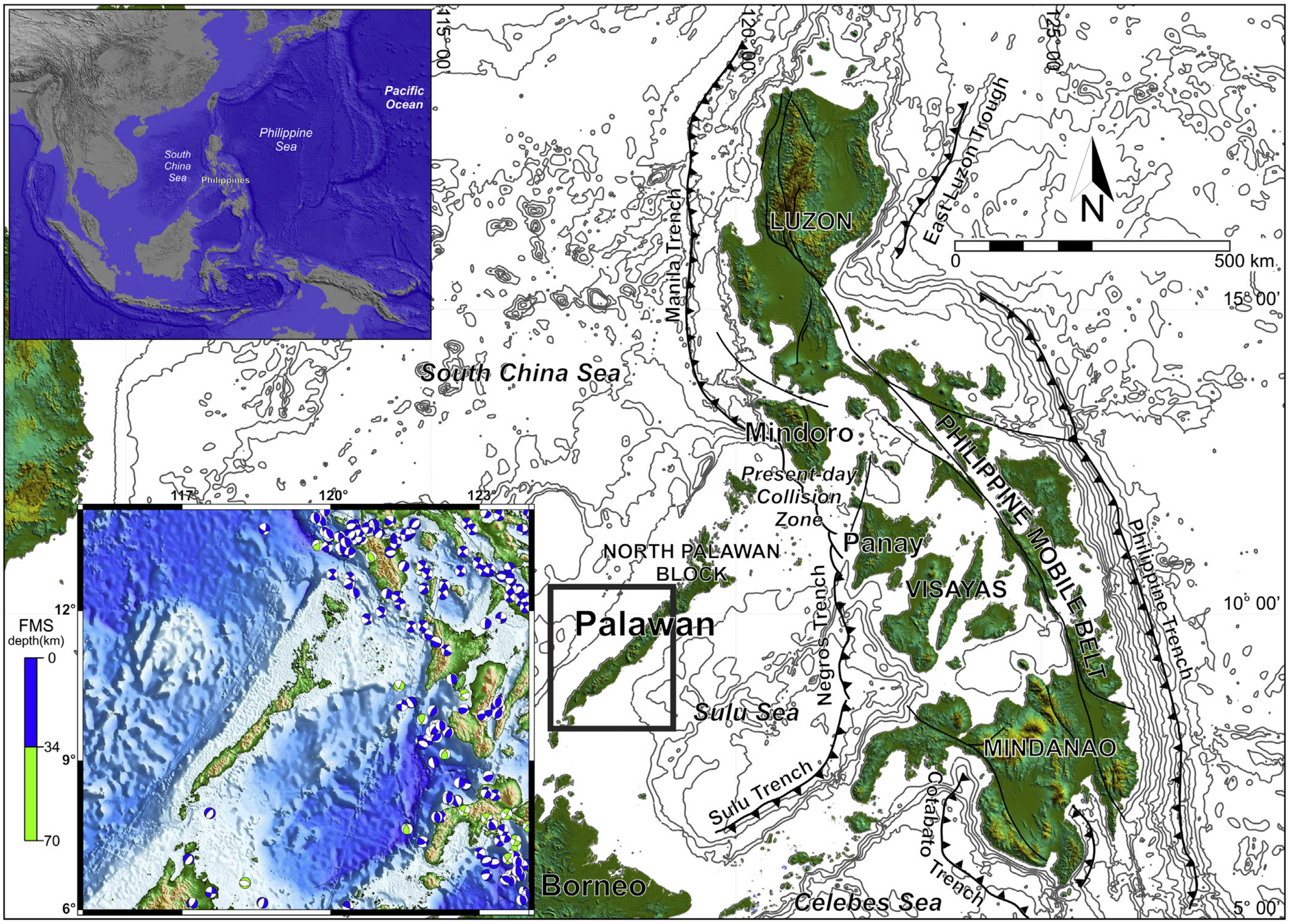

Figure 1. Regional Tectonic Setting of Palawan (regional location shown on upper inset). The island is situated at the south-eastern margin of the South China Sea. The northeastern edge of the northern half of the island is colliding with the western edge of the Philippine Mobile Belt while its central and south sections are seismotectonically stable. Lower inset shows distribution of focal mechanism solutions (*source*: Global Centroid Moment Tensor Project) around Palawan Island showing the nature of earthquakes at the collision zone and the absence of seismicity in the central and southern sections of the island. Smallest inset shows coverage of study area (Fig. 2) Land topography is from SRTM (Jarvis et al., 2008), bathymetry is from GEBCO (2009).

Taylor and Hayes, 1983; Mitchell et al., 1986; Wolfart et al., 1986; Rangin et al., 1990; Yumul et al., 2008; Aurelio et al., 2012a). The southern half is underlain by ophiolites believed to be derived from an ocean basin that started forming in Cretaceous times (MMAJ-JICA, 1988; Rangin et al., 1990; Yumul and Datuin, 1990; Mitchell et al., 1986; Santos, 1997). The tectonic boundary between the continental microblock in the north and the ophiolites in the south remain the subject of discussion. Some authors (*e.g.* Saldivar-Sali, 1978; Hamilton, 1979; Holloway, 1981) consider the Ulugan Bay Fault as the boundary between the 2 terranes, while others (*e.g.* MMAJ-JICA, 1988; Mitchell et al., 1986; Rangin et al., 1991; Suzuki et al., 2000, 2001; Taguibao et al., 2012) locate the boundary on thrust zones near the underground river in Sabang, north of the Ulugan Bay area. In the south, the ophiolites are seen to be overlain by late Neogene shallow marine clastic sequences, but also underlain by an Eocene turbiditic sequence in the form of a tectonic window (Aurelio et al., 2012b; Taguibao et al., 2012). Because of this setting, Palawan Island has often been considered as an "old" terrane where the youngest deformational events are those related to ophiolite emplacement (Mitchell et al., 1986; MMAJ-JICA, 1988; Aurelio, 1996). This paper aims to unravel previously unrecognized tectonic events including those that post-date ophiolite emplacement, as well as to better understand a recently recognized but still poorly understood tectonic wedge formation (Steuer et al., 2013). For this objective this paper presents recent information gathered from onshore structural transects and offshore 3-D seismic surveys in central and south Palawan. Results are analyzed in the context of their implications in the evolution of the southeastern margin of the South China Sea.

2. Methodology

This work correlates structural data collected in onshore central and south Palawan, with those gathered from 2D and 3D seismic surveys in the adjoining sea to the west (Fig. 2).

2.1. Onshore structural transects

Onshore data presented in this work were gathered mainly from a structural mapping campaign in late 2010, covering over 250 km of traverses along rivers, mountain trails, coasts and roads of central and south Palawan. Data gathered consist mainly of structural measurements such as faults, joints, fold axes, shear bands and foliation (C–S structures), and bedding planes. Structural sections traversing different areas in the island were generated to show the structural relationships of the different geologic formations that