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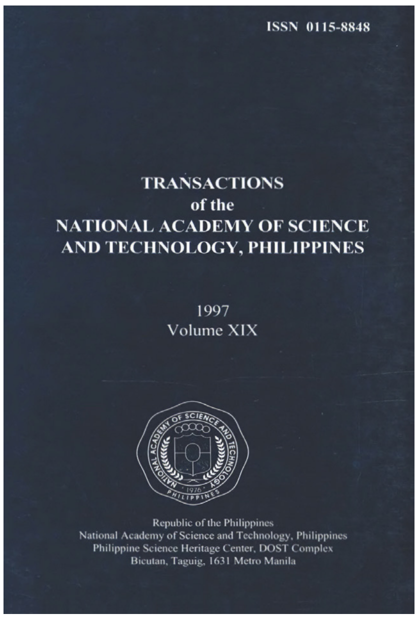

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DELINEATION OF THE SUBIC BAY FAULT ZONE IN ZAMBALES, LUZON, PHILIPPINES

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ABSTRACT

The Zambales ophiolite Complex (ZOC) is a well-studied exposure of upper mantle-crustal sequence in the Philippines This ophiolite complex is subdivided into three massifs - Masinloc, Cabangan and San Antonio - which are cut by several structures. Reconnaissance gravity and magnetic surveys were conducted in the southern portion of the Zambales Ophiolite Complex to delineate gross structural features. The resulting geophysical anomalies define a major structural feature called the Subic Bay Fault Zone. This confirms the results of earlier field, petrograhic and geochemical studies which suggested the presence of a structural boundary between the Cabangan Massif (which represents a mid-ocean ridge mantle suite0 and the San Antonio Massif (which represents an arc crust). The results of this work do not only contribute to an understanding of how this ophiolite complex evolved but more importantly identifies a geologic structure which must be taken into consideration in any infrastructure development in this particular area.

INTRODUCTION

The Zambales Ophiolite Complex (ZOC), although one of the most studied upper mantle-crust sequence in the Philippines, had most of the studies concentrated on the northern portion (Masinloc Massif) of the ophiolite. The ZOC is made up of three massifs, Masinloc, Cabangan and San Antonio as one goes from north to south (Figure 1). The Masinloc Massif is divided into two blocks, the Acoje and Coto, which on the basis of geochemical and petrological evidences are recognized to preserve island arc and transitional mid-ocean ridge (MOR) – island arc (IA) characteristics, respectively (e.g. Hawkins and Evans, 1983; Geary et al, 1989; Yumul, 1989). This ophiolite complex is an allochthonous terrane bounded on the east and west by the Central Valley Suture and West Luzon Shear, respectively (Karig, 1983). Previous workers have shown that the Masinloc, Cabangan and San Antonio Massifs are cut by very young faults resulting into the formation of grabens in between these massifs (Figure 1). Available paleomagnetic data and palinspathic reconstruction show that the ZOC came from the south. The source is thought to be either the Celebes Basin or the Paleocene-Eocene southwest subbasin of the South China Sea (e.g. Fuller et al, 1983; Karig, 1983; Honza, 1991; Yumul, 1994).

In this paper, additional data will be presented regarding the geology of the central-southern ZOC corresponding to the Cabangan and San Antonio Massifs, respectively. This paper presents geological evidence that will argue that the present-day configuration of the ZOC is a product of the southward translation through the West Luzon Shear/Subic Bay Fault Zone of the San Antonio Massif from the north to its present position. The knowledge that may be derived from this work hopefully may help in understanding how other exposed crust-mantle sequences have evolved through time and space.

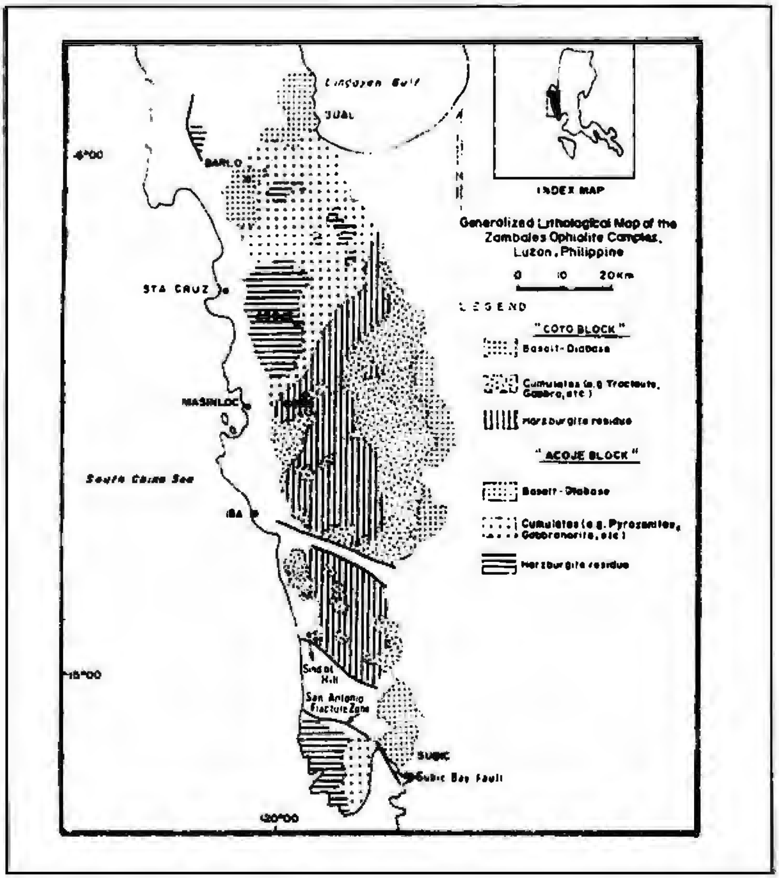

Figure 1.

GEOLOGY OF THE ZAMBALES OPHIOLITE COMPLEX

The Eocene Zambales Ophiolite Complex is a complete ophiolite suite composed of residual harzburgites and lherzolites, layered to massive ultramafic and mafic cumulates, dike-sill complexes and volcanic rocks. It is composed of three massifs – Masinloc, Cabangan and San Antonio (Figure 1). The Acoje block preserves island (IA) signatures while the Coto block manifests transitional mid-ocean ridge (MOR) – IA characteristics (e.g. Yumul, 1989; Evans et al, 1991). The geology of the Masinloc Massif has been extensively discussed in the literature (e.g. Nicolas and Violette, 1982; Bacuta et al, 1990; Rossman et al, 1989) and what will be presented in the geology of the Cabangan and San Antonio Massifs.

The Cabangan Massif is made up of residual harzburgites, a thin transition zone dunite and gabbros. The sheeted diabase like complex and pillow basalts are found in the southeast portion of this massif specifically in the Subic-Olongapo area (Figure 1). The residual harzburgites, of MOR affinity based on spinel chemistry, are cut by numerous IA diabase - diorite - microgabbro dikes (Yumul et al, 1990). The harzburgites exhibit protogranular to porphyroclastic textures (terms after Mercier and Nicolas, 1975). Harzburgite- and dunite-hosted refractory-type chromitites occur as bands, pods and lenses (Yumul, 1992). The dunites manifest an equigranular texture. The gabbro outrcops encountered are mostly massive and are principally made up of plagioclae, clinopyroxene and olivine which exhibit mesocumulate to orthocumulate textures (e.g. Wager and Brown, 1968; Irvine, 1982).

Intensely tectonized, layered clinopyroxenites and gabbronorites are exposed as hills (e.g. Sindol Hill) along the western edge of the Cabangan massif (Figure 1). These clinopyroxenites and gabbronorites, as will be shown, later, are allochthonous blocks which are not related to the generation of the Cabangan Massif. In the Subic - Olongapo area, sheeted diabase dikes intruded into pillow basalts are exposed. The sheeted diabase dikes are not related to the diabase - diorite - microgabbro dikes intruded into the Cabangan Massif residual harzburgites. The basalts are porphyritic to aphyric and are usually pillowed.

The San Antonio Massif, on the other hand, is composed of harzburgites - lherzolites, a transition zone dunite and a well-developed layered clinopyroxenite - gabbronorite unit distributed from west to east. An east-west traverse from the western most portion of the San Antonio massif to the Cabangan massif Subic - Olongapo area defines a complete ophiolite suite. Geochemical data show that this complete ophiolite sequence is actually a JUXTAPOSED IA terrane (San Antonio Massif) and a MOR/ marginal basin - like crust (Subic-Olongapo area, Cabangan Massif) (Yumul et al, 1990).

The San Antonio Massif harzburgites - lherzolites are fertile and cannot be directly parental to the overlying arc-related dunites and layered ultramafic - mafic sequence (e.g. Yumul, 1992). Textures range from protogranular to porphyroclastic. The transition zone dunite, with equigranular texture, is host to matallurgical-type chromitites. The layered clinopyroxenites, together with the dunites, are well-exposed along the southern coast of the San Antonio Massif. These rocks are characterized by large, equant, euhedral clinopyroxene crystals defining adcumulate textures. The massive to layered gabbronorites have orthopyroxene as an early crystallizing cumulus phase. Textures range from adcumulate to mesocumulate.

A direct comparison of the San Antonio and Cabangan Massifs show their distinct differences:

	SAN ANTONIO MASSIF
Crystallization order	OL ± SP → PX → PL
Residual periidotite	Lherzolite-harzburgite
Cumulate sequence	Well-developed transition zone dunite Well-developed ultramafic cumulates-dunite, websterite, wehrlite, clinopyroxenite Orthopyroxene-rich mafic cumulates-gabbronorite, norite, norite-gabbro with gabbro and anorthosite
Chromitite deposits	Metallurgical type
	CABANGAN MASSIF
Crystallization order	OL ± SP →PL → PX
Residual peridotite	Harzburgite
Cumulate sequence	Thin transition zone dunite No layered ultramafic cumulate Clinopyroxene - rich mafic cumulates - gabbro, troctolite, olivine gabbro with anorthosite
Chromitite deposits	Refractory type

Available geological and geochemical information show that the the Acoje block of the Masinloc Massif and the San Antonio Massif are correlatable in terms of geologic setting and lithological distributions.

DISCUSSION

San Antonio Massif: terrane translation through the Subic Bay Fault Zone

A straight east - west traverse from the San Antonio Massif to the Subic - Olongapo area of the Cabangan Massif defines a complete ophiolite sequence (Figure 2). Nevertheless, the sheeted diabase dike complex and pillow basalts exposed in the Subic - Olongapo area have transitional mid-ocean ridge basalt (MORB) - island arc tholeiite (IAT) characteristics. On the contrary, the mineral chemistry of the San Antonio Massif dunites, layered clinopyroxenites and gabbronorites point to an island arc environment of formation similar to that of the Acoje block.

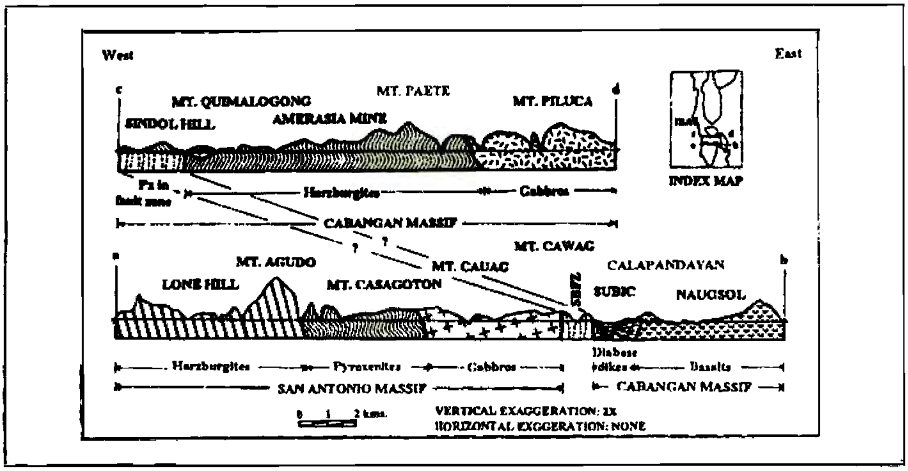

Figure 2.

The difference in the geochemical signature between the San Antonio rock suites of arc affinity and the transitional MORB - IAT diabase - pillow basalts of the Cabangan Massif strongly suggest that a tectonic contact between the two massifs is responsible for their juxtapositioning.

Considering all available information, the San Antonio Massif is believed to have been rifted from the Acoje block and translated southward to its present position. Translation was made possible through movements along the West Luzon Shear/Subic Bay Fault Zone. This will explain the presence of the tectonized layered clinopyroxenite - gabbronorite hills found along the western edge of the Cabangan Massif. These hills were left during the translation process. A fault zone, which is called here as the Subic Bay Fault Zone, separates the San Antonio island arc terrane from the Subic-Olongapo MOR-like crust.

Subic Bay Fault Zone: Geological evidence

There are two possibilities that can be thought of with regards to the origin and configuration of the SBFZ. The SBFZ can be considered as a splay of the West Luzon Shear Zone of Karig and others (1986) or that it can just be a splay of the San Antonio Fracture Zone (Yumul et al, 1990). Magnetics and gravity data do not support the presence of the San Antonio Fracture Zone (Dimalanta and Yumul, 1996). It is more viable to model the SBFZ as the southeastern extension of the West Luzon Shear.

Available magnetic and gravity anomaly maps both delineate a distinct linear feature (Figures 3a and 3b). This feature is defined on the basis of nearly linear and parallel contour lines. The rather large and steep magnetic and gravity gradients is associated with the geophysically-defined fault zone which corresponds to the Subic Bay Fault Zone (Dimalanta, 1996).

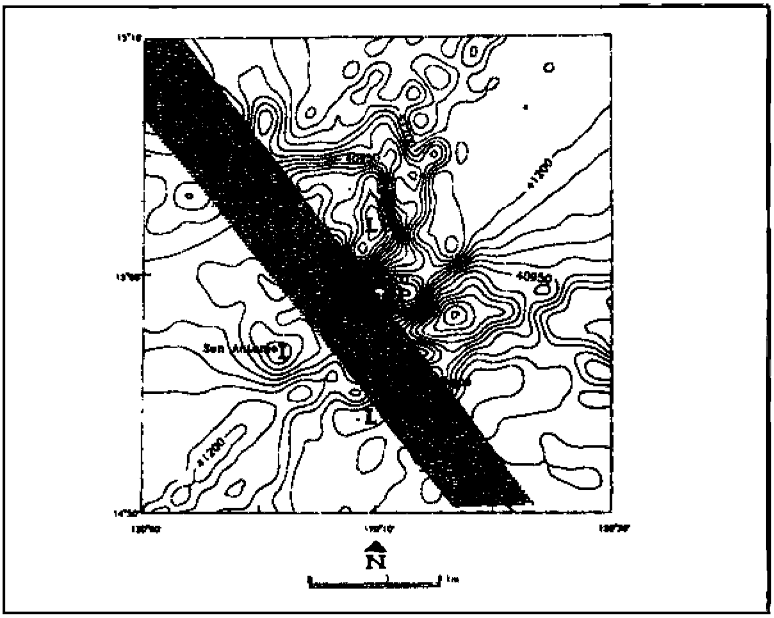

Figure 3a.

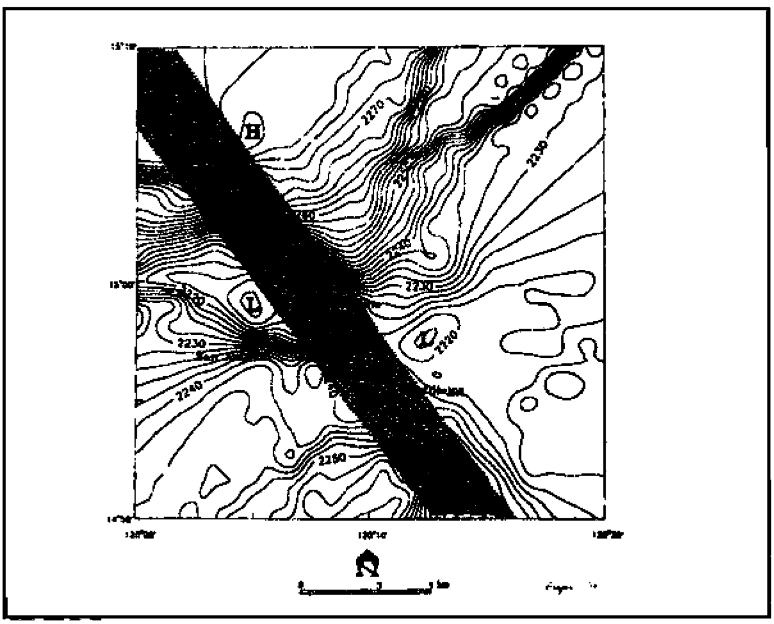

Figure 3b.

More importantly, the recognition of the SBFZ presents a different regional distribution of structures in the ZOC. Our available data do not support the presence of normal faults and a graben in the area between the Cabangan and San Antonio Massifs (Figures 4a and 4b).

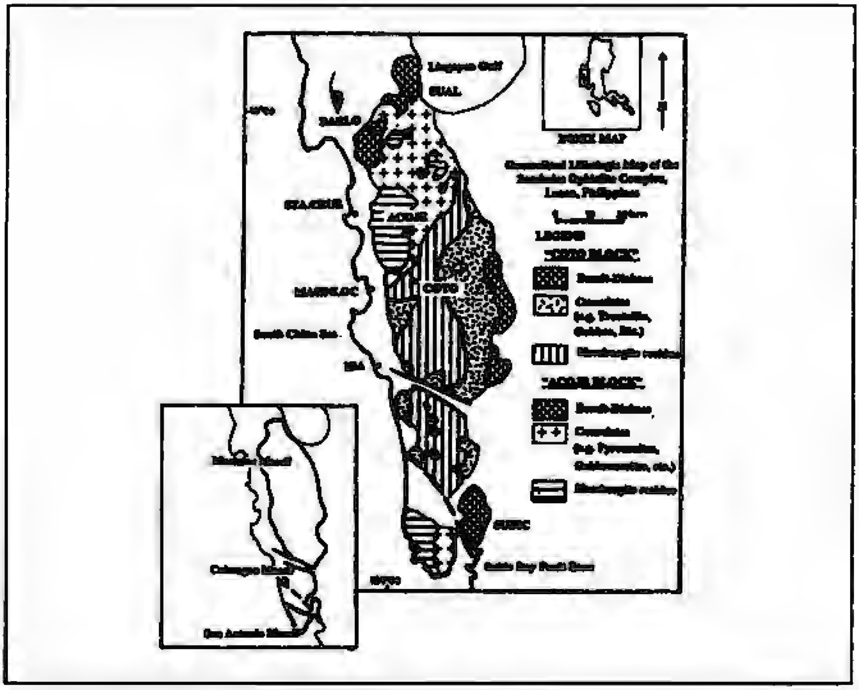

Figure 4a.

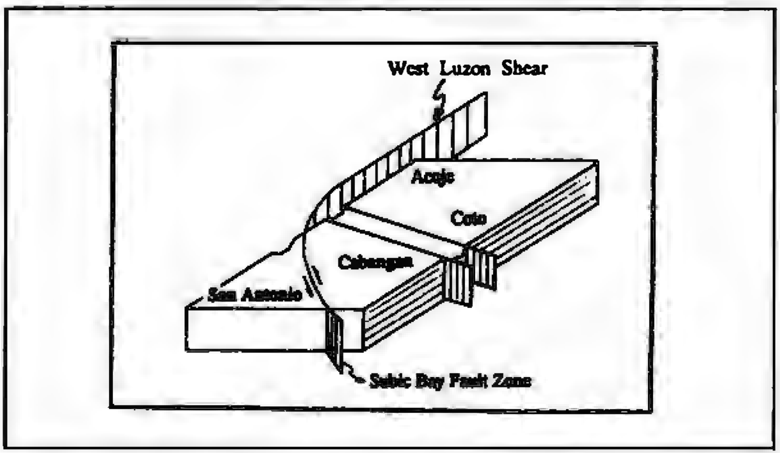

Figure 4a.