Miocene Planktonic Foraminiferal Biozonation for South Sumatra Basin, Indonesia

Djadjang Jedi Setiadi[1], Hendarmawan[1], Edy Sunardi[1], Eddy Arus Sentani[2], and Johanes Hutabarat[1]
[1]Faculty of Engineering Geology, Padjadjaran University, Indonesia
[2]PT. Elnusa Tbk

Abstract

Planktonic foraminifera are widely utilized for marine sediments analysis and recent developments in the geochronology of planktonic foraminifera has improved their values as a tool for sedimentary basin analysis.
Assessment on the applicability of the "standard" foraminiferal biozonations (e.g., Bolli, 1966; Blow, 1969; and Postuma, 1971) to the biostratigraphy data of the South Sumatra Basin suggests that the standard zones, which are mostly interval-zones defined by first occurrence events, are hardly applicable to the biostratigraphy data derived from the examination of well-cuttings routinely and continuously used in most sedimentary basin studies in Indonesia.
The proposed biozonation in this paper were constructed based on two considerations, i.e. information on the biostratigraphy events as indicated in regional- and global-scale biozonation schemes and the occurrence of foraminifera species in the South Sumatra Basin.
The correlation between the proposed zonation and that of Blow's (1969) scheme suggests that the proposed zonation is basically a Blow's zonation and, accordingly, may be perceived as a modified Blow's zonation for South Sumatra Basin.

Keywords: *planktonic foraminifera, biostratigraphy zonation; South Sumatra Basin*

INTRODUCTION

Planktonic foraminiferal zonation scheme is one of the most important tools for the study of sedimentary basins. Fossils represented in the zonation schemes provide practical age control that is critical for understanding of basin evolution and are useful for correlation of marine sedimentary basin fills.

The planktonic foraminiferal zonation that have been used most in Indonesia basins studies is that of Blow, originally established almost 50 years ago in 1969. Most of the zones in the Blow zonation, however, are interval-zones defined by first occurrence events that are hardly applicable to the biostratigraphy data derived from the examination of well-cuttings routinely and continuously used in most sedimentary basin studies in Indonesia.

This paper proposes a Miocene planktonic foraminiferal biozonation for South Sumatra Basin that is more applicable for subsurface basin studies than most of "standard" zonation as it gives special emphasizes to the last appearance datum (LAD) of every species that may have bio chronostratigraphic significance. It may be perceived as a modified form of the Blow zonation (1969), designed specifically to accommodate subsurface biostratigraphy information derived from the study of borehole cuttings and the types of Miocene planktonic foraminifera observable in the South Sumatra Basin sediments.

GEOLOGIC SETTING

Largely onshore, the South Sumatra Basin is situated on the southern end of the island of Sumatra (figure 1). It is partially separated from the Central Sumatra Basin to the north by a large exposure of crystalline and metasedimentary basement (*i.e.*, the Tigapuluh Mountains) and from the Sunda Basin in the Java Sea to the southeast by the Lampung High and its northward extension in the islands of Bangka and Belitung. To the northeast, the South Sumatra Basin fills thin out over the Sunda-land basement, while its west and southwest side is limited along the margins of the Barisan Mountains.

The South Sumatra Basin comprises a series of semi-connected NNW-SSE

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trending depressions, formed during the early Tertiary rifting phase (Adiwidjaja and De Coster, 1973; De Coster, 1974; Suhendan, 1984; Daly *et al*., 1987; Pertamina-Beicip, 1985; Pertamina BPPKA, 1997; Barber and Crow, 2005; Barber *et al*., 2005; De Smet and Barber, 2005) (figure 1). The Tertiary depositional fill of the South Sumatra Basin began when the aforementioned depressions were filled with locally sourced continental volcaniclastic sediments of the Lahat Formation (Suhendan, 1984; Pertamina-Beicip, 1985; Barber *et al*., 2005; De Smet and Barber, 2005) (figure 2).

When the structuring associated with the rifting phase waned during the late Oligocene time, the early evolutionary stage of the South Sumatra Basin was marked by transgression as a result of thermal sag and eustatic gain (Netherwood, 2000; Barber *et al*., 2005). The sediments of the Talangakar Formation were deposited then in basinal lows. The Talangakar was deposited in a diverse range of environments and it consists of interbedded sandstones, shales, and coals.

With continued transgression into the early Miocene, the Baturaja Formation developed on structural highs as low-relief, low-energy, carbonate-mud-dominated banks (Situmeang *et al*., 1992; Longman *et al*., 1992). The Gumai Formation, which consists almost exclusively of fine-grained siliciclastic rocks with thinly bedded sandstone and limestone intercalations, were deposited off-bank in deeper water. During the middle Miocene maximum transgression, the Gumai seal across the region, including those formerly covered by carbonate buildups (De Coster, 1974).

During middle Miocene, the variations in the angle and rate of convergence in the Sumatran subduction system leading to extension or compression in the back arc basinal areas (Barber *et al*., 2005). The event was manifested by the uplift of the Barisan Mountains, the increasing volcanic activities in the forearc region, and the formation of anticlines and faulted anticlines in the South Sumatra Basin (Netherwood, 2000; Barber *et al*., 2005). A middle Miocene – Pliocene regressive phase of deposition commenced with the shallow-marine to deltaic Air Benakat and Muaraenim Formations, which consists mainly of sandstone and fine-grained siliciclastic rocks with coal bed intercalations in the Muara Enim Formation.

As compression and volcanism continued, sedimentation from the Pliocene onward were dominated by the increasing volcanic materials from the west and southwest of the basin, leading to the deposition of the Kasai Formation (Pleistocene) that rests with local unconformity on the Muaraenim Formation. The Kasai is composed of conglomerates, tuffaceous sandstones, and tuffs with lignite and silicified wood.

DATA AND METHODS

Raw data consulted for this paper—*i.e*., the borehole occurrences of planktonic foraminifera species in the subsurface South Sumatra Basin—were retrieved from paleontology and biostratigraphy reports of a total 30 exploration wells. Original paleontology or biostratigraphy analyses were conducted by various service companies from 1971 to 2001.

The bulk of the aforementioned biostratigraphy data derived from ditch cutting samples. Interval of analyzed samples were not necessarily the same from one well to another; they were ranging from about 3 m to about 100 m. Sidewall cores of selected horizon were also analyzed in almost all studied wells. Several "standard" planktonic foraminiferal zonation schemes—those proposed by Bolli (1966), Blow (1969), Postuma (1971), Srinivasan and Kenneth (1981), Bolli and Saunders (1985)—as well as regional zonation schemes (Pringgoprawiro *et al*., 1978; Ikebe and Chiji, 1978; Van Gorsel, 1988; Kadar *et al*., 1996; Van Gorsel *et al*., 2014) were assessed for their applicability to the available biostratigraphy data from the South Sumatra Basin. At the same time, the stratigraphic range of foraminifera observable in Miocene sediments of the South Sumatra Basin was revised to accommodate the results of recent

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studies (*e.g.*, Berggren *et al.*, 1995; Wade *et al.*, 2011; Li *et al.*, 2015; BouDagher-Fadel, 2015). The results of the assessment were used to construct a planktonic foraminiferal zonation for the South Sumatra Basin (figure 3), using the biostratigraphy zonation nomenclature of Wade *et al.* (2011).

DEFINITIONS OF PLANKTONIC FORAMINIFERAL ZONES		
***Globorotalia kugleri* Zone (N4)**		
Definition	:	Biostratigraphic interval between the FAD of *Globorotalia kugleri* Bolli and the LAD of *Globorotalia kugleri* Bolli.
Category	:	Taxon range zone (TRZ).
Estimated age	:	22.96-21.12 Ma (Gradstein *et al.*, 2004; Chunlian *et al.*, 2012; Li *et al.*, 2015), Early Miocene.
Remarks	:	This zone is equivalent to the *Globorotalia kugleri* Zone of Bolli (1966), Postuma (1971), Gradstein *et al.* (2004), Li *et al.* (2015). *Globigerina ciperoensis* Bolli has its extinction near the base of this zone, at an estimated age of 22.90 Ma (Gradstein *et al.*, 2004a; Li *et al.*, 2015). As such, its first occurrence may be used as a proxy for the base of N4 zone.

DEFINITIONS OF PLANKTONIC FORAMINIFERAL ZONES		
***Globoquadrina binaiensis* Zone (N5)**		
Definition	:	Biostratigraphic interval between the LAD of *Globorotalia kugleri* Bolli and the LAD of *Globoquadrina binaiensis* Koch.
Category	:	Highest-occurrence zone (HOZ).
Estimated age	:	21.12-19.09 Ma (Gradstein *et al.*, 2004; Chunlian *et al.*, 2012; Li *et al.*, 2015), Early Miocene.
Remarks	:	The LAD of *Globoquadrina binaiensis* Koch, which is proposed to mark the top of this zone, has been known as one of those that mark biostratigraphic events in Indonesia (Pringgoprawiro *et al.*, 1978; Van Gorsel, 1988; Kadar *et al.*, 1996; Van Gorsel *et al.*, 2014) and beyond (Pearson and Chaisson, 1997; Chunlian *et al.*, 2012; Gradstein *et al.*, 2004). A general practice of using the FAD of *Globigerinita insueta* Cushman and Stainforth to mark the top of N5 zone (*e.g.*, Blow, 1969; Berggren *et al.*, 1995), is not followed in this paper due to the scarcity of nominate species in the South Sumatra Basin.

DEFINITIONS OF PLANKTONIC FORAMINIFERAL ZONES		
***Catapsydrax dissimilis* Zone (N6)**		
Definition	:	Biostratigraphic interval between the LAD of *Globoquadrina binaiensis* Koch and the LAD of *Catapsydrax dissimilis* Cushman and Bermudez.
Category	:	Highest-occurrence zone (HOZ).
Estimated age	:	19.09-17.54 Ma (Gradstein *et al.*, 2004; Chunlian *et al.*, 2012), Early Miocene.
Remarks	:	*Catapsydrax unicavus* Bolli, Loeblich and Tappan has its extinction at the top of this zone, at an estimated age of 17.54 Ma (Berggren *et al.*, 1995; Gradstein *et al.*, 2004; Li *et al.*, 2015). As such, its LAD may be used as an alternative to mark the top of N6 zone.

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DEFINITIONS OF PLANKTONIC FORAMINIFERAL ZONES		
***Globigerinatella insueta* Zone (N7)**		
Definition	:	Biostratigraphic interval between the LAD of *Catapsydrax dissimilis* Cushman and Bermudez and the FAD of *Praeorbulina sicana* de Stefani.
Category	:	Partial range zone (PRZ).
Estimated age	:	17.54-16.40 Ma (Berggren *et al*., 1995; Gradstein *et al*., 2004; Wade *et al*., 2011; Chunlian *et al*., 2012), Early Miocene.
Remarks	:	*Globigerinoides altiaperturus* Bolli has its extinction at the top of this zone, at an estimated age of 16.40 Ma (Kadar *et al*., 1996; Chunlian *et al*., 2012). As such, its LAD may be used as an alternative to mark the top of N7 zone.

DEFINITIONS OF PLANKTONIC FORAMINIFERAL ZONES		
***Praeorbulina sicana* Zone (N8)**		
Definition	:	Biostratigraphic interval between the FAD of *Praeorbulina sicana* de Stefani and the FAD of *Orbulina suturalis* Brönnimann.
Category	:	Partial range zone (PRZ).
Estimated age	:	16.40-15.10 Ma (Berggren *et al*., 1995; Gradstein *et al*., 2004; Wade *et al*., 2011), Middle Miocene.
Remarks	:	According to Thompson and Abbott (2003), *Praeorbulina glomerosa curva* Blow and *Praeorbulina glomerosa circularis* Blow in Southeast Asia region have their extinction near the top of this zone, at an estimated age of 15.00 Ma. As such, their LAD may be used as proxies for the top of N8 zone.

DEFINITIONS OF PLANKTONIC FORAMINIFERAL ZONES		
***Orbulina suturalis* Zone (N9)**		
Definition	:	Biostratigraphic interval between the FAD of *Orbulina suturalis* Brönnimann and the FAD of *Globorotalia peripheroacuta* Blow and Banner.
Category	:	Lowest-occurrence zone (LOZ).
Estimated age	:	15.10-14.23 Ma (Berggren *et al*., 1995; Gradstein *et al*., 2004; Wade *et al*., 2011), Middle Miocene.
Remarks	:	*Praeorbulina transitoria* Blow has its extinction near the top of this zone, at an estimated age of 14.24 Ma (Chunlian *et al*., 2012). As such, its LAD may be used as a proxy for the top of N9 zone.

DEFINITIONS OF PLANKTONIC FORAMINIFERAL ZONES		
***Globorotalia peripheroacuta* Zone (N10)**		
Definition	:	Biostratigraphic interval between the FAD of *Globorotalia peripheroacuta* Blow and Banner and the FAD of *Globorotalia praefohsi* Blow and Banner.
Category	:	Lowest-occurrence zone (LOZ).
Estimated age	:	14.23-13.74 Ma (Wade *et al*., 2011), Middle Miocene.
Remarks	:	*Globorotalia peripheroronda* Blow has its extinction near the top of this zone, at an estimated age of 13.77 Ma (Wade *et al*., 2011). As such, its LAD may be used as a proxy for the top of N10 zone.

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DEFINITIONS OF PLANKTONIC FORAMINIFERAL ZONES		
***Globorotalia praefohsi* Zone (N11)**		
Definition	:	Biostratigraphic interval between the FAD of *Globorotalia praefohsi* Blow and Banner and the FAD of *Globorotalia fohsi* Cushman and Ellisor.
Category	:	Lowest-occurrence zone (LOZ).
Estimated age	:	13.74-13.34 Ma (Wade *et al.*, 2011), Middle Miocene.
Remarks	:	The existence of this zone in South Sumatra Basin is questionable as the present available data shows no record of foraminifera having their extinction in this zone (see discussion below).

DEFINITIONS OF PLANKTONIC FORAMINIFERAL ZONES		
***Globorotalia fohsi* Zone (N12)**		
Definition	:	Biostratigraphic interval between the FAD of *Globorotalia fohsi* Cushman and Ellisor and the LAD of *Globorotalia fohsi* Cushman and Ellisor.
Category	:	Taxon range zone (TRZ).
Estimated age	:	13.34-11.75 Ma (Wade *et al.*, 2011), Middle Miocene.
Remarks	:	The existence of this zone in South Sumatra Basin is questionable as the present available data could not be used to recognize the top of the Blow's (1969) N11 zone (see remarks in *Globorotalia praefohsi* zone above and discussion below).

DEFINITIONS OF PLANKTONIC FORAMINIFERAL ZONES		
***Globigerinoides ruber* Zone (N13)**		
Definition	:	Biostratigraphic interval between the LAD of *Globorotalia fohsi* Cushman and Ellisor and the FAD of *Globigerina nepenthes* Todd.
Category	:	Partial range zone (PRZ).
Estimated age	:	11.75-11.55 Ma (Wade *et al.*, 2011), Middle Miocene.
Remarks	:	*Globigerinoides subquadratus* Brönnimann has its extinction near the top of this zone, at an estimated age of 11.46 Ma (Wade *et al.*, 2011). As such, its LAD may be used as a proxy for the top of N13 zone.

DEFINITIONS OF PLANKTONIC FORAMINIFERAL ZONES		
***Globorotalia nepenthes - Globorotalia mayeri* Zone (N14)**		
Definition	:	Biostratigraphic interval between the FAD of *Globigerina nepenthes* Todd and the LAD of *Globorotalia mayeri* Cushman and Ellisor.
Category	:	Concurrent-range zone (CRZ).
Estimated age	:	11.55-10.46 Ma (Wade *et al.*, 2011; Li *et al.*, 2015), Late Miocene.
Remarks	:	*Globorotalia siakensis* LeRoy, at least in low latitude region, is presently regarded as the synonym for *Globorotalia mayeri* Cushman and Ellisor (see discussion by Bolli and Saunders, 1985). The LAD of *Globorotalia siakensis* LeRoy in South Sumatra Basin, therefore, may be used as an alternative to mark the top of N14 zone.

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DEFINITIONS OF PLANKTONIC FORAMINIFERAL ZONES		
***Globorotalia continuosa* Zone (N15)**		
Definition	:	Biostratigraphic interval between the LAD of *Globorotalia mayeri* Cushman and Ellisor or the LAD of *Globorotalia siakensis* LeRoy and the FAD of *Globorotalia acostaensis* Blow.
Category	:	Partial-range zone (PRZ).
Estimated age	:	10.46-9.79 Ma (Wade *et al*., 2011; Li *et al*., 2015), Late Miocene.

DEFINITIONS OF PLANKTONIC FORAMINIFERAL ZONES		
***Globorotalia acostaensis* Zone (N16)**		
Definition	:	Biostratigraphic interval between the FAD of *Globorotalia acostaensis* Blow and the FAD of *Globorotalia plesiotumida* Blow and Banner.
Category	:	Lowest-occurrence zone (LOZ).
Estimated age	:	9.79-8.52 Ma (Wade *et al*., 2011; Li *et al*., 2015), Late Miocene.

DEFINITIONS OF PLANKTONIC FORAMINIFERAL ZONES		
***Globorotalia plesiotumida* Zone (N17)**		
Definition	:	Biostratigraphic interval between the FAD of *Globorotalia plesiotumida* Blow and Banner and the FAD of *Globorotalia tumida* Brady.
Category	:	Lowest-occurrence zone (LOZ).
Estimated age	:	8.52-5.51 Ma (Wade *et al*., 2011), Late Miocene.
Remarks	:	*Globoquadrina dehiscens* Chapman, Parr and Collins has its extinction near the top of this zone, at an estimated age of 5.80 Ma (Berggren *et al*., 1995). As such, its LAD may be used as a proxy for the top of N17 zone. According to Berggren *et al*. (1995), *Globorotalia lenguaensis* Bolli has its extinction at the top of N17 zone. As such, its LAD may be used as an alternative to mark the top of N17 zone.

DEFINITIONS OF PLANKTONIC FORAMINIFERAL ZONES		
***Globorotalia tumida* Zone (N18)**		
Definition	:	Biostratigraphic interval between the FAD of *Globorotalia tumida* Brady and the FAD of Sphaeroidinella dehiscens
Category	:	Lowest-occurrence zone (LOZ).
Estimated age	:	5.51-5.48 Ma (Wade *et al*., 2011), Late Miocene.

DISCUSSION

As it is indicated clearly from previous section, the proposed zonation (figure 3) has been constructed based on regional to global biostratigraphic events that have proved as time-honored datums. At the same time, however, we present secondary datums that may serve as proxies for those primary datums, especially in subsurface studies when the majority of biostratigraphic data derived from ditch cutting samples.

The correlation between the proposed zonation and that of Blow's (1969) original scheme and those proposed by Berggren *et al*. (1995) and Wade *et al*. (2011) (figure 4) suggests that the proposed zonation is basically a Blow's zonation and, accordingly, may be perceived as a modified Blow's zonation for South Sumatra Basin. The general similarity between the proposed zonation and the regional biozonation scheme (Lunt, 2013, in Van Gorsel *et al*., 2013) indicates that the proposed zonation may

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be used as a basis to correlate the results of biostratigraphic studies in the South Sumatra Basin with those of studies conducted in other Southeast Asia basinal areas.

The existence of Blow's (1969) *Globorotalia fohsi* and *Globorotalia praefohsi* zones in South Sumatra Basin is questionable as the present available data could not be used to recognize them. The taxonomic problem pertaining to Fohsella lineage (see Berggren *et al*., 1995 and Wade *et al*., 2011 for discussion on that matter) may also contribute to the void recognition of the *Globorotalia praefohsi* zone in South Sumatra Basin. Both, however, may be combined to form a *Globorotalia praefohsi – Globorotalia fohsi* concurrent-range zone (N11-N12).

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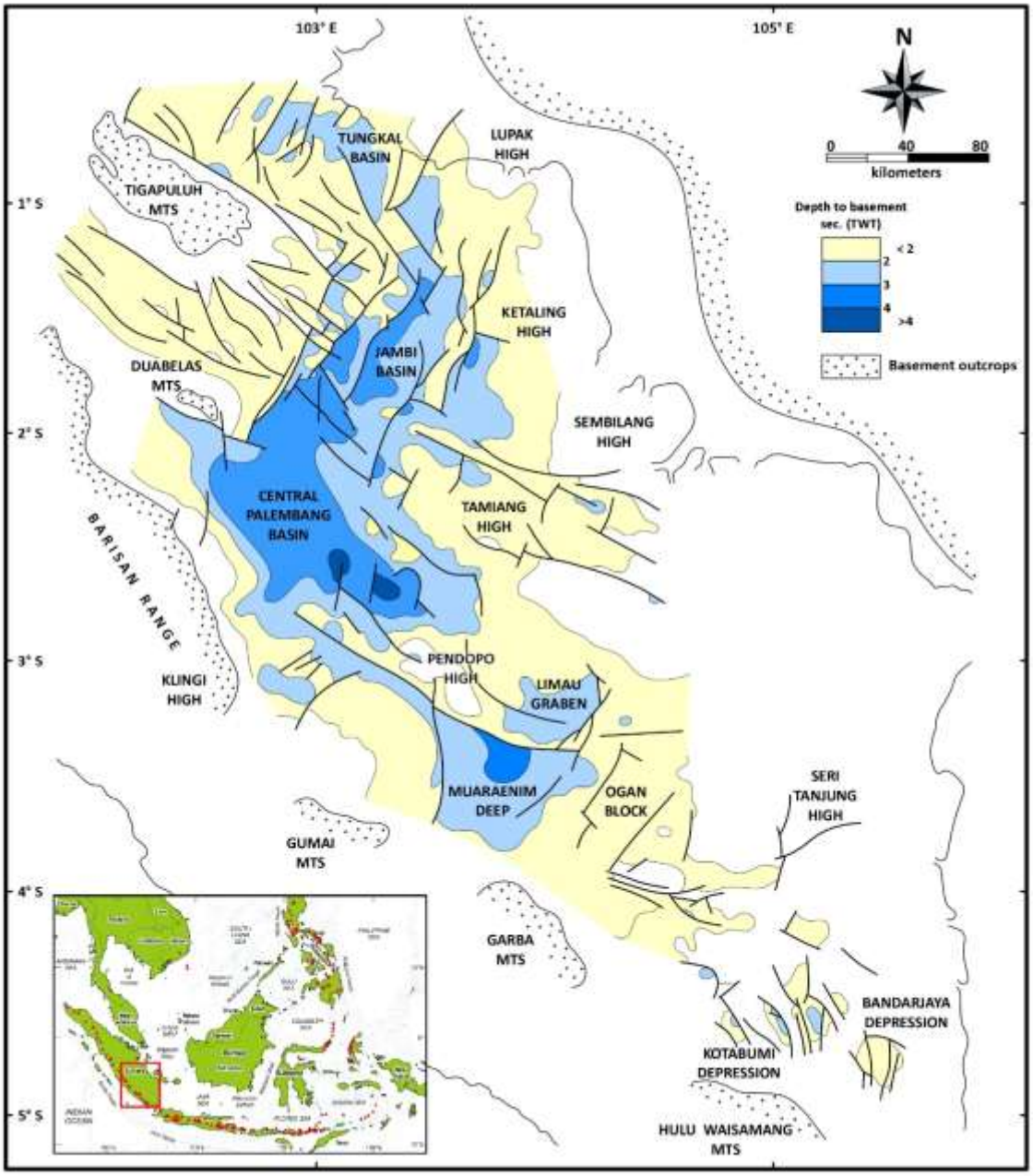

Figure 1. Geotectonic constellation and structural configuration of the South Sumatra Basin (modified from Pertamina-Beicip, 1985).

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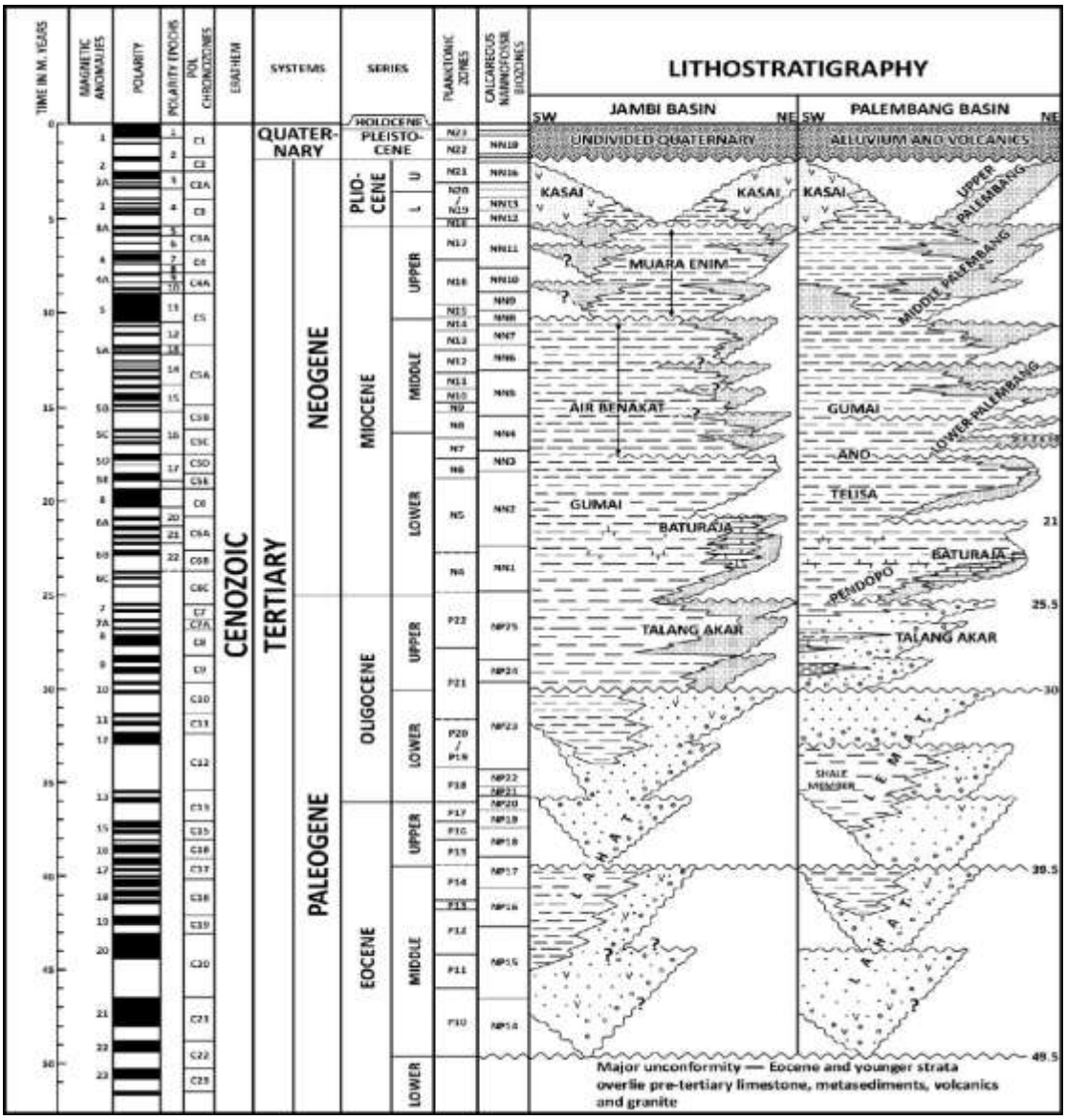

Figure 2. Lithostratigraphic scheme of the South Sumatra Basin (modified from Pertamina BPPKA, 1997).

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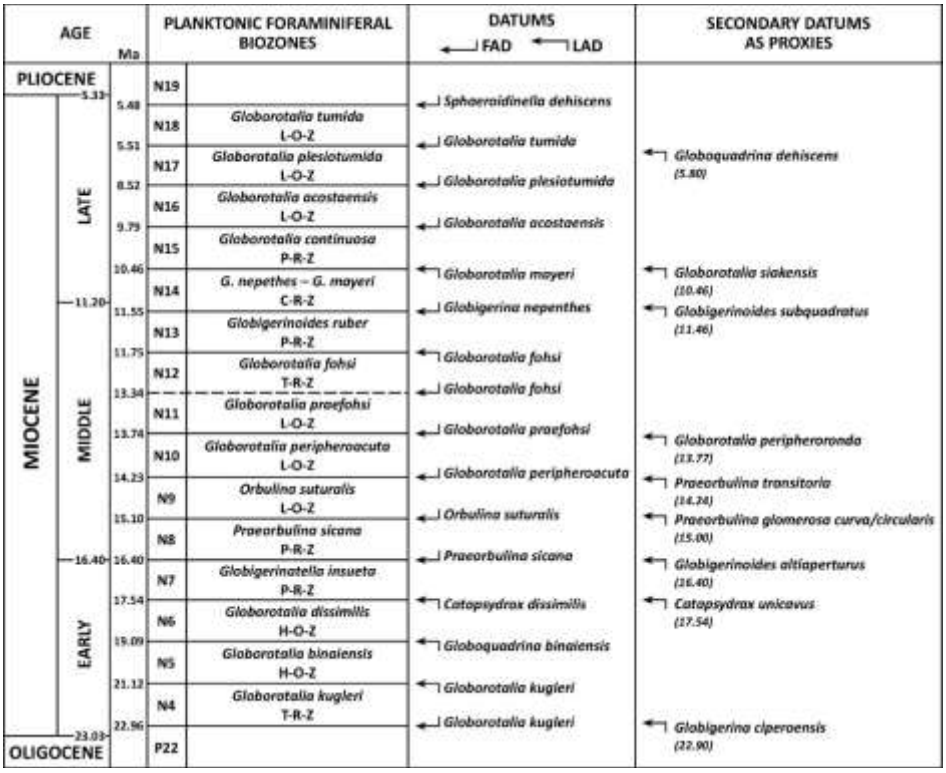

Figure 3. Proposed Miocene planktonic foraminiferal biozonation for South Sumatra Basin.

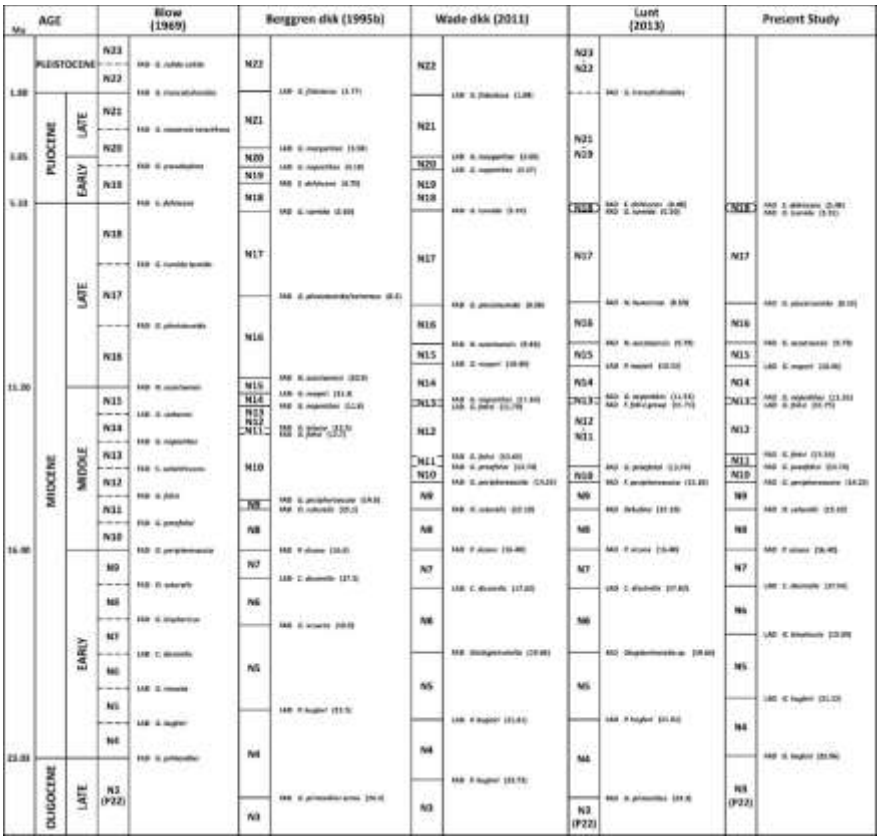

Figure 4. Correlation between the proposed biozonation with some "standard" (Blow, 1969; Berggren *et al.*, 1995; Wade *et al.*, 2011) and regional (Lunt, 2013) biozonation schemes.

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