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A REVIEW OF DOLOMITES IN SOUTHEAST ASIA

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ABSTRACT

This manuscript summarises published data on the distribution, habit, and current inferred models for dolomite occurrence in carbonates from southeast Asia. The presence of dolomite has significant implications for hydrocarbon exploration and production, as it may affect reservoir porosity, permeability, and connectivity to petroleum source areas. It may also be a factor in generation of undesirable non-hydrocarbon gases.

This work is by no means exhaustive, given the paucity of published data on dolomites in the region, and there is considerable scope for further study. The extended abstract presented herein is modified from a review on SE Asian dolomites (Carnell and Wilson, submitted) submitted to a Geological Society of London Special Publication on 'The Geometry & Petrogenesis of Dolomite Hydrocarbon Reservoirs'. The reader is referred to this Geological Society volume for the full manuscript, which contains descriptions of known SE Asian dolomites, discussions on their origins, together with maps, diagrams and tables showing the occurrence and characteristics of dolomites in Pre-Tertiary, Paleogene and Neogene carbonates.

INTRODUCTION

In Southeast Asia, carbonates are geographically and temporally widespread, and comprise major reservoir units in many basins (Wilson, 2002). They range in age from Precambrian to Recent, but are best known and most extensively studied in the Neogene where they have major economic significance (Fulthorpe and Schlanger, 1989). The carbonates are readily divisible into pre-Tertiary, Paleogene and Neogene forms (Wilson, 2002; Wilson and Rosen, 1998; Carnell and Wilson, submitted). As with limestones, dolomite is widespread in the region with its distribution reflecting the overall distribution of carbonates (Table 1). However, despite occurring widely in time and space, dolomite is volumetrically minor and patchily distributed. Many carbonates contain little or no dolomite (e.g. Tonasa Fm., Sulawesi, Wonosari Fm., Java) whilst others (e.g. Ratburi Gp., Thailand) are extensively dolomitised, with dolomite present as both cementing and replacive phases (Table 1). Where present, dolomite not only affects the original physical and chemical characteristics of limestones but can also have an important influence on reservoir quality, with both constructive and destructive effects evident.

Pre-Tertiary carbonates generally form part of the economic basement and as a consequence are little studied and poorly understood. Dolomites in these carbonates (Figure 1) are perhaps best known from the platform carbonates of the Ratburi and Saraburi Gps. in Thailand (Chinoroje, 1993; Baird and Bosence, 1993; Heward et al., 2000), and the oolitic grainstones of the Manusela Fm., of Seram (Kemp, 1992; Nilandaroe et al., 2002).

Paleogene carbonates are widely developed in the region and are most commonly developed as extensive foraminifera dominated carbonate shelfal systems around the margins of Sundaland (e.g. Tampur Fm., North Sumatra Basin and Tonasa Fm., Sulawesi) and the northern margins of Australia and the Birds Head microcontinent (e.g. Faumai Fm, Salawati Basin). Dolomite is variably recorded in these carbonates (Figure 2) and the Tampur Fm., for example shows extensive occurrence of xenotopic dolomite (Barliana et al.,2000).

Neogene carbonates (e.g. Peutu Fm., North Sumatra) are commonly areally restricted, reef dominated and

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developed in mixed carbonate-clastic systems. These Neogene carbonates most typically show a strong diagenetic overprint with leaching, recrystallisation, cementation and dolomitisation all widespread. Dolomite is variably distributed and shows evidence that its occurrence is influenced by facies, karstification, proximity to carbonate margins and faults (Figure 3).

The origin of dolomite in Southeast Asia is poorly understood and a number of models have been invoked. The most popular and persistent of these models is dolomitisation in the mixing zone. More recently an association of dolomitisation and karstification has been noted. Many authors have suggested dolomite derivation from compacting clays with the dolomitising fluid derived from dewatering clays and/or Mg-rich fluids liberated by smectite-illite transformations (Table 1).

As well as influencing reservoir quality, dolomitisation has also influenced the distribution of non-hydrocarbon gases. This is best documented in North Sumatra where carbon dioxide occurs in quantities ranging from 0% to 85%. There are a number of possible mechanisms for generating this CO_2 (e.g. mantle degassing) although the most likely origin is considered to be the widely dolomitised Eocene Tampur Fm. which forms effective basement for much of the basin (Caughey and Wahyudhi, 1993). High heat flows are suggested to have resulted in the thermogenic decomposition of limestone and dolomite with CO_2 produced as a by-product.

DOLOMITE DISTRIBUTION AND HABITS

Although dolomite comprises a small part of the total volume of carbonates in Southeast Asia, it is spatially and temporally widespread, reflecting the distribution of the precursor limestones. On a formation and reservoir scale, dolomite content and distribution are highly varied from absent to abundant (Carnell and Wilson, submitted).

Many workers record the presence of dolomite without commenting on dolomite habit, distribution and origins. Most information is available on Neogene carbonates, reflecting their economic importance to the region, although even here the knowledge base and understanding of dolomite is patchy. Although there are significant shortfalls in the availability and quality of data, it is clear that in Southeast Asia, dolomite occurs in both cementing and replacing habits. On the basis of the available data dolomites appear to be variably distributed, but are often associated with a) particular facies, b) specific parts, or surfaces within, platforms or buildups, and c) secondary compaction-, or tectonic-induced, features.

a.) *Facies associated:* Overall dolomite is most widely encountered as a replacive phase associated with argillaceous carbonates (Berry, 1976). In formations such as the Baturaja, Batuputih and Vanda carbonates, dolomite was most commonly reported in deposits containing greater than 7-10% terrigenous mud (Tonkin et al., 1992, Netherwood and Wight, 1992). In these argillaceous deposits dolomite occurs as microcrystalline to finely crystalline rhombs, which are locally arranged into clusters. Although many authors record the presence of this dolomite, its paragenesis is generally not interpreted. Park et al., 1995 note that this form of dolomite is enclosed in early fringing cements, and they interpret it as an early phase developed prior to significant compaction of mudstones. However, in other argillaceous deposits microcrystalline dolomites post-date the formation of dissolution seams and are interpreted as a burial feature (Ali, 1995).

Where pure carbonates have been affected, dolomite typically replaces the micrite matrix first. This is a reflection of micrite - with a large surface area to volume ratio, and a high number of nucleation sites - being more reactive than larger particles. Dolomite replacing micrite matrix tends to be fabric retentive and commonly contains a high degree of microporosity. Based on diagenetic relationships it is generally inferred that this is a relatively early diagenetic phase, although later dolomitisation is also locally suggested (e.g. Manusela Fm., Seram).

b.) *Associated with specific parts of, or surfaces within, platforms or buildups:* Many authors have noticed an association between dolomite and exposure surfaces, with dolomite developed as a cementing and replacive phase. Examples in which dolomites are well developed below exposure surfaces are seen in the Luconia Platform (Epting, 1980), the Baturaja Formation (Park et al., 1995) and the Tacipi Formation

(Mayall and Cox, 1988). This dolomite developed in association with syn-depositional exposure and later exposure related to post-burial uplift. In a number of examples, dolomite formation post dates initial karstification, since dolomite cements precipitated in vugs or cavities (Park et al., 1995).

Sun and Esteban (1994) suggested that dolomites are commonly encountered in specific parts of SE Asian carbonate platforms, namely their basal parts, and along their flanks. However, the occurrence of dolomites in the basal parts of platforms has only been reported from Miocene carbonates in Northern Sumatra (e.g Peutu Formation). In contrast, the Baturaja Formation of Southern Sumatra is most commonly dolomitized in its upper part. However, in most carbonates in the region, dolomitization is not associated with either the upper of lower parts of carbonate successions. Replacive dolomites are reported from the flanks of buildups in the Berai (Saller and Vijaya, 2002) and Kais Formations (Livingstone et al., 1992). In many of these formations in which dolomites are associated with specific parts of platforms, a number of dolomite occurrences are in clay-rich facies (Livingstone et al., 1992; Park et al., 1995). Other cases of dolomites occurring in specific parts of platforms have been linked to fluids derived from underlying or adjacent compacting shales.

c.) *Associated with secondary compaction-, or tectonic-induced, features*: Dolomite is commonly encountered as a late diagenetic stage associated with stylolites where it occurs as a replacive form and as a cement. When replacive, the dolomite tends to occur as non-ferroan rhombs within and adjacent to the stylolites, but it also occurs as a microcrystalline replacement of adjacent fabric. Dolomite developed as a cement is seen to occlude tension gashes and pre-existing pores in the precursor fabric. Stylolite associated dolomite is volumetrically minor and as such is prone to be overlooked in the literature.

Dolomite is widely encountered as a fracture filling cement (e.g. Baturaja Fm.), but also occurs as a replacive phase associated with fractures (e.g. Taballar Fm. and Rajamandala Limestone). Dolomite cements associated with stylolites and fractures may be either planar, or non-planar saddle, dolomites. Where replacive dolomites are associated with fractures, the degree of dolomitization decreases away from fractures. It is inferred that fractures were important conduits, providing pathways for dolomitizing fluids to move along and into adjacent limestones.

MODELS FOR DOLOMITE ORIGIN

Although dolomite is widely recognised in Southeast Asia, few studies provide suitable data to enable the origins of dolomitizing fluids to be evaluated. As a consequence, the processes by which carbonates have been dolomitised remain poorly understood. Most available published data suggests dolomitisation has taken place in the mixing-zone. In examples, such as the Tacipi, Baturaja and Luconia carbonates, this is supported by stratigraphic, textural and isotopic data. However, for a number of other formations, isotopic data is not available and a mixing zone origin for dolomitization has been suggested without providing substantiating evidence (Hendarjo and Netherwood, 1986). The perceived dominance of mixing zone dolomitisation in the Neogene is perhaps to be expected since most of the studied carbonates are reefal and by their very nature susceptible to mixing zone processes. Dolomitisation in response to exposure is also widely hypothesised and in the past may well have been underestimated or misidentified. As with mixing zone processes, the deposition of carbonates (particularly Neogene carbonates) close to sea level makes them susceptible to exposure (e.g. by eustatic sea level fluctuations) and subsequent karstic processes. Isotopic signatures in dolomite cements precipitated in karstic cavities in the Baturaja Formation record progressive re-emplacement of marine fluids (i.e. mixing zone dolomitization) following karstification (Park et al., 1995).

The microcrystalline replacive dolomite rhombs found in organic-rich, argillaceous sediments have at least two origins, based on textural relationships and isotopic data. An early diagenetic phase recognised in the Baturaja Formation has been related to sulphate reduction through the oxidation of organic material (Park, et al., 1995). In a number of other argillaceous carbonates, such as the Tigapapan and Vanda Limestones, microcrystalline dolomites are late diagenetic features and formed at intermediate burial depths. During compaction, the dewatering of shales and the transformation of smectite to illite are thought to have provided the fluids causing this dolomitization (Ali, 1995). Although these dolomites are widespread in the region, it is probable that their occurrence has been under-reported since they are present in poorly studied, tight argillaceous limestones with low reservoir potential.

Dolomites with a methanogenic origin have been reported in Southeast Asia. Ali (1995) recorded the presence of dolomite cements in the Tigapapan unit of Sabah with light carbon isotope signatures and suggested that the carbon was derived from the action of methane-oxidizing bacteria. Calcite cements with a similar isotope signature have also been reported in the Sunda basin (Park et al., 1995), although here precipitation from fluids expelled from the Banuwati Fm. source rock is envisaged. Dolomite (and calcite) precipitation from methane-derived fluids is potentially more widespread than has been reported to date and may merit further study.

Many authors favour an interpretation of dolomite formation from Mg rich fluids derived from the clays that commonly encase the precursor limestone. As described above, dolomites are very common in carbonates with a significant component of admixed clays, and the available evidence does support the compaction of shales in generating dolomitising fluids. However, only a few carbonates successions, which overlie or are laterally adjacent to shales, have been dolomitised in their base or margins respectively. Most Neogene carbonates are developed as part of mixed carbonate-clastic deposystems and as such should be prone to dolomitisation by this process. However, this is clearly not the case and there is considerable variation in the extent of dolomitisation both within and between units. The Kais Fm. for example is extensively dolomitised whereas the Baturaja Fm. shows only limited dolomitisation. Even within the Kais Fm. there are significant variations in the degree of dolomitisation, with Kasim Utara Field more extensively dolomitised than Walio Field. In the Berai and Kais Limestones, which are dolomitised along their flanks, dolomitisation was preceded by dissolution. It may be that dolomitising fluids cannot penetrate into carbonate formations unless fracturing and/or dissolution provide suitable conduits. In the case of the Berai Limestone, dissolution porosity is inferred to be related to acidic water compacting out of adjacent shales. It is possible that reduction of organic material within muds is playing a significant role in dissolution during burial, and/or dolomitisation. During moderate to deep burial of organic-rich shales, acidic waters can be generated associated with the maturation of organic material. The Klasafet Fm. acts as both seal and source to the Kais Fm. and has been suggested as a possible source of dolomitising fluids. It is possible that the increased organic component to the Klasafet Fm. gives it greater potential for dolomitisation than those muds which surround the Baturaja Fm. Internal variations within the Kais and Klasafet Fms. may account for varying degrees of dolomitisation of Kais Fm. fields.

Globally many models for dolomite formation favour an evaporitic component to their formation, and indeed some authors have suggested that this is a process that can be applied to Southeast Asia. For example, Sun and Esteban (1994) have suggested an evaporitic origin for dolomites in SE Asia with dolomitisation occurring during sea level lows and during dry seasons. Ali and Abolins (1999) suggested that this model might provide an alternative mechanism for dolomitisation to mixing zone dolomitisation for the Luconia Platforms. The isotopic data for these dolomites does not support an evaporitic origin, although it cannot be used to distinguish between a reflux or mixing zone model. However, such interpretations of evaporitic models for dolomitisation are very much the exception, with most workers considering conditions in the Tertiary to be unsuitable for evaporitic processes to have operated. In addition to a lack of evaporite minerals, palaeoclimatic evidence suggests that throughout most of the Tertiary, with the possible exception of the late Miocene and Pliocene, conditions have been too humid to allow the development of hypersalinity (Frakes, 1979; Morley, 2000). In summary the interpretation of dolomitisation by evaporitic processes is not supported for Tertiary carbonates based on independent lithological, isotopic or climatic data for the region.

Although dolomitisation of carbonates by evaporitic processes is considered to be unlikely in the Tertiary it is possible that such processes were operating during the Pre-Tertiary. For example, dolomites seen in the Permian and Carboniferous have replaced limestones, which were deposited on shallow platforms that show evidence of at least localised restriction. These carbonates were deposited on terranes that were translocated across Tethys from Gondwana and in so doing passed through more arid climatic zones (Ziegler, 1990; Rees et al., 1999).

The Ratburi Gp. of Thailand shows evidence of dolomitisation from fluids associated with granite emplacement. Here dolomitisation is extensive with dolomite developed as an early replacive phase and as a late stage cement. It is uncertain as to whether the earlier phase of dolomite is derived from marine-meteoric mixing or marine water circulation, whereas late stage cements are considered to be associated with high temperature fluid circulation in response to granite emplacement in the Cretaceous. Recent studies have suggested that “karstic” porosity in offshore areas may in reality be attributable to the action of similar fluids (Heward, et al., 2000). Given the extensive tectonic activity in the region and repeated phases of granite emplacement, it is possible that dolomites derived from high temperature fluid circulation may be more extensive than is currently recognised.

INFLUENCE OF DOLOMITE ON RESERVOIR QUALITY

Dolomite has had a mixed influence on reservoir quality, but overall is often associated with good porosity and permeability characteristics. Best reservoir quality tends to occur where dolomite is developed as a replacive phase (e.g. Central Luconia and Kais Limestone). It may be that early fabric retentive dolomites are preserving original porosity by preventing later compaction. Replacive dolomites, such as those formed in argillaceous carbonates, or sometimes those associated with late diagenetic events, often have low porosities and permeabilities. In the case of the dolomitization of argillaceous carbonates, dolomites are developed in essentially non-reservoir lithologies, and as such had a minimal effect on reservoir quality. In general replacive dolomite has a greater influence on permeability than on porosity. Replacive dolomite is commonly associated with reduced porosity, although this is offset by a relative improvement in permeability. For example, James (1983) summarising Indonesian and Malaysian carbonates reports average porosities of 10% and 20% for dolomite and limestone respectively but similar average permeabilities for both (100mD).

When occurring as a cement, dolomite has a destructive influence on reservoir quality with these cements reducing both porosity and permeability. The extent of this reservoir quality reduction depends on the amount of cementation that has taken place. In the Kasim Utara Field (Kais Fm., Salawati Basin), an initial improvement in reservoir quality as a result of dolomitisation has been offset by later widespread dolomite cementation.

In addition to directly influencing reservoir quality in terms of porosity and permeability, dolomite also has an indirect influence on petroleum systems in the region by acting as a source of non-hydrocarbon gases. As can be seen in the North Sumatra Basin the distribution of CO_2 can be a major factor influencing reservoir viability, and can make an otherwise attractive target uneconomic. As a consequence, knowledge of dolomite distribution, potential CO_2 kitchens and potential pathways (“basin plumbing”) can have a considerable impact on exploration and production strategies.

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REFERENCES CITED

Ali, M.Y. and Abolins, P., 1999. Central Luconia Province *in* The Petroleum Geology and Resources of Malaysia. Petronas, p.369-392

Ali, M.Y., 1995. Carbonate cement stratigraphy and timing of diagenesis in a Miocene mixed carbonate-clastic sequence, offshore Sabah, Malaysia: Constraints from Cathodoluminescene, Geochemistry and Isotope Studies. Sedimentary Geology, Vol. 99, p.191-214.

Baird, A. and Bosence, D., 1993. The Sedimentological and Diagenetic evolution of the Ratburi Limestone, peninsular Thailand. J. Southeast Asian Earth Sciences, Vol. 8, p.173-180.

Barliana, A., Burgon, G. and Caughey, C.A., 2000. Changing perceptions of a carbonate gas reservoir: Alur Siwah Field, Aceh Timur, Sumatra. Proceedings

27th Annual Convention Indonesian Petroleum Association, p.159-176.

Berry, J.T., 1976. Aspects of diagenesis and porosity in Indonesian Miocene carbonates. Proceedings of the Carbonate Seminar, Special Volume, Indonesia Petroleum Association, p.109-111.

Carnell, A.J.H. and Wilson, M.E.J. Wilson, submitted. Dolomites in Southeast Asia, a mixed bag (examples, possible origins and implications for hydrocarbon exploration). *In* The Geometry & Petrogenesis of Dolomite Hydrocarbon Reservoirs. Geological Society of London, Special Publication.

Caughey, C.A. and Wahyudi, T. 1993. Gas reservoirs in the Lower Miocene Peutu Formation, Aceh Timur, Sumatra. Proceedings 22nd Annual Convention Indonesian Petroleum Association, vol. 1, p.191-218.

Chinoroje, O., 1993. Petrographic studies of Permian Carbonates in Southern Thailand, Journal of Southeast Asian Earth Sciences, Vol. 8, p.161-171.

Epting, M., 1980. Sedimentology of Miocene carbonate build ups, Central Luconia, Offshore Sarawak. Geol. Soc. Malaysia, Bull. Vol.12, p.17-30.

Frakes, L.A., 1979. Climates through geologic time. Elsevier Scientific Publishing Company. Amsterdam. 31 pp.

Fulthorpe, C.S., Schlanger, S.O., 1989. Paleo-oceanographic and tectonic settings of early Miocene reefs and associated carbonates of offshore Southeast Asia. American Association of Petroleum Geologists Bulletin 73, p.729-756.

Hendarjo, K.S. and Netherwood, R.E., 1986. Palaeoenvironmental and diagenetic history of Kais Formation, K.B.S.A., Irian Jaya. Proceedings 15th Annual Convention Indonesian Petroleum Association, vol. 1, p.423-438.

Heward, A.P., Chuenbunchom, S., Mäkel, G., Marsland, D. and Spring, L., 2000. Nang Nuan Field, B6/27, Gulf of Thailand: karst reservoirs of meteoric or deep burial origin? Petroleum Geoscience, vol. 6, p.15-27.

James, S.J., 1983. Micritization and calichification: their recognition and implications. Proceedings 12th Annual Convention Indonesian Petroleum Association, vol. 1, p.81-106.

Kemp, G., 1992. The Manusela Formation – an example of a Jurassic Carbonate unit of the Australian Plate from Seram, Eastern Indonesia. *in* Siemers, C.T., Longman, M.W., Park, R.K. and Kaldi, J.G. (eds) Carbonate Rocks and Reservoirs of Indonesia: A Core Workshop. IPA Core Workshop Notes No. 1, p.11-1 to 11-41.

Livingstone, H.J., Sincock, B.W., Syarief, A.M., Sriwidadi and Wilson, J.N., 1992. Comparison of Walio and Kasim Reefs, Salawati Basin, Western Irian Jaya, Indonesia. *in* Siemers, C.T., Longman, M.W., Park, R.K. and Kaldi, J.G. (eds) Carbonate Rocks and Reservoirs of Indonesia: A Core Workshop. IPA Core Workshop Notes No. 1, p.4-1 to 4-37.

Mayall, M.J. and Cox, M., 1988. Deposition and diagenesis of Miocene Limestones, Sengkang Basin, Sulawesi, Indonesia. Sed. Geol. Vol.59, p.77-92.

Morley, R.J., 2000. Origin and evolution of tropical rain forests. John Wiley & Sons, Ltd., 362 pp.

Netherwood, R.E. and Wight, A.W.R., 1992. Structurally-controlled, linear reefs in a Pliocene delta-front setting, Tarakan Basin, Northeast Kalimantan. *in* Siemers, C.T., Longman, M.W., Park, R.K. and Kaldi, J.G. (eds) Carbonate Rocks and Reservoirs of Indonesia: A Core Workshop. IPA Core Workshop Notes No. 1, p. 3-1 to 3-40.

Nilandaroe, N., Mogg, W., and Barraclough, R., 2002. Characteristics of the fractured carbonate reservoir of the Oseil Field, Seram Island, Indonesia. Proceedings 28th Annual Convention Indonesian Petroleum Association, p.439-456.

Park, R.K., Matter, A. and Tonkin, P.C., 1995. Porosity evolution in the Batu Raja carbonates of the Sunda Basin – windows of evolution. Proceedings 24th Annual Convention Indonesian Petroleum Association vol. 1, p.163-184.

Rees, P.M., Gibbs, M.T., Ziegler, A.M., Kutzbach, J.E. and Behling, P.J., 1999. Permian climates: evaluating model predictions using global paleobotanical data, Geology, Vol. 27, p.891-894.

Saller, A.H. and Vijaya, S., 2002. Depositional and diagenetic history of the Kerendan carbonate platform, Oligocene, Central Kalimantan, Indonesia. Jl. Pet. Geol., Vol. 25, p.123-150.

Sun, S.Q. and Esteban, M., 1994. Paleoclimatic controls on sedimentation, diagenesis and reservoir quality: lessons from Miocene carbonates. American Association of Petroleum Geologists Bulletin 78, p.519-543.

Tonkin, P.C., Temansaji, A. and Park, R.K., 1992. Reef complex lithofacies and reservoir, Rama Field, Sunda Basin, Southeast Sumatra, Indonesia. *in* Siemers, C.T., Longman, M.W., Park, R.K. and Kaldi, J.G. (eds) Carbonate Rocks and Reservoirs of Indonesia: A Core Workshop. IPA Core Workshop Notes No. 1, p. 7-1 to 7-46.

Wilson, M.E.J., 2002. Cenozoic carbonates in SE Asia: Implications for equatorial carbonate development. Sedimentary Geology 147 (3-4), p. 295-428.

Wilson, M.E.J. and Rosen, B.R., 1998. Implications of paucity of corals in the Paleogene of SE Asia: plate tectonics or centre of origin? *In* Hall, R. and Holloway, J.D. (eds) Biogeography and Geological Evolution of SE Asia. p. 165-195.

Ziegler, A.M., 1990. Phytogeographic patterns and continental configurations during the Permian Period. *In*: McKerrow, W.S & C.R. Scotese (eds) Palaeogeography and Biogeography. Geol. Soc. of Lond. Memoir, p. 363-377.

TABLE 1

REPORTED DOLOMITE OCCURRENCES IN CARBONATE FORMATIONS FROM SE ASIA (SEE CARNEL AND WILSON, SUBMITTED). TABLE ALSO SHOWS IF ISOTOPIC DATA HAS BEEN RECORDED, WHETHER THE DOLOMITES ARE ASSOCIATED WITH ANY SPECIFIC FEATURES AND IF A DOLOMITIZATION MODEL HAS BEEN INFERRED

		Dolomite type:				Isotopic data:			Associated with:								Inferred origin related to:						
Age	**Number of carbonate formations reported with dolomite occurrence**	**Microcrystalline replacive**	**Replacive**	**Cement**	**Not reported**	**Delta 18O**	**Delta 13C**	**86/87Sr**	**Mixed siliciclastics**	**Adjacent siliciclastics**	**Subaerial exposure**	**Dissolution**	**Fracturing**	**Coralline algae**	**Restricted facies**	**Not recorded**	**Marine-meteoric mixing**	**Marine water**	**Igneous emplacement**	**Shale compaction/dewatering**	**Subaerial exposure**	**Burial**	**Not reported**
Pre-Tertiary	19	1	4	1	15	1	1	0	5	6	1	1	4	0	?1	9	1	1	1	1	0	0	17
Paleogene	11	6	6	4	3	1	1	0	5	4, ?1	3, ?1	2	4, ?1	3	1	1	0	0	0	1	0	1	10
Neogene	34	14	10	10	16	4	4	3	17	10	9, ?1	5	7	6	?2	6	6, ?1	0	0	4	3, ?2	1	24
Total	64	21	20	15	34	6	6	3	27	20 ?1	13 ?2	8	15 ?1	9	1 ?3	16	7, ?1	1	1	6	3, ?2	2	51

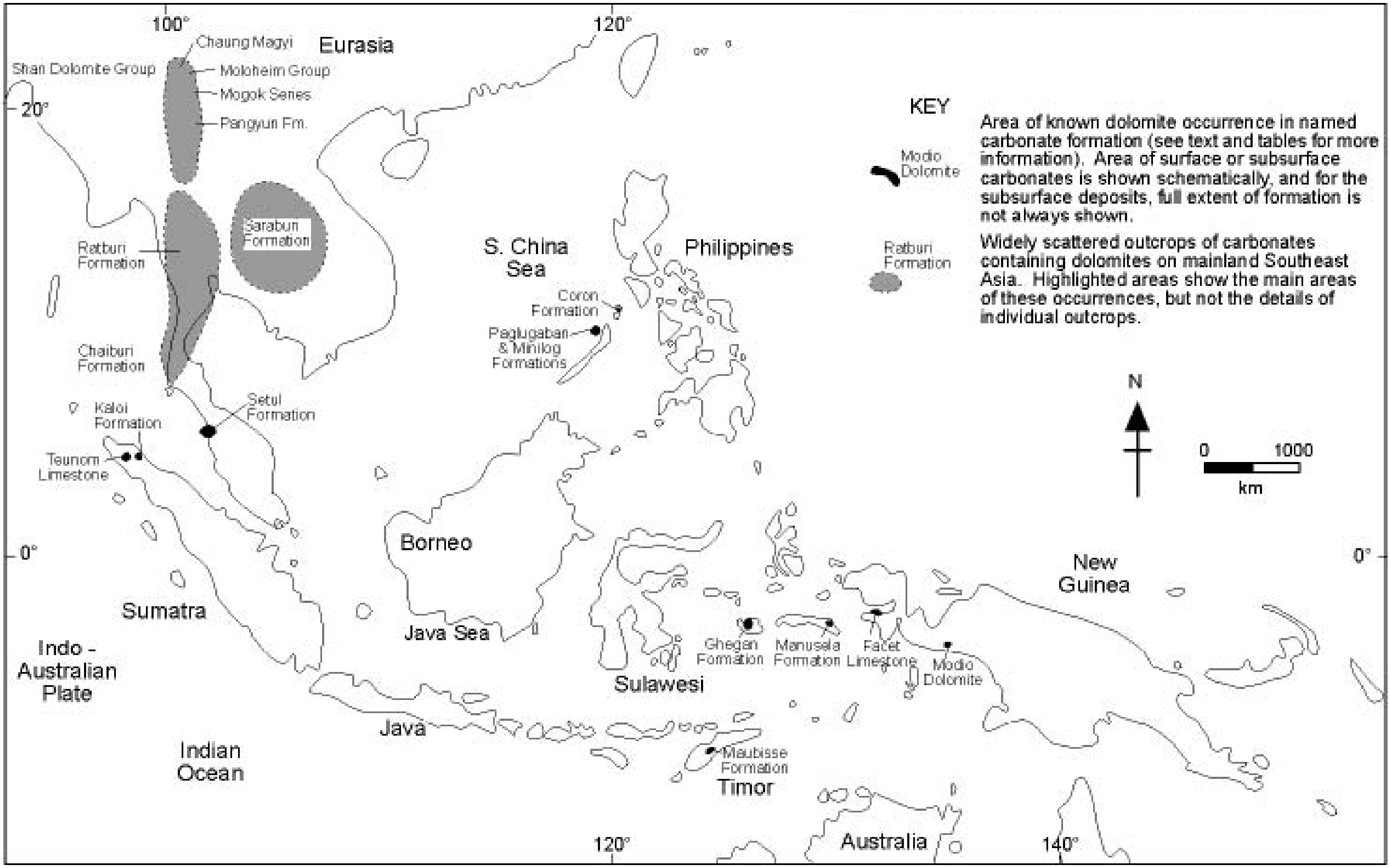

Figure 1 - Known dolomite occurrence in Pre-Tertiary Carbonates.

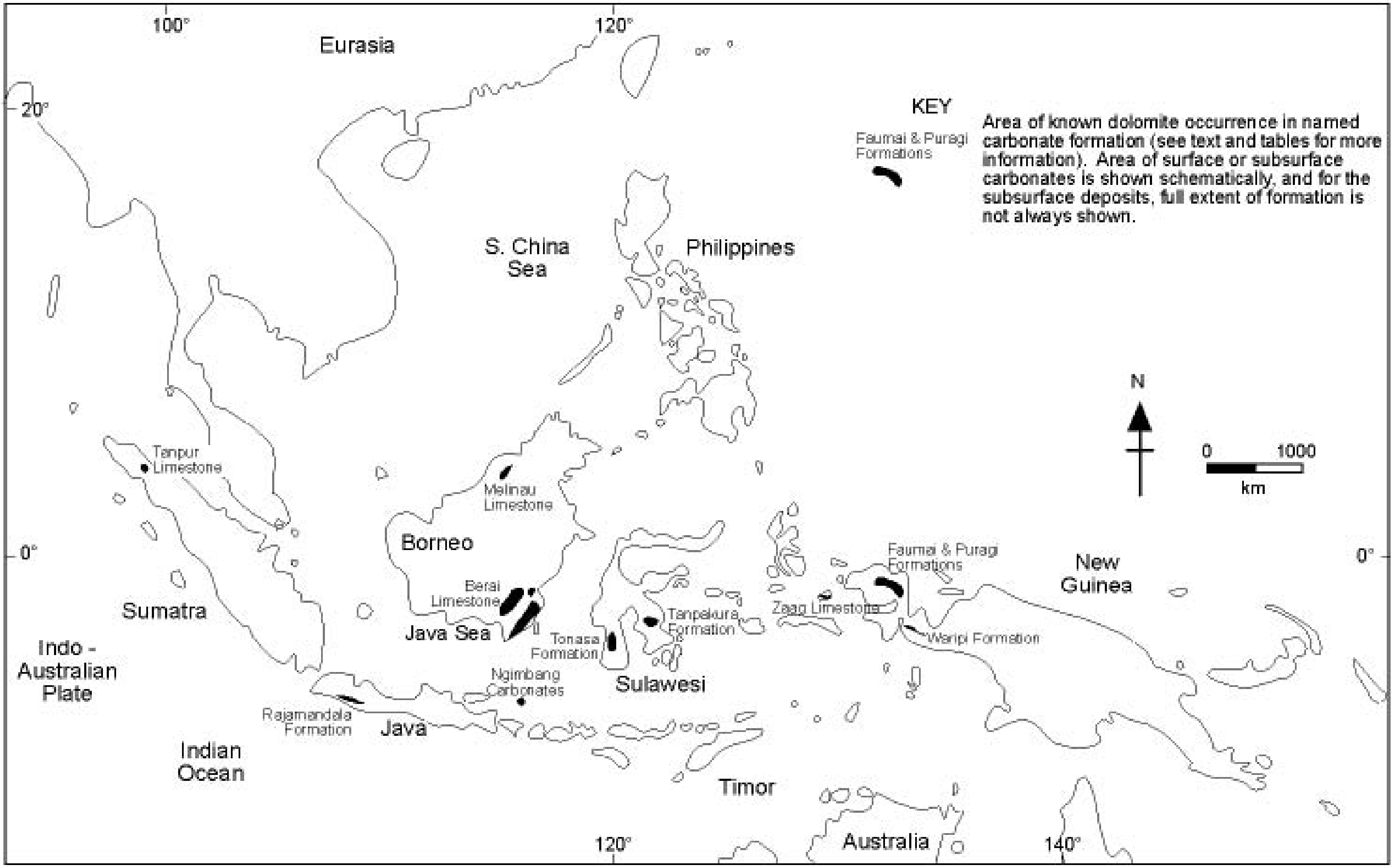

Figure 2 - Known dolomite occurrence in Paleogene Carbonates.

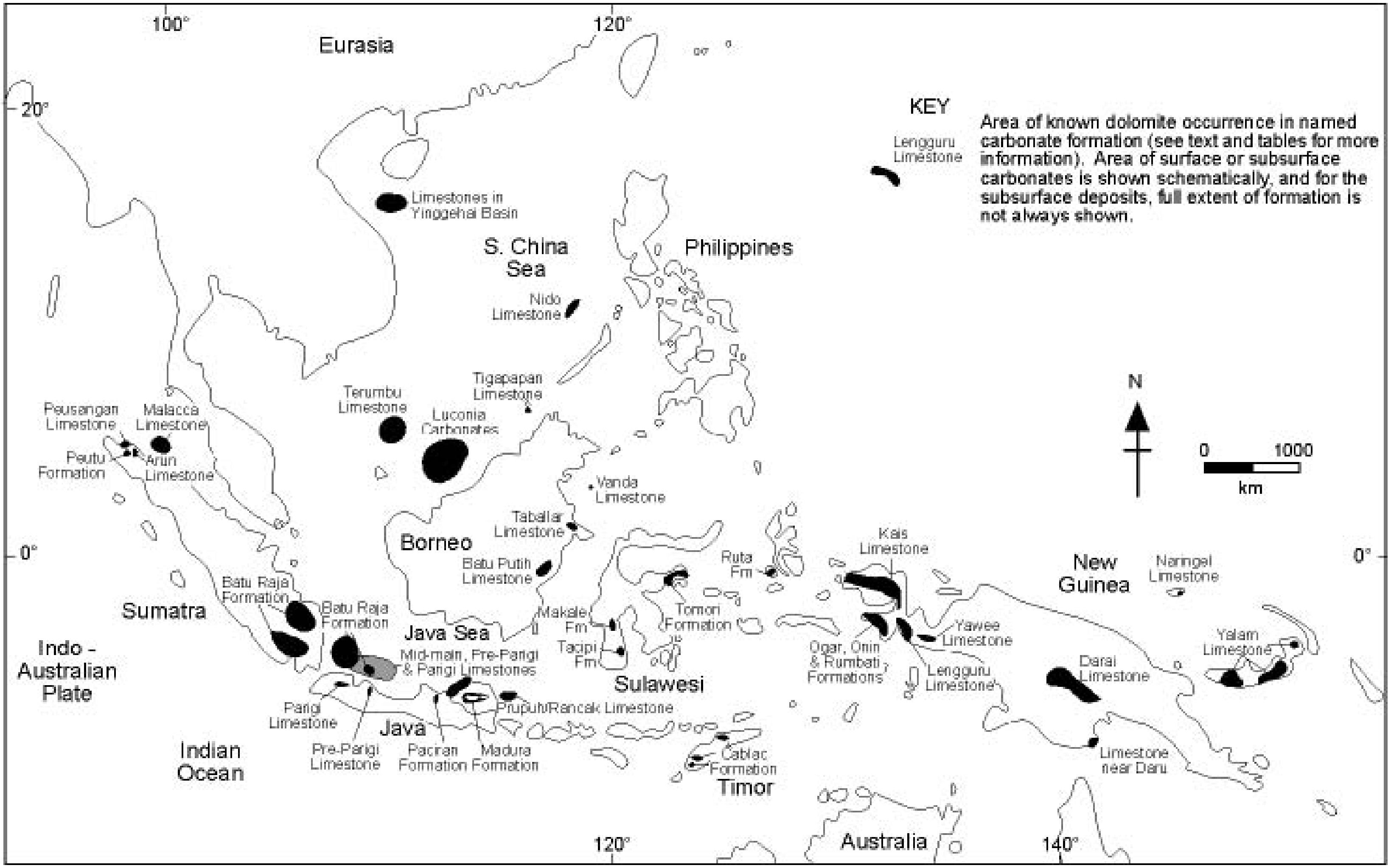

Figure 3 - Known dolomite occurrence in Neogene Carbonates.