BIBLIOGRAPHY OF THE GEOLOGY OF INDONESIA
AND SURROUNDING AREAS

Edition 7.0, July 2018

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XI. HYDROCARBONS, COAL, MINING

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XI. HYDROCARBONS, COAL, MINING

XI. HYDROCARBONS, COAL, MINING ................................................................. 30
XI.1. Hydrocarbon Occurrences/ Assessment ......................................................... 30
XI.2. Hydrocarbon Source Rocks, Oils and Gases ............................................... 41
XI.3. Coal ................................................................. 58
XI.4. Minerals, Mining ............................................................................ 73

This chapter XI of Bibliography 7.0 contains 87 pages with ~545 titles on hydrocarbon occurrences, hydrocarbon source rocks, coal and mineral deposits, primarily of the Indonesian region. It is subdivided into four sub-chapters. Papers in this chapter tend to be of a more general or regional nature; the majority of papers on hydrocarbons, coal and mineral deposits are specific to a region or locality, and are therefore listed in the chapters of areas in which these are located.

Papers date back to the 1860’s, reflecting the early interest of the colonial government and private parties in the economic potential of oil, coal and mineral deposits of Indonesia. Actual mining activity by local and Chinese miners dates back to the 1700-1800’s, especially in the gold, tin and diamond districts of Kalimantan and Sumatra.

XI.1. Hydrocarbon Occurrences/ Assessment

Sub-chapter XI.1 of Bibliography 7.0 contains 117 references on oil and gas, mainly regional papers on plays discovered and undiscovered resources, etc. Papers on hydrocarbons or play elements in a basin, fields or wells are in the chapters in which they are located.

Figure XI.1.1. Discovered oil-gas producing resource of Indonesia- SE Asia (Longley 2005, from IHS).

Indonesia has been a significant oil and gas producer since the first discoveries in North Sumatra and East Java in the late 1800’s. Oil production peaked at around 1.5-1.6 MBO/day from ~1977-1998, and has been declining since then due to limited exploration successes, making Indonesia a net importer of oil since 2004.
Indonesia is still a net gas exporter. An elegant overview of Indonesia's Tertiary basins and petroleum geology is Netherwood (2000).

The presence of oil and gas fields in conventional oil and gas occurrences is controlled by four parameters: source, reservoir, seal and trap. Reservoir rocks, which can be any kind of porous rocks. In the Indonesian region these are predominantly sandstones (non-marine, shallow marine and deep marine), and in shallow marine carbonates, with both primary and secondary porosity. Fractured basement rocks on highs with onlapping source sediments can also be significant reservoirs locally (Sumatra, Vietnam).

A recent technological development is 'unconventional' oil and gas production, from tight source rocks like shale oil, shale gas and coalbed methane. Despite its potential and several exploration projects in Indonesia, it has not led to commercial production yet.

**Oil and gas seeps**

Like in many other parts of the world, oil exploration in Indonesia started with drilling shallow wells on oil seeps, which had been known in various parts of the country (mainly East Java, North and South Sumatra and East Kalimantan) since before the mid-1800's (Junghuhn 1854, De Greve 1865, Von Baumhauer 1869, Link 1952, Thompson et al. 1991).

![Figure XI.1.2. Distribution of oil (green) and gas (red) seeps in the Indonesian region.](image)

Oil and gas seeps tend to be prevalent in two settings (MacGregor 1995):

1. Basin margins, where lateral seals are lacking: Some of these may represent ongoing oil generation; examples include the Iliran/ Palembang High asphalt field in South Sumatra (Ziegler 1922, Holis et al. 2004, Firmansyah, 2007);
2. Above recent faults, particularly reverse faults These mainly represent destruction of underlying oil accumulations in uplifted structures that no longer generate oil, like the Pleistocene inversion structures of Sumatra.

As argued by MacGregor (1995) and others, the presence of hydrocarbon is a good news- bad news story: the good news is that there is an active hydrocarbon system, the bad news is that it is leaking to the surface. Areas with oil-gas seeps therefore may be viewed as areas with a high chance of finding hydrocarbons, but unlikely to contain large fields. Conversely, areas with no seeps may have a lower chance of finding hydrocarbons, but when present fields may be large.

A good example of this principle is in Sumatra: the North and South Sumatra basins have common seeps and numerous small to medium size fields, that were found early in the exploration cycle (late 1800's). The Central Sumatra basin has no surface seeps, but contains the largest oil fields and by far the largest total reserves, which were first discovered relatively late (1940's). (Figure XI.1.3)
Asphalt terranes
Large oil seeps may develop into near-surface tar sands/asphalt terranes. The largest asphalt deposits of Indonesia are in Buton, which have been intermittently exploited since 1925 (Bothe 1928, Hetzel 1936, Ubaghs and Zeylmans van Emmichoven 1947, Satyana 2011, 2013). (Figure XI.1.4). Buton asphalt represents oils sourced from marine bituminous oil shale of the Late Triassic Winto Formation, but has now impregnated overlying limestones and sandstones of the Miocene Tondo and Sampolakosa Formations.

Other examples of asphalt terranes in Indonesia:
- South Sumatra Tanjung Laut/Illiran High, 50 km WNW of Palembang: six asphalt terranes along the Palembang sub-basin margin (Ziegler 1922, Firmansyah et al. 2007);
- West Java Kromong Mountains, ~20 km West of Cirebon: four small deposits of asphalt-impregnated Miocene limestones along faults of an andesite-cored anticlinal structure (Mannhardt 1920, Buning 1922, Harsono Pringgoprawiro et al. 1977).

Figure XI.1.4. Cross-section showing near-surface asphalt impregnation in Miocene rocks in Panah asphalt terrain, Buton (Hetzel 1936).
In Eastern Indonesia onshore oil and gas seeps are known mainly from Seram, Timor, Buton (asphalt deposits), East Sulawesi and the Birds Head of West Papua (Figure XI.1.4.). Many of these can be linked to Late Triassic and Jurassic source rocks.

Surveys of oil slicks to detect offshore hydrocarbon seepage were carried out over several marine basins of Indonesia (Thompson et al. 1991).

Submarine oil and gas seepage was demonstrated recently in deep water basins of East Indonesia, using multibeam bathymetry, backscatter surveys and targeted piston coring programs (Decker et al. 2004, Noble et al. 2009, Orange et al. 2009, etc.). This was then used to high-grade exploration areas.

![Map of Eastern Indonesia showing oil and gas seeps](image)

*Figure XI.1.5. Oil and gas seeps in Eastern Indonesia (Livsey et al. 1992).*
Early history of oil and gas exploration in Indonesia

The earliest oil discoveries in Indonesia were made between 1885-1900 in North and South Sumatra, East Java, Kutai basin, Tarakan and Seram island. Almost all the early wells were on surface anticlines with oil or gas seeps (e.g. Figure XI.1.6).

An overview of the earliest oil industry in Indonesia is by Poley (2000) ‘Eroica- the quest for oil in Indonesia (1850-1898)’ (see also Van Gorsel, 2009). The oil industry in Indonesia started with private entrepreneurs drilling shallow wells around surface oil and gas seeps. The first shallow oil well was drilled in 1871 near Cirebon in Central Java, which established the presence of oil, but never led to production. The first producing oil discovery was in 1884 at Telaga Said, North Sumatra. This was the beginning of the Royal Dutch company in 1890. Shell Transport and Trading discovered oil in East Kalimantan in 1897 (Sanga-Sanga). The first discovery in East Java was the Kuti Field near Surabaya in 1888, followed by discoveries in the Cepu area at Kawengan (1892) and Ledok (1893).

Figure XI.1.6. Example of oil-bearing anticlinal structure: SW-NE cross-section across part of the Kampung Minyak oilfield, S Sumatra (Tobler 1906).

Figure XI.1.7. Early map of West Indonesia oil basins and potential additional prospective areas: predicting oil and gas fields should be present in the Central Sumatra Basin (Molengraaff, 1921).
After the formulation of the anticlinal theory the prime exploration method became the drilling of onshore surface anticlines. In the early 1900s much effort went into surface geology mapping in basinal areas with seeps. Virtually all production before WW II was from shallow depths (<1000m).

In an interesting paper by Molengraaff (1921) it was reported that experience has taught that the majority of large oil-fields originated in long enduring synclines where these are marginal areas of sedimentation along the coasts of continents and showing a map suggesting that Central Sumatra and NW Java basins are the right setting for the occurrence of petroleum (Figure XI.1.7). No oil had been discovered in these basins yet, but these two basins would become some of the most prolific oil and gas basins of Indonesia after the 1940's.

Several of the companies established by the earliest explorationists eventually merged into the Royal Dutch Company for the exploration of oils fields in the Netherlands East Indies. In 1907 'Royal Dutch' merged with Shell Transport and Trading Company to become multinational Royal Dutch/Shell. Its Indonesian subsidiary Nederlandsche Petroleum Maatschappij (BPM) had a near-monopoly in the East Indies and had procuring oil fields in all known productive basins, with refineries in North and South Sumatra, East Java and East Kalimantan.

American operators came to Indonesia in 1912, initially through Netherlands-registered subsidiaries. First was the Nederlandsche Koloniale Petroleum Maatschappij (NKPM), a subsidiary of Standard Oil of New Jersey, which later would become Stanvac (Exxon + Mobil consortium). NKPM first drilled some minor discoveries in East Java between 1913-1916 (Tremboel, Petak, etc.), then became more successful with a string of discoveries in South and Central Sumatra after 1915. Lack of communication between New York headquarters and the Pendopo drill site around Christmas 1921 delayed instructions to stop drilling after the well had drilled through the traditional regressive-Palembang Formation target. This led to the accidental discovery of a deeper sandstone play in the transgressive series and to the largest oil field in the East Indies at that time (Talang Akar- Pendopo; 350 MBO produced). Jirak (1930), Benakat (1932) and other discoveries then firmly established the Americans as the second significant oil company in the Netherlands Indies.

Caltex (Chevron and Texaco consortium) followed in 1931, operating as Nederlandsche Pacific Petroleum Maatschappij (NPPM). Exploration in the Central Sumatra coastal plains lead to two small discoveries in 1940, followed by the shallow giant Duri field in 1941. No commercial production had been established yet in Central Sumatra by the outbreak of WW II. The Minas discovery well (largest oil field in SE Asia) was drilled by Japanese occupation forces in 1944 on a location prepared by NPPM before the invasion.

BPM (Shell) remained the dominant company until World War II (WW-II). Very few new discoveries were made in the NE Java Basin after ~1910, as all obvious surface anticlines had been drilled. However, discoveries in South Sumatra, North Sumatra and E Kalimantan through the 1920s-1930s strengthened their position as the dominant player in the Indies (76% of the country's total production in 1940).

The 1938 BPM Tanjung discovery was the first (and only significant) field discovered in the Barito Basin, SE Kalimantan (Siregar & Sunarjo, 1980). This was also the first oil discovery in Eocene rocks; all earlier discoveries in Indonesia were in Miocene-Pleistocene beds. The 1939 Lirik field discovery by NKPM/Stanvac opened up the prolific Central Sumatra basin.

In New Guinea oil exploration activities had been ongoing since the 1920s in eastern New Guinea (now Papua New Guinea; Wade 1927, APC 1961, Carey 1990), encouraged by common oil and gas seeps there. The NNGPM consortium was formed in 1935 by the Big Three oil companies (BPM, Stanvac and Caltex) to explore the entire western half of New Guinea (then Netherlands New Guinea). The first minor oil discoveries were in the Birds Head, at surface oil seeps at Klamono in 1936 (the deeper reef play here was not discovered until ~1950), followed by oil in anticlinal structures Wasian (1939) and Mogo (1941).

Very little of the geological results of 'Big 3' oil exploration activities before the pre-Japanese invasion were published. Notable exceptions are the publications of Tobler (1906) for South Sumatra petroleum areas near Muara Enim and the Tobler (1913, 1918) reports petroleum-bearing anticlines of the Jambi sub-basin, South Sumatra. Brief summaries on some of the classic oil basins were published long after the main action (Weeda 1958 on East Borneo and East Java, Wennekers 1958 on South Sumatra, etc.).
### Earliest oil-gas discoveries in Indonesia and key references

<table>
<thead>
<tr>
<th>Region</th>
<th>Discoveries</th>
<th>References</th>
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<tbody>
<tr>
<td>East Java (Cepu)</td>
<td>Kawengan-1892, Ledok-1893, Semanggi-1896, Tungkul-1901, etc.</td>
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<td>East Kalimantan (Kutai)</td>
<td>Sanga Sanga-1897</td>
<td>(Jezler 1916, Jefferies, 1980)</td>
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<td>North Sumatra</td>
<td>Telaga Said-1885</td>
<td>(Skeels &amp; Cooper 1985)</td>
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<td>Telaga Said-1885</td>
<td>(Skeels &amp; Cooper 1985)</td>
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<td>South Sumatra</td>
<td>Kampung Minyak-1896</td>
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### Oil-gas discoveries in the late 1960’s- early 1970’s and key references

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<thead>
<tr>
<th>Region</th>
<th>Discoveries</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>NW Java Arjuna basin (ARCO)</td>
<td>Arjuna B-1968 (Scheidecker &amp; Taiclet 1976), E1-1968 + 6 others by 1973</td>
<td></td>
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<tr>
<td>Central Sumatra (Caltex)</td>
<td>Zamrud-1975</td>
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<td>West Natuna (Conoco):</td>
<td>Udang-1974 (Mattes 1979)</td>
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</tbody>
</table>
Oil gas discoveries in new play areas/deeper plays since 1980’s and key references

1. Banggai-Sula Basin, East of Sulawesi Miocene carbonates
2. Madura Straits Miocene carbonate buildups
   - BD-1987 (Kusumastuti et al. 2002), Jeruk-2004 (Santos)
3. Deep water Mahakam Delta/ Makassar Straits Plio-Pleistocene clastics
   - West Seno (Redhead et al. 2000, Guritno et al., 2003, Gallup et al. 2005), Gandang, Maha, etc.
4. Madura Straits Pliocene Globigerina calcarenites (= extension of late 1800s onshore E Java play)
   - MDA, Oyong, Maleo-2002 (Triyana et al. 2007)
5. East Java Pleistocene volcanoclastic turbidites play
6. Deep water Australian NW Shelf (Indonesian and East Timor segments) Middle Jurassic clastics
   - Sunrise-Troubadour (Seggie et al. 2000, 2003)

Deeper plays in established basins:
1. Sumatra- Fractured Basement below traditional Miocene clastics and carbonates play
   - NE Beruk-1976, Central Sumatra (Koning & Darmanto 1984)
   - Sumpal-1994, South Sumatra (Zeliff & Bastian, 2000, Chalik et al., 2004)
2. Bintuni Basin, West Papua- Jurassic sandstones below the Miocene carbonates play
3. NE Java onshore- Oligocene-Early Miocene carbonate buildups below traditional Mio-Pliocene clastics play:
4. Seram- Triassic fractured carbonate play below traditional Plio-Pleistocene clastics play
5. East Java Sea- Eocene carbonates and clastics below traditional Oligocene- Early Miocene carbonate play
Sedimentary basins

Hydrocarbons and coal deposits are intimately associated with sedimentary basins. In the Indonesian region almost all hydrocarbon-bearing basins are of Tertiary age. Mesozoic basins with oil-gas fields only in the greater NW Australia- New Guinea region, and are part of the NW Australian rifted passive margin.

Most basins in Indonesia have now been explored for hydrocarbons, but at different degrees. PND (1996) classified Indonesians by petroleum exploration activity into mature (14), semi-mature (9) and frontier (18) basins.

Figure XI.1.8 Sedimentary basins of Indonesia (Herman Darman (2014, at http://geoseismic-seasia.blogspot.com/).

In the Indonesian region many basins and basin types have been identified (Figures XI.1.8, XI.1.9).

Most oil-gas fields are in Sundaland region of West Indonesia and in the adjacent Malaysian and Thailand waters of the Sunda Shelf. Two main basin types may be distinguished:

1. Sundaland Cenozoic intra-continental rift basins, controlled by the plate-wide extension, starting in early Middle Eocene time (~45 Ma; Pubellier and Morley 2014 or 49 Ma; Morley 2014). These are the most prolific oil basins, due to the happy combination of excellent Eocene- Oligocene lacustrine and deltaic source rocks and Late Miocene - Pleistocene inversion events creating large anticlinal inversion structures.

2. Large Neogene delta systems around the Sundaland margin (Mahakam and Tarakan of East Kalimantan, Baram, Rajang and West Luconia of North Borneo). Some of these deltas may actually prograde over oceanic marginal basin crust. Source, reservoir, seal and structure all formed within the delta system itself.
The oil basins of Sumatra and Java have often been called 'back-arc basins', because of their present-day position behind the modern Sunda volcanic arc. However, their formation and subsidence history can not be tied to subduction-driven back-arc extension, but rather to a plate-wide extension that formed similar mid-Tertiary rift basins away from the arc (e.g. Malay Basin, Natuna basins).

Figure XI.1.9. Sedimentary basins of Indonesia, grouped by discovered oil-gas volumes. Green = >5 Bboe, Light Green = 1-5 Bboe, Yellow = 10-1000 MMboe, Pink = 0-10 MMboe (Doust and Noble 2008).

Finally, access to oil and gas data has been a problem in Indonesia since the start of the oil industry. Vast amounts of surface and subsurface geological and geophysical data have been acquired by the oil industry, but most of this data has stayed in confidential company files and government agency repositories (PND).

Fortunately, after the early 1970's, many petroleum-related publications have appeared in the Proceedings of Annual Conventions of the Indonesian Petroleum Association (IPA).
XI.2. Hydrocarbon Source Rocks, Oils and Gases

This sub-chapter XI.2 of Bibliography 7.0 contains 141 papers on Hydrocarbon source rocks. These are primarily papers of a general or regional nature; many additional papers dealing with source rocks of specific areas are grouped under their area's chapters.

Recent regional review papers on Indonesian source rocks/ petroleum systems include Doust and Sumner (2007), Doust and Noble (2008) and Satyana (2010, 2017).

Effective hydrocarbon source rocks in Indonesia have a patchy, discontinuous distribution, which makes some areas highly prolific, but other large regions non-prospective. Understanding regional source rock distribution is therefore probably the single most important factor in hydrocarbon exploration.

**Thermogenic oil and gas generation**
Commercial hydrocarbon accumulations are all found in sedimentary basins, with hydrocarbons formed from the degradation of organic material, through both thermal (thermogenic) or biological (biogenic, bacterial) breakdown processes. The vast majority of oil and gas can be linked to thermal maturation of organic-rich sediments, typically at depths 3-4 km or more.

The minimum organic content of an efficient source rocks appears to be around TOC of 1-2%. Normal marine shales from oxygenated marine environments do not have TOC's high enough to generate oil or gas. To be an effective oil or gas source higher-than-normal organic matter is required, which usually means low-oxygen seafloor environments. Such conditions may be met in restricted (silled) basins (Salawati basin, Tomori basin), or in areas and at times when an oxygen-minimum zones develops in an oceanic environment (more common in Mesozoic hothouse climates than in Tertiary?).

**Biogenic gas**
Low-temperature biogenic gas forms from bacterial degradation of plant material in lakes, wetlands and swamps. In the shallow subsurface biogenic gas also forms in peat and low-rank coals, and also in deep marine sandstones rich in plant debris (Katz 1995, Subroto et al. 2007, 2009, etc.).

Biogenic gas may form shallow, producable gas accumulations, like in:
- Plio-Pleistocene submarine fan sands of Makassar Straits (Saller et al. 2006);
- Late Miocene- Pliocene calcarenites in Madura Straits (Noble and Henk 1996, 1998, Satyana and Purwaningsih, 2003);
- Miocene carbonates in the Sumatra forearc basins (Dobson et al. 1998);
- East Java Sea Lengo and Mustika wells (Pireno et al. 2016);
- Late Miocene- Pliocene shallow gas in Central Sumatra basin (Yuwono et al. 2010, 2012);
- Plio-Pleistocene clastics of North New Guinea basins (Niengo, Waropen, Ramu; Barrett 1997, 1999);
- Late Miocene shallow carbonates of the Salawati basin (Satyana et al. 2007)
- deep marine turbidites of the Late Pliocene Bengal Fan off Myanmar (Shwe and other fields; Yi et al. 2015).
- most of the gas hydrates in deep water basins (see below).

Biogenic gases are typically >99% methane (CH4) and can generally be distinguished from thermally matured (thermogenic) gas by their 'light' d13C carbon isotope ratios (Satyana et al. 2007).

**Inorganic methane gas**
There is also some evidence for the existence of inorganic methane gas formation, in particular associated with the serpentinization of ultramafic igneous rocks (Satyana 2005). Examples of likely inorganic gas seeps have been described from the Philippines (Abrajano et al. 1888, 1990), and from the Tanjung Api gas seep on the North coast of the East Arm of Sulawesi. At the latter coastal location methane emanates from ultramafic rocks and has unusually heavy d13C isotopes, leading Subroto et al. (2004) to suggest a possible abiogenic origin. Not many other examples of inorganic gas generation have been identified.

Inorganic hydrothermal methane has also been sampled at oceanic spreading centers (e.g. Marianas Trough, Horibe et al. 1987); The latter appear to be associated with high He and CO2.
- **Source rock types and ages**

In the Indonesian region two main petroleum systems are present, which are intimately linked to the two major continental plates, i.e. Eurasia and Australia New Guinea (Figure XI.2.1).

![Regional Petroleum Systems Groups](image)

**Eurasian petroleum systems**

In West Indonesia (and surrounding Sundaland) all oil and gas has been linked to Cenozoic sediments. Two groups and several sub-groups from different tectonic-depositional settings can be distinguished:

1. Paleogene intracontinental rift basin sources: (a) synrift Eocene-Oligocene restricted lacustrine sources, (b) Eocene-Miocene late rift and post-rift coal-bearing fluvio-deltaic formations;
2. Sundaland margin Neogene deltas, mainly around East and North Borneo, sourced mainly from dispersed plant material in fluvio-deltaic deposits and associated delta-derived deep water sediments.

One ‘rule-of thumb’ for source types in the SE Asia Cenozoic suggested by Doust and Lijmbach (1997) was that (1) proximal basins or basin environments are more oil-prone (lacustrine algae), (2) more distal, marine basins and environments have high gas potential and (3) intermediate basins and deltaic environments generate both oil and gas.

**Australasian petroleum systems**

In East Indonesia and adjacent Papua New Guinea and the Australian NW shelf the hydrocarbon system is driven mainly by Jurassic and Cretaceous source rocks, but Tertiary-sourced are present as well.

Jurassic marine shales are believed to source the oils in the Upper Jurassic-Lower Cretaceous reservoirs in the PNG foldbelt. Permian coals were probably the main source for the large gas fields in Bintuni Bay, W Papua. Upper Triassic marine bituminous shales were responsible for the tar sands of Buton, the oil seeps on Timor island, and the small oil fields of NE Seram. These oils may have high sulfur content (Satyana et al. 2013).

Miocene- Pliocene marine shales, probably in tectonically restricted basins, are believed to be the oil source in the Salawati Basin of the Birds Head, West Papua (e.g. Satyana 2009), and the Tomori Basin of East...

Pacific petroleum systems
The third petroleum province of the Howes (2011) refers to the relatively minor and little-studied oil and gas occurrences in the Neogene successor basins of northern New Guinea. Oil and gas seeps are present in the area (e.g. Musu et al. 2015), but no commercial discoveries have been made so far.

Source rocks, and the oils generated from them, can be classified in three main categories: lacustrine (most productive?), fluvio-deltaic /coaly (most common?) and marine (most common in East Indonesia?). (Figure XI.2.2; Robinson 1987).

Lacustrine source rocks
Many of the oils in SE Asia have been tied to lacustrine source rocks. They are source rocks rich in algal material that formed and was preserved in relatively deep lake basins. The algal kerogens are derived mainly from freshwater green algae *Botryococcus* and *Pediastrum* (Sladen 1997, Sefein et al. 2017).

Lacustrine source rocks appear to be the most productive. They are relatively common in the early rift phase of the intra-continental Paleogene basins of Sundaland. In addition to the right tectonic setting this probably also required a humid-warm climate. They tend to produce light, waxy oils, at relatively early stages of maturation. Wax content of lacustrine-sourced oils of Malaysia- West Indonesia varies from 10-35%, up to 45%.

Late Eocene lacustrine shale deposits sourced most of the oils in the Central Sumatra Basin (Pematang Formation Brown Shale), and probably in many of the Cenozoic rift basins of Malaysia and Thailand. They can be observed in outcrop in the Ombilin Basin of Central Sumatra. Lacustrine shales were also encountered in wells in the Middle-Late Eocene of wells in South Makassar Straits.
**Coal source rocks**

Before the mid-1980’s conventional wisdom held that coals were a good source of hydrocarbon gas, but did not generate oil. Now it is accepted that in the Cenozoic basins of tropical SE Asia fluvio-deltaic coals and coaly clastics can also generate oil, but probably only under specific conditions (MacGregor 1994, Thompson et al. 1994).

Only liptinite-rich coals (>15-20% of total macerals) appear capable of generating significant amounts of liquid hydrocarbons, while vitrinite-rich coals are gas-prone source rocks (Teerman and Hwang 1989).

Oils generated from SE Asian Cenozoic coals may be primarily from the waxy cuticles of leaves. This is a common feature in plants from brackish-water (mangrove) environments, so coals and associated coaly mudrocks from paralic, brackish water settings may have a higher content of oil-prone kerogens (Brown 1989, Thompson et al. 1994, Todd et al. 1997, Saller et al. 2006).

**Biomarkers**

Certain organic chemical components in oils or source rocks can be traced to plants or animals ('molecular fossils' or reflect particular depositional settings. These are called 'biomarkers' and can be a powerful tool in the interpretation of the origin of oils, correlations to source rocks, depositional environment and maturity.

A recent review of the use of biomarkers in Indonesia is Satyana (2016). Additional references are listed in the table below.

Biomarkers are generally identified from Gas Chromatogram/ Mass Spectrometer (GC/MS) diagrams. In biodegraded oils this method becomes more difficult, as biomarker peaks are highly suppressed.

Biomarker interpretation is a specialist field. A brief selection of commonly used biomarker indicators in oil-source rock interpretation:

1. Pristane- Phytane ratio. The Pr/Ph ratio is used used an indicator of depositional environment: ratios can be very high (> 3) in coal-sourced oils, low ratios (<2) indicate marine sources, very low ratios (<1) reducing depositional environments if.

2. Sterols that have been tied to organisms: C28 dominates in phytoplankton (green algae and diatoms), C27 in zooplankton and red algae, C29 is common in higher land plants and certain algae. A dominance of C27 steranes is almost always associated with marine organisms.

3. Oleanane is identified from the 18B(H) peak on mass chromatograms and is believed to derive from angiosperm flowering land plants. These evolved sometime in the Late Cretaceous, so its presence is commonly used to identify Late Cretaceous and younger oils. However, absence of oleanane needs to be used with caution. It does not always mean pre-Late Cretaceous age of source rocks, but may reflect absence of land-derived plant material in marine facies (e.g. some Salawati basin oils are of Neogene, but have no without oleanane (PT Robertson Utama 2000, etc.). Also, not all Cenozoic terrestrial organic facies rocks in SE Asia contain oleanane (Murray et al. 1997).

4. Gammaceranes peaks (between C31 and C32 peaks on chromatograms) are often linked to high salinities, or to stratified water columns.

**Carbon Isotopes**

Carbon d13C isotopes have been used to differentiate between oils of marine versus non-marine origins, Organic matter form marine rocks is isotopically heavy (d13C from -19 to -23 ‰), while terrestrial organic matter is light (d13C from -24 to -31 ‰). However, interpretations are not always straightforward (Williams and Williams 1994).

**High-CO2 gases**

CO2 is a common component of hydrocarbon gases in Indonesia. It reduces the caloric value of the gas and is a greenhouse pollutant when released into the atmosphere. CO2 can originate from multiple sources, i.e. from the mantle, volcanic degassing, thermal breakdown/ metamorphism of carbonate (carbonate metamorphism), high maturation of organic material, etc..

Examples of high-CO2 gas in the Indonesian region:

1. East Natuna basin: in large Natuna D-Alpha carbonate buildup gas field has 67-82% CO2, possibly from degradation of carbonate (Cooper et al. 1997);
2. North Sumatra: gases in North Sumatra commonly have 20-30% CO2 (NSB area, Kuala Langsa, etc.), all presumably from thermal breakdown of deep carbonate formations. The highest CO2 is in areas underlain by Tampur dolomite (McArthur and Helm 1982, Caughey and Wahyudi 1993).
3. South Sumatra: locally >40% CO2 in gases from the Corridor Block; partly inorganic / (Suklis et al. 2003);
4. onshore West Java: several wells with >50% CO2 (Cooper et al. 1997);
5. onshore NE Java Basin: Cepu area with gases up to 25-78% CO2 (Satyana et al. 2007);
6. East Java Sea around Bawean Arch: wells with 75-85% CO2 gas, possibly related to volcanic degassing (Satyana et al. 2007).

**Gas hydrates**
Gas hydrates, also known as 'clathrates', are layers of 'frozen' gas deposits, that occur in sediments in many deep water areas, mainly in water depths over 600-1000m and between ~200-700 meters below the seafloor. Whilst they are usually buried in sediments not far below the seafloor, they may also be found exposed on the seafloor of (e.g. South China Sea at water depth of 1130m; Zhang et al. 2017).

Gas stored in hydrates represent enormous gas volumes, but exploitation has not yet been technically and commercially viable.

The base of the Gas hydrates stability zone is often identified on seismic lines as a 'Bottom Simulating Seismic Reflector' (BSR). This is a commonly bright reflector that runs parallel to the sea floor, but often cuts across sedimentary bedding.

Most of the gas in hydrates is >99 % methane and appears to be of biogenic origin, formed from microbial breakdown of detrital plant material at shallow depths. This is especially likely where BSR's cover very large areas. In some cases hydrates contain heavier hydrocarbon gases, of probable thermogenic origin from deeper horizons. Such thermogenic hydrates are more likely where BSR's are limited to areas over anticlinal structures, that focused gas seepage to the seafloor.

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In the Indonesia/ SE Asia region region gas hydrates have been identified in numerous deep water areas:
- Java- Sumatra forearc region (Kopp 2002, Bahar et al. 2005);
- Makassar Straits (Jackson 2004a, b, Sassen and Curiale 2006, Zhang and Wright 2017);
- offshore NW Borneo (Behain 2005);
- Celebes Sea off N Sulawesi (Delisle et al. 1998, Neben et al. 1998);
- Andaman Sea (Chopra 1985, Satyavani et al. 2008, 2014, Rose et al. 2014);
- offshore Seram (Hardjono et al. 1998);
- Ara Trough (Priyanto et al. 2015);
- South China Sea (He et al. 2009, Zhang et al. 2017);
- Timor Sea (McKirdy and Cook 1980),
- Rakhine Basin off Myanmar (Mann et al. 2017);
- SW Pacific, etc.

Gas hydrates are stable only in a narrow range of (low) Temperature and Pressure. Bottom Simulating Reflectors (BSR) can therefore be a useful tool to calculate temperature gradient/ heat flow if water depth, bottom water temperature and depth below seafloor are known (deep BSR's indicate low geothermal gradients) (Delisle et al. 1998, Hardjono et al. 1998, Courel et al. 2011, Shankar and Riedel 2013, 2014, Priyanto et al. 2015, etc.).
Some suggested reading - Hydrocarbons and Source (a selective listing of significant papers)

History of Discovery: Pertamina 1986, Poley 2000


Gas geochemistry: Satyana et al. 2007, Subroto et al. 2007


XI.3. Coal

The 152 references in sub-chapter XI.3 of Bibliography 7.0 on coal deposits are primarily papers of a general or regional nature. There are many more papers on coal deposits from certain areas, but these are in the chapters on the areas in which they are located. A major, recent review of the history of coal exploration and production in Indonesia is by Friederich and van Leeuwen (2017).

A number of papers in this chapter discuss recent exploration projects for coalbed methane gas, in South Sumatra and Kalimantan. Many of these projects have been in low-rank coals with biogenic gas. Although most authors agree on its potential, there are no plans for commercial development yet (Hadianto 2000, Stevens and Sani 2001, Hadianto and Stevens 2005, Lalean 2010, Moore 2010, 2011, Susilawati et al. 2013, Harrington 2016, etc.)

Also included are a series of papers on depositional environments of coals, i.e. the peat swamps of Borneo and Sumatra. Modern peat swamps are found mainly within ± 10° of the Equator, commonly in coastal plain settings, with a humid climate and clays substrates that enable ever-wet conditions (e.g. Page et al. 2006, 2012, Morley 2013).

Coal is an important commodity for Indonesia and occurs primarily in Tertiary deposits. The most significant coal deposits of SE Asia are in the Middle-Late Miocene of southern Sundaland (Borneo, Sumatra; Figure XI.3.1), followed by Eocene coals from the same regions.

![Figure XI.3.1. Principal Cenozoic coal-bearing basins in Indonesia (from Bowe and Moore 2015).](image)

Coal mining started in the mid-1800's in SE Kalimantan (Pengaron; Figure XI.3.2.) and West Sumatra (Ombilin). The mines were operated by the Netherlands East Indies government as a strategic resource to fuel steamships in the region, to reduce dependence on coal that until then was imported mainly from Wales and Australia.
Initially only the higher-grade coals were of interest, i.e. the Eocene-age coals of the Barito basin and Pulau Laut (SE Kalimantan), Eocene coals in the Ombilin basin (West Sumatra), as well as some Miocene coals of the Kutai Basin (East Kalimantan) and Middle-Late Miocene coals around andesite intrusions at Bukit Asam (SE Sumatra) and the Bengkulu Basin (SW Sumatra), the grade of which was locally thermally-enhanced by Late Neogene andesitic intrusions.

From 1941 to the 1980’s coal production in Indonesia was minimal (e.g. 0.2 Million Tons in 1972), partly driven by the global shift away from coal to oil in running ships and power plants. Since the 1980’s the thicker, but lower rank M-L Miocene coals (closer to lignites) have become attractive and numerous open pit mines are currently active in the in the Barito and Pasir Basins of SE and East Kalimantan).

**Historic coal mining developments**

The first coal mine in Indonesia is the underground Oranje Nassau mine near the Riam Kiwa River at Pengaron, in the Barito Basin, SE Kalimantan. It opened in 1849, but closed in 1884 (Figure XI.3.2).

![Figure XI.3.2. W-E cross-section across Pengaron coal mine in Eocene coal, Barito Basin, SE Kalimantan (Hooze, 1893). This government-operated mine was the first and one of very few underground coal mines in Indonesia.](image)

There is still active coal mining in this part of the Barito Basin, in both Eocene and Middle Miocene deposits, but it is all in open pit mining.

Another old underground coal mine development that is still ongoing is the Ombilin mine complex at Sawahlunto, in the Ombilin intermontane rift basin, NE of Padang, West Sumatra (Figure XI.3.3). This coalfield was first discovered in 1868 and its geology was described in detail by Verbeek (1875). Initial reserves estimates were about 200 million tons.

Mining started in 1892, by the Netherlands Indies colonial government, and the Ombilin mines have been in continuous government-operated production since then. Coal is produced from three major seams (A,B,C; 1-5m thick) in the Eocene Sawahlunto Formation. Coal is also produced from the Poro Member of the overlying Oligocene- Early Miocene Sawah tambang Formation.
The Eocene Ombilin coal beds are mainly composed of vitrinite (av. 90%), with minor liptinite (av. 6%), inertinite (av. 2%) and minerals (av. 1% clay, pyrite). Most coals in the area are thermally unaltered coal with vitrinite reflectances of 0.55-0.77% (sub-bituminous- high volatile bituminous rank). Some coals near igneous intrusions are of higher grade, with Vr of 3.4-4.7% (anthracite) (Santoso and Daulay 2005).

The third long-running, government operated coal mine is in the Lematang/Tanjung coal fields of South Sumatra, which started with the Bukit Asam coal mine South of Muara Enim in 1916, and is still operational today. A good recent review of coal distribution and characteristics in the Muara Enim area is by Sanusi et al. (2014). Coals are found in the Middle- Late Miocene Middle Palembang Formation (= Muara Enim Fm), which is ~700m thick and contains ~90m coal in 11-12 horizons (Mannhardt 1921, Ziegler 1921, Schurmann 1922).

The four main coal horizons are, from old to young: Merapi (D; 8-10m), Petai (C; 5-8m), Suban (B; 7-10m) and Mangus (A; 14-22m). Thinner coals are found above and below these horizons. Coals are composed of wood (incl. palm), amber, leaves and cuticles, fungi and pyrite. In coal petrographic terms Bukit Asam coal is composed of vitrinite (88-91%), liptinite (4.2-5.0%), inertinite (4.1-5.5%) and mineral matter (mainly clay, quartz and minor pyrite (Pujobroto 1997, Amijaya 2006).

Most coals are of relatively low rank (sub-bituminous; Rv 0.35-0.45%), but were locally altered to high-grade anthracite (Rv ~2.0%) around Pleistocene andesite intrusions and sills at Bukit Asam (Hirschi 1916, Mukherjee 1935, Iskandar 1994, Pujobroto 1997).

Smaller coal occurrences
On Java thin Eocene, Oligocene and Early- Middle Miocene coal beds are known from multiple localities in West Java (Eocene of Bayau and Gunung Walat, Cimandiri, Late Miocene of Bojongmanik etc.), Central Java (Nanggulan Eocene) and NE Java (Middle Miocene Ngrayong Fm), but except for small-scale native diggings, none of these coals have been mined commercially.

Other similar non-commercial coal deposits, some with local-use exploitation, are known from SW Sulawesi and the Melawai Basin (NW Kalimantan).

No commercial coal deposits are known from Eastern Indonesia. Thin Miocene- Pliocene coals are present in the North New Guinea, Salawati and Bintuni basins of West Papua, the latter in the appropriately named ‘Sleenkool Formation’.

Mesozoic coals are rare in Indonesia. Thin Middle Jurassic coals are present in wells in the Bintuni Basin, West Papua, and in outcrops of the Early- Middle Jurassic Bobong Formation on Taliabu, Sula Islands (Kusnama et al. 2007, Kusnama 2008).

Permian coals are important economically in Eastern Australia ( Bowen Basin, etc.), but in Indonesia only thin Permian coals are found in West Papua (outcrops and wells in the Birds Head and West part of the Central Range) and South Sumatra (West Jambi Basin Mengkarang Fm), These are of limited or no commercial value.
**Coal depositional environments**

Coal deposits started out as peat, which can be deposited, in a variety of paralic sub-environments, Peat forms only where the production of organic plant material exceeds the rate of decomposition of plant organic matter by oxidation, fungii, bacteria, etc.. Normal tropical soils are poor in organic matter, because of rapid oxidation rates in high temperatures.

Preservation of peat biomass therefore requires an oxygen-deficient environment, which means permanent saturation by water. In tropical SE Asia three types of peat accumulations may be distinguished:

1. **'Basin peat'** (= 'topogeneous peat', 'low peat'). Forms in poorly-drained low-lying areas with stagnant water, such as swamps or mires. These peats are relatively vulnerable to clastic influx and mineralization from fluvial flooding events;
2. **'Domed peat'** (= ombrogenous peat', ombrothrophic peat, 'high peat', etc.). Domed peat-accumulations may form on higher ground as raised peat bogs above impermeable soils, in coastal and inland regions, and are relatively low in ash and sulfur. This requires a humid climate of high year-round precipitation;
3. **Detrital peat**: reworked peat beds and eroded peat deposits form up to 2.5m thick detrital peat accumulations as high-tide beach ridges along the Mahakam delta front (Allen 1985, Allen and Chambers 1998, Gastaldo, Allen and Huc 1993).

The formation of peat/coal therefore requires (or is facilitated by) a number of conditions, including:
- geographic setting (fluvial floodplain/upper delta plain);
- permanently humid climate, with no significant dry seasons;
- sufficiently prolific vegetation;
- rate of rise in groundwater table ('transgressive', increase in accommodation).

![Figure XI.3.4. Distribution of peatlands in SE Asia (after Rieley et al., 1996 in Wust et al. 2007).](image)

Many of the fluvial-coastal plains of Indonesia/SE Asia are home to vast peat-covered lands (Figure XI.3.4). Most modern lowland peat deposits here are all very young, starting formation in the mid-Holocene (~5500 years BP), when sea level was at a maximum and vast areas of the coastal plain were flooded, after stabilisation of the rapid sea level following the Last Glacial Maximum lowstand. Many of the coastal peat deposits of Indonesia started off as mangrove swamps and were replaced by freshwater swamp forests as shorelines prograded (e.g. Wust et al. 2007).

In Sarawak today's peat depositional systems are up to 11,400 km² in area, while individual peat deposits are >20m thick and 1000 km² in area. A typical succession shows basal high-ash, high-sulfur, degraded peats, that are overlain by low-ash, low-sulfur, well preserved peats (Esterle and Ferm 1994, Staub and Esterle 1994; Figure XI.3.5).
Figure XI.3.5. Typical profile across a domed peat deposit, Baram River, Sarawak, showing upward-decreasing ash and sulfur contents (Esterle and Ferm 1994 in Friederich et al. 2009).

Peat-to-coal compaction
Peat deposits will be reduced to 10% of the original peat thickness when compacted to mature, bituminous coal. Holocene peat deposits in Indonesia tend to be only up to ~20m thick, but some Miocene coal beds can be 90m thick. Such thick coal beds are therefore likely composed of multiple, stacked cycles of paleo-peat mire deposits (Shearer et al. 1994).

Coal distribution in time, paleoclimate
Widespread coals obviously reflect widespread freshwater and brackish water peat deposition. In addition to geographic setting climate probably also has an important role in coal formation.

In the Cenozoic basins of Western Indonesia significant coal deposits appear to be concentrated in two or three periods of globally warm climate periods (e.g. Morley 2013):
1. Middle- Late Eocene (Tanjung Fm of Barito and Asem Asem basins, Sawahlunto Fm of West Sumatra, Ngimbang Fm in NE Java Basin, Nanggulan Fm in Central Java, Bayah Formation in SW Java, Silantek Fm in SW Sarawak?);
2. Middle- Late Miocene: Warukin Fm of Barito Basin, Balikpapan Fm of Mahakam delta system, Middle Palembang Fm of South Sumatra, etc.).

Probably the third most significant period for coal development was in the latest Oligocene (-Early Miocene?), although these appear to be of limited commercial significance:
- Sihapas and Talang Akar Formations of Central and South Sumatra;
- Cibulakan/ Cimandiri Formations of West Java.

These periods all correspond to globally warm climate periods, and that are probably associated with high eustatic sea levels (e.g. Morley 2013). Intervening cooler periods probably had more seasonal climates with distinct dry seasons that probably 'killed' significant peat development.
**Coal stacking patterns**
Not much has been published on the sequence stratigraphic significance and stacking patterns of coal beds in Indonesia. While small coal deposits may be expected anywhere in an alluvial or coastal plain setting, laterally extensive, stacked coal beds probably always signify an overall transgressive setting (mid-late lowstand wedge and early-middle highstand time in the model of Bohacs and Suter, 1997; Figure XI.3.6).

![Figure XI.3.6. Distribution of coal beds in a sequence stratigraphic model (Bohacs and Suter, 1997)](image)

Interestingly, a transgressive stacking pattern was already described almost 100 years ago in the Middle-Late Miocene Middle Palembang Formation of South Sumatra (Hartmann 1921, Figure XI.3.7).

![Figure XI.3.7. W-E Diagrammatic cross-section across part of South Sumatra, showing 'transgressive backstepping' of Middle Palembang Formation coals (Hartmann, 1921)](image)
Some suggested reading: Coal (not a complete listing of significant papers)


XI.4. Minerals, Mining

This sub-chapter XI.4 of Bibliography 7.0 lists 137 papers on mineral deposits that are of a general or regional nature. As for the previous chapters on hydrocarbons and coal, the vast majority of papers on economic mineral deposits is on individual occurrences, and can be found in the chapters on the areas in which they are located. A metallogenic map of Indonesia was published by the Geological Survey (Harahap and Abidin 2013).

Mineral deposits are generally closely related to magmatic-tectonic events. Westerveld (1939, 1949) characterized the metal ore occurrences in Indonesia as 3 or 4 main provinces:
1. Tin mineralization of Bangka and Billiton islands, associated with Triassic granites;
2. Gold-silver mineralization on Sumatra and Java, associated with Cretaceous and post-Miocene intrusives

**Gold, silver, copper**

Primary gold-silver-copper deposits in SE Asia are all related to magmatic-volcanic arcs, most of them of Late Tertiary age, The SE Asia-West Pacific contains >160 deposits, including porphyry, skarn, epithermal, volcanic-associated massive sulfide, disseminated sediment-hosted and other mineralization styles (Garwin 2013).

Not all magmatic arcs contain significant mineralization. Some authors suggested that most gold-copper deposits did not form during steady-state subduction, but during episodes of tectonic reorganization like subduction reversal (e.g. Solomon 1990, Barley et al. 2002).

Figure XI.4.1. Major and minor gold-copper deposits in the Indonesian region, all associated with Neogene magmatic arcs (pink) and orogenic belts with significant Neogene magmatism (purple). (Garwin 2013).

**Tin**

Numerous papers have been published on the tin deposits of the Indonesian 'Tin Islands Bangka, Belitung and others, dating back to the 1800's. The tin deposits in Indonesia are part of the SE Asia tin belt that stretches from Myanmar through West Thailand, the Malay Peninsula to the Indonesian tin islands (Bangka, Belitung, Singkep, possibly extending into western Kalimantan).

Primary tin deposits are around 'post-collisionsal tin granites' with Sn-W-Sb minerals, that formed during excessive thickening of continental crust after collision of two continental plates.
The SE Asia tin-bearing granitoid belt is actually composed of two parallel belts of granites in the Malay Peninsula and western Thailand (Hutchison 1983, Pittfield 1987, Schwartz et al. 1995):
1. Eastern belt and Main Range of Late Triassic (- Early Jurassic?; mainly 220-200 Ma) granites that formed during or shortly after the Late Triassic closing of the Paleotethys suture, extending from Thailand through the Malay Peninsula to the Indonesian Tin islands Singkep, Bangka and Belitung;
2. Western belt of Late Cretaceous tin-bearing granites in northern Peninsular and West Thailand and Myanmar, probably extending into North Sumatra (~80 Ma Hatapang granite; Hamidsyah and Clarke 1982, Johari 1988).

Primary tin deposits of the Tin islands occur as cassiterite-bearing hydrothermal veins in and around Late Triassic granite plutons. Veins are usually in country rocks of isoclinally folded, steeply dipping Perman-Triassic metaclastics with radiolarite beds of the Pemali Group. Only a few of these primary vein systems were mined commercially on Bangka island:
- Kelapa Kampit mine, Belitung, was intermittently active since 1908 and reached a depth of almost 300m subsea (Groothoff 1916, Meyer 1975, Adam 1960);
- Pemali mine at the SE side of the Klabath batholith (Akkersdijk 1932, Wisoko 1981, Ko 1984, Ruswandi 1988, Schwartz and Surjono 1991);

Exploitation of tin (cassiterite) on Bangka, Belitung and Singkep islands and surrounding offshore areas has been ongoing since the early 1700's, with >95% of extracted tin coming from onshore and offshore Quaternary placer deposits that formed from chemical weathering and erosion of granite and surrounding mineralized rocks. Economic cassiterite placers appear to be limited to an area within 15 km from the contacts with granitic mother rocks, with the largest number of known tin placers ~5-12 km from granites (Kanayama 1973). These deposits are now largely depleted (Figure XI.4.2).

![Figure XI.4.2. NW-SE cross-section from Singkep- Cebia to Bangka island, showing steeply dipping Permo-Triassic metasediments, intruded by Late Triassic granitoids, overlain by thin Miocene sediments and a Pleistocene Alluvial Complex of 30-45m deep tin-bearing incised valleys and very thin Late Quaternary sediment cover (Aleva, 1973).](image)

Tin is also present outside the traditional Tin islands off East Sumatra, presumably related to the same belt of Triassic- Early Jurassic tin granites:
1. East Sumatra presence of Late Triassic granites and tin placer deposits (Bukit Batu, Sungai Isahan, Tigapuluh Mountains, Siak area, etc.; Neeb 1902, Brouwer 1915, Van Es 1930, Harahap and Harmanto 1987, Schwartz and Surjono 1990, etc.). Many of the alluvial tin placer deposits in the Siak area were exploited in the 1700's-1800's by local and Chinese miners (Everwijn 1867, Rolker 1891), but were already largely depleted by 1900 (Neeb 1902).
**Diamonds**

Diamonds have been mined for centuries, from four widely separated districts across Kalimantan and SW Sarawak (Figure XI.4.3). The name Kalimantan is supposed to come from 'Kali Mas Intan', meaning 'rivers of gold and diamonds'. A recent review of the 'Sundaland diamonds' is by Van Leeuwen (2014).

Gascuel (1901) reported that the Borneo diamond mining industry was already in serious decline over 100 years ago, but there is still ongoing diamond mining activity in the Martapura area of SE Kalimantan today.

All mining has been in small-scale operations by local and Chinese miners, from is in Quaternary fluvial-alluvial deposits (Halewijn 1838, Schultz 1843, Croockewit 1852, Posewitz 1885, Hooze 1893, Wing Easton 1894, 1895, Doorman 1906).

![Figure XI.4.3. Alluvial 'diamond fields' are relatively widespread in Kalimantan and SW Sarawak (Posewitz ?).](image)

The widespread distribution of diamond-bearing Quaternary river terraces all over Kalimantan and SW Sarawak does not clearly point to any source rocks from which they have been eroded. Diamonds have also been observed in Upper Cretaceous and Eocene sediments of SE Kalimantan, and their generally abraded nature suggests they may have gone through multiple cycles of erosion and redeposition (Hovig 1930).

Possibly related but apparently less common diamond occurrences have been described from East Sumatra (SW of Pakanbaru; ‘T Hoen 1931) and from West Thailand and Myanmar (Figure XI.4.4). In the latter areas they are spatially associated with Carboniferous-Permian glacial pebbly mudstones of the Phuket series on the Sibumasu Block, which were deposited along the NW Australia/ Gondwana margin (Aranyakanon 1955, Garson et al. 1975, Wathanakul et al. 1998, Griffin et al. 2001).
Figure XI.4.4. Alluvial diamond occurrences (yellow) in Kalimantan, Sumatra and SE Asia. Also showing 'Sibumasu' Late Carboniferous- Early Permian glacio-marine deposits (blue) (Van Leeuwen 2014).

Re/Os age dating of sulphide inclusions from one Kalimantan diamond gave an Archean crystallization age of 3100 Ma (Smith et al. 2009).

There has been much debate on the origin of the Kalimantan diamonds (see references in Table below, and Bibliography), including the ultramafic rocks of the Meratus Range, the kimberlite-like Pamali breccia in the Meratus Range (Koolhoven 1935), etc., but none of these are still accepted.

One likely scenario, as suggested by Griffin et al. (2001), is that the diamonds from Kalimantan, East Sumatra and West Thailand all originated from Paleozoic or older igneous rocks in Northern Australia and arrived in Sundaland by tectonic transport and sediment redistribution. They were initially eroded and redeposited in Carboniferous-Permian glacial deposits in rifts along the NW Australian margin, which were then transported with the Sibumasu Block to the Asian margin in Permian-Triassic time, and subsequently re-eroded and redeposited in the Kalimantan region as early as early Late Cretaceous.

If the Kalimantan diamonds did indeed transit through an intermediate detrital stage in Late Paleozoic Sibumasu terrane sediments, this would have interesting plate tectonic implications. The Cretaceous-Recent sandstones of Kalimantan and Central Sumatra would have been eroded from 'Sibumasu' basement, and parts of Kalimantan could be underlain by or bordered by an extension of the Sibumasu Terrane. This may require modification of some of the prevalent recent plate reconstruction scenarios for the amalgamation of the Borneo region (e.g. Metcalfe, Hall).

**Nickel, chromium, cobalt**

Nickel and chromium are widely disseminated in ultramafic (mantle) rocks, but commercial deposits require concentration of ore minerals in weathered lateritic zones. They are currently mined in the ophiolites of East Sulawesi and Halmahera; the Soroako mine in East Sulawesi has been operational since 1977. Small scale chromite mining took place in Gebe in the 1970's.

Lateritic nickel-chromite deposits are known from ophiolite outcrop regions in (Sopaheluwakan 1985, Ernowo and Oktaviani, 2010):
1. East Sulawesi: several areas in the East Sulawesi Ophiolite terrane, including Kabaena Island. Initially explored in colonial time (Adam 1922, Dieckmann and Julius 1925). Commercial nickel exploitation in the Matano area by PT INCO since the early 1970's (Golightly et al. 1979, Rafianto and Tutuko 2010).

2. Cyclops Mountains of NE part of West Papua (Ubaghs 1955).


4. Waigeo Island, West Papua

**Other minerals**

Iron ore deposits are relatively widespread in Sumatra and Kalimantan, but have been little explored or exploited (Subandrio 2014). Potential iron deposits include:

- iron (magnetite) sands of South Java;
- lateritic iron ores associated with ultramafic rocks in Eastern Indonesia and SE Kalimantan (Dieckmann 1922, Gisolf 1924, 1928, 'T Hoen 1924, Swamidharma 2015)
- epithermal magnetite-hematite mineralization around granites in South Sumatra and Central Sulawesi (Hovig 1917, 1918, Utoyo 2008);
- 'banded iron ore' in metamorphic rocks of Sumatra (Subullussallam, Tanggamus) and SW Kalimantan (Kendawangan) (Elbert 1909, Subandrio and Tabri 2006, Subandrio 2007, 2014).

Relatively small uranium prospects are known from Tertiary sediments in North Sumatra (Koesoemadinata and Sastrawiharjo 1988, adjacent to Triassic granite) and in veins associated with Upper Cretaceous Sukadana Granite in Central Kalimantan (Subiantoro et al. 2003). No commercial uranium mines have ever been operational in the Indonesian region.

Small-scale manganese mining has taken place along the Southern Mountains of Java (presumably in weathering zones of Early Miocene andesitic volcanics; Fermin 1951; Figure XI.4.5).

![Figure XI.4.5. Manganese ore localities (triangles) across the Southern Mountains of Java (Fermin 1951).](image)

Another interesting recent small-scale manganese mining development is in Cretaceous oceanic pelagic deposits in SW Timor. Manganese occurs both as small nodules and as thin MnO layers, which may be fueled by nearby ocean floor hydrothermal vents (Idrus et al. 2012, 2013).

Noteworthy concentrations of Rare Earth Elements (REE) have been documented in various granites of the tin islands, West Kalimantan, Sulawesi, etc. (Setijadji 2014, Syaeful et al. 2014, Aryanto and Kamiludin 2016, Setiawan 2018). Commercial exploitation targets would probably require concentrations in lateritic weathering deposits and associated placers. There is no commercial REE exploitation yet.
Some suggested reading: Mineral deposits (not a complete listing of all significant papers)

General reviews

Gold, tectonic controls

Tin

Nickel, chromite

Diamonds
XI. HYDROCARBONS, COAL, MINING

XI.1. Hydrocarbon Occurrences/Assessment

(Additional references on hydrocarbons/fields that are specific to one region are listed under these regions)

(Only 5% of Indonesia current oil production from E Indonesia, but higher potential)

(Stratigraphic traps require charged petroleum system, favourable basin and reservoir architectures, low dips and good seal integrity. Paleogene rift basins: syn-rift source and reservoir sands; 'early post-rift' phase with better quality reservoir sandstones and reef carbonates; 'late post rift' transgression with marine shale regional seal. Late Tertiary 'orogenic' phases trigger migration up flanks and create structures at shallower levels. Potential for large reserves in stratigraphic traps. Unexplored basins in Asahan Offshore PSC, N Sumatra and Biliton PSC, W Java discussed)

(Review of oil and gas fields and seeps in Tertiary of Myanmar. Descriptions of gas fields Yenangyaung, Singu, Lanywa, Yenangyat-Yethaya, Minbu-Palanyon, Indaw, etc.)


(78 oil-gas fields in 12 basins with reserves and production data to end 1972)


(Eight basin areas, peripheral to Sunda Shield exhibit general continuity of Tertiary sedimentary cycles, but each basin unique structural, stratigraphic and temperature gradient character, reflecting its individual plate tectonic setting. With examples of Tertiary depositional cycles and hydrocarbon occurrences from E Java Sea and NW Palawan)

(Papers and papers and discussions from seminar held in Lexington, May 1967)

(Oil producing areas in Netherlands Indies in 'geosynclinal areas' of Tertiary sediments, that were subsequently folded)


Cockcroft, P.J. & K. Robinson (1988)- Chemistry of oilfield waters in South East Asia and their application to petroleum exploration. Proc. SE Asia Petroleum Expl. Soc. (SEAPEX) 8, p. 221-238. (Most subsurface formation waters in SE Asia fresh-brackish and range from meteoric bicarbonate to connate chloride-calcium waters. Predominance of fresh waters may be related to depositional environment and relatively young age of sediments which are typically undergoing compaction and dewatering)


('Chance and challenge of old oil fields in Indonesia'. Listing of early 1900's oil fields in N, C and S Sumatra (12+6+35), Java- Madura (33), Kalimantan (11) and West Papua (8) with potential for redevelopment. With cumulative production, number of wells and year of abandonment)


('Petroleum and its occurrence in Netherlands Indies'. Very early paper on petroleum occurrences and surface seeps in Netherlands Indies, and description of oil samples in now defunct 'Colonial Museum' in Haarlem. All seeps on Java N of volcanic arc (except one in Banyumas), and not related to volcanism. Most seeps in sandstone beds of Lower Tertiary and commonly associated with gas seeps, mud volcanoes and salt water wells. Listing of seeps in West Java (Priangan, Cirebon), C Java (Semarang, Rembang, Banyumas, Madiun, Solo), East Java (Surabaya, Madura, Pasaruan, Kediri). Also in Sumatra (Palembang), Kalimantan (SE), Sulawesi (Manado) and East Seram. No maps, figures)


(online at: https://babel.hathitrust.org/cgi/pt?id=coo.31924081565537;view=1up;seq=279)

('History of the petroleum industry on Java'. Brief history of petroleum exploration on Java-Madura since. With total production figures from 300 to 33,625 tons in 1890-1918)


('Rocks and minerals from Netherlands East Indies- 4: petroleum'. Early, popular review of occurrence and properties of petroleum in Indonesia)


('The petroleum industry, in particular that of Netherlands East Indies: overview modified for holders of petroleum shares')


(Abbreviated version of Fletcher and Soeparjadi (1976) paper in SEAPEX Conference)


(online at: http://www.searchanddiscovery.com/documents/2008/08119gunawan/images/gunawan)

(Overview of old and new plays in Indonesian basins)


Ibrahim, A., N. Pudyo, A. Satyana & S. Saputra (2006)- Exploration hot zones in Kalimantan and Eastern Indonesia: a two decade review. Proc. SEG Ann. Meeting, New Orleans 2006, p. 1-5. (Extended Abstract) (>160 exploration wells drilled in last two decades with success ratio of 41% and discovered in place reserves of 6 BBOE. Most attractive plays are Jurassic Roabiba-Plover Play system (Tangguh, Abadi gas fields), Jurassic carbonates (Oseil), and Miocene carbonate in collision zone (Tomori))


Junghuhn, F. (1865)- Brief gerigt aan Zijne Excellentie den Gouverneur-Generaal van Ned. Indie omtrent de exploitatie van aardolie op Java. Tijdschrift Nijverheid Landbouw in Nederlandsch-Indie 11, p. 357-361. (‘Letter to His Excellency the Governor-General of Netherlands Indies regarding the exploitation of petroleum on Java’. Oil seeps present at several localities in e Cirebon Residency, but bitumen is tar-like. Also, none of thousands of hot springs contain oil, chance of successful exploitation of petroleum from wells on Java is deemed to be low. Recommends to drill saltwater well in Grobogan Plain instead)
(Nearly all of Indonesia’s petroleum resources in 13 of 44 sedimentary basins. W Indonesia, underlain by Sunda continental block, contains >% of present petroleum reserves and exploration reached early-middle maturity. Undiscovered recoverable petroleum resources of Indonesia are 10 BBO and condensate, and 95 Tcf gas (not including 60 Tcf of discovered, but undeveloped gas))

(Many W Indonesian Tertiary basins similar geologic history, beginning with transgression, followed by bathyal conditions, and terminating with regression ate end of basin evolution. Transgressive facies with excellent petroleum potential in all basins, and greater reserves than regressive facies. Heavy paraffinic oil expected in transgressive strata, light paraffinic or asphaltic oil in regressive facies)

(Geology of oil and gas textbook, with examples from Indonesian basins)

(Basement reservoirs main contributor of oil production in Vietnam. In Indonesia production from basement rocks has been minimal, but recent large gas discovery in pre-Tertiary fractured granites in S Sumatra)


(Australasia (SE Asia, Australia, PNG and NZ) viewed by many as mature exploration province since glory days of 1960’s-1970’s, but at least seven lightly drilled provinces with significant remaining potential)

(1981 USGS oil-gas resource estimate of Indonesia. See also later version by Riva (1983))

(The geological setting of petroleum terrains of the Dutch East Indies’. Dutch version of Molengraaff 1921)

(online at: www.dwc.knaw.nl/DL/publications/PU00014628.pdf) 
(Majority of large oil-fields in world in long enduring geosynclines, where these are marginal areas of sedimentation along coasts of continents. In Indonesia main proven oil basins all along edge of Sundaland. Accurately predicted NW Java and C Sumatra as settings to look for new oil-gas fields)

Three main petroleum systems in SE Asia: (1) rift-sag basins on continental crust (Sumatra- W Java, Malay basin, etc.), (2) Miocene platform carbonates (Sumatra, Luconia shoals, Salawati, Malampaya) and (3) shallow to deep water deltas, largely M- Late Miocene in age (E Bengal, Kutei, NW Borneo)

(Offshore producing Tertiary sedimentary basins in Indonesia account for 34% of total daily oil production and 12% of cumulative production. Most offshore production from basins that are geological continuation of onshore basins (NW Java, Sunda, Kutai))


(Somewhat dated, mostly non-technical book on Indonesian oil industry and history)

(Geological evidence does not indicate vast hydrocarbon reserves in S China Sea)

(E Indonesia underexplored. Structural and stratigraphic trapping models and geochemical data on E Sulawesi, Seram and Irian Jaya indicate possibilities for exploration plays in Tertiary and Mesozoic)

(86% of E Indonesia basins are deep sea basins and rel. little explored frontier areas; little or no G&G)

(History of 19th century oil exploration in Sumatra, E Java, E Kalimantan)

(Review of six Oligocene- Miocene hydrocarbon plays along E and SE Sundaland margin)

(Early, general paper on Indonesian basins. S part of Sunda Shelf many Tertiary sedimentary basins and intervening uplifts. Main oil production in W Indonesia is from Oligocene-Miocene regressive and deeper transgressive sandstone series, except in E Kalimantan, where producing zones range from Eocene- Pliocene. Carbonate rocks becoming prime objective, especially in E Java-Madura basinal area)


Redfield, A.H. (1922) - Petroleum in Borneo. Economic Geology 17, 5, p. 313-349. (Early review of petroleum discoveries on Borneo, including Tarakan, Sanga Sanga in E Kalimantan and Miri district of Brunei)


Robinson, K. (1985) - Assessment of undiscovered conventionally recoverable petroleum resources in Tertiary sedimentary basins of Malaysia and Brunei. Bull. Geol. Soc. Malaysia 18, p. 119-132. (online at: https://gsmpubl.files.wordpress.com/2014/09/bgsm1985005.pdf) (Undiscovered petroleum resources assessment suggests mean 8 billion B Oil and 80 TCF gas remaining to be discovered in Malaysia and Brunei)


(10 proven economic hydrocarbon play types in Indonesia: (1) Paleogene regressive clastics of Java-Sumatra-Kalimantan (Talang Akar, Tanjun); (2) Neogene regressive clastics of Java-Sumatra-Kalimantan (Wonocolo, Warukin); 3. Neogene deltaic complex of Kutai-Tarakan (Handil, Tarakan); (4) Neogene deep water clastics of Kutai-Tarakan (W Seno); (5) Oligo-Miocene carbonate platforms of Sumatra- Java (Kaji Semoga); (6) Neogene pinnacle reefs (Arun, Banyu Urip, Kasim); (7) Fractured volcanics of Sumatra-Java (Suban, Jatibarang); (8) Australian Mesozoic marginal rift grabens (Vorwata-Tangguh); (9) Neogene microcontinental collisions (Tiaka, Donggi-Senoro); (10) Neogene island arc-Australian passive margins (Oseil-Bula). Five additional play types with indications of hydrocarbons: (11) Subvolcanic North Serayu, C Java (Karangkobar-Cipluk); (12) Paleogene rifted structures of Makassar Straits (Kaluku type); (13) Neogene reefs of Sumatra-Java forearcs (Singkel Ibu Suma); (14) Papuan fold-thrust belt (Cross Catalina) and (15) N Papua Neogene volcanoclastic sediments (Niengo))


(In Indonesia 974 exploration and appraisal wells drilled from 2002-2015, 617 onshore and 357 offshore. Of 676 new field wildcats 310 encountered hydrocarbons, adding in-place resources of 18,500 MMBOE. Discoveries in W Indonesia in 5 plays: (1) Paleogene rift sections of Sumatra, W Java, W Natuna; (2) pre-Cenozoic fractured basement in S Sumatra, W Java, E Java; (3) Oligo-Miocene carbonate build ups of E Java and U Kutai; (4) Mio-Pliocene deep-water turbidites of N Makassar and Tarakan; (5) Mio-Pliocene growth-faults of delta progradation of Tarakan Basin. In E Indonesia in 2 plays (Jurassic and Miocene). With details on significant discoveries and dry wells)


(US Geological Survey estimated mean 1.6 billion barrels of undiscovered conventional oil and 17 trillion cubic feet of undiscovered conventional natural gas in three geologic provinces of Thailand. Most of undiscovered conventional oil and gas in offshore Thai Basin Province)


(Tight gas and shale gas accumulations may exist in Triassic clastics of Khorat Plateau Province. Shale oil and shale gas may be present in extensional structures in Thai Cenozoic Basins Province. Coalbed gas does not appear to be viable resource in N Thailand)


(SE Asia undiscovered conventional oil and gas resources in 23 geologic provinces. Oil mean total is 21.6 Billion BO (range 8.9-41.6); gas mean total 299 TCFG (range 129-557) and mean natural gas liquids 9.1 Billion barrels. About 70% of oil in 6 provinces: Baram Delta/Brunei-Sabah, Kutei, S China Sea Platform, E Java, Cuu Long and Thai Basins. About 60% of gas in 6 provinces: Kutei, Greater Sarawak Basin, East Java, Baram Delta/Brunei-Sabah, S China Sea and Nam Con Son Basin)

(USGS assessed undiscovered conventional oil and gas in five geologic provinces of the PNG, E Indonesia, and E Timor: (1) oil mean total 5.78 MMBO (2) gas mean total is 115.2 BCFG. Of undiscovered oil 36% in Timor Thrust and Seram Thrust provinces, 37% in fold-thrust belts of PNG and Irian Jaya. Undiscovered Gas mean estimates for PNG Fold Belt 18.1 BCFG, Arafura Platform 15.9 BCFG and Bintuni Basin 20.8 BCFG)


(General overview E Indonesia discoveries, plays)

(Offshore oil exploration in Indonesia started in 1967. In 1973 exploration by 21 companies in 27 (some very large) contract areas. 91 offshore exploration wells drilled in 1971)

(online at:http://psdg.bgl.esdm.go.id/kolokium%202008/ENERGI%20FOSIL/ etc.)
('Review of heavy oil and coalbed methane gas in Indonesia'. With maps of occurrences and assessed volumes)


(online at: https://gsmpubl.files.wordpress.com/2014/09/bgsm2004018.pdf)


(online at: https://www.eia.gov/analysis/studies/worldshalegas/pdf/Indonesia_2013.pdf)
(Highest shale gas and shale oil potential in Indonesia in oil-prone, lacustrine shales in C and S Sumatra basins. Kutei and Tarakan basins of Kalimantan also thick lacustrine source rock shales with oil- gas potential. Indonesia has estimated 46 TCF gas and 7.9 BBO of risked, technically recoverable shale gas and shale oil resources out of 303 TCF and 234 BBO of risked shale gas and shale oil in-place)

(online at: www.eia.gov/analysis/studies/worldshalegas/pdf/Thailand_2013.pdf)

(One of annual overview reports on Indonesia petroleum industry. Available from www.usembassyjakarta.org)

(‘On oils in the Netherlands Indies’. Recorded 44 oil seeps in Java. Also occurrences on Borneo, Sumatra, Ceram, E Sulawesi)

(‘On oils in the Netherlands Indies’. Same paper as above)

(online at: www.lemigas.esdm.go.id/publikasi/read/scientific/1/)
(Porosity depth models derived from core samples from 549 wells in 8 producing sedimentary basins in W Indonesia)


(Permeability anisotropy in both sandstones and carbonate rocks in wells in Indonesia (KV/KH) generally below 1.2. Carbonate rocks greater portion of data above 1.2)
(online at: www.iatmi.or.id/assets/bulletin/pdf/2007/2007-09.pdf)

('Our colonial mining industry, II, Petroleum'. Early popular overview of oil industry in Indonesia)


(Brief review of hydrocarbon exploration activities in Indonesia. Of 60 sedimentary basins in Indonesia only 38 explored. 14 basins produce oil and gas)
XI.2. Hydrocarbon Source Rocks, Oils and Gases

(Additional references on hydrocarbon source that are specific to one region are listed under these regions)

(Petrographic and geochemical study on low rank coals from Muara Enim Fm, S Sumatra. Coals can generate gas and oil, but with huminite reflectance 0.35-0.52% threshold to generate and expel oil not yet reached)

('Indications of biogenic 'swamp gas' in waters of the Mahakam Delta. Numerous indications of biogenic methane in shallow seismic profiles and cores in shallow sediments of Mahakam Delta distributary channels)

(online at: http://ejournal.mgi.esdm.go.id/index.php/jgk/article/view/201/191
('The distribution pattern of gas charged sediment in seafloor of Sidoarjo, East Java'. Belt of biogenic shallow gas-charged sediments on shallow seismic profiles off Porong Delta, Madura Straits)

(Liptinite maceral "resinite" important constituent of Tertiary coals in W Indonesia, probably from resins of Dipterocarp family tropical lowland trees. Samples from Miocene of Kutei Basin and Oligocene of Ardjuna Basin (off NW Java) have abundant resinite, particularly in vitrinite-rich delta plain coals. Resinites hydrogen-rich, but not paraffinic, suggesting resinite not significant contributor to terrestrially-derived oils in these basins, but contribute cyclic hydrocarbons and biomarkers to these oils)

(online at: www.searchanddiscovery.com/documents/2013/10475barber/ndx_barber.pdf)
(N Australia-E Indonesia-PNG Gas Province of Late Paleozoic-Mesozoic age overwhelmingly gas-prone (80% of all hydrocarbons discovered to date). Distribution of oil- vs. gas-prone source rocks controlled by successive Permian-Mesozoic passive margin extension, rifting and breakup, overprinted by global eustatic cycles and tectonic interaction with W Papua-PNG foldbelt. Two major source rock types: (1) oil-prone Organofacies B (only in local Oxfordian-Kimmeridgian syn-rifts and PNG foreland basins); (2) Organofacies D/E much more widespread, in U Permian-Jurassic lower delta-plain coals)

(Piston core survey in E Indonesia with many samples with migrated hydrocarbon. Not much detail)

(Interstitial light hydrocarbons in 12m long piston cores from deepwater offshore NW Papua (no locality details; all deemed to be of biogenic origin)


(Six Phanerozoic petroleum supersystems in Australia, three of these also in E Indonesia. Source rock intervals in Cambrian, Ordovician, Late Devonian, E Carboniferous, Permian, Triassic, Late Jurassic and Cretaceous. Petrel gas field in Bonaparte Basin example of Gondwanan Supersystem accumulation in Late Permian sandstones with earliest Triassic marine shale seal. Similar system may be operating in Bintuni Basin)


(On mangrove-derived organic matter as likely hydrocarbon source, and mangrove forests as a highly productive ecosystem and ideal place for accumulation and preservation of organic matter)


(High Temp Gas Chromatography can provide paleoenvironmental information on geologic source of oils and bitumens. Oil from Salawati Basin in Irian Jaya and Telisa Shale extracts from C Sumatra show profiles consistent with marine sources. C Sumatran high-wax oils consistent with fresher water lacustrine source)


(Vitrinite reflectance may be suppressed and lead to erroneous predictions of hydrocarbon generation in sedimentary basins. Case studies include Bunga Orkid-1 (Malay Basin))


(General overview of petroleum source rocks)


(Potential sources of CO2 include mantle degassing, reaction (metamorphic and diagenetic) of carbonates and catagenesis of coals)


(Part 2 of Western Indonesia paper. M Eocene most effective source interval in W Indonesia rift basins)


(On the occurrence of the C28 and C29 lupanoid hydrocarbons in crude oils and their use in oil-source correlations. With examples from Kutai Basin, E Kalimantan)

(Occurrence of oil-prone, terrigenous Eocene source potential in extensive areas of E Borneo and W Sulawesi, and oil-prone, lacustrine Eocene potential in S part Makassar Strait. Eocene-sourced oil accumulations known in Barito Basin (Tanjung Field). Extent of other Eocene-sourced accumulations (e.g., Tengkawang oil of E Kalimantan, surface seeps in SW Sulawesi, Pangkat oil tests in S Makassar Strait) not determined)


(E Borneo and W Sulawesi oils show partial or total lacustrine signature. C Indonesian oils with partial or complete lacustrine signature include Pantai-1 (off E coast Borneo) and Pangkat-1 (S Makassar Strait). Both oils elevated 4-methylsteranes. Pangkat-1 oil with beta-carotane, elevated sulfur (S = 2.1%) and very light carbon isotope ratios (d13C = -30.3 ppm). Very low maturity levels, possibly early generation from Type I-S kerogen deposited in hypersaline setting. Other C Indonesian oils reveal lacustrine source signature indicating freshwater depositional setting. Paleogene rifting between Borneo and Sulawesi provided potential development of oil-prone lacustrine source rocks)


(Salayar Basin off SW Sulawesi, at S-most extent of Makassar Strait in Indonesia. Cretaceous- M Eocene rifting created Dewakang graben, followed by inversion through M Miocene. Depositional models and regional data suggest lacustrine, oil-prone sources in Paleocene, and oil-prone coaly sequences in M Eocene. Both source facies proven to E and NE at basin margins. Eocene 'Kelara Limestone' source for low-wax, low-asphaltene oil in basin center. Underlying Eocene coals- coaly shales analogous to oil-prone Barito Basin sapropelic coals, and responsible for oil seeps in SW Sulawesi. Possible occurrence of older, lacustrine oil-prone sources in Salayar Basin significant upside to exploration. Oil-prone sources mature in deepest parts of basin)


(Geochmical characteristics of 31 Eocene-Miocene oils/seeps, Eocene coal and Eocene resin from C Myanmar suggest Eocene resinous shale/coal is source for oils)


('Coal as a source of hydrocarbons: a case study in the Kutai and Barito Basins'. Coals good potential petroleum source rocks)


Davis, R.C., S.W. Noon & J. Harrington (2007)- The petroleum potential of Tertiary coals from Western Indonesia: relationship to mire type and sequence stratigraphic setting. Int. J. Coal Geology 70, p. 35-52.

(500 deltaic sediments analysed from 14 basins in W Indonesia. Main peat-forming episodes: (1) Paleogene syn-rift transgressive, (2) Paleogene-Neogene post-rift transgressive, (3) Neogene regressive. Paleogene syn-rift coals more hydrogen-rich than Neogene coals and more oil-prone. Pliocene coals from regressive sequence in Sumatran fore-arc very hydrogen-poor. Systematic increase in HI with increasing rank suggests pyrolysis underestimated petroleum potential in low rank coals. Vitrinite type more important for petroleum potential than liptinite content. Four coal sub-types: I, II and III low ash coals and likely deposited in raised mires. Sub-type IV hydrogen-rich, high-ash Eocene coals, deposited in submerged mire. Highly degraded peats result in hydrogen-rich coals with higher proportion of detrital vitrinite. Degree of degradation related to time peat spends in zone of influence of water table; unlikely related to tectonostratigraphic setting)
(Most SE Asia basins similar geological history of Early Tertiary graben formation, fill and transgression, followed by E-M Miocene marine transgression and Late Tertiary regressive deltaic progradation. Main source rocks: (1) Early synrift lacustrine (Oligocene- E Miocene), oil prone; (2) Late synrift transgressive deltaic (Oligocene- E Miocene), oil and gas prone; (3) Early postrift marine (E-M Miocene transgression), mainly gas prone; and (4) Late postrift regressive deltaic (M Miocene-Pliocene), oil and gas prone. Lacustrine shales, fluvi-deltaic coals/coaly shales and organic-rich marine shales generated light waxy oils and abundant gas of region. Proximal basins and environments more oil prone, more distal basins and environments more gas potential; intermediate basins and environments both oil and gas prone)

(Four Petroleum System Types (PSTs) corresponding to main stages of geodynamic basin development (1) oil-prone Early Synrift Lacustrine in Eocene-Oligocene deeper parts of synrift grabens, (2) oil and gas-prone Late Synrift Transgressive Deltaic in shallower Oligocene- E Miocene portions of synrift grabens, (3) gas-prone Early P ostrift Marine of E Miocene transgressive period, and (4) oil and gas-prone Late P ostrift Regressive Deltaic of shallowest Late Tertiary basin fills. Mixing of predominantly lacustrine to terrestrial charge has taken place. Grouped basins according to dominant PSTs and identified 'basin families', termed proximal, intermediate, distal, Borneo and E Indonesian, according to paleogeographic relationship to Sunda craton)

(Shell view of SE Asia Tertiary basins. Four types of petroleum systems, correlating with basin evolution stages (early and late synrift, early and late postrift). Petroleum system types characteristic environmentally-controlled source, reservoir and seal lithofacies which, in combination with structural trap style, determine hydrocarbon habitat. Variations in tectonostratigraphic evolution due to differences in paleogeographical position and proximity to late Tertiary collisions. This is reflected in volumes, field sizes and oil-gas ratios)

(Bitumens stranding along coastlines of Northern Territory, W Australia, S Australia, Victoria and Tasmania with biomarker signatures similar to SE Asian oils. Comparison with C Sumatra Minas and Duri lacustrine oils shows very similar isotopic patterns to waxy bitumens from Australian coastline. Asphaltic bitumens from S Australian coastline lighter carbon isotopes)

Edwards D. & J. Zumberge (2005)- The oils of Western Australia II: Regional petroleum geochemistry and correlation of crude oils and condensates from Western Australia and Papua and New Guinea. GeoMark Research Ltd. (Unpublished multi-client study)

(On composition of crude oils from BPM fields in N and S Sumatra (oils with asphalt base, rich in benzine), E Kalimantan (medium oils with paraffin or with asphalt base with common aromatic and unsaturated hydrocarbons), Tarakan (heavy oils with asphalt base) and Java (oils with paraffin and asphalt base))


GEOMARK (1993)- Far East oil study. 15 volumes. (Unpublished multi-client report on oils chemistry)
(On fluid inclusion geochemistry, with examples from Timor Sea, etc., NW Australia)

(Cenozoic strike-slip tectonism in SE Asia generated many short-lived, but deep basins. Formed ideal sites for lakes during Oligocene- Miocene early basinal history. Examples from N Thailand basins with lacustrine mudstone and coal with Type I, hydrogen-rich kerogen, with good hydrocarbon generation potential)


(First authors to suggest relation between uncommon triterpanes in crude oils from SE Asia and dammar (resinous material from Dipterocarpaceae angiosperm hardwood trees common in SE Asia))

(Most source rocks of SE Asia, Australia have strong humic component and therefore large gas-generating capacity, so Far East largely a gas province. Most source rocks Paleocene-Miocene age. Source rock maturity and post-maturity in many cases reached in Neogene to Recent times. Retention of gas may have been inadequate in areas of strong Neogene folding (e.g. Sumatra, E Kalimantan, Burma Tertiary basins)

(Distributions of steroidal and triterpenoidal alkanes and aromatic hydrocarbons in oils, coals and shales from Mahakam Delta suggest high relative abundances of components of higher-plant origin, agreeing with Type III organic matter interpretation. Source for Handil oils must have present depth of at least 3000m)

(Arjuna Basin of NW Java contains high-wax crude oil. Pyrolysis-gas chromatography shows potential precursors of long chain (waxy) paraffins in coals of Talang Akar formation, and are most abundant in those that are rich in 'matrix liptinite' (better expulsion potential than vitrinite-rich coals))


(In SE Asia gas fields CO2 may vary from <10% to 90% in same basin. Multiple possible origins for CO2, incl. from mantle, carbonate metamorphism, maturation of organic material, etc.). Tectonic setting, basement fault density, reservoir temperature and reservoir pressure are key elements controlling CO2 abundance)

(Hydrocarbons generated from lacustrine source rocks in Paleogene rift basins of offshore China and SE Asia account for 95% and 48% of total petroleum resources in these areas. Two models of source rock distribution
(1) Bohai Bay basin model with widely distributed, thick, deep lacustrine shale; (2) Asri- C Sumatra basin model with rel. thin, shallow lacustrine shale of limited distribution


(Lacustrine source rocks >80% of Indonesia's known petroleum reserves. Nonmarine source systems not universally distributed. Factors favoring lacustrine source development: tectonic development of narrow basins, subsidence rates in excess of sedimentation rates, rainfall rates in excess of evaporation but insufficient to support growth of rain forests, lack of winter storms, and limited seasonality of surface temperatures)


(Significant proportion of global gas reserve-base not thermogenic but of bacterial origin. Several Indonesian basins, with high sedimentation rates, locally high TOC and rel. low T gradients, may be suitable for biogenic gas generation)


(Rift basins contain disproportionate amount of petroleum relative to their area and sediment volume, but not all rifts contain organic-rich deposits, nor are all organic-rich deposits volumetrically significant. Includes examples from C Sumatra, etc.)


(Multiple gas formation mechanisms, reflected in bulk and isotope geochemistry; can be used to decipher gas accumulation history)


(Crude oil data suggest four crude oil families in C Sumatra. Source rock data indicated only one effective oil source, Pematang Brown Shale. Facies variations in Brown Shale may explain differences in crude oils)


(Considerable variation in ability of coals to generate hydrocarbons. With exception may be of algal-dominated coals, coals generally do not contribute to petroleum resource base. Lacustrine source rocks account for 90% of petroleum resource base of Indonesia, 95% of China's)


(Contribution of coal to accumulated hydrocarbons controversial. Only alginate produces molecular fingerprint that resembles crude oil, hydrocarbons generated by vitrinite do not. Vitrinite generates minor quantities of hydrocarbons and is not viable oil source. Algae and bacteria probably represent basis for all crude oils)


(also in J. Inst. Petrol. Technologists 7, 37, p. 209-233)

(Plummer 1921 AAPG review): In Kutei region in E Borneo Miocene Pliocene deltaic deposits overlie glauconitic marls, limestones and marls of E Miocene and Eocene age. Oil originated in lower Miocene and Eocene marls and limestones and migrated upward, saturating delta deposits. Oil accumulated along Sanga Sanga fold (Sanga Sanga and Sambodja oil fields). Deeper oil rich in paraffin wax; oils from higher levels in or above coal beds poorer in paraffin and richer in aromatic and asphaltic constituents. In Miri field where coal is absent, oil also low in aromatic and asphaltic content. At Perlak in Sumatra where coal is also absent oils lower in aromatic and asphaltic constituents than oils of Moera Enim, Sumatra, where coal seams present)

(Oils from Pertamina wells in N Sumatra basin suggest two oil sources: (1) E Oligocene synrift Bampo Fm (early generation, now overmature; oils mostly biodegraded) and (2) post-rift Late Oligocene- M Miocene Baong-Belumai Fms)


(online at: www.lemigas.esdm.go.id/id/pdf/buku_populer/Buku%20Gas%20Metana%20Batubara.pdf)

('Coal methane gas: new energy for the people'. Review of coalbed methane principles, occurrences in Indonesia (Sumatra, Kalimantan), extraction, economics, etc.)


(General discussion of offshore satellite slicks in SE Asia)


('The Helium content of natural gases from the oil wells'. Analyses of 15 gases from Java, Sumatra, Borneo and sera. Highest He content in Bula field, Seram)


(General discussion of oil-gas seepage. Most common in young sediments that were folded, faulted and eroded and on basin margins. With 3 maps showing oil seep distribution on Sumatra (fig. 38), Borneo (fig. 39) and Java (fig. 40), based on information from Standard-Vacuum Oil Company)


(Overview of E Indonesia source rocks. Main source rock ages Late Permian, Late Triassic (restricted marine oil-source in Buton, Seram, Timor, Buru), E-M Jurassic (coaly and marine facies in New Guinea), Miocene (Salawati, Sengkang basins).


(General Asia hydrocarbon source discussion, mainly dealing with Borneo Baram and Mahakam deltas)


(Coal-bearing sequences are significant oil generators only in very specific and relatively uncommon settings. Coals primary or important secondary source facies in Australasia/ SE Asia. In other regions of world no evidence they expelled major oil, but sourced significant amounts of gas. Liquid hydrocarbons restricted to two 'fairways'. (1) Tertiary angiosperm assemblages within 20° of Paleo-Equator and (2) Late Jurassic-Eocene gymnosperm assemblages formed on Australian and associated plates)


(Majority of Indonesian oil provinces with belt of seeps on basin edge. Relationship between seeps and reserves good on basin scale, but poor at sub-basin and field scale. Seeps in W Indonesia controlled by extent of Plio-
Pleistocene structural inversion over oil-bearing portions of backarc basins. Less disturbed extensional fabric of C. Sumatra less seepage than inverted fabric of N and S Sumatran basins, despite higher oil reserves. Active seeps frequent over active reverse faults and eroded steep Sumatran basins, despite higher oil reserves. Active seeps frequent over active reverse faults and eroded steep anticlinal crests. High success rate of wells near seeps, but most seeping fields shallow and small. In inverted areas, oil generation usually no longer active and surface oil shows represent destruction of oil pools. Larger fields generally basinward of seep belt.

(Study of Eocene-Miocene lacustrine source rocks from undisclosed well offshore China)

(online at: http://archimer.ifremer.fr/doc/00109/22074/19716.pdf)
('Occurrence of methylotrophic methane-producing bacteria in deep-sea sediments from Makassar Strait (Indonesia)'. Competition between sulfate reducing and methane producing bacteria one of main factors controlling biogenic methane genesis in anoxic marine sediments. Methylotrophic methanogenic bacteria found in shallow marine sediments, and methanogenic bacteria able to produce methane from methylamines in sediments from oceanic trench at depth of 2000m in Makassar Strait)

(Bitumen strandings in N Territory of Australia are paraffinic oils, probably from natural submarine oil seeps in Money Shoal Basin. Probably derived from Cretaceous or younger non-marine or deltaic source rocks (see also Summons et al. 1993))

(Two types of variations with depth of d13C values of gases observed in multilayered gas fields in SE Asia (E Kalimantan?). In normally pressured zones steady increase of d13C values of methane with depth; in overpressured zones first decrease with depth, then regular trend. Experiments on pyrolysis of Mahakam Delta coal show closed pyrolysis carbon isotope trends very similar to high pressured reservoirs; normal pressured reservoirs follow values of semi-open pyrolysis. Gas distributions and d13C isotope composition may be explained in terms of degree of opening of system: high P reservoirs fairly closed systems, with in situ gas generation, normally pressured zones more open and subject to lateral migration)

(Organic petrology and geochemistry of lignite from Muara Enim Fm (S Sumatra), shales from Sangkarewang Fm (Ombilin Basin) and Brown Shale Fm (C Sumatra). All potential for unconventional oil and gas)

(Oleananes derived from angiosperm plants. Abundance of oleananes in terrigenous oils and sediments may be sensitive to changes in early diagenetic conditions and need to be used with caution as age and source markers in fluvio-deltaic and lacustrine petroleum systems. Oleananes absent from base of Eocene coal seam affected by postdepositional seawater intrusion. In deltaic sediments from S Sumatra Basin, oleanane/hopane is strongly correlated with indicators of marine influence. Angiosperm-derived Miocene coal from Philippines, deposited under freshwater conditions, abundant aromatic oleanoids but no oleananes)

(Distribution of oleananes and bicadinanes, land plant biomarkers in many SE Asian oils, can be used to better define maturity and depositional environment of effective source rocks)


(Biomarker and n-alkane isotope profiles for Late Cretaceous/Tertiary oils from SE Asia, China, PNG, etc., interpreted with respect to six kinds of source rock depositional settings: fluvio-deltaic (S Sumatra, NW Java, NE Kalimantan, etc.), freshwater transitional, lacustrine (C Sumatra), saline lacustrine, marine deltaic and marine carbonate. Oleanane/hopane ratio may overestimate higher plant contribution to marine oils)


(online at: www.bgl.esdm.go.id/publication/index.php/dir/article_detail/719)

(Interbedded black shale and limestone of M Miocene Baong Fm in N Sumatra Basin similarities with Barnett Shale of Fort Worth Basin, therefore Baong Fm may also become commercial gas resource)


(Results of geochem analysis of deep sea floor samples from ten ‘Black Gold- TGS' areas in Indonesia, suggesting presence of mainly marine-origin Mesozoic and Tertiary source rocks)


(Angiosperm biomarkers include oleanane isomers 18a(H) and 18b(H) oleanane, also C30 angiosperm markers lupane and taraxastanes. Rearranged oleananes probably formed by dehydration and rearrangement of higher plant triterpenoids; present in all 25 oleanane-containing oils used. Include analyses from Kutei Basin and Lufa seep, PNG)


(Successful laboratory experiment in generating biofuel from cultures of marine diatoms)

Okui, A. (2005)- Characteristics of non-marine dual petroleum systems in Southeast Asia. In: Oil and gas from the Cenozoic non-marine source rocks in East Asia; a point of contact between petroleum system and Earth system, Sekiyu Gijutsu Kyokaishi (J. Japanese Assoc. Petroleum Technologists), Tokyo, 70, 1, p. 91-100.

(Miocene coal formerly thought to be main source rock in basins in and around Indochina Peninsula in SE Asia. However, new investigations reveal important role of Oligocene lacustrine source rocks)


(Black Gold-TGS methodology of deep water hydrocarbon seeps detection from multibeam bathymetry and backscatter surveys)


('Application of organic petrology in basin analysis and hydrocarbon exploration in several basins in Indonesia and Australia'. Brief review of organic petrology in Miocene of S Sumatra, Triassic of W Timor and Permain-Triassic of Bowen Basin, NE Australia)


Petersen, H.I., H.P. Nytoft, M.B.W. Fyhn, N.T. Dau, H.T. Huong, J.A. Bojesen-Koefoed & L.H. Nielsen (2012)- Oil and condensate types in Cenozoic basins Offshore Vietnam: composition and derivation. Proc. Int. Petrol. Techn. Conf. (IPTC), Bangkok 2012, 1, IPTC 14383, p. 612-621. (Vietnamese shelf several petroleum-producing Cenozoic rift basins, including Song Hong, Cuu Long, Nam Con Son and Malay-Cho Thu basins. Cuu Long Basin is main oil-producing basin, with paraffinic oils from lacustrine source. Lacustrine oils also known from N margin of Song Hong Basin. Oil with coaly biomarker signature in the Nam Con Son Basin; also condensates from Song Hong Basin contain high proportions of higher land plant biomarkers. Oils from N margin of Malay Basin suggestive of coaly source)

Petersen, H.I., H.P. Nytoft & L.H. Nielsen (2004)- Characterisation of oil and potential source rocks in the northeastern Song Hong Basin, Vietnam: indications of a lacustrine-coal sourced petroleum system. Organic Geochem. 35, p. 493-515. (Oil in B10-STB-1x well in NE Song Hong Basin, Vietnam, has typical lacustrine-coaly geochemical features. Presence of lacustrine source rocks in basin indicated by high-amplitude seismic reflectors in undrilled half-grabens and outcrops of Oligocene immature mudstones and humic coals at Dong Ho (Type I kerogen, TOC 8-17%, HI >500) and on Bach Long Vi Island (TOC 2-7%, HI 200-700))

Petersen, H.I., Vu Tru, L.H. Nielsen, Nguyen A. Duc & H.P. Nytoft (2005)- Source rock properties of lacustrine mudstones and coals (Oligocene Dong Ho Formation), onshore Song Hong Basin (northern Vietnam). J. Petroleum Geol. 28, p. 19-38. (Oligocene lacustrine mudstones and coals outcropping at N margin of mainly offshore Song Hong Basin include oil-prone potential source rocks. Organic material in mudstones mainly amorphous (Type I), up to 19.6% TOC and Hydrogen Index values 436-572 mg HC/g TOC. Only 0.5 wt.% TOC required to saturate source rock to expulsion threshold. Coals and coaly mudstones dominated by huminite (Type III kerogen) and contain terrestrial-derived liptodetrinitite. Coals generate at or before maturity of vitrinite 0.97%Ro)


(Study of organic matter of recent deltaic sediments cored in Misedor core hole, Mahakam delta, E Kalimantan)


(Geochemistry of 22 oils from C Sumatra basin. Two groups, both sourced from lacustrine facies in Pematang Fm: (1) Minas, Oki and Libo fields (with botryococcane, heavy C-isotopes, etc.); (2) Kotabatak area, Kotagar, Nusa, NW Minas (Telisa Fm) (no botryococcane, light C-isotopes, etc.))


(Geochemical study of Tertiary-sourced oils and oil stains from Salawati Basin, Bintuni Basin, E Sulawesi Basin and oil seeps from PNG N New Guinea Basin. Presence of angiosperm-derived biomarkers (oleanane) used to distinguish Tertiary-sourced oils, but oil stains lacking oleanane from S Salawati Basin included, due to similarity to main group of Salawati oils. All oils similar and derived from mixture of marine-derived organic matter and terrigenous debris, deposited in marine facies, and deeper marine time-equivalents of carbonate reservoir horizons or slightly younger, more open marine horizons)


(Indonesia source rocks lacustrine, fluvo-deltaic and marine. Lacustrine source most productive (most oil in C Sumatra, some Sunda Basin, possibly oil in W Natuna). Fluvial-deltaic source rocks sourced oil in majority of foreland/back-arc basins of W Indonesia. Marine source rocks in E Indonesia (Salawati, E Sulawesi). Pre-Tertiary (Permian/Jurassic) oil source in Bintuni and Bula (Seram) and possible source in E Sulawesi and Banggai-Sula. Lacustrine oils low-medium gravity, waxy, low sulfur and often high C30 4-methyl steranes. Marine oils low-medium gravity, low wax, medium-high sulfur oils and high C27-C29 diasteranes and steranes. Fluvo-deltaic oils from higher plants medium-high gravity, waxy, low sulfur and abundant C30 alkanes)


(Gas-oil- condensate in Upper Miocene in deep-water Kutei Basin, off E Kalimantan, derivated from land-plant source material. Best source rocks are deep-water sandstones with coaly fragments, pieces of wood, resinite, and other coaly debris. Laminar coaly fragments are dominant, and were leaf fragments, carried into deep water by turbidity currents during lowstands of sea level. Kutei Basin deep-water shales contain mainly silt-size vitrinite grains with poor generative qualities. Liquids from leaves high wax contents)


(Geochemistry of natural gases in Indonesian basins, using 350 gas occurrences. Both thermogenic and biogenic (bacterial) gas types recognized. Thermogenic gases generally <95% methane and heavier C isotope ratios (>45‰). Biogenic gases >98% methane and lighter C isotope ratios (< -60‰). Thermogenic gases dominate in Indonesia. Biogenic gases mainly in W Sumatra fore-arc basins, E Java Basin and foredeep of Sorong Fault Zone, NW Papua. High CO2 mainly inorganic origin (thermal destruction of carbonates or volcanic degassing). H2S in some gas fields due to thermo-chemical sulfate reduction of deep, hot carbonates)


(Tertiary basins around Sundaland of W Indonesia and its drifted parts (S Makassar Strait, W & S Sulawesi, and Bone Basins) initially formed in Mid- Late Eocene. Thick Paleogene sediments in rift and early post-rift phases of basins contain important hydrocarbon source rocks. Biomarkers and carbon isotopes of oils allow identification of Paleogene lacustrine, fluvio-deltaic and marine source facies)


(Similar to paper above. Paleogene source rocks in Sundaland basins include lacustrine facies (most significant: C Sumatra, Sunda-Asri, S Sumatra, W Natuna) to carbonateous shales and coals of fluvio-deltaic and paralic facies (S Sumatra, W Java, E Java, Barito, W Sulawesi) and marine facies (N Sumatra))


(~350 crude oils analyses used to identify different petroleum systems in Far East. Oils separated into three groups: terrigenous, lacustrine, and marine. More specific geochemical criteria allowed establishment of subgroups of oils according to specific source environment)


(122 oils analyzed. Majority of oils either ‘lacustrine’ or ‘terrigenous’ Tertiary source. Two oils from N Sumatra marine signature. Several oils from C and S Sumatra mixed characteristics)


(Brief review of hydrocarbon microseepage surveys. Microseepage predominantly vertical, so surface anomalies may approximate size and shape of hydrocarbon accumulation. Little detail)


(Maturity of oils and sediments derived from catagenetic products of plant material. Polycadinene indices tested for Tertiary oils from S Sumatra, PNG, New Zealand and Australia. Bicadinane maturity indicator continues to change into oil window and may be useful in ranking relative maturity of oils)

(Hydrocarbons derived from fresh dammar resin are compared to those in Miocene fossil resins and Miocene-sourced oils in Mahakam Delta. Dammar resins undergo few chemical changes during early diagenesis. Bicadinanes are absent in immature resins, but form upon heating in lab or subsurface)


(online at: http://espace.library.curtin.edu.au)

(22 oils and sediments analysed for biological marker compounds. Compounds typical of carbonate-rich source rocks identified. Sediments and oils from N Sumatra Basin contain very different biomarkers)


(online at: www.fttm.itb.ac.id/galeri/prediction.pdf)

(Some Indonesian gas fields with biogenic gas, characterized by dryness (>99% methane) and light carbon isotopes (-61 to -67‰). One field producing biogenic gas in E Java Basin, probably derived from Plio-Pleistocene. Similar situation in Tomori, Sulawesi. Plio-Pleistocene sediments in Indonesia generally high sedimentation rates, low thermal gradients and high organic content, thus potential source for biogenic gas)


(Ratios of hopanes types geochemical biomarker in oils and sediments reflect sample maturity, with higher norhopanes in more mature samples. Incl. examples from Triassic oils from Seram and Buton asphalt)


(30-norhopanes as carbonate biomarker proposed recently. Three types of source rocks in N Sumatra Basin: shale, carbonaceous shale and calcareous shale. n-Alkanes and steranes can only be used to distinguish two source types since shale and calcareous shale show similar characteristics. Recognition of three source types can only be observed using the hopane distribution. One crude oil can be correlated to calcareous shale and two crude oils are correlative to shale source rock. Crude oil of coaly shale type is not found during this study)


(oleanoid ratio OR1 correlates with vitrinite reflectance, and may be maturity indicator)
Biogenic gas formed at \( T < 75^\circ \)C is dry (>95% methane) and isotopically light (<55‰). May contribute >20% of global gas resources. Biogenic gas large component of gas produced from E Java. Other favorable sites for biogenic gas are basins with young sediments (Plio-Pleistocene), high sedimentation rates (>50 m/My) and low Temp (0-75°C)


(Overview of Indonesia basins and petroleum systems)

(Study of biodegraded oils and stains from wells in Arafura, Bonaparte and Carnarvon basins. Biodegraded Arafura 1 oil shares many characteristics with E Paleozoic oils of Canning Basin)

(online at: http://ijog.bgl.esdm.go.id/index.php/IJOG/article/view/165/165)
(Review of hydrocarbon occurrences in Pretertiary 'basement' in Sumatra (granitoids and metamorphics in NE Beruk, Suban, Sei Teras), Kalimantan (Tanjung granitoid, volcanics, metamorphics) and Seram (Oseil Mesozoic limestone))

(Oil shale and coalbed methane studies in Sumatra and Borneo)

(Geochem study of 11 outcrop coal samples from M Miocene Balikpapan Group near Samarinda. Analysed coals have potential to expel oils ranging from borderline gas condensate to high-wax, paraffinic- naphthenic-aromatic oil. Non-volatile, paraffinic oil potential of Mahakam Delta coals controlled primarily by abundance of leaf- and cork-derived macerals. These macerals expected to be more abundant in thin, planar mire coals and coaly mudstones than in thicker, raised mire coals owing to better preservation potential of surface leaf biomass under higher groundwater levels in planar mires)

(Hydrocarbon compounds in surface sediment of Setiu Wetland analysed and characterized using GCMS. Terrestrial plants input (epicuticular plant waxes) are dominant contributor of organic compounds in the sediments with a minor input from marine phytoplankton (algae) as well as bacteria)


(Hydrous pyrolysis experiments on Miocene Muara Enim Fm lignite from Bukit Asam, S Sumatra. Lignite is liptinite-rich (32% of total macerals); resinite is the most abundant liptinite maceral (13.7%). Rock Eval Hydrogen Index values of 483 mg HC/g OC. Significant amounts of liquid hydrocarbons assimilated by vitrinitic matrix of coal prior to expulsion, making vitrinite-rich coals poor oil source rocks. Only liptinite-rich coals (>15-20% of total macerals) appear capable of generating significant amounts of liquid hydrocarbons but expelled product will probably be low. Most Sumatran coals not liptinite-rich (typically 5-10%))


(Expulsion efficiency is critical factor in potential of marginal source rocks to provide adequate hydrocarbon charge. Expulsion efficiency in marginal source rocks highly variable due to amount of hydrocarbon generation and adsorptive capacity of certain organic matter assemblages. Numerous examples of marginal source rocks in Indonesian region. With case study of Telisa Fm in Sumatra.)


(>200 oil analyses. W Indonesia 2 main petroleum systems: Tertiary lacustrine and Tertiary terrigenous, with additional marine petroleum system in N Sumatra and E Natuna. E Indonesia 3 main systems: Tertiary marine carbonate, Mesozoic marine carbonate and Mesozoic marine siliciclastic)


(ALF surveys over Sumatra Forearc, Java Forearc, Billiton Basin, Salayar, Spermonde, S and N Makassar, Bone, Gorontalo and Halmahera Basins. Hydrocarbons seeping from all basins except Java forearcs, though further analysis is required. Areas of greatest interest are Billiton, S Bone and S Makassar basins)


(Coals and associated shales important oil source rocks in some deltaic environments. Formation of hydrogen-rich kerogen either by concentration of plant cuticles and spores after reworking of delta top freshwater peats, or by accumulation of delta margin peats under saline conditions. Examples include Oligo-Miocene Talang Akar Fm of S Sumatra-NW Java (perhydrous vitrinite source of isotopically light waxy oils with biomarkers from tree resins). Waxy oils also produced in Sunda Basin (derived from algal kerogen in older, lacustrine Banuwati Fm shales (low contents of land plant biomarkers and heavier carbon isotopic signature))


(Coals are oil source rocks in many Tertiary basins of SE Asia. Precursors of these hydrogen-rich and oxygen-poor coals are coastal plain peats in everwet tropical climate. Distribution, petrography and chemistry of coaly Miocene source rocks present in Kutai Basin described)

(Most SE Asian Tertiary petroleum from paralic (higher land plant) source, although larger proportion of oil from lacustrine algal sources. Lacustrine sources mainly in Paleogene syn-rift lakes, paralic coals and coaly mudrocks in Miocene post-rift. Oil-prone source rocks preferentially paralic between lower coastal plain and lower estuary/delta front facies, perhaps involving mangrove system. Younger plays more gas prone. Significance of biogenic gas poorly understood. Vertical migration common; lateral migration restricted to ~20 km or less from kitchen)


(Chemical composition of fossil resin from Miocene outcrop in Lumapas, Brunei, compared to Recent counterpart dammar from trees of family Dipterocarpaceae, to establish nature of precursor of bicitadines)

(Structurally related hydrocarbons consisting of one or more sesquiterpane units in saturated and aromatic hydrocarbon fractions of crude oils from SE Asia (Java, Sumatra, Malaysia). Thought to originate from cadinene polymer present in dammar resins from angiosperms like Dipterocarpaceae trees, which depolymerises on thermal stress)


(Lacustrine rift systems sourced large portion of SE Asia hydrocarbons. Description of rift systems Bandar Jaya- S Sumatra, Kampar Kanan- C Sumatra, Petchabun-Thailand (all Paleogene- humid) and Dongting-China (Cretaceous-Paleogene; arid))

(Rift architecture, sequences and sedimentary geochemistry of four Palaeogene and one Cretaceous/ Paleogene graben systems: Bandar Jaya Basin (S Sumatra), Kampar Kanan Basin (C Sumatra), Ombilin Basin (W Sumatra), Phetchabun Basin (N Thailand) and Dongting Basin (China). Geochemical characteristics of source rocks described in context of depositional systems)

(Palawan non-waxy oils traditionally interpreted as marine sourced. Oils from recent Calauit fields characteristics of non-marine algal source)

(Review of carbon isotopes of 174 lacustrine sourced oils and 109 lacustrine source rocks suggest carbon isotopes can not be used to differentiate between marine and lacustrine environments)
XI.3. Coal

(Additional references on coal that are specific to one region are listed under these regions)


(Organized coal mining in Indonesia started in 1849 at Pengarom, SE Kalimantan. Most important surface mine in Indonesia Bukit Asam in S Sumatra, opened in 1919. Coal deposition requires paralic-limnic environments with slow subsidence, mainly in backarc basins)


(Brief report on geochemical analysis of 8 coal samples from Sumatra (3; Eocene-Miocene), Kalimantan (3; Eocene-Miocene), W Papua (Timika, Permian) and S Sulawesi (1; Eocene)


(Most of Indonesian coal Paleogene and Neogene age, low-moderate rank and low ash and sulfur. Tectonic and igneous activity resulted in significant rank increase in some basins. Eight coal samples described from Sumatra, Kalimantan, Sulawesi and Papua)


(Study of 7.3m peat core a 733 cm-long core from Air Hitam peatland in Jambi Province. In last ~7800 years site covered by dipterocarp-swamp mixed rainforest during first 2000 years, after which freshwater swamp taxa more important, in particular Durio trees. At ~4500 years ago swamp vegetation shifted to pole forest with Pandanus thickets in response to change from minerotrophic to ombrotrophic conditions)

Estimates for CBM potential ranged up to 450 TCF, but realisation of resource limited so far. Main CBM targets Miocene coal seams in S Sumatra and Kutai Basins. S Sumatra coal seams generally thicker (5-25 m) than Kutai Basin and laterally continuous over 10s of km. 54 PSCs since 2008. 84 CBM core and pilot wells drilled by 18 operators. Gas contents generally higher in Kutai Basin (2-10 m³/t) than in S Sumatra Basin (<3 m³/t). Gas saturations tend to be >80% at depths >300m. Gas dominated by biogenically-derived methane).

(Study of changes in organic matter during early thermal maturation in Mahakam delta Tertiary coals)

(Mahakam delta coals all stages between peat, lignites and bituminous coals. Mechanisms of early maturation are loss of oxygenated compounds, aromatisation and condensation of organic matter, similar to other coals)

(Diagenetic evolution of coal from Mahakam delta. Carbon loss during diagenesis mainly as CO2, hydrogen loss mainly as H2O. Hydrocarbon production negligible, in accordance with absence of bacterial methane accumulations in Mahakam Delta. δ13C of coals becomes ~2 per mil more positive with diagenesis)

(online at: https://open.library.ubc.ca/cIRcle/collections/ubctheses/831/items/1.0075286)
(Organic matter characteristics of Holocene surface peat layers in 3 raised ombrothrophic peat deposits on E coast of Sumatra. Thickness of peat 3-12m, age 4500/4000 yrs and younger)


(Chemical analyses of domed peat deposits of Baram River delta. Four end members distinguished, which can be traced to type of plants and degree of degradation. Pollen from center of deposit indicates succession from mangrove substrate followed by fresh water peat forest, then stunted vegetation)

(Peat studied in several geologic settings, including coast of Sarawak and delta of Batang Hari River, Sumatra. Most deposits are domed bogs in which peat accumulation continued above surface of surrounding soil. Typical sequence of environments from pond stage, through grassy marsh, through forested swamp to heath dome stage, with associated changes in acidity and ash, volatile matter, carbon, hydrogen, nitrogen, sulfur and oxygen contents, as well as trace elements. Ombrotrophic peat deposits of tropical Sarawak and Sumatra thick and extensive, low-ash and low-sulfur, and high heating values)

(Although gas resource probably huge, CBM is yet to be proved that it can be produced economically)

(online at: www.gsm.org.my/products/702001-100999-PDF.pdf)
(Review of coal resources in Malaysia: 98% in Sarawak and Sabah. All coal of Tertiary age and quality ranges from lignite to anthracite, with bituminous coal predominant. Largest known coal deposits in Merit Pila and Mukah-Balingian in Sarawak and in Meliau basin in south C Sabah.)


(Review of terrestrial coal bearing sedimentary sequences where oil-prone organic material was deposited in SE Asian Tertiary. Autochthonous coal deposits more favourable oil sources than allochthonous coals. Lacustrine environments may be most prolific (Botryococcus-derived) oil source in SE Asia)


(online at: www.australiancoal.csiro.au/pdfs/cook_daulay.pdf)


(Five types of exsudatinite in E Kalimantan coals)


(Most Kalimantan coal mainly low rank with high moisture content. Most coal currently exploited medium-high rank)

(Indonesian coals rich in vitrinite and variable contents of liptinite. Inertinite rare to sparse, with exception of a few (typically Neogene) coals. No major differences between Paleogene and Neogene coals. Most coals low in rank. Coals, and associated dispersed organic matter, important source rocks for some oil accumulations)


(online at: http://jurnal.tekmira.esdm.go.id/index.php/imj/article/view/301/186)

('A contribution to the knowledge of the Netherlands Indies coals'. Mainly on composition and quality of coal in 'Oranje Nassau' government-operated coal mine at Pengaron, Barito Basin, SE Kalimantan, which produced
coal since 1848. Five Eocene coal horizons, three of which deemed suitable for use on navy steam ships. Ash content 2.7-6.3%)

De Gruyter, P. (1940)- Een voorlopige classificatie der Indische steenkolen, gericht op hun technische toepassing. De Ingenieur in Nederlandsch-Indie (III) 7, 12, p. ('A provisional classification of the Indonesian coals, aimed at their technical application. First part mainly of general coal classification properties')

De Gruyter, P. (1941)- Een voorlopige classificatie der Indische steenkolen, gericht op hun technische toepassing- vervolg. De Ingenieur in Nederlandsch-Indie (III) 8, 1, p. 1-14. ('A provisional classification of the Indonesian coals, aimed at their technical application- continued'. Second part mainly on properties of Bukit Asam coal. S Sumatra, also Ombilin, Borneo)


Dehmer, J. (1993)- Petrology and organic geochemistry of peat samples from a raised bog in Kalimantan (Borneo). Organic Geochem. 20, 3, p. 349-362. (Peat cores, from margin and center of tropical raised bog from Sebangau River near Palangkaraya. Peats from margin of raised bog more decomposed than center and basal peats more decomposed than peats from upper layers. Basal peats deposited under mesotrophic conditions and more seasonal climate)


Esterle, J.S. (1999)- Can peats be used to discriminate local subsidence from regional tectonism? Examples from Sarawak, Malaysia and Sumatra, Indonesia. In: H. Darman & F.H. Sidi (eds.) Tectons and sedimentation of Indonesia, FOSI-IAGI-ITB Regional Seminar to commemorate 50th anniversary of Van Bemmelen's Geology of Indonesia, Bandung 1999, p. 24-28. (Holocene peats of E Sumatra and Sarawak started forming at ~6000 BP and are models for formation of coal measures. Two modes of peat accumulation, one where it keeps up with clastic sedimentation (rel. high preservation potential), and one where it outstrips clastic sedimentation (rel. poor preservation potential))


(Study of two Recent (<5,000 yrs) domed peat deposits at Baram River (Sarawak) and Jambi area (Sumatra), examined as modern analogues for coal. Both in microtidal alluvial-deltaic plain settings, similar vegetation. One deposit convex, mature dome, rising 10m above river level; the other is low-gradient dome, rising only 1 m above river level but with concave base up to 6m below. Both deposits eroded by adjacent rivers)

(Assessment of potential volumes of deep-seated coal in Sumatra and Kalimantan)

(Sumatran rain-fed and domed (ombrogenous) mires used as models for thick coal deposits worldwide. Kumpeh and Dendang peatlands between anastomosing Batang Hari and Kumpeh Rivers domed topography despite meander channels and tributaries forming re-entrants into peatlands and flood-plain levee sediments. Resulting peat deposits small area (240-540 km2), discontinuous, lenticular, <9 m thick. Endapan domed to flat peatland from edge of Batang Hari and Kumpeh Rivers to coast, is blanket-like (4000 km2) peat deposit, >11m thick. Raised peatlands along rivers reflect buildup of flood sediments that sustained robust vegetation, which in turn, accumulated raised peat (<9 m) that reduced extent of flooding. Flat coastal peatlands (Endapan) reflect peat accumulation (>11m) from stunted vegetation removed from flood-sustaining nutrients)

(online at: www.searchanddiscovery.com/abstracts/pdf/2010/hedberg_indonesia/abstracts /ndx_friederich.pdf)
(Modern domed peat swamps in Sumatra and Sarawak may be used as analogues of Tertiary coals of Kalimantan)

(Indonesia economic coal deposits mainly of Eocene and Miocene-Pliocene age and mainly in Kalimantan and Sumatra. Formed from peat deposits in equatorial paleoclimate. Some peats domed peats, which grew above normal water tables in climate of year-round rainfall, are low in ash and sulphur and locally thick (Miocene coals). Eocene coals typically thinner, with higher contents of ash and sulphur. Eocene coals formed mainly in extensional tectonic settings. Miocene-Pliocene coals in range of tectonic settings)


(SE Asia Cenozoic coal-bearing basins grouped in five regions: N Sundaland, S Sundaland, Philippines, W Myanmar and E Indonesia; first three discussed here. Most significant coal deposits of SE Asia in Neogene of S Sundaland (Borneo, Sumatra), over extensive coastal plains in regressive setting. Coal deposits of N Sundaland (i.e. SE Asian continental) in small disconnected non-marine grabens, and are areally restricted. S Sundaland resided mainly within ± 10° of equator, with paleoclimate conducive to ever-wet conditions. N Sundaland resided >10°N of equator, probably monoossonal with annual dry periods. Etc.)

(Review of geologic setting and 160 years history of coal exploration and commercial production in Indonesia. Coal exploration and production of Eocene and Miocene coal started in late 1800's in SE Kalimantan and W and S Sumatra. Very limited production from World War 2 until 1980s when modern coal mining industry started to develop. In 2005 Indonesia became world’s largest coal exporter)


(Borneo Holocene peats are models for Tertiary coals. Sarawak Rajang River delta- coastal plain with extensive peat up >13 m thick in ombrogenous peat domes, deposited over Pleistocene podzols when sea level stabilized at 7.5 ka and delta progradation started. Mahakam River delta also began progradation at this time, but no peat accumulation. Rajang River clays up to 60% mixed layer and expandable clays that restrict pore water flow in tidal and overbank deposits, promoting accumulation of organic matter. Mahakam River low % mixed-layer and expandable clays in system)

(Leaves are easily degradable and rarely preserved in coals. May be preserved in acid-water filled depressions)

(In Mahakam Delta fluvial distributary channels are main conduits for transport of plant parts to delta front, where they are commonly reworked into up to 2.5m thick accumulations, onlapping interdistributary tidal flats. Allochthonous peat composed of fragmented canopy detritus from various sources, including leaves, cuticles, wood, petiole parts, damar (dipterocarp resins), fruits, and seeds. Deposits occur as high-tide beach ridges)

(Mainly on commerciality and regulatory environment of Indonesian CBM projects)


(Statistics of coal and coalbed methane resources in Indonesia. CBM resource of Indonesia estimated 2.89 Tm3, with greatest resource in S Sumatra, followed by Ketungau and Kutai basins on Kalimantan)

(Brief overview of Indonesian basins with coalbed methane potential. Over 12.7 Tm3 (450 TCF) of CBM resources identified in 11 basins.(similar paper to to Stevens and Hadiyanto 2004))


Hope, G., U. Chokkalingam & S. Anwar (2005)- The stratigraphy and fire history of the Kutai Peatlands, Kalimantan, Indonesia. Quaternary Research 64, p. 407-417. (Equatorial peatlands of Kutai lowland generally 4-10m thick, but some sections >16m thick. Deposition of peat started ~8000 yrs ago after flooding of basin by Mahakam River. Earliest vegetation is Pandanus swamp which grades upwards to dipterocarp-dominated swamp forest. Peatland expanded laterally and rivers maintained narrow levee-channels through swamp. Fires of 1982 and 1997 burnt up to 85% of vegetation)


Hutton, A., B. Daulay, Herudiyanto, C. Nas, A. Pujobroto and H. Sutarwan (1994)- Liptinite in Indonesian Tertiary coals. Energy Fuels 8, 6, p. 1469-1477. (Indonesian Tertiary coals similar compositions with vitrinite dominant maceral group. Most coals abundant secondary liptinite, especially exsudatinite but also fluorinite. Association of exsudatinite with oil suggests it is an indicator of early stage oil generation, and probably intermediate product in pathway vitrinite/ liptinite to oil. Where exsudatinite present in other rocks it should be termed bitumen)


(Tertiary coals found mainly in basins of W Indonesia, on continental crust of Sunda shield. Tectonostratigraphic settings include (1) syn-rift deposits, (2) post-rift Transgressive sequence and (3) 'syn-orogenic' Regressive sequence In E Indonesia lignite/ coal in West Papua syn-orogenic basins)


('Depositional framework of Tertiary coals in Indonesia')


(Overview of Indonesian Tertiary basin types and coal basins of Sumatra, Kalimantan, W Java and W Sulawesi. More detailed discussions of W Sumatra Ombilin Basin, S Sumatra Bukit Asam and E Kalimantan)


(Modern and ancient Cenozoic peat cycles commonly evolve from inundated wetland assemblages to more elevated and well-drained forest. Changing floral compositions result from changes in substrate wetness during peatland aggradation in high rainfall settings. Includes some discussion of SE Asian peatlands)


(Account of Medco S Sumatra work on Sekayu and Rambutan CBM projects)


(Most of Indonesia’s coalbed methane resources from low-rank coals and of biogenic origin, requiring different assessment than more mature strata. Macroporosity-permeability in low rank coal largely function of cleat spacing, which may vary with coal composition. High moisture content reduces gas holding capacity)


(Guidebook to 4-day fieldtrip in Paleo-Mahakam delta deposits around Samarinda-Batikapapan)


(On similarities between Indonesian and New Zealand low rank coal seam gas reservoirs)


(Study of SE Kalimantan Eocene coals required new procedures which relates megascopic appearance to petrographic character. Highest concentration and best preservation of plant parts in banded coal)


(Palynological study of 6 sediments cores from Holocene lowland peat swamp along Sebangau River near Palangkaraya, C Kalimantan. Peat formation started abruptly over freshwater topogenous swamp with common Graminae and Lycopodium. Local river patterns may have changed markedly during Holocene)

Morley, R.J. (2013) - Cenozoic ecological history of Southeast Asian peat mires based on comparison of coals with present day and Late Quaternary peats. J. Limnology 72, 2s, p. 36-59.
(Tropical peat swamps more widespread in Sundaland than any other equatorial region, with ombrotrophic, rheotrophic and brackish mangrove peat swamps. Cenozoic deposits from area rich in coals. Extensive brackish water peats formed M-L Eocene and M-L Miocene, often laterally very extensive. Rheotrophic peats formed widely through most of Cenozoic. Ombrotrophic kerapah type peats are first recognised in Late Oligocene. Kerapah peats sometimes developed great thickness. Basinal peats increased during Miocene. No convincing evidence for doming in Cenozoic peats has yet been noted)

(Brief review of coal seam geometries and coal sedimentology)


(Kalimantan coals wide variation in quality. Neogene coals generally low rank. Eocene coals locally high rank and of coking coal quality. Descriptions of coking coal deposits in N Barito (Buntok) and Upper Kutai (Muara Teweh) basins)

(Same paper as above?)


(Inorganic geochemistry of three domed ombrogenous peat deposits in Riau (Siak, Bengkalis peats) and W Kalimantan (Keramat peat). Mineral matter limited to small amounts from allogetic sources of dryfall, rainfall
and diffusion from substrate pore water. In interior of deposits much of mineral matter is authigenic. Ash yield (av. 1.1%) and sulfur content (av. 0.14%) generally low, but exceed 5% and 0.3% near base of deposits. Domed ombrogenous peat deposits will result in low ash and sulfur coal, even if marine rocks adjacent to coal)


(Study of peat swamp forest composition in upper Sungai Sebangau area, S of Palangkaraya, C Kalimantan. Peat thickness up to 10m. Radiometric age dating suggest young peat (~400- 1760 yr BP) overlying older peat (~6-10.3 ka))


(Review of SE Asia peatlands. Most AE Asia peatlands in low altitudes, and almost all domed/ ombrogenous. Geogenous peatlands confined to edges of coastal lagoons, banks and floodplains of rivers and margins of upland lakes. C Kalimantan peatland surface rel. flat: gradient (7.6m over 5500m). Ash in ombrogenous peats generally <1%. Most SE Asia peat deposits started to form around 4000- 5500 yr BP.; some Borneo peats older, up to 29,000 yr BP.)


(Peat accumulation rates in SE Asia studied peatlands average 1.3 mm/year, highside 4-6 mm/year)


(98% of Malaysian coal in Tertiary of Sarawak and Sabah. Quality ranges from lignite to anthracite, mainly bituminous coal. Summaries of Merit Pila and Mukah-Balingin coal fields, Sarawak, and Meliau coal, Sabah)


(online at: www.dwc.knaw.nl/DL/publications/PU00011853.pdf)
('On peat and swamps in the Netherlands Indies'. Swamp areas subdivided into: (1) regionally extensive coastal peat swamps of Sumatra and Borneo and (2) 'topogenous' raised mires on the plains of Java, Sumatra and mountains of Java, Sulawesi and Buru. Mainly on plant and pollen distributions)

('Peat research in the Netherlands Indies: an outline of the problems')

('Peat and peat exploitation in Indonesia'. Brief general overview with map of distribution of peat deposits in Indonesia)

(Brief review of peat distribution and peat types in Indonesia)


(Review of coal reserves, coal properties, production, transportation, etc. in Indonesia. Little or no geology)

(online at: www.ccop.or.th/download/pub/43as_ii.pdf)
(Recent studies identified approximately 450 TCF of prospective CBM resources in 11 onshore coal basins in Indonesia including S Sumatra, Kutai and Barito Basins)


(N Thailand Tertiary coal and oil deposits similar palynological associations to Borneo region. Oldest coal-oil deposits of Late Oligocene- E Miocene age and dominated by Botryococcus or related algae. Thick-walled lamaginites and temperate spores- pollen in some areas. Thin-walled lamaginite dominant in late M Miocene time. Resinite, suberinite, and cutinite dominant in forest swamp coals; alginate, cutinite and lycopodium spores dominant in lacustrine environments. Liptinite macerals can be major source of oil and gas)


('Petrology of coals from Sumatra and Kalimantan: types, ratings and applications')

Santoso, B. (2017)- Petrographic characteristics of selected Tertiary coals from Western Indonesia according to their geological aspects. Indonesian Mining J. 20, 1, p. 1-30.
(online at: http://jurnal.tekmira.esdm.go.id/index.php/imj/article/view/178/110)
(Tertiary coals from W Indonesia (Sumatra, Kalimantan, Java) similarities and differences. Coals dominated by vitrinite (detrovitrinite, telovitrinite), common liptinite (resinite, cutinite, suberinite) and rare inertinite (semifusinite, sclerotinite, inertodetrinite) and mineral matter. Differences reflect differences in climate and peat conditions. Vitrinite reflectance variations caused by variations in burial and effects of igneous intrusions)

(Indonesia coal reserves 36.6 billion tonnes. Economic coal resources mainly in Tertiary basins of Sumatra (67.4% of total) and Kalimantan (32.2%). Minor resources on Java (0.2%), Sulawesi (0.1%) and W Papua (0.2%). 59% of coal classified as lignite, 26.6% sub-bituminous, 14.4% bituminous and 0.4% anthracite)

(Three well drilling program for CBM evaluation in Late Miocene lignite- sub-bituminous coals of Muara Enim Fm indicates favourable gas content: average 3.55 m3/t (125.31 scf/t) at depth of 410- 812m)

(Modern peat deposits up to ~20m thick and will compact appreciably during burial, whereas coal beds can be 90m thick. Thick coal beds likely composed of multiple, stacked paleo-peat bodies. Three types of bounding surfaces seen in modern peat bodies can be used to distinguish individual paleo-peats in coal beds)


(online at: http://horizon.documentation.ird.fr/exl-doc/pleins_textes/pleins_textes_5/b_fdi_18-19/26068.pdf)
(Profiles of modern peat deposits in Sebangau valley (<1 to >3m thick) near Palangkaraya, S Central Kalimantan. Peat formation tied to podzolization led to decrease of microbiological activity, thus facilitating accumulation of non-decomposed organic matter, and to bad drainage)


Staub, J.R. & J.S. Esterle (1994)- Peat-accumulating depositional systems of Sarawak, East Malaysia. Sedimentary Geology 89, p. 91-106. (Sarawak prograding coastal depositional systems contain domed peat-accumulating environments in which low-ash, low-sulfur peats are deposited in areas of active siliciclastic sedimentation. Depositional systems up to 11,400 km² large, individual peat deposits >20m thick and 1000 km² in area. Basal high-ash, high-sulfur, degraded peats overlain by low-ash, low-sulfur, well preserved peats)


Supardi, A.D. Subekty & S.G. Neuzil (1993)- General geology and peat resources of the Siak Kanan and Bengkalis Island peat deposits, Sumatra, Indonesia. In: J.C. Cobb & C.B. Cecil (eds.) Modern and ancient coal-forming environments, Geol. Soc. America (GSA), Spec. Paper 286, p. 45-62. (Modern peat deposits cover 48,000 km² on lowlands of Riau Province, Sumatra. Two peat dome areas studied. Domes formed in last 5000 yrs, on flat surface, growing 4-5 mm/yr in first 1000 yrs, then 2 mm/yr for past 3500-4000 years. Low ash and sulfur content)


(Indonesia has abundant coal resources. Most coals thermally immature, but composed of hydrogen-rich organic components suitable for biogenic methane production. Gas isotope results from pilot wells in S Sumatra interpreted to indicate biogenic origins for methane)

(Review of coalbed methane potential of Indonesia. Most prospective basins in descending order: S. Sumatra, Barito, Kutai, C Sumatra, N Tarakan, Berau, Bengkulu, etc.)


(Good overview of modern peat formation and distribution in W Indonesia)

Van Diest, P.H. (1871)- De kolenrijkdom der Padangsche Bovenlanden en de mogelijkheden van de voordelige ontginning. Stemler, .Amsterdam, p. 1-76.
(online at: https://books.googleusercontent.com/books/.. )
('The coal resources of the Padang Highlands and the possibilities of profitable exploitation'. Historic economic evaluation of Ombilin coalfield in West Sumatra. Ombilin coals relatively high in carbon (79-80%) and low in ash (0.27-0.95%), Sulfur 0.34-0.87%)

Van Dijk, P. (1858)- Over de waarde van eenigen Nederlandsch-Indische koolsoorten. Natuurkundig Tijdschrift Nederlandsch-Indie 15, p. 139-158.
('On the value of some Indonesian coal types'. Brief discussion of coals SE Kalimantan, Bengkulu-Sumatra)

(online at: http://edepot.wur.nl/109967)
('Some observations on original peat bogs in Indonesia for comparison with the Holland-Utrecht peat area')

('Our colonial mining industry, III, the coal industry'. Popular 1917 booklet on coal mining industry in Indonesia)


(online at: www.geog.le.ac.uk/carbopeat/media/pdf/yogypapers/p2.pdf)

(online at: https://ijog.geologi.esdm.go.id/index.php/IJOG/article/view/289/260)
('Critical study of the known coal occurrences on Java')

(Lateral variations in Plaie peat forest W of Samarahan, Sarawak. Peat thickness 0.2-2.3m, increasing to W)
XI.4. Minerals, Mining

(Many additional references on minerals/mining that are specific to one region are listed under these regions)


('Volcanogenic Massive Sulphide deposits: characteristics and distribution in Indonesia'. Reprinted in Metalogeni Sundaland I (2014), p. 263-273. Polymetallic Massive Sulfide deposits always associated with volcanics and sediments. VMS deposits in Indonesia two types (1) Kuroko-type Sangkaropi (S Sulawesi, Cu-Pb-Zn), (2) Lerokis and KaliKuning (Wetar), with stratabound Au-Ag bodies of sedimentary exhalative origin)


(Radioactive minerals found in several areas in W and E Indonesia)


('Occurrences and application of manganese ores'. Review of manganese ores in Indonesia)


('Phosphate'. Brief review of phosphate occurrences in Indonesia. Usually associated with bat caves. No commercially significant deposits)


('Iron ores in the Netherlands Indies')


('Iodine'. Review of iodine occurrences in Indonesia, mainly from wells in Tertiary basins of East Java, north of the volcanic arc)


('Bauxite exploitation of the Netherlands Indies Bauxite Exploitation Company on Bintan'. Brief history of exploitation of bauxite in SE Bintan island, which started in 1935, continued during Japanese occupation, then resumed in 1947. Bauxite believed to have formed from lateritic weathering of hornfels (Van Bemmelen 1940))


(Regional stream sediment surveys combined with radiometric measurements carried out over large areas in C Sumatera, but results disappointing. In NE Thailand more favourable conditions in Tertiary sandstone basins)

(The mineral riches of the Netherlands East Indies' First countrywide review of mineral occurrences in Indonesia, including oil, coal, tin, iron, diamonds, etc.)


(online at: https://d28rz98at9fks.cloudfront.net/81527/Jou1998_v17_n4_p097.pdf) 
(Porphyry copper-gold deposits in PNG (Panguna, Wafi, Ok Tedi), W Papua (Grasberg), Sumbawa (Batu Hijau), Philippines, generally associated with andesitic volcanics and diorite to quartz diorite intrusions. Cu-Au porphyries generally in island arc tectonic setting, Cu-Mo porphyries in continental margin or cratonic settings. Some deposits localized at fault intersections (Grasberg, Batu Hijau). Depth of emplacement ~1-2 km; mineralization may extend 1.5 km vertically (Grasberg). Many formed in island arcs after period of reversal in arc polarity)

(Mainly summary of Uranium deposits in Kalan Region, W-C Kalimantan, explored in 1970’s by CEA- BATAN. U deposits hosted by Paleozoic meta-sediments and meta-volcanics)

(‘On the occurrence of sulfur and natural sulfur minerals in Netherlands Indies’. Brief review of sulfur occurrences associated with Quaternary volcanoes of Indonesia)

(‘Investigations into potentially mineable quantities of sulphur in craters of volcanoes in the Netherlands East Indies Archipelago’. Reviews of sulfur deposits on volcanoes on Java (Kawah Putih, Tangkuban Perahu, Ciremai, Dieng), Sumatra (Tapanuli residency), Sulawesi (N Sulawesi, Una-Una) and Flores)


(‘Minerals of Indonesia’. Listings of occurrences of 4 precious metals, 6 ferrous metals 7 non-ferrous metals, coal, and 30 industrial minerals. Published by Indonesian Department of Mines).

(Brief review of sediment-hosted Pb-Zn-Ag in Indonesia at Kelapa Kampit (Belitung). Also identified in 1997 at Sopokomil, N Sumatra)

(Broad overview of Indonesia mineral resource assessment)

(Nickel laterites are products of intense weathering in humid climate of Mg-rich or ultramafic rocks which have primary Ni contents of 0.2-0.4%. Over 50% of global resources of nickel laterites in New Caledonia, Indonesia, the Philippines and Papua New Guinea)

(online at: www.bgl.esdm.go.id/publication/index.php/dir/article_detail/412)  
(Indonesian chromite deposits widely distributed in E Indonesia and result of weathering of ophiolite rocks in SE Kalimantan, Sulawesi, Maluku, Halmahera, Gebe, Gag, Waigeo, and Papua)

(Different types and (Tertiary) ages of bentonite deposits present across Java, mainly formed by devitrification of glassy tuffs/ash)


(Gold- copper deposits in SE Asia and W Pacific mainly in Neogene (25-1 Ma) magmatic arcs, and mainly in porphyry and epithermal deposits. Region contains >160 deposits, including porphyry, skarn, epithermal, volcanic-associated massive sulfide, disseminated sediment-hosted and other mineralization styles)

(Similar to Garwin 2013, above)

(online at: www.nzpam.govt.nz/cms/pdf-library/minerals/conferences-1/098_papers_60.pdf)  
(Summary of research project on characteristics of hydrothermal alteration associated with low sulfidation, gold-silver epithermal deposits. Deposits investigated were Ladolam (PNG, Pleistocene), Gosowong (Halmahera, Pliocene mineralization in Miocene andesitic rocks) and Mt Muro (Miocene mineralization in Oligocene andesitic rocks))

Bibliography of Indonesia Geology, Ed. 7.0

(online at: https://pubs.usgs.gov/cp/46/plate-1.pdf)

(online at: http://pubs.usgs.gov/cp/46/report.pdf)
(see also Palfreyman et al. 1996 for SW Quadrant))

(online at: http://pubs.usgs.gov/sir/2010/5090/d/sir2010-5090d_text.pdf)
(Regional review of volcanic and magmatic arc systems of SE Asia, known porphyry copper occurrences and probabilistic assessment of areas with potential porphyry copper resources. Estimate of undiscovered copper resources in study area (~288 Mt) is ~3.5 times amount of copper in identified resources (84 Mt))

('Metallogenic map of Indonesia'. 1: 5M scale map of mineral deposits and mineralization zones of Indonesia)

('Metallogeny of Sundaland, vol. I'. Reprint collection of scientific papers by Prof. Dr. H.Z. Abidin from 1987-2012)

('Metallogeny of Sundaland, vol. II'. Second reprint collection of scientific papers by Prof. Dr. H.Z. Abidin from 1994-2005)

(In Indonesia REE minerals monazite, xenotime and zircon are associated with tin, uranium and gold in alluvial deposits. REE range from 30-400 ppm in sands on Bangka and Belitung REE minerals, and are by-product of tin ore mining and extraction. Also: lower grade monazite and xenotime as alluvial in Kampar and Riau Islands, REE minerals in uranium alluvial in W Kalimantan)

(Brief overview of distributions of offshore hydrocarbons, tin, chromite, iron sand, manganese nodules, etc. Not much detail)

(Brief review of mineral occurrences and production in Indonesia: tin (Bangka, Belitung, Karimata Islands?), bauxite (W Kalimantan), nickel (SE Sulawesi), gold, silver, manganese, iron sand (S Java, W Sumatra), copper (W Papua))


(Brief review of offshore cassiterite placer deposits of Burma, W Peninsular Thailand, W Malaysia and Indonesian tin islands Singkep, Bangka, Billiton)
(SE Asian Tin Province stretches for ~1800 miles from mainland Burma and NW Thailand to Tin Islands of Indonesia. E and W belts granites of several distinct ages and types, associated with different primary tin deposits)


Hosking, K.F.G. (1982)- The nature and significance of the pleochroism of the cassiterites of the Southeast Asian Tin Belt. In: Ore Genesis, Soc. Geology Applied to Mineral Deposits, Spec. Publ. 2, Springer, p. 753-759. (Tin belt of SE Asia composed of two parallel E and W belts, with primary tin deposits of different ages and types in each. Intensely red-pale cassiterites with Ta and possibly Nb in lattice, restricted to W belt and are paramagnetic; brown-pale colour pleochroic (also due to Nb/Ta or W in lattice) in both belts and may be ferromagnetic. Tin sources in both belts crustal, in W belt comparatively rich in Ta and Nb, E belt rel. rich in iron)


Hovig, P. (1918)- Contactmetamorfe ijzerertsafzettingen in Nederlands-Indie. Natuurkundig Tijdschrift Nederlandsch-Indie 77, 1, p. 71-104. (online at: http://62.41.28.253/cgi-bin/..) ('Contactmetamorphic iron ore deposits in the Netherlands Indies'. Investigation of two contact metamorphic iron deposits: (1) C Sulawesi (Salo-Talimbangan, 12 km NW of Rante Pao) and (2) S Sumatra Bukit Rajah. No maps or figures)

Hovig, P. (1920)- De ertsafzettingen van Nederlandsch Indie. In: Algemeen Ingenieurs Congres, Batavia 1920, sect. 5, Mijnbouw en Geologie, Mededeeling 1, p. 1-60. ('The ore deposits of the Netherlands Indies'. Old review of occurrences of iron, manganese, gold-silver, copper, tin, etc. No figures, maps)

Hovig, P. (1923)- 's Lands mijnbedrijven. Vereeniging voor Studie van koloniaal maatschappelijke vraagstukken 15, Kolff, Weltevreden, p. 1-89. ('The country's mining enterprises'. Booklet on Netherlands Indies mining companies, mainly on coal mines and mainly on the business side of the industry, with little or no geological information. Author is pessimistic about profitability of government-operated coal mines, but these are important for strategic reasons)

Hutchison, C.S. (1978)- The impurities of Southeast Asian tin ore concentrates. Warta Geologi 4, 2, p. 39-44. (online at: https://gsmpubl.files.wordpress.com/2014/09/ngsm1978002.pdf) (Review of 'impurities' in tin ore concentrates from smelters in W Malay Peninsula, SW Thailand and Bangka-Belitung, Indonesia. Tin concentrate generally of cassiterite with 70-75% Sn content)

Hutchison, C.S. (1988)- The tin metallogenic provinces of S.E. Asia and China: a Gondwanaland inheritance. In: C.S. Hutchison (ed.) Geology of tin deposits in Asia and the Pacific, Selected papers from Int. Symp. Geology of tin deposits, Nanning, China, 1984, Springer Verlag, p. 225-234. (SE Asia is composite of stable continental blocks which rifted from N margin of Australia. Tin was carried in continental infrastructure of these blocks, which are all of Gondwanaland ancestry. Tectonic events which have
greatest continental crustal involvement are most important in mobilizing tin into economic concentrations. Main metallogenic events are Malayan-type collisions between two continental blocks, resulting in crustal thickening and S-type granite batholiths: (1) Mesozoic belt formed by collision of Sinoburmalaya, Burma Plate, Qantang-Tangla, and Lhasa-Gandise blocks with E Asian Continent, (2) Caledonian E China belt)


(Primary tin deposits overwhelmingly associated with acid igneous or quartz-rich hydrothermal rocks; genetically related to granites. Distribution of tin deposits suggests anatexis of sialic crust most likely cause of evolved SiO2 and K2O rich tin granites. Tin commonly associated with high sphene and biotite)


(Discussion of massive base metal sulphide deposits, which formed on sea floor by chemical precipitation from metalliferous hydrothermal fluids. Many geological characteristics of massive base metal sulphides duplicated in barite, manganese, iron-tin, iron skarn and base metal deposits of C and E belts in Peninsula Malaysia (Sokor, Bukit Besi, Bukit Bangkong, Tasek Cini) and extensions N into Thailand (Pinyok) and S into Indonesia (stratiform zinc-lead-silver at Kelapa Kampit and Selumar, Belitung))


('Review of gold deposits in ophiolite complexes in Indonesia'. On little-known gold occurrences in Bobaris and Meratus Mts in S Kalimantan, Tanah Grogot in E Kalimantan, Bombana in SE Sulawesi and CycloopsMts/Lake Sentani in NE West Papua. No commercial occurrences identified yet)


('Rare Earth Elements in tailings from tin mining on Singkep Island'. Tailings of former tin mines on Singkep island (probably also on Bangka, Belitung) contain 123-368 ppm Rare Earth Elements (REE) in monazite, etc. In concentrate up to 5800 ppm)

Jackson, K.J. & H.C. Helgeson (1985)- Chemical and thermodynamic constraints on the hydrothermal transport and deposition of tin: II. Interpretation of phase relations in the Southeast Asian tin belt. Economic Geology 80, p. 1365-1378.

(On Thailand- Malay Peninsula tin deposits. Hydrothermal mineral assemblages in SE Asian tin deposits consist of quartz, cassiterite, muscovite, K-feldspar, topaz, magnetite, and rarely, hematite, fluorite, tourmaline, and zinnwaldite. Assemblage estimate to have formed at ~350°C and 500 bars)


(Indonesia potential for yttrium group REE mainly in xenotime from cassiterite placers in Tin Islands, particularly Belitung, and likely equivalents in Tigapuluh Mts and Bangkinang areas of Riau, Sumatra. Areas with (mainly pre-Jurassic) granitic intrusions with favorable characteristics for lithophile rare metal mineralization mainly in Sumatra, Banggai-Sula islands and W Papua)


(Ultramafic rocks exposed in many parts of Indonesia. May be source of Fe, Cr, Platinum-Group Minerals, V, Ti, Ni, Co and Cu deposits)


(Brief review of Indonesia petroleum and mineral deposits)


('The tin, niobium and tantalum deposits of SE Asia')


(Indonesian offshore minerals tin and iron sand already exploited. Recent data on offshore gold, silver, quartz sand, coal and zircon discovered by Marine Geological Institute expected to become future reserves. Offshore aggregates in Java Sea and Malaka Strait potential construction materials)


(online at: http://jurnal.tekmira.esdm.go.id/index.php/imj/article/view/611/473)

(Review of coastal iron sand deposits in Indonesia. Black or gray iron sands in Sumatra, Java, Bali and Nusatenggara Islands largely derived from denudation of andesite and 'Old Andesite Fm' enriched in magnetite and ilmenite minerals. Coastal zones, especially S parts of Neogene Sunda Banda magmatic arc from N Sumatra to E Indonesia, potential areas for iron sand deposits)


(Miyamoto, H. (1943)- Mineral resources of Lesser Sunda and Molucca islands. J. Geography, Tokyo, 55, 7, p. 229-236. (online at: www.jstage.jst.go.jp/article/geography1889/55/7/55_7_229/_pdf) (In Japanese. Mainly literature review. No maps or sections)

(Mohr, E.C.J. (1934)- Diatomeeenarde (kieselgur) in Ned.-Indie. De Indische Mercuur, 26 December 1934, p. 3-15. ('Diatomaceous earth in Netherlands Indies'. Very brief review of diatomite occurrences in Indonesia, incl. Samosir (Lake Toba) and Cirebon, Cicurug areas of Java)

(Molengraaff, G.A.F. (1910)- Das Vorkommen und die Gewinnung von Eisenerz in den Niederlandischen Kolonien. In: The iron ore resources of the world, 11th Int. Geol. Congress, Stockholm 1910, 2, p. 993-996. (online at: https://babel.hathitrust.org/cgi/pt?id=nyu.33433089972370;view=1up;seq=489) ('The occurrence and exploitation of iron ore in the Netherlands colonies'. Very brief listing of known iron ore occurrences in Indonesia: Gunung Besi (Sumatra; hematite), Teluk Betung (S Sumatra; magnetite), Banyumas (Java; iron sand) Gunung Tambaga (SE Kalimantan; hematite). None producing. All of questionable commercial value)

(Muller, D. & D.I. Groves (2015)- Direct associations between potassic igneous rocks and gold-copper deposits in volcanic arcs. In: Potassic igneous rocks and associated gold-copper mineralization, 4th Ed., Mineral Resource Reviews, Springer, p. 97-190. (Examples of direct associations between potassic igneous rocks and copper-gold deposits include: (1) Late Oceanic Arc associations: Ladolam gold (Quaternary, Lihir Island, PNG); Emperor gold (Tertiary, Viti Levu, Fiji), Dinkidi copper-gold (Miocene, Didipio district, Philippines); and (2) Post-collisional Arc associations: Grasberg copper-gold (Pliocene, W Papua), Misima gold (Pliocene, Misima Island, PNG); Porgera gold (Miocene, PNG))
(online at: https://pubs.usgs.gov/cp/42/plate-1.pdf)

(online at: http://pubs.usgs.gov/cp/42/report.pdf)

(Brief overview of distribution of porphyry copper deposits in SE Asia. No figures)

(Oversight of mineral deposits in SE Asia (China, India, Indonesia)- Pacific (Japan, Australia, New Zealand)


(Brief review of Indonesian mineral provinces. Malaya orogen (Late Jurassic) characterized by cassiterite-bearing pegmatites and veins. Pyrosomatic iron and copper ores tied to Sumatra orogen (U Cretaceous). Epithermal gold-silver important in Sunda orogen (M Miocene) in W Sumatra and S Mountains of Java. West Papua separate unit, with lateritic deposits in N and gold-silver-copper in C Range)

(Mainland SE Asian metallogeny related to history of accretion of Gondwanan terranes. Late Carboniferous-Triassic development and accretion of arc/ back-arc belts fringing Indochina block important metallogenic period in SE Asia. IndoSinian orogenic gold in Raub-Bentong zone of Malaysia. Late Triassic first phase of SE Asian tin-tungsten belt, related to IndoSinian late orogenic granites. Re-initiation of subduction outboard of collision zones along W Sibumasu margin and E Indochina-South China margin in Late Triassic- Jurassic. In S China- Indochina, Jurassic-Cretaceous ‘Yanshanian’ magmatism evolved from I-type to A-type in continental arc setting and associated with mineral systems. On W Sibumasu margin, Late Cretaceous second phase of tin-tungsten mineralisation associated with A-type magmatism. Porphyry copper-gold and epithermal systems in C Myanmar arc belt in Oligocene- Miocene)

(online at: http://jurnal.tekmira.esdm.go.id/index.php/imj/article/view/590/452)
(Indonesia iron resources include (1) primary iron ore (hematite, magnetite; 17%), (2) iron sand; commonly used for cement industries (8%) and (3) lateritic iron ore (limonite, from weathered ultrabasic rocks) used as coal liquefaction catalyst (75%). With listings of main iron sand deposits (10) and lateritic deposits (10) and primary iron ore deposits (10))

(online at: https://pubs.usgs.gov/bul/1301/report.pdf)
(Rare Earth Elements ore deposit types in SE Asia mainly placer and ion adsorption (weathered granite) types. Placer monazite and xenotime mostly in ilmenite-series granite areas of SE Asian Sn Belt. Few prospective areas identified in Indonesia, except possibly Bangka, with possible placer REE from tailings of Sn processing or from beach sand)

(Rare Earth Element in mainland SE Asia (nothing in Indonesia))

(In Japanese. Mainly literature compilation of 'Tin Islands' geology)

(Study of REE potential in Indonesia. Prospectivity in areas of continental crust, where multiple events of granitoid magmatism took place. Tin Islands and West Kalimantan granitoids may be linked. REE exploration targets in Indonesia: (1) primary alkaline-peralkaline igneous rocks, (2) lateritic deposits, and (3) placer monazite (xenotime; byproducts of placer tin mining))

(REE most likely associated with Mesozoic granitic rocks in W Indonesian, i.e. Tin islands (Bangka, Belitung, Bintan and Singkep) and west C Kalimantan. Tin islands similar geology with REE-producing China and SE Asia granite belts)


(Indonesia has range of precious and base metal deposits typical of Cenozoic volcano-plutonic arcs. Porphyry Cu-Au, skarn Cu-Au and low-sulphidation epithermal Au economically most important, including world-class ore bodies. Also present: porphyry Mo, sediment-hosted Au, high-sulphidation epithermal Au and volcanogenic massive sulphide Au. 70% of deposits discovered by regional geochemical surveys)

(Includes data from Indonesia-Philippines porphyry copper deposits. Grasberg, Ok Tedi and Porgera in New Guinea, Ladolam and Panguna in nearby islands and Baguio in N Philippines all very young and emplaced during rapid tectonic uplift induced by collision processes)

(Review of 101 case histories of metal deposits discovered in Circum-Pacific region in last 40 years)


(Tertiary-Quaternary porphyry copper-gold deposits of SW Pacific rim (Luzon, New Guinea, Bougainville, Guadalcanal, Fiji) mostly formed after reversal of arc polarity. Where this reversal has not occurred (New Zealand and Japan), porphyry copper-gold deposits absent or scarce. Gold enrichment of magmas may be result of two-stage melting)

('The strategic commodity chromite, geology technology and its potential in Indonesia'. Chromite known from several areas in Indonesia (associated with peridotites): SE Kalimantan, Latau, Barru, Malili, Halmahera, Gebe. Small scale mining in Gebe in 1970's, but most deposits in Indonesia non-commercial at the moment)

(Iron ore deposits widespread in Sumatra and Kalimantan, but little explored. 'Banded' iron ore deposits probably related to Mesozoic submarine hydrothermal activity described from Subullusalam (Aceh, N Sumatra), Tanggamus (Lampung, S Sumatra), Kendawangan (W Kalimantan; ore mined from late Mesozoic Pinoh meta-sedimentary complexes), and Balaisebut iron ore mineralization (NE of Pontianak, NW Kalimantan, in Sanggau area))

(Widespread epithermal gold deposits associated with subduction volcanism in Indonesia. Gold production from 1899-1989 130 tonnes: 80 from Bengkulu (W Sumatra), 10 from Cikotok (W Java), 20 from N Sulawesi) + additional production from Kalimantan and West Papua)

(Same paper as Sunarya 1989. Gold mining in Indonesia began in 1899. Early mining from epithermal lode deposits hosted by volcanics in W Sumatra and W Java, with subsequent discoveries in Kalimantan (Kelian, Mt Muro, Muyuo, etc.) and on Flores-Wetar. Porphyry copper- associated gold in Ertsberg (Irian Jaya), N Sulawesi and Bacan. Alluvial gold exploited on Sumatra, Kalimantan and Sulawesi)


(Exploration for tin deposits has been ongoing in Indonesia over ~300 years. Indonesia is part of tin belt from Myanmar in N through Malaysia to Singkep, Bangka and Belitung islands in Indonesia in S. Discovery of alluvial tin deposits becoming harder as obvious geological targets are exhausted and topographical conditions become more difficult)


(REE Regions in Indonesia with potential REE resources in Bangka Belitung, Kalimantan and W Sulawesi)


(online at: www.bgl.esdm.go.id/publication/index.php/dir/article_detail/682)

(Indonesia has beach placer, alluvial and lateritic types of titanium deposits. Sumatra, Java and Flores with beach placers of iron sands, derived from Tertiary volcanics. Alluvial deposits associated with cassiterite alluvial from Triassic-Jurassic granites of Bangka-Belitung Islands. Lateritic deposits associated with bauxite and nickel in Riau, Kalimantan, Sumatra ad Sulawesi)


(Using vegetation anomalies on satellite imagery to target nickel laterites)


(Overview of mineral deposits in Indonesia as known during WW-II)


(Reprint of Ter Braake (1944))


('Diatomaceous earth in Indonesia')


('Bauxite in Netherlands Indies'. Lateritic weathering of probably basic igneous rocks lead to formation of bauxite. Occurrences in Indonesia on islands of Banka and Bintan)


('Minerals from the Netherlands Indies as raw materials for local industry'. A brief review)


Bibliography of Indonesia Geology, Ed. 7.0 www.vangorselslist.com July 2018
(N Flores and Timor with many scattered occurrences of manganese)

(online at: http://jgsm.geologi.esdm.go.id/index.php/JGSM/article/view/82/123)
('Characteristics of red jasper in S Java based on SEM and XRF analysis'. Red, yellow and green jasper widespread in Indonesia. Red jasper most common, especially in S Mountains of Java. All S Java samples same cryptocrystalline texture. Red color from Fe, Cr, and V. High Ti content in Pacitan red jasper)

('The mineral wealth of the Netherlands East Indies and the future mining politics there'. Early review of mineral potential of Indonesia. Argues that potential is limited to orogenic belts. Gold-silver deposits found only in areas with Late Tertiary acid volcanics, tin in Paleozoic granites, etc.)

(Sulfur deposits in Indonesia are of volcanic origin. Pure sulphur produced from sublimation of volcanic gases from solfatara fields in extinct and active volcanic regions. Crater lakes contain sulfuric mud with >40% sulfur. Potential crater deposits in Sumatra (Namora Langit, Sorik Merapi), Java (Kawah Putih, Telaga Bodas, Tangkuban Perahu, Kawah Karaha, Siterus, Idjen) and N Sulawesi (Mahawu, Telaga Masem))

(Review of platinum-group mineral occurrences in Indonesia. Generally in placer deposits derived from ultramafic rocks. Main occurrences in SE Kalimantan (placers in front Meratus Range). Traces of platinum-group in N Sumatra (Woyla River), C Sumatra (Bengkalis, Riau), South Java (Cilacap, Jampang Kulon), S Sulawesi)