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History of geoscientific investigations in West Kalimantan, Indonesia

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The first reliable geological data from journeys by Europeans into the interior of Kalimantan between 1816 and 1850 came from Schwaner. Dedicated geological investigations started in 1850 with the establishment of a Mines Department (Mijnwezen), which sent the geologist Everwijn on eight trips (1853—1857) to check reported mineral occurrences and prepare geological maps and reports. Results were discouraging. In 1879, a 20 year period of mineral investigations and geological mapping was initiated by van Schelle and continued by Wing Easton. It covered the south Sambas, Singkawang, and western Sanggau Quadrangles. Posewitz in 1892 published an English translation of his review of work done since 1826. In 1883-1884, the eastern region of West Kalimantan was for the first time geologically reconnoitred by a private expedition led by Molengraaff. After Wing Easton's departure in about 1900, there was a hiatus in field work, though several consolidating reviews were published. From 1923 to 1932, another systematic mapping project covered most of West Kalimantan, resulting in reports on the eastern and western regions. Geological and mining activities were reduced during and after World War II. New legislation in 1967 promoted foreign investment, leading to regional searches for various minerals and increased geological research. Since 1972 several countries including Australia have undertaken mapping projects jointly with Indonesian government departments, using a wide range of survey methods.

Introduction

A joint venture between the Department of Mines and Energy of Indonesia and the Australian International Development Assistance Bureau (AIDAB) undertook systematic regional mapping of West Kalimantan in the 1980s. This work, the Indonesia-Australia Geological Mapping Project (IAGMP), was carried out by the Geological Research and Development Centre, Indonesia (GRDC) in cooperation with the Australian Geological Survey Organisation (AGSO, then the Bureau of Mineral Resources), from 1983 to the end of 1989. The results have been prolific: more than fifty published and unpublished records, reports, maps, explanatory notes, and journal papers have been produced (Bladon & De Keyser, 1989). The present paper is a somewhat different kind of contribution to the knowledge of West Kalimantan.

In a country like Indonesia, where most pre-World War II literature is in Dutch (and some in German and French), access to information is denied to most English-speaking workers, and even to the younger Indonesian geologists. This paper therefore provides an overview of the history of geoscientific investigations in West Kalimantan, especially the pre-World War II investigations (Figs 1,2), to redress access and language problems with the older literature. Mineral occurrences are not reviewed here, but they are dealt with in individual IAGMP Data Records.

Some highlights of our research for this paper include the rediscovery of the original thin-section collections examined by Gisolf and van Bemmelen (1939), van Bemmelen's large scale sampling locality maps, and details of a forgotten multi-level underground mine.

History to 1816

Gold was known to occur in West Kalimantan as early as the Hindu period, from about the eighth century AD. Princely envoys from the Sambas/Landak states, dressed in clothes woven of gold wire, apparently carried gifts of gold to the Emperor of China in 977 AD and 1406 AD (Posewitz,1892). After the 13th century, the first Chinese began to enter West Kalimantan, but it was not until the 18th century that, attracted by diamonds and gold, they began to immigrate in great numbers from southern China, settling in the Sambas and Landak regions. They were not given official mining rights until 1760 AD when the Prince of Mempawah allowed his goldfields to be worked by the Chinese. Soon afterwards they seem also to have taken over the gold workings and surrounding territory of the Sultan of Sambas, which led to clashes with the Dayaks and coastal Malay inhabitants. The first large Chinese settlements were at Montrado and Larah; between 1775 and 1780 the Chinese expanded their activities to the Mandor area. They introduced systematic alluvial working practices, and also began working vein deposits to limited depth. Since diamonds were an even more important export product, much sought after by the Dutch East Indies Trading Company, the Chinese worked the alluvial diamond fields of Landak from the early 1800s to the early 1820s, after which production declined.

The first European contact with West Kalimantan was made by the Dutch East Indies Trading Company, formed in 1602, which started trading along the shores of Borneo in 1606, establishing trading posts in Landak and at Sukadana. Although the company charted the island's coast line, they jealously guarded their trading sources and secrets, and actively discouraged exploration of the unknown inland regions by banning travel into the interior and treating the preparation of maps and charts as a criminal offence. This barren period lasted until the company's dissolution in 1789.

European reconnaissance

During the Napoleonic wars, the Indonesian territories were occupied by the British government under Governor Sir Stamford Raffles from 1811 to about 1816, after which the Dutch started to regain their influence in Kalimantan. The Dutch government then began efforts to improve the general knowledge of the Indonesian Archipelago, including its geography, ethnography, biology, and geology. A 'Commission of Natural Sciences' was established. From 1816 to 1850, scientists of various nationalities came to Indonesia on a wave of idealism and enthusiasm. The earliest expeditions were to Kalimantan, because of its rumoured mineral wealth and potential.

Results of these expeditions were mixed. Many of the young investigators succumbed to tropical illnesses, or died in accidents or in armed attacks. Indonesia was then still largely covered by dense tropical rainforest, and the lack of local knowledge, and difficulties of access, communications and transport, all severely hampered the explorers.

At about the same time, the country was reconnoitred and traversed by many administrative officers. Although these did not contribute much to geological knowledge, they accumulated a wealth of data and prepared topographical maps and sketches.

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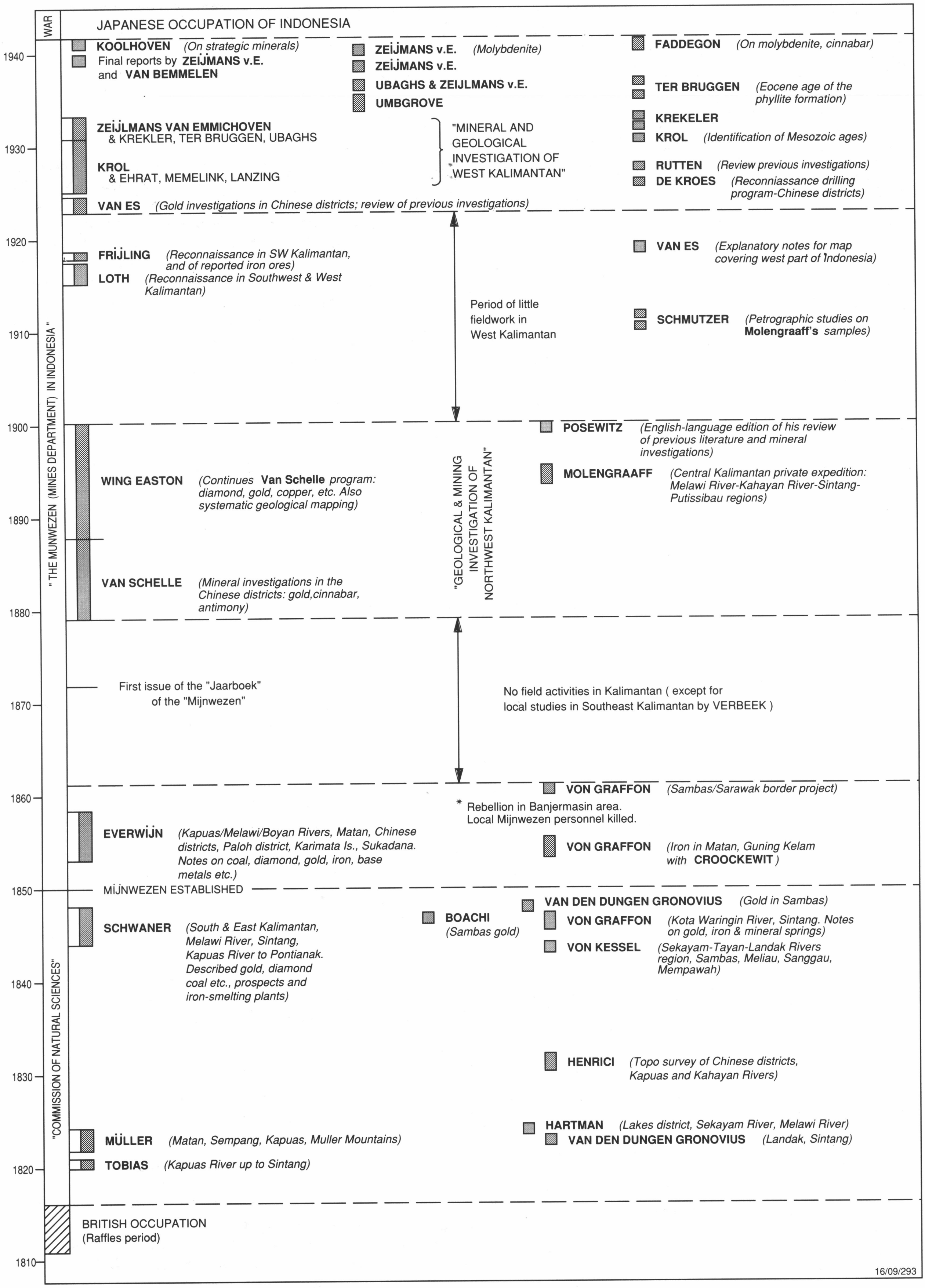

Figure 1. Chronology of pre-World War II investigations in West Kalimantan.

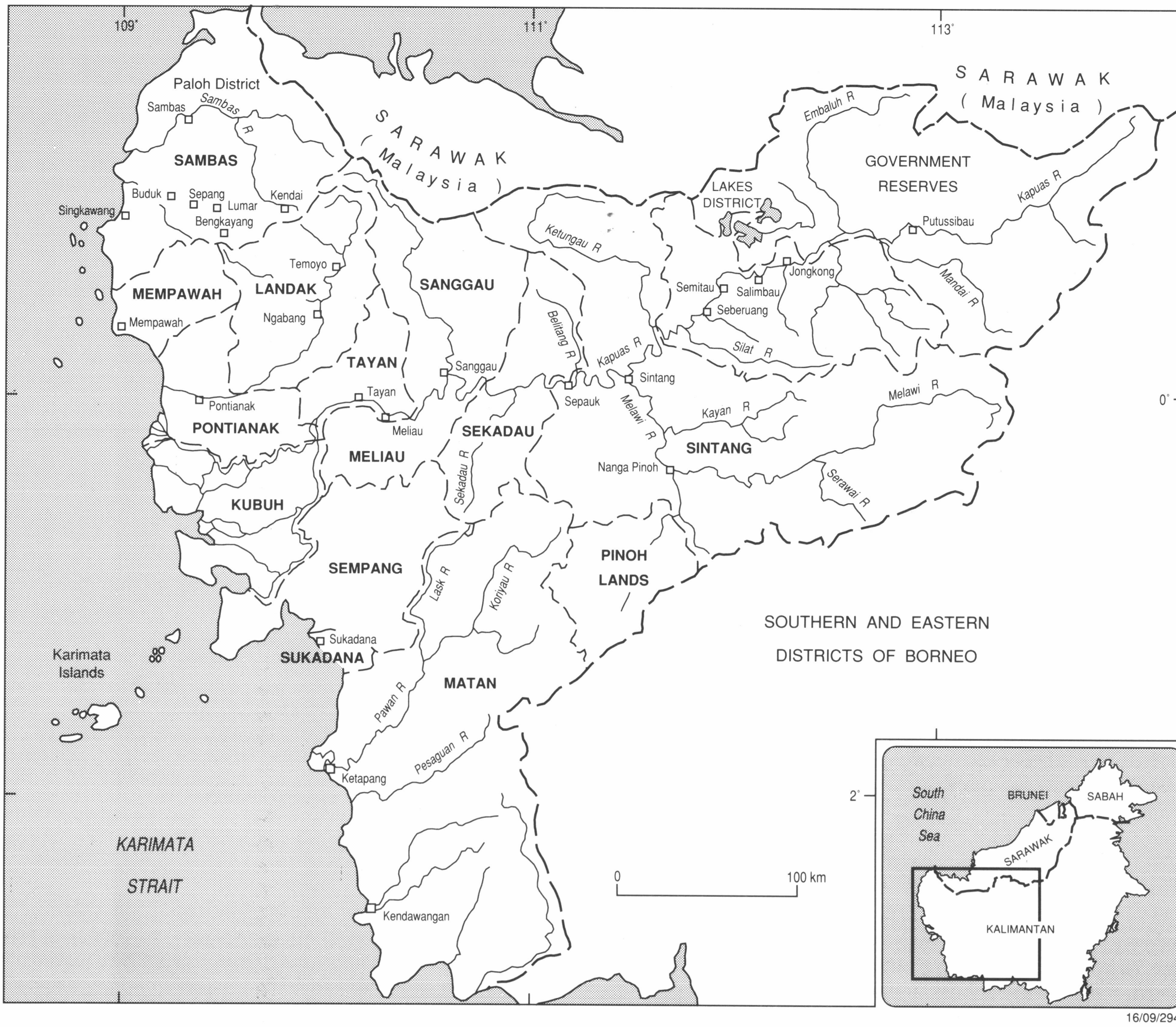

Figure 2. Pre-World War II administrative districts of West Kalimantan.

Commission of Natural Sciences

The most important explorer at that time was Dr. C.H. Schwaner, a German member of the Commission of Natural Sciences, and one of the few with a geological background. Between 1844 and 1847 his travels took in the Martapura River (where he discovered coal deposits), the south coast of Kalimantan, the Barito River, and the crossing of the watershed between the Barito and Mahakam Rivers. He travelled up the Kahayan and Katingan Rivers, crossed the divide between South and West Kalimantan (old Dutch divisions), and via the Melawi River arrived at Sintang, whence he continued down the Kapuas River to Pontianak. He died in 1851 from tropical fevers.

His geological work included the discovery of many Tertiary coal deposits, the description of gold and diamond panning activities and of iron-smelting works by the dayaks, and the recognition of extensive Tertiary formation as well as a very large granite batholith in the Katingan area. Fortunately, his valuable reports were saved and posthumously published (Schwaner, 1853, 1854).

Another member of the Commission of Natural Sciences, the German H. von Gaffron, initially accompanied Schwaner as a draftsman. Though Schwaner is usually credited as the first European traveller to cross from South to West Kalimantan, von Gaffron had already done so via Kotawaringin, the Lamandau River to its origin, and then by the Pinoh and Melawi rivers to Sintang.

In 1846 von Gaffron was commissioned to explore the unknown western part of South Kalimantan for coal. This work brought him also to the old district of Matan, which covers most of the KETAPANG Sheet area. Here he prepared a map of all 'known' and suspected mineral occurrences. Von Gaffron (1853) was the first to report on 'extensive' iron ore in the Kotawaringin district of TUMBANG MANJUL[3].

In 1854 he was appointed 'Assistent Resident' based in Sintang, and made several journeys on the Kapuas River and some of its tributaries. His last job in Kalimantan, in 1859, was a secret mission mapping the boundary between SAMBAS and Sarawak. Von Gaffron had a long and adventurous career. However, he was not much of a geologist, and published a note on a 'famous giant diamond' in Matan which was later found to be just a piece of a large quartz crystal.

[3] Capitalised area names refer to 1: 250 000 Quadrangle areas.

Trips by Administrative officers: Tobias, Hartman, Müller, von Kessel, Henrici, van den Dungen Gronovius

The first European to travel up the Kapuas River was J. H. Tobias, who reached Sintang in 1820, making a map on the way. In 1822, D. J. van den Dungen Gronovius made a topographical sketch map of the Landak region, and also reached Sintang. In 1823 Hartmann, too, journeyed up the Kapuas River as far as the Lakes district and the Jongkong tributary. On a second trip he reached Merenkiang (Mengkiang) on the Sekayam River, and travelled up the Melawi River to its junction with the Kayan River.

In 1822 G. Müller became Inspector of the Interior Provinces, and undertook a number of topographical surveys, starting in the districts of Sempang (Simpang), Matan and Sukadana. He apparently reported the possible presence of tin in the region. (This error was perpetuated by von Gaffron in 1845 in his map of known or suspected mineral occurrences). In 1823 Müller mapped the west coast from Sambas up to Cape Datuh (Datu) and the Rajang (Redjang) River in Sarawak, where the hostile attitude of the locals induced him to return to Sambas. He then travelled up the Kapuas River, making topographical sketch maps on the way. He mapped the Lakes district, and reached the Sibau River. In 1824 he attempted to cross Kalimantan from east to west, and was the first European to cross the boundary between East and West Kalimantan. He was murdered on the Bungan River by Punan dayaks (Rutten, 1927), and his notes were lost.

From 1830 to 1831, A. H. Henrici made a topographical survey of the gold-rich Chinese Districts, which extended from southern SAMBAS to SINGKAWANG, the Landak region, and the northwestern corner of NANGATAMAN. He also prepared a large, 16 sheet topographic map of West Kalimantan (Posewitz, 1892).

In 1843, O. von Kessel journeyed from the Kapuas River north to the Sarawak border, through the districts of Landak, Tayan, Meliau, and Sanggau, mapping at 1: 250 000 scale (Posewitz, 1892). His unpublished map was later used in making 'Versteeg's Atlas' (no further details known). Von Kessel (1850) described the hydrological features of the country, and was the first to report gold and diamonds in the region. Van den Dungen Gronovius (1847) reported on gold diggings in the Sambas district.

This ended a period of *ad hoc* investigations and travelling expeditions by administration officers and enthusiastic members of the Commission of Natural Sciences, few of whom (with the exception of Schwaner) knew much about geology or mineralisation. Most of the work was cartographic, and much information also became available on the geography, ethnography, botany, and zoology of Kalimantan. However, in many cases reports and samples were lost, mainly because of canoe accidents, hostilities, or disorganised means of transport.

The first professionals 1850-1879

Establishment of the Mijnwezen

The establishment in 1850 of a department of Mines, or Mining office, heralded the beginning of systematic scientific investigations of the mineral deposits and geology of West Kalimantan. The Mijnwezen in Nederlandsch Oost-Indië, initially headquartered in Bogor (Buitenzorg), was later transferred to Jakarta (Batavia), and finally settled in Bandung. Its aim was the investigation of the country's mineral potential.

The scientific staff of the 'Mijnwezen' consisted solely of mining engineers until 1909, as professional geologists were not produced by the Dutch universities until then. The first three geologists were recruited in 1909, and occupied temporary positions. In 1928—1929 the first few palaeontologists (Umbgrove, Gerth, Tan Sin Hok) and one petrologist were taken on. Up to 1904, the official strength of scientific staff was 15 mining engineers, but this number was not often maintained during the earlier years because of illness, death, or extended sick leave. After 1904, additional mining engineers were recruited as temporary officers, bringing the total up to a maximum of 79 earth scientists in 1930, including 8 geologists, two palaeontologists, and one petrologist. Between 1930 and World War II the number fell back to fewer than 40 positions.

Initially, rock and fossil collections were sent to specialists of international standing for further study, until Mijnwezen's own experts could take over. In its first two decades, the Mijnwezen published its reports in a general periodical covering all the natural sciences in Indonesia: the *Natuurkundig Tijdschrift voor Nederlandsch-Indië*. In 1872 the first issue of the Jaarboek (annual report) of the Mijnwezen was published.

During the first few years of the Mijnwezen, there were still a few non-Mijnwezen explorers in West Kalimantan. Von Gaffron was active in the upper Kapuas River region and along the SAMBAS/Sarawak border. In 1854 J. H. Croockewit, a 'chemicomineralogist', visited Gunung Kelam (Klam), 20 km east of Sintang, in the company of von Gaffron, and described the mountain as being composed of argillaceous sandstone (Croockewit, 1856). G. A. F. Molengraaff later identified the rock correctly as a porphyritic microgranodiorite. Croockewit also reported on the salt water springs near the Spauk (Sepauk) River, and described the Paloh district in SAMBAS (Croockewit, 1855). In 1855 he was engaged by the government to examine the occurrence on the Kapuas and Melawi Rivers of coal, used to fuel steamships on the Kapuas.

At the time the Mijnwezen was established, the Chinese Districts were in turmoil. Trouble had arisen when the Chinese miners and traders organised themselves into 'kongsis', gradually becoming more powerful and suppressive, and thus coming into conflict with the indigenous population. The Sultan of Sambas requested assistance from the Dutch, who could do little initially as their only garrison, at Sukadana, consisted of some 15 soldiers. Monterado was occupied in 1854, and the kongsis dissolved.

Everwijn's travels

Towards the end of this period of unrest, the Mijnwezen organised its first official geological and mineralogical expedition in West Kalimantan. Mining engineer Everwijn made a series of long journeys, to check the reported mineral occurrences, make geological observations, and prepare maps of the country traversed.

Everwijn made 8 trips (Fig. 3) between 1853 and 1857, three along the Kapuas River and its main tributaries (in 1853, 1856, and 1857), the others involving investigations in the SINGKAWANG, KETAPANG/KENDAWANGAN, SAMBAS, SANGGAU, and part of TUMBANG MANJUL areas. The resulting map (Everwijn, 1879) represented the first true geological sketch map of parts of West Kalimantan. Unfortunately, Everwijn's work was carried out during, and just after, the last few months of the troubles in the Chinese Districts, and was impeded by the still uncooperative attitude of the native population.

Everwijn's three Kapuas River journeys. Everwijn's first Kapuas River voyage was a preliminary investigation of reported coal occurrences in the Salimbau, Jonkong (Djonkong), and Bunut (Boenoet or Boenot) regions. In the Salimbau region (between Suhait and Jongkong), outcrops of coal beds 30 cm and 90 cm thick were found in two localities, with some coal rubble

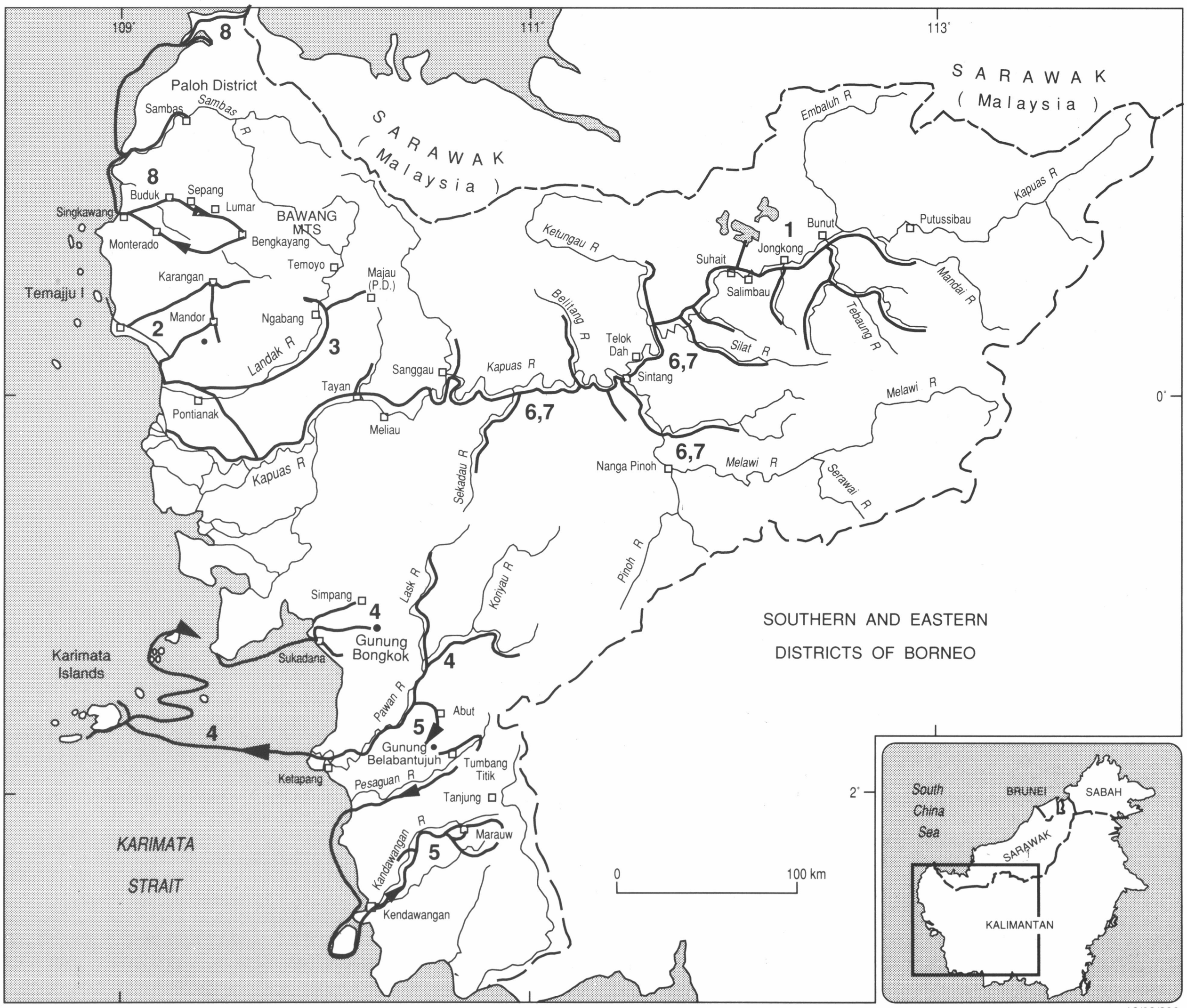

Figure 3. Traverses by Everwijn (1879).

at a third site, all of good to very good quality. Locally the overlying sands were auriferous. Along the Embau River 17 km south of Jongkong, fragments of coal of excellent quality were found, but no outcrops. In places along this river, coarse sands and gravels contained some gold and locally also a few diamonds. About 18 km upstream of the Boyan (Bojan) River (a tributary of the Bunut), fairly good quality coal 30 cm and 60 cm thick was exposed in several places. Half an hour up the Tebaung River, and one hour up the Mentibah River, coal beds 40 cm and 1 m thick were found, of indifferent quality. Overlying sands in the latter river again contained some gold.

On his second and third trips along the Kapuas River, Everwijn continued his search for coal, this time downstream from Salimbau. A few kilometres up the Seberuang River he discovered marly limestone beds with numerous 'nummulites'. This locality became a well known site, and the so called 'nummulites' were reidentified first as *Patellina scutum* or *P.trochus* by von Fritsch (1875), then as *Orbitolina concava* (Martin, 1898), *Orbitolina scutum-trochus* (Yabe & Hanzawa, 1931), and most recently as *Orbitolina lenticularis* by Hashimoto & Matsumaru (1974).

Everwijn lacked the opportunity to visit high quality coal beds and some alluvial gold reported from the upper reaches of the Silat River, and a 30 cm thick high-grade coal layer at TalokDah (a little upstream of Sintang) reported by Croockewit. He went partly up the Ketungau, Melawi, and Pinoh Rivers, finding only traces of coal and coaly shale in the latter two. At Sintang, he found alluvial gold at the confluence of the Melawi and Kapuas Rivers, and some gold workings not far from Sintang, about 1.5 km inland from the Melawi. He noted Chinese-owned alluvial gold workings north and south of the river banks upstream and downstream from Sanggau, straddling the boundary between SANGGAU and NANGATAMAN. Diamonds were found in the auriferous gravels south and southeast of Sanggau village, probably just within NANGATAMAN. Everwijn concluded that downstream from Salimbau no exploitable coal seams existed, and that those found were more properly classified as brown coal.

Just downstream from Tayan, Everwijn found gold being won from high level alluvials along the north bank of the Kapuas, and was shown brown coal samples from near Cempedeh (or Tiang-Kandang) Mountain.

Mandor-Mempawah-Karangan area visit. Early in 1854, Everwijn travelled to the Mandor-Mampawa region within SINGKAWANG to check on the gold mining activities reported by Boachi (1846). His first target was Gunung Tampi (now Gunung Segiangan), where copper ore was supposed to have been discovered around 1850 by an English naturalist working in Sarawak, who accidently strayed across the border into Kalimantan. As Gunung Tampi lies more than 100 km from the Sarawak border, Everwijn rejected the story and concluded that it was a Dutch army captain who had first visited Gunung Tampi in 1851 and had found native copper there. However, many years later Krol (1929c) discovered another Gunung Tampe, on the Sarawak/SAMBAS border; the reported rich copper ore had come from a small copper-silver-gold deposit a dozen kilometres west of this mountain, on the Bayur (Bajoer) river on the southeastern flank of Gunung Asuansang. Everwijn had visited the wrong mountain, but his error remained undetected in the literature as Krol's report was never published.

From Gunung Tampi, Everwijn travelled to the Mandor-Karangan area, where he described the gold workings at Gunung Snaman (Senaman, now Semubueh) which spread out along the base of the mountain, on the slopes, and along the crest. The gold is derived from impregnations and veinlets of finely disseminated gold-bearing pyrite on the crest. On his return to Pontianak Everwijn also recorded granite cut by dioritic veins on the islands of Penibungan and Temaju, but found no trace of mineralisation.

Visit to Landak River region. In March 1854, Everwijn travelled to the middle reaches of the Landak River, where he located small alluvial diamond workings. Thinking that the diamonds were derived from micaceous and siliceous slates and phyllites, he expressed surprise that such rocks had not yet been exploited. From near Ngabang, he walked northeast more or less along the Belintian River to 'Majau' (not found on any available maps, but possibly in the vicinity of Bunan and Sungaitaras, 25 to 30 km east from Ngabang), where he visited the Chinese-owned alluvial and lode gold workings. On the way he noted sandstones which probably correlate with the 'post-Triassic' sandstones later described by Wing Easton from the Singkawang region, and which were thought to be late Cretaceous or perhaps even early Tertiary sandstones. The Chinese miners at Majau had dug eight trenches, and were digging another one which they planned to sink down to about 17 m, the maximum depth their primitive methods enabled them to reach. The mineralisation appeared to be associated with a pyritiferous quartz vein, and Everwijn speculated that the ore grade would increase in depth, seeing the efforts made by the miners to deepen the trench.

Sukadana-Sempang-Matan region. From May to August 1854, Everwijn visited the Sukadana-Simpang-Matan region in KETAPANG and the southeastern part of NANGATAMAN, to check the tin mineralisation previously reported by Müller and von Gaffron. Everwijn recorded syenites in the Sukadana district, and granite at the Palong Mountains (Gunung Bongkok), but found no trace of tin. Going up the Pawan and Biya rivers, he described granites and syenites, as well as sandy and shaly sediments which locally had been contact-metamorphosed to slates and hornfels. Strangely enough he did not recognise the widespread volcanics as such but, judging from his map, mistook them for hornfelsed sediments. Going north along the Laur River, he discovered some old high level alluvial gold workings at the NANGATAMAN border which appear to have been small or of low grade as they had already been deserted by the Chinese miners.

Finally, Everwijn visited many of the Karimata Islands, found to consist mainly of granites, intruding some altered claystones and ferruginous claystones. Again, no trace of tin could be found.

Southern Matan district. In 1855 Everwijn visited the southern part of the Matan district, including south KETAPANG, the northwestern corner of TUMBANG MANJUL, and the northeastern corner of KENDAWANGAN, completing his trip by travelling down the Kendawangan River to the coast.

His main intention was to check the tin potential of the region, following the identification of cassiterite in one of a series of samples collected in 1852 by an army officer. Everwijn first visited the Abut (Aboet) locality on the north side of Mount Belabantujuh (then known as Gunung Malajoe, or Malayu in modern spelling[4]) in south KETAPANG, where the tin-bearing sample had been collected. He was told that in about 1845 Chinese miners had been working alluvial deposits west of Abut, but that profits had been so meagre that the place was soon abandoned. Walking south, past the granitic Gunung Malayu, he found old gold diggings on the south side of the mountain, which according to the locals had been mined in 1825 (some of these pits were relocated by members of the IAGM Project in 1984). Again, however, there was no trace of tin ore. Next, Everwijn sailed to the mouth of the Kandawangan River and continued upstream to the northeastern quadrant of KENDAWANGAN, whence he traversed on foot to the northwestern corner of TUMBANG MANJUL, making geological observations on the way. He came to some weakly auriferous sands, but found no trace of tin.

Paloh region and Chinese districts. In 1857, Everwijn visited the Paloh region in northern SAMBAS to check the area for iron, copper, and tin occurrences. According to legend, iron ore had been mined and smelted by the Chinese and Dayaks long before Everwijn's days, and he indeed discovered remnants of two smelting furnaces and a few occurrences of very low-grade and inferior iron ore, though there was no sign of large, rich deposits. Nor was there any trace of the expected copper and tin. He then walked the coastal track to Cape Datuh (Datu) and into Sarawak, describing the geology but not finding any minerals.

A month later Everwijn visited the Buduk (Boedoek) area on the SINGKAWANG/SAMBAS border, where native copper was reportedly being won from alluvial sands. He was shown rich alluvial gold placers and some small lode-gold deposits in pyritiferous quartz veins cutting variegated slates. This gold was very fine and contained appreciable amounts of what was said to be the gold-telluride sylvanite and locally some bismuth. Everwijn did not find any platinum, although Boachi (1846) had written that much platinum was found in association with the gold at Buduk, but that the miners considered it to be a useless mineral. Boachi added that in earlier years the platinum had indeed been sold, but that because of low profits the practice had been stopped.

Everwijn returned to Singkawang via the villages of Sepang, Lumar, Bengkayang, and Montrado in the Chinese Districts, a distance of 135 km. On the way he noted grey, bluish, and variegated slates and shales, in places alternating with argillaceous sandstone beds, whereas the Bawang Mountains and the mountains near Singkawang were granite. Everywhere he found Chinese-owned alluvial gold workings in both recent and terrace alluvium. The purest gold seemed to be that of Sepang. Near Bengkayang and Monterado some lode gold occurred, as at the Hang-mooi-sang (also Han-Muy-San, Hang-oei-san, Hamisan) mine about 10 km north of Monterado. A vein 2 m thick, with a 75 cm core of quartz and gold-bearing(?) pyrite, was being worked to a depth of about 15 m, the practical limit.

In 1871, high grade lead and zinc ore was found by locals near Marouw on the Kandawangan River, about 14 km south of the

[4] See Appendix 1 for spelling variations between pre-War War II and post-World War II Bahasa Indonesia.

KETAPANG border at Tanjung. In 1876 about 43 tonnes of this ore were sold in Singapore by a Chinese miner. The exact location cannot be pinpointed as the topographic names mentioned in the reports are not shown on the available maps. The ore consisted of sphalerite and galena with associated pyrite. Cretier (1879) published a chemical analysis, and later LeRoy & Croes (1880) prospected the area, finding ore at two isolated sites, but nowhere in situ as a lode or vein. Everwijn wrote two small reports on the occurrence.

Everwijn's final report. In a final review, Everwijn (1879) presented his somewhat surprising opinions on the geology of West Kalimantan. He thought that all the 'neptunic' slaty/shaly deposits in the areas visited were of the same 'very old' age; that there were no Mesozoic rocks in West Kalimantan; and that there was no evidence of volcanic activity either recently or in the past, since he had not come across any volcanic rocks, nor had he seen any mountains that remotely resembled a volcano. As mentioned earlier, he had indeed travelled over volcanic deposits but had thought them to be contact-metamorphic rocks.

Everwijn's report was generally negative about the mineral potential of West Kalimantan. Tin, the main mineral sought, was conspicuous by its absence. The only coal worth considering, in the Salimbau area, was too remote. The diamond deposits were largely mined out, and no large scale mining seemed possible, nor were the copper, lead, and iron occurrences of much interest. As for gold, alluvial deposits were largely exhausted, but there appeared to be some potential in lode-gold mining: Everwijn argued that the Chinese miners had no technical experience in working underground veins or in the mechanical and chemical extraction of gold from the ores, nor did they have the proper tools to go deeper than 15 m. Hence he suggested that an experimental shaft should be sunk to 40–50 metres on a selected prospect. He compared the gold-telluride-bismuth-pyrite veins at Buduk with similar lodes in Colorado, drawing attention to the fact that the latter became rich only at depths of 33 to 50 m below the surface.

During a rebellion in the Banjermasin district in southeastern Kalimantan in 1881, all Mijnwezen personnel in the area were killed. This, combined with the disheartening effect of Everwijn's report, led to a 20 year period during which fewer expeditions were undertaken.

First systematic geological and mining investigations 1879-1900

Van Schelle

In 1879, 25 years after Everwijn's travels, a new period of activities by the Mijnwezen set in when C.J. van Schelle began a 6-year program of investigations of minerals and coal in West Kalimantan (the 'Geological and Mining Investigations in Northwest Borneo'), mainly in the Chinese Districts, the Landak region, and the upper Kapuas River. At the same time, a start was made with the systematic topographic mapping of the western region by a qualified surveyor's team.

Van Schelle's numerous reports include an informative historical summary of the rise and fall of the Chinese kongsis; detailed descriptions of the methods of gold winning; descriptions of alluvial and vein-gold workings around the Monterado (1883b, 1887b) and Bengkayang (1883a, 1887a) centres, and in the Seminis and Sepang areas and the Sekadau mountains in Sambas (1884b); the first gold production statistics (1882); visits to small copper and lead occurrences around Monterado; the gold veins near Melassan in the southwestern corner of SILAS; search for mercury and antimony near Lumar, Uduk, and in the upper Sekayam River and Jambu (Djamboe) River (an old name for one of the upper branches of the Landak River); investigations of iron ore at Pajilu (Padjiloe) near Monterado, and of hematitic iron ore in the upper reaches of the Sambas River; a study of the good quality coals near Napan at the Boyan River in the Bunut region (1883c), used to fuel steamships on the Kapuas; and a report on the cinnabar occurrences of West Kalimantan (1887c).

He reported rumours that the Kendai region (northwest area of SANGGAU) and the upper reaches of the Darit or Menyukai River still contained rich unexploited gold placers. He also concluded that, contrary to Boachi (1846), there was no platinum in the Sambas district. He produced (van Schelle, 1884a) a 1: 500 000 scale map of all mineral localities within the area bounded by the Sambas and Landak Rivers.

In 1879 van Schelle became the first geologist to visit the region between the Lakes district and the Embaluh River, near the Sarawak border. The trip was made under protection of an army escort because of the hostile attitude of the Batang Lupar dayaks. He found the border mountains to consist of 'old slate' with quartz veins, and collected many rocks and fossils, which were unfortunately lost in a canoe mishap on the Kapuas.

In the Chinese Districts, van Schelle recognised an east–west trending, strongly folded formation of siliceous slate, sandstone, and conglomerate, intruded by granite and volcanics, and unconformably overlain by Tertiary sandstones. He was the first to apply the term 'Oude Lei Formatie' ('old slate formation') to all the folded slaty/shaly beds in West Kalimantan, to which he attributed a Devonian age. He did not explain his reasoning for this, but Wing Easton (1914) stated that van Schelle equated the slates with similar rocks of supposedly Devonian age in Sumatra).

In the northwestern corner of SANGGAU van Schelle discovered the small volcanic cone of Gunung Melabu (van Schelle, 1886), composed of flows and pyroclastics of hornblende andesite. He also found extensive sheet basalts in the Ledo area and thought that their origin was in the Bawang Mountains. Near the township of Siluas he found massive beds of limestone which he suggested could be reefal deposits of unknown age. He further distinguished Senonian sediments, Tertiary sandstones with coal layers and shaly beds (Eocene?) and younger argillaceous sandstone, shale, and mudstone. Fossils found by van Schelle in the Seberuang River, and originally thought to be 'nummulites' by Everwijn, were identified as the possibly Cretaceous foraminifer *Patellina* by K. von Fritsch (1879).

Van Schelle also collected fossils from shale near Sepang (SAMBAS), which were dated by Martin (1898) as Mesozoic, possibly Cretaceous. This was disputed by Wing Easton (1899b) who found ammonite imprints at Sepang and near Lumar which were identified by Krause as *Harpoceras radians* of Liassic age. Age determination from fossils was more problematic then, and the rocks at the different fossil locations belonged to different stratigraphic horizons. Everwijn's statement 20 years earlier, that Mesozoic deposits did not exist in West Kalimantan, was therefore invalidated.

Review in English of investigations in Kalimantan

By the 1880s a significant amount of data on Kalimantan had been compiled. Almost all reports were in Dutch, and to most people Borneo still remained an unknown and mysterious island. As late as 1886 an Austrian journal (*In* Posewitz, 1982)stated that in Borneo 'no one has yet succeeded in navigating the larger rivers for any distance from the mouth'. At least 60 years earlier, the first European travellers had gone up the Kapuas River all the way to the Lakes district!

In 1889 the Hungarian Theodor Posewitz, who had served as an Officer of Health in Kalimantan, published a detailed summary in German of all previous investigations and mining reports. An

English translation followed (Posewitz, 1892). His work, notwithstanding geological shortcomings, was a most valuable contribution which made Dutch sources accessible to German and English speaking scientists.

Regional mapping by Wing Easton, 1885– ~1900

In 1885, N. Wing Easton joined van Schelle's team as second mining engineer, and took over the leadership when van Schelle was transferred in 1887. A five year lull in field activities followed, during which the fossil collections of van Schelle were described and identified by Prof. K. Martin of Leiden University who established the presence of Mesozoic strata in areas where van Schelle had expected a Devonian age for his 'old slate' formation.

Geological investigations were resumed by Wing Easton and his assistant Koperberg in 1893, after the completion of a new topographic map which was of a very high standard even by today's criteria. Wing Easton regretted the heavy stress on economic geology that had characterised van Schelle's work. He therefore undertook a more systematic regional geological mapping program to support exploration efforts. In contrast to van Schelle, Wing Easton paid much attention to geological syntheses and to the genesis of mineralisation. In line with Martin's recommendations, he tried to bring more clarity in the geological relationships between Mesozoic and supposed Palaeozoic formations.

Investigations involved the region covered by SINGKAWANG, western SANGGAU, and southern SAMBAS and SILUAS up to 01°15' N latitude. The results were published in a voluminous work in German, with 10 geological maps at 1: 100 000 scale (Wing Easton, 1904) (Fig. 4).

Wing Easton (1889) found two alleged volcanic cones (Sitong and Pando) in northwestern SANGGAU; discussed the diamond deposits along the Landak and upper Sekayam Rivers (Wing Easton, 1894); reported the discovery by his assistant Koperberg of ammonites in a limestone bed near Temoyoh on the Landak River; reported on the geology along the Kapuas River (Wing Easton, 1899a) and on the copper occurrences around Mandor (Wing Easton, 1899b); and gave a geological overview of West Kalimantan (Wing Easton, 1914).

In his reports (one of which included a very useful locality map) on the Landak diamonds, Wing Easton (1894, 1895) suggested that the diamonds were derived from basic igneous rocks. This followed an earlier reference by Posewitz (1889) reporting a statement by a Professor Lewis in the USA that the usual host rocks of diamonds are serpentines (altered peridotites). From 1925 onwards Wing Easton adopted this belief. Everwijn (1879) had thought that the Landak diamonds were derived from veins in the basement slates, and the theory current in Wing Easton's days was that diamonds were produced in acid igneous rocks.

By visiting at least 27 copper-bearing localities within a radius of 5 km of Mandor, Wing Easton and Koperberg confirmed Everwijn's and van Schelle's conclusions that there were no good copper and lead prospects in the region.

On his trip to the Kapuas River area, Wing Easton (1899a) collected many fossils from a large number of localities, including the Silat River and some of its tributaries, the Seberuang, Melawi and Kayan Rivers. They were described by Martin (1898), increasing the knowledge of Mesozoic and Tertiary deposits in the region.

The ammonite fauna collected by Koperberg at Temoyoh on the Landak River was described by Krause (1904) and dated simply as Cretaceous. Wing Easton believed the fauna was Cenomanian. The problem of determining the age of Mesozoic strata in West Kalimantan and Sarawak recurred for later investigators such as Icke & Martin (1905), Vogel (1902), Krause (1911), Yabe & Hanzawah (1931), von Koenigswald (*in* Zeijlmans van Emmichoven,1939), Hashimoto & Matsumaru (1974) and JICA (1982). Ages were sometimes updated more than once, when fossils were found to have been misidentified, or when the age range of certain species had to be expanded. The latest age given for the Seberuang locality is now early Aptian to earliest Albian. In the Chinese Districts van Schelle's 'Devonian old slate formation' has been split into Triassic, Jurassic, and Cretaceous units, as a result of later investigations (e.g. JICA, 1982).

Wing Easton subdivided the 'old slates' into a lower phyllite section and an upper, slightly sandy shale or slate section which also contained 'diabase porphyrites'. He guessed that their ages ranged from 'possible Palaeozoic or Lower Triassic' to 'Upper Triassic, perhaps even Lower Jurassic'. The Triassic age was based on the identification of *Monotis salinaria*, a fossil given to him by a prospector, the precise sampling location of which unfortunately could not be retraced.

Fossils collected later by Wing Easton indicated that more and more areas of 'Devonian old slate' were Lower Jurassic and Cretaceous. He subdivided his Jurassic succession tentatively into four conformable units of locally calcareous shales and thin sandstone (Upper Lias; Lower, Middle, and Upper Dogger) based on lithological and palaeontological differences. This succession is underlain by Upper Triassic or Lower Jurassic 'transitional beds' which he equated with Molengraaff's 'Danau Formation'. It is overlain by thick-bedded sandstones which Wing Easton guessed to be Malm or Lower Cretaceous. The unconformably overlying 'Plateau Sandstone' of Molengraaff (1900, 1902) from the SINTANG/PUTUSSIBAU area, was considered by Wing Easton to be Upper Miocene. Earlier, Wing Easton had cautiously spoken of post-Triassic sandstone, which also included Upper Cretaceous sandstones. He mapped two suites of volcanics younger than the 'Plateau Sandstone', and thought they were Pliocene to Quaternary: a hornblende-andesite and dacite suite, and a younger sheet basalt.

Wing Easton's final report and conclusions

Wing Easton's final report (1904) is largely a description of his traverses. He was proud of his work, stating that, although many areas were only reconnoitred, at least the geology of those localities that he had mapped 'in detail' had been resolved 'with great accuracy'. The report is not easily digestible, and suffers from an awkward rock nomenclature and from unusual concepts that he believed to be undeniable facts.

Wing Easton's unit of 'Quartz Porphyries' is rather contrived. It encompasses a large number of unrelated rock types of different origin, including rocks in which quartz is rare, rocks that are not porphyritic, and even sedimentary quartzitic rocks which he mistook for extremely acid end members of a magma series ('eruptive quartzite', 'quartzitic quartz porphyry').

He considered that the 'Quartz Porphyries' were the cause of all mineralisation in the region, and were the formation from which the 'Plateau Sandstone' arenites had been derived by weathering and disintegration. He was so convinced of this that he predicted excellent gold potential in the 'Plateau Sandstone', and assumed that each large body of this formation had to have a 'quartz porphyry' core. He therefore occasionally drew outcrops of 'quartz porphyry' within large bodies of the sandstone formation on his maps where they had not been observed in the field, but where he predicted they should be. When he was later transferred to Sumatra, he convinced headquarters to restrict a planned gold exploration program exclusively to areas of rhyolitic deposits. These guide lines were subsequently ignored by the field geologist.

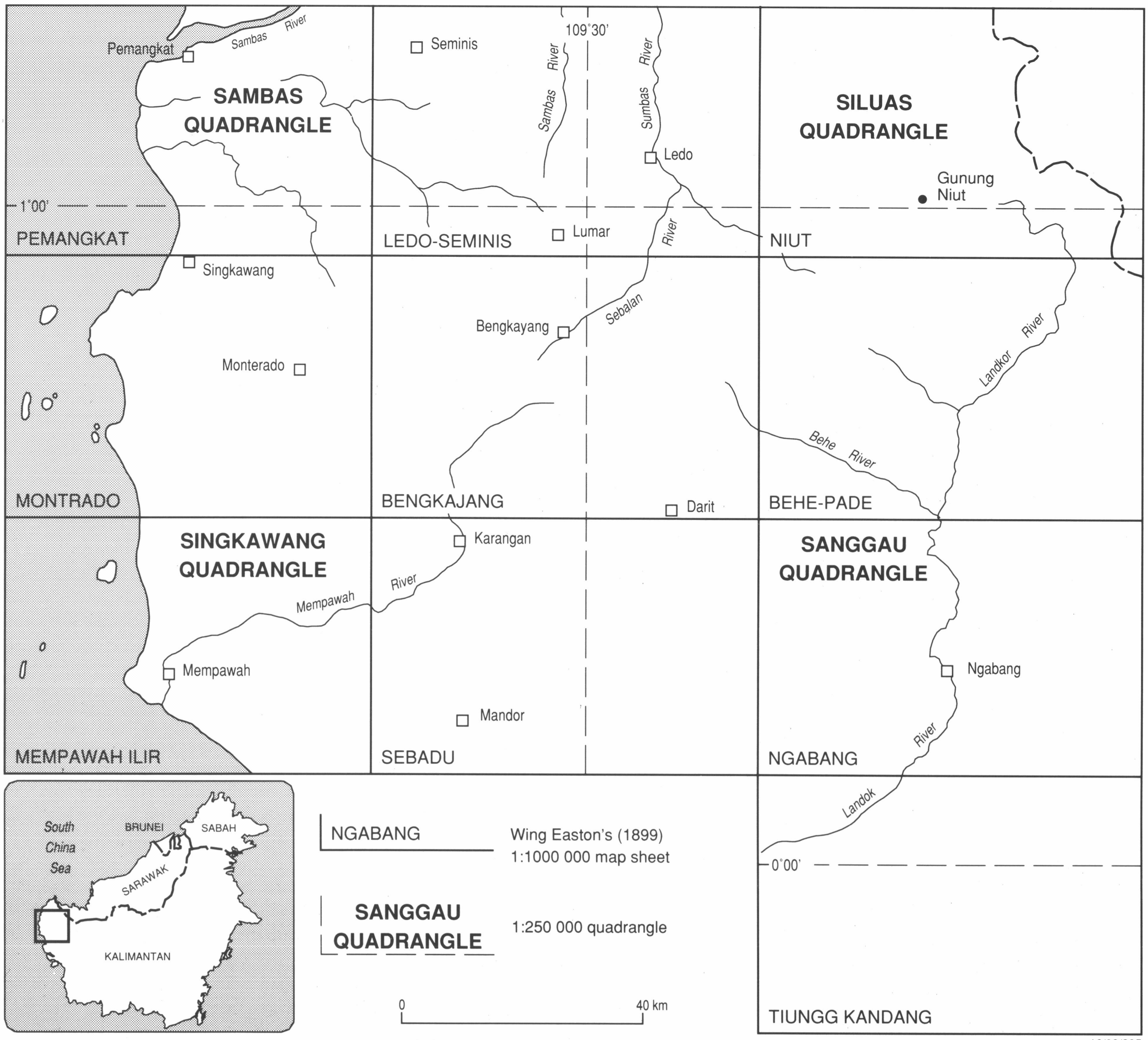

Figure 4. Area covered by Wing Easton's (1904) map sheets.

Wing Easton believed that the granites in West Kalimantan were the oldest 'primeval' rocks of early Proterozoic or even Archaean age. Ignoring previous reports of contact-metamorphic effects, he maintained there were none. Later (Wing Easton, 1914) he admitted that some rare granites might be younger.

The departure of Wing Easton ended 20 years of steady, systematic geological mapping in the Chinese Districts and some traverses in the Kapuas River drainage area, which had led to the recognition of large tracts of Jurassic and Cretaceous and probably also Triassic deposits at the expense of the 'Devonian' old slates, and the realisation of new problems that needed further work. Although he left West Kalimantan in about 1900, he retained his interest in the region and occasionally published papers on the 'Plateau Sandstone', the genesis of diamonds, and the origin of the Indonesian Archipelago (see below).

Molengraaff, 1893–1894: central east Kalimantan travels

While Wing Easton was working in the western part of West Kalimantan, Molengraaff began the first professional geological investigations in the central-eastern part of West Kalimantan (Molengraaff, 1900, 1902). Molengraaff led a privately financed and organised expedition in 1893-1894 which covered parts of PUTUSSIBAU, PEGUNUNGAN KAPUAS, SINTANG, and TUMBANG HIRAM. His fossil collections were described by Newton & Holland (1899), Hinde (1900), Krause (1897) and others, and parts of his rock specimens were studied by Schmutzer (1909, 1910). In his clear, well written report, Molengraaff summarised the main points of the geology of west and east Kalimantan, updating his ideas in later papers (e.g. 1914).

Molengraaff found regions of amphibolites, amphibole-chlorite-quartz schists, and glaucophane schist, and regarded them as of Archaean age, though he later added that some of them could possibly be metamorphosed parts of the 'Danau Formation', a view reinforced by Schmutzer (1909).

IAGMP workers recently included these rocks in their Busang Complex (Surono & Noya, 1989), for which a Triassic age was obtained by K/Ar dating. Molengraaff also described spectacular domes and peaks of dacitic and rhyolitic volcanics, currently known as Sintang Intrusives. Schmutzer (1910) described garnet-bearing amphibole andesites from the Sungai Embau drainage area, 20-45 km south of Jongkong, SINTANG. Garnet in one sample occurred as an alteration product of amphibole, together with aggregates of chlorite, iron oxides, pyroxene, and calcite. In another sample the garnet was in feldspar phenocrysts which it replaced, and was not an older inclusion.

Molengraaff's 'Danau Formation' consisted of a complex of siliceous sediments (including quartzites, cherty slates, and radiolarites) and basic volcanics (including dolerite, basalt, tuff, agglomerate, and spilite). The formation is rich in radiolaria, for which Molengraaff accepted Hinde's (1900) date of post-Palaeozoic, possibly Jurassic. Molengraaff had found 'Danau Formation' outcrops overlain by Lower(?) Cretaceous sediments. Wing Easton correlated his Triassic to Lower Jurassic 'transitional beds' in the Chinese Districts with the 'Danau Formation'.

Later authors tended to consider them Triassic (e.g. van Es, 1918; Umbgrove, 1935; Krekeler, 1933; ter Bruggen, 1935), and Krol (1930) distinguished between a Lower Cretaceous clastic subdivision and a pre-Norian (Upper Triassic) subvolcanic unit. Zeijlmans van Emmichoven (1938) even placed the formation in the Permo-Carboniferous to Upper Triassic.

Molengraaff gave the name 'Plateau Sandstone' to the thick-bedded sandstone complexes which unconformably overlie the Cretaceous and older formations, and occur as mesas and plateaus (commonly blockfaulted) from SAMBAS in the west to perhaps as far east (Rutten, 1927) as the upper and middle Mahakam River region. The name was adopted by Wing Easton and others. Although Molengraaff at first considered the possibility that the 'Plateau Sandstone' might be older than the Melawi deposits, foraminifera from similar rocks in the Mahakam area to the east showed a late Miocene age (*in* Rutten, 1927, who expressed doubt as to whether the sampled rocks were 'Plateau Sandstone'). Since Molengraaff's work, the 'Plateau Sandstones' have been studied by many investigators in Kalimantan and Sarawak. They have been split into a number of separate units with different names and with ages ranging from Senonian to Oligocene and possibly Miocene. The name 'Plateau Sandstone' is no longer used.

European attempts at mining and prospecting

European mining concerns from 1889 tried to enter the gold prospecting and mining business which for so long had been a monopoly of the Chinese. The Goudexploratie Maatschappij 'Bengkayang' prospect at the western foot of the Bawang Mountains was at a site teeming with Chinese alluvial miners (Goudexploratie Maatschappij 'Bengkayang', 1898, 1899, 1900), and the company expected to find a good source of gold in the area.

The first mining engineer and manager reported two 'rich gold-bearing quartz lodes', one of which was running 2 oz of free gold per ton. He was succeeded by another engineer who downgraded the prospect somewhat, recommended sinking in depth on the lodes, and taking up alluvial grounds. An experienced consultant then recommended further expenditure on alluvial gold instead of the lodes. The second engineer was sacked for incompetence, and his replacement reported that the area of good alluvial gold was greatly exaggerated. By then finance, as well as the patience of the Directors, had run out and the venture was disbanded. This appears to have been a common pattern among European companies attempting to get into gold mining, which failed because of undercapitalisation, mismanagement, lack of experience, and underestimation of access and transport problems.

Various dredging ventures met similar fates. They encountered problems such as rough river beds with obstructing sandstone bars; thick beds of sticky clay; concentration of gold in thin basal gravel layers often at near-unmanageable depth, and resting on irregular, stony bedrock; abundant decaying masses of tree trunks; and a lack of gold placers suitable for dredging. These problems endure. Recent Australian ventures in Kalimantan have failed because of undercapitalisation. Australian dredging companies in the Monterado region have experienced similar difficulties.

1900-1923, a period of review

Between 1900 and 1920, the only field work in Kalimantan was done by J. E. Loth in 1916-1917, and H. Frijling in 1917. Fossil samples collected by Molengraaff and Wing Easton were described by Krause (1897, 1904, 1911) and Icke & Martin (1905), and rock samples of Molengraaff were examined by Schmutzer (1909, 1910). Several papers and reviews were published, by Wing Easton (1904, 1914, 1917, 1921), van Es (1918, 1919, 1923), Hövig (1913, 1917), 't Hoen (1917), van Lier (1918) and Grondijs (1917).

Wing Easton's papers

Following Wing Easton's Final Report (1904), he reviewed (1914) the geology of West Kalimantan, maintaining his intrusive 'Quartz Porphyry' group, denying the existence of contact-metamorphic phenomena, and dating the granites as Precambrian. He conceded that the 'Plateau Sandstone' may have been deposited during a large transgression, as Molengraaff (1914) had suggested. Later, ignoring the presence of coal beds in the formation, he speculated (Wing Easton, 1917b) that the associated red mudstone of the 'Plateau Sandstone' might indicate formation in a desert environment. In spite of criticism by van Es (1921) and others, the desert environment model seems to have had some support for similar arenites in Sumatra (see Wing Easton, 1917b).

Wing Easton (1921) was the first geologist to apply Wegener's theory of continental drift, published in 1920, to the origin of the Indonesian Archipelago. He concluded that Indonesia and Malaya had no genetic connection with Southeast Asia, and noted many geological, morphological, and faunal differences between the eastern and western parts of Indonesia. These observations could be accommodated by assuming that east and west Indonesia had originally formed part of a protoantarctic continent, with west Indonesia on the western side of Wilkesland, east Indonesia on the eastern side. The west Indonesian part probably started to drift during the Triassic, while Australia began to move during the Eocene, preceded by the eastern Indonesian part. The western Indonesian part would have arrived at its present site before the Ice Age, while the eastern part settled as late as the Quaternary. Wing Easton's ideas foreshadowed modern plate tectonic theories, which became popular about half a century after Wing Easton's publication!

Loth's travels

J. E. Loth (1918), a mining engineer with the Mijnwezen travelled through parts of TUMBANG MANJUL, KETAPANG, SANGGAU, SINTANG, and perhaps other Quadrangle areas, but the route is not described in his report. He briefly discussed various known formations such as the 'Danau Formation', Melawi beds, Bukit Alat sandstone and Ketungau beds, and mentioned Cenomanian deposits along the Kembayan River, at Beduai, and in other places. He noted that the *Orbitolina*-bearing Cenomanian sediments along the Kembayan River transgressively overlie the granite that had intruded 'Danau Formation' deposits, as the basal conglomerate contained pebbles and boulders of the granite. Consequently this granite had to be Upper Mesozoic but pre-Cenomanian. He concluded that the Bukit Alat sandstone was Eocene, because it resembled Eocene sandstone deposits elsewhere in Indonesia, and because of the chemical composition of the coal layer in the sandstone.

In Loth's view, the Bukit Alat sandstone unconformably overlies the Melawi beds (named by Martin), and he concluded therefore that the latter were most likely to be Upper Cretaceous ('Senonian'), in spite of the Lower Tertiary age determined by Krause and by Martin on fossil evidence. Later, Rutten (1927), a Dutch palaeontologist, criticised Loth's conclusion: the unconformity was by no means accepted fact, and in his opinion there was either no unconformity or at most a very slight disconformity. Rutten suggested that Loth had discarded Martin's fossil determinations without sufficient proof that they were wrong.

Frijling's (1920) visits to the Kotawaringin, Matan, and Pinoh regions

Mining engineer H. Frijling (1920) was sent out in 1917 by the Mijnwezen to evaluate iron ore deposits mentioned by von Gaffron (1853) in the regions of Sampit and Kotawaringin in southwestern Kalimantan, and part of KETAPANG (Matan) and the Pinoh Lands in West Kalimantan. Frijling's geological observations were limited. He found a predominance of granitic rocks, covered in part by 'effusive products of the granitic magma'. More mafic granitoids noted in a few localities were considered to belong to the marginal facies of the main granite bodies. He divided the sedimentary rocks into two groups:

- moderately dipping quartzites with tuffaceous shales, sandstones, greywackes, marly limestones, and limestone, commonly showing contact-metamorphic effects (especially the limestones) where close to granite;
- gently dipping sandstones, argillaceous sandstones, and sandy shales, in which no contact effects were observed; of probable Tertiary age.

Frijling confirmed the existence of von Gaffron's iron ores, and found additional occurrences in southeastern KETAPANG. The deposits are described in an anonymous report (Anon, 1921) probably by Frijling. Two distinct classes of iron ore were recognised: the magnetite–hematite ores and the limonitic ores, the former being regarded as the result of 'pneumatolytic contact-metasomatism' by adjoining post-Triassic granitoids. The report suggested that the limonitic ores represented gossans over base metal deposits. Frijling's original maps (stored in the GRDC archives) showed some iron ore localities in the Semuhar-Ayerdoea area ('Riam Danau') and south of Ayerdua in the northeastern border zone of KENDAWANGAN.

Van Es review of West Kalimantan geology

L. J. C. Van Es (1921, 1923), a geologist and mining engineer of the Mijnwezen, published reviews of geology in West Kalimantan. He concluded that many of Wing Easton's 'Quartz Porphyries' were actually hornfelsed sediments; that the granites, far from being the oldest primeval rocks, must be younger than the Triassic formations because of the observed contact metamorphic effects, and were probably younger than Jurassic. He alone considered the 'phyllitic old slates' to be contact-metamorphosed Triassic beds. He said that some steeply dipping sandstones which both Molengraaff (1902) and Wing Easton (1904) had included in the 'Plateau Sandstone' were somewhat older strata of the Cretaceous 'platy sandstones'. He criticised Wing Easton's habit of drawing outcrops of 'Quartz Porphyries' within 'Plateau Sandstone' where none had been observed, and his ideas about the 'Quartz Porphyries' bringing mineralisation in the region.

Van Es pointed out that mineralisation was around the margins of granites, often within contact aureoles, and Wing Easton's 'Quartz Porphyries' were commonly hornfelsed rocks. The presence of mineralisation in those 'porphyries' was therefore not surprising. Van Es studied Frijling's rock samples, and concluded that many of Frijling's 'Quartz Porphyries' were hornfelsed sediments, which Everwijn 100 years before had correctly mapped as metamorphic shales.

Van Es also suggested that the Eocene Melawi, Ketungau and Belitang Basins once formed one large entity, which became split into three parts by erosion.

A few other published and unpublished reports appeared between 1900 and 1923, including notes on the Sinturu gold mineralisation north of Bengkayang (Hövig, 1913), a summary of contact-metamorphic iron ores in Indonesia (Hövig, 1917) and of ore occurrences of Indonesia by 't Hoen (1917), an overview of the mining industry in Indonesia (van Lier, 1918), and of mercury ores in Indonesia (Grondijs, 1917). They are of little significance.

Systematic mapping of West Kalimantan, 1923-1932

From about 1923 to 1925, van Es was involved in gold investigations in the Chinese Districts, and this work grew into the 'Mineral and Geological Investigation of West Borneo' program (West Borneo Program), led by Krol from 1925 to 1931. When Krol retired in 1931, the leadership was transferred to Zeijlmans van Emmichoven who stayed in that function from 1931 to the end of the Program in 1932.

The West Borneo Program undertook exploration in the following areas (see Fig. 2 for locations):

1925 Reconnaissance of the Paloh District, northern Sambas, by Krol and his assistant Ehrat.

1926 Reconnaissance of the Tayan District and Sarawak, by Krol, Ehrat, and Memelink (Ehrat 1926).

1927 Tayan, Meliau, South Matan and Sarawak, by Krol and Lanzing.

1928 North Matan, Sempang, Pinoh Lands, Kubu, and Sanggau, by Krol, and Lanzing in part.

1929 Sanggau and South Sekadau, by Krol.

1930 Mostly the eastern part of West Kalimantan, with a traverse to the Rajang (Redjang) River in Sarawak, by Krol assisted by ter Bruggen and later also Krekeler.

1931 Krol returned to The Netherlands on sick leave. Field work continued in eastern West Kalimantan and adjoining Sarawak, by Zeijlmans van Emmichoven, Krekeler, and the engineer Ubaghs.

1932 Continuation of field work to mid-1932, by Zeijlmans, Krekeler, and Ubaghs. End of Program.

The region previously mapped by van Schelle and by Wing Easton was excluded from the program, as their work was considered to be satisfactory.

The West Borneo Program, unlike previous surveys, concentrated on the regional geology of a very extensive area instead of focusing on scattered ore and mineral occurrences. The two reports published in 1939 by van Bemmelen and Zeijlmans contain much information, although interpretation of the stratigraphy in West Kalimantan and adjoining Sarawak shows a number of errors which have become clear from later investigations (e.g. see Haile, 1955b). Several thousand thin-sections were described, and 33 chemical rock analyses were made from the western area alone. Because of the paucity of field data and the lack of index fossils, the geological maps were far from reliable, and the geological boundaries sketchy (van Bemmelen). The same applied to the eastern area, which extended from the Sekayam River east to the border with East Kalimantan.

Zeijlmans van Emmichoven's report on the eastern part of West Kalimantan was published in 1939. Krol's illness prevented him from producing a report on the western part. After Krol's death in 1933, the task of compiling a report from his notes fell to van Bemmelen, who had never worked in Kalimantan. He had to rely mostly on the thin-section descriptions by Gisolf (undated) and Esenwijn in 1928, and on Krol's unpublished reports (1929a—d) and field notes, for his report (van Bemmelen, 1939).

The reports of Zeijlmans van Emmichoven (1939) and van Bemmelen (1939) were extensively used by the IAGMP geologists, who revised many of the ideas and stratigraphical opinions expressed in them, redefined old formations and created new ones, brought clarity to some of the problems, and introduced new data on geological ages and large-scale structural elements. The work of Zeijlmans and van Bemmelen has been compiled in the Data Records for the various Quadrangles (unpublished), and in many separate publications. The unpublished reports of their co-workers on which these volumes are based deserve some attention.

Krol (1929?a) confirmed that copper ore had been found near Mount Tampi in the Paloh District in 1846 by a straying English naturalist from Sarawak, and noted that Everwijn had been directed to the wrong mountain of similar name in the Mandor area. The ore sampled by Krol's party assayed 3.8 g/t Au, 8.8 g/t Ag, and 8% Cu (not 8 g/t Cu as printed in van Bemmelen, 1939, 309).

Krol wrote explanatory notes (Figs 5—7) on various Quadrangles including DATO & KUCHING (Krol, 1929?b) and the Paloh region (Krol, 1929?c), and a detailed report on the ore vein systems at Gunung Selakean east of Bengkayang (Krol, 1928?), where he mapped five ore veins containing gold, silver, lead, copper, zinc, arsenic, and traces of bismuth. The thickness of the veins ranged from 30 cm to over 2.3 m, over lengths from 30 m to 650 m. The mineralisation was described as closely related to andesite-induced processes.

Krol (1930a) suggested that Triassic, Jurassic, and Cretaceous strata could be identified and mapped on the basis of their different strike directions, but this attracted little support (Krekeler, 1932b)

The geologist Krekeler worked for the Mijnwezen mainly in the Sekayam/upper Landak River and the Ketungau and Belitang Rivers areas, and also made traverses in Sarawak and along the upper Melawi River. His unpublished reports (1933b, c, 1934) contained detailed observations along well described routes that can be easily retraced. He collected numerous fossils, tried hard to deduce the ages of various formations, and included sketches and locality maps, and descriptions of thin-sections. His work was thorough and conscientious, and he probably deserved much greater credit than he seems to have received.

Other separate publications on the Program's work were by Krekeler (1932a, 1933a) on a new occurrence of Permo-Carboniferous and Triassic rocks and fossils in Sarawak; and by Esenwein (1932) on corundum and diaspore pebbles ('lebur' stones) in the diamond fields of West and Southeast Kalimantan. Ubaghs and Zeijlmans van Emmichoven published a joint paper (1936) on the Palaeogene of Borneo.

Zeijlmans van Emmichoven also published a paper on the Eocene south of the Keriau River (1935), a summary of the geology of Central Kalimantan (1938), and a paper on the Tertiary west of the Lakes district (Zeijlmans van Emmichoven & ter Bruggen, 1935). Ter Bruggen published an article on the lower Tertiary in phyllitic facies in West Kalimantan (1932), and a thesis on the Eocene age of the phyllite formation in Central Borneo (1935). This led to a spirited public debate with Zeijlmans, who was firmly convinced of a Cretaceous age (Zeijlmans van Emmichoven & Ubaghs, 1936 a–c; ter Bruggen, 1936). Later work supported ter Bruggen's opinion, though some of the phyllites are indeed Cretaceous.

Other activities, 1923 to World War II

Working independently of the West Borneo Program, De Kroes (1926) from 1922 to 1925 carried out government auger and Bangka drilling programs for gold in selected areas of the Chinese Districts (Fig. 8), as well as a reconnaissance auger drilling traverse from Bengkayang to the Landak River, panning numerous alluvial and soil samples on the way. The results were generally disappointing.

In 1927, Rutten reviewed the geology of Indonesia, up to the end of van Es's work. He noted with satisfaction that geologically, the Indonesian part of Borneo was better known at his time than the Malaysian part. He was inclined to believe van Es's conclusion that many of the 'Quartz Porphyries' of Wing Easton were hornfelsed rocks, but criticised van Es for not having provided hard evidence in the form of thin-section descriptions and photographs, pointing out that Wing Easton's work had been the result of 'years of untiring field work and laboratory studies' and therefore warranted a more convincing presentation of counter arguments. Rutten also took a midway position between the two mutually opposed opinions of Wing Easton and van Es regarding the age of the granites. He was the first to suggest that there were two main ages, with the younger granites distributed in a northern belt, and the older granites in the Schwaner Mountains and the southwestern part of Kalimantan. Lastly, Rutten rejected van Es's idea that the phyllitic 'old slates' were contact-metamorphic sediments, stating that they were 'typical products of regional metamorphism'.

Rutten was not convinced that the three small volcanoes described by van Schelle (1886) and Wing Easton (1889) from northwestern SANGGAU were indeed volcanoes, and he disclaimed van Schelle's assertion that the Gunung Melabu volcanics contained nepheline[5]. Rutten (1927) summarised the work of Krause, Vogel, and other palaeontologists on the collections gathered by van Schelle, Koperberg, and Wing Easton. These collections indicated that significant parts of the so-called Triassic 'old slates' were Jurassic and Cretaceous, although finds of *Monotis salinaria* indicated that some of the 'old slates' were indeed Triassic.

Wing Easton (1925) had proposed that diamonds were derived from altered peridotites (sensu lato). He had a published debate in 1930-1931 with the Mijnwezen mining engineer P. Hövig on diamond genesis (Wing Easton, 1933), Hövig maintaining that diamonds were produced in acid igneous rocks. An excursion to south Kalimantan, led by W.C.B. Koolhoven, resolved the question when some small diamonds were found in a 'weathered ultrabasic rock' which resembled the 'blue ground' of the South African diamond fields (Wing Easton, 1933). Hövig (in a postscript to Wing Easton, 1933) gracefully acknowledged defeat. Much later (Bergman & others, 1987) it was found that the 'intrusive ultrabasic breccia' is more likely to be of sedimentary origin.

An independent engineer, H. Witkamp (1932 a, b), carried out field investigations of diamond concessions in the Sekayam River area for a private concern. His detailed report contained a locality map and described his six terrace levels and their relation to the diamond occurrences. According to Witkamp the diamonds had been transported over very long distances from their area of origin.

[5] This is still possible as leucite basalt has been described by H.A. Brouwer (*in* Rutten, 1927) from the source area of the Kayan River in LONG NAWAN, showing that alkali basalts do exist in Kalimantan.

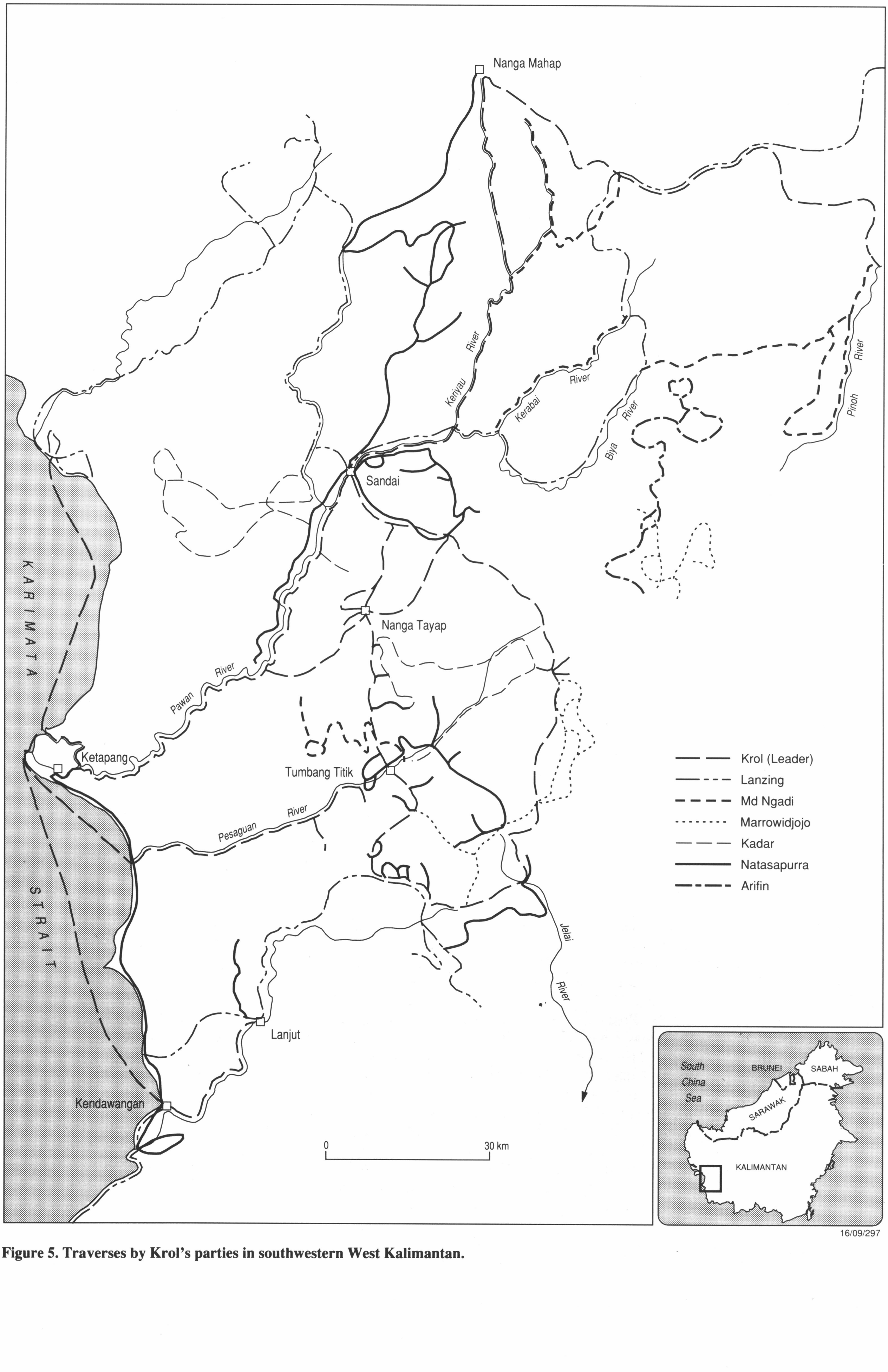

Figure 5. Traverses by Krol's parties in southwestern West Kalimantan.

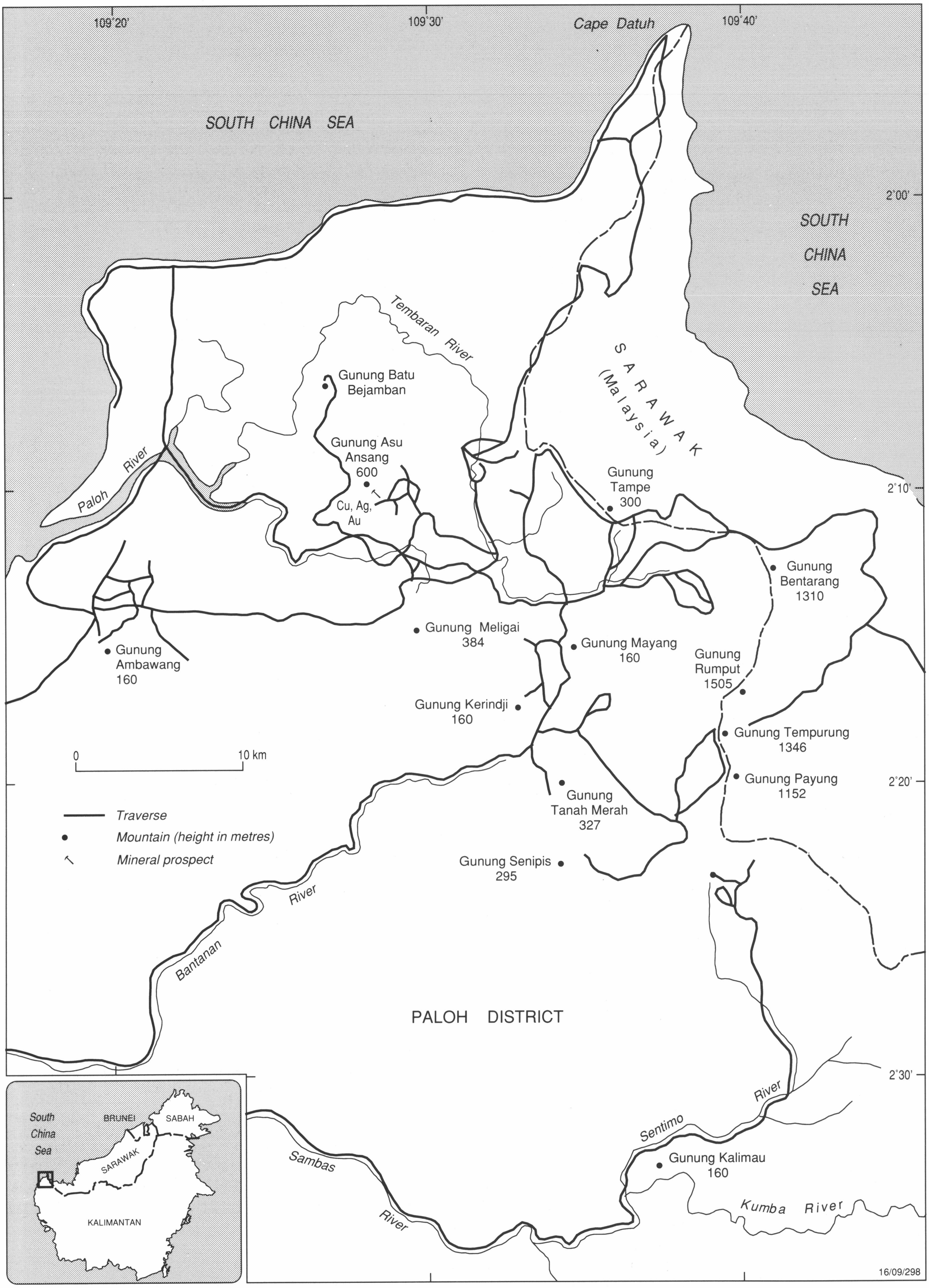

Figure 6. Krol's traverses in the Paloh district, northern SAMBAS.

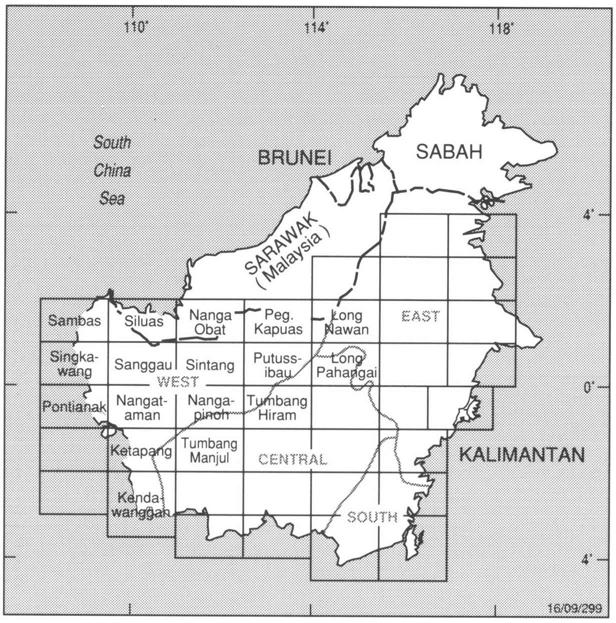

Figure 7. Location of 1: 250 000 Quadrangles covering West Kalimantan.

Umbgrove (1934, 1935a) rejected Wing Easton's 13 year old theory of continental drift solution, and the Dutch geomorphologist G. L. Smit Sibinga (1935) responded in defense of Wing Easton.

Schlaich (1939) reconnoitred the Melawi Basin in 1939 for the BPM/Shell oil exploration company. He noted many contradictions in the older literature. Although Zeijlmans van Emmichoven (1938) considered the 'Plateau Sandstone' to be an upper sandy facies of the Palaeogene 'Melawi Series', with the Silat Shale representing a lens within the 'Plateau Sandstone', Schlaich concluded that the 'Plateau Sandstone' was Eocene, and disconformably or unconformably overlies the 'Melawi Series' (also Eocene). Despite a few oil indications in a limnic facies lens of the Silat Shale, Schlaich concluded that the stratigraphic conditions were not favourable for the formation of economic oil reserves. However, he did recommend a closer investigation of one or two anticlinal structures.

At the completion of the West Borneo Program in 1932, systematic geological field work ceased, and activities were confined to studies of mineral occurrences and the writing of reviews. Much of this work remained unpublished because of the sudden interruption of World War II, with Japanese forces occupying the country in February 1942.

J. G. H. Ubaghs (1940), a Mijnwezen geologist, reviewed various copper, lead and zinc occurrences, the Selakian veins, the Chinese district copper shows, and the Kendawangan lead-zinc pods in West Kalimantan, but did not contribute anything new. From his discussion of the Tampi copper locality it is clear that he had not read Krol's report and was still unaware that Everwijn had investigated the wrong mountain. In his review of diamonds in Kalimantan (1941), he noted that both Wing Easton (1904) and Krol (1920) had recorded three diamondiferous areas in West Kalimantan: Landak, Sekayam River, and the Kapuas River near Semerangkai. Van Es had recorded many more locations, including the Menyukai (Menjoekai) River which according to Wing Easton (1904) did not contain diamonds. Van Es probably confused Darit village on the Menyukai River with the locality Nanga Darit in the Upper Sekayam basin, where diamonds had been recorded. Everwijn (1879) had mentioned two additional sites on the Kapuas River, within 20 km upstream and downstream of Sanggau.

Zeijlmans van Emmichoven (1939b), too, reviewed the mining industry in Kalimantan and its economic future. He stated that since 1889 several European managed gold mining companies were established, which had generally been short-lived and unproductive. Two mines opened in 1935 and 1936 had had some success, though output in one (Serantak) had strongly declined in the 4 years of its existence. Production in the other mine (Pandan) had shown a healthy increase. Despite this, Zeijlmans remained very pessimistic about the future of the gold mining industry and the potential of the known occurrences of base metals, diamonds, mercury, molybdenum and other ores.

However, in 1941 Zeijlmans van Emmichoven (1941a, b) adopted Everwijn's view that ore grades might increase with depth, and agreed that the Chinese miners could not delve deeper than 15 m. He drew attention to large discrepancies between field and laboratory gold assays of finely disseminated sulphidic ore. In one case, the field determination was 0.055 g/t Au, and the laboratory chemical assay result was 17 g/t Au. In another case, the results were 0.4 g/t Au (in the field) and 4.0 g/t Au (laboratory). Similarly, gold values from the Hang-Moei-San mine obtained by the laboratory were about 300 times higher than those obtained in the field. Zeijlmans therefore concluded that the potential of sulphidic vein gold deposits could not be written off, because efficient extraction of very fine-grained gold from sulphides should be feasible by modern technology. He also recommended that future exploration include testing in depth, as suggested by Everwijn many years before. The underground Pandan mine was used to demonstrate increasing richness in silver content with depth, and smaller increases in gold. According to an analytical result slip Zeijlmans found at the mine, a channel sample of the main vein in depth contained 8.16% Cu, 170 g/t Au, and 156.4 g/t Ag.

At the instigation of Zeijlmans van Emmichoven, the small molybdenite shows first reported by Wing Easton from the headwater region of the Ledo River, 10 to 13 km northwest of Bengkayang, were investigated in detail by Faddegon (1941b), who located eight outcrops of molybdenite-quartz veins in granite. The molybdenite was commonly coarsely crystalline (in books up to 1 cm across), but also occurred finely disseminated in impregnation zones. Accompanying minerals included pyrite, some chalcopyrite, scheelite, and sparse magnetite and hematite. 'Casserite', mentioned in his report, could not be found by JICA (1982) geologists who suspected that Faddegon had mistaken some sphalerite for cassiterite in his thin-sections. Faddegon concluded that the molybdenite deposits had no economic potential.

Zeijlmans van Emmichoven (1940a) investigated another molybdenite prospect at Mount Benaul, 20 km southwest of Ngabang, where the mineral had first been found in about 1900. He found a little molybdenite in only one of the four pits dug, and considered the prospect to have little potential.

In 1941, Faddegon (1941a) visited the cinnabar prospect at Sekireh, near Lumar. Although generally thought that cinnabar was derived from the hydrothermally altered basic volcanics at the prospect (Van Schelle, 1884a, 1887c), Faddegon concluded that the mineral was genetically associated with a silicified quartz keratophyre in the locality.

The Mijnwezen geologist M. A. Koolhoven (1941) advised the Dutch East Indies government on a proposal to reserve two areas (in central Sumatra and West Kalimantan) that contained prospects of strategic minerals. His report contained two appendices: one by Faddegon on Sumatra, the other by Zeijlmans van Emmichoven (1941b) on various metals in West Kalimantan.

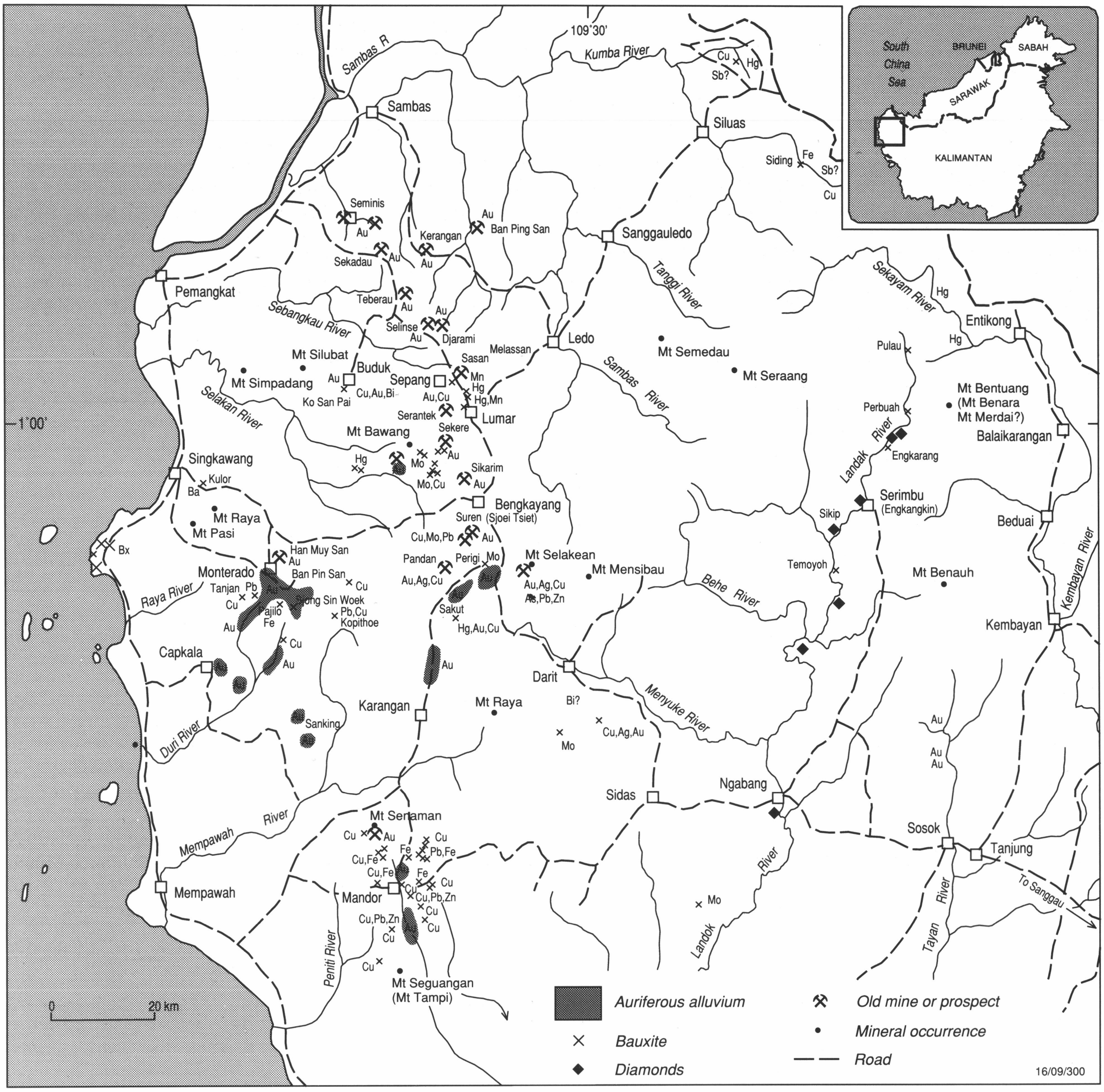

Figure 8. The Chinese districts.

1942-1966: the dead years of World War II and its aftermath

During the War, geological investigations were scarce or remained unreported. The Japanese did carry out some small-scale mining of manganese from three localities in the Lumar area (Hirata, 1944; Tarring & Bellows, 1952) and mercury from the Tebaung (Nambah) River in PUTUSSIBAU (Surono & Noya, 1989). Small-scale geological surveys probably accompanied those activities.

After the War, times remained turbulent during the Indonesian struggle for independence. There was a marked decline in mining because rehabilitation and modernisation of existing mines was hampered by lack of capital, and private investment was not encouraged (Sigit, 1973). A few papers were written abroad, including the following:

Beltz (1944) reviewed sedimentary basins in Indonesia and their potential for oil deposits. In West Kalimantan this included the Melawi River Basin, which he described as a lower Tertiary embayment of thick terrestrial deposits and volcanics interbedded with some brackish water deposits, perhaps with some marine incursions. An oil seep was reported from the eastern end of the basin in shales of presumed Eocene age.

Zeijlmans van Emmichoven (1946) reviewed the cinnabar occurrences around Lumar, originally discussed by van Schelle (1884a, 1887c) and later investigated by Faddegon (1941a). According to Zeijlmans, the quartz keratophyre contained irregular pipe like cavities filled with clay very rich in coarse cinnabar, which also impregnated the cavity walls in finely disseminated form.

De Roever (1946) summarised Zeijlmans 1946 report, adding that 'most mercury deposits in the world are associated with great tectonic lines ... and many are genetically related to young igneous rocks'. He noted that the mercury deposits in the Boyan River region, too, were associated with such zones of tectonic disturbance, and occurred in Cretaceous sedimentary regions, which in West Kalimantan often have some bituminous content.

The most important contribution was a compilation and synthesis of the geology and mineralisation of Indonesia by van Bemmelen (1949, reprinted 1970), commissioned by the Dutch government. Van Bemmelen lost his original manuscript during the War, and took three years to rewrite it.

In 1952, Tarring & Bellows made a quick reconnaissance of mineral deposits in the Chinese Districts, including a gold vein at Gunung Serantek west of Lumar, the manganese prospects northwest of Lumar, cinnabar at Sekere, bauxite at Roban on the Bengkayang road 3 km from Singkawang, and kaolinite in a swamp 5 km southeast of Singkawang. They also mentioned the existence of a stockpile of manganese ore at Sentete on the Sambas River, left there by the Japanese.

Westerveld (1952) published a tectonic scheme of Indonesia in which four orogens in ever widening zones spread themselves towards the Indian Ocean, each orogen characterised by a specific mineralisation pattern, composition, and age. In his view, West Kalimantan belonged to the Late Jurassic Malayan Orogen which also included the Malay Peninsula and the Indonesian tin islands. Katili (1974) found numerous discrepancies in this scheme and concluded that it could not be used as a basis for mineral exploration.

In 1954, Westerveld compared the radioactivity and chemistry of the granites of West Kalimantan with those of the tin islands, and concluded that the chances of discovering tin deposits in West Kalimantan were slim.

In 1960, the IMCO, C.Itoh, & Meiji Mining companies investigated low-grade bauxite deposits discovered after the War along the coast 15-20 km southwest of Singkawang township. A second report was produced a year later (Meiji Mining, C.Itoh, & Kishimoto Schoten). The four bauxite bodies overlie granodioritic rocks.

When the Geological Survey Department of British Borneo was established in 1949, and started their own systematic geological surveys, the Dutch literature became of growing interest to their geologists. A selection of 10 Dutch written papers was therefore translated into English (see Haile, 1955a), including papers by Krekeler, Krol, ter Bruggen, and Zeijlmans van Emmichoven & Ubaghs. There were a number of points on which the Sarawak geologists disagreed with the old Dutch ideas; they are summarised by Haile (1955b) and include the age and relationships of the 'Danau Formation', the phyllite formation, the fault system west of the Lakes district, and the Kantu and Engkilili Beds.

1967-1990: from slow recovery to accelerating development

Government policy after 1965 strongly favoured mineral exploration and development. In 1967, the Foreign Capital Investment Law was introduced, together with the New Mining Law, and competitive bids were invited from private companies for the exploration of 53 separate units of potential mineral-bearing land, averaging 9000–10 000 km^2 (Sigit, 1973). Geological investigations started to concentrate on age determinations, palaeomagnetics, and regional structural and tectonic syntheses culminating in plate tectonic theories. Later, Indonesian government agencies undertook joint projects in partnership with overseas governments and institutions. The Indonesia-Australia Geological Mapping Project was one of the latest and most comprehensive examples of such joint projects.

Exploration for oil, gold, uranium, tin, diamonds, bauxite

One of the first companies to enter Indonesia on the basis of the New Mining Law was ALCOA, whose Indonesian offshoot Alcoa Minerals of Indonesia (PT Alcomin) from 1967 to 1971 prospected for bauxite in large parts of the country, including West Kalimantan, where large tonnages of low grade bauxite were outlined in the Sandai region, KETAPANG. However, economic feasibility was marginal, and exploration ceased when prices slumped on the world market. The Billiton Maatschappij included the coastal zone of southwest Kalimantan in an exploration program for offshore tin deposits between the Karimata Islands and the Kalimantan coast. Between 1969 and 1979 a joint BATAN/CÉA (Badan Tenaga Atom Nasional/Commissariat à l'Énergie Atomique of France) search for uranium in a huge part of Kalimantan resulted in the discovery of a mineable deposit in the Ela Ilir (or Kalang) region, NANGAPINOH. Its geology and mineralisation are described in several papers (in International Atomic Energy Agency, 1988).

Over the years a number of oil and mineral companies have prospected and explored in West Kalimantan, but their amassed data have remained largely confidential. Among the oil companies have been the BPM (Bataafse Petroleum Maatschappij, i.e. the Shell exploration branch) (Schlaich, 1939), BP Petroleum Development Ltd. (Buchan,1973), Union Oil Company of California (Wories, 1974) and Total and Elf-Aquitaine of France, following a reconnaissance by Pertamina. All of these companies showed interest in the Melawi and/or Ketungau Basins. Some of the mineral exploration companies and semi-government agencies that have looked into West Kalimantan are Anaconda (including diamonds), BP Minerals International, the French Commissariat à l' Énergie Atomique (CÉA) in joint venture with BATAN, and Esso Minerals. Most attention has focused on gold and diamonds, but the BATAN/CÉA Joint Venture was specifically searching for radioactive minerals.

The last 5 years have seen a remarkable boom in gold exploration, after an improved 'fourth generation' Contract of Work (COW) made entry more attractive to foreign interests. In West Kalimantan these have included BP Minerals, Pelsart, Duval, Jimberlana Minerals, Rio Tinto Indonesia, Jason Mining, Dominion Mining and Reniso Goldfields. Successful finds have been made in East and Central Kalimantan, but not yet in West Kalimantan, where Rio Tinto Indonesia has had problems with its gold dredging operations at Mandor (opened up in late 1988), and development work appears to be continuing on the Monterado alluvials. As in the old days, many companies have proved to be small and undercapitalised and, when hit by the October 1987 share market crash, tried to sell off their interest to more powerful concerns.

The history of mineral exploration by foreign companies in Indonesia 1967-1991 has recently been reviewed in a very useful paper by van Leeuwen (1991), who discussed various technical aspects, certain geological features of the more important new discoveries, and the evolution of the Contract of Work system.

Geological investigations

Geological investigations after 1967 started to concentrate on age determinations and regional structural and tectonic syntheses, later followed by a long list of plate tectonic papers which reached the most contrasting and varied range of conclusions imaginable. In neighbouring West Sarawak, systematic geologic mapping programs since the end of World War II have added greatly to understanding of the geology there. Those related to the geology of the border zone with West Kalimantan include Haile (1954, 1957), Wilford (1955, 1965), Wolfenden & Haile (1963), Wilford & Kho (1965) and Tan (1979, 1982).

Muller (1968) dated the microflora in 'Plateau Sandstone' samples from the Kayan and Penrissen areas in Sarawak as Senonian-Eocene. Haile (1972) preferred the (post-)Eocene ages suggested by larger foraminifera, saying that 'dating by pollen is not well established in Southeast Asia' so that the microflora age could be unreliable. Pollen from a shale specimen collected by Haile

(1973) from an outcrop mapped as Triassic(?) 'Ketapang Complex' on the Pawan River, Ketapang Sheet, was determined to be Cretaceous by H.J.Barten of Brunei Shell Petroleum Company, which led Haile to suggest that most of the formation might be Upper Cretaceous.

A palaeomagnetic investigation including radiometric dating on igneous samples was made in the NANGATAMAN, KETAPANG, and KANDAWANGAN areas (Haile & others,1977), and further radiometric dating from the Tambelan and Bunguran Islands (Haile & Bignell, 1971) established mostly Cretaceous ages. Other radiometric dates were obtained by the French during their joint BATAN/CÉA uranium exploration (Guéniot 1976). The latest radiometric ages of granites and volcanics have been obtained during the IAGMP.

Hashimoto & others (1975) reviewed Cretaceous palaeontology and ages in Southeast Asia, including Borneo, and Hashimoto & Matsumaru (1974) redefined the *Orbitolina* fauna from the Seberuang Cretaceous.

The Cretaceous and Tertiary stratigraphy of Borneo and its equivalent in West Kalimantan was discussed in considerable detail in an interesting unpublished work by Buchan (1973), who used invalid formation names unknown in the published literature.

Controversy still exists about the age, correlation, and palaeoenvironment of the various rock units on either side of the border. For example, estimates of the age of the phyllitic unit ('old slate formation', 'phyllite formation', 'Sembakung Formation', etc.) have ranged from Devonian to Eocene! Structural complications commonly obscure normal boundary contacts. Molengraaff, for example, had already recognised the existence of a 250 km long, east-west running fault zone which separates the phyllitic formation in the north from the 'Danau Formation' to the south. According to Haile (1957), the 'Danau Formation' interfingers with the flysch sediments of the Lupar Formation in Sarawak. Buchan (1973) bundled together the 'Danau Formation', the Lupar Formation (in West Sarawak), and the Bunguran Beds (on the Natuna Islands), creating a 'Danau Group' which, together with the Ujut Group and another group, is part of his 'Rajang Supergroup'. On fossil evidence, Haile attached a Late Cretaceous age to the 'Danau Formation' in Sarawak.

Buchan further described the Ujut Group as a thick flysh sequence which included his 'Sembakung Formation'. In northeastern West Kalimantan this sequence had been called the 'phyllite formation' by ter Bruggen (1932, 1935), and 'old slate formation' by Molengraaff. The latter was uncertain of the age of the 'old slates' (which he regarded as a continuation of the 'old slates' of the Chinese Districts), suggesting at one stage that the unit was older than the Danau Formation, and on other occasions that it might be Tertiary.

Buchan's (1973) age for the 'Sembakung Formation' in Sarawak is Late Cretaceous to Middle and Late Eocene, which agrees with the age estimates of both ter Bruggen (1935, 1936) (Eocene) and Zeijlmans van Emmichoven (Zeijlmans van Emmichoven & Ubaghs, 1936a, b) (Late Cretaceous). The equivalent formation in West Kalimantan has been renamed the Embaluh Group by the geological team of the IAGMP, and is thought to be Eocene.

Tan (1982) found Early Eocene nannofossils in the sheared pelitic matrix in his Lubok Antu Melange in the Lupar Valley, West Sarawak. The melange consists of blocks of Lower Cretaceous radiolarian chert; Upper Cretaceous greywacke and slate; ?Cretaceous and Eocene limestone; mudstone, sandstone, hornfels, basalt, spilite, gabbro, and serpentinite. He postulated that the melange was caused by early Tertiary southeast subduction of oceanic crust.

Pulunggono (1985) reviewed the history of geological investigations and theories in the general region of Sundaland, concentrating on Sumatra, and barely touching on West Kalimantan.

The global structural setting and development of Borneo have been discussed by many authors. The earliest (Wing Easton, 1921) used Wegener's continental drift theory (see above). Some 40-50 years later, the structural setting of Borneo was described in terms of the geosynclinal concept (e.g. Haile, 1969, 1972; Klompé & others, 1961). With the renaissance of a revamped continental drift theory in the form of plate tectonics, a spate of papers has been published since 1972 on the origin of the global features in the Southeast Asian and western Pacific region (e.g. Hamilton, 1972, 1973, 1979; Haile, 1973a, b, 1979, 1981; Katili, 1973, 1974, 1975; Pupilli, 1973; Ben-Avraham & Uyeda, 1973; Hamilton, 1976; Ben-Avraham, 1978; Shield, 1979; Ridd, 1980; Taylor, 1980, 1983; Audley-Charles & others, 1981; Stauffer, 1983; Hutchison, 1984; Sengör & Hsü, 1984; Sengör, 1985, 1986; KeRu & Pigott, 1986). In these speculations, Borneo was variously thought to have been derived from Southeast China, Indochina, the Antarctic (Wing Easton, 1921), a cluster nestled in between North and South America, Southeast Asia, and Australia before the opening of the Pacific Ocean (Shields,1979), or as an agglomerate of microcontinents derived from southeast China and Western Australia

Joint Indonesian/foreign agency projects

After 1970, several countries undertook joint projects with Indonesian government agencies. Following Indonesian/American reconnaissance geochemical sampling in the region from 1970 to 1973, a joint Indonesian/Belgian geochemical survey (Viaene & others, 1981) carried out detailed geochemical sampling in the Gunung Pasi/Gunung Rajah area between Singkawang and Monterado, with accompanying geological mapping to correct Wing Easton's (1921) old map and to assist in interpretation of geochemical results.

A detailed Indonesian/Japanese joint venture program of geological, geophysical, and geochemical investigations was undertaken over a three-year period from 1979 to 1982 (JICA, 1982), encompassing an area of roughly 1500 km^2 straddling the border between SINGKAWANG and SANGGAU. Survey methods included airphoto interpretation, mapping, geochemical and geophysical surveys, petrographical and palaeontological studies, chemical analyses, radiometric dating and mineral studies. Results included recognition of granites of two different age groups; a subdivision of the Upper Triassic/Jurassic stratigraphy; and clarification of the types and distribution of mineralisation.

The program concluded that:

- the 'Matan Complex' in the KETAPANG area may be correlated with the Jurassic sediments in the JICA survey area;
- two ranges of granite ages exist: 124-95 Ma and 27-20 Ma. The granitoids belong to the calc-alkaline series and are of the 'magnetite-type';
- West Kalimantan appears to form part of the Cretaceous magmatic arc that extends from South China through the southern part of Indochina to West and Central Kalimantan;
- about six types of mineralisation can be recognised, involving gold, base metals, molybdenite and manganese. They are genetically associated mostly with the Late Cretaceous to Miocene plutonic and subvolcanic events;
- stream sediment sampling and geological mapping can together outline mineralised zones on a regional scale;

- soil geochemistry and geophysics along with detailed geological surveying are very effective in estimating the distribution range and grade of mineralised zones in detail.

In view of the detailed character of the JICA survey, it is somewhat surprising that the long-lost Pandan mine was not rediscovered.

Acknowledgements

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Appendix 1. Spelling of Bahasa Indonesia

Pre-World War II written Bahasa Indonesia used spelling rules based on Dutch phonetics. Since Indonesia obtained its independence, spelling conventions have changed. This might cause some confusion when reading pre-War reports, and the following explanation of the main differences is therefore provided:

Old	*New*	*Pronunciation*	*Examples*
oe	u	as in broom, doom	boekit → bukit goenoeng → gunung batoe → batu
tj	c	'tj' as written Almost, but not quite, as 'c' in church	tjap = cap Tjitaroem → Citarum
j	y	'y' as in yellow	Japen → Yapen Soerabaja → Surabaya
dj	j	'j' as in jovial	djalam → jalan djam → jam
c	s	before the vowel 'e' a normal 's' sound	Ceram → Seram

Thus, 'Tjiandjoer' has become 'Cianjur', 'Tjioedjoeng' is 'Ciujung', 'tjatjing' is now 'cacing', 'tandjoeng' is 'tanjung', etc. The unstressed 'a' is usually written 'e' in the Dutch custom, as in 'Melajoe' for Malayu, where the stress falls on the second 'a'. Note that the pronunciation remains the same. Many Indonesians preferred to retain the old spelling of their names, others conformed to the new spelling. Therefore we may find, side by side, Suharto and Soeharto, Sukarno and Soekarno, Yanus and Janus, Priharjo and Prihardjo, etc.