

History of geological mapping in Sabah (late 19th Century-1951)

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Abstract: The early history of geological mapping in Sabah can be divided into two successive periods, each finalized by an attempt at a synthesis. The initial work of pioneer explorers (1880ies–1890ies) was summarized in T. Posewitz's publication (1892); the work by professional geologists (early 1900-late 1930ies) was synthesized by M. Reinhard and E. Wenk's publication (1951).

Keywords: T. Posewitz, F.G. Witt, F. Hatton, J. Pletzer, C. Schmidt, R. Pilz, K. Stamm, J. Wanner, M. Reinhard, E. Wenk

INTRODUCTION

The gradual penetration in the interior parts of Sabah by explorers and later by scientists is reflected in an evolving picture of its geology, at first blurred with many gaps and misinterpretations, leading progressively to a more precise understanding of both its physical geography and its structural and stratigraphic composition.

In an historical perspective, the records left by geologists from the late part of the 19th century till the middle of the 20th century demonstrate the evolution of geological models, from a rigid to a dynamic earth, from a broad-brush portraying of the rocks to a fine-scale characterization, from vague chronostratigraphic concepts to constrained age determinations, from rough ideas about depositional systems to an unconformity-based analysis of the stratigraphy.

A step-wise series of such improvements is noted in successive geological maps from the northeastern corner of Borneo, ranging from 1892 to 1951.

As we follow the progresses made in the geological mapping of Sabah, it is important to remember the magnitude of the tasks facing the field geologists, as mentioned by M. Reinhard (1924): “...consider the drawbacks which handicap geological investigations in a tropical country like Borneo. Every square yard is covered with thick jungle, and outcrops are only found along running water. The geologist's task is reduced to mapping the rivers and noting the strike and dip and the nature of the exposed rocks. In making the map he will be able to interpret the geological features of a country, if its structure is not too complicated.”

PIONEERING EXPLORATION AND GEOLOGICAL MAPPING OF KALIMANTAN

To put the progress of the geological mapping in Sabah in context, it is worth mentioning that similar efforts were undertaken earlier in Kalimantan.

In 1816, the Dutch government created a “Commission of Natural Sciences” which fostered scientific exploration of the Indonesian Archipelago (Keyser & Noya-Sinay, 1992). As from 1822, administrative officers posted in Kalimantan carried out a number of inland journeys and started with mapping river and mountain systems, while

occasionally making geological observations. G. Müller, Dr. C.H. Schwaner and H. von Graffon unraveled much of the geography of South and East Kalimantan, while also making geological observations. Unfortunately their original reports are difficult to access today.

A “National Advisory Committee” was set up in 1837 (Poley, 2000), but detailed scientific work, including the geological mapping of Kalimantan, started soon after the establishment of the Department of Mines (“Mijnwezen in Nederlandsch Oost-Indië”) in 1850. Trained geologists such as R. Evervijn, C.J. van Schelle, Wing Easton and, above all, G.A.F. Molengraaff (1900) made giant progress in unraveling the stratigraphy and structural grain of Kalimantan. Molengraaff carried out detailed geological studies, particularly on the western part of Central Borneo and a part of South Borneo. Results of his work carried out in 1893-94, include high-resolution geological maps and cross-sections. Geologists working in Sabah could then adopt an important part of Molengraaff's Central Kalimantan stratigraphic scheme.

PIONEERING EXPLORATION AND GEOLOGICAL MAPPING OF SABAH (1880S-1890S)

The mainland region extending almost in a straight NW-SE line from the Klias Peninsula northeast of Brunei to the port city of Tawau at the border with North Kalimantan was the last segment of Borneo to be explored. In the early 1880s, as soon as the North Borneo Chartered Company had been founded (1881), a series of expeditions were sent for the first time into this vast area. These reconnaissance journeys proceeded from the coast up into the interior through the main river systems.

Led by explorers who generally had a fair knowledge in natural history, these exploratory trips were primarily aimed at establishing if precious metals and gems, as well as coal, could be found in commercial quantities. With the exceptions of the letters written by Ferencz György Witt and the letters and notebooks left by the geologist Frank Hatton, virtually no documents are available today that contain geological information gathered through these

journeys. No maps were constructed, no geological cross-sections drawn, few stratigraphic sections logged and scarce measurements such as dip and strike were made.

Entire trips lack any documentation, such as those made on the Segama River by gold prospectors in the year 1883-1904 (Reinhard & Wenk, 1951).

Geological results from this initial period of journeys into the “terra incognita” of Sabah are extremely scarce, despite the large sums of money invested in this endeavor. Perhaps one of the reasons explaining this situation is the fact that Sabah has the most complicated geological history of any part of Borneo, subsequently it was extremely difficult for explorers and geologists alike to make sense out of the stratigraphic and structural complexities they were facing, particularly in the pre-Tertiary sequences. As M. Reinhard writes (1924): “*Cherts and radiolarites, ophiolites (serpentine, gabbro, troctolite, diabase, variolite, spilite) shales and sandstones, conglomerates and breccias, are intricately intermingled. (...) The strata are not only strongly squeezed and bent, but stress has modified even the intimate structure of the rocks, which are dynamically metamorphosed. One will scarcely find sandstone banks of any extent; they have been broken up and lumps of irregular shape and dimension float in an argillaceous matrix, which has been pressed into the cracks of the brecciated sandstones.*”

“It is possible to establish the stratigraphical sequences and the folds, whenever the strike and dip measured are a differential part of a structure. This is no longer the case in an overthrust region, and here this surveying method, the only possible one, fails. The result is chaos and all attempts to interpret it are unfruitful. Our detailed original survey in regions where the Danau formation exists, illustrate this clearly.”

“The whole Danau formation gives the impression of a tremendous breccia.”

THEODOR POSEWITZ'S GEOLOGICAL SKETCH MAP OF BORNEO, 1892

The first geological map of Sabah, actually a geological sketch map of the entire island of Borneo drawn at a scale of 1: 2,414,000 was published by T. Posewitz in 1892 (Figure 1).

Born in Budapest, Theodor Posewitz studied medicine before working for 3 years as a military doctor in the Dutch East Indies. While posted in southern Borneo (Bandjermassin, Barabei and Teweh), he dedicated himself to studying geology, compiled and published all available data regarding discoveries, travels and geological investigations on the island. He summarized the knowledge at the time in the form of a book (Posewitz, 1889, 1892), including a series of four maps: (1) *Traveller's Routes in Borneo*; (2) *Index Map of Borneo showing political divisions and the state of our information with regard to the Geography and Geology of the Island*; (3) *Geological Sketch-Map of Borneo*; (4) *Distribution of Useful Minerals in Borneo*.

Posewitz's publication marks the first attempt to synthesize the entire geology of Borneo, integrating the data gathered in Kalimantan (recorded mainly in Dutch), with those of Sarawak, Brunei and Sabah.

Background to Theodor Posewitz's *Geological Sketch Map of Borneo*, 1892

In order to construct his geological sketch map of northeast Borneo, Posewitz relied on the descriptions left by J. Peltzer (1881), F. G. Witt (1881/1882) and F. Hatton (1882). Useful data left by these travellers are extremely sketchy and it is surprising that a geological map could be drawn based on these reports. In addition, the geography of Sabah was itself largely unknown and the topographic knowledge was restricted to the coastal areas, which had been mapped by the British Admiralty. With these two large uncertainties at the core of his work, Posewitz was very daring in his proposition.

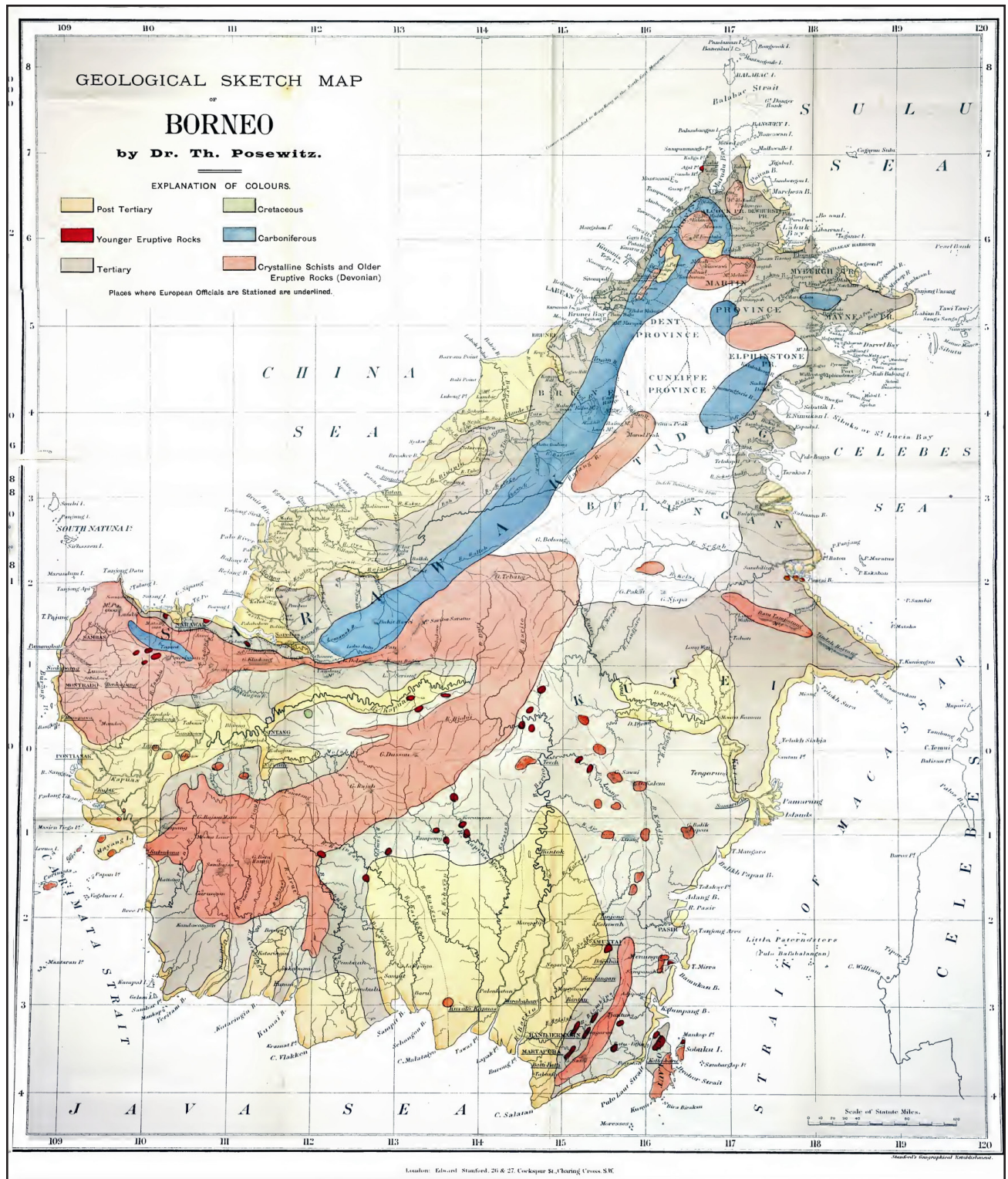
Some examples of data available to Posewitz are quoted below, selected as the most representative descriptions of geological interest from each of the sources.

J. Peltzer's travels through northeast Sabah (Peltzer, 1881) were primarily aimed at discovering land suitable for the cultivation of coffee; geological notes when recorded are of an extremely general nature. For example, on his trip from Papar to Kimanis (1879), Peltzer left the following description of the Lampiau Mountains: “*The neighbouring mountains are formed by sandstone, iron peroxide, a little basalt, quartz and limestone, which constitute the ground composition of Central Borneo's mountains*” (p. 378).

F.G. Witt's diaries (Witt, 1882; Bécsi, 2016) are at times a little more explicit in their geological descriptions, but barely. While travelling from Marudu Bay to Tambunan, Witt recorded the following (November 26th, 1880): “*The drift in these streamlets contains a large proportion of opaque quartz and clay nodules of a cream colour. The main part of the gravels is composed of serpentine and of the waste of the mountains in the background, no doubt a granitic formation.*”

Being a trained geoscientist, Frank Hatton had much stronger credentials (Hatton, 1886; Wannier, 2017a) but his early death resulted in much of his geological observations being restricted to his diaries and letters sent to his family, as he could not finalize any report. In December 1882, shortly before his accidental death, he wrote his last letter to his father: “*I have yet Siquati to finish, Kinoram geological report, with maps, etc.*”

While going up the Pinungah River, Hatton made the following, significantly more detailed observations (February 7th): “*On the right bank (...), coal cropping up in small seams, one-half to one foot wide, landslide sandstone. On the left bank (...) about 300 yards below the outcrop on the opposite bank, coal also. Outcrop only in isolated pockets in fire-clay. (...) Enormous deposits of ferrous hydrate in the water, indicating large quantities of iron below. Means at disposal not sufficient to enable me to bore, and surface outcrops all I can go by. 220° and 40°, N.E. and S.W., line*



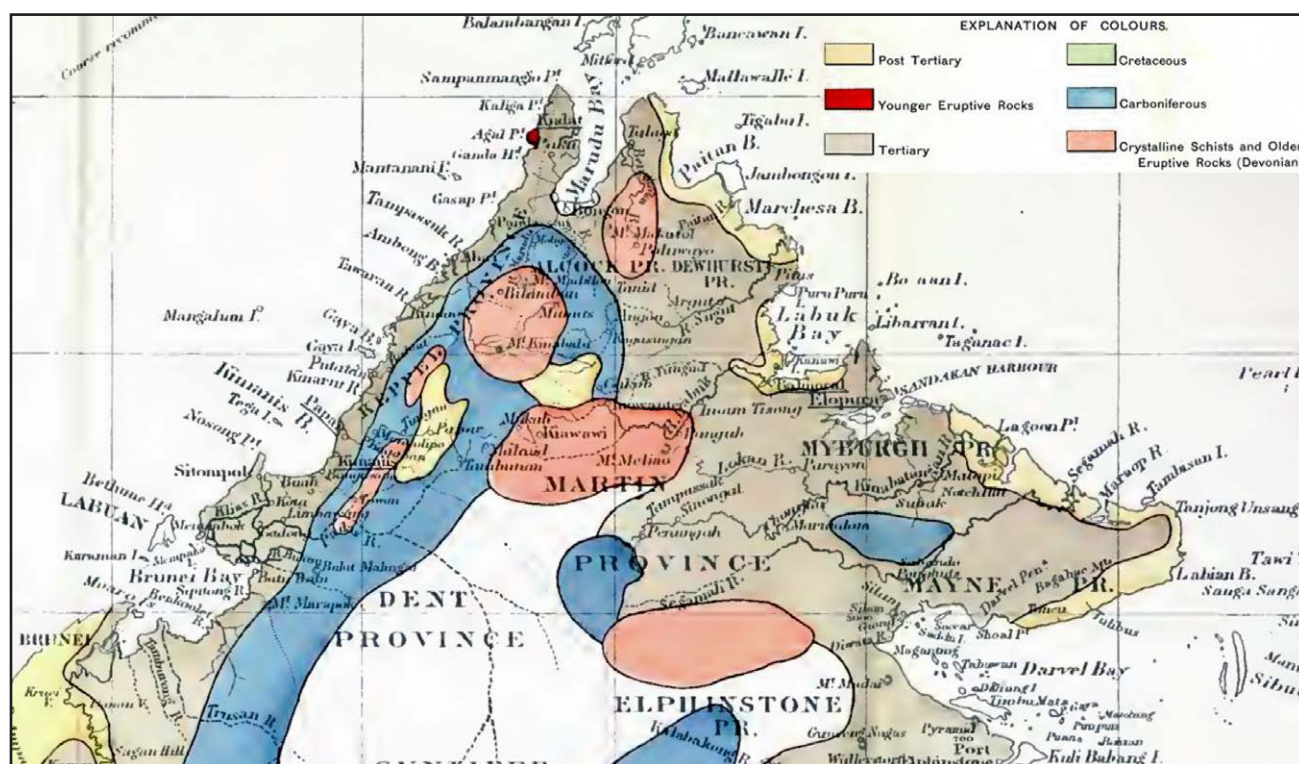


Figure 2: Detail of T. Posewitz's "Geological Sketch Map of Borneo", 1892 showing the NE portion of Borneo. For scale, refer to Figure 1.

At first glance, it is surprising to note that Sabah, being the area in Borneo with the least geological coverage, shows one of the highest level of detail on the map!

A detailed look at Sabah (Figure 2) reveals that the Crocker Range is interpreted as Carboniferous in age, with the Kinabalu "granite" representing a window into the older basement. While these two interpretations are obviously off the mark, as we know today, it would be wrong to assume that Posewitz treated the subject superficially. His analysis of the Carboniferous is heavily referenced, is based on the Sumatra analog (Carboniferous limestones overlying coarse clastics) and the age is backed up by the mention of plant remains and bryozoan in a publication. As a further diagnostic criteria characterizing the Carboniferous, he quotes the marked step towards higher elevations of the Paleozoic strata as compared with the "Tertiary" coastal ranges, the higher induration of the rocks as well as the presence of ores (e.g. antimony) in the limestones.

The Melinau Limestones of Mt. Api and the underlying clastics of the Mulu Formation are interpreted respectively as Carboniferous limestones and "older" Carboniferous clastics. "The Carboniferous formation is of great extent in Northern Borneo. It appears to extend from Sarawak to the Bay of Murudu, and to be greatly developed in North-eastern Sabah, and in the in-lying States of Tidung and Bulongan. The Carboniferous formation has already been described for Sarawak proper, where the Carboniferous Limestone contains antimony. It must, however, also occur in Eastern Sarawak (upper basin of the Batang-Lupar and Eedjang), for antimony ores are found there. These have been recently worked, and are probably of the same age

as the antimony ores in Sarawak proper, whence may be drawn a posteriori the conclusion that the rock in which they occur is also Carboniferous Limestone.

In Brunei, lying to the inland side of some low sandstone hills (Tertiary), are some limestones alternating with sandstones, and forming elevations of 2,000-8,000 feet, e.g., Mount Malu (sic) (8,000 feet), which was ascended by St. John in the fifties."

"From here the Carboniferous formation appears to extend as an immense band along the coast as far as the northeastern point; it is separated from the sea, however, by a parallel strip of Tertiary hills. Thus the river Padas cuts through a mountain chain, running along the coast in a N.E. and S.W. direction, in which is Mount Jumma (4,000-5,000 feet high), composed of a highly-inclined sandstone formation; the river Lawas also traverses a high chain of limestone mountains in its' upper and lower courses." (Posewitz, 1892).

The Cretaceous is shown to have a widespread presence on the map, though the description of this stratigraphic interval is extremely short (about 1 page of text) and the basis for the age assignment being the presence of the foraminiferal genus *Patellina* (in fact probably *Orbitolina*) recorded in Central Kalimantan.

Posewitz mentions: "How far this formation extends is uncertain. Up to the present only its existence has been proved, but this is in so far of great consequence, as it is the first proof of the existence of Mesozoic strata in the Indian Archipelago."

Regarding the presence of Tertiary strata in Sabah, Posewitz presents a fair assessment of the degree of understanding reached at the time: "Our knowledge of the

Tertiary beds of North Borneo is as deficient as it is with regard to the structure of the mountain chains. Only on the island of Labuan have they been more carefully studied, namely by Motley. In the remaining districts only their occurrence has been noted. If we judge by the description given of them, we must conclude that they have a wide distribution: and they present the same character as in the rest of Borneo, consisting of sandstones, with intercalated beds of coal and limestone reef in which edible birds' nests occur. Eruptive rocks of younger age, such as have traversed Tertiary strata in other parts of Borneo, are also mentioned as occurring in North Borneo".

FIRST MODERN GEOLOGICAL MAPS OF SABAH (1904-1951)

It was the arrival of professional geologists, advising companies on the oil potential in Sabah that led to the first detailed geological maps and cross-sections to be made. Much of the attention was focused on the Tertiary series as older stratigraphic units were deemed to have no petroleum potential.

From 1908 till 1915, the British North Borneo Company, the British Borneo Petroleum Syndicate Ltd and later the Nederlandsche Petroleum Koloniale Maatschappij (NPKM) carried out extensive geological work in Sabah. Mining engineer R. Pilz (1913) was the first to describe his exploration journeys. Results from the comprehensive campaigns in eastern Sabah were published in later years (Wanner, 1921; Reinhard, 1924). Results of the fieldwork carried out in northeastern part of Sabah during the period 1913-1915 by G. Niethammer and W. Holz and their

assistants E. Hartmann and J. Zurkirch were never officially published. Both Hotz and Niethammer published abundantly on their results, albeit as internal reports of the NKPM, none of which is readily available for consultation today (Reinhard & Wenk, 1951).

During the years 1935-1939, the Royal Dutch/Shell Group carried out wide-ranging geological fieldwork, detailed topographic mapping and aerial photographic surveys. Results from these and the older field campaigns were summarized in Bulletin No. 1 of the newly formed Geological Survey Department of the British Territories in Borneo (1951); this publication provided a comprehensive synthesis of the geological knowledge on Sabah, acquired before World War II (Wannier, 2017b).

CARL SCHMIDT'S TECTONIC MAP OF THE BRUNEI BAY AREA, 1904

Professor Carl Schmidt, a professor at Basel University was the first professional geologist to visit North Borneo (1899) as part of a trip that also included Sumatra and Java; he studied the area of Brunei, Labuan and the Klias Peninsula. His observations were published in 1901 and 1904.

Prospecting for oil, Schmidt was primarily interested in the structural make-up of the country; his "*Tectonic Map of the Brunei-Bay Region*" (*Tektonische Karte des Brunei-Bai Gebietes*) published in 1904 was the first such sketch map that portrayed the structural grain of parts of Sabah. Drawn at a scale of 1:316,800, it shows trending anticlinal and synclinal axes, dip and strike measurements, oil and gas occurrences as well as the location of mud volcanoes and wells (Figure 3). Six geological cross-sections were constructed. An

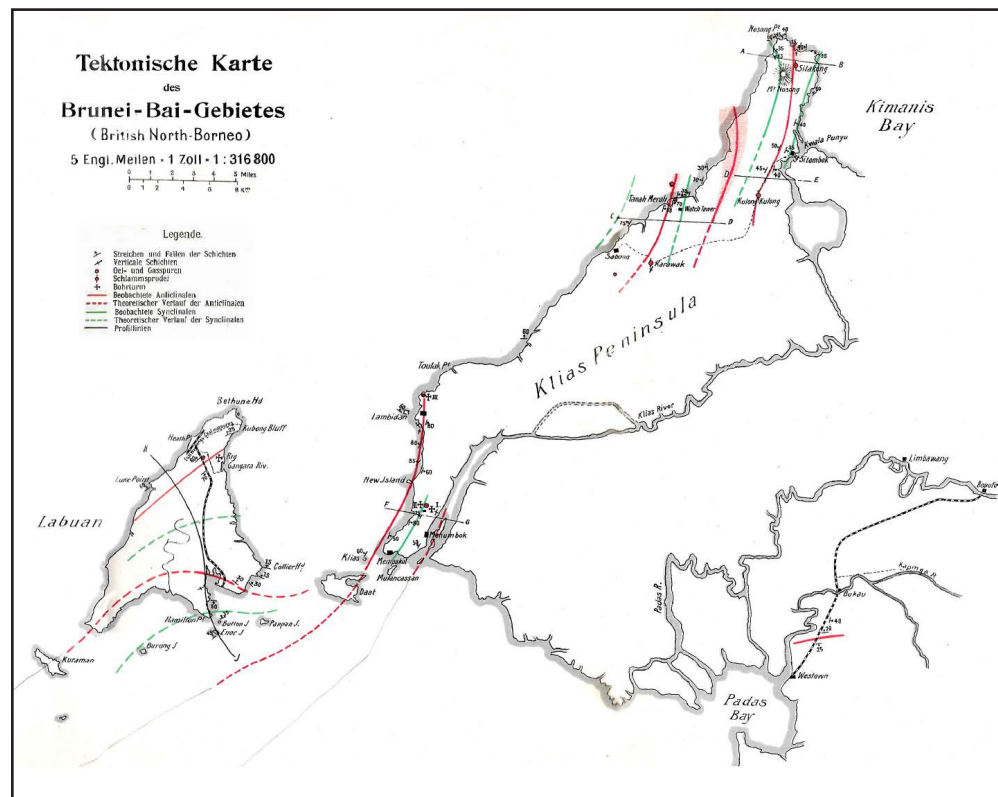


Figure 3: C. Schmidt "Tectonic Map of the Brunei-Bay Region" (*Tektonische Karte des Brunei-Bai Gebietes*), 1904.

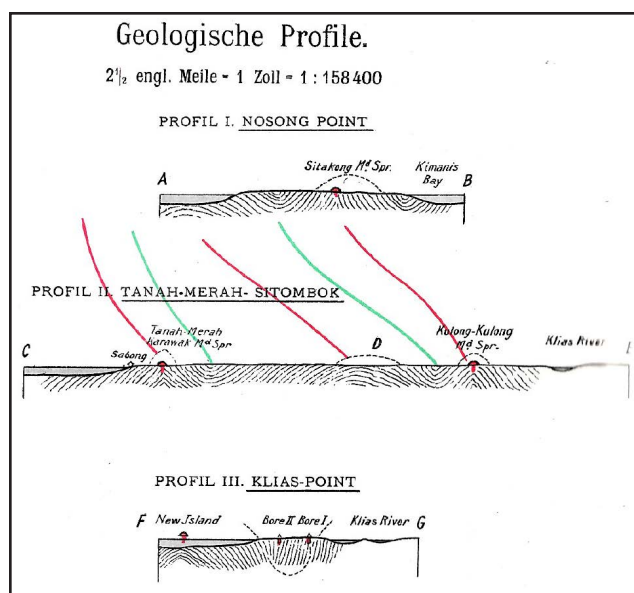


Figure 4: Excerpt from C. Schmidt tectonic map showing the geological profiles through Nosong Point, Tanah-Merah-Sitombok and Klias Point.

excerpt of Schmidt's map including geological profiles drawn through Nosong Point, Tanah-Merah-Sitombok and Klias Point is shown for reference on Figure 4.

Being primarily interested in the Tertiary series, Schmidt referred to some conflicting age dating of the Labuan coals (Eocene vs Neogene), but he did not carry out any stratigraphic research himself. He described surface oil and gas shows, and referred to existing shallow wells (2 in Labuan and 3 in the Klias Peninsula) and an oil-producing pit in Labuan.

As far as regional stratigraphy is concerned, Schmidt relied on Posewitz's geological map, drawn as an insert in his tectonic map. Thus, referring to Mulu, he writes: "*In Brunei, the 9,000ft high Mt Mulu consists of Carboniferous (?) limestones.*" (Translation from the German), following Posewitz's interpretation, yet with an added interrogation mark.

Schmidt concluded his prospectivity assessment with the following statement: "*The study area does not appear particularly favorable for the presence of productive oil horizons as the axis of the anticlinals comprise steeply dipping beds*" (Translated from the German).

RICHARD PILZ'S MAP OF BRITISH NORTH BORNEO (1913)

Richard Pilz was a German mining engineer, engaged in the years 1909-1911 by the British North Borneo Company to carry out field work in Sabah. His tasks were to make a systematic evaluation of the already discovered mineral and coal deposits and, as far as possible, to cross the country in order to gain an understanding of its geological composition.

During multiple month-long trips, Pilz crossed twice the country from the Marudu Bay in the direction of Sandakan

and made an overland journey from the East to the West coast of Sabah. Pilz was a sharp observer and a meticulous geologist who left valuable results of his exploration journeys (Pilz, 1913).

Pilz based his analysis of the Sabah geology on the carefully worked out example of Central Kalimantan published by Molengraaff (1900). He also corrected Posewitz's assumptions regarding the Carboniferous age of the high mountain chains of Borneo. The original age dating was based on poorly preserved fossils that could not stand detailed scrutiny. Furthermore, after detailed evaluation of these formations, Wing Easton (1904) had already concluded in the complete absence of macro fossils in the so-called "Carboniferous". Instead, Pilz argued that the stratigraphy of Sabah consists of Jurassic to Cretaceous deepmarine sediments with Radiolaria (Danau Formation), overlain by Tertiary clastic and carbonate sediments. He also mentions the presence of thick conglomerate accumulations, which he assigns to the "Diluvial".

Pilz made sharp field observations: he noted in particular that diabase and associated tuffs can be seen laying concordantly with the radiolarites of the Danau Formation ("*Als die ältesten Vertreter der Eruptivgesteine sind die Diabase und deren Tuff zu betrachten, welche mit den Schichten der Radiolarite meist konkordant eingeschaltet sind*"). As we know today this association of volcanic and sedimentary rocks forms part of an ophiolite suite. The diabase rocks are described as been intruded by diorites (Segamah), tonalities (Kinabalu) and andesites (Mt. Prai in the Darvel Bay), clearly implying a younger age for e.g. the Kinabalu pluton. This is contrary to the model of Posewitz, where the granitoid rocks of Mt Kinabalu were considered as Early Paleozoic in age. Pilz found that the youngest tuff deposits are of Miocene age, being interbedded with Neogene clastics in the Sandakan region. A young Tertiary age for volcanics in Sabah was thus established for the first time.

In another new fundamental observation, Pilz observed an unconformity between the Cretaceous (Danau Formation) and Tertiary sediments.

Pilz's Map of British North Borneo (*Karte von Britisch-Nordborneo*; Pilz, 1913) is drawn at a scale of 1: 2,707,790 (Figure 5); it shows the distribution of three types of geological formations: eruptive rocks, Tertiary and older sediments and diluvial and alluvial deposits. Larger parts of Sabah where no observations could be made are left blank. Pilz also writes that the exact location of the boundary between the various formations could not be mapped based on his journeys and that further detailed studies are needed to establish them ("*Eine genaue Festlegung der Grenzen der verschiedenen Formationen, welche im Text erwähnt werden, war auf Grund der Ergebnisse meiner Reisen nicht möglich und muss Spezialaufnahmen überlassen werden.*").

Having investigated the presence of mineral ores in Sabah and their mining potential, Pilz concluded soberly that all the efforts directed at establishing a commercial basis for their development had failed ("*Die Erfolge der*

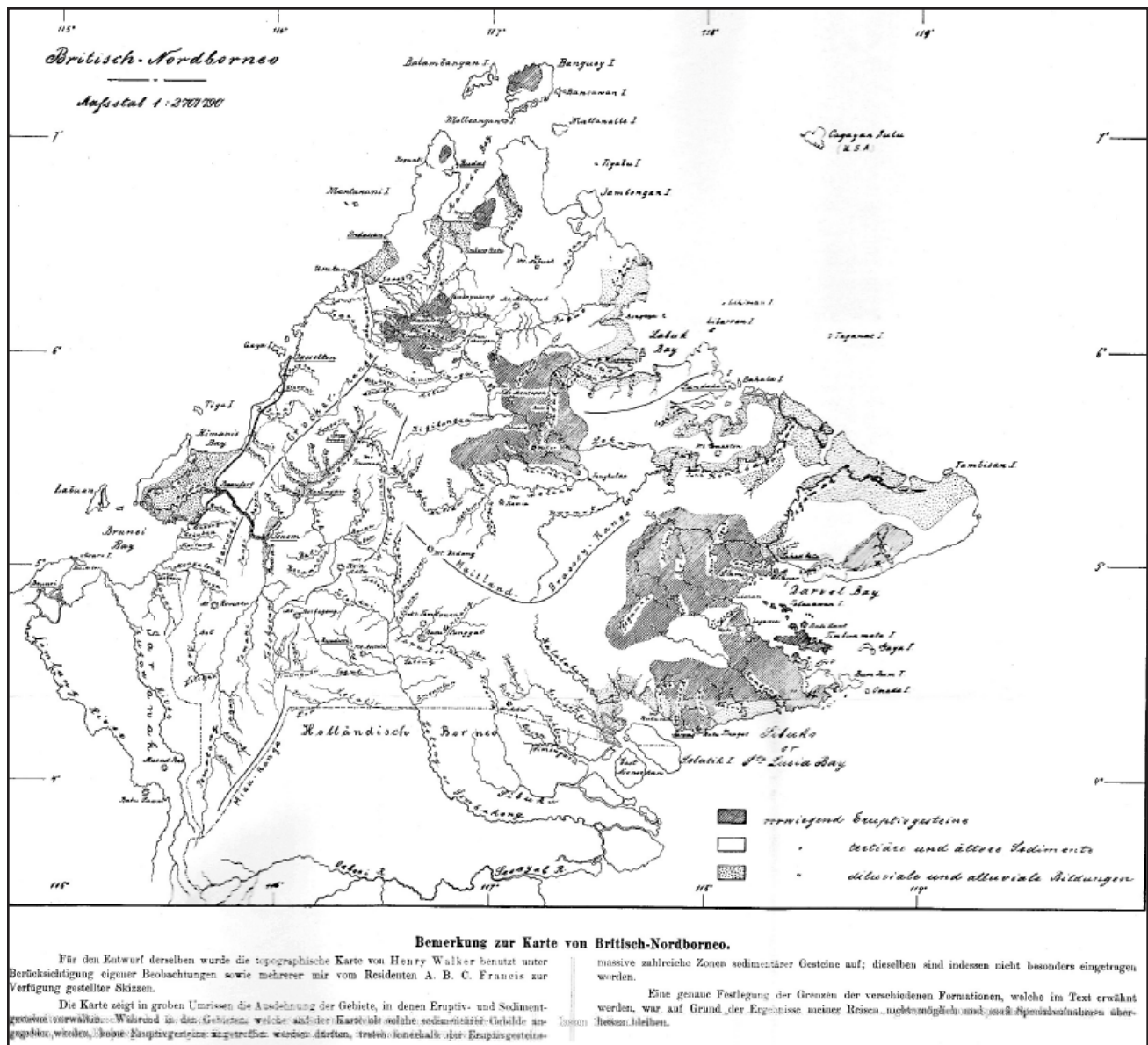


Figure 5: R. Pilz's Map of British North Borneo, 1913.

auf die mineralischen Bodenschätze des Landes gerichteten Untersuchungen sind, wie aus vorstehendem hervorgeht, bisher leider ohne Bedeutung gewesen"). However, attempts at developing agriculture had showed much promise and these ultimately, in Pilz's eyes, were to deliver a significant economic value for Sabah ("Eine umso glänzendere Entwicklung hat dafür das Plantagenwesen während der letzten Jahre zugenommen.").

THE WANNER-STAMM GEOLOGICAL SKETCH MAPS OF EASTERN SABAH (1921)

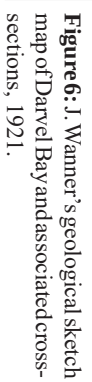
In the years 1913-1914 and on behalf of the NPKM, Dr. Kurt Stamm carried out geological fieldwork in the greater Darvel Bay-Segama River area, along the Siagau River, a tributary of the Kalabakang and in the greater Sandakan Bay area. As a German citizen, he returned to his native country at the outbreak of World War I, was sent fighting to

the front where he died in combat in January 1915, aged 27.

His papers and the part of his rock collections that made it home were handed over by his father to Dr. J. Wanner with a request to make these data available to the scientific community.

J. Wanner was an accomplished geologist who had travelled to South-East Asia and published on the geology of Sulawesi and the Moluccas. In 1921, he issued a publication including the Stamm diaries ("Reiseberichte und Einzelbeobachtungen") and he added his own interpretation and geological summary ("Zusammenfassung"). This publication (Wanner, 1921) also includes sketch maps of the geology of the studied areas accompanied by key cross-sections.

The very detailed observations made by K. Stamm supplemented by the analysis of his rock collection enabled J. Wanner to draw a comprehensive picture of



the stratigraphic and structural composition of the study area. Separate geological sketch maps were produced for the Darvel Bay-Segama River area, the Sandakan Bay area, the Silibukan, Tinkaju, Sapagaja and Siagau river systems.

The stratigraphy was subdivided into (1) pre-Tertiary, (2) older Tertiary, (3) young Tertiary and (4) Quaternary. Each subdivision is extensively described and the age dating are based on the presence of index foraminifera. The structural history is also analyzed in detail; two main phases of deformation are identified within the Tertiary: a severe phase of folding and faulting at the boundary between Paleogene and Neogene followed by a milder, intra-Neogene folding phase. The possibility for an older phase of deformation (post-Danau Formation) is also mentioned.

One of J. Wanner's geological sketch maps, the one showing the geology of Darvel Bay drawn at scale 1:100,000 and the associated cross-sections is illustrated here for reference (Figure 6).

MAX REINHARD'S GEOLOGICAL SKETCH MAP OF THE SE COAST OF BRITISH NORTH BORNEO, 1924

Max Reinhard was one of the first oil geologists to set foot in Sabah. Under contract by the NPKM (1911-1914) and later by the Standard Oil Company (1914-1915), he carried out field work in Sumatra, Java and Borneo (Sabah), before moving to Venezuela and Colombia. In 1916 he returned to his native Switzerland and followed an academic path in the Universities of Bern, Geneva and ultimately Basel.

From February 1913 until April 1914, M. Reinhard was in charge of field investigations in the SE coast of Sabah; three other geologists, F. Spiegelhalter, K. Stamm and H. Jezler, assisted him. The team established their headquarters on Sibatik Island.

Publications on the results of their studies were severely delayed due to the outbreak of World War I and many of the rock samples that were sent to Europe never reached their destination. In his publication (Reinhard, 1924), Reinhard describes the physiography of the Cowie Harbour region and Simporna Peninsula and constructed large panoramic sections of the coast. In the section describing the geology, Reinhard subdivides the stratigraphy into the following units: (A) Recent and Quaternary deposits: swamps, dunes, alluvial deposits, and coral reefs; (B) Tertiary formation: shales, sandstones, conglomerates, limestones, and lignites; (C) Tertiary volcanic rocks: andesite, trachite, labradorite; (D) Danau formation: sandstones, shales, conglomerates, breccias, radiolarite, ophiolite, granite, and metamorphic schists; mainly pre-Tertiary, including possibly lowest Tertiary.

Whenever present, Tertiary larger foraminifera are identified down to the genus level; by today's standards the age dating mentioned in the report appear to be mostly correct. Describing the Tertiary stratigraphy of the Cowie

Bay area, Reinhard mentions: "...we were able to distinguish here several lithologically well-defined divisions. Two mighty sandstone complexes, the Susui and the Kapilit sandstones, are separated from each other by the Tambalunan shales. The Kapilit sandstones rest again on a thick argillaceous horizon, the Kalabakang shales, representing the lowest division of the Tertiary complex."

Referring to the structural features of the study area, Reinhard writes: "The Tertiary is folded. We can state, as a rule, that the older the Tertiary horizons are the more they have been affected by orogenetic disturbances. The folding process is thus disharmonic and the resulting folds are diapire. This very peculiar kind of diastrophism takes place whenever strong sedimentation goes hand-in-hand with folding."

"In the Cowie harbour region, the oldest Tertiary, the Kalabakang shales, have been squeezed and crumpled into most intricate folds and the intercalated sandstones have been broken and brecciated. The youngest Tertiary, however, the Susui sandstones, have merely been waved. The disharmony of the folds is moreover exaggerated by the difference of resistance offered by a sandstone or an argillaceous complex towards the folding forces. Shearing planes result and rigid sandstone beds will be pushed over wrinkled shales. This has been observed on a rather large scale on the upper Kalabakang river."

"Much more interesting than the relatively simple folds of the Tertiary regions would be the knowledge of the structure of the Danau formation. Unfortunately, our investigations fail to advance the solution of this puzzling problem."

"A wide area of Borneo, corresponding with the extension of the Danau formation, represents for us the remnant of an extensively overfolded and overthrust mountain belt."

The "Geological Sketch Map of the South East Coast, British North Borneo from surveys by M. Reinhard, K. Stamm, H. Jezler and F. Spiegelhalter, 1913-1914" was published by M. Reinhard in 1924 (Figure 7). It is drawn at a scale of 1:750,000 and is accompanied by five geological cross-sections (Figure 8) and two panoramas from the Cowie Harbour region.

The entire coast of Sabah, from Cowie Harbour to Labuk Bay as well as the main river systems was mapped geologically, leaving blank spaces in the inter-fluvial regions and in much of the deep interior of Sabah. One parallel result of the work of M. Reinhard and his team is the correction on existing maps of the course of the Tambalunan river systems that had been improperly charted.

MAX REINHARD AND EDUARD WENK'S GEOLOGICAL MAP OF THE COLONY OF NORTH BORNEO, 1951

Following disappointing exploration results by NKPM and the outbreak of World War I, no new geological work was carried out in Sabah until 1935 when the Royal Dutch/Shell Group decided to carry out a new and comprehensive

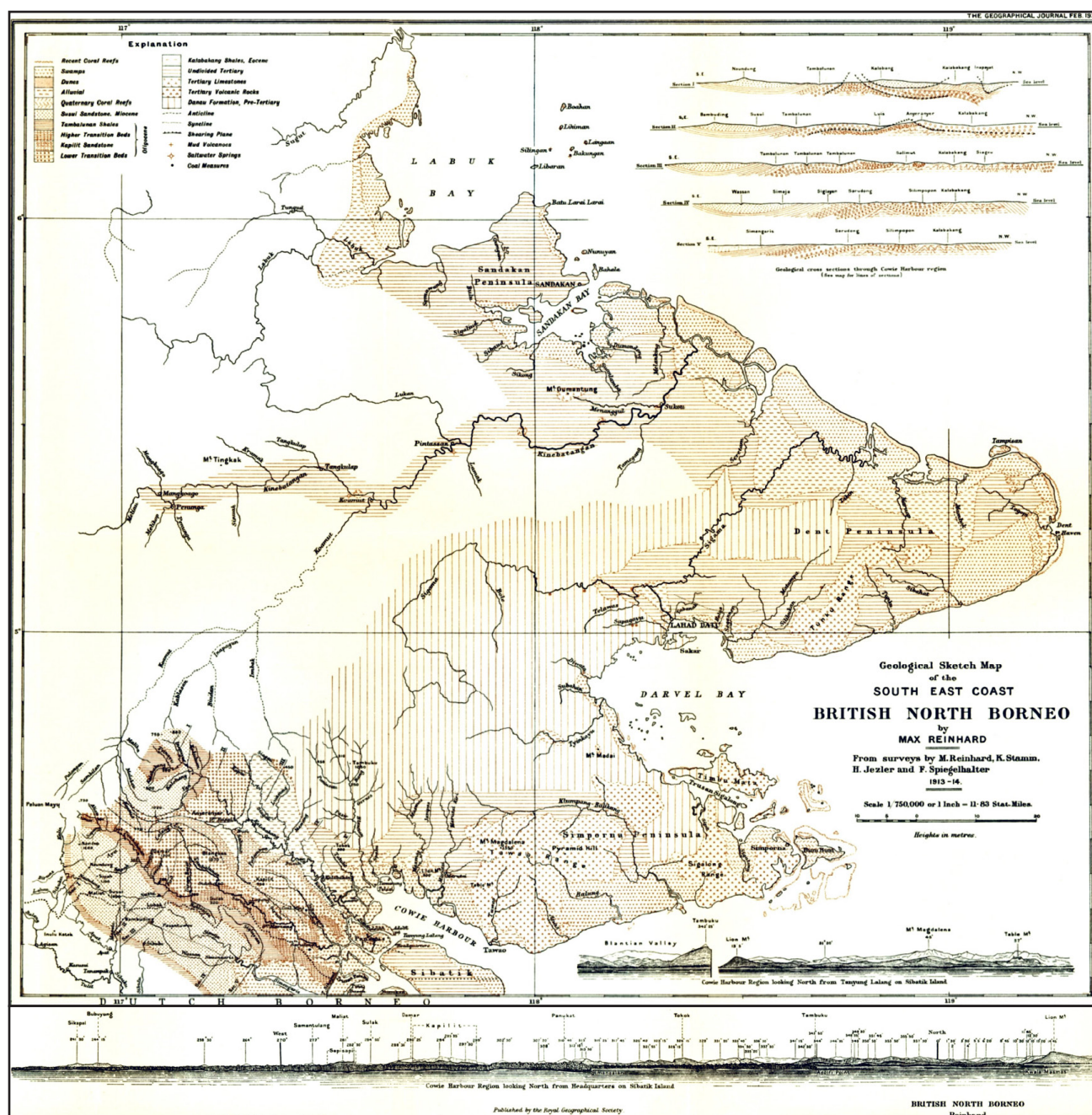


Figure 7: M. Reinhard's "Geological Sketch Map of the South East Coast, British North Borneo from surveys by M. Reinhard, K. Stamm, H. Jetzler and F. Spiegelhalter, 1913-1914", 1924.

fieldwork campaign. Work by Shell geologists was abruptly stopped by the outbreak of World War II; during these years of acute crisis many geological data were destroyed while others, such as rock sample collections, vanished while being transported to Europe.

After the war, as global reconstruction was being pursued on all fronts, the Royal Dutch/Shell Group engaged Prof. Max Reinhard and former Shell geologist Dr. Eduard. Wenk, both from the University of Basel, to compile all data available on the geology of Sabah. This effort culminated with the publication in 1951 of "Geology of the Colony of North Borneo" in Bulletin No. 1 of the newly established Geological Survey Department of the

British Territories in Borneo (Reinhard & Wenk, 1951; Wannier, 2017b).

The full-colour "Geological Map of North Borneo" published in Bulletin No. 1 is drawn at a scale of 1: 500,000 (Figure 9). It shows the distribution of (1) the Pre-Tertiary: Crystalline schists, Slate Fm, Danau Fm; (2) the Tertiary igneous rocks: plutonic, effusive and pyroclastics; (3) the Tertiary sediments: Undivided Tertiary, Kalabakang shale, Eocene Kulapis beds, Aquitanian Sugut beds, Miocene Bongaya beds, Pliocene Ganduman beds and Plio-Pleistocene Togopi beds; (4) Quaternary.

It is accompanied by a coloured "Structural map of North Borneo and adjacent Philippine Islands" drawn at a

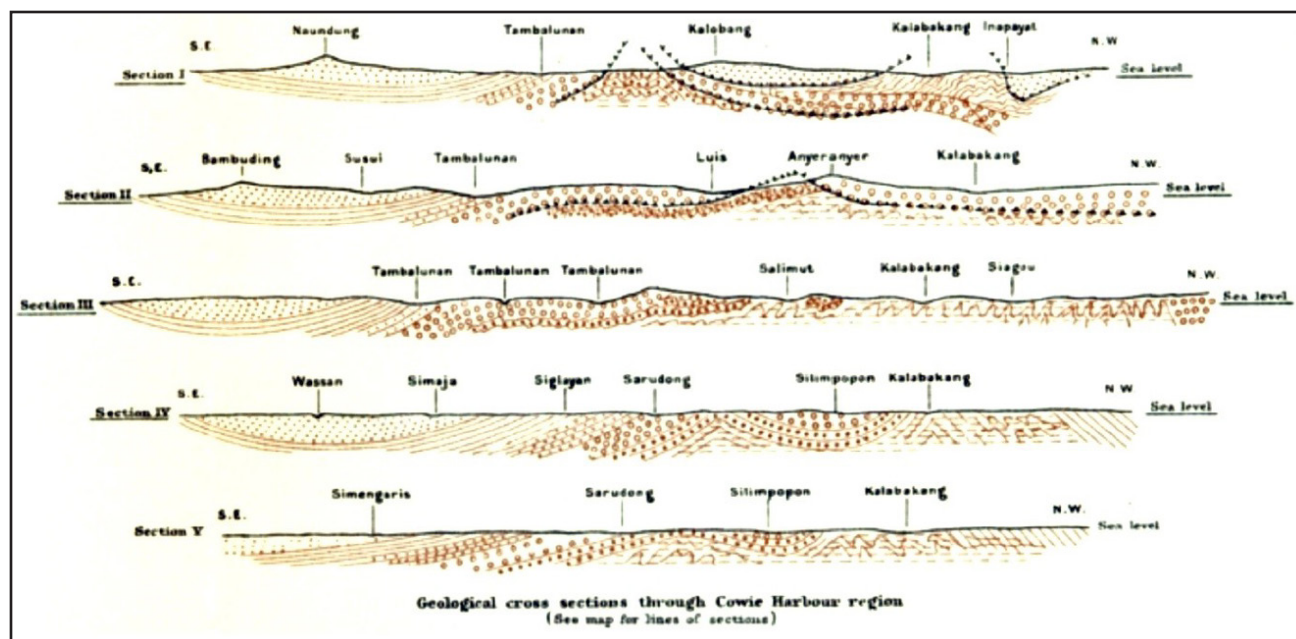


Figure 8: M. Reinhard "Geological cross-sections through Cowie Harbour region", 1924.

scale 1:2,500,000 and by 8 other, smaller scale geological sketch maps.

The geological map has lots of white spaces with no data, giving it an odd look. However, it faithfully portrays what was known at the time, and what was yet to be known. Extrapolations by the authors from the known to the unknown have been kept to a minimum. The dip and strike measurements indicated on the map outline the routes taken by the geologists and the location of the actual control points for the map. The map further shows the anticlinal and synclinal axes, the location of mud volcanoes and of surface seeps, as well as the position of wells.

CONCLUSIONS

Making large scale, regional geological maps is necessarily a collaborative process: a country geological map is usually the result of separate mapping campaigns by multiple geologists, each one working a smaller area. The final map is itself the result of a compilation and harmonization effort, assembling all pieces of the puzzle into a coherent picture.

In the case of Sabah, virtually all the early non-systematic geological data compilation that went into the Theodor Posewitz map proved to be of no value when Max Reinhard and Eduard Wenk assembled their *Geological Map of North Borneo*.

This reflects the significant change that happened at the turn of the 20th century in the way geological data were handled and recorded. The older way was casual, non-systematic, did not involve dip and strike measurements nor the stratigraphic logging of outcrops. The solid basis for the geological mapping of Sabah was only established when professional geologists arrived in the field and when a more rigorous and scientific approach was followed, including the collection of rock samples for later laboratory analyses.

Much progress has been made since M. Reinhard and E. Wenk's geological map was published, but new versions of the geological map of Sabah are essentially a series of updates of the 1951 *Geological Map of North Borneo*.

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REFERENCES

- Bécsi, G., 2016. Van de Hongaarse poesta naar Noord-Borneo: De reisjournalen van Ferenc Wittl. Acta Neerlandica, 13, 69-145.
- Hatton, F., 1886. North Borneo: Explorations and Adventures on the Equator. New York, Scribner & Welford. 342 p.
- Keyser, F. de & Noya-Sinay, J., 1992. History of geoscientific investigations in West Kalimantan, Indonesia. J. Australian Geology & Geophysics, 13, 251-273.
- Molengraaff, G.A.F., 1900. Borneo-Expeditie. Geologische verkenningstochten in Centraal Borneo. Met atlas. E.J. Brill, Leiden. 529 p.
- Peltzer, J., 1881. Bornéo. Bulletin de la Société Belge de Géographie, 297-305 (part 1); 377-402 (part 2).
- Pilz, R., 1913. Geologische Studien in Britisch-Nordborneo. VI Jahresbericht der Freiburger Geologischen Gesellschaft; 51 Sitzungsbericht 12 November 1912. Freiberg in Sachsen, 12-39.
- Poley, J. Ph., 2000. Eroica. The Quest for Oil in Indonesia (1850-1898). Kluwer Academic Publishers. 174 p.
- Posewitz, T., 1889. Borneo. Entdeckungsreisen und Untersuchungen. Gegenwärtiger Stand der geol. Kenntnisse. Verbreitung der nutzbaren Mineralien. Berlin.
- Posewitz, T., 1892. Borneo: its geology and mineral resources. Translated from the German by F. H. Hatch. London, Edward



- Stanford. 495 p.
- Reinhard, M., 1924. Contributions to the Physiography and Geology of the South-East Coast of British North Borneo. The Geographical Journal, Vol. 63, No. 2 (Feb., 1924), 121-134.
- Reinhard, M. & Wenk, E., 1951. Geology of the Colony of North Borneo. Geological Survey Department of the British Territories in Borneo, Bulletin No. 1. London. 160 p.
- Schmidt, C., 1901. Observations géologiques à Sumatra et à Borneo. Bull. Soc. Geol. France. IV Série, T. 1., 260-267.
- Schmidt, C., 1904. Über die Geologie von Nordwest-Borneo und eine daselbst entstandene "Neue Insel". Gerlands Beitr. zur Geophysik, Bd. VII, Heft 1." Leipzig, 121-136.
- Wanner, J., 1921. Beiträge zur Geologie und Geographie von Nordost-Borneo. Ergebnisse einer von Dr. K. Stamm in den Jahren 1913- 1914 ausgeführten Reise, nach seinen hinterlassenen Aufzeichnungen und Sammlungen zusammengestellt und unter Mitwirkung von Prof. H. Bücking bearbeitet. Neues Jahrb. Min. Geol. Pal., 45 Beilage-Band. Stuttgart, 149-213.
- Wannier, M.M.A., 2017a. Early Explorers Fatal Destiny in the Jungle of Sabah. Warta Geologi, 43(2), 63-66.
- Wannier, M.M.A., 2017b. "Geology of the Colony of North Borneo" (1951): The first fundamental publication on the geology of Sabah. Geol. Soc. of Malaysia Bull., this issue.
- Wing Easton, N., 1904. Geologie eines Teiles von West-Borneo. Batavia, Jaarb. Mijnw. Ned. O.-Ind.
- Witti, F.G., 1881. Diary of F. Witt, Esq., during an Excursion across North Borneo from Marudu Bay to Sandakan. London.
- Witti, F.G., 1882. Diary of F. Witt, Esq., during an Excursion in North Borneo from Marudu Bay to Papar by the Eastern Slopes of Mount Kinabalu. London.

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